Sustainable-Affordable Housing for the Poor in Kerala

Proefschrift

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door

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on Wednesday, 20 December 2006 at 10.00 o'clock

by

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1. SCOPE OF RESEARCH

1.1 Introduction

Housing embodies many concepts such as comfort, safety, identity and above all, it has central importance to everyone's quality of life and health, with considerable economic, social, cultural and personal significance. Access to safe, healthy shelter and basic services is essential to the overall (physical, psychological, social and economic) well-being of a person. It is also a critical component in the social and economic fabric of all nations. No country is yet satisfied that adequate housing has been delivered to the various economic groups that make up its populace. It persists globally as a problem irrespective of the economic status of the countries, but differs in its nature and gravity. Homelessness is the most visible and extreme form of this and often connected with lack of basic facilities like drinking water, drainage and sanitation. It is estimated that there are more than hundred million homeless, having absolutely nowhere to live, and about one billion people inadequately housed throughout the world. Overall, at least six hundred million people live in shelters that are life threatening or health threatening in developing world cities (Tipple et al., 2005, UN 2005, Erguden, 2001, UNCHS 1996,). These figures are rough estimates, as measuring global homelessness is extremely difficult. Most data are known to be undercounts, relying on service provider statistics that do not include the entire homeless population. In addition to the difficulties in counting mobile and hidden population; the data collection on global scale is impeded by inaccurate and limited or non existent data collection in many countries and variation in the definition of homelessness. Anyhow, it is clear that the current and worsening global shelter situation needs serious concern. The persistence and growth of poor shelter conditions, particularly in the developing countries, is a stumbling block to socio-political stability and economic development (UNCHS, 1990). It urges the need for scaling-up housing supply and has become a focus of policy debate. A holistic approach is imperative to assess the housing demands, analyse the issues and solve the problems of those people who are not able to afford their housing due to lower economic status and inaccessibility to common property resources.

Housing has widely been acknowledged as a human right rather than being a basic need. Since the adoption of Universal Declaration of Human Rights[♣] in 1948, the human right

♣ "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing, medical care, necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control." (Article 25(1), Universal Declaration of Human Rights).

to adequate housing has been repeatedly reaffirmed (UNCHS, 2000). The Millennium Development Goals have identified improving housing conditions as an integral part of the global development agenda (UN, 2005). It is recognized that adequate shelter for all and sustainable human settlements development cannot be isolated from the broader social and economic development of countries. Also they cannot be set apart from the technological advancements and environmental protection. All these factors are indispensable and mutually reinforcing components of sustainable development. Inadequate and insecure shelter will lead to social and political instability and will hamper economic development. In this sense, global shelter conditions are closely linked to the achievement and maintenance of world peace and economic stability. The economic and political self-reliance, social justice, and an environmentally sound quality of life are factors, which lead to sustainable development.

1.2 Housing situation; issues and concerns

Human settlements problems are of a multidimensional nature. They vary even from individual to individual, rural to urban, and obviously from country to country both in terms of quantity and quality. The unmet demand for housing, along with poverty, has led to the emergence of slums in many poor countries as a solution to affordable housing for low-income people. This is particularly true in third world countries where the majority of the housing activities are being done by acquiring land through purchase or invasion. In such cases, poor people with limited income and know-how construct their own houses with available resources, and gradually improve the structure in due course of time. As a result in most cases, the quality of housing is miserable with insufficient basic services, unhygienic surroundings, lack of access to safe water and proper sanitation. Hence quantitative housing deficits in most countries (even very poor ones) are relatively small, suggesting that the housing problem is largely qualitative rather than quantitative (World Bank, 2005).

The housing problem of low-income countries differs greatly from that experienced in developed economies, and further rural and urban housing also exhibit their own peculiar characteristics. There is a number of constraints that slow down the housing development programmes and the development of a sustainable habitat. Lack of effective implementation strategies, inadequate supply of affordable land and infrastructure, inadequacy of housing finance systems are a few among such constraints. Inadequate access to affordable building materials is one of the major limitations of the poor in developing countries to provide adequate housing for them. Out of the total cost of house construction, building materials contribute more than fifty percent in developing countries like India. The gap between the rising demand and the stagnating, and in many cases declining, production levels is widening at an alarming rate, leading to the spiralling of prices of building materials in many developing countries, seriously affecting the affordability of housing for the vast majority of the population (UNCHS, 1993). Along with these, the depleting resources and energy consumed during extraction, processing and transportation of raw materials is another serious concern questioning the sustainability of building process.

1.2.1 India

The housing situation in India was not so much aggravated in the beginning of the twentieth century. According to the census records there was a surplus of 1.8 million houses in 1901. This continued till 1941. The Second World War totally changed this situation. It became worse in 1947. About 7.5 million of displaced persons migrated to India, owing to the partition of the country into India and Pakistan (First Five Year Plan (1951-56) document, Government of India). Fig. 1.1 shows the variation in the housing gap over the last fifty years.

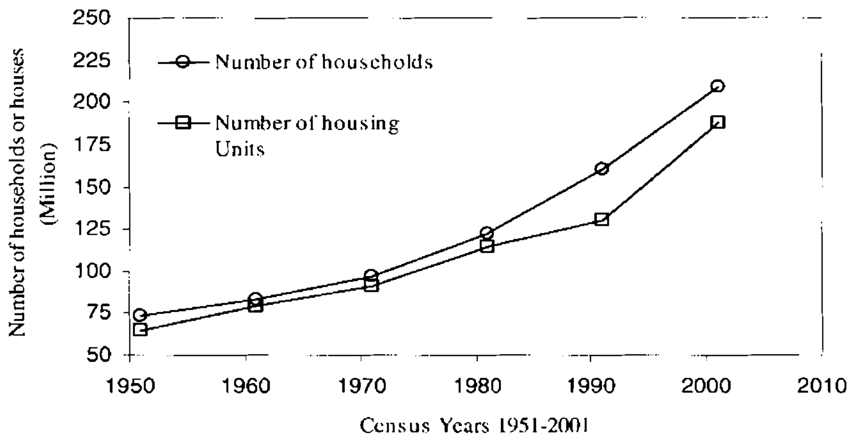

Figure 1.1 Housing gap in India during the period 1951- 2001

The latest census reports of India shows a housing deficit of twenty-two million housing units. Nearly half of the existing housing stock (48.2%) is either made of non durable or temporary materials and the housing problem is even bigger in terms of quality than quantity (Government of India, 2001). Every two out of the five households in India live in extremely poor quality houses. The World Bank's recent human development report says that 32% of the total population in India has still no access to improved sanitation and 14% has no access to safe drinking water (World Bank, 2005). Also the slum population in India (42.6 million people) accounts for 15% of the total urban population. In such cases, people themselves with little or no assistance from public agencies build shelters, which are even devoid of basic amenities. The situation in the rural areas is also not better.

Rapid population growth (Table 1, Appendix 1.2), increased urbanization, relatively low investments in housing and widespread poverty have created serious shelter problems in India. Population growth and urbanization trends have a profound impact on people's access to shelter, contributing to the proliferation of slums, increased demand for infrastructure and services, and declining quality of life for the poor. Additional key factors that have aggravated India's critical housing situation include institutional deficiencies, especially among state and local housing agencies, and regulatory constraints to new housing development and investment such as the Urban Land Ceiling (and Regulation) Act of 1976 and the state rent control acts (ADB, 2000).

The strategy for rural housing in India is based on the observation that housing activity in rural areas is based on land rights and access to resources, and not on the cash economy (Government of India, 1998). The shelter problem, having a multidimensional nature with its main roots in poverty, seems to be aggravated by the scarcity and inaccessibility to common property resources, inadequate institutional capacities and legal and financial frameworks.

1.2.2 Kerala

Kerala, situated on the south-west coast of Indian sub continent (see Appendix 1.1 and 1.2 for general and topographic details), is well ahead in the field of social development and better living conditions compared to other parts of India. Over the past couple of decades, Kerala has drawn both international and national attention for its achievements in demographic transition, with fertility reaching below the replacement level and mortality under five. In terms of per capita income and production, Kerala with an agrarian economy is lagging behind many of the Indian states. However, in terms of Human Development Index (HDI) and life standard of people, Kerala is much ahead of most of other states in India (Tables 3, 4, Appendix 1.2). It is also one of the densely populated states (819 persons/ sq.km) with 3.43% of the total Indian population. The high population density of the state may be mainly due to good climate, fertile land and good rainfall. Literacy as a qualitative attribute of the population is one of the most important indicators of socio-economic and political development of a society. The state's achievements in literacy (90.9%), education, birth rate (0.94) etc. are even comparable to many of the developed countries. Table 5 (Appendix 1.2) shows a comparison of Kerala situation with few neighbouring countries.

The housing situation in the state is quite different from other parts of India. Kerala has got a unique settlement pattern with the dwellings made in individual plots and scattered all over the habitable areas. This is in striking contrast with the nucleated village system prevalent throughout the rest of India. The public housing schemes implemented in Kerala showed greater performance in terms of the magnitude of investment and physical achievements and could considerably reduce the housing gap. The official estimates predicted that if the present trend in house construction continues, by the year 2006 all people in Kerala would have their own houses (Government of Kerala, 2003). However, a closer inspection of the current housing situation in Kerala reveals another side of this picture. Despite many positive advances, visible slum-like areas occur in human settlements in rural parts of the state, and many inhabitants are deprived of basic facilities like drinking water and sanitation (Gopikuttan, 2002).

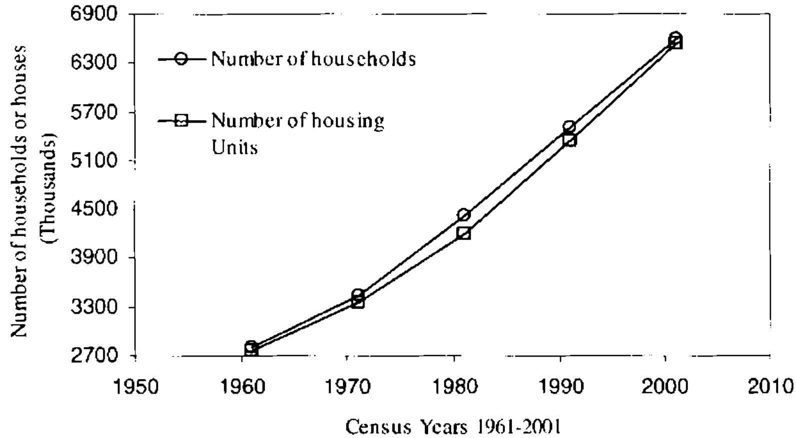

Figure 1.2 Housing gap in Kerala during the period 1961- 2001

Traditional residential buildings in Kerala show a reflection of the socio-economic inequalities in the society in the early days. Rich people, mostly belonging to the higher castes were living in palatial buildings, but the houses of the poor people were in miserable conditions. Only the people belonging to higher castes were able to utilize the services of artisans and craftsmen for the building process. However, the poor used to help each other in putting up their shelters by using locally available materials. No wages were paid other than food. But during the period from early 1970s, the situation started changing. Social reform movements and economic changes in the society wiped off the ill effects of caste systems from the society. This was also visible in the housing situation. People started building palatial houses using the readily available, energy intensive materials like concrete, cement, and bricks replacing the indigenous materials such as mud, laterite, thatch etc. This generated changes in the employment sector and the wage structures, especially in the rural areas. But this modern technology with its undue stress on costly and energy intensive materials like steel and cement was beyond the reach of majority of the population. In order to overcome these problems for solving the urgent housing demand, the Government of Kerala promoted cost-effective construction techniques and innovative materials. However, the present housing situation in Kerala shows that the public housing schemes could not solve the housing problems of poorest sections in the rural areas. Also the "Cost Effective and Environmentally Friendly" (CEEF) technology, which was actually meant for helping the weaker section seems to have failed to reach the expected beneficiaries (Gopikuttan, 2004). This may be due to the inability of the poor in getting the awareness, non-availability of skilled labour, technical assistance etc on this technology. It can also be due to the mismatch in the perceptions of the poor and the government. Further it seems that government intervention has aggravated the dependence and diminished the self-reliance of the rural poor (Glaeser, 1995).

In addition to this, housing and other related development activities have created severe environmental problems in Kerala. Long stretches of paddy fields are now kept barren or used for clay mining or developed as house plots in the state. This has created serious environmental issues in the neighbourhoods such as water logging, inadequate drainage facilities, non-availability of drinking water etc. This also resulted in the decline of more than a half a million hectares of area under paddy cultivation during the last two decades (Government of Kerala, 2004). Conversion of paddy fields means abandoning a highly developed and complex wetland agro ecosystem and hence affecting the environmental balance.

Conservation and effective use of renewable and non-renewable resources is a prime concern in the building process. Building materials constitute more than half of the total construction cost for an average residential building in Kerala. A substantial part of this is the cost of cement. A sustainable alternative to cement could provide a significant contribution towards the provision of low-cost building materials, and consequently to affordable shelter. An approach to affordability along with addressing environmental concerns could be a better alternative. The potential of rice husk ash; an agricultural waste from paddy, as a cement replacement material has significance in this context as an affordable and environmentally friendly building alternative.

The problem of housing in Kerala can be characterised mainly as a problem of sustainable housing rather than quantitative deficit. Causes could be either due to:

Policy aspects

- Lack of proper housing policies or implementation,
- Lack of access to resources, lack of infrastructure and facilities,
- Lack of local government controlling and monitoring,

- Lack of networking among institutions engaged in housing,
- Non-accessibility for easy finance,
- Lack of proper housing guidance, standards and specifications or

Technology aspects
- Unavailability of affordable materials,
- High cost of materials and skilled labour,
- Unawareness of cost reduction techniques,
- Improper usage of available technology,
- Blind usage of conventional (modern) materials,
- Lack of trained and skilled labourers) or a combination of both.

This situation hence urges the need of a closer evaluation on the various factors preventing the poor households from satisfying their housing needs in the midst of increased public interventions and favourable environment.

1.3 Significance of housing in sustainable development

Housing activity is very closely linked to the macro-economy. Investments in this sector not only improve and add to the existing stock of housing units, but also improve the working and living conditions. It generates a significant share of employment-typically around 9% worldwide-and often helps lead national economies out of recession as it did in the United States in 2001 and 2002 (Ferguson et al., 2003). In India, the National Building Organization has estimated that an investment of Rs.10 million (about US$ 1 million) in building construction at the 1980-81 wage rate generated 624 work-years in on-site employment (420 unskilled and 204 skilled) and 1000 work-years in direct employment in the building material industry and other supporting sectors (Moavenzadeh, 1987). Like all other development activities, housing has also got a monetary and subsistence component. Even if it is a self-help or family activity in rural areas, it needs building materials, tools and skilled labour as input factors. Besides creating an individual product, the new or repaired shelter and the combined input factors also contribute to national product and thus increase the overall national wealth.

Housing has a crucial role in the development of human settlements. Protection and conservation of the environment need serious concern during and after the building process. Sustainable construction is a holistic process aiming to restore and maintain harmony between natural and built environments, and create settlements that affirm human dignity and encourage economic equity (CIB and UNEP, 2002). Hence sustainable housing development also needs environmentally-friendly technological innovations.

Improving shelter requires a better understanding of the mechanisms governing housing availability. That requires better data and better policy-oriented analysis, so that housing policy can be formulated in a more global comparative perspective, and the accomplishments and lessons learned in one country can be drawn on by others. This comparative perspective can help countries chart their paths, formulate realistic development objectives, and measure their achievements over time and compare them with other countries in similar circumstances (World Bank, 2005). The efficient supply of housing is also closely associated with sustainable-affordable construction techniques and building materials; therefore these processes need to be studied in an integrated way.

1.4 Research objectives

In the context of the above discussions, the main goal of this thesis is to contribute to a more sustainable solution to the present housing problem in developing countries. In order to address this objective and to conceptualize the problem from the perspective of the households a thoughtful and holistic approach based on the concepts of sustainability is needed. The objectives of this research can therefore be listed as follows.

1. To develop a better understanding of the present housing situation and the problems relating to sustainable human settlements in developing countries, based on an integrated approach that combines both the perspective of the households (users), and as well as the concept of sustainable development.

2. To develop and test a methodology based on this new integrated perspective to evaluate the success and failure factors of public intervention in housing the poor, and to suggest appropriate recommendations to contribute to public policies for sustainable development.

3. To adapt and apply this integrated approach in the evaluation of the building process, to suggest modifications and to explore a few sustainable technologies appropriate for the local conditions, utilizing renewable or locally available waste materials.

In order to reach these objectives, research questions are formulated and presented in the succeeding section.

1.5 Research questions

The housing situation in Kerala has been selected as the main focus of this thesis. Since the prime objective of this research is to develop a holistic perspective for identifying the problems relating to shelter, the main question has been formulated to achieve this goal in the context of Kerala.

Main question
How to develop an integrated framework for analyzing (both for the evaluation of policy and building process) the housing problem of the poor (from their own perspectives), and what sustainable materials or technological options can be suggested along with policy recommendations for achieving sustainable-affordable housing in Kerala?

Sub questions

1. How can the housing problems be evaluated from the perspective of the users, in such a way as to contribute to sustainable development?

2. What are the various policy approaches in the previous years in India (Kerala) in addressing the shelter problems of the poor and how far have the different schemes been successful in achieving sustainable housing development?

3. What is the real housing situation of the poor households in Kerala and what policy recommendations can be proposed (particularly for the economically weaker sections) for sustainable-affordable housing so as to contribute to sustainable development?

4. Does the present building process in Kerala contribute to sustainable housing? If not what are the recommendations for modifying it?

5. How could rice husk ash pozzolana be developed locally as a sustainable alternative to replace cement for the primary building applications in Kerala?

1.6 Methodology and chapter scheme

This thesis has adopted both social science and technology approach in reaching different objectives. In total there are seven chapters. This is illustrated in the figure (Fig. 1.3). Literature review, personnel interviews and household surveys are conducted in the first part and experimental technical research has been carried out in the second part. The succeeding text describes the methodology adopted for each chapter.

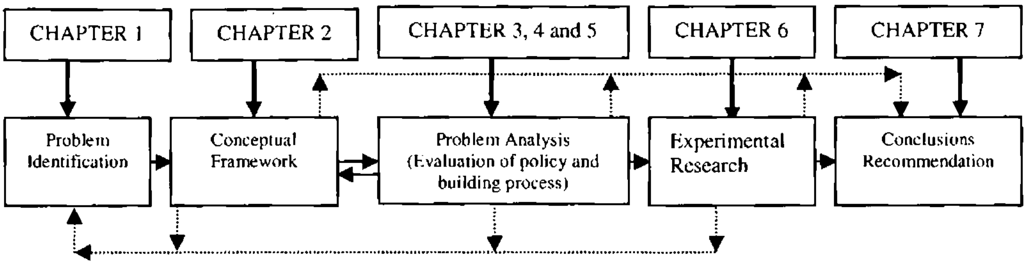

Figure 1.3 Thesis structure

Chapter 2 - This chapter explores the concepts of sustainable-affordable housing and introduces a general conceptual framework to evaluate the housing situation from the perspective of the users. This framework helps in understanding the problem from the perspective of the households specifically in terms of their basic needs and suggests solutions that contribute to sustainable-affordable housing.

Methodology - A literature survey has been carried out for exploring the concept of sustainable-affordable housing. Value focused thinking proposed by Keeney (Keeney 1992; Keeney et al., 2005) has been used in this chapter for structuring objectives and developing the framework. Various findings from notable researchers were also utilized at this stage of research for structuring and defining the objectives of sustainable-affordable housing.

Chapter 3 - This chapter presents an evaluation of the public housing policy for Economically Weaker Sections[1] (EWS) in the state. Three schemes (One Lakh Housing Scheme, Indira Awaas Yojana and Total Housing Scheme) are identified from each phase reflecting similar approaches in international housing policies, their uniqueness in implementing agencies and other peculiar characteristics. The evaluation of these schemes was done in three stages. The first two stages of analysis (A I and A II) are presented in this chapter. Analysis I (A I) evaluate the goals of the government policies in the selected schemes. The second stage (A II) assesses the real situation in the field from the viewpoint of an observer (the researcher). An overview of the evolution of housing policy in the developing world, subsequent changes in the low-income housing

[1] Families with monthly household income less than Rs. 2500 ($ 65)

policy of India with specific attention to the case of Kerala are also discussed in this chapter.

Methodology - A methodology based on the conceptual framework from chapter 2 is employed in the analysis to understand the problem through a sustainability perspective and to investigate the success and failure factors of public intervention in housing the poor. The information collected from the official reports of government of India, Kerala, local or self governments, implementing agencies and other secondary sources are taken as the basis of Analysis I. Data for this chapter are also collected from reports of international agencies like the World Bank and UNCHS (on the evolution of present housing policy in developing countries).

Chapter 4 - This chapter presents the third stage (Analysis III - AIII) of evaluation to assess the real situation in the field. An evaluation of the housing situation in Kerala based on household surveys and case studies from the selected housing schemes is presented in this chapter. A discussion on the present housing situation of Kerala with respect to different aspects of sustainability and a comparative analysis of the public initiatives in low income housing with examples from other parts of the world is also presented. Based on these evaluations and comparative study strategies are formulated for sustainable-affordable housing in Kerala.

Methodology - The information employed for this part of analysis is based on household surveys from Kerala. These surveys were conducted using a structured questionnaire prepared on the basis of the conceptual framework. A scheme of analysis is prepared for each aspect of sustainability based on the "objectives hierarchy model" of the conceptual framework and the questions are transformed into measurable criteria. The Statistical Package for Social Sciences (SPSS-Version XI) is employed for the analysis of household data. Some examples of enabling strategies from UNCHS, Global Best Practice database are discussed in this chapter to see how they have tackled the problems of low-income housing in similar contexts.

Chapter 5 - This chapter gives an evaluation of the prevailing building process in Kerala. It presents the guidelines for selecting environmentally-friendly and as well as affordable technological options. This chapter also discusses the potential an affordable alternatives (rice husk ash) suitable to the specificities of Kerala. Basic principles and examples from straw bale construction in The Netherlands and India are presented as the appendix of this chapter.

Methodology - The evaluation has been done using a methodology based on the conceptual framework from chapter 2. The information employed for the evaluation of the prevailing building process in Kerala is supported by the knowledge which has learned from the researcher's experiences from practise, by field studies, data collected from household surveys and desk research.

Chapter 6 - This chapter deals with the experimental study which has been conducted on the rice husk ash samples under controlled conditions in the lab and from different field ovens to compare the performance of the ovens and to identify the most feasible method to produce a reactive pozzolana as an alternative to cement for building applications requiring lower strengths.

Methodology - The first phase of the research discusses the parameters, which influence the reactivity of the pozzolana from rice husk under controlled conditions in the laboratory. Literature work has been carried out for collecting information on the previous researches. An in-depth characterization of rice husk ash samples produced from different temperature-duration-cooling regimes in the controlled laboratory condition had been conducted as a function of combustion conditions using X-ray diffraction (XRD), ^{29}Si magic-angle spinning (MAS) nuclear magnetic resonance (NMR), chemical analyses, conductivity measurements and microscopic analysis.

For the second phase of this research, ash samples from three different types of field ovens (annular enclosure, brick oven and pit arrangement) are investigated for loss on ignition, soluble silica, pozzolanicity and X-ray diffraction. Malvern apparatus has used for the particle size analysis and Brunauer- Emmett -Teller analysis is employed for the investigation of specific surface area of rice husk ash samples. The long-term strength of these rice husk ash pozzolanas (from field ovens and optimized condition in the lab) with lime or cement is investigated through lime reactivity test and compressive strength test.

Chapter 7 - This chapter gives the general conclusions and recommendations of this research together with an insight into the scope for further studies. Recommendations for the practical implementation of the policies to contribute to sustainable-affordable housing development in Kerala are also presented in this chapter.

APPENDIX 1.1

Figure 1 Map of India showing the position of Kerala
(Source: http://cs101.sewanee.edu/map.gif , last accessed on 22/08/2006)

APPENDIX 1.2

General physiographic and climatic features of Kerala

In terms of the topographical characteristics, Kerala may be divided in to three regions such as Lowland, High land and mid land. *Low land* (10.2%) stretches along the Arabian Sea and population density is highest (Coastal area). This region is characterized by marine landforms consisting of beach ridges and beaches with swamps and lagoons. The low land region is well known for its backwaters with extensive rice fields and coconut trees. *High land* (48%) stretches along the Western Ghats and population density is lowest (Hilly area). It slopes down from the Western Ghats, which rise to an average height of 900m, with a number of peaks well over 1,800m in height. The soil varies widely in depth and texture. Plantation crops including tea, coffee, rubber and cardamom are grown in highlands. *Mid land* (41.8%) lies between low land and high land, with altitudes ranging from 7.5 to 75 meters above mean sea level, is made up primarily of valleys. The terrain is undulating, with numerous rivers, small hills and valleys. Laterite and lateritic soils cover around 60% of the total geographical area of Kerala.

Kerala is the land of Rivers and backwaters. 44 Rivers (41 west flowing and 3 east flowing) cut across Kerala with their innumerable tributaries and branches, but these rivers are comparative small and being entirely monsoon-fed, practically turn into rivulets in summer, especially in the upper areas.

Climate - Kerala falls with in the realm of tropical climate and dominant feature is monsoon. It has a warm and pleasant tropical monsoon climate. The climate is pleasant from September to February. The summer months are warm and humid with a mean max temperature of about 33°C. March to May is the hottest, with temperature reaching more than 32°C. Lowest temperatures are experienced during the month of December and January.

Winter Maximum	21 °C	Minimum	18°C
Summer Maximum	33 °C	Minimum	27°C

Wind - Wind over the state is seasonal and wind speed attains 40 to 50 km/hr during and before the monsoon rains.

Rain fall - Kerala receives a good annual rainfall, varying from 1250 to 5000 mm. The normal annual rainfall of Kerala is 3107 mm. (national average is 1197 mm). The State has the benefit of the Southwest and Northeast monsoon. Although, quantum wise the rainfall received is high, its distribution shows temporal and spatial variations. On an average, the number of rainy days is in the range of 120-140 in a year. The highest rainfall occurs in the high ranges of Idukki district, where it exceeds 5000 mm.

APPENDIX 1.3

Table 1 Population growths and the 'Housing gap' in India (in million)

Census Year	Population	Number of households	Number of housing units	Housing gap
1951	360.9	73.4	64.4	9.0
1961	439.2	83.5	79.1	4.4
1971	547.2	97.1	90.8	6.3
1981	685.2	122.6	114.4	8.2
1991	846.3	160.6	129.6	31.0
2001	1025.3	209.2	187.1	22.1

Source: Census reports, Government of India

Table 2 Population growths and the 'Housing gap' in Kerala (in thousands)

Census Year	Population	Number of households	Number of housing units	Housing gap
1961	16,904	2,808	2,754	54
1971	21,347	3,433	3,362	71
1981	23,454	4,423	4,195	228
1991	29,033	5,513	5,342	171
2001	31,839	6,595	6,540	55

Source: Census Reports, Government of India

Table 3 Comparative statistics with neighbouring Indian states

State	Area (sq.km)	Density of population per sq.km	Literacy	HDI 2001	HPI 1991	Below poverty line 1999-2000 (%)	*Unemploy -ment 1999-2000 (% of labour force)	**Per capita net state domestic product 1997-98
Kerala	**38863**	**819**	**90.92**	**0.64**	**19.9**	**12.7**	**8.6**	**2490**
Tamilnadu	130058	478	73.47	0.53	29.3	21.2	2.6	3141
Karnataka	191791	275	67.04	0.48	32.7	20.0	1.4	2866
India	**3287263**	**324**	**65.38**	**0.47**	**39.4**	**26.1**	**2.3**	**2840**

Source: www.kerala.gov.in, Census reports, *NHRD 2001 Planning commission, ** National Human Development report 2001, ***Eleventh finance commission report 2000

Table 4 Comparative Statistics, Housing and amenities in Kerala with neighbouring Indian States

State	Permanent houses (%)	Owned houses - Tenure status (%)	Toilet facility (%)	Electricity connection (%)	Availability of drinking water within the premises and near (%)
Kerala	68.1	92.6	62.1	70.2	88.1
Tamilnadu	58.5	77.7	39.9	78.2	87.9
Karnataka	54.9	78.5	58.9	78.5	78.1

Source: Census Reports, Government of India, 2001

Table 5 Comparison of Kerala with neighbouring countries

Country	Area in Sq.km	Density of population	Population below poverty line 2002 (%)	Human Development Index (HDI) 2003	Human Poverty Index (HPI) 2003 (%)	Life expectancy at birth 2003	Literacy of total population (%)	GDP index	Population growth rate (%)	Population with sustainable access to an improved water source (%) 2002	Population with sustainable access to improved sanitation (%) 2002
Malaysia	329,750	73	15.5	0.796	8.9	73.2	88.7	0.76	1.8	95	96 (1990)
Thailand	514,000	127	13.1	0.778	12.8	70.0	92.6	0.72	0.87	85	99
China	9596960	136	4.6	0.755	12.3	71.6	90.9	0.65	0.58	77	44
Sri Lanka	65610	309	25.0	0.751	18.0	74.0	92.3	0.61	0.79	78	91
Vietnam	329,560	253	50.9	0.704	21.2	70.5	90.3	0.54	1.04	73	41
Indonesia	1919440	126	27.1	0.697	17.8	66.8	87.9	0.59	1.45	78	52
Bangladesh	144000	1002	49.8	0.520	44.1	62.8	43.1	0.48	2.09	75	48
Pakistan	803,940	202	32.6	0.527	37.1	63.0	61.7	0.51	2.03	90	54
India	3287590	329	28.6	0.602	31.3	63.3	64.8	0.56	1.4	86	30
Kerala	**38,863**	**819**	**13**	**0.64**	**15**	**73**	**90.9**	**0.64**	**0.94**	**86**	**84**

Source: The World Bank, Human Development Report, 2005,
World fact Book, http://www.cia.gov/cia/publications/factbook/index.html
http://www.undp.org.in/programme/undpini/factsheet/kerala.pdf

2 SUSTAINABLE-AFFORDABLE HOUSING: A FRAMEWORK FOR CONCEPTUALIZATION

2.1 Introduction

This chapter introduces a conceptual framework identifying different aspects of sustainable-affordable* housing for evaluating problems and formulating strategies. Housing problems are multi-dimensional and urge the reconciliation of the interests of different stakeholders. A holistic approach that gives due emphasis to the diverse elements of sustainability is needed to define it from a proper perspective. The proposed framework addresses the problems relating to human settlements and sustainable developments in developing countries based on an integrated approach from the perspective of the households (users) as well as on the concepts of sustainability. Value Focused Thinking is employed in this framework for structuring objectives and criteria.

This chapter is organized in five sections. Section 2.2 explores the concept of sustainable-affordable housing and identifies different objectives. A detailed investigation has been carried out in section 2.3 to identify the various criteria to measure the objectives defined, by covering all sectors of sustainable development. Section 2.4 presents the conceptual framework.

2.2 Sustainable-Affordable Housing

Shelter is one of the basic needs of human beings next only to food and clothing. Besides being a basic necessity, it is also a source of identity that has a considerable effect on the overall psychological well-being of the inhabitants. The perception of housing has undergone some remarkable changes over the years and has more significance in the present day world than it had even two decades ago. Home ownership brings out significant economic security and social status to a household. But for shelter-less persons it can create profound social change in their existence, by endowing them with identity, security and above all creating a feeling of being a part of the society. Housing also acts as a matrix that strengthens family and community ties. The concept of home in that sense is much bigger than that of house. It implies to the provision of food, clothing, and housing with a proper environment that affords protection from the weather, offering security and well-being. It is also a valued place

* Even though the concept of 'sustainability' includes 'affordability'; in order to give special emphasis to the extremely low economic status of poor households, sustainable housing is addressed here as "sustainable-affordable housing" throughout this research.

regarded as a refuge or place of origin where a person is able to develop his social relationships. In other words, a home fulfils physical needs by providing security and shelter from weather and climate. It fulfils psychological needs by providing a sense of personal space and privacy. It fulfils social needs by providing a gathering area and communal space for the human family, the basic unit of society. In many societies, it also fulfils economic needs by functioning as a centre for commercial production and there by generating wealth. The significance of housing in social development should not be neglected in these respects. It is also a crucial component of the built-up environment and an intrinsic element in the economic development of all nations. In this domain, housing and development activities are also related to environmental issues and technological advancements.

The human right to adequate housing is enshrined in international law and can be traced to the Universal Declaration of Human Rights, which was unanimously adopted by the world community in 1948. A focus on the right to adequate housing is thus essential for the promotion of human development.

A habitat normally refers to the area or physical environment where an organism or ecological community lives or occurs. Human habitat and human settlement are synonyms to each other. Housing is a primary component of human settlement. Human activity and economic growth affect the natural environment, and if growth is not achieved in an environmentally sustainable way, its effect on poverty and human well-being will be disastrous. Housing development thus plays an important role in achieving sustainable development. Sustainable development is often defined as development that "meets the needs of the present without compromising the ability of future generations to meet their needs" (WCED, 1987). 'Meeting the needs of the present' refers to the development aspects of sustainability, which includes economical, social, cultural and political issues. The second phrase of the definition 'without compromising the needs of the future' mostly refers to environmental issues (Ebsen et al., 2000). The Johannesburg Summit of the United Nations proposed the so-called 'three-pillar' concept (or Tripple Bottom Line-TBL model) of 'People, Planet, Prosperity (Profit)' to reflect the requirement of sustainable development as the balancing of economic and social development with environmental protection. Sustainable development can be considered as maintaining a delicate balance between the human need to improve lifestyles and feeling of well-being on one hand, and preserving natural resources and ecosystems, on which we and future generations depend.

Housing development can be considered as a pioneering step for sustainable development and has got multi-objective and multi-institutional relevance. Human settlements have to function in a sustainable way to achieve this objective of sustainable habitat. Therefore sustainable human settlement should enable to live in a manner that supports the state of sustainability and the principles of sustainable development and has institutional, social and economic systems that will ensure their continued existence (CIB, 2002). Sustainable habitat could be thus described as a way of developing and maintaining the living environment that support human health (both physical and psychological), satisfying shelter needs along with protecting and preserving the nature for future generations.

According to Gibson et al. (2005: 56-58), traditional concepts of sustainability are used to be depicted as circles of sustainability with a certain ordering; economy prevailing over society, prevailing over ecology or the other way around (Fig. 2.1). They say that since the idea prevailed that humans play a major role in the character and functioning of many biophysical systems, depictions suggesting uni-directional lines of dependency are insufficient and more often represented as intersecting circles.

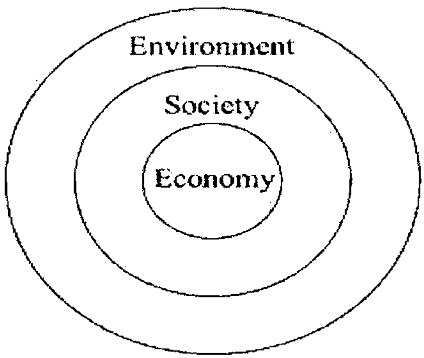

Figure 2.1 Circles of sustainability; economy immersed in society, society immersed in ecology (source: Gibson et al., 2005)

Many of the approaches on sustainability are actually examples of 'integrated assessment', derived from environmental impact assessment (EIA) and strategic environmental assessment (SEA), but which have been extended to incorporate social and economic considerations as well as environmental ones, reflecting the triple bottom line approach to sustainability. These integrated assessment processes typically either seek to minimise 'unsustainability', or to achieve TBL objectives. Both aims may or may not result in sustainable practice (Pope et al., 2004).

Sustainable housing can be conceptualized in the same way as sustainable development, to maintain a balance between the present and future housing needs. In order to satisfy the present needs, sustainable housing should be affordable to the users (particularly poor households). Thus, sustainable housing from the perspective of the users can be defined as housing that is accessible and affordable to them, and meets their housing needs. Social and cultural factors influence the primary requirements of housing.

Affordability or the economic capacity of an individual plays a significant role in achieving these requirements. Technology acts as a catalyst to help in realising this, by providing affordable options suiting the individual needs and changing circumstances. In developing countries, where the majority of housing investments are carried out through self-help or mutual help activities, sustainable technological options demand specific consideration in making the houses more affordable and feasible. But technological innovations can either accelerate or decelerate the process of sustainable development as it has got both positive and negative impacts on the environment. Protecting the environment is a fundamental aspect of sustainable development. It includes the improvement of essential ecological processes, biological diversity and the natural resource base (Veron, 2001).

The physical quality of life is very dependant on the environment in which man, who is also part in it, as an individual and as part of a group, can survive and grows physically and culturally. Often housing investments which require high investments are set apart and people have to be satisfied with poor housing conditions. The definition of sustainable-affordable housing for the poor can thus be modified as "housing which is accessible and affordable to satisfy the housing needs of people whose income does not enable them to afford their housing suitable for their needs in the formal housing market". In this definition, the term 'accessible' refers to the feasibility to fulfil those present and future needs. The basic housing need of an individual is often a reflection of his or her socio-cultural needs. In that way sustainable-affordable housing is related to *socio-cultural* (basic needs) and *environmental* aspects (present and future needs) of sustainability. The term 'affordable' in the definition mainly implies the affordability by the individual in fulfilling these needs. Innovative technological options are necessary for affordable housing solutions. In this sense it is connected to the *economic sustainability* and affordability of sustainable *technological* options. Developments in the economy and social changes should be able to sustain ecology and improve potential resources for future generations. In the context of global population growth and the Earth's finite resources, the way in which human beings are accommodated or sheltered is a major and integral part of the imperative to maintain a global environmental equilibrium. Hence sustainable building processes should be able to give emphasis on environment friendly technologies utilizing locally available waste materials and renewable resources. Therefore this framework assigns equal importance to all these four aspects of sustainability in sustainable housing and accepts their interdependence to each other.

The quadruple (People, Planet, Prosperity, and Project) concept of sustainable buildings put forward by Duijvestein is also based on the principles of sustainable development. It adds one more 'P' to the 3P concept of the UN. Hence from the triangle it changes to a tetrahedron as shown in the Fig. 2.2. This fourth 'P' for Project refers to design quality, which includes the aspects such as beauty, robustness, biodiversity and the relations through the scales (Dorst et al., 2004, http://www.boomdelft.nl/). According to this concept, the tetrahedron can be used to show the importance of and the relations between the four qualities. The most important quality can be placed on top, but in all cases has to be based on and supported by the three others.

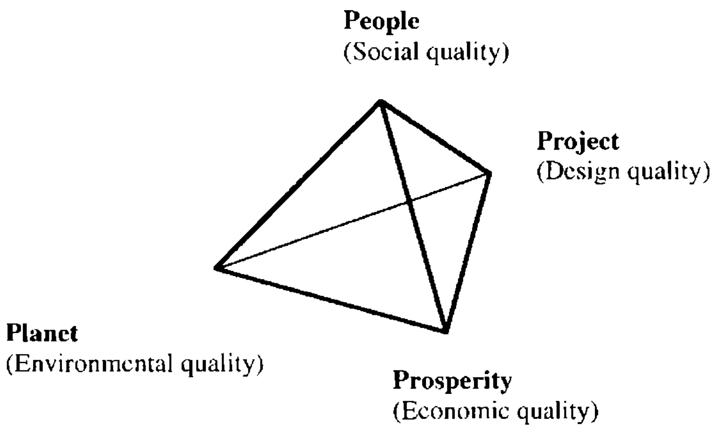

Figure 2.2 Sustainable buildings (Dorst et al., 2004)

Since sustainable-affordable housing requires sustainable and accessible technological alternatives, the traditional concept of sustainability (PPP) has to be upgraded in the context of sustainable housing with an additional technology factor. This is also in agreement with the quadruple concept of sustainable buildings put forward by Duijvestein (Fig. 2.2). The fourth 'P' for Project is directly or indirectly related to technological sustainability. Sustainable-affordable housing development can thus be conceptualized as a combination of four significant aspects of sustainability, namely socio-cultural, economic, technological and environmental sustainability. This concept is also in agreement with Islam (1996). According to him sustainability in housing may be understood in terms of ecological sustainability, economic sustainability, technological sustainability, cultural sustainability and social sustainability.

As many conceptualizations of sustainability have been around, their common denominator seems to be integration. For instance, the Millennium Ecosystems Assessment (MES, 2005) depicts linkages between ecosystems, services and human well-being, and focuses on the interactions between interrelated categories. As an alternative to the TBL, Gibson (2001) promotes the use of a principles based approach to sustainability assessment, in which sustainability criteria are derived from sustainability principles rather than TBL goals. He argues that a principles-based approach emphasizes interconnections and interdependencies between the pillar areas rather than promoting conflicts and trade-offs. Therefore, a principles-based approach could avoid some of the inherent limitations of the TBL approach to sustainability (Pope et al., 2004, 2006; Gibson, 2006). The basic model for sustainable-affordable housing proposed in this research also adopts this principle based approach based on our definition on sustainable-affordable housing for the poor.

Sustainable-affordable housing development can thus be conceptualized as a combination of four significant aspects of sustainability, namely socio-cultural, economic, technological and environmental sustainability (Fig. 2.3). After Pope et al. (2004), we also consider equal significance to the four aspects of sustainability. The interdependence of these four factors and their equality are considered as the pre assumptions of this concept (This pre supposition will be re-visited further and tested in chapter 4 under the context of Kerala).

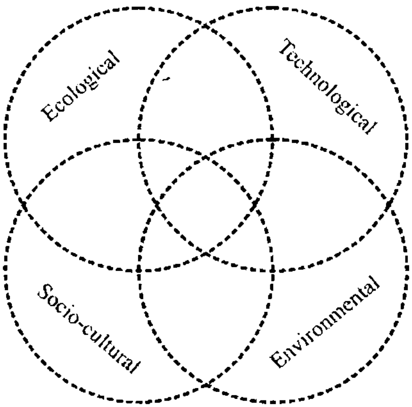

Figure 2.3 Basic concepts for sustainable-affordable housing

This basic concept for sustainable-affordable housing can be elaborated further using a methodology resembling that of Value Focused Thinking (VFT). The foundation for any analysis is a set of objectives and a set of alternatives for achieving those objectives. There are desired properties for this collective set of objectives that, when possessed, can greatly enhance the value of any subsequent analysis (Keeney, 1992; Keeney et al., 2005). According to Keeney, values are principles used for evaluation, and we use them to evaluate the actual or potential consequences of action and inaction, of proposed alternatives, and of decisions. To think of these values in a decision process: the decision should be a real problem, it should be of great importance, and it should be complex and have no absolute solution. This approach can be used to uncover hidden objectives, to direct the collection of information, to improve communication, to facilitate collective decision making, and to guide strategic thinking.

Value Focused Thinking (Keeney, 1988) is therefore a methodology that is well suited for handling these kinds of multi-objective problems. It helps in identifying the needs of the households (from the perspective of households and as well as based on the principles of sustainable development) and developing different potential solutions to meet their housing needs. The evolution and nature of housing problems differ from country to country depending on local social, economic and political contexts. This methodology provides a means to reveal and address the multiple objectives considering that all development efforts have resource constraints and facilitate in driving the project in the right direction. The succeeding section explains the significance of the different objectives of sustainable-affordable housing and their interrelations to each other.

2.3 Objectives of sustainable-affordable housing

Since housing is a primary component of habitat, sustainable housing development activities can directly contribute to the development of sustainable habitat. Sustainable habitat can be achieved through promoting housing development by balancing social progress, enhancing economic growth, propagating innovative technology along with conserving and protecting the environment and natural resources for future life and development.

As explained in the previous section, sustainable-affordable housing embraces four objectives of sustainability, namely socio-cultural, economic, technological, and environmental (Fig. 2.4). A list of criteria has been prepared to measure these objectives and assess the present housing situation based on the concepts of sustainable-affordable housing. The ensuing text explains these objectives on the basis of different criteria. It defines and structures fundamental values under each aspect of sustainability, and further guides in integral decision making.

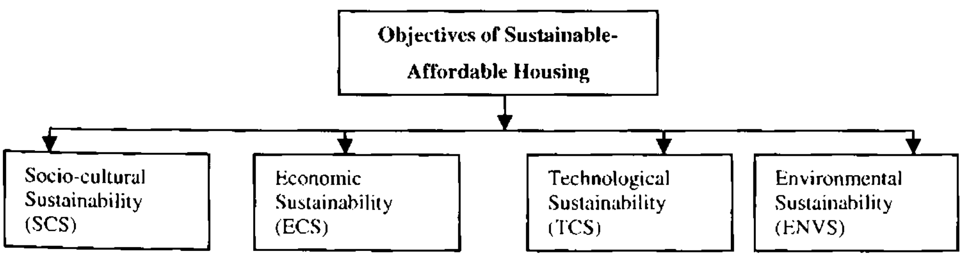

Figure 2.4 Objectives of sustainable-affordable housing

2.3.1 Socio-cultural sustainability

An adequate shelter is not only a human right, but also a base for human dignity and relationships. All human beings are knowingly or unknowingly deeply rooted in their homes, and this has a remarkably high influence in the development of their character and well-being. Proper housing helps in the free development of an individual, and creates a platform for playing an active role in the social and cultural life of the community (Springer, 2000). Social and cultural factors are strongly interdependent. They often interlock and are sometimes indistinguishable (Chiu, 2004). Sustainable housing should respond to the socio-cultural needs and practices of the beneficiary households and communities. It is focused on housing development that promotes social interaction of individuals and cultural enrichment of the community and aimed to reduce the inequality of housing between social classes (Islam, 1996). At the same time it accelerates the improvement in social developments, relations and interactions.

The various criteria for defining socio-cultural sustainability in housing have been identified as adaptability, equality, integration of amenities and services; self-help housing or beneficiary participation and community involvement (Fig. 2.5).

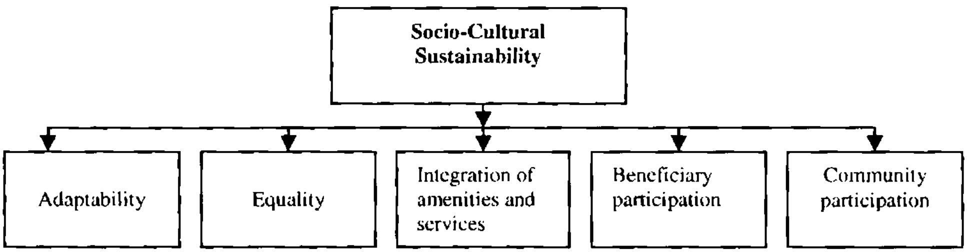

Figure 2.5 Socio-cultural sustainability

Adaptability - The concept of shelter is much broader than mere housing. It differs from individual to individual depending on household size, culture, tradition, profession and way of living. The house design should be flexible enough to incorporate the changing needs of the individuals (family size, profession etc.). The provisions for future expansions or the flexibility to changing needs is an essential criterion. For instance the housing requirements change when children are born, or grow up, or marry, get children themselves, and so on. Also in the case of professional requirements, the housing needs of a fisherman are quite different from those of a farmer. The flexibility to fulfil these varying needs is defined as the adaptability in housing.

In most communities, the house is treated as part of the identity of the individual labelling their status. People do not want to live in a house, which stigmatizes them as belonging to a low-income class, even if it is all that is affordable to them. The design and the materials used for the house should correspond to the user's way of living and local building traditions (Ebsen et al., 2000).

Equality - This objective has to be considered with utmost care as it forms the basis for socio-cultural sustainability. Equality in housing development refers to that, segregation or grouping of a particular group of people based on income, religion or any other criteria should not reflect in their housing and should not prevent them from participating in social activities. Different groups of people within the society should be able to participate equally.

This means that the poor should not be exposed or stigmatized based on a specific type of design or materials and grouping their houses to a particular region. The location and type of houses necessarily reflect social inequalities. This also affects social relationships, day-to-day living, and ultimately the future generations of the inhabitants. Briefly, the mutual relationship between housing and social structure creates a vicious circle perpetuating a lack of social privileges and inherited advantages creating a social problem (Jayaram, 1988).

Integration of amenities and services - Sustainable shelter requires the integration of essential culture or local specific amenities (privacy, security, lighting etc.) and public infrastructure facilities. It also refers to location, making the journey to work feasible. At community level, social amenities like schools, libraries, recreation centres, medical facilities, police stations need to be integrated into settlements (UNCHS, 1996).

Self-help housing and beneficiary participation - Sustainable housing development can be perceived as a means to improve the livelihood conditions and self-dependence of the inhabitants. The users build houses to suit their needs and hence self-help or participatory approach in housing brings desirable changes that lead to sustainable housing (Eldemery, 2002). Turner's three laws on housing are important in this context (Turner et al., 1972).

First Law - When dwellers control the major decisions and are free to make their contribution to the design, construction, or management of their housing, both the process and the environment produced stimulate individual and social well-being. When people have no control over, or responsibility for, key decisions in the housing process the dwelling environment may become a barrier to personal fulfilment and burden on the economy.

Second Law - Dweller satisfaction is not necessarily related to the imposition of standards.

Third Law - Deficiencies and imperfections in one's housing are infinitely more tolerable if they are his or her responsibility than if somebody else's.

Community Participation - Ensuring community participation is an important aspect of sustainable housing. For the lower income population, communal action, whether in the political, social or economic realm, permits a scale of activity impossible as individuals (Jenkins, 1999). Community development is a key to unlocking higher levels of mutual advantage as well as more effectively and equitably accessing state and economic resources. Successful community involvement requires support from the public sector through training, empowerment, financial assistance and guidance. Community participation is also necessary to develop housing clusters to create sustainable residential neighbourhoods. The possibilities are greatly multiplied when governments actively try to foster development simply by bringing people into the process (Eldmery, 2002).

2.3.2 Economic sustainability or Affordability

Economic sustainability or affordability in housing should be embedded in an economic development strategy, which strengthens the economic self-reliance of household members. Even though the housing problem arises as a symbol of poverty, mere financial assistance usually does not help the poor in providing housing. Affordability by a household in any part of the world depends on its command over the various resources required for housing. The poor often cannot afford to accept public housing assistance due to the lack of economic sustainability or affordability of the housing programmes.

Affordability by the households, their basic shelter needs, and their pre-requisites or resources for housing development has been identified as the essential criteria for measuring economic sustainability of housing (Fig. 2.6).

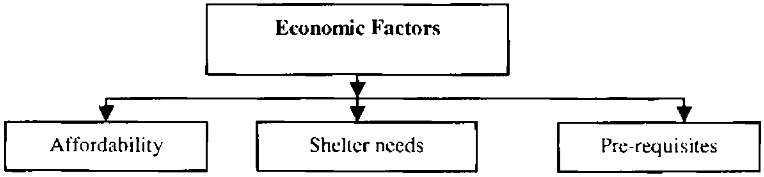

Figure 2.6 Economic sustainability or Affordability

Affordability - Affordability by the households must be given right priority before planning any housing development programme. The most important financial resources are the actual and potential savings by the inhabitants out of their income. This probably represents between 10 to 15% of all personal incomes (Turner, 1976). Housing programmes may be linked to some form of programmes like employment generation or income generation activities, enabling the poor to afford their own houses and to maintain them (Bhattacharya, 1994).

Affordability by households can be measured either by their (i) minimum capability to own a house - capability may be in terms of employment, income, assets, skills or any other entitlement for constructing and maintaining the house and (ii) their ability to repay the loan components, if any.

Pre-requisites - Access to land, resources and basic infrastructure is a pre-condition for affordable housing (Bhattacharya, 1994). Houses cannot be built and managed or maintained without resources, infrastructure and land to build on. The economic sustainability of housing is a function of the value of those resources and the costs of the ways in which they are employed (Turner, 1976).

Shelter needs - Affordable housing can said to be sustainable only if it provides basic facilities and amenities essential for the well-being of the inhabitants. According to UNCHS (1990) country-specific modes of adequate shelter are suggested as sustainable solutions since they are environmentally appropriate, economically attainable and therefore realistic. For instance, an affordable type design of a house with minimum essential facilities may sometimes unrealistic, if it cannot fulfil the basic housing needs of the households.

Millions live in poor housing conditions where there are high rates of unemployment coupled with poverty and lack of basic amenities. As the improvements and developments in society are related to economic development, socio-cultural sustainability is closely linked to economic sustainability. Economic growth is a key in providing the means to meet basic needs, to ease poverty, and to generate employment, the factors essential for sustainable development (Veron, 2001). Housing activity is closely linked to the macro-economy. It is capable of producing employment and growth. Investments in this sector not only improve and add to the existing stock of housing units, but also improve the working and living conditions. The housing sector is employment-intensive. It generates employment during the construction period and also during its life for proper maintenance providing employment opportunities for skilled as well as unskilled labour (Glaeser, 1995; Tiwari, 2001).

2.3.3 Technological sustainability

Conventional building materials are beyond the reach of the majority of the world population due to their poor affordability (UNCHS, 1993). Besides the escalation in the cost of building materials, raising environmental concerns due to the extensive exploitation of natural resources connected with general construction and other housing development activities urge the search for alternative technological options. It is now generally agreed that development in the low-income countries must proceed in parallel with a general global application of new technologies, which are both less resource intensive and less environmentally damaging (Spence et al., 1995). In both these respects, technological sustainability is connected to economic and environmental aspects of sustainability. It is also related to socio-cultural sustainability, as technological innovations reflect social demands, and those are in general culture-specific. Sustainable construction can be described as a way of designing and constructing buildings that support human health (physical, psychological, and social) and which is in harmony with nature, both animate and inanimate (Hendriks, 2001).

Feasibility, functionality, strength, durability, reliability and environmental friendliness are identified as the basic necessities for technological sustainability (Fig. 2.7).

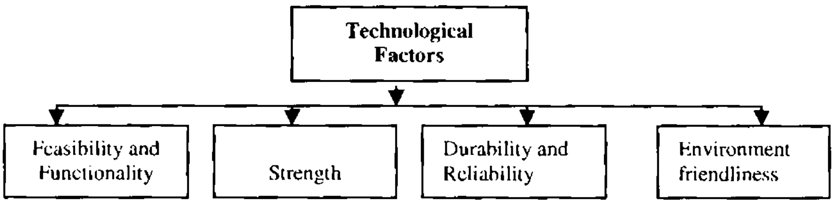

Figure 2.7 Technological sustainability

Feasibility and Functionality - The technological innovations should be feasible to the users. Technology which utilizes local resources, unskilled labour, locally available and renewable materials can be said to be sustainable. It should be able to benefit as many people as possible and should be flexible and also functional, i.e. adaptable to the changing needs of the community; at the same time it must be affordable and workable at community level.

Strength - The techniques of construction and materials used should be strong enough to meet the basic strength parameters appropriate to the local circumstances.

Reliability and Durability - These are closely related to the strength parameters and figure essential criteria for long- term sustainability. Durable refers to the property of a material, building section or construction that can resist any unacceptable deterioration of relevant functional characteristics through specific chemical, physical and mechanical loads over a certain period of time (Hendriks, 2001).

Environment friendliness - Environmental friendliness of technological options in sustainable constructions refers to the minimized usage of renewable and non renewable resources, extensive utilization of waste materials and as well as minimizing the impact of waste products and pollution.

2.3.4 Environmental sustainability

Environmental sustainability requires the alleviation of poverty if it is to be meaningful (UNCHS, 1996). Many environmental problems often actually originate from lack of development and environmental degradation, in turn leading to poverty. Overall, the concept of sustainable development suggests a potentially positive relationship between socio-economic development and environmental sustainability (Veron, 2001). The positive environmental changes generate economic empowerment, enhance social capital and build institutional capacity. In order to be sustainable, developments in the economy and social changes should be able to sustain ecology and improve potential resources for future generations. We have entered an era in which no country is isolated and secure from the impacts of the environmental conditions of its neighbours. All countries have a stake in each other's present and future well-being (UNCHS, 1990). Environmental sustainability is the most significant concept of sustainability as it takes care of the demands of future generations along with the present needs.

According to the World Watch Institute, building construction consumes 40% of the raw stone, gravel and sand, 25% of the virgin wood, 40% of energy and 16% of water used annually worldwide (Roodman et al., 1995). The construction industry is involved in activities that adversely affect the environment through the over-exploitation of non-renewable resources. It may result in stripping of top soil, destructing natural topography, resulting in problems like erosion, landslides, and also causing detrimental effects to local hydrology. This also contributes to the loss of fertile soil and to destruction of agricultural land, along with the depletion of natural resources and pollution of the environment by the emission of dust, debris and toxic gases as by products of the building process. Statistics of total energy consumption show that the proportion of energy consuming for building activities in the developing world is 35% of the total annual energy consumption. It utilizes energy for the development or production and transportation of materials and machinery, building and also for the maintenance activities.

Annually more than two million residential buildings are constructed in India apart from the construction of commercial and industrial buildings. Bulk annual consumption of materials like cement (more than 75 million tonnes), steel (more than 10 million tonnes) and bricks (more than 70 billion tonnes) for these construction activities contribute to the emission of greenhouse gases to the atmosphere (Reddy et al., 2001). Good environmental performance is important to mitigate the impact of climate change and depletion of resources to attain a sustainable habitat. The National Measures for Sustainable Building in the Netherlands include measures of six environmental themes: energy, water, materials, indoor environment, surrounding environment and miscellaneous (Hendriks, 2001).

Efficient use of renewable and non-renewable resources, proper land management, provision of healthy surroundings, basic infrastructure facilities and waste management have been identified as the basic criteria for achieving environmental sustainability in housing (Fig. 2.8).

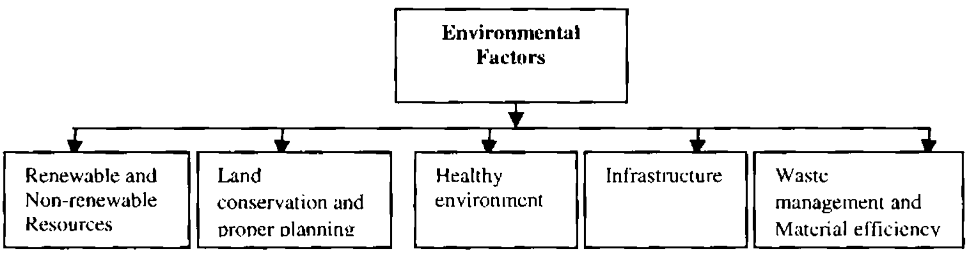

Figure 2.8 Environmental sustainability

Renewable and non-renewable resources - Minimizing or effectively utilizing the resources and promoting the usage of sustainable resources are the main concern in this context. Especially energy and other non-renewable resources in household activities and the building process need specific attention. The overexploitation of natural resources should be restricted. The recycling or reuse of water, rainwater-harvesting systems can be included as essential aspects along with basic infrastructure facilities.

Land conservation and proper planning - Modern housing development has a major impact on the environmental system. Damage to sensitive landscapes including scenic, cultural, historical and architectural must also be given due consideration. The unrestricted and unplanned growth of housing development should be prevented.

Healthy environment - The habitat as well as the nearby environment should be favourable to the healthy development of inhabitants, both physically and mentally.

Planning of both the indoor and outdoor environment need prime concern with respect to ventilation, thermal comfort and lighting through proper planning and orientation.

Infrastructure - Infrastructure can be divided into two components, social infrastructure and physical infrastructure. The social infrastructure refers to educational and health care facilities. The physical infrastructure includes water supply, sanitation, drainage, transportation, solid waste management and land management. The provision of physical infrastructure must be seen as a prerequisite to achieve sustainable human settlements (Choguill, 1996). Infrastructure development is essential to improve the quality of life for human beings as well as the protection of the environment.

Waste management and material efficiency - The processes involved in the provision and use of housing have a significant role in the contribution of solid waste. Household activities also supplement to the accumulation of waste further polluting the environment. Construction and demolition debris accounts about 15-30% of solid waste by weight representing a major component of all municipal solid waste (Kartam et al., 2004). Reducing material wastage has several benefits. It reduces global material consumption and in the long term, also the amount of demolition waste. It also reduces construction costs, making houses more affordable. When properly done, recycling waste as building materials is a convenient way to reduce the environmental impact of the construction industry (CIB and UNEP, 2002).

Environmental sustainability of sustainable housing development should consider the following objectives as basic requirements for sustainable housing developments. It should be able to ensure -

Basic infrastructure by

- Provision of drinking water
- Provision of drainage and sanitation
- Waste disposal
- Provision of electricity

Energy efficiency by

- Minimizing the use non renewable energy in daily household activities
- Utilizing alternative solutions for renewable energy

Water efficiency by

- Reuse of water
- Protecting water quality
- Rainwater harvesting methods should be integrated with housing projects

Land management

- Conservation of agricultural land
- Proper regulatory measures should be taken against uncontrolled land reclamation for clay mining, housing and other development

Indoor environment

- Improving air quality
- Improving thermal comfort

Surrounding environment

- Improving biodiversity

Waste management

- Proper disposal and recycling of household waste

Based on the above discussions on different aspects of sustainable-affordable housing, Fig. 2.9 presents an objectives hierarchy model for sustainable-affordable housing. This framework can be used for evaluating the present housing issues or formulating the guidelines for new housing projects for achieving sustainable housing development.

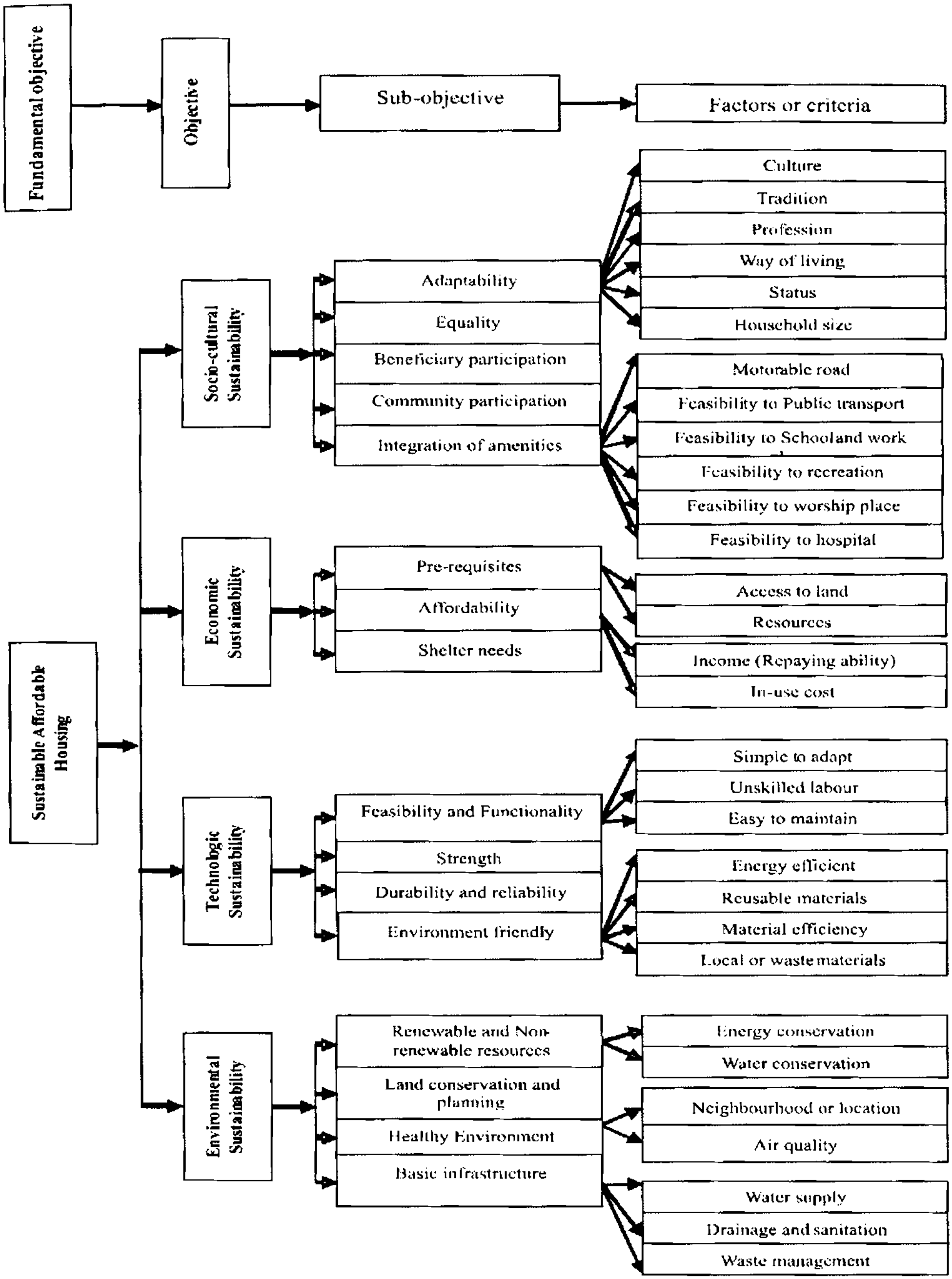

Figure 2.9 Objectives hierarchy model for sustainable-affordable housing (CF_I)

2.4 The conceptual framework for sustainable-affordable housing

The macroeconomic performance sets the overall resource framework for human settlements in all countries. Although there is a clear correlation between economic growth, the level of urbanization, the quality of shelter and basic services provided, and social indicators, there are many exceptions to this rule: policy can make a difference, even when resources are scarce (UNCHS, 1988). This advocates the need for a strong supportive institutional (policy) framework, including a wide range of inputs and expertise to deal with all different aspects, the actors involved and their actions at various levels, to accelerate and integrate the process of development in a sustainable manner.

The existence of inappropriate regulations and inefficient planning systems can also cause havoc with housing supply for the poor majority. Thus housing policy for people living in poverty has multi-objective and multi-institutional relevance (UNCHS, 1990). At the strategic level, sustainable development principles and approaches should be integrated into policy strategies and into the planning process. A hard-core policy framework is thus inevitable for the efficient working of implementation systems, which can optimize the limited resources and integrate the various actors. It is also essential to create a 'pull' from the side of beneficiaries rather than being a 'push' from the authorities in achieving the development of sustainable housing.

The proposed conceptual framework for sustainable-affordable housing (Fig. 2.10) is thus a combination of objectives (CF_1, Fig. 2.9) and strategies (CF_2) for sustainable-affordable housing. CF_1. Objectives for sustainable-affordable housing enlist the criteria for sustainable housing development, and helps in analysing the housing issues. CF_2, strategies for sustainable-affordable housing, is intended to assist in formulating policy recommendations supporting sustainable-affordable housing utilising the criteria set out in the first phase as guidelines.

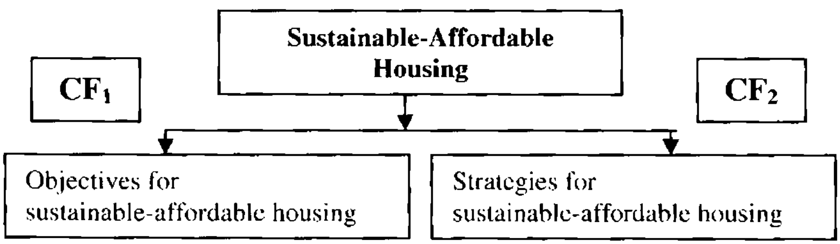

Figure 2.10 Conceptual framework for sustainable-affordable housing

Policy reforms in the housing sector require a country-specific approach of applying the appropriate instruments to the conditions, challenges, and constraints in each country (World Bank, 1993). Since housing is a region-specific activity, these strategies can be formulated only after the evaluation of housing situation using CF_1. In this framework CF_2 can be considered as a mechanism for achieving the objectives as derived from the analysis using CF_1.

2.5 Conclusion

The basic conceptual model for sustainable-affordable housing shows the interdependence of the four factors of sustainability and as well as their equality. These are the pre-assumptions of this model and will be tested under the context of Kerala.

The conceptual framework developed in this chapter can be used as a general tool for analyzing the housing problems and as well as formulating improved policies for housing the rural poor in any of the developing economies. However, this framework needs some modifications for applying to the housing problems of developed countries as it has peculiar differences in the needs, requirements and specifically in the concept of shelter from that of less developed economies.

The Objectives hierarchy model (CF_1) analyzes the needs and requirements of the beneficiaries from their own viewpoints and enlist them under the heads of different objectives of sustainable development. Based on the analysis of CF_1, strategies have to be formulated according to the requirements of sustainable-affordable housing. CF_2 brings up integrated strategies for addressing the housing problem as defined by CF_1, considering the regional requirements.

This conceptual framework will be applied and tested in this thesis in analyzing the housing situation of the poor in Kerala and formulating strategies for sustainable housing development.

3 PUBLIC HOUSING POLICY IN KERALA: HISTORY AND EVALUATION

3.1 Introduction

This chapter presents an evaluation of the public housing policies for the economically weaker sections (EWS) in Kerala. It also presents an overview of the evolution of housing policies in the developing world and subsequent changes in the low-income housing policy of India, with specific attention to the case of Kerala. A methodology based on the conceptual framework from chapter 2 is applied in the analysis. This evaluation helps to understand the problem through a sustainability perspective and investigates the success and failure factors of public intervention in housing the poor. Data for this chapter are collected mainly through review of the literature from reports of international agencies like the World Bank, UNCHS, Five Year Plan documents of government of India (details of housing policy and housing programmes) and the official reports of government of Kerala. Field observations and information from household surveys are also used for the analysis.

This chapter is comprised of five sections. After this introductory part, section 3.2 presents an overview of the evolution of present housing policy in India followed by the advancements in the developing countries. This is succeeded by the public housing initiatives in Kerala. Section 3.3 gives the evaluation of public housing schemes in the state. This evaluation has been done in two stages; (i) from the perspective of the government and (ii) from the perspective of the observer. Section 3.4 gives the conclusion.

3.2 Evolution of housing policy

Before the world wars, housing was given low priority and left to private enterprise. It only raised the attention of both national and international agencies only after the Second World War. The most significant agents were the United States and United Kingdom together with the United Nations. They offered guidance and assistance to the national governments. It was a period of pioneering initiatives in housing policies in most countries of the developing world (Harris et al., 2003). Since 1945, housing policy had undergone a major shift throughout the world. The World Bank entered the housing field only in 1973. Later in 1978, the United Nations Centre for Human Settlements-Habitat (UN-Habitat, http://www.unhabitat.org/) was established as the lead agency within the UN system for coordinating activities in the field of human settlements development.

A paradigm shift in policies has taken place from the initial 'provider' approach (1945 to 1960) to the present 'facilitator' approach (1980s onwards) through an approach based on aided self help and mutual help (1960 to 1980). The Global Strategy for Shelter (GSS) to the Year 2000, adopted in 1988, emphasized the need for improving production and delivery of shelter, revising national housing policies through an enabling strategy, and offered useful guidelines for the realization of adequate shelter for all by the beginning of twenty-first century. Thereafter, in 1996, a 'Habitat Agenda' was called for by UNCHS as a global plan of action at the second United Nations Conference on Human Settlements (Habitat), held in Istanbul, Turkey. This global agenda adopted by 171 countries contains over hundred commitments and six hundred recommendations on human settlements issues. Despite the progress in developing countries in the past two decades in low- income housing policy, the gap between policy formulation and the implementation process is widening, and the housing situation of lower income groups is far below being satisfactory (Erguden, 2001).

Homelessness or poor housing conditions often reflect the amplitude of poverty. In today's market-based society, needs are fulfilled based on the financial ability of the individual rather than its importance. As a result, the poor have to be satisfied with lowest quality of housing and living environments provided by the commercial market. They cannot afford to pay the economic rent for housing accommodation of even the minimum standards. In this context, this discussion on the public efforts in solving the housing problem should be helpful in analysing the problem and providing fruitful solutions. Particularly in India, with the highest number of poor population in the world, public support plays a significant role in ensuring adequate supply of affordable housing to the poor. The succeeding section presents a discussion on the evolution of housing policy in the developing countries and corresponding public housing efforts in India (Kerala).

3.2.1 Developing countries

The aftermath of Second World War raised a huge demand of housing throughout the world. Policies at that time were mainly guided by these demands and by decolonisation. Among the developing countries, the first countries to develop housing programs were the colonies of the European countries, and their initiatives were prompted, guided, and partially funded by their colonial masters. As decolonization proceeded during the 1950s and early 1960s, the responsibility for promoting housing policy passed from colonial governments to the United States and the Soviet Union, themselves imperial powers, and to international agencies, initially the United Nations and later the World Bank. Since the 1960s, these agencies have appeared to have a dominant influence upon the evolution of housing policy in the developing world (Editorial, Habitat International, 27, 2003). Researchers have identified three phases in the evolution of housing policy since 1945: public housing (1945–1960s), sites-and-services or aided self- help (1972–1980s), and market enabling (1980s–present) (Harris et al., 2003; Giles, 2003).

Phase I (Public housing, 1945-1960) - Public housing policy was sometimes described as 'Permanent housing for rent' (UK Information Service, 1960 cited in Harris et al., 2003). The Governments' role in the public housing policy for low-income housing was that of a 'Provider' of public housing. Houses were in the form of permanent construction units, often apartments, with the assumptions to ensure affordable and effective housing delivery, eliminating unsanitary conditions, to replace squatter settlement. But they implemented the policy in the same way as in industrialized countries without much thought about differing contexts into developing countries (Pugh, 1994). High building standards coupled with the use of imported materials made the housing expensive. Also the occupants were forced to adapt to unfamiliar living spaces, which were designed to suit European climates and cultural norms. Eventually, in a number of countries, the occupants of public projects were allowed to adapt and extend their dwellings in ways that made them both more affordable and more suitable (Tipple, 2000). Additional problems often included the challenge of managing projects. This 'product' approach, requiring large subsidies per unit, resulted in the formal sector (developers and financial institutions) and could satisfy only a fraction of household demand. Also it failed to generate the market mechanisms necessary to convert homeownership into an economic as well as a social good (Ferguson et al., 2003). Most experts, and all international agencies, soon concluded that public housing could not solve the housing problem in the developing world, and viewed it as inappropriate and expensive (Harris et al., 2003; Gulati, 1985). Solutions urged by Turner and some of his followers argued that the poor people should be aided rather than hindered in their attempts to solve their own housing problems, through self help or mutual aid.

Phase II (Sites-and-services or aided self- help, late 1960-80) - The public housing phase between 1945 and the late 1960s was replaced by an enthusiasm for 'sites and services'. Under this method, the government generally provides land, plans the lay-out of the site and circulation, secures land tenure for the occupants, and installs facilities for water supply and waste disposal or play grounds and other community needs. The building of housing units is left to the residents by whatever means is available to them. Until the early 1960s, aided self-help was consistently endorsed by the leading international housing agencies including the United States and United Nations. In addition to aided self-help, the UN emphasized enabling strategies. These usually involved support to the building and building materials industries (Giles, 2003). The World Bank's entry into the international housing field in the early 1970s is generally supposed to have opened up a new era and has had a large impact upon the theory and practice of the housing situation in developing countries. The Bank's endorsement of 'sites and services' was consistent with the UN's continuing emphasis on self-help

(World Bank, 1972). These efforts brought out considerable changes in a comparatively short period of two decades. The first phase of the Bank's theory and practice of low-income housing was based upon neo-liberalist political economy, with emphasis upon individualism, free markets, and 'user pays' principles. The state's roles were seen as facilitative and limited, mainly being expressed in providing infrastructure, utility services, and title to land. The intention was to make housing affordable to low-income households without the payment of subsidies, in contrast to the heavily subsidized public housing approach. In the years 1972-1982, the Bank took a project-by-project approach, using its financial power to steer policies towards affordability, cost recovery and replicability. Housing standards and methods of construction were to be set within affordability, using budget limits to define feasible standards rather than following professionally derived building standards to determine (excessive) budget levels. Self-help housing has relevance and significance throughout the evolutionary changes in policy from 1972 to 1993, but its significance and relevance in overall housing policy varies. In the 1970s it occupied a central position, thereafter its position changed to being an element in overall policy, which widened to include housing finance, macroeconomics, and whole housing sector development (Pugh, 1994).

Phase III (Whole sector development or market enabling, since 1980) - One of the perceptions that emerged in Vancouver UNCHS summit in 1976 was to consider human settlements as an integral part of national development. The role of the government as an enabler of public housing was called for. By the mid-1980s the World Bank also adopted a second phase approach (1983 to 1989) centred upon linking housing sector development to national economies. This fundamental shift of the governments from provider to enabler reflects a growing understanding of the importance of housing as an economic good (Zearley, 1993). It commenced with the channelling of loan assistance through housing finance systems, using these as conduits for broad allocation to households. One major thrust of these reforms was to mobilize household savings, in particular, and to draw these into the housing capital section of the capital market (Pugh, 1991). This approach had important implications in widening the agenda of housing policy reform. Policies and practices have been switching emphasis since the mid 1980s from a focus upon a project-based approach, for example, in sites and services schemes, to whole housing sector development. The third phase policy (post 1989) evolved from the second phase and was concerned with housing finance and macro-economic conditions, and it became expressed publicly in the World Bank's strategic housing policy review set to the theme of 'housing: enabling markets to work' (World Bank, 1992). The main thrust of this phase is the growth and development of the whole housing sector in its urban and national context. In a whole sector housing development perspective, policy makers and professionals have been urged to understand housing as one that connected to development policy, to the macro-economy, to anti-poverty policies, to infrastructure services, to land policies and land management, to capital market and financial systems, and with a focus upon low-income groups in their housing opportunities. The third phase joints together the World Bank, the United Nations Centre for Human Settlements, and the United Nations Development Programme (UNDP) (Pugh, 1994). UNCHS serves as a focal point for monitoring progress on implementation of the Habitat Agenda. The available information suggests that follow-up activities on the Habitat Agenda's goal of "adequate shelter for all" have strengthened the focus on the implementation of the Global Strategy, with specific reference to promoting the principles of enablement, partnership and participation, as well as to topics related to the realization of housing rights, improvement of the access of low-income groups to elements of shelter delivery (such as land, finance and building materials) and the diversification of shelter policy to more effectively address the needs of vulnerable groups and people with special needs. The implementation of the Habitat Agenda has also strengthened the trend of utilizing the shelter sector as a driving force for the promotion of economic development and as an effective entry point for poverty eradication and social development. Perhaps the single most important development in policy and planning over the last two decades has been the shift to the "enabling approach". The underlying philosophy of the enabling approach seems to be accepted by all, yet concrete implementation remains weak, and many countries lack the detailed time-frame, sub-objectives and resources required to turn policies into strategies (UNCHS, 1996).

The public housing approach in India also had gone through a series of changes over the years since independence before getting its present form of national housing and habitat policy. It exhibits a similar kind of policy shift as in other developing countries from the earlier Public Housing phase to the present whole sector development concept.

3.2.2 Housing policy: India

There were no major officially sponsored housing programmes in India before independence (1947) other than a few isolated attempts to house their employees by the central and provincial governments. Independent India was facing crucial problems like rehabilitation of refugees, migration of rural population to urban areas, high population growth rate like most of the other newly independent countries. About 7.5 million displaced persons came into India from Pakistan and the problem had been tackled to a great extent by providing planned colonies and townships in various parts of the country. It is in this connection that the central government undertook a first large scale housing programme for persons other than their employees. Ulhas Nagar near Mumbai, Sardar Nagar near Ahmedabad, Gobindpur and Hastnapur in Uttar Pradesh, Chandigarh, Faridabad and Nilokheri in Punjab are among the major colonies constructed for the refugees.

The immediate responsibility of the government of independent India was the provision of reasonably decent accommodation in the urban areas within the limited funds. They followed a central planning model of development through the Five-year Plans and various social housing schemes for different sections of the society were introduced to solve the housing problem in India. Right from the first Five-year Plan period (1951-56) housing has been given importance, though not adequate when compared to the magnitude and nature of the problem. Financial allocation for housing as a percentage of total investment in the economy was as high as 34% in the first Five-year Plan but has come down to as low as 2.4% in the tenth (2002-07) Five-year Plan (Five-year Plan documents; Rao, 2004). The ensuing text presents the details of different housing programmes introduced by the central government through the Five-year Plans.

In the first Five-year Plan (1951-56), the emphasis was given on institution building and on construction of houses for government employees and weaker sections. But during the second Plan period (1956-61), the scope of housing programmes was extended to a greater extent to the poor. The government adopted the concepts of welfare state and gave priority to housing the masses in decent environment, especially slum dwellers, industrial workers and low-income groups. One of the earliest efforts in the matter of public housing was the social housing scheme introduced during this period.

The integrated subsidized housing scheme for industrial workers and other economically weaker sections in the society (1952) is considered as a landmark in India's social housing history. The scheme was meant to provide developed plots or two-roomed single or multi storey houses on a rental basis subject to certain cost ceilings. Minimum standards were also ensured for the houses under this scheme. The central government provided fifty per cent subsidy and the rest as loan to state governments, or Statutory Housing Boards, employers and registered co-operative societies of industrial workers for construction of tenements. It was decided in 1979 to transfer the tenements to the occupiers at actual cost on hire purchase basis.

The Low-income group (LIG) housing scheme (1954) was initially intended to provide loans or grants to persons whose annual income does not exceed Rs. 6000 (€ 120) to meet their housing requirements. Later during the third Five-Year Plan it was extended to weaker section of the community with an annual income of Rs.1800 (€ 36) and less. The assistance was restricted to 80% of the estimated cost of construction, including land and was subjected to a maximum of Rs. 8000 (€ 160). The implementing agencies were governmental and semi governmental organisations and cooperatives.

Subsidized housing scheme for plantation workers (1956) was introduced to assist the planter companies to provide housing for the plantation workers with the help of loans and subsidies from the central government. Small two-roomed houses with low ceiling costs were provided.

Slum clearance and improvement scheme was introduced in 1956 in the central sector to provide for the rehabilitation of slum families and also for improvement of slums. The tenements were constructed by slum clearance boards and housing boards and the slum dwellers were charged nominal rents. This scheme was transferred to the state sector in 1969.

<u>The village housing project scheme (1957)</u> provided the grant of loans for construction of houses by villagers to the extent of 80 per cent of the cost of construction.

The formal housing finance sector in India had its beginnings in the 1960s when the government, through its various schemes for public and low-cost housing, was the sole provider of housing finance. All the schemes at that time provided housing loans at lower rate of interests but could not reach the lowest strata of the society. The rental-housing scheme provided rented accommodation could also benefit the employees of the state government only.

The housing programmes in the third Plan (1961-66) were focused on the co-ordination of efforts of all agencies and orienting the programmes to the needs of low income groups.

<u>Subsidized rental housing scheme for the EWS introduced</u> during 1964-65 provided the poor with either developed plots or two roomed house in a developed plot on rent. The land acquisition and development scheme introduced during this period also made developed plots available at reasonable prices to people belonging to lower income groups.

The balanced urban growth was the high priority of the fourth Plan period (1969 to 1974).

<u>Environmental improvement of urban slums</u> was undertaken during 1972-73 and provided financial assistance to the states for expansion of water supply, sewerage, paving of streets, the provision of community latrines, etc., in slum areas.

1970s marked two significant developments in the housing finance sector. During this period a public sector housing company, Housing and Urban Development Corporation (HUDCO in 1970) and the first private housing finance company (HFC), Housing Development Finance Corporation (HDFC in 1977) were established. HUDCO served as the principal institution to finance government-supported housing programs, whereas HDFC introduced mortgage financing to India and has become the largest and most successful in the country.

The main thrust of the programmes in the fifth Plan (1974-79) was directed towards ameliorating the conditions of the backward sections of the society by augmenting the programmes for the construction of housing colonies by state housing boards and provision of house sites for landless labourers in rural areas.

During the initial phases (1950to1979) of social housing, the schemes were mainly directed towards the construction of formal housing. Apart from the houses constructed for slum dwellers and industrial labourers, the only section of people who benefited specifically from public sector support for housing has been the employees of the government and public sector enterprises. During this period the houses constructed for low income groups totalled only about 336,000 (sixth Five year Plan report). The government's realization of the ineffectiveness of its programmes, together with their unwillingness or inability to increase the housing investment, has led to a gradual change in policy and pursuance of programmes that involving 'site and service' and self-help (Slingsby, 1989). Self-help housing, innovative construction techniques and utilization of the local building materials gained more importance and was promoted during this phase. The 'Minimum Needs Programme' and the 'Twenty Point Economic Programme' introduced during the Fifth Plan aimed at improving the housing situation of the poor.

The housing programmes during the sixth Plan (1980-85) put emphasis on integrated provision of services along with shelter. Construction of houses was included as one of the major activities under the National Rural Employment Programme (NREP-1980) and Rural Landless Employment Guarantee Programme (RLEGP-1983).

The increasing housing demand forced the government to entrust major responsibility of house construction to the private sector. A three-fold role was assigned to the public sector during the seventh Plan (1985-90) period, namely mobilisation of resources for housing, provision for subsidized housing for the poor and acquisition and development of land. The role of institutional finance and the promotion of building material technology were also given due priority in the Seventh Plan. In 1988, the National Housing Bank (NHB) was established as an apex bank for housing finance. The National Housing Bank's responsibilities include establishing guidelines for housing finance institutions to ensure sound financial management, refinancing mortgage loans made by qualified housing finance institutions, and mobilizing formal sector resources into housing finance. Based on the success of HDFC a number of new housing finance companies were subsequently established during the 1980s to enter into the mortgage lending market.

Indira Awaas Yojana (IAY) was launched during 1985-1986 with the objective of providing assistance to the Below Poverty Line (BPL) rural households. Selection of construction technology, materials and design was left entirely to the choice of beneficiaries. From the year 1993-94 the scope of IAY was extended to cover non-scheduled castes and scheduled tribes and below-the-poverty-line families in the rural areas.

Even though housing activities in India were guided and monitored through the policies prescribed in the successive Five-year Plans, there was no clear pronouncement of an integrated policy covering all issues relating to housing. Housing has got a new thrust after the proclamation of 1987 as the International Year of Shelter for the Homeless (IYSH), by the United Nations. A comprehensive National Housing Policy (NHP) was drafted in 1987 in connection with the IYSH initiatives in India.

The post-1990 period can be seen as the era of housing sector reforms in India. Massive housing programmes have been launched, throughout the country by the respective state governments. Keeping in line with the UN declaration of Global Shelter Strategy 2000, the government of India reformulated the housing policy and introduced as the National Housing Policy (NHP) of India in 1992. The recognition that the physical dwelling unit is not the sole element of housing and that the provision of basic services like potable water, sanitation, drainage, electricity and such other services are integral to housing was reflected in the housing schemes during that period.

During the eighth Plan (1992-97) period, significant activities were undertaken towards the implementation of Agenda 21, endorsed at the Rio de Janeiro environment meeting of 1992. This document had laid stress on the deteriorating situation in human settlement conditions, assessed to be a result of low levels of investment because of resource constraint and recommended promotion and improvement of activities in eight priority areas. There is an enormous shortage in the housing sector and major deficiencies in the housing-related infrastructure. The key objective of the NHP-1994 was to provide access to adequate shelter for all. This necessitated a policy shift to encourage the private and cooperative sectors to play a major role in housing sector, modifying the existing legal and regulatory regime. This position was reiterated and elaborated in the National Housing and Habitat Policy* (NHHP) of 1998. This policy aims in providing "Housing for all" with an emphasis on extending benefits to the poor and deprived. It has spelt out its objectives and priorities as follows:

- To create surpluses in housing stock and facilitate construction of two million additional dwelling units each year in pursuance of National Agenda for Governance.
- Providing affordable, good quality shelter options for the citizens, especially the vulnerable group and the poor.

* http://www.ciionline.org/sectors/61/Images/nhhp1998.pdf (Accessed on 22'nd May 2006).

- Ensuring infrastructure facilities and easy accessibility to drinking water and basic sanitation to all dwelling units.
- Facilitating the easy access to land, finance and technology.
- Progressive shift from a subsidy based housing scheme to cost sharing or cost recovery-cum-subsidy schemes for rural housing.
- Protecting and promoting the cultural heritage, architecture and traditional skills.
- Using the housing sector to generate more employment and achieve skill up gradation in housing and building activity.
- Using technology for modernizing the housing sector to increase efficiency, productivity, energy efficiency and quality.

The ninth Plan (1997-2002) gave special attention to households at the lower end of the housing market. The government shifted to the role of a facilitator with the concept of sustainable development. An action plan for rural housing has accordingly been prepared. Several innovative schemes were introduced by the central government in 1999, namely the credit-cum-subsidy scheme, Innovative stream for rural housing and habitat development, Samagra Awaas Yojana and Rural building centres to achieve 'shelter for all' by twenty-first century, and to accelerate the process of sustainable development.

The credit-cum-subsidy scheme for rural housing was launched to facilitate construction of houses for rural families who have some repayment capacity. The scheme aimed in eradicating homelessness from the rural areas of the country. The funds shared by the central government and the states were in the ratio of 75:25. The target group under this scheme is rural households having an annual income up to Rs. 32000/-. However, below the poverty line, rural households were given preference.

Innovative stream for rural housing and habitat development was introduced with a view to encourage the use of cost effective, environment-friendly, scientifically tested and proven indigenous and modern designs, technologies and materials. The objective of the scheme was to promote or propagate innovative and proven housing technologies, designs and materials in the rural areas.

The Samagra Awaas Yojana was introduced with a basic objective to improve the quality of life of the people as well as overall habitat in the rural areas. The scheme facilitates convergence of the activities of different departments involved in rural development such as housing, sanitation, drinking water, electricity, rural technology etc.

The ministry of rural development has launched a scheme facilitating the setting up of a network of Rural Building Centres (RBC) through the length and breadth of the rural areas during this period. The scheme represents the spirit of the enabling strategy by which access to appropriate technologies and capacity building at the grassroots level is achieved for affordable housing. A rural building centre could be set up by the state governments, rural development agencies, credible Non-Government Organizations (NGO), private entrepreneurs, professional associations, autonomous institutions and corporate bodies, including public sector agencies provided that they have the minimum requirements as specified by the central government (NHHP).

Table 3.1 gives a list of all the social housing schemes implemented by the government of India since independence. It is interesting to see the replication of same kind of policy shift as the one that noticed in the housing policy put forward by the international agencies.

In the same way during the initial phase (Phase I) from 1945 to 1960, government of India took the role of a provider of public housing. This was followed by sites and service and aided self help as the second phase from late 1960 to 1980. The third phase (1980 to present) with the facilitator approach along with promoting the sustainable habitat concept through housing programmes shows progressive shift for rural housing strategies from target orientation to a demand driven approach. This is well reflected in the housing programmes of the current Plan period (2002-07) also.

However, in India housing being a state subject, housing policy is required to be essentially formulated and implemented by state governments and local governments. Each state government is required to frame its own approach to the problem of human settlement; following the guidelines in the national housing policy. The ensuing text explains the corresponding changes in the housing situation of Kerala and the political approaches of the successive governments during those periods.

Table 3.1 Different Housing Schemes of the Government of India

No:	Housing Scheme	Year of Launch	Target groups	Policy shift
1.	Integrated subsidized housing scheme for industrial workers and EWS	1952	Industrial workers and other economically weaker sections	**Phase I** Public Housing **(1945 to 1960)**
2.	Low income group (LIG) housing	1954	Low income group household with regular income	
3.	Subsidized housing for plantation workers	1956	Plantation workers	
4.	Slum clearance / improvement scheme	1956	Rehabilitation of slum dwellers	
5.	The Village housing projects scheme	1957	Villagers and landless agricultural workers	
6.	Middle Income group (MIG) housing scheme	1959	Loan scheme for middle income groups	
7.	Rental housing scheme for state government employees	1959	State government employees	
8.	Subsidized Rental housing scheme for E.W.S	1964-65	Economically weaker sections	**Phase II** Site-and – Service And Aided Self- help **(1960 to 1980)**
9.	Provision of house sites to land less agricultural labourers	1964	Landless workers in rural areas	
10.	Land acquisition and development scheme	1967	Slum dwellers, industrial workers, LIG and MIG households	
11.	Environment improvement of urban slums	1972	Slum dwellers	
12.	Minimum Needs Programme	1974	Rural landless labourers	
13.	Rural house site cum house construction scheme	1980	Landless rural poor	
14.	Rehabilitation Housing Scheme	1984-85	Households who lost their houses in natural calamities and belonging to EWS	**Phase III** Market enabling (Facilitator or Whole sector development) **1980s** onwards
15.	Indira Awas Yojana	1985	Economically weaker sections	
16.	Rajiv One million Housing Scheme	1987	Economically weaker sections	
17.	Night shelter scheme for pavement dwellers	1990	Pavement dwellers	
18.	National slum development programme	1996	Slum dwellers	
19.	Two million housing programme	1998	Economically weaker sections	
20.	Samagra Awaas Yojana (SAY)	1999	Economically weaker sections in rural areas	
21.	Credit cum subsidy scheme for housing	1999	Rural households with repayment capacity	
22.	Innovative Stream For Rural Housing & Habitat Development	1999	Economically weaker sections in rural areas	
23.	Vaalmiki Ambedkar Awas Yojana (VAMBAY)	2001	Economically weaker sections in urban slums	

3.2.3 Housing policy: Kerala

State intervention in the housing sector in Kerala was initiated in 1950. Until 1970 it was limited to implementing the schemes of central government, and the progress was unimpressive mainly because of the low priority to housing and lack of mechanisms to implement housing schemes. The various housing schemes implemented in Kerala till 1971 had produced only less than twenty-five thousand houses in twenty years (Paulose, 1988). The Kerala State Housing Board (KSHB) was constituted in the year 1971 with a view to formulate and implement various housing construction schemes, as well as housing loan schemes for catering the housing needs of public belonging to various income groups in the state. The Kerala State Housing Board implements various scheme, and its main sources of finance are institutional loan from HUDCO, LIC (Life Insurance Corporation), HDFC and grants from the state government. The board has so far (1971-2001) assisted the construction of 575,000 houses under various schemes, out of which 79% are for economically weaker sections (Government of Kerala, 2001). However, the major plan schemes implemented by the housing board are Subsidized Aided Self-Help Housing Scheme (SASH), Rehabilitation housing scheme, the Co-operative housing scheme for economically weaker sections, the subsidized self help housing scheme and Chengalchoola slum improvement scheme.

The first massive housing scheme, the <u>One Lakh Housing Scheme</u> (OLHS) for the poor with community participation was implemented in Kerala during the year 1972-76. This was a pioneering initiative of the state government, and it marked a remarkable change in the low-income housing situation of Kerala. It was designed for the poor landless agricultural labourers, who have not received homesteads under the Kerala Agrarian Relations Act. In 1971, the government of India announced a scheme for giving free house plots to landless agricultural workers all over India. The state government decided to give houses also practically free of cost along with this. Funds were raised by collecting donations from the public, free labour from members of voluntary agencies, students and beneficiaries themselves. At the time of launching the scheme there were 960 panchayats in the state. The target was fixed at the rate of hundred houses in each panchayat and thus a total of 96,000 (roughly 100000-one lakh) houses, but they could finish only 60,000 houses. The scheme was discontinued in 1976-77, mainly because the government had decided to evolve new schemes to benefit a higher number of households. The main feature of the scheme was that no expenditure was incurred for overhead costs and services. Both administrative and technical assistance were made available through the voluntary efforts put up by officers and public.

The report and recommendations of the expert committee appointed by the state government to evaluate the OLHS emphasized the importance of beneficiary participation and the involvement of voluntary agencies. These recommendations lead to the launching of a new scheme in July 1983 named as "<u>Subsidized Aided Self-Help</u>

Housing Scheme" (SASH) for the economically weaker sections. The scheme is called 'aided' because the voluntary agencies and the government help the beneficiaries in mobilizing finance, arranging technical assistance, procurement of materials etc. One third of the cost was given as subsidy by the government. The details of SASH were worked out in a systematic manner by analyzing previous schemes, adopting cost reduction techniques in housing and by involving voluntary agencies. A clear shift in governmental policy is visible in this scheme from the earlier schemes by introducing the involvement of voluntary agencies and beneficiary participation.

The devastating damage due to natural calamities during 1984-85 had rendered thousands of families in the state homeless. The government of Kerala launched a new scheme namely Rehabilitation housing scheme with a view of rehabilitating the economically weaker sections in rural areas, who lost their houses. The scheme is designed in such a way as to tap the available institutional finance to the maximum extent possible, especially from such agencies as housing and urban development corporation, consortium of banks, the housing development finance corporation etc.

The Nirmithi Kendra movement was started during this period (1986) at Kollam district, with the objective of promoting Cost Effective and Environmentally Friendly (CEEF) techniques for the construction of houses. This model was acknowledged by the central government in 1988 and decided to establish as a network of 'Building Centres' throughout the country in each districts with the help of HUDCO. Later in 1989 Kerala State Nirmithi Kendra (KESNIK) was established as an apex body to District Kendras in Kerala.

The housing programmes for the Eighth Five Year Plan (1992-97) were in accordance with the national housing policy. The priorities and programmes are designed as a sub-set of the long term policy orientation. The government of Kerala also formulated its housing policy in 1994 in line with the national housing policy. The salient features of the housing policy put forward by the state are the following.

- Distribution of house plots free of cost to landless workers in rural areas.
- Direct and indirect subsidy for house construction to weaker sections.
- Involving voluntary agencies co-operative societies and beneficiaries themselves in the housing process.
- Experimentation and propagation of new construction techniques and improved building materials.
- Imparting training to masons in new construction techniques.

- Ensuring basic facilities by providing drinking water, sanitary latrines, and smokeless chulahs[‡] in a phased manner.
- Mobilization of financial resources for housing from financial institutions like HUDCO, HDFC, LIC, Nationalized banks etc.

Table 3.2 gives an overview of the major EWS housing schemes in Kerala. Apart from the state government schemes, central government schemes (Centrally Sponsored Schemes-C.S.S) are also implemented through different departments and local government agencies within the state. The rural development department of each district is engaged in the implementation of centrally sponsored schemes through the different block Panchayats.

Among the schemes listed in Table 3.2, only few of the central government schemes are implemented in Kerala. Indira Awaas Yojana (IAY 1985-96), Rajiv one million housing scheme (1987-92), Credit cum subsidy scheme for housing (1999), Samagra Awaas Yojana (SAY, 1999) are the major centrally sponsored schemes implemented in the state.

Maithri Housing Scheme is the most recent scheme of Kerala State Housing Board introduced in 1996. Under this scheme, it was proposed to construct 100,000 houses per annum. Beneficiary selection was done by the grama panchayat through the grama sabhas according to the guidelines of this scheme. Till the end of the year 2004, KSHB has assisted the construction of 282,238 houses under this housing scheme (Government of Kerala, 2004).

From the ninth Five year Plan (1997-2002) onwards the local governments are actively involved in housing. People's Planning Campaign - PPC (Appendix 3.1), a process of democratic decentralization launched in Kerala in August 1996 with the aim to achieve sustainable development through people's participation in the planning and implementation process, addressed twelve sectors of development including housing and social welfare. Total Housing Scheme was an ambitious project undertaken during people's planning campaign for fulfilling the housing needs of the poor in three major districts of the state namely, Thiruvananthapuram, Kollam, and Thrissur. It was planned to solve the housing problem by people's participation. Along with the three main organizations involved in cost-effective building construction in Kerala such as Habitat Technology Group, Costford, and the Nirmithi Kendra; HUDCO and the government engineering department were identified for implementing the scheme. During the first two years of the campaign 98,494 houses were constructed, equivalent to about hundred houses in each panchayat.

[‡] Energy efficient oven for cooking

Table 3.2 Achievement of major E.W.S housing schemes: Kerala

No	Scheme	Total number of houses	Implementing agency	Target groups	Policy approach
1	Subsidized Housing Scheme for Industrial Workers	1120	Central Government	Industrial workers and Mine workers	
2	Village housing project Scheme (1958)	10606	Central Government	Economically weaker sections	
3	Subsidized Rental Housing scheme for E.W.S(1964-65)	5336	Central Government	Economically weaker sections	
4	Huts/Houses for rural workers	11698	Central Government	Rural workers	**Phase I** Public Housing
5	Low income group housing Scheme	30984	Central Government	Low income group household with regular income	
7	Kudikidappukar Housing Scheme	7306	Central Government	All the 'Kudikidappukars' (free tenants)	
8	Provision of house sites to landless agricultural labourers (1964)	36789	Central Government	Landless agricultural workers	
9	One Lakh Housing Scheme(1972)	60,000	State Government	Landless agricultural workers and economically weaker sections	
10	Co operative housing scheme for economically weaker sections	54589	State Government	Economically weaker sections in the rural areas.	
11	National Rural Employment Programme (N.R.E.P- 1980)	30426	Central Government	Rural unemployed youth	
12	Rural Landless Employment Guarantee Programme	40829	Central Government	Rural unemployed youth	**Phase II** Aided Self-help or Mutual help (With partial financial assistance)
13	Subsidized Aided Self-help housing scheme with cooperation of voluntary agencies	29675	State Government	Economically weaker sections	
14	Rehabilitation Housing scheme (1984-85)	165739	State Government	Households who lost their houses in natural calamities and belonging to EWS	
15	Jawahar Rozgar Yojana/ Indira Awas Yojana (1985)	127480	Central Government	Economically weaker sections	
16	Scheduled Caste(SC)/ Scheduled Tribe(ST) Development corporation	44840	State Government	Economically weaker sections Belonging to SC or ST	
17	Tribal welfare Department	11558	State Government	Economically weaker sections Belonging to ST	**Phase III** Market enabling Or Facilitator and Whole sector development
18	Scheduled Caste(SC) Development Department	51787	State Government	Economically weaker sections Belonging to SC	
19	Fishermen Housing	61299	State Government	Fisher folk	
20	Kerala State Co-Operative Housing Federation	142400	State Government	Economically weaker sections	
21	Flood Loan Schemes (1992)	15,235	State Government		
22	Maithri Housing Scheme (1996)	2,63,778	State Government	Economically weaker sections	
23	Total Housing Scheme (1999)	98,494	State Government	Economically weaker sections	

The review of the evolution of the present housing policy in Kerala reveals a reflection of global policy changes during the corresponding periods, but with minor modifications to cope with the interests of political leaders and policies of the respective governments. State government intervention in public housing was a remarkable turning point in the housing policy of Kerala. It was pioneered by the launching of OLHS, with the role of the government partially as a 'provider' of public housing. Even though the International agencies that were constantly advocating public housing have shifted their role from this approach by that time (1970s), the government of Kerala promoted this with few modifications. The beneficiaries got the houses almost free of cost but with a minor financial contribution.

The housing schemes implemented during the fifth Five year Plan (1974-79) addressed the issue of rural housing as part of the minimum needs programme. The basic principle of shelter provision under this scheme can be said to be one of 'aided self-help', whereby the government selects the potential users (beneficiaries), arranges for financing and administrative procedures, and the users provide the entire or part of the labour input. This, new shift in policy was in line with the international policies based on aided self-help and mutual help marking the second phase. The rural employment programmes like National Rural Employment Programme (NREP) and Rural Landless Employment Guarantee Programme (RLEGP) introduced during those periods also followed the same approaches together with IAY/JRY. This shift in policy is also vivid in the 'Subsidized Aided Self-Help Housing Scheme (SASH)', launched in Kerala during 1983-1985.

The 1990s witnessed significant changes in housing policy starting with the NHP, which envisaged the government's role as a facilitator of housing activity, rather than one of provider; this position was reiterated and elaborated in the National Housing and Habitat Policy of 1998. As a result, government contributions to housing finance have fallen to less than nine percent, compared with twenty three percent, four decades ago (Asian Development Bank, 2000). This policy, which addresses the issues of sustainable development, infrastructure and strong public private partnership for shelter delivery, is truly a mirror image of the whole sector development concept of UN and World Bank and is also well reflected in the present housing schemes (Credit cum subsidy scheme for rural housing, Rural building centres, Total housing scheme etc.) of the country. In 1996, with the decentralization movement, local governments started getting involved in different development activities. The 'Total Housing Scheme (THS)' was introduced during this period (1998) with the concept of whole sector development with the local or self government as the implementing agencies.

Proper housing delivery is essential for sustainable housing. The housing delivery process in Kerala will not be clear without addressing this. Appendix 3.2 of this chapter explains the roles of different actors and stakeholders involved. Succeeding sections present an evaluation of the public housing schemes in Kerala based on the conceptual framework.

3.3 Evaluation of public housing schemes : Kerala

The housing situation in Kerala is rather different from other parts of India. Public housing schemes in this state were showing greater performance in terms of magnitude in investment and physical achievements and in considerably reducing the housing gap. About eighty percent of the housing support provided by the state during the last three decades has gone to economically weaker section housing. The average increase in the housing stock was sixteen percent during the period of 1991-2001 as against the population growth of nine percent (Government of Kerala, 2004). Despite the positive trend in the housing conditions, a close analysis shows that the poor and lower segments in the society very often do not get the necessary assistance for the actual construction and completion of houses. Though the poor manage to get support, projects often fail due to many reasons. The recent census report of India (Government of India, 2001) shows that among the total population in Kerala 14% has no access to drinking water and 16% has no toilet facilities. Visible slum-like areas occur in human settlements in rural parts of the state with many inhabitants still deprived of basic facilities like drinking water and sanitation. All these necessitate the evaluation of public housing in Kerala.

It is difficult to carry out the evaluation of all schemes due to their enormous numbers, and it is also not necessary due to the similarities among the schemes. Hence a proper selection has to be done from the major schemes for making the evaluation more meaningful.

3.3.1 Scheme selection and peculiarities

Three schemes are identified from each phase on the basis of their representative nature in policies with those of the international agencies, their uniqueness in implementing agencies and other peculiar characteristics. The schemes chosen are (i) One Lakh Housing Scheme, (ii) Indira Awaas Yojana and (iii) Total housing scheme. Table 3.3 gives an idea of the selection criteria and peculiarities of the selected schemes.

Table 3.3 Scheme selection and peculiarities

Distinctive phases in Policies and Approaches	Housing Schemes selected	Implementing agencies	Peculiarities of the schemes
Provider Approach **Phase I**	One Lakh Housing Scheme OLHS (1972)	State government	First scheme implemented by the state government. It could create a revolutionary movement in the low income housing scenario of Kerala with the involvement of the entire state. Massive scheme
Aided Self- help/ Mutual help approach **Phase II**	Indira Awaas Yojana IAY (1985)	Central government	Centrally Sponsored Scheme Beneficiaries are responsible for the entire building process, making a feeling of proud and involvement in their house building.
Facilitator / Habitat development concept **Phase III**	Total Housing Scheme THS (1999)	Local/Self government	First scheme implemented by the local governments A series of training camps were organised to achieve 'Habitat Literacy' in the application of appropriate technologies, which are cost-effective, environmental friendly using locally available and affordable materials responding to physical, social and climatic needs of the region. Insisting beneficiary participation and local people in the construction activities. Massive programme.

3.3.1.1 One Lakh Housing Scheme (OLHS)

This was the pioneering initiative of the state government in the public housing situation of Kerala. Any family with out a house site of their own belonging to economically weaker section was eligible to get a house under this scheme. Beneficiary selection was done under the direct supervision of concerned panchayats and controlled by the district collector. Each household was required to pay a nominal amount in eleven equal monthly instalments.

Funding of the project - Funds were raised by collecting donations from the public, free labour from members of voluntary agencies, students and the beneficiaries themselves. Each earning member in the state was requested to donate at least one day's income to the scheme fund. All students in the state had contributed to the housing fund. The main idea was to create a feeling on involvement in the minds of the people and to make them proud of having participated in this great movement of helping the poor and shelter less in the state. The main feature of the scheme was that no expenditure was incurred for overhead costs, such as appointment of additional staff, purchase of tools and plants etc. All services, both administrative and technical were made available through the voluntary efforts put up by officers and public.

Type design - There was only one type design for the entire state. Each block has two houses in a back-to-back position with the longer wall as the common wall with two rooms and a kitchen with in a total plinth area of 23 sq.m.

Technical specifications - The houses were built by locally developed materials utilizing cost reduction techniques.

3.3.1.2 Indira Awaas Yojana (IAY)

Indira Awaas Yojana was launched during 1985-86, aimed in providing houses free of cost to rural people below the poverty line belonging to scheduled casts and scheduled tribes (SC/ST), freed bonded labourers and non-SC/ST people. It is a Centrally Sponsored Scheme (CSS) implemented by the state government. The fund distribution and work management were carried out by District Rural Development Agency (DRDA). Financial assistance was shared in the ratio 75:25 between the central and the state governments.

Selection of beneficiaries - Grama panchayat did the selection of beneficiaries through grama sabhas restricting the number to the target fixed by DRDA, from the list of eligible households, according to IAY guidelines and as per priorities fixed. The minimum requirement for eligibility under this scheme was the ownership of land (minimum of eighty square metres).

Type design - No type design was prescribed for this scheme except that the plinth area of the houses was restricted to be around twenty square meters. The houses should be designed in accordance with the preferences of the beneficiaries keeping in view the climatic conditions and the community perceptions and cultural attitude. Construction of sanitary latrine and smokeless Chula forms an integral part of IAY houses.

Involvement of the beneficiaries - Beneficiaries are responsible for the whole building process.

Financial assistance - IAY is a fully subsidized scheme and under this the entire money was distributed to the beneficiaries in four equal instalments. The beneficiaries were able to receive the instalments only after the completion of each specified stage of construction.

Technical specifications - Technical specifications for IAY houses proposes the use of local materials and low cost technology developed by various institutions. Technology using bricks, cement and steel on large scale is not recommended. As far as possible, cement is substituted by lime and lime surkhi[‡] manufactured locally. Due to increase in price of bricks, it is considered desirable to substitute burnt bricks with sun dried bricks of earth-soil-cement.

3.3.1.3 Total Housing Scheme (THS)

Total Housing Scheme was an ambitious project undertaken during People's Planning Campaign for fulfilling the housing needs of the poor in the three major districts of the state namely, Thiruvananthapuram, Kollam, and Thrissur. It was planned to solve the housing problem by people's participation. Along with the three main organizations involved in cost- effective building construction in Kerala such as Habitat Technology Group, Costford and the Nirmithi Kendra; HUDCO and the government engineering department were identified for implementing the scheme.

Identifying houseless people and beneficiary Selection - Surveys were conducted in each Panchayats for locating the houseless people and potential beneficiaries. People below poverty line were identified and beneficiaries were selected based on the selection criteria. Scores were assigned for beneficiaries based on the criteria and these score sheets were submitted in support of selection of beneficiaries.

Technical specifications - To utilize locally available materials and environmentally friendly technology.

Building materials - A database of the housing situation, including the requirement of materials, was prepared for future use. It was planned to repair and maintain houses and rebuild only those houses that had become structurally unstable. Anticipating the urgent demand and consequent increase in the prices of building materials, a price freeze in the rates was implemented for a period of three years during the implementation of Total Housing scheme.

Training programmes - A series of training camps were organised for masons and engineers, mainly in the application of appropriate technology. About two hundred engineers were trained in each of the three districts using the barefoot engineer's concept of training. More than ten to fifteen thousand people were given hands-on training in the art of masonry and basic construction. The training given was mainly in the application of appropriate technologies, which are cost-effective, environmentally friendly using locally available and affordable materials responding to physical, social and climatic needs of the region. The training also gave some orientation in the management of the land, trees, water and infrastructure of the premises. Awareness programmes were also conducted among beneficiaries, politicians, administrators and

[‡] Burnt clay or powdered bricks

government officials to achieve 'habitat literacy'. The main aim of this programme was to unmask the technology and hence to break the gap between architect, builder and the common man to develop a friendly change in the building sector.

Beneficiary participation - Beneficiaries had given the freedom to design their own house plans according to their needs. A core house concept was adopted and allowances made for future expansion. This core house was roughly worked out to be about 30 m^2, including a living room, a bedroom, a kitchen and a toilet.

Financial assistance and funding for the project - Financial assistance to the beneficiary households was provided in the form of grant of Rs. 35,000 (≈ € 700) to construct houses costing not less than Rs. 44,000 (≈ € 880). Local self-governments in the districts made an initial deposit of Rs. 10000 per house on the basis of which HUDCO sanctioned a loan of Rs. 35000 per house. The grama panchayat (Rs. 7000), block panchayat (Rs. 1500) and district panchayat (Rs. 1500) shared the deposit amount. HUDCO sanctioned the loan amount for a fixed term of eleven years at an annual average interest rate of ten per cent.

3.3.2 Sustainability analysis for selected schemes

The sustainability analysis has been carried out in three stages using the criteria derived from the conceptual framework. First stage of analysis (Analysis I) has been done to evaluate the perspective of the government regarding the schemes and the second as well as the third stages (Analysis II and III) for assessing the real situation in the field.

Analysis I (perspective of government)

This has been done in order to get a better overview of the selected schemes from the perspective of the government while on formulating the housing programmes. It has been discussed and analysed using the different criteria of the objective hierarchy model (CF_1), on the basis of the information from the official reports, documents on the corresponding schemes and from other secondary sources. The question addressed through this analysis is:

How far has the government programmes succeeded in incorporating sustainability concepts in the conceptualization stage of housing schemes?

Analysis II and III (Perspective of beneficiaries or the real situation)

These parts of the analysis have been done to analyse the real housing situation of the beneficiaries. Analysis II is based on the researcher's observations from the field, and

Analysis III based on the information from the household surveys. The latter will be discussed in detail in chapter 4. The observer's evaluation[§] (Analysis II) has been done in order to make a comparative evaluation between both perspectives using a common tool. Since each household do have their own perception of sustainability, it may not be possible to bring them into a common scale. Instead, an observer's view point helps in comparing the concept and practice using the same scale of assessment along with assessing the reasons for mismatch. The question addressed in Analysis II is:

What is the present housing situation of households and how far have the different government schemes been successful in achieving sustainable housing development?

A methodology based on the conceptual framework discussed in chapter 2 is employed for the sustainability analysis of the housing schemes to evaluate the research questions. According to this framework sustainable affordable housing can be achieved by fulfilling four different objectives of sustainability, namely, socio-cultural, economic, technological and environmental. As explained by the framework each of these aspects has to satisfy different criteria (see Fig. 2.10).

Since it is not possible to quantify the various criteria at these stages, a check has been made to assess whether the selected housing schemes have considered the particular criteria in both these stages of analysis. A three level valuing scheme is adopted for this check varying between 0 and 20 as 0, 10 and 20.The values are assigned as YES (Y) = 20 (for considering that particular criteria) NO (N) = 0 (for ignoring the criteria) and if they have partially (P) considered that criteria a value of P = 10 is given. Hence there is a greater chance of subjectivity in both the analysis. To overcome this, in the third stage of evaluation, a detailed analysis has been done based on the household surveys and a more accurate level of valuing system (5 point level between 0 and 20, see Appendix 4.2, chapter 4). This is also strengthened by the evaluation based on case studies.

Two assumptions are also made in this analysis, such as-

1. All aspects of sustainability carry equal weight.
2. The various criteria taken to assess the sustainability aspects also carry equal weight.

A scale of 0 to 100 has been assigned to measure the different aspects of sustainability by conceiving the first assumption. Table 3.4 gives a detailed analysis from both the perspectives on each aspects of sustainability of the selected schemes based on the assumptions made.

[§] The information collected during the household surveys and case studies are the basis for this analysis.

This analysis (Table 3.4 and Fig. 3.3) gives a comparative report on the selected schemes based on each aspects of sustainability. Among the selected schemes, THS has the maximum value for all the factors of sustainability in Analysis I and OLHS has the least value. It means that the selected schemes show a gradual improvement in the perspective of the government towards the problem with respect to the concepts of sustainability as it moves from OLHS to THS (1970 to 2000).

Table 3.4 Sustainability analyses from the perspectives of the government (A I) and the observer (AII)

Socio-cultural sustainability (SCS)						
Criteria	OLHS		JAY		THS	
	A I	A II	A I	A II	A I	A II
Adaptability	N	N	Y	P	Y	P
Equality	Y	N	Y	Y	Y	Y
Integration of amenities and Services	Y	Y	P	N	P	N
Beneficiary participation	P	P	Y	Y	Y	Y
Community involvement	Y	Y	P	N	Y	P
Total score (100)	**70**	50	**80**	50	**<u>90</u>**	<u>60</u>

Economic sustainability (ECS)						
<u>Affordability</u> Skills/ Assets	P	N	P	P	Y	P
Repaying ability or ability to maintain the house	P	N	P	N	P	N
<u>Shelter needs</u> Minimum requirements	Y	P	Y	Y	Y	Y
<u>Pre-requisites</u> Land	Y	Y	P	N	Y	N
Accessibility to resources	Y	Y	P	N	Y	N
Total score (100)	80	<u>50</u>	**60**	30	**<u>90</u>**	30

Technological sustainability (TCS)						
Feasibility Labour	Y	Y	P	P	Y	P
Materials	Y	Y	Y	P	Y	P
Functionality	N	N	Y	Y	Y	Y
Strength	Y	P	Y	P	Y	P
Durability & Reliability	Y	P	Y	P	Y	P
Total score (100)	**80**	60	**90**	60	**100**	60

Environmental sustainability (ENVS)						
Energy conservation	N	N	Y	P	Y	N
Water conservation	N	N	N	N	P	N
Land conservation & proper planning	Y	Y	P	N	Y	N
Healthy environment Location/air quality/pollution	Y	P	Y	P	Y	P
Infrastructure	P	N	Y	P	Y	P
Toilets Drinking water	Y	P	P	N	P	N
Drainage & waste management	N	N	N	N	N	N
Total score (140)	70	40	80	30	100	20
Total score (100)	**49**	28	**56**	21	**70**	14

The environmental sustainability of the selected schemes shows comparatively lower values as compared to other objectives of sustainability in both the perspectives (Fig. 3.3), even though they demonstrate a clear upward trend towards sustainability from One lakh to Total housing scheme as in socio-cultural and technological factors in the conceptualisation stage of the schemes. However, the economical sustainability of IAY was comparatively lower than OLHS and THS in the conceptualisation stage. This could be attributed to the provider approach of OLHS and enabling approach of THS.

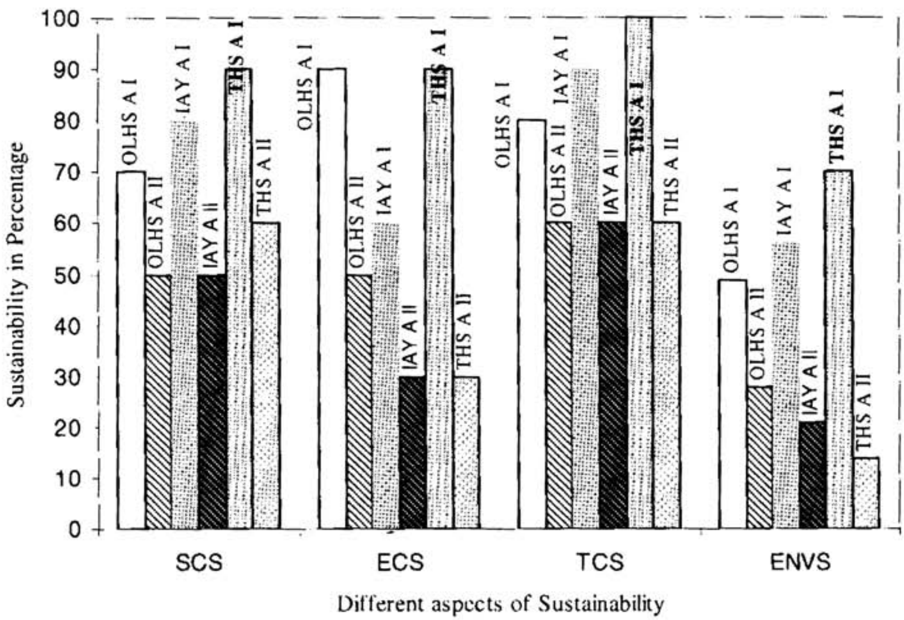

Figure 3.3 Comparison of different aspects of sustainability from the perspective of Government (A I) and observer from the field (A II) for different housing schemes (For figure legend, see table 3.3)

However, the real situation in the field revealed through the observer's perspective (A II) is quite different from Analysis I, and only shows minor variations (Fig. 3.3) among the schemes. Also the values of sustainability are far less than those from Analysis I. This verifies the mismatch between policy objectives and outcomes. It also shows the ineffectiveness of policies in making concept into practice.

3.4 Conclusion

The discussion of the evolution of present housing policy in India (and Kerala) gives a better understanding of the public initiatives in solving the problem since independence. It is interesting to see the same kind of policy shifts in the approaches of the government over the years as in the other developing countries. However, the preliminary phase of the evaluation on the public housing schemes in Kerala gives a rather different picture and points towards the inefficiency of implementation strategies with regard to sustainability aspects. The results of this basic analysis can be grouped as follows.

- Irrespective of the different policies of the government, the representative schemes selected for evaluation from each phase of policy do not show much difference in the end results and all of them seem to have partially failed even from achieving their goal as set by the government in respective periods. Mismatch between the perceptions (goals) of government and the real situation of the beneficiary households (results) is clear from the evaluation. This shows the ineffectiveness of different policies and necessitates the need for effective policies for proper implementation.
- The negligence of different environmental factors is clear from both the perspectives and can be considered as one of the main reasons for the development of slum-like human settlements in the rural areas of Kerala.
- The economic sustainability of housing schemes from Analysis I shows a comparatively lower value for IAY than the other two schemes. This proves the failure of enabling strategies in this scheme, even in the conceptualization stage.

Chapter 4 presents Analysis III, a detailed evaluation from the perspective of beneficiary households with the support of information collected from household surveys and case studies, to find out the reasons for this mismatch and the factors affecting the failure of housing programmes.

Appendix 3.1

People's Planning Campaign (PPC)

Democratic decentralization is the process of devolving the functions and resources of the state from the centre to the elected representatives at the lower levels so as to facilitate greater direct participation by citizens in governance (Isaac, 2000). People's Planning Campaign (PPC), a process of democratic decentralization launched in Kerala in August 1996 with the aim to achieve sustainable development through people's participation in the planning and implementation process, based on the belief that people know what is good for them. It addressed twelve sectors of development including housing and social welfare; identified key issues, problems and solutions, and prioritized the needs. In order to ensure transparency and participation without compromising on the technical requirements of planning, a sequence of phases, each with distinctive objectives, central activities and training programmes was drawn up. People's planning campaign opened up possibilities of more direct participation of the masses in day-to-day governance. But unfortunately it was discontinued after 2001 because of the change of government in Kerala.

Appendix 3.2

Stakeholders in housing and Public Housing Delivery process in Kerala

International agencies (IA) generally have a limited funding, advisory and monitoring role in shelter related development projects in India. The central government (CG, Government of India) only overviews the state level programmes, lays down policy perspectives and builds up data system for the entire country. The state government finds out the funding for housing programmes in the State through budgetary allocations, Plan funds from the central government, taking loans from international agencies or from Housing Finance Institutions (HFI).

Public sector housing is basically the responsibility of the state government. There are more than twenty agencies engaged in government sector for housing the poor in Kerala. Rural development department, Kerala State Co-operative Housing Federation, Kerala State Co-operative Agricultural and Rural Development Bank and Nationalised Banks are the major government departments in the housing sector other than Kerala State Housing Board. The housing programmes of the state are implemented either through these agencies or through the local government. The rural development department of each district is engaged in the implementation of the schemes sponsored by the central government (Centrally Sponsored Schemes- C.S.S) through the different block panchayats (local government- LG). Other than implementing the housing programmes of central and state governments, local governments may also endeavour housing programmes of their own with the assistance of international agencies or housing finance institutions. The local governments may either provide the financial assistance directly to the low-income households (LIH) or will be implementing the housing schemes through the Nirmithi Kendras (Building Centers) or through non-governmental organizations (NGOs) or Community Based Organizations (CBOs), or with the assistance of private building companies (BC). The majority of the housing programmes nowadays in Kerala are providing partial financial assistance to the poor with the intension of creating a facilitative environment to provide houses by their own. Low-income households with limited access to formal sources of market-based housing finance, approach local money lenders and other informal sectors for further housing assistance and construct their houses mostly with the help of local masons and carpenters. Most recently, rural building centres (RBC) were set up through out the country for promoting appropriate technologies and capacity building at the grassroots level for achieving affordable housing.

The role of different stakeholders involved in the process of public housing delivery in Kerala from international agencies to the low income beneficiaries are briefly explained below.

International Assistance (IA) - international agencies, except the World Bank, had rare influence in public policy or execution of large housing programmes in India (Revi, 1990). The external assistance in housing has come from Germany, Japan, Netherlands, United Kingdom, United States, International Finance Corporation, UNICEF, World Bank and the Asian Development Bank (ADB). Germany has extended several lines of credit to HUDCO and HDFC for low-income housing schemes and the establishment of rural building centers throughout the country. The United Kingdom has extended grant assistance for habitat improvement projects in six cities nationwide. Under its Housing Guarantee Program, the United States Agency for International Development (USAID) began lending to HDFC in 1983 to help HDFC to expand its operations as the first private sector housing finance organization in India. Although ADB's involvement in India's housing sector has been relatively recent, it is now the major international lender in the sector and plays a leading role in supporting the government's policy and institutional reform agenda. ADB's first loan for housing to HDFC under the Karnataka Urban Infrastructure Development Project was targeted lending for low-income housing and slum improvement schemes.

Central government (Government of India) - Ministry of Urban Development and Ministry of Agriculture and Rural Development have the responsibility for urban and rural shelter activities of the country. The role of the central government is restricted in facilitating the housing development activities by providing financial assistance, promoting research activities, furnishing infrastructure facilities, creating favourable environment and monitoring.

State government (Government of Kerala) - The Housing or Urban Development Ministry and Ministry of Rural Development at the state level are the co-coordinating authorities in the area of both urban and rural shelter respectively. Each of the state governments has also created state-level housing boards (HB) for this purpose. Other than HB's there are a number of state government departments to implement housing schemes for specific occupational groups and under privileged sections. State government is acting as a means of central government in implementing the development activities and establishing the positive atmosphere. They also will be providing financial assistance, promoting research activities, furnishing infrastructure facilities, creating favourable environment and finally implementing the schemes.

Local government - Corporations, Municipalities and panchayats constitute the local government. They are the ultimate implementing agency of many of the housing programmes of the central and state governments. They get the financial assistance either directly from the State government or from the central government through the district rural development department.

Rural development department - In each district there is a district rural development agency (DRDA) for looking after the development activities connected with the rural areas of that particular district. The housing schemes sponsored by the central government implemented by local government are directed through DRDA.

Research and Development activities (R&D) - All institutions, universities and research-oriented agencies constitute this group. They are getting support from both CG, SG and also from international agencies for research and development activities. Most of the research works on housing is carried out either through government laboratories or through academic institutions. Council for Scientific and Industrial research (CSIR), Central Building Research Institute (CBRI), Structural Engineering Research Centre (SERC), Forest Research Institute (FRI) are few of the main government institutions working in this field. A number of academic institutions in the country also undertake research work in shelter related areas.

Rural Building Centres (RBC) - The Ministry of Rural Development from 1st April 1999 has launched a Scheme facilitating the setting up of a network of Rural Building Centres (RBC) through the length and breadth of the rural areas. These are centres for promoting appropriate technologies and capacity building at the grassroots level for achieving affordable housing. Technology transfer and information dissemination, skill up-gradation through training and production of cost-effective and environmentally friendly material components are the primary objectives of the setting up of rural building centres. A rural building centre can be set up by the State governments, rural development agencies, credible non-government organizations (NGO), private entrepreneurs, professional associations, autonomous institutions and corporate bodies, including public sector agencies provided that they have the minimum requirements as specified by the Central government (NHHP).

Housing Finance Institutions (HFI) - All housing financing agencies such as the public sector, banks and the private sector constitute this group. Major housing financial institutions in Kerala include Life Insurance Corporation (LIC), Housing and Urban Development Corporation (HUDCO), National Housing Bank (NHB), Housing Development Finance Corporation (HDFC) and nationalised banks. They provide long-term housing loan to individuals and to housing agencies for refinancing to individuals. HUDCO is an influential financing agency with the main aim of funding state governments for infrastructure and development. LIC, Housing Finance, GICHFL (General Insurance Corporation Housing Finance Limited), PNBHFL (Punjab National Housing Bank Housing Finance Limited, SBIHF (State Bank of India Housing Finance) are also the major players in the public sector. Almost all banks throughout India provide housing finance. Among the private sector HDFC is the main finance institution in India providing home loans to individuals.

Local financing agencies (LFA) - The informal sector plays a significant and sustained role in the provision of the housing finance of low income households. Different sources such as individual moneylenders, community-based financial institutions (CFI), non governmental organizations (NGOs), small private banks and all local financing agencies, which are easily accessible to them, constitute this group. With the exception of government-sponsored housing programs, formal housing finance institutions are reluctant to lend to low-income households because of factors such as the relatively high transaction and service costs, irregular and unsubstantiated income sources, and the absence of collateral in the form of title to real property. Consequently, the remaining funding requirements derive from informal sources that largely consist of individual efforts with the help of CFIs, NGOs, employer financing, and moneylenders. Informal sources contribute as much as 79 percent of the finance for new construction in urban areas and 88 percent in rural areas (ADB, 2000).

Non-Governmental Organizations (NGOs) and community based organizations (CBOs) - The roles of NGOs and CBOs in human settlement activities are well recognized by the National Housing and Habitat Policy (1998). They are actively involved in activities like community development, building material research and also in implementing government programmes. Most of the NGO's at the grass- roots level are merely assisting in the implementation of state policies and programmes, and there fore enjoy financial and/ or administrative support from various public agencies. NGO directly involved in shelter production process may also provide certain critical inputs such as legal assistance, finance etc. to the community.

Building Companies (BC) - The engineers, architects, private builders, real estate developers and all the other private agencies involved in construction activities including the formal sector builders constitute this group. The large contractors undertake business for rich individuals, cooperatives, private developers and public agencies. Planning, design, organization of labour and materials etc. are all organized by these contractors. The small-scale contractors operate as individuals or firms undertake the whole building process besides providing supervision of construction work, and architectural and engineering services. This is the largest provider of housing among the household sector, especially among the middle and higher income groups.

Local builders (LB) - Local masons and carpenters including the informal sector constitute this group. Low- income households purely depend on the local masons and contractors for their housing needs.

Low Income Households (LIH) - All the beneficiaries of the public housing schemes and the non- beneficiaries belonging to the economically weaker section (EWS) constitute this group of actors. They build their houses with their own labour, using the services of

4 PUBLIC HOUSING POLICY IN KERALA: EVALUATION OF HOUSEHOLD SURVEYS AND CASE STUDIES

4.1 Introduction

This chapter presents an evaluation of the housing situation in Kerala based on household surveys and case studies from the selected housing schemes. A comparative analysis of the Kerala situation with examples from other parts of the world is also presented in this chapter. The details on household surveys and case studies from selected households are presented in section 4.2 to disclose the real situation of the beneficiary households. This helps in understanding the bottlenecks of poor households on approaching the problem. Section 4.3 deals with the evaluation of household data (Analysis III, section 3.3.2). The Statistical Package for Social Sciences (SPSS) is employed at this stage of analysis to get a comparison of the different aspects of sustainable-affordable housing in different housing schemes from the perspective of the beneficiaries, and to test their interrelations as conceived by the conceptual framework. Section 4.4 presents a few examples of enabling strategies from the UN-habitat's (United National Center for Human Settlements-UNCHS) Global Best Practice database to have a comparative approach and to see how they have tackled the problems of low income housing in similar contexts (UNCHS, 2004). A discussion of the results of the evaluation of the public initiatives in the low income housing of Kerala with respect to different aspects of sustainability is presented in section 4.5. Based on these evaluations, strategies (section 4.6) are formulated for sustainable-affordable housing developments in Kerala. Section 4.7 presents the conclusions.

4.2 Household survey and case studies

The household survey was conducted among the beneficiaries of One Lakh Housing Scheme (OLHS), Indira Awaas Yojana (IAY) and Total Housing Scheme (THS) from Kollam and Alappuzha districts, during the months of May and June 2005. The selection of beneficiaries has been done on a random basis. Out of the total of fifty-six households interviewed, eighteen were from OLHS, twelve from IAY and twenty-six from THS. The surveys were conducted using a structured questionnaire prepared on the basis of the conceptual framework. The original version of the questionnaire is presented in Appendix 4.1 of this chapter. There were 143 main questions and a few general questions (to help the interviewer to write his remarks). Other than the specific questions regarding their personnel details and details on the housing, most of the questions were with multiple answers. The respondent had the freedom for selecting the answer from the group or writing down his own remarks. Table 4.1 gives a structure of the questionnaire. A scheme of analysis (Appendix 4.2) has also been prepared from this questionnaire for each aspect of sustainability based on the "objectives hierarchy model" (Fig. 2.9) of the conceptual framework and the questions are transformed into measurable criteria.

Table 4.1 Structure of the household survey schedule and purpose

Research questions addressed

Q: What is the real situation of households and how far are the housing schemes successful in achieving sustainable development?

Q: Why does the housing problem of the EWS persist in Kerala despite "active and effective" (according to official records) state intervention?

	Structure of Questionnaire	Purpose	Criteria
1	**General information**, regarding the general details of the household such as their age, marital status, job etc.	The information collected from these questions can be used to assess the **socio-cultural aspects** of the household, educational back- ground and profession.	Inequality and Stigmatization Household size Adaptability
2	**Economic status of the household** - This section deals with the questions concerning the economic status of the household to assess their income, savings, liability and pattern of expenditure.	To assess the financial status or **affordability** of the households and hence to determine the economic sustainability of the housing scheme.	Housing condition Self- dependency Liability for housing Savings and Assets Skills
3	**Housing details** – This section has got two parts. The first part deals with the details of their previous house, its location, type and the basic facilities they had. The second part consists of questions concerning the details of the present house. It includes the details of the building process, technology adopted, sources of funding. Also there are questions concerning the various measures adopted for conservation of resources and neighbourhood	Details of previous housing are collected to assess their social progress and improvement in life. Details of building process helps in understanding the **technology** adopted. It also helps in assessing the feasibility and awareness on innovative options and other resources including finance. To assess the **quality of the surrounding environment** and various conservation measures adopted to protect the environment.	Shelter needs Infrastructure Accessibility to affordable technological options. Accessibility to resources including easy finance. Beneficiary Participation. Community/NGO'S involvement. Unhealthy surroundings. Basic infrastructure facilities like drinking water and sanitation. Waste management.
4	**Needs, Aspirations , Plans_** - This final section of questions is mainly concerned with the future plans of the household	To assess their preferences in technology, their attitude towards **CEEF technology** and to assess their needs and aspirations that has to be considered in formulating housing schemes.	Feasibility Availability CEEF technology
5	**General remarks of the interviewer**	To assess the overall situation of the household and their lifestyle.	

A few outstanding cases are selected as case studies from the household surveys for further evaluation based on the criteria specified by the conceptual framework. The succeeding section presents them in detail. This helps in understanding the genuine problems of beneficiary households from their own perspectives.

4.2.1 Case studies from One lakh housing scheme

Households from Thrikkadavoor panchayat (Kollam district) and from a One lakh housing colony of Alappuzha district (North Punnapra panchayat-Ward III) were randomly selected for interviews.

There were eighty-two OLHS beneficiary households, distributed among four colonies (Vettuvila, Neeravil, Melemangadu and Pandaruvila) of Thrikkadavoor Panchayat. Eighteen selected households were interviewed. The general housing conditions of these colonies were satisfactory with basic infrastructure facilities like provision of public water supply, electric connection, motor-able road, nearness to schools, hospital and worship places. But most of the houses were in deplorable conditions due to lack of proper maintenance, requiring urgent attention and repair.

The households from the colony of Punnapra panchayat were selected with a special intention. They were lucky to get an additional financial assistance of Rs. 40,000 (nearly € 800) for reconstructing their twin houses as independent dwellings. At the time of this household survey during early May 2005, all the houses in that colony were in a stage of reconstruction. Three of the households were interviewed. Even though these households were happy with the additional financial assistance for reconstruction, they were complaining about the following things.

- most of the beneficiaries were forced to demolish the extensions or renovations they have added to the original OLHS houses in the fear that, if they do not accept this assistance from the government, they may not able to receive further assistance for renovating their houses in the future;
- they were not given enough time to make a plan on arranging the resources and scheduling the works as they were given a short notice to take decisions, and above all;
- the financial assistance was not sufficient for both demolition and reconstruction.

Among the interviewed households, few of the interesting cases are presented below as case studies from this scheme.

Case study1

Criteria for selection: The insignificance of socio-cultural aspects in this housing programme is clear from this case study. This story tells us that stigmatization and inequality of houses is a major problem questioning the acceptability of a house even though it has enough facilities to cater the present needs.

Identification number 12 - This family with a household size of four is from Vettuvila One Lakh housing colony. Even though the household is satisfied with the present facilities of the house, the head of household wants to sell the property and buy another house outside the colony because of the twin house design and stigmatization of OLHS houses. His father-in-law was the original beneficiary of the scheme and was living in this house since 1972 with his wife and three children. He was a beedi[1] worker for daily wages and was happy with his house. They were maintaining the house regularly with timely repairs and hence even after thirty-three years, the house is in better condition compared to neighbouring houses. The-present inhabitants include a young man, his wife, their two year old daughter and mother-in-law.

Case study 2

Criteria for selection: This case study is a good example for poor significance to socio-cultural aspects like lack of adaptability (household size, varying requirements), increasing self-dependency of the household (Economic sustainability) and shabby surroundings (Environmental sustainability)

Identification number 14 - This is the case study of a family of household size seven from Neeravil One Lakh Housing colony. They are living in that house since 1972. Other than the old man, the head of household (original beneficiary), his wife and younger son; their elder son is also living in the same house with his family of two kids. Both of his sons are earning money through daily labour. One of them is a mason and the other a coconut plucker. Their house has a temporary extension for a kitchen with tar sheet roofing, thatched walls and bare flooring. In addition to this, they have another extension for cattle shed. They have a small shop for tiny things (sweets, cigarettes etc) in front of their house on the open veranda. Their housing condition is very pathetic with the shabby extensions and the poor surrounding environment, with the cracks in the walls, broken flooring and a leaking roof. Even though the family has a comfortable financial situation, without liabilities and with some savings in the bank; they are not at all bothered to spend money for improving their present housing. At the same time they are looking forward for further government support to improve their housing situation.

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[1] Beedi is an indigenous cigarette in which tobacco is rolled in a tender leaf and tied

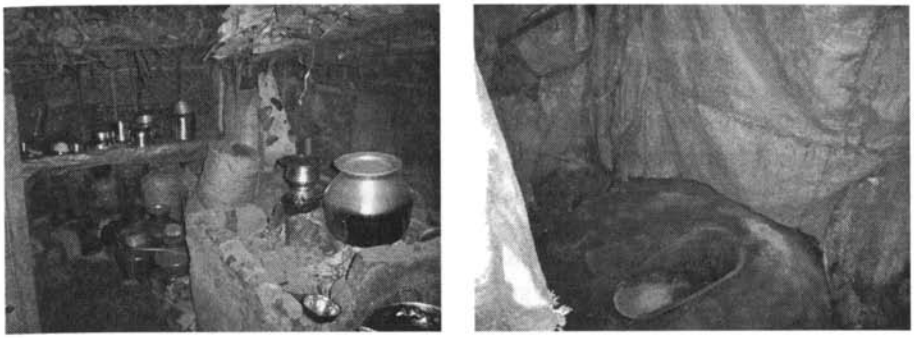

Figure 4.1 Basic facilities of OLHS house of case study-2

Case study 3

Criteria for selection: This case study is an example of the improper assistance of Government without understanding the actual situation in the field and generalising the problem (poor economic sustainability).

Identification number 1 - This is the story of a household from the OLHS colony of Punnapra panchayat, Alappuzha district. They were living in their one lakh house since 1972. The head of the household had a regular employment at that time and was able to cater the timely maintenance and repair works for his house. After eighteen years, in 1990, they renovated their house by adding one more room and providing additional space to kitchen and living room. He could meet these expenses by taking loans and using the savings. They spent nearly an amount of Rs. 30,000 (€ 600) for renovations at that time. But recently during February 2005 the panchayat authorities further provided them a grant (non refundable) of Rs. 40,000 (€ 800) under an up-gradation scheme for OLHS, for separating the twin houses as independent ones. The household was thoroughly confused in receiving this funding as they do not have enough land to reconstruct their house by detaching it from the old one without demolishing the renovations. But finally, they were forced to accept this assistance in the fear of receiving no more funds to separate their twin houses in the future. The household is now worried about the construction of their new house, since the present financial support from the government is not enough for both demolition and reconstruction. Also the head of household is afraid to take further loans in his old age, since he has no regular income and suffering from ill health.

4.2.2 *Case studies from Indira awaas yojana*

IAY is a centrally sponsored scheme implemented in a unique manner through out the whole state. IAY households from Thrikkadavoor, Punnapra and Kanjikuzhy panchayats were interviewed. These houses were independently constructed by each household according to their own requirements and hence all of them were totally different to each other. The beneficiaries themselves did the whole building process in this scheme. They made their own arrangement for the construction by engaging skilled workmen along with contributing the family labour. Thus a sense of pride could be noticed among the IAY households whereas this was lacking in the case of most of the OLHS beneficiaries. Few of the interesting case studies are presented below.

Case study 4

Criteria for selection:

- *Poor economic sustainability (lack of feasibility to affordable housing finance and poor basic shelter needs)*
- *Insignificance to socio-cultural and technologic aspects (lack of proper guidance and awareness on cost-effective technological alternatives)*
- *Poor consideration on environmental issues (Environmental sustainability)*

Figure 4.2 IAY houses from Murundal, Perinadu, Kollam

IAY houses, Murundal, Perinadu, Kollam - These six IAY houses are constructed on a partially converted agricultural area in the Thrikkadavoor panchayat, near to Thamarappally Jayandi colony and at a distance of about 1.5 km from Anchalummodu junction. Two of them are occupied by the households. Among the rest, one of the houses is in the finishing stage with partial roofing where as the other three are completed up to lintel level only.

Identification Number 68 - This household had occupied their unfinished house in August 2004. The household size is four including an old couple and their young daughters. This household got a financial assistance of Rs. 25,000 (€ 500) for purchasing the house plot under a scheme for the scheduled castes from the Block panchayat other than the housing assistance from IAY. Since the costs of normal house plots were high, they bought cheap agricultural land and reclaimed it. But the present condition of their house plot is so bad that their house is floating in the middle of a marshy land. The situation of their neighbours is also not different. The household started with their building process in early 2002 but could not finish the house till now. Since they could not manage with the completion of their house in the corresponding financial year, they lost the privilege of getting the full financial assistance from IAY scheme and could only receive the first three instalments. But they occupied the house in 2004 after managing with the minimum essential facilities. Even now, they are not having the basic facilities like toilet, drinking water and need to depend their neighbours.

Identification number 67 - This household including an old mother, her son, daughter-in-law and her young daughter is living in a temporary tent near to their unfinished IAY house for the last three years. They also got the financial assistance for purchasing house plot and have a similar story as their neighbour. But they could not manage to make their house to a liveable one and also find it difficult to repay the existing loans they took for constructing the house. The materials stored near their house site are also getting ruined without being used.

Identification number 65 - This household was lucky in finishing their house within the stipulated time (one year) and hence could receive the full privilege of the Scheme. Along with their neighbours, they also received the assistance in 2002, but could manage to occupy their house in 2003 April. For developing the plot and constructing the house they were forced to take loans from private lending agencies at higher rates of interest. Now, even after two years they are not able to repay a single penny towards the capital because of the high interests. This household has only minor pending works for their house. But they are seriously thinking of selling their house in fear of their rising debts.

Case study 5

Criteria for selection: This case study shows that

- *Self-help and mutual help alone could not solve the housing problem.*
- *Importance of general support and empowerment other than financial assistance.*
- *Technological un-sustainability of the scheme; technological innovations not reaching to the poor people.*
- *Economic un-sustainability of housing programmes; difficulties in getting affordable housing finance.*

IAY household from Kanjikuzhy - This household including a mother and nine-year old daughter got their house sanctioned under the 2003 scheme, and could partially finish it into a liveable one in a period of four months. She lost her husband unexpectedly during this period and could not do the finishing works. According to her, the household and their neighbours contributed most of the labour and never employed any labour from outside. They had also taken a loan (Rs. 10,000) with higher rates of interest from a private bank to meet the excess expenditure. Only conventional methods of construction were employed in the building process, and this poor lady was even unaware of the cost reduction techniques.

4.2.3 Case studies from Total housing scheme

The two earlier schemes discussed (IAY and OLHS) have a uniform implementation pattern and hence are unique throughout the state. But the Total Housing Scheme was implemented only in the three major districts of the state, namely Thiruvananthapuram, Kollam, and Thrissur. Household surveys were conducted among the THS households of Thrikkadavoor panchayat (Kollam). Some of the households were from Sivodayam colony, where the housing programme was implemented through Habitat technology group, an organisation involved in cost-effective construction techniques in the state. The rest of the households constructed their house by their own way. The most interesting finding of the household survey is that neither the households nor the implementing agencies were successful in meeting any of the basic objectives of the scheme. The households other than the inmates of Sivodayam colony constructed the houses as in any other scheme like Mythri or IAY. However, the households of Sivodayam colony had a totally different experience, in some respects similar to the provider approach of OLHS. The case studies explain the real situation.

Case study 6

Criteria for selection:
- *Poor significance given to socio-cultural aspects in this housing programme.*
- *Lack of correlation between socio-cultural aspects and economic aspects in housing leading to the increased dependency of the households towards public support.*
- *Failures in implementing new technology.*
- *Lack of basic facilities.*

Sivodayam colony is located at a distance of about 300 m from the Kadavoor junction (Thevally-Anchalummodu road), behind the Government Ayurveda hospital. This is a colony of scheduled caste households belonging to the vedar* community of Hindu religion. They are living in the same place since 1960. At the time of this survey, there were twelve households. Initially there were only ten households with each having a land ownership of five cents (equivalent to 200 m^2). They were provided with free houses in 1960 through Kudikidappukar housing scheme (centrally sponsored scheme). Later in 1976 they could electrify their houses with the support from the panchayat. The severe flooding in 1975-76 caused serious damages to their houses. They approached the authorities for repair and maintenance. But they could only get nominal assistance. Again after the flooding in 1986, the government further supported the colony members with a new housing assistance. The households were provided with partial financial assistance and food grains (Rs 6000 + 2 sacks of wheat) as support for reconstructing their houses. They were able to rebuild their houses with this assistance and also by utilizing the materials from the old house. Their second house was provided with the facilities of two rooms, kitchen, toilet and a small open veranda. In 1999, the households of Sivodayam colony again approached the panchayat for the financial assistance for repairing their houses. But this time they were lucky enough to be blessed with their new house -Third house from the Government-under Total Housing Scheme!

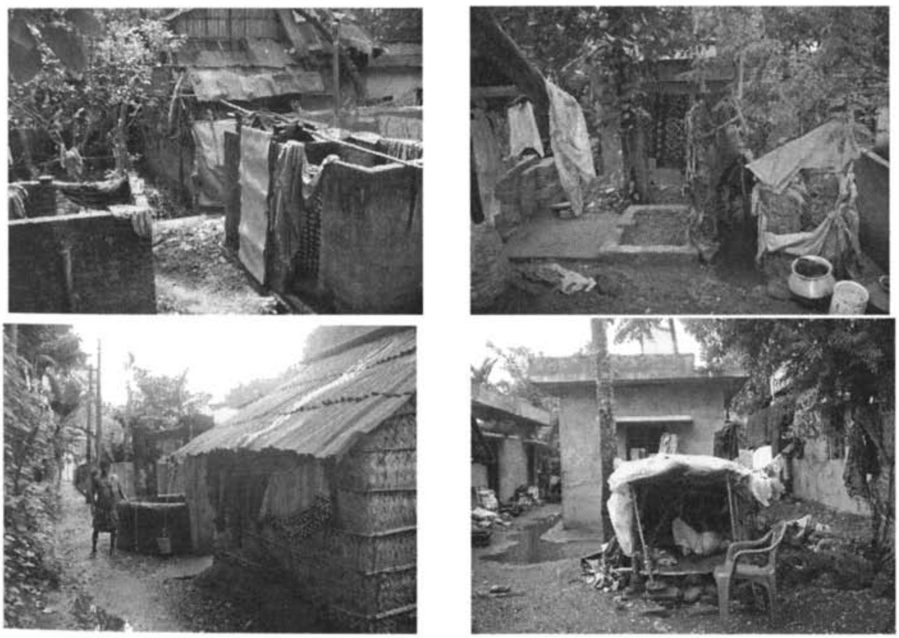

Figure 4.3 Basic infrastructure and surrounding environment; Sivodayam Colony

The implementation of this housing scheme was entrusted to the Habitat technology group, an appropriate technology group in Kerala. Habitat's role was that of a facilitator between the local government and the beneficiaries. As part of the THS programme, training was given to engineers and masons and they were also involved in the construction of these houses. But according to the beneficiary households they did not receive any effective training in skilled jobs. Also they were not at all involved in material selection or other construction activities other than unskilled jobs.

The same type of designs was employed for all the houses. Initially the house plan was proposed with a living room, bedroom, kitchen and a toilet. Since they had their old toilet from their previous houses, the households opposed the construction of the new one and preferred to use that space in the new house to increase the area of kitchen. The construction of eleven houses was started simultaneously in early 2000 after demolishing the existing houses. The twelfth house was kept as such for keeping construction equipments and materials. All the households were moved to temporary sheds in the premises. Cost effective and environmentally friendly (CEEF) technology (rat trap bond for super structure and filler slab for roofing) was employed for the construction of houses. Engineers and trained masons were involved in this. One of the houses collapsed in the beginning during construction and training. But they continued with the rest. Unfortunately, the Habitat group left the project half way after finishing the roofing of three houses.

The colony members approached the panchayat for completion of houses. And after repeated requests, protests and picketing of authorities, the panchayat authorities were forced to entrust the balance works to another contractor. He managed to finish the roofing of rest of the houses. Altogether the building process continued for long four years and at the end beneficiaries decided to occupy their unfinished houses. Now their houses can be said to be in liveable conditions even though they do not have any front and back doors and essential needs. Also these houses do not have electric connection which, the beneficiaries had in their old houses. These new houses are also without sanitation and drainage facilities, the basic amenities which they had earlier.

Case study 7

Criteria for selection: This case study is a good example for the

- *Mismatch in the perceptions of government and beneficiary household*
- *Poor significance given to socio- cultural factors in housing; problems due to lack of proper guidance and improper utilisation of resources.*
- *Technological un-sustainability of housing scheme; CEEF technology not reaching to the needy.*
- *Economic un-sustainability of housing programmes; difficulties in the feasibility of affordable housing finance.*
- *Poor infrastructure facilities.*

Identification Number 30 - The head of this household is an old lady. She is living together with the families of her two sons and daughter. The household size is ten including four children. Even though there are three earning members in that family, their financial situation is not that better. She took a housing loan for Rs. 70,000 (€1400) in the year 2002 from Kerala state housing board (KSHB) for the construction of her house, but could not pay any of the instalments other than the first. Considering their poor financial situation, KSHB had exempted them from the penalty. Even with these concessions, they find it very difficult to repay the money. She has already invested an amount of Rs. 225,000 (€ 4500) for the construction of her house by spending all their savings. Even after all this investment, the housing situation is also not that good. They are living in that house for the last three years. But till now the house is not completely finished. It is only the structure of a three bed room house having an area not less than seventy square metres. They are not even having the facility of a bath room. Also they do not have any drinking water facility and depend on the public water tap at a distance of about 200 m from their house. Location of the house is also not that satisfactory as they need to walk a distance not less than one kilometre for getting the public transport facility.

4.2.4 Conclusions from the field research

Table 4.2 summarizes the outcomes of the field research.

Table 4.2 Field research observations and relation to different aspects of sustainability

Sustainability aspects	One Lakh Housing Scheme (OLHS)	Indira Awaas Yojana (IAY)	Total Housing Scheme (THS)	References for remarks
Socio – cultural factors	**Twin houses (Flexibility);** All inhabitants were dissatisfied in the twin house arrangement of houses due to privacy problems and other reasons. The common wall in the middle separating two houses is not extended up to the ceiling. So the privacy of the households was very much affected by the noises from the neighbouring house as well as smoke and smell during cooking. They even need the consent from their neighbours for renovating the houses. **Less space to accommodate the household (Adaptability).** There was no enough space for the household members to sleep, children to study and to make prayer. **Increasing self dependency**	No community involvement Poor integration of amenities and services	Poor integration of amenities and services No community involvement	Case study-1 Case study-2 Case study-4 Case study-7
Economic factors	Poor concern on the basic shelter needs	**Financial assistance not sufficient**: All of the household were strongly arguing for increasing the assistance. Improper utilisation of resources	**Financial assistance not sufficient** Inaccessibility to resources including easy finance	Case study-3 Case study-4 Case study-7
Technological factors	**Poor quality** of materials, especially wood used for doors, windows and roofing	**Feasibility of technological innovations** Even though IAY has guide lines to utilise locally available materials and technology, the beneficiary household are not having any know how or getting any assistance for using this.	Lack of proper guidance **Inaccessibility** to affordable technological options	Case study-2 Case study-4 Case study-6 Case study-5 Case study-7
Environmental factors	**Poor sanitation** and drainage facilities	**Poor sanitation** and drainage facilities Improper land management	**Poor sanitation** and drainage facilities	Case study-2 Case study-4 Case study-7
Interviewer's remarks	**Poor Housing conditions**: Most of the houses were overcrowded with more than one potential family. These houses were not able to satisfy their minimum shelter needs like sleeping space, cooking space and even a comfortable moving area and were in unliveable conditions. Cracks developing in the common central wall are a major problem that could be noticed in almost all the houses. Also the building materials used for the houses, especially the wood used for the doors, windows and roof trusses were in severe deteriorating stages. **Sanitation and Drainage**: All the colonies were having very bad sanitation facilities with unhygienic latrines and toilets. No facility was provided for the drainage and waste management.	**Financial assistance**: Since the financial assistance from this scheme was not sufficient for completing the houses, the beneficiaries were compelled to take some external loans from private banks or individuals even though they need to pay high interests in return. Some of the interviewed families were in heavy debt traps due to this. **The sanitary latrine and smokeless Chula** is the integral parts of IAY. But due to the lack of sufficient funding, most of the interviewed households were not able to construct these. **Technical assistance and general awareness:** Inaccessibility to innovative technological options was major problem among the households. The local masons can easily influence the poor beneficiaries. Since the beneficiaries are not having any proper idea regarding the area of the house, the materials required and also the total cost; there are chances of misguidance and failure of programme. **Minimum land ownership criteria of** IAY is a barrier to the poor landless households **Poor sanitation and toilets** – Beneficiaries are only giving secondary importance to these facilities and looking for further support from the government.			

4.3 Analysis III (From the perspective of households)

This section presents an evaluation of the different aspects of sustainable-affordable housing in the selected housing schemes from the perspective of the households. The information collected from the household surveys is evaluated with the help of the Statistical Package for Social Sciences (SPSS). SPSS is a software package used for conducting statistical analysis, manipulating data, and generating tables and graphs that summarize data. SPSS-Version XII is used in this analysis.

This analysis helps in comparing the sustainability aspects of selected housing schemes, their interrelations (Fig. 2.3), and in identifying those factors which contribute to the development of sustainable-affordable housing. The scheme of analysis presented in Appendix II has been employed for comparing the sustainability of selected housing programmes, based on different criteria as specified by the conceptual framework. This analysis has been carried out to achieve the following objectives.

1. To compare different aspects of sustainability between the schemes.
2. To assess the correlation between different sustainability aspects.
3. To compare the total sustainability among the selected schemes.

4.3.1 Comparison of different aspects of sustainability between the schemes

The T-test used in this analysis helps to compare different aspects of sustainability on the corresponding housing schemes. The T-value for each aspect is calculated as the ratio of the difference between the corresponding means of two selected schemes to the square root of the sum of the variance of the two groups. When the T-value is larger than the critical value, the result is considered to be significant. A level of 5% significance is adopted for this analysis to ensure a chance of 95% on the reliability of the results.

The T-test can compare only two housing schemes at a time. Since we have three schemes, the comparison has been done through three stages. Tables 4.3, 4.4 and 4.5 present the significance of different aspects of sustainability between OLHS and IAY, OLHS and THS, IAY and THS, respectively.

Between OLHS and IAY, a significant variation (Fig. 4.4 and Fig. 4.2) can be seen only in the aspects of economic sustainability ($2.439>1.701$, significance $0.021<0.05$) and environmental sustainability ($2.350>1.753$, significance $0.034<0.05$). The accessibility of the households to their basic shelter needs very much depends on the economic sustainability of that particular housing scheme. The case studies of IAY households (case study No.4) point towards the economic un-sustainability of this scheme. Even after availing the so-called facilitative environment from the Government and owing an additional financial burden, the households were not able to satisfy their basic shelter needs. However, in the case of OLHS the beneficiary households were able to meet these basic needs as the houses were provided by the government for free of cost. The provider approach of OLHS helped in ensuring the minimum basic infrastructure facilities to the households. These can be counted as the reasons for the significant variations in economic as well as environmental sustainability for both these schemes. However the other two aspects of sustainability, namely socio-cultural sustainability and technological sustainability (Fig. 4.4 and Fig. 4.6), do not show much variation between these two schemes.

Table 4.4 Significance of different aspects of sustainability between OLHS and THS

Sustainability aspects	**T value**	**Critical value of T**	**Significance of 'T' value between the schemes (5% level is indicated by a value less than 0.05)**
Socio-cultural sustainability (SCS)	1.631	1.684	0.110
Economic sustainability (ECS)	0.052	1.684	0.959
Technological sustainability (TCS)	0.368	1.684	0.715
Environmental sustainability (ENVS)	3.485	1.684	0.001
Total Sustainability	0.650	1.684	0.519

Table 4.4 shows the results of the T-test for comparing the different sustainability aspects between OLHS and THS. Only the values for environmental sustainability (3.485>1.684, significance 0.034<0.05) showed a significant variation between these two schemes.

Table 4.5 Significance of different aspects of sustainability between IAY and THS

Sustainability aspects	**T value**	**Critical value of T**	**Significance of 'T' value between the schemes (5% level is indicated by a value less than 0.05)**
Socio-cultural sustainability (SCS)	1.461	1.697	0.153
Economic sustainability (ECS)	2,168	1.697	0.037
Technological sustainability (TCS)	0,335	1.697	0.740
Environmental sustainability (ENVS)	0,179	1.697	0.859
Total Sustainability	0,707	1.697	0.484

Comparison of sustainability aspects between IAY and THS show significant variation only in the case of economic sustainability (Table 4.5). The case study (No. 6) of households from Sivodayam colony (THS) is somewhat similar to the case of OLHS households with regard to the aspect of economic sustainability. The variation of different aspects of sustainability between the schemes is also clear from Fig. 4.1 to Fig. 4.4.

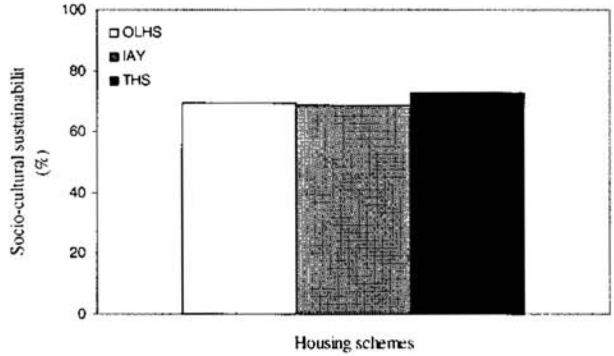

Figure 4.1 Socio-cultural sustainability

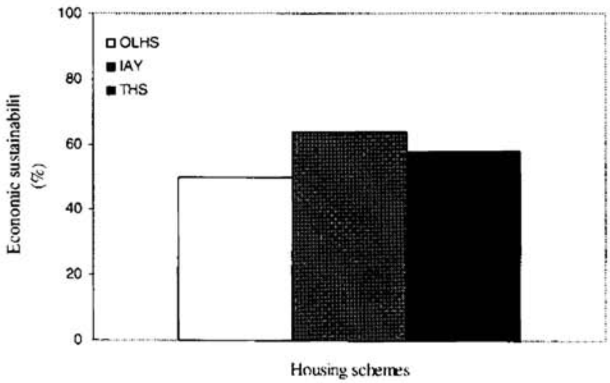

Figure 4.2 Economic sustainability

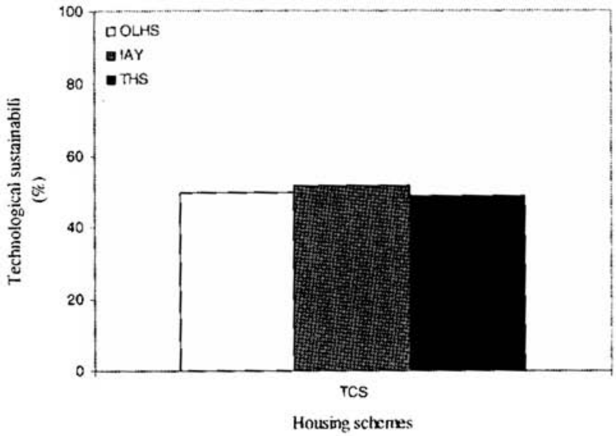

Figure 4.3 Technological sustainability

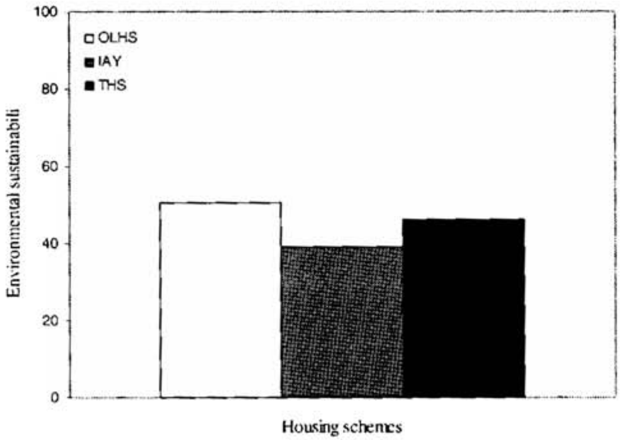

Figure 4.4 Environmental sustainability

A significant variation can be seen only in the case of environmental sustainability and economic sustainability (Fig. 4.4 and Fig. 4.2) between the selected schemes. However, the other two aspects of sustainability, socio-cultural sustainability and technological sustainability do not show much variation between the schemes (Fig. 4.1 and Fig. 4.3).

4.3.2 *Correlation between different aspects of sustainability within the schemes*

According to the concepts of sustainable-affordable housing (Fig. 2.3, Chapter 2), all the four aspects of sustainability should be correlated to each other. The strength of the correlation between the aspects is considered as an important factor on the sustainability of housing schemes.

A correlation analysis has been performed to quantify the strength of association between the different aspects of sustainability. The Pearson's correlation (r) is used to find the degree of linear relationship between two variables. It can have a value anywhere between -1 and 1. The value for r = 0.00 (no correlation) implies that there is no relationship between the two variables and ±1.00 indicates strong correlation. The larger the absolute value of r, the association (positive or negative) between the variables is considered as stronger. Generally, correlation above 0.80 is considered high. Different colours are used here to indicate the strength of correlation between variables. The interrelation between different aspects of sustainability within each scheme can be assessed from this analysis.

Table 4.6 Significance of correlation between different aspects of sustainability within OLHS

Aspects of sustainability	**Socio-cultural sustainability SCS**		**Economic Sustainability ECS**		**Technological Sustainability TCS**		**Environmental sustainability ENVS**		**Total sustainability**	
	r	s	r	s	r	s	r	s	r	s
SCS			0.524	0.026	0.197	0.433	0.476	0.046	0.652	0.003
ECS	0.524	0.026			0.646	0.044	0.658	0.003	0.923	0.000
TCS	0.197	0.433	0.646	0.004		-	0.557	0.016	0.759	0.000
ENVS	0.476	0.046	0.658	0.003	0.557	0.016		-	0.835	0.000
Total sustainability	0.652	0.003	0.923	0.000	0.759	0.000	0.835	0.000		

'r' refers to Pearson's correlation and 's' refers to significance.

■ Strong correlation, r value above 0.80, ▩ Good correlation, r value between 0.6 and 0.80,

□ Poor correlation, r value less than 0.60

It can be seen that the total sustainability of the One Lakh housing scheme has rather higher significance to economic and environmental aspects than the other two aspects. This can be attributed to the provider approach of this scheme in ensuring the minimum housing needs (through free houses) and basic infrastructure facilities. However the socio-cultural sustainability has the lowest correlation to the total sustainability (significance-0.003 and r-0.652) of this scheme. This indicates the low acceptability of this housing programme (with regard to socio-cultural aspects) among the users. The case studies (No.1 and 2) of households from Vettuvila and Neeravil housing colony are examples to explain this. The stigmatization of OLHS houses in the first case and factors like increased dependency to government support and less adaptability of the type design in the second case has contributed in the lowest significance of socio-cultural sustainability in the total sustainability of this scheme.

Relation between the sustainability aspects within OLHS

- The poor correlation of socio-cultural sustainability with economic sustainability (significance-0.026, r-0.524) and environmental sustainability (significance-0.046, r-0.476) gives an indication of the poor living conditions of the households and lack of basic infrastructure facilities (a criterion for environmental sustainability). Different case studies of OLHS support these findings.
- Economic sustainability of One Lakh housing scheme has significant correlation to technologic sustainability (significance-0.044, r-0.646) and environmental sustainability (significance- 0.003, r-0.658). The insignificant correlation between technologic sustainability and socio-cultural sustainability (significance-0.433, r-0.197) indicates the poor involvement of households in the building process and the significant correlation between technologic and economic sustainability indicates the role of the affordability of the household in maintaining the sustainability of building process.

Indira Awaas Yojana (IAY)

Table 4.7 gives the significance of correlation between different aspects of sustainability within IAY. The socio-cultural sustainability of this scheme has only very little significance in the total sustainability indicating the poor acceptance of this scheme. Similar to OLHS, economic sustainability is the most influential aspect in this scheme. In IAY also there is no correlation between technologic sustainability and socio-cultural sustainability.

Relation between the sustainability aspects within IAY

- Socio-cultural sustainability is only related to environmental sustainability. The significant correlation of socio-cultural sustainability with environmental sustainability (significance-0.010 and r-0.708) indicates fulfilment of the basic infrastructure facilities. Also the poor correlation of environmental sustainability and economic sustainability (significance - 0.042 and r - 0.592) indicates the role of the economic capacity of the households in providing the basic infrastructure. At the same time there is no correlation between socio-cultural sustainability and economic sustainability (significance-0.142 and r-0.661). This shows the poor affordability of the housing schemes especially in providing the basic shelter needs.

- Economic sustainability of this scheme has correlations to all the other aspects of sustainability except socio-cultural sustainability. The case study (No. 4) of households from Murundal is an example to this and indicates the failure of enabling strategies in this scheme. This also shows the dominant role of the affordability of households in providing basic housing facilities over the policy initiatives. The insignificant correlation between the socio-cultural factors and technology (significance-0.457 and r-0.238) reveals the lesser feasibility and awareness of the households on innovative technological options. Hence the correlation between economic sustainability and technologic sustainability (significance-0.001 and r-0.845) indicates the dependence of technological sustainability on the purchasing power of the households.

Table 4.7 Significance of correlation between different aspects of sustainability within IAY

Aspects of Sustainability	Socio-cultural sustainability SCS		Economic Sustainability ECS		Technological Sustainability TCS		Environmental sustainability ENVS		Total sustainability	
	r	s	r	s	r	s	r	s	r	s
SCS		-	0.142	0.661	0.238	0.457	0.708	0.010	0.544	0.067
ECS	0.142	0.661		-	0.845	0.001	0.592	0.042	0.880	0.000
TCS	0.238	0.457	0.845	0.001		-	0.532	0.075	0.871	0.000
ENVS	0.708	0.010	0.592	0.042	0.532	0.075		-	0.854	0.000
Total sustainability	0.544	0.067	0.880	0.000	0.871	0.000	0.854	0.000		-

Total Housing scheme (THS)

In THS, all the sustainability aspects except technological sustainability have significant influence on the total sustainability. Their strength varies in the order of ECS >ENVS >SCS>TCS. Unlike the other schemes, socio-cultural sustainability has a better significance (r -0.728) in the total sustainability of THS. This can be explained by the comparatively better acceptance of Total Housing Scheme compared to the other schemes. Case study (No. 7) of THS household reveals the difficulties of the household in accessing finance, feasible technological options and problems due to the lack of proper guidance. These factors lead to the lack of correlation between different aspects of sustainability and also to the un-sustainability of this scheme.

Relation between the sustainability aspects within THS

- The poor correlation of socio-cultural sustainability with environmental sustainability (significance-0.094, r-0.448) and economic sustainability (significance-0.125 and r-0.414) indicates the lack of the basic infrastructure facilities poor affordability of this housing scheme. The insignificant correlation of environmental sustainability with economic sustainability (significance-0.075, r-0.473) also shows the importance of the affordability of the households in providing the basic shelter needs. Case study (No. 7) of THS household is an example for the economic un-sustainability of this scheme and explains the insignificance of socio-cultural sustainability with economic sustainability.
- The insignificance of correlation between technological sustainability with socio-cultural sustainability (significance-0.275, r-0.301) reveals the lesser feasibility and awareness of the households on innovative technological options and proves the lesser affordability of technological options. The insignificant correlation of technological sustainability with environmental sustainability indicates limited utilization of environmentally friendly technology in the building process of THS.

Table 4.8 Significance of correlation between different aspects of sustainability within THS

Aspects of sustainability	Socio-cultural sustainability SCS		Economic Sustainability ECS		Technological Sustainability TCS		Environmental sustainability ENVS		Total sustainability	
	r	s	r	s	r	s	r	s	r	s
SCS			0.414	0.125	0.301	0.275	0.448	0.094	0.728	0.002
ECS	0.414	0.125			0.247	0.374	0.473	0.075	0.843	0.000
TCS	0.301	0.275	0.247	0.374			0.243	0.383	0.501	0.057
ENVS	0.448	0.094	0.473	0.075	0.243	0.383			0.750	0.001
Total sustainability	0.728	0.002	0.843	0.000	0.501	0.057	0.750	0.001		

4.3.3 Correlation between different aspects of sustainability between the schemes

Table 4.9 shows the significance of correlations between different sustainability aspects between the selected schemes.

Table 4.9 Significance of correlation between different aspects of sustainability between the schemes

Aspects of Sustainability	Socio-cultural sustainability SCS		Economic Sustainability ECS		Technological Sustainability TCS		Environmental sustainability ENVS		Total sustainability	
	r	s	r	s	r	s	r	s	r	s
SCS			0.320	0.032	0.201	0.187	0.505	0.000	0.620	0.000
ECS	0.320	0.032			0.596	0.000	0.354	0.017	0.832	0.000
TCS	0.201	0.187	0.596	0.000			0.396	0.007	0.747	0.000
ENVS	0.505	0.000	0.354	0.017	0.396	0.007			0.737	0.000
Total sustainability	0.620	0.000	0.832	0.000	0.747	0.000	0.737	0.000		

Among the different aspects, socio-cultural sustainability has the lowest and economic sustainability has the strongest significance in the total sustainability of these schemes. The influence of different aspects of sustainability on total sustainability varies in the order of ECS > TCS > ENVS > SCS.

Relation between the sustainability aspects between the schemes

- The insignificance in correlation of socio-cultural sustainability with environmental sustainability (significance-0.000 and r-0.505) gives an indication of the insufficient basic infrastructure facilities.
- Socio-cultural sustainability has correlations to all the other aspects of sustainability (though not strong) except technological sustainability. Case study of IAY households (No. 4) and THS households could be suggested as examples to explain this. However, all other aspects are significantly correlated to one another. The insignificance of this correlation between the socio-cultural factors and technology (significance-0.187 and r-0.201) reveals the lesser feasibility and unawareness of the households on innovative technological options. At the same time, there is a significant correlation between economic sustainability and technologic sustainability (significance-0.000 and r-0.596). This indicates the influence of the economic capacity of the households over the policy initiatives in accessing different technological options.
- The highest significance of economic sustainability and least significance of socio-cultural sustainability in the total sustainability of these schemes also verify the excessive dependence of housing schemes on the affordability of the household.

4.3.4 Comparison of total sustainability among the schemes.

The total sustainability of different schemes is calculated as the sum of the four aspects of sustainability and their mean values are taken for comparison. A comparison of the results of A I, A II (refer section 3.3.2) and A III can be seen in fig. 4.5. The total sustainability values of the schemes from the viewpoints of governments (AI, represented by white columns in the figure) show a clear upward trend towards the concept of sustainable-affordable housing.

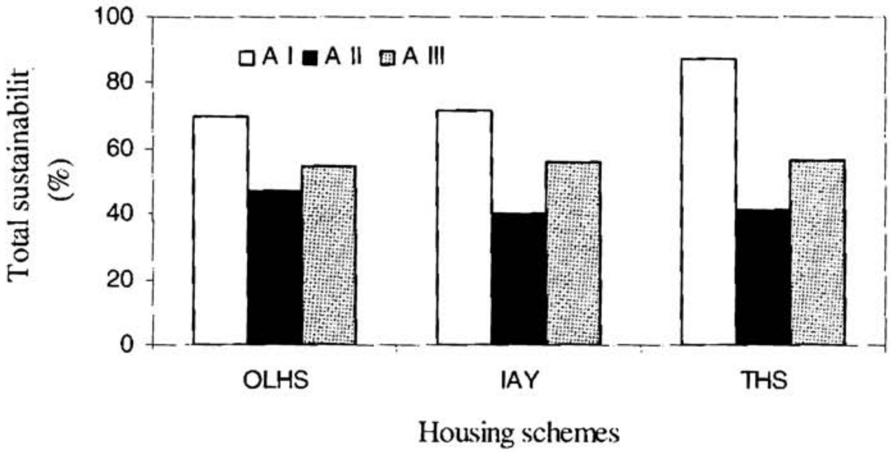

Figure 4.5 Comparison of total sustainability in One Lakh Housing Scheme (OLHS), Indira Awas Yojana (IAY) and Total Housing Scheme (THS) from the perspective of government (AI), perspective of an observer (AII) and from the perspectives of the households (AIII)

However, the evaluation based on the observer's perspective (AII, represented by black columns in the figure) and the beneficiaries' viewpoint (AIII, represented by grey columns in the figure), present nearly invariant results, and very different as compared to the perspective of the government, with much lower values of sustainability and also with only small variations between the three schemes.

4.3.5 Conclusions from the statistical analysis

The evaluation of public housing schemes in Kerala points towards the failure of implementation strategies, because of the lack of integration of the four main aspects of sustainable-affordable housing, namely socio-cultural, economic, technological, and environment factors. The SPSS analysis of the selected schemes leads to the following conclusions:

- The socio-cultural sustainability of housing programmes always showed an insignificant role in the total sustainability. This indicates the poor acceptance of these housing programmes among the users.
- The economic factors of housing schemes in all the cases had a vital role in the total sustainability of the schemes than compared to other aspects. This shows the importance of both the affordability of the household as well as the housing schemes in sustainable housing development.
- The evaluation of different housing programmes reveals the excessive dependence of the sustainability of housing programmes on the economic status of the households (to afford and maintain the houses) over the policy initiatives of the government. This confirms the failure of enabling strategies and shows the poor correlation between socio-cultural factors and economic factors in housing.
- The low correlation between socio-cultural sustainability and technological sustainability in the selected housing schemes verifies the un-sustainability of the present building process in Kerala. It points towards the ignorance of the households on the building process, the proper utilization of resources, and their difficulties in accessing innovative technology.
- The comparatively lower significant role of technological factors in the total sustainability of schemes reveals the failure of innovative technological options in making housing affordable.
- The technological sustainability in all the cases had a strong correlation with economic sustainability. This indicates the importance of the affordability of technological options.

4.4 Examples of housing programmes from other countries

This section presents three examples of enabling strategies taken from the Global Best Practise data base of the United Nations Center for Human Settlements. This comparative perspective of housing strategies is helpful in evaluating the case studies and in formulating effective implementation strategies. However, affordable housing solutions should be based on region-specific approaches and requirements, these strategies cannot be replicated as such.

4.4.1 The People's Housing Process (PHP), South Africa (Department of Housing, South Africa, 2003, 2004, 2005)

The People's Housing Process (PHP) in South Africa has been initiated to assist people who are poor and homeless or inadequately housed. The rationale for the policy is based on a growing awareness that the majority of homes within South Africa, as well as in other developing countries, were built by the people themselves. On this basis, the government concluded that the activities of people in housing themselves deserve formal recognition and concrete support from the state. The objective of the project is to develop support mechanisms for building capacity at all levels to enable people to address their own housing needs. The policy aims to support the poorest of the poor families who usually only have access to housing subsidies and who wish to enhance their subsidies by building or organizing the building of their homes themselves. Usually these families cannot access credit or accumulate significant savings to enhance their subsidies. The People's Housing Process supports the creation of Support Organizations to secure subsidies, to provide land to build, to provide technical, financial, logistical and administrative support to the beneficiaries (envisaged through Housing Support Centres). The People's Housing Partnership Trust (PHPT) is established by the South African government to support the People's Housing Process through capacity building and engaging with national, provincial and local governments, and civil society. Since its inception, PHPT has been able to train people in construction skills, housing design and safety; to train community facilitators; and to establish project implementation systems and housing support centres. At national government level a joint United Nations Development Programme (UNDP) and United Nations Centre for Human Settlements (UNCHS) project assists the People's Housing Partnership Trust which is to drive the support programme to the Support Organizations.

Examples from People's Housing Process

Cape Town PHP (UNCHS, 2004)

The Development Action Group's (DAG's) People's Housing Process consisted of three housing consolidation projects formed by the communities living in these areas. The projects: Masithembane, Homeless and Squatters Housing Project (HOSHOP) and Sinako Ukuzenzele were initiated in 1997 and implemented in 1999-2002. DAG provided technical advice and support to community organizations and training to community members. Partnerships between the People's Housing Partnership Trust (PHPT), the Western Cape Provincial Housing Development Board, and the Tygerberg Administration within the City of Cape Town together with the community-based organizations were the key to successful implementation of the projects. A total of 638 houses were built and occupants took part in training and capacity building workshops. Over seventy people were employed as builders in the projects and another twelve people were employed in the three housing support centers. Material suppliers in the low cost housing market have subsequently employed community members who worked in the support centers. Approximately twenty people (Housing support centre staff and committee members) received ten days training on the management of housing projects followed by ten days of practical construction training. In addition, ten builders in the HOSHOP project and thirty builders in the Masithembane project received in-depth on-site construction skills training over a period of a few months.

According to UNCHS report, this program fully meets the basic criteria of impact, partnership and sustainability as well as the additional considerations of leadership and community empowerment, gender equality and social inclusion, and innovation within local context and transferability.

Thabong PHP (Stewart et al., 1999)

The New Housing Company was responsible for the implementation of the project. They came into agreement with other stakeholders such as (i) the Provincial Housing Board (PHB) for the funding, (ii) a firm of quantity surveyors, for verifying the delivery of materials and administering the accounts, (iii) a material supplier for on-site delivery of materials, (iv) a community representative committee (steering committee) for the interaction with the beneficiaries, (v) the Basic Employment Skills Training (BEST) project for the rendering of technical advice and (vi) each beneficiary as the private client for the completion of application forms and the placing of orders. A steering committee was also established and had community representation from political parties, community organizations, churches, businesses, women and youth organizations, and the health and education fraternity. Regular meetings were held with the steering committee to report on the progress made. This was also the forum where minor practical, political and administrative problems were discussed and usually resolved.

According to Stewart et al. (1999), the diversity of design and assumed quality of life as opposed to the monotony and uninviting lifestyle projected by mass housing projects, stand out as a key feature of Thabong people's housing process. Table 4.10 gives a quick review of the different strategies adopted in the People's Housing Process of South Africa for sustainable housing development.

Table 4.10 Sustainability Analysis: People's Housing Process (PHP), South Africa

Sustainability Aspects	Strategies
Socio-cultural Factors Adaptability	Beneficiaries were given freedom of choice for their houses from a list of housing packages to suit their requirements (e.g.: Thabong PHP)
Equality	The diversity of design as opposed to the common feature of mass housing projects was a positive factor in Thabong PHP
Beneficiary participation	People built houses for themselves
Community participation	The People's Housing Partnership Trust (PHPT) established by the South African government supported the People's Housing Process through capacity building and engaging with national, provincial and local governments, and civil society.
Integration of amenities	No specific information on this criteria
Economic factors **Pre-requisites**	Housing support organizations are meant to ensure: securing housing subsidies for the families Facilitating the acquisition of land on the basis of secure tenure; and Providing technical, financial, logistical and administrative support regarding the building of their homes.
Affordability	This policy aims in supporting the poorest of the poor families who usually only have access to housing subsidies and who wish to enhance their subsidies by building or organizing the building of their homes by themselves. The People's Housing Partnership Trust (PHPT) supported the People's Housing Process through capacity building by training people in construction skills, housing design and safety etc.
Shelter needs	No specific information on this criteria
Technological Factors	Technical support was ensured and innovative technology was made feasible with the help of support organizations
Environmental Factors	No specific information on this criteria

4.4.2 The Grameen Bank (GB) low-cost housing programme, Bangladesh (Ahmed, 1998)

The Grameen Bank concept was originated in 1976 on recognizing that it is poor people's lack of access to capital rather than their capacity to repay that perpetuates their poverty. This project started with the provision of credit facilities to the rural poor without formal collateral, with the intension of creating a stable income through income generating activities and protecting them from the exploitation of money lenders. The basic concept is to form groups of five members and loans disbursed through peer guarantee. The formation of the groups - the key unit in this credit programme - is the first necessary step to receive credit. Loans are initially made to two individuals in the group, who are then under pressure from the rest of the members to repay in good time. If the borrowers default, the other members of the group may forfeit their chance of a loan. The loan repayment is in weekly installments spread over a year and simple interest of 20% is charged once at the year end. The collateral system of peer support means that families help each other out with payments if necessary to ensure that all repayments are made on time. This project was quite effective in terms of loan recovery, proved successful and was institutionalized as the Grameen Bank in 1983.

The Bank extended its support to house-building in 1984, by acknowledging that the diminishing supply of building materials, their spiraling prices, and the beneficiaries' inability in raising the substantially high capital for housing as the main stumbling blocks of the poor in housing themselves. The house loans are available only to existing Grameen Bank borrowers who have a hundred per cent repayment record and who have completely repaid their first two loans for income generation activities. The loans have to be repaid over a period of five years in weekly installments with an interest rate of eight percent. Together with the housing loans, each borrower receives also some pre-cast building components. The structural system is based on a standard module, and the pre-cast building materials are mass produced off-site and made available to the self-helpers at low prices.

The Grameen Bank has developed two standard house designs. However, the houses vary in appearance throughout the country even though they have the same basic structural components. There are four reinforced concrete pillars on brick foundations at the corners of the house and six intermediary bamboo or concrete posts, with bamboo tie beams, wooden rafters and purlins supporting corrugated iron roofing sheets. This provides stability in the flood and strong monsoon wind, and protection from the heavy rain during the monsoon season. In cases of severe flooding the house can be dismantled and the components stored and reassembled later. A sanitary latrine is also proposed with each house. Families can build the houses themselves, with the help of friends and neighbours. Local skilled carpenters carry out the roof construction for many families. Loans are also available to purchase homestead land for landless households.

Table 4.11 presents an overview of the strategies adopted in Grameen Bank Housing Programme with respect to different aspects of sustainable-affordable housing.

Table 4.11 Sustainability Analysis: Grameen Bank Low-Cost Housing Programme, Bangladesh

Sustainability Aspects	Strategies
Socio-cultural Factors Adaptability Equality	The Grameen Bank has developed two standard house designs. But the houses varied in appearance throughout the country even though they have the same basic structural components
Beneficiary participation	Families built houses themselves with the help of friends and neighbours.
Community participation	Community participation was ensured through group lending approach and mutual help
Integration of amenities	No specific information on this criteria
Economic factors **Pre-requisites**	Loans were made available to purchase homestead land for landless households. Provided credit facilities to the rural poor without formal collateral with the intension of creating a stable income through income generating activities and protecting them from the exploitation of money lenders.
Affordability	The housing loans were available only to existing Grameen Bank borrowers who have a 100 per cent repayment record and have completely repaid their first two loans for income generation activities.
Shelter needs	No specific information on this criteria
Technological Factors	Pre-cast building materials were mass produced off site and made available to the self-helpers at low prices.
Environmental Factors	No specific information on this criteria

4.4.3 Million Houses Programme (MHP), Sri Lanka (Lankatilleke, 1986)

In 1985 the Government of Sri Lanka launched the Million Houses Programme, the objective of which was to provide basic shelter for the entire population by 1989. Through this programme, the Government changed their role to an enabler in housing development and encouraged low income households in both urban and rural areas to build their houses and settlements by providing assistance to resolve land tenure problems, to obtain housing loans at low interest rates and to provide basic environmental services such as water, sanitation, access to roads, electricity and community centres. A variety of loan packages were made available depending on the needs of the household and their ability to make repayments.

The National Housing Development Authority (NHDA) was responsible for the implementation of both urban and rural sub-programmes. The approach was evidently characterized by community participation through enabling strategies. The Community Action Plan and Management approach (CAP) sees people as the main resource for development rather than as an object of the development efforts or as mere recipients of benefits. The role of the Government through the National Housing Development

Authority and the Urban Local Authorities is to support this process whenever necessary. A Community Development Council (CDC) had to be established in the beginning with the involvement of urban and rural low-income settlements. These councils are considered to have a central role in the community action planning approach. They were supposed to act as intermediaries between the population of low-income settlements and the external agencies, articulating the needs and the problems felt by residents to the external organizations, taking decisions, formulating plans, executing projects and monitoring the implementation of a multitude of undertakings. Technical and financial assistance were given by the UNICEF under its Urban Basic Services Program (UBSP) through the CMC and the NHDA. United State Agency for Intentional Development (USAID) supported the NHDA for housing loan program.

Table 4.12 Sustainability Analysis: Million Houses Programme, Sri Lanka

Sustainability Aspects	Strategies
Socio-cultural Factors Adaptability	No specific information on this criteria
Equality	No specific information on this criteria
Beneficiary participation	People built their own houses.
Community participation	A Community Development Council (CDC) was established with the involvement of urban and rural low-income settlements. These councils were supposed to act as intermediaries between the population of low-income settlements and the external agencies, articulating the needs and the problems felt by residents to the external organizations, taking decisions, formulating plans, executing projects and monitoring the implementation of a multitude of undertakings.
Integration of amenities	Social infrastructure was identified through issue specific workshops and provided solutions
Economic factors Pre-requisites	A variety of loan packages were made available depending on the needs of the household and their ability to make repayments
Affordability	No specific information on this criteria
Shelter needs	No specific information on this criteria
Technological Factors	Technical assistance was provided in the building process
Environmental Factors	Basic infrastructure facilities were ensured.

The CAP method consists of a structured series of workshops organized for community members who have expressed interests in improving their shanty settlement. At such workshops, community members interact as partners with the staff of the National Housing Development Authority, the local authority and the non-governmental organizations. They discuss the problems of the community, identify solutions and formulate plans of action. The community takes responsibility for implementing these action plans in collaboration with the NHDA and other organizations, and for maintaining and managing the built environment after the completion of the project. Normally, an initial two-day workshop is held at a community centre within the settlement, for (about 30) representatives of the community, to identify their socio-economic and physical issues and plan strategies to tackle. These were followed by a variety of one or half-day issue-specific workshops, depending upon the needs of the community and the stage of implementation. Examples of issue-specific workshops are planning principles and technical guidelines, community building guidelines and rules orientation to housing information services. According to Lankatilleke (1986), official from National Housing Development Authority, the experience of two years of implementation of the MHP, clearly demonstrated that it is a generative process; generative in the form of strategy development, planning techniques, operation, consciousness raising and most importantly in learning. The self-realization of the potentials inherent in the actors leads to a great degree of satisfaction and also to self-confidence. According to UNCHS (1996), Sri Lanka's Million Houses Programme represents one of the best urban examples of action planning to date. Table 4.12 gives the list of strategies adopted in this scheme.

The Million Houses Programme of Sri Lanka with the CAP method resembles the People's planning campaign of Kerala and could act as an effective tool in ensuring the basic infrastructure facilities, accessing resources or prerequisites for sustainable housing through community participation. People's housing process (South Africa) and Grameen Bank housing scheme (Bangladesh) are good examples in enabling strategies.

4.5 Discussions and Evaluation

The evaluation of the public housing schemes in Kerala reveals a totally different side of the housing situation of the state than projected by the official documents. It proves that the real situation cannot be evaluated based on numerical data alone. Instead, it also requires the viewpoint of beneficiaries. The succeeding text gives a discussion of these outcomes based on the different aspects of sustainable-affordable housing.

4.5.1 Socio-cultural sustainability (SCS)

The case studies of different households conclude the following shortcomings as the primary failure of housing programmes in terms of socio-cultural sustainability in housing.

- Lack of flexibility or little adaptability of OLHS houses to the future requirements

- Increased dependency of households on Government support.
- Poor involvement of OLHS beneficiaries in the building process.
- Poor involvement of the community in the building process of IAY and THS.
- Poor integration of amenities and services for IAY and THS.

Incremental transformations and extensions can improve the original housing facilities and make it adaptable to the changing needs of households. However, the case studies of OLHS reveal that only very few of the households were able to make their homes adaptable through transformations and extensions. Others found the houses unsuitable to their present needs mainly because of the peculiar design of the twin houses. The willingness of people to invest their energy, initiative and their savings or other material resources depends on the satisfaction they experience or expect as a result (Turner, 1976; Tipple, 1996). According to the latter the quality and the transformations on the houses in the course of time reflect the attitude of the inhabitants towards their houses. Also the maintenance of existing housing areas and their continued improvement over time through local initiatives can enhance long-term social relationships, which are essential for socio-cultural sustainability of housing development.

The ownership of houses under one lakh housing scheme was conferred to the households purely as a gift from the government. Beneficiary involvement was meagre or rather nil in the housing process and has had to accustom to the facilities given. It seems that this provider approach could only diminish their self-reliance and they became more dependent on public support. Along with this, the type design of OLHS houses was turned out as a sign of their identity stigmatizing the inhabitants as belonging to lower income category. The mass housing feature of this scheme also contributed to the segregation of a specific group of people into a particular locality or colony. The majority of the interviewed households were oppressed by this and had a feeling of being inferior to others in society. The case study of the household (case study No.1) from Vettuvila OLHS is a typical example of this stigmatisation. With the same reason of stigmatization of OLHS, some of the IAY/THS households seemed to be more satisfied with their houses than their OLHS neighbours, even though they had a poor housing condition as compared to their neighbours. On the basis of this, the abysmal housing conditions in OLHS houses can be understood as the result of poor beneficiary involvement and the stigmatization of houses. The case study of Sivodayam colony (THS) is also an example to poor beneficiary involvement and stigmatization. On the other hand the quality of houses from the case studies of other households from THS and IAY show the importance of beneficiary involvement in the building process.

Community involvement was a major supporting factor in the case of OLHS houses. The significance of OLHS even now is mainly because of this. According to Jenkins (1999), community development is a key to unlock higher levels of mutual advantage as well as more effectively and equitably accessing state and economic resources. For the lower income population, communal action, whether in the political, social or economic realm, permits a scale of activity impossible as individuals. This is rather true in the case of OLHS houses. But the houses constructed under THS and IAY could not gain any benefits from community involvement and were implemented only with the beneficiary involvement under partial government support. Although the underlying concept of THS was one similar to that of People's Housing Project, South Africa, the case studies from THS reveal that there was hardly any community participation in the houses constructed under this scheme, other than the Sivodayam colony case study. But even in this case, the technical agency employed for facilitating the building process became like a contractor and the houses degraded to the status of conventional contractor-built type designs. Community resources can bridge the gap but only if the community is committed to, and feels responsibility for, the programme. The community must therefore be fully involved in decision-making on programme direction and priorities and should be assigned responsibility for tasks where there is a clear connection between input effort and output benefit (UNCHS, 1988).

The provision of physical infrastructure must be seen as a prerequisite for the sustainability of human settlements and for achieving of basic human needs. This was a positive factor of OLHS since their colony was provided with motorable road, facilities like schools, worship places, hospitals and markets in the near by area. However in IAY and THS, houses were constructed by the households individually in their own plots and hence the situation was different for each of the households. Planned development is needed for the development of a locality as a good residential neighbourhood and this is an advantage of mass housing schemes.

4.5.2 *Economic sustainability or Affordability (ECS)*

Affordability or economic sustainability of the housing schemes in Kerala was always a deep concern among the households as well as the authorities. The case studies also support this because of the following issues.

- Poor housing conditions
- Problems connected with land ownership
- Incomplete houses
- Additional financial burden
- Insufficient housing facilities and
- Lack of access to basic resources for housing

Poor housing condition often exposes the poverty of the household and reflects their economic status. The accessibility of the households to their basic shelter needs depends on the economic sustainability of that particular housing scheme. The case studies of different households points towards the inaccessibility in achieving these basic means.

The story of IAY households (Case study No. 4) tells us their difficulties in accessing the basic resources for housing. One of the households (Identification Number 68) from this case study fully relied upon a contractor as they did not have any idea of the building process. However their neighbour's family (Identification Number 67) utilized daily labourers in skilled activities and contributed the household labour in unskilled jobs. Unfortunately, both the households were not able to finish the house in the stipulated time frame of the project due to the scarcity of materials, necessary finance and skilled masons. Thus they could not avail the full support from the scheme and ended up with an incomplete house and a financial burden. Also, in the third case, though the household could manage with the procurement of materials at higher price and arranging skilled workers to complete the building process in the time frame of the project, they now seriously face a financial crisis. The case study of THS (case study No. 7) also reveals the ignorance of the household in the building process, cost reduction techniques and above all in the proper utilization of resources. In spite of owing a big liability for housing and draining out all their assets and savings, they could not meet their basic shelter needs. Although the household built their house also considering their future requirements, it failed to serve even their primary housing needs. The accessibility to basic resources including affordable technological options and proper guidance are thus inevitable for economic sustainability and the above case studies reveal the disability of the poor in accessing this.

The affordability by a household is also based on the relationship between monthly household income and repayment of housing loans (Dewit et al., 1989). The Grameen Bank housing loan programme needs special mention in this context. The basic intention of Grameen bank programme was to create a stable income through income generating activities by the initial loans. Once this has been achieved, a long term loan for housing is provided. Also the peculiarity of this programme is its greater flexibility in accessing a variety of loans for housing according to the needs of the households. Although there are a few shortcomings in Grameen Bank housing programmes such as lack of trained technical supervision, difficulties in the transportation and installing of building components, usage of energy-intensive imported materials (corrugated iron sheets, cement) and lack of satisfactory guidelines for settlement design and planning, this housing programme shows that enabling people to build better housing for themselves through institutional intervention has potential for promising results (Ahmed, 1998). This is also evident from Thabong case study. This project was initially met with objections from beneficiaries since it was difficult to convince people that through quality building material and technical advice, they would be able to build houses that would satisfy more of their needs than with contractor built houses of typical specifications. But later it turned out to be a great success with the involvement of beneficiaries and community participation (Stewart et al., 1999). Enabling the poor to build and maintain their houses can be indeed helpful rather than providing the houses free. The case study of Sivodayam colony households also confirms this. It shows that all the help from the government was only helping them in increasing their dependence rather than improving their self-reliance. This was also confirmed by case study (No. 2) of the household from the Neeravil OLHS. Even after long years of occupancy in that house, they still do not feel the house as their own and looking forward for further government support for minor repairs.

A study conducted by Shiferaw (1998) on the self-initiated transformations of public-provided dwellings in Addis Ababa, Ethiopia shows that the quality of the extensions to the original core houses were found depending very much on the security of tenure, their command over resources and feasibility to technological options. According to him the extensions to government-provided dwellings can turn to a valuable resource for improving the housing conditions of the low-income group only if these spontaneous and individual actions are technically, logistically and legally supported by the formal sector. The negligence of household from Neeravil OLHS colony (No. 1) to their pathetic housing condition could be either due to their increased dependence of the public support for further improvement of their house and their less accessibility to affordable building processes. It can also be due to the security of tenure since most of the households from the OLHS were not provided with the ownership documents.

The case study of OLHS households (Case study 3) from Punnapra panchayat tells us the irrationality in the Governmental support. In this case study, financial assistance was provided to the OLHS households for detaching their house from their neighbour's, without considering the present situation of any of the houses. Hence the poor household was forced to demolish his original house along with the modifications made in the due course of time. The Thabong case study can be cited as an example in this context to show the significance of beneficiary involvement in decision making especially in a project which deals with the modification or renovation of the existing houses. In such situations, the project has to address individual needs rather than perceived mass needs. In the Thabong project the beneficiaries were given freedom of choice for their houses from a list of housing packages to select the appropriate option to suit their requirements. A similar kind of approach considering the needs of households and specific situations of present houses would be helpful in improving the OLHS houses rather generalising the solution. Otherwise public assistance may be a burden to the household than being a support as in the case of this particular case study.
Home ownership in developing countries has a tremendous social value - arguably more than in advanced countries, but largely fails to perform its economic functions. Housing delivery can be harnessed as a vehicle for job creation through strategically designed settlements and construction programmes. Identifying and promoting housing activities as a development programme rather than a welfare activity can indeed lead to economic sustainability.

4.5.3 Technological sustainability (TCS)

The household surveys and case studies endorse the concern over the following factors on the technological sustainability of housing programmes in Kerala.

- Scarcity of affordable materials and availability of skilled labour
- Feasibility and affordability of technological options
- Lack of technical guidance or supervision in the building process
- Poor know-how on the building process
- Poor know-how on the cost effective alternatives
- Excessive use of energy-intensive materials

The houses under OLHS were constructed by utilizing local materials, local labour and adopting cost reduction techniques in all stages of construction. The provider approach in this housing scheme and the uniformity in implementation throughout the state helped in ensuring proper technology and maintaining standards. Owing to this, the situation of majority of OLHS houses even after thirty years is passable, despite the fact that most of the households did not pay any attention in proper maintenance and repair for their houses. But the main problem that could be noticed in most of the houses under this scheme is the development of cracks in the long central wall which separates the two adjacent houses, which could be attributed to the peculiar design of twin houses. In addition to this, the design and technology adopted for these houses also showed very little flexibility for further modifications. The case study of the household from Punnapra panchayat (Case study No. 3) can be cited as an example. This household was very concerned to improve their housing facilities and could also modify their house. But they could not retain these modifications and were compelled to demolish the entire building when there was a demand for detaching their house from their neighbour's house.

The case studies of IAY and THS reveal that none of the houses under these schemes were successful in utilizing cost-effective technological options in their building process as anticipated by the government and were only adopting the conventional technological solutions. Even though IAY has specific guidelines for empowering and involving the beneficiaries in skilled jobs, utilization of local materials and self building, discouraging the involvement of contractors and excessive utilization of energy intensive materials like bricks, cement and steel in the building process, none of the beneficiaries were even aware of these requirements of the scheme. And also they had an inferior attitude towards local materials. The case study of IAY beneficiaries (case study No. 4) can be quoted as an example to disclose the difficulties of the beneficiaries in accessing technological options, affordable materials and getting proper guidance on the building process. All three households in this case study were extremely poor and were solely depending on government support. In spite of their financial disability, they were forced to entrust a contractor (Identification Number 68) primarily due to their incapability in the building process. Their only involvement was that of a mediator between the panchayat and the building contractor in transferring the money. The household fully relied upon the contractor as they did not have any idea about the technology used, materials and even the expenses incurred for the construction. Two other households under this case study were also ignorant on the cost reduction techniques, utilization of local materials and were blindly depending on the advice of local masons. These case studies show the difficulties of the beneficiaries in accessing suitable technology and affordable alternatives. Although, the Grameen Bank housing loan programme could help the poor households to certain extent in solving these types of problems, lack of trained technical supervision together with transportation and installing of pre fabricated building components was a major draw back. These examples point towards the need for timely guidance or supervision, technical training and familiarity of building process as the key factors of sustainable technology. The Thabong case study from South Africa can be cited as a best example in such a situation to show the importance of technical supervision and training. On-site advice and training was given for the beneficiary households during the building process. This was necessary as the houses were all at different stages of completion and had different house plans. It also became necessary to advice people on the materials and quantities required especially to those having plans of their own. This advice was given at a centrally located site-office from where all activities were co-ordinated. The households (women in particular) set the trend by requesting training and soon also started assisting neighbours, friends and people incapable of building. According to Stewart et al. (1999) some of the beneficiaries who acquired building skills through training could make it as an income generating opportunity after the completion of this project. This case study also explains the significance of beneficiary involvement in building process especially in the selection of technology and materials.

Even though Total Housing Scheme was implemented with a similar concept of employment generation through housing and whole sector development, case studies and field surveys reveal the failure of policies. A series of training camps were said to be organised for masons, engineers and government officials to achieve 'Habitat Literacy'. The training was given mainly in the application of appropriate technologies, which are cost-effective, environmental friendly, using locally available and affordable materials responding to physical, social and climatic needs of the region. According to the concept of the Government, the main aim of this programme was to unmask the technology and to break the gap between architect, builder and the common man to develop a friendly change in the building sector. It was intended to enable the common man to build and maintain his house by his own efforts. But the real picture sketched out through the household surveys is really alarming. Whatever told, read and heard was a different story than the actual situation. The case study of Sivodayam colony is a better example. One of the major appropriate technology groups were involved in the construction. They signed an agreement with government officials for the implementation of the housing programme. As part of habitat literacy and empowerment of the common man, training camps were also said to be conducted for the households of this colony. But their present housing situation is not that satisfactory. According to the beneficiaries, they could not receive any skilled training in technology or production of building materials. Also they are still not aware of any of the cost effective technological options and not convinced on its strength and durability.

The case studies and household surveys also reveal the inefficiency of cost effective and environmentally friendly technology innovations in reaching the poor. It could not gain that popularity and acceptance especially among the poor households due to lack of proper awareness. The study of Gopikuttan (2004) on technology options in housing for the economically weaker sections in Kerala supports this. He argues that CEEF technology actually meant for helping the weaker section seems to have failed to reach the expected beneficiaries. Irrespective of the housing schemes, the majority of the interviewed households have not even heard of the CEEF technology. Those few who responded positively to this question were also not interested in using it or convinced of the strength. The main reasons they told to support their arguments were the unavailability of skilled labour and lack of confidence on strength and durability. Hence they are forced to depend on the available modern or conventional technological alternatives even though those were not affordable to them. Since the public housing schemes in Kerala were formulated with a presumption of using cost effective technology, the choice of conventional energy intensive building process is basically against this concept and contribute up to the failure of housing schemes. The difficulties in feasibility, acceptability, non-awareness and as well as the lack of confidence in the new technological options aggravate the housing problem along with other aspects of sustainability. These factors urge the necessity of a detailed evaluation of the prevailing building process in Kerala. The succeeding chapter deals with this analysis and present suitable guidelines for the selection of sustainable building process under the context of Kerala.

4.5.4 Environmental sustainability (ENVS)

Environmental sustainability of housing schemes in Kerala raises greater concern on the sustainability of housing development activities in Kerala since it is not getting the desired attention both in the conceptualization stage and as well as in the perception of beneficiaries in real situations. The following objectives which need immediate attention are:

- Insufficient basic services
- Excessive conversion of agricultural land for housing
- Poor concern over the utilization of non renewable resources

- Utilization of energy intensive building materials

Environmental Sustainability is an equally important aspect of sustainable housing as the other three and it deals with the needs of future generations along with satisfying the present needs. The former part is the most ignored sector. It deals with the conservation and protection of resources, both renewable as well as non-renewable. None of the housing schemes was seriously concerned with this objective, and the actual situation in the beneficiary households was not so different. Poor households who are sweating even for their daily bread are more concerned with their immediate needs rather than with their future. The case study of IAY households (case study No. 4) is a good example. They purchased cheap agricultural land and developed as house plot since they could not manage to get any other affordable housing plot. They were not at all bothered by the environmental implications and even not aware of that. Changes in land use patterns, the exploitation of paddy fields and haphazard growth of housing development activities have created severe problems such as water logging, non-availability of drinking water and ultimately the degradation of the natural resources and changes in the micro climate of Kerala. Conserving and protecting resources needs crucial attention to achieve environmental sustainability. None of the schemes could take any positive step towards this aspect.

Needs of present generation is also a prime objective of environmental sustainability. It deals with the quality of environment and infrastructure facilities. Development of an adequate infrastructure base is inevitable for sustainable habitat. In the case of OLHS, the houses were constructed in a clustered manner fixing a density of twenty houses to an acre (approximately 4047 m^2) of land with twenty percent of area utilized for roads and open spaces. Even in this case, government intervention failed to provide the essential infrastructure facilities like proper sanitation and drainage. Also most of the OLHS households had only poor toilet facilities and literally no permanent bathing facilities. A temporary open shed either with a thatched wall or with a protection of polyethylene sheets is a unique feature of their toilets or bath rooms. The case study (No. 2) of OLHS households from Neeravil colony is a good example of their poor surroundings.

Even though IAY guidelines were giving importance to healthy surroundings and infrastructure development, the real situation of the households is pathetic (Case study No. 4). Two of the households from this case study (Identification No. 67 and 68) do not have any type of toilet facility and need to rely on their neighbours for this basic need. The situation of THS households is also not different. The households of Sivodayam colony also had no toilets with their new houses as they denied the facility to increase the area of their houses. Most surprisingly, it is interesting to notice that none of the households are bothered on providing the basic facilities like toilets and drinking water utilizing their housing assistance and looking for further support from the Government for satisfying their needs. The new houses without toilets are a common feature of the public housing schemes in Kerala and also an indication of the increased dependence of households on governmental support.

The evaluation of the public housing schemes in Kerala advocates the reform of Government policies towards practical solutions for sustainable housing development. Housing statistics confirms that quantitative housing deficits are relatively small in Kerala. But the evaluation of public housing initiatives in Kerala begs immediate attention on the gravity of other shelter related problems. Based on these analysis and discussions, the succeeding section presents a few strategies for sustainable-affordable housing in Kerala.

4.6 Strategies for sustainable-affordable housing in Kerala

Housing policy for people living in poverty has multi-objective and multi-institutional relevance. This section comes up with a few strategies for the development of sustainable-affordable housing. They are identified as: Policy measures for socio-cultural sustainability (PSCS), Policy measures for economic sustainability or Affordability (PES), Policy measures for technological sustainability (PTS), Policy measures for environmental sustainability (PEVS).

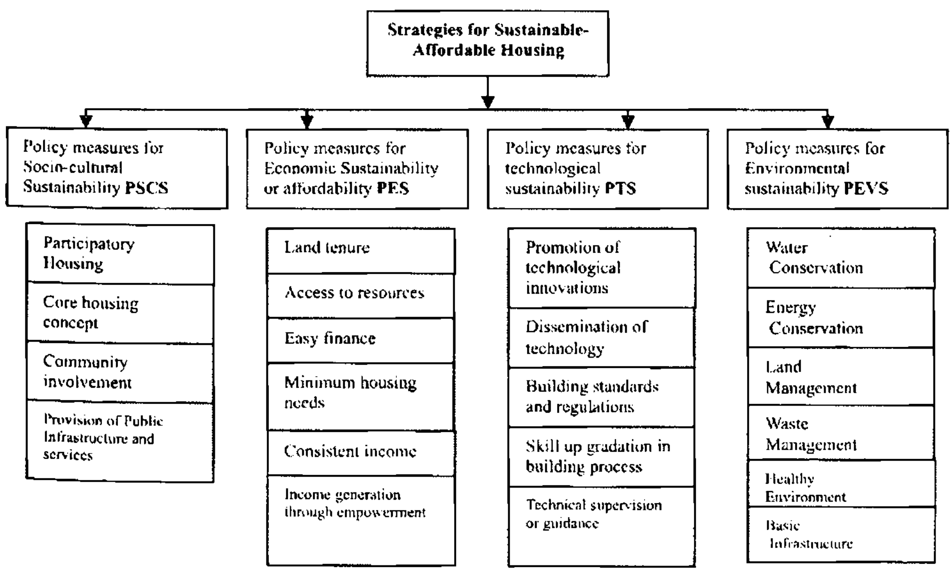

Figure 4.6 CF_2 - Strategies for sustainable-affordable housing

This modified (based on evaluation) framework (CF_2)-Strategies for sustainable-affordable housing (Fig. 4.6) can be considered as a mechanism for achieving the objectives as derived from the analysis of case studies and evaluation of housing surveys using CF_1.

4.6.1 *Policy measures for socio-cultural sustainability (PSCS)*

The evaluation of public housing schemes in Kerala highlights the un-sustainability in socio-cultural factors as one of the main pitfalls of the housing programmes. Since housing has got more personal significance than social interests in the perception of an individual, socio-cultural sustainability in housing primarily depends on the attitude of the inhabitants towards their houses. Therefore policies for sustainable housing should give importance in ensuring household participation in all the levels (from planning to finish) of the building process. This could help in considerably improve their self-reliance and lead to better living standards. Ensuring community participation is the next important milestone in this aspect of sustainable housing. Community involvement can accelerate the social significance of housing development by ensuring, integrating and maintaining infrastructure facilities and rescuing the low income households from the evils of social exclusion.

Policy measures for achieving socio-cultural sustainability in housing can be listed as follows.

- Stimulate participatory housing through involvement of households and with the support of community. Community action plan approaches in the Million Houses Programme in Sri Lanka and People's Housing Process from South Africa are good examples in ensuring both community participation and beneficiary involvement. Refining and improving the concept of People's Planning campaign in Kerala could be suggested as a recommendation.
- Promotion of core housing concepts with flexibility for future expansion should be considered on the planning stage itself and ensured with the provision of vacant plots, infrastructure facilities and formative designs.
- Households should be given the freedom of choice for their house from a list of housing programmes to select the appropriate option to suit their requirements.
- Careful neighbourhood planning of the houses should be taken by mixing different income levels of the society in the same locality and ensuring adequate infrastructure facilities and community services to -
    - ensure the inhabitants to take part in community activities, improving social relations and intermingling with others.
    - avoid the segregation of a community based on income, religion or other social criteria.

- discourage the stigmatization of houses either through type design, material usage or any other methods.

4.6.2 Policy measures for economic sustainability or affordability (PES)

The ability of the households to own as well as maintain their houses plays an equally important role in the sustainability of housing development as the economic sustainability of the housing programmes. Government support for housing could help the poor households in supplementing their efforts, only if they are self-reliant to meet their immediate daily needs. Improving and maintaining consistent income should be the prior step in satisfying their housing needs. The next step is facilitating or empowering the poor through enabling strategies to improve their access or command over various resources, necessary for housing. Strategies and housing policies at this stage should be able to tackle the problems connected with land tenure, subsidies, accessibility to easy loans, resources and other obstacles connected with building process. Effective policy measures should be taken for implementing the different objectives of economic sustainability in housing. It can be listed as follows.

- Ensuring consistent income: Grameen Bank Housing Loan programme is an excellent example. It can also be done by-
  - Empowering the poor in the different activities of building process like production of building materials and other skilled labour training,
  - Housing schemes for the economically weaker sections should be coordinated and integrated with poverty alleviation programmes.
- Accessibility of resources: This is a prerequisite for affordable housing. The priorities of different households and problems connected with ensuring different resources such as land tenure, supplementary loans, building materials, labour and other infrastructure facilities needed for housing activities may vary. The Community action plan approach of Sri Lanka could be a better solution. Issue-specific workshops and gatherings organized among the group of households together with the involvement of community and programme officials could sort out the problems and come up with more efficient solutions. The concept of People's Housing Process of Kerala also needs special mention at this context. Improving the accessibility of the households to loans and subsidies could help in further strengthening their ability to afford housing.
- Feasible loans: Promoting micro finance institutions in the model of Grameen Bank is a sustainable solution. A variety of loan packages should be made available depending on the needs of the household and their ability to make repayments.
- Minimum housing needs: Since the sustainability of affordable housing depends on the fulfilment of basic shelter needs, proper monitoring and controlling of housing development activities should be done to ensure it. Organizations or small groups of beneficiary households together with the involvement of community and

programme officials like the Support organizations (South Africa) or Community development councils (Sri Lanka) should be able to fix a minimum specification for ensuring the basic shelter needs and regulate the house building process.

4.6.3 Policy measures for technological sustainability (PTS)

Feasibility to sustainable technological options is one of the main stumbling blocks of the poor in providing their housing. This is aggravated by the exorbitant prices of building materials and inaccessibility to common property resources. Evaluation of the present building process in Kerala pleads for effective dissemination of cost effective and environmentally friendly technology through convincing examples and post-delivery services. Technology promotion activities, awareness programmes and skill upgrading or training programmes should be promoted through policy initiatives. Building regulations and standards also need important consideration. Policy measures for technological sustainability should include following strategies for guaranteeing technological sustainability of housing programmes.

- Timely guidance and technical supervision should be ensured in the building process by intervening technology institutions or organizations as in the case of People's housing Process in South Africa. Strengthening the activities of Building Centres and making them responsible for ensuring the quality of houses could also be a sustainable solution. Their intervention could also help in solving the problems related to material scarcity, unavailability of skilled labour and also in maintaining the technical standards.
- Technology promotion activities and awareness programmes should be accelerated to make the technologies more accessible and affordable to the users.
- Stimulate research activities in appropriate technology by :
    - utilizing locally available or waste materials, which are cost efficient, abundant in supply.
    - utilizing renewable, reusable and recyclable materials.
    - utilizing environment friendly methods to provide affordable housing solutions suitable to the requirements of Kerala.
    - demanding the usage of less energy intensive materials and methods
    - demanding unskilled labour, renewable resources and decentralised production
- Regularise building standards and regulations to ensure and maintain normal construction standards and quality for sustainable housing.
- Building rules and standards should be revised to incorporate the technological innovations.
- Environment friendly construction techniques could be promoted by providing tax exemptions or additional incentives to buildings utilizing this technology.

4.6.4 Policy measures for environmental sustainability (PEVS)

The case study of households from different housing schemes reveals the appalling housing situation of the poor with insufficient basic facilities like provision of drinking water, sanitation and drainage. Even though both the present and the future needs of the household with regard to environmental sustainability do not seem to get any attention in the housing programmes of Kerala, the urgent basic needs of the household has to be fulfilled with due priority. Provision of basic infrastructure facilities, conservation of natural resources, efficient usage of water and energy are integral parts of sustainable housing. Policies should be formulated considering these requirements.

- Policy measures should be able to ensure basic infrastructure facilities (drinking water, drainage and sanitation, waste disposal) to the households.
- Policy measures should ensure energy efficiency in household activities by integrating alternate solutions for renewable energy and conservation of resources.
- Rainwater harvesting methods should be integrated with housing projects.
- Proper regulatory measures should be taken for conservation of agricultural land and against uncontrolled land reclamation for clay mining, housing and other development activities.

4.7 Conclusion

The evaluation of public housing schemes in Kerala verified the mismatch between the aims of government policies and the real situation of beneficiary households. It underlines the failure of different housing policies with respect to sustainable housing development and identifies that though there were different policies over the years (1970 to 2000), they could not lead to significantly different outcomes. The results of the evaluation urges the integration of different aspects of sustainability through efficient implementation strategies, suitable for the socio-economic and cultural specifications of the state co-ordinating the involvement of beneficiary households, local communities, non-governmental organizations, and local government. The policy measures for sustainable-affordable housing should give prime concerns in improving the self-reliance of households through consistent income and their accessibility to resources together with proper utilization of resources. Ensuring infrastructure facilities is also vital in sustainable housing development.

Appendix 4.1

This is the original version of the questionnaire used for the household surveys. The interviewer was asking the questions to the households in the local language (Malayalam) and writing down their responses by herself.

Sustainable- Affordable housing for rural Kerala

Household survey schedule

I. General information

1. Identification number ☐ 2. Name of the Scheme IAY/ THS

3. Name of the Panchayat

4. Ward ☐ 5. House number ☐

6. Name and address of the head of the household

7. Caste/Religion

Details of household members

Household size (8)	Relationship with the head (9)	Age (10)	Sex (11)	Educational qualification (12)	Activity status/ Occupation (13)	Approximate monthly Income (14)	Marital Status (15)	Place of work (16)
Total								

- Place of work code: Within the Panchayat -1, Outside, but within 5km-2, with in 5 to 10- 3, Outside district- 4, outside state - 5, Gulf countries - 6, Other countries -7
- Married - 0, Unmarried - 1, widow - 2, widower -3, Divorcee - 4
- Activity status code: Employed - 1, Unemployed - 2, Ex service - 3, Retired- 4, Housewife - 5, Student - 6, Child -7, Old age - 8, Gulf returned - 9, Working in foreign countries -10

I. Economic status of household

18. Average monthly income of the household in total

Land ownership

19. Land ownership (in cents) House plot
20. Land owned other than house plot Agriculture land ☐ other ☐
21. Total area in cents
22. Approximate plinth area of the house in Sq.m
23. Are there any domestic animals in your house? Yes [1] No [0]
24. If yes.

Item	Number	Giving milk/egg/ meat	Approximate daily earning	Approximate daily expense

Cow [1] Goat [2] Pig [3] Buffalo [4] Hen [5] Duck [6] Others

Furniture

25. Chair ☐ 26.Bench ☐ 27. Stool ☐ 28.Table ☐

29. Desk ☐ 30. Coat ☐ 31.Bed. ☐ 32. Alma rah ☐

33. Mixi ☐ 32. TV ☐ 33. Radio ☐ 34. Music system ☐

35. Telephone ☐ 36. Electric fan ☐ 38. Electric iron ☐ 39. Cycle ☐

40 Motor bike/scooter ☐ 41. Any other vehicle ☐ 42. Approximate gold ☐

Montly Expenditure		Monthly Savings	
Item	Amount	Item	Amount
43. Food		52. Chitty	
44. Medicine		53. Savings bank	
45. Education		54. Post office savings	
46. Electricity		55. Insurance	
47. Water		56. Any other	
48. Cooking gas/ fuel			
49. Periodicals			
50. Any other			

51. Total expenditure 57. Total savings

Liabilities

58. Do you have any liabilities? Yes [1] No [0]

59. If yes,

Loan Source	Amount	Rate of interest	Monthly instalments	Purpose	Remarks

Purpose code Marriage of children [1] House construction [2]

House repair/ maintenance [3] Vehicle purchase/Repair [4] Education [5]

Medical / health purpose [6] any other [7]

Source code Nationalised Banks [1] Private banks [2] Individuals [3]

Co- operative banks [4] Relatives & friends [5] other source [6]

60. Approximate debt amount

61. Repayment of debt: Promptly [1] Not repaying the instalments regularly [2]

Has to repay the last 5 instalments [3] 5 to 12 months [4] More than 1 year [5]

62. Do you able to repay the existing loan Yes [1] No [0]

63. If not, why?

III. Housing details

Previous house

64 From where do you migrate to the new house? The same place [1]

Same panchayat, parental house [2] same panchayat, not parental house [3]

Outside panchayat, but same district [4] Different location than above [6]

65 Why did you migrate to this new house? Old house not liveable [1]

Not enough facilities [2] destroyed by natural calamities [3]

was staying in rented house [4] Other reasons (Specify) [5]

66 Did you satisfy with the location? Yes [1] No [0]

67 Specify reason

68 Type of old house

Foundation

Walls

Roof

Flooring

69. Facilities Living room + Kitchen [1]

Living room + Kitchen+veranda [2] Living room + Kitchen+bedroom [3]

Living room + Kitchen+bed room+ veranda [4] Other than above (specify) [5]

Single multi purpose room [6]

70. Did you have toilet? Yes [1] No [0]

71. If yes, type Single pit [1] Two pit [2] With septic tank [3] Other types [4]

72 Bath rooms Temporary shed [1] Permanent room [2] Public well/ pond [3] Public water tap [4]

73. Drinking water

Own Well [1] Neighbour's well [2] Pond [3]

Public well [4] Public water tap [5] Other (specify) [6]

74 Was the house electrified? Yes [1] No [0]

75. Cooking fuel used? Wood [1] Kerosene [2]

Others (specify) [3]

Present house

76 Year of Sanction

77 Year of construction

78 Year of occupation

79 Duration of building process

80 Are you the original beneficiary of the scheme? Yes [1] No [0]

81 Present situation of the house Completed, good condition [1] Completed, but needs repair [2]

Uncompleted with minor works remaining [3] uncompleted, needs major works to finish [4]

Unliveable condition, major repairs to be done [5] demolished [6] other than this (specify) [7]

82 Did you follow type design? Yes [1] No [0]

83 If not, what additional facilities added? Purpose?

84. Do you have latrine? Yes No

85. If yes, Type Single pit [1] Two pit [1] With septic tank [1] Other types [1]

86 Latrine Integrated with H.S [1] Another Scheme [2] Provided by owner [3]

87 Bath rooms Temporary shed [1] Permanent room [2]

Public well/ pond [3] Public water tap [4]

88 Drinking water Own Well [1] Neighbour's well [2]

Pond [3] Public well [4]

Public water tap [5] Other than this [6]

89 Drinking water Integrated with H.S [1] Another Scheme [2]

Provided by owner [3] Sharing with neighbour [4]

90 Any water/ energy conservation methods adopted? Yes [1] No [0]

91. If yes, what are the measures adopted?

92 Is the house electrified? Yes [1] No [0]

93. If yes, by whom?

Integrated with H.S [1] by the owner [2] by another scheme [3]

94 Any methods adopted for drainage and waste disposal? Yes [1] No [0]

95 If yes, what are they?

Electricity [3]

Location of the house

97. Are you satisfied with the location of the house? Yes [1] No [0]

98 If not why?

Work place away [1] Educational facilities away [2] environmental problems [3]

Bad neighbourhood [4] No hospital facility [5] other reasons (specify) [6]

99. Environment Air pollution [1] Dusty [2]

Healthy [3] Unhygienic [4]

100. Neighbourhood Good residential area [1] Industrial area [2]

Slum like area [3] Low-income settlement [4]

other (specify) [5]

101. Type and nature of land of house plot
Developed agricultural land [1] Ordinary plot [2]

102. Distance to nearest motor able road

103 Distance to nearest worship place

104. Distance to nearest health centre

Building Process

105. What was the total cost of construction?

106. Source of Funds

Source	Amount	Rate of interest	Monthly instalment	Paid instalments	How many left unpaid	Number of instalments to pay

107 Any form of community involvement in the building process? Yes [1] No [0]

108 Involvement in:
Material contribution [1] Labour contribution [2] both [3]
Financial assistance [4] All the above [5]

109. Any involvement of NGO'S/ CGO's Yes [1] No [0]

110 If yes, who was involved?

111 Involvement in:
Material contribution [1] Labour contribution [2] both [3]
Financial assistance [4] Technical assistance [5] All the above [6]

112 Beneficiary involvement Yes [1] No [0]

113 If yes, involvement in
Financial contribution [1] Material contribution [2]
Labour contribution [3] Planning [4] All the above [5]

114 Material contribution of beneficiary
Produced by beneficiary [1] purchased [2] materials from old house [3]

115. Labour contribution: skilled [1] unskilled [2] both [3]

116 Involvement of local masons skilled [1] unskilled [2] both [3]

117 Involvement of CEEF technology institutions / Building centres Yes [1] No [0]

118 If yes, their involvement in:
Material supply [1] Labour supply [2]
Training [3] Technical advice [4] All the above [5]

119. Who were the implementing agency/ officer?

120. Role of implementing agency
Financial contribution [1] material supply [2] training/ technical advice [3]
Limited to giving stage certificates [4] All [5] Any other support [6]

Materials used

Structure	Materials	Source	Difficulties encountered
121. Foundation			
122. Walls			
123. Roof			
124. Flooring			

Material code

Laterite [1] Rubble [2]

Bricks [3] Hollow blocks [4]

Stabilized mud block [5] others (specify) [6]

Roof code

R.C.C [1] Filler slab [2]

Shell roofing [3] M.P tiles [4]

A.C Sheet [5] Tin sheet [6]

Al sheet [7] Thatch [8] other (specify) [9]

Flooring code

not finished [1] Cement plastered [2]

Red/ black oxide [3] Others (specify) [4]

125. Do you find any progress in your quality of life since you moved to your new house?

Yes [1] No [0]

126. If yes, what are they?

Improvement in: the studies of children [1] health condition [2]

Better value/status in the society [3] All [4]

127 Are you satisfied with the facilities provided by the government?

Yes [1] No [0]

128. If not, what else you expect from the government?

To construct the houses completely according to their type design [1]

To provide partial financial support and provide technical assistance, training and facilitate the construction [2]

To give full financial support [3] other than this (specify) [4]

Repair/ Renovation

129. Have you ever renovated your house since occupation?

Yes [1] No [0]

130. If, yes, what additional facilities added?

One more room [1] 2rooms [2]

one room + Veranda [3] Toilet facilities added [4]

Other than this (specify) [5]

131. Source of money for renovation

Source	Amount	Rate of interest	Monthly instalments	Remarks

Any repair works done after occupation? Yes [1] No [0]

132. If yes, what are they and frequency of repair?

133. Source of money for repair

Source	Amount	Rate of interest	Monthly instalments	Remarks

134. Are you satisfied with the present facilities in the house? Yes [1] No [0]

135. If not, what else facilities you need?

136. What is the source of money you are looking forward?

Needs, Aspirations, Plans

137. Do you have any plans to construct a new house? Yes [1] No [0]

138. If yes, what facilities you want to provide as additional to your existing house?

139. What materials would you prefer to use?

Structure	Materials	What are the advantages of these than the present materials
Foundation		
Rubble		
Walls		
Roof		
Flooring		

140. What source of resources you are looking forward to realize your dream house?

Savings | selling out the assets

more government support | Others (specify)

141. Would you prefer to use the innovative materials developed by yourself (after getting training) for your new house?

Yes [1] No [0]

142. If not, why?

143 Are you interested to get trained on CEEF technology?

Yes [1] No [0]

144. If not why?

145. Are you interested in using CEEF Technology for constructing your house?

Yes [1] No [0]

146. If not why?

147. Your opinion on using Locally available materials such as:

Mud

Laterite

Treated wood

Agricultural wastes

Industrial waste

148. Your opinion in using:

Exposed brickwork

Filler slabs

Cavity walls

Prefabricated construction

Any special comments?

Interviewer's Remarks

Present condition of the house & household

Living environment

Water management

Waste disposal

Location

A rough plan

Living room	Veranda	Bed room	Kitchen	Remarks

Area of the house

Indirect questions to beneficiary

- Do you have any inferior feeling to live in this house? (Any form of stigmatisation or grouping of people)
- *Do you consider this house as an asset? If not why?*

Specific remarks and suggestions for improvement

Appendix 4.2
Sustainability Analysis (OLHS/IAY/THS)

Scheme of Analysis

Socio-cultural sustainability		
Adaptability		
Household Size	Number of potential families = 1	20
	A single family with young children and household size 4-6	16
	Potential family.>1, but additional rooms	12
	2 potential family including old parents size 4-6	8
	A family of 4 -grown children/PF>1 with insufficient additional rooms	4
	Number of potential families >1	0
Equality		
Segregation or grouping of a people of a particular category based on income or caste(feeling inferior)	No	10
	Yes	0
Integration of amenities and services		
Motor able road	Within 100m	20
	100m to 200m	10
	> 200m	0
Nearest bus stop	Within 500m	20
	500 to 1km	10
	> 1km	0
School Hospital Worship place	Within 2km	20
	2km to 5km	10
	>5km	0
Work place	Within the Panchayat	20
	Outside but within 5km	10
	>5km	0
Beneficiary Participation		
Planning Finance Material contribution Labour	Total building process	20
	Planning, material, labour	16
	both material and skilled labour	12
	Any two from labour/ material/finance	8
	Partial material / labour/ financial contribution	4
	No involvement	0
Community/NGO'S Involvement		
Planning Finance Material contribution Labour	Total building process	20
	Planning, material, labour	16
	both material and skilled labour	12
	Any two from labour/ material/finance	8
	Partial material / labour/ financial contribution	4
	No involvement	0

Economic sustainability (ECS- 1AY/THS)		
Pre requisites		
Savings	50 to 75%	20
	25 t0 50% of income	15
	10 to 25% only	10
	less than 10%	5
	No savings	0
Affordability		
Liability for housing	No/ yes, but paid already	20
	Yes, but paying back regularly	15
	yes, not so regular in payments, but can pay	10
	yes, paying back the interest only	5
	yes, not yet repaid the instalments	0
Housing condition	Completed, good condition	20
	Completed, but minor works in pending	15
	liveable, but needs major works to finish	10
	liveable, but only minimum facilities, major works pending	5
	Not liveable, incomplete or poor condition	0
Shelter Needs		
Bathing space	Permanent space with latrine/ independent space(good condition with door and roof)	20
	permanent room without roof or proper door	10
	Temporary shed or pond	5
	No facility	0
Sleeping space	Enough privacy for couples and adults	20
	Can adjust	10
	Not enough space, but no one sleeps outside	5
	Some one has to sleep outside	0
kitchen space	Enough	20
	Moderate	15
	Small, but can manage	10
	Part of another room using as kitchen	5
	Cooking in temporary kitchen outside the house	0

Technological sustainability(TCS)		
Feasibility		
Technology for Roof and Wall	R.C.C , filler slab Rat- trap bond	0
Simple, Easy maintenance and unskilled labour	Flemish bond and ordinary brick/cement block masonry	10
	Tile roofing/ sheets	20
Labour availability	Plenty	20
	Fairly	10
	Rare	0
Quality of labour (Strength)	Good	20
	Moderate	10
	poor	0
Functionality (Further changes in design)	Easy	20
	Fair	10
	Not possible	0
Comfort	Good	20
	Fair	5
	Poor	0
Safety from thieves , natural calamities, fire hazards etc	Good	10
	Fair	5
	Poor	0
	Moderate	5
	Intensive	0
Materials for Roof and Wall	Locally available/produced	20
Availability	Locally purchased	10
	No local availability	0
Reusability	Good	20
	Fair	10
	Poor	0
Energy Requirement	Zero	20
	Moderate	10
	Intensive	0

Environmental Sustainability (ENVS)		
Renewable and Non renewable resources		
Energy Any energy conservation measures adopted?	Yes	20
	No	0
Water Any water conservation (reuse) measures adopted?	Yes	20
	No	0
Land conservation and proper planning		
Land	Natural plot	20
	low lying / hilly area	10
	Developed agricultural land	0
Healthy Environment		
Quality of surroundings	Good	10
	Moderate	5
	Poor	0
Neighbour hood	Good residential area	10
	Low income settlement	5
	Slum like settlement	0
Basic Infrastructure		
Toilets Is the latrine facility integrated with scheme?	yes, constructed with this house	20
	Using the same latrine with the old house	10
	later constructed by the owner/ through another scheme	5
	No	0
Latrine type	septic tank, permanent room good condition	20
	Single / two pit ,permanent room	16
	Single / two pit ,permanent room, no roof/door	12
	Two Pit with temporary shed	8
	Single pit -temporary shed	4
	no latrine	0
Water supply Is the drinking water facility integrated with scheme?	yes	20
	integrated, but not sufficient	10
	no	0
[2]Drinking water source	Own facility	20
	Public facility within 200m	16
	Neighbour's facility within 200m	12
	Public facility at a distance greater than 200m	8
	Neighbour's well at a distance greater than 200	4
	scarcity of drinking water	0

[2] Access to water refers to drinking is defined as having water located within 200 meters of the dwelling (UNCHS,2000)

5 EVALUATION OF TECHNOLOGY OPTIONS: KERALA

5.1 Introduction

This chapter presents a comprehensive evaluation of the prevailing building process in Kerala and proposes two sustainable building alternatives. The evaluation has been done using a methodology based on the conceptual framework from chapter 2. The analysis and discussions on the public housing schemes in Kerala (chapter 3 and 4) urge the need for feasible technological options for affordable housing. This argument also confirms the findings of Gopikuttan (2002, 2004), who argues that a clear understanding of the technology suitable to the specificities of the state is inevitable for meaningful public intervention in the housing sector of Kerala. Above all the inter-relationship between technology and wider socio-cultural, economic and environmental factors need more attention in the context of sustainable development. All this necessitates a thorough evaluation of the technological options based on the concepts of sustainable development.

This chapter is organized in six sections. Section 5.2 presents the evolution of the present building process in Kerala. This is followed by (Section 5.3) an overview of the popular technological options in housing. The succeeding section deals with the analysis of these building alternatives (Section 5.4). It has been done in two stages. The first phase is an evaluation of the prevailing building alternatives based on the conceptual framework. However, in the second phase, a categorization or grading of basic building materials and technological alternatives based on embodied energy has been done. On the basis of this, section 5.5 comes up with certain specific considerations for the selection of new building alternatives and proposes two sustainable building alternatives. They are (i) Rice husk ash (RHA) Pozzolanas; a partial replacement for cement and (ii) Straw bale (SB) construction; an alternative technique for walls. Basic details of straw bale construction and few examples from the Netherlands and India are presented as appendix 5.2 of this chapter.

5.2 Evolution of the present building process: Kerala

This section presents an overview of the evolution of the prevailing building processes in Kerala followed by a quick insight into the history of present technology.

5.2.1 *Traditional building process*

Traditional Kerala architecture is based on the principles of Vastu Sasthra (science related habitation). It considers the astrological placement of the Sun, Earth, and other planets during the actual construction along with the location of the site, its shape, the proposed building's shape, the facing direction of the building, the location of gates, entry doors, doors to each room, windows, and the general design of the building. The basic theories of Vastu Sasthra are closely connected with astrological principles. Therefore, deviation from the accepted rules was believed to cause detrimental effects to those who use the building or the artisans who had constructed it. Thus the technology demanded highly skilled craftsman and precision in the entire work. The whole process was under the control of a head craftsman. Also the building process was based on caste-related social customs and traditions. It had a great influence on the overall building process, such as the type of buildings, materials used for construction, technologies employed, labour involved etc. Absence of wage labour relations and the supremacy of the caste system was a distinguishing characteristic (Harilal et al., 2000; 2002). Houses belonging to each caste had a common name of identification revealing their appearance and technology used. The quality and size of houses diminish as we go down to the caste scale. The "Pulaya's" (lowest division of caste) hut was considered as the smallest unit of accommodation (Government of India, 1891). The caste system provided the framework for occupational division of labour. Only the upper class enjoyed the privilege of employing the services of artisans, and the poor people used to build their houses with self-help or mutual help using locally available materials. This situation continued till the early 1970s.

5.2.2 *Modernisation of the building process*

The social reform movements and the larger process of modernisation of Kerala since independence and later the formation of Kerala state had effectively overcome many social and caste-based restrictions in all sectors of life including the building process. Following the 1973 hike in oil prices, the majority of youth from Kerala migrated to the gulf countries in search of better employment opportunities and there was a significant inflow of remittances to the state from the Middle East. Income windfalls and exposure to the outside world brought out greater changes in their aspirations, desires and preferences. A major part of the investment at that time was in the housing sector. Average prices of indigenous building materials (sand, clay) increased by about fifteen to twenty times during this period (1978-80). Free access to the natural materials was denied and traditional practice of community co-operation in house building became non-practicable. At the same period, the factory-produced materials (cement, steel) showed an increase of less than ten fold (Gopikuttan, 2002). The share of construction sector in the gross domestic fixed capital formation of Kerala for the last two years of 1970 was more than 90% (Gopikuttan, 1988).

The number of new residential buildings has also showed a steady increase. This housing boom was the combined effect of economic, social, institutional and cultural changes occurring during those days. Land reforms conferred ownership on land to those who had earlier been landless labourers. Also the popularity of One lakh housing scheme generated the importance of having own houses, even among the economically weaker sections. These social changes and subsequent investments in housing favoured the excessive use of energy-intensive building materials like cement, steel and bricks, replacing the traditional materials. Table 5.1 gives a picture of the changes in the material use pattern from 1961 to 2001.

Table 5.1 Changes in material use pattern in Kerala (in percentages)
Source: Census of India 1961, 1991 and 2001

Building elements	**Traditional materials (Lime, mud, grass, thatch, bamboo, wood)**			**Modern materials (Burnt bricks, stone, tiles, concrete, GI and other metal sheets)**		
	1961	1991	2001	1961	1991	2001
Roof	74.1	25.2	11.2	25.9	74.8	86.1
Wall	63.7	35.4	30.4	36.2	62.7	68.5

The modernisation of the building process during those periods opened up a new era of technology in the housing sector of Kerala. It resulted in the vanishing of environmentally-friendly Kerala architecture. The most adverse effect of this process was the excessive dependence on energy-intensive building materials. Only 0.1% of houses had concrete as roofing material in year 1961, but the latest census reports shows figure of 26.5% in 2001 (Government of Kerala, 2004). These changes in the technology consequently generated changes in the employment sector and the wage structures, especially in the rural areas, and intermediaries or agents emerged for all sectors of the building process, including supply of materials and labour. As a result, even for small constructions except kutcha houses, the households are forced to depend on these intermediaries, and this further increased the cost of construction. Wages of skilled labourers increased many-fold. Also this modern technology with its undue stress on costly and energy-intensive materials like steel and cement is not affordable to the majority of the population. In addition to this, these materials consume large amounts of non-renewable natural resources like energy, minerals, and topsoil affecting the environment. In order to overcome these problems and to solve the urgent housing demand, the government of Kerala promoted cost effective construction techniques and innovative materials.

5.2.3 *Emergence of Cost Effective and Environmentally Friendly (CEEF) technology*

The paradigm shift in the housing policy from a public housing approach to the one based on aided self-help during the beginning of 1980s also facilitated the introduction of cost-effective technology in the housing sector of Kerala. Several non-governmental organizations sprung up in early 1980s with affordable technological options. Mr. Laurie Baker, a well known British-born architect, settled in Kerala, took the lead in this effort. Based on his principles, Alternative Technology (AT) initiatives and institutions like Centre of Science and Technology for Rural Development (COSTFORD) and Nirmithi Kendra came up in the eighties to save the poor from the exploitative tendencies of the intermediaries (Gopikuttan, 2004).

5.2.3.1 Centre of Science and Technology for Rural Development (COSTFORD)

COSTFORD is registered as a non-profit voluntary organization in 1984 under the chairmanship of Mr. Laurie Baker. It has a taskforce of people from different disciplines such as architects, engineers, economists, geo-physicists, scientists, advocates, accountants, doctors, industrial consultants, educationalists and social workers. COSTFORD, in general, has two main foci of activities, namely, social activities and construction activities using appropriate building technologies. The focus is to empower and enable the weaker sections of the society to improve their living conditions by the application of appropriate and people-friendly technologies. Promotion of non-commercial building practices, which discourage the role of intermediaries from the building process, is also among their priorities.

For their core activities, COSTFORD is supported by the Central Government departments like Department of Science and Technology and the department of Rural Development together with the department of local Self Government, Government of Kerala and Housing and Urban Development Corporation (HUDCO). For activities such as training they get funding from the State Department of Science and Technology.

5.2.3.2 Nirmithi Kendra

The devastating flood during the year 1985 and the consecutive rehabilitation works connected with it in the coastal areas of Kollam district opened up a new era of cost-effective and environmentally-friendly (CEEF) building technology through Nirmithi Kendras. India's first "Nirmithi Kendra" (Building Centre) was set up in Kollam for bringing out affordable solutions for housing. Arising from the success of the Nirmithi movement in Kerala, the ministry of urban development and HUDCO decided to start a national programme of setting up a net-work of building centres through out the country. Later in 1989, the Kerala State Nirmithi Kendra (KESNIK) was established as an apex body to all the District Kendras. At present there are now twenty eight centres in the State with nine centres under State Government, Fourteen under District administration and five under the control of different non Governmental organizations. These Kendras were started with the following objectives.

- Technology transfer from 'lab' to land
- Dissemination of these technologies to the masses
- Skill up-gradation and training for artisans in innovative and cost-effective technology options
- Production of cost-effective building components using local resources and making these available through local sales outlets
- Construction of housing and public buildings using the trained workforce and the components produced by the building centres
- Provision of guidance, information and counselling to people on proven, innovative and cost-effective building materials and technology options.
- Effective utilization of locally available building materials.

Box 5.1

Cost Effective and Environmentally Friendly technology (CEEF)
(Source: Collin, 1999)

The appropriate technology propagated by the Nirmithi Kendras emphasizes cost effectiveness and environmental friendliness in the building process and is popularly known as Cost Effective and Environmentally Friendly (CEEF) technology. It is distinctive in (i) the use of locally available materials, (ii) minimizing the use of energy intensive materials like cement and steel, (iii) ensuring local participation, (iv) combining traditional architecture with modern styles and (v) designing the building according to the lay out of land.

CEEF technology buildings in Kerala are characterised by brick masonry walls (without plastering) with rat-trap bond or Flemish bond, filler slab roofs and pre-cast cement concrete door/window frames. Pre-cast lintels and use of brick arches or corbelling is a common feature of CEEF buildings. Natural ventilation in the rooms is facilitated through artistically designed brick jalis (small openings in the brick walls) and there by reducing the use of glass.

The organisational structure of Nirmithi Kendras is in the form of a charitable society registered under the Scientific and Charitable Societies Registration Act 1955 (ACT XII). Their financial needs were met by tying up with various training, employment generation and rural development schemes for production of building materials and construction of low-cost houses. Each Kendra gets an initial grant of Rs 200,000 (roughly € 4000) the from central government through HUDCO in addition to the state government allotted grant and 1.5 to 2 acres of land for setting up the centre.

International recognition was accorded to Nirmithi Kendra when the United Nations Commission for Human Settlements at its fourteenth session in Nairobi (May 1993) adopted a resolution recommending governments to set up institutions modelled on the Building Centres at the national, provincial and grass root levels. Later in 1996, Nirmithi movement was declared as a Global best practice by UNCHS at the Second United Nations International Conference Convention on Sustainable Human Settlement which held in Istanbul.

In line with the initiatives of COSTFORD and Nirmithi Kendra several other appropriate technology organisations also came into active involvement in the building scenario of Kerala. Habitat Technology Group established in 1987 as a charitable agency, committed to the concept of green and humane architecture is a major organisation among them.

The National Housing and Habitat Policy of 1988 encouraged all the state governments to facilitate the training of construction workers by administering development programmes through Building Centres, and promoting the decentralised production and use of low-cost building materials from local resources.

The appropriate technology initiatives in Kerala are based on the assumption of abundant supply of labour and availability of indigenous building materials. Their focus is to create maximum employment opportunities and to provide livelihood security to the poor by constructing their own houses. The government of Kerala supported the AT initiatives in the state through financial assistance and providing facilitative environments. Most of the public housing schemes are also formulated with a concept of utilizing the options of CEEF technology. The evaluation of the public housing schemes in Kerala (chapter 4) shows that despite the continued efforts of CEEF technology institutions in the state, the dissemination of these technologies to those houseless people who are in need of affordable solutions has not been very successful. It clearly points towards the difficulties of the poor households in accessing affordable technological options. These aspects urge the need for modifying the present CEEF technology options to suit the needs of end users. Selection of materials and technologies for the building construction should satisfy the felt needs of the user as well as the development needs of the society, without causing any adverse impact on environment (Reddy et al., 2001).

5.3 Popular building alternatives in Kerala

A mixed mode of construction can be seen in the traditional buildings of Kerala. The stonework was restricted to the plinth and laterite[1] was used for the walls. The roof structure in timber frame was covered with palm or coconut leaf thatching for most buildings and rarely with tiles, only for palaces or temples, till the mid of twentieth century. The exterior of the laterite walls were either left as such, or plastered with lime mortar. Mud construction was also one of the most common methods of making cost effective and sustainable habitat in the ancient days in Kerala. Since earth or soil is readily available everywhere, it can be utilized for constructing a very good monolithic, sustainable structure. The indigenous adoption of the available raw materials was the dominant feature of traditional constructions in Kerala.

The natural building materials available for construction in Kerala are stone, laterite, timber, clay and palm or coconut leaves. Granite is a strong and durable building stone; however its availability is restricted mostly to the highlands only. However, laterite is available in most parts of Kerala. The quarrying and extraction of these two are less energy intensive, and it does not require much skilled labour. So it can be used for foundations and superstructure, in places where it is locally available. Cement, steel, and bricks are the other popularly used building materials in Kerala for the last three decades. The CEEF technology initiatives in the state since 1980 opened up the market for alternative materials such as ferro cement, hollow and solid concrete blocks, rubble filler blocks and most recently, for interlocking blocks. The recent interest in promoting traditional mud construction is a positive sign towards sustainable building process in Kerala.

5.3.1 Foundation and basement

The superstructure of a conventional residential building in Kerala with 23 cm thick brick wall is usually constructed by keeping the wall centrally over stone or laterite masonry basement of 45 cm (both width and thickness) in normal soil conditions. The cost-effective construction techniques promoted by Laurie Baker put forward the suggestion of keeping the brick wall flush with the outer side of basement. This arrangement can not only enhance the inside room area but also prevent the entry of rain water to the foundation through the joints between basement and wall.

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[1]Laterite is a surface formation in tropical areas which is enriched in iron and aluminium and develops by intensive and long lasting weathering of the underlying parent rock.

According to Central Building Research Institute (CBRI), New Delhi, a 30 cm thick stone foundation can be an affordable option instead of a 45 cm thick foundation, without compromising the strength. Utilization of mud mortar instead of cement mortar in foundation is a popular cost effective option adopted for low rise buildings in Kerala. Reinforcing the soil in the foundation trench with layers of bamboo can be an alternative foundation in places were stone is not locally available and bamboo is plenty. This technology is widely practiced by COSTFORD.

Sand piles (load bearing), arch foundation and stub foundation are the other alternative options for foundations. Arch Foundation can be either made of brick or stone masonry depending on the availability of material and the load to be transmitted. In this type of foundation the walls are supported on arches springing from a series of square cement concrete bases. The load from the superstructure is transmitted through these arches and distributed to the ground through the foundation bases. Stub foundation consists of a series of brick or stone masonry stubs resting on cement concrete bases. At the plinth level they are tied by a grade beam. Both arch foundation and stub foundation are labour intensive and suitable for good soil conditions and low rise buildings.

5.3.2 Walling or superstructure

The conventional technology for walls in Kerala is brick masonry in English bond* or laterite masonry. Rat-trap bond masonry is an innovative and popular technological option in brick masonry introduced by Laurie Baker. It is like a cavity wall construction and has got the following peculiarities (Becker, 1993c).

- Strength of this masonry is equivalent to standard 23 cm wall, but consumes 20% less number of bricks
- Good thermal comfort due to the cavity in between the bricks
- Good appearance
- The overall saving cost of this wall compared to the 23 cm conventional brick wall is 26%
- Labour intensive technology

* English bond is made up of alternating courses of stretchers and headers. This produces a solid wall that is a full brick in width. It is fairly easy to be laid and is the strongest bond for a one-brick-thick wall.

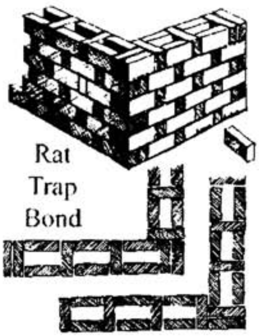


Figure 5.1 Schematic representation of rat trap bond masonry (Source: Baker, 1993c)

CEEF technology also promoted other technological options such as stabilized mud blocks, hollow or solid concrete blocks, Ferro cement, rubble filler blocks, interlocking blocks as affordable choices for walling.

Stabilized mud blocks (SMB) – Mud, sand and appropriate stabilizer (cement or lime) is compacted using a machine to form a building block. After twenty eight days of curing, the stabilized mud blocks are used for wall construction. Major advantages of SMB are energy efficiency (70% energy saving compared to burnt bricks), economy (20-40% savings in cost compared to brick masonry) and pleasing appearance (Reddy, 2004).

Ferro cement - Ferro cement is a composite material consisting of cement-sand mortar (matrix) reinforced with layers of small diameter wire meshes. It has wide range of application in housing as wall panels, roofing channels, tiles, trusses, door shutters, cup boards, lintels, sunshades and water tanks. Ready availability of materials, architectural flexibility, low level production technology and better utilisation of available human resources are considered as the advantages of Ferro cement construction.

Hollow and solid concrete blocks - These are the widely accepted CEEF technology walling options in Kerala. As the Ferro cement products, these blocks can also be produced on site without much skill and know-how.

Rubble filler blocks – This is an alternative technological option for superstructure prevailing in Kerala. Instead of coarse aggregates of specified sizes using in solid concrete blocks, stone or brick ballasts of different sizes according to their availability can be used. They are placed in different layers in the mould in a matrix of cement sand mortar and compacted using a machine.

The scarcity of timber is a major problem making it inaccessible to the poor. Hence the present CEEF technological options in the building process in Kerala make minimum use of it. Timber is mainly used for the door and window openings as shutters and frames. Pre-cast concrete door and window frames are being used widely in Kerala as alternative choices. According to Baker (1993a), one square foot of window can cost up to ten times the cost of the simple brick or stone wall it replaces. A honey combed wall (*jally* work) can be an affordable option in many of the cases to replace a window.

Lintels and beams are usually made of cement and steel. Very often lintel is not at all necessary for a door or window opening up to 1.2 m width. Ordinary bricks placed on edges can also serve the purpose of a lintel in that case. Brick arch are less expensive and more aesthetic than concrete lintels (Baker, 1993a).

Replacing lintels and beams with arches and corbelling is a common practise adopted by the CEEF houses in Kerala. Brick arches can replace beams over a span of up to 4.5 m. Corbelling is also a type of arch in which one brick is slightly projected (maximum length of projection is one fourth of the length of brick) outwards from the bottom coarse of bricks and this arrangement is followed to span an opening. Pre-cast reinforced concrete lintels can also be an alternative affordable option to conventional lintel. They are usually 7.5 cm thick and 23 cm wide with 3-10 mm mild steel bars for openings up to 1.8 m. Use of pre-cast lintel considerably speeds up construction of wall, besides eliminating the work of shuttering and centring.

Mud is the most environmental friendly sustainable building material available in almost all places. The CEEF technology initiatives in Kerala are constantly advocating the promotion of mud construction as an affordable alternative. Adobe or sun dried bricks and stabilized mud blocks are the widely accepted technology in mud construction in Kerala. Most of the soils available in Kerala are suitable for mud construction and if otherwise stabilizers can be used for making it suitable to the purpose. Lime and other local materials like straw, cow dung, sugar, molasses, tannic acid, coconut oil etc can be sustainable options as stabilizers based on availability.

5.3.3 Roofing

The scarcity of timber and the safety concerns with respect to theft and natural calamities diminished the popularity of tile roofing and promoted concrete roofing (Table 5.1). Filler slab construction, shell roofing and other pre-cast roofing techniques are the popular CEEF technology options against the expensive reinforced concrete slab.

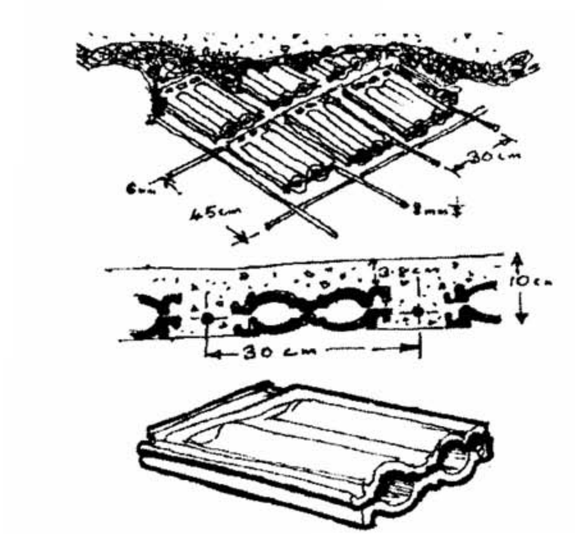


Figure 5.2 Schematic representation of filler slab with M.P tiles as filler material (Source: Baker, 1993a)

Filler Slab – This roofing technique is more popular in Kerala than any other technological alternatives due to the economical advantages and comfort with respect to other prevailing roofing options. They are basically solid reinforced concrete slabs with partial replacement of concrete in the tension zone by a filler material. Use of such filler material can result in reduction in dead weight of reinforced concrete slab, savings in cost as well as energy of the roof or floor system (Reddy et al., 2001). In Kerala, Mangalore pattern (M.P) roofing tiles are used commonly as the filler material.

Pre-cast concrete funicular shells, pre-cast concrete ribbed slab and pre-cast 'L' panels are other CEEF technology option in roofing. Pre-cast 'L' panels are very economical and do not need any shuttering.
Funicular shells are doubly curved shells under the action of uniformly distributed loads. Usual size of a funicular shell is 1m x1m and weight 65 kg. These shells can be cast by simple masonry moulds.

Pre-cast concrete ribbed slab can be used for floors, and roofs (flat as well as sloping) in single and multi-storeyed buildings. This roofing technique requires simple shuttering. The overall saving compared to the conventional reinforced concrete slab is 22 to 30% (North East India Regional Databank).

Table 5.2 gives a list of alternative technological options available in Kerala. Even though there is a number of sustainable options available in India, only very few are in practice in Kerala.

Table 5.2 Technology for different phases of construction

Building elements	Traditional materials or Technology	Conventional materials or Technology (Presently in use)	Prevailing CEEF technology options			
			Commonly used in Kerala		Available in India and not popular in Kerala	
			Building materials	Technology	Building materials	Technology
Foundation and Basement	Laterite Rubble	Laterite Rubble Concrete		Sand Piles Mud with bamboo reinforcement	Latoblocks Sand – lime bricks Mud- concrete blocks Steam cured lime stabilized bricks	Brick arch foundation Stub foundation
Building blocks or superstructure	Wood Laterite Mud Rubble	Bricks Solid /hollow concrete blocks	Adobe Stabilized mud blocks. Rubble filler blocks Ferro cement Solid concrete blocks Hollow concrete blocks Interlocking blocks	Rat trap bond Flemish bond	Building blocks from industrial and agricultural wastes	Straw bale technology Rammed earth wall Ferro cement wall panels
Binder	Mud/ clay Lime Gypsum Cow dung	Cement Lime	Mud Combination mortar (cement-lime-sand)		Lime or cement pozzolana Stabilized mud mortars Cement/Lime soil mortar	
Roofing	Wood Palm leaves Thatch Tiles(since 1759 only)	Concrete Tiles Aluminium sheets Asbestos Cement sheets Galvanised Iron sheets FRP sheets Asphalt sheet		Filler Slabs Funicular shells Pre cast concrete ribbed slab Ferro cement Channel or shell units L Panel roofing	Ferro cement tiles Bamboo mat corrugated roofing sheet	Pre-cast brick panels Micro concrete roofing (MCR)tiles Fly ash MCR tiles Jack arch with bricks and pre-cast RCC joists Corbelled brick pyramid Brick vaults and Domes Fal-G vault Fibre-cement roofing sheets and tiles
Lintels or Beams	Wood or stone lintel Brick corbelling Brick Arches		Brick	Pre cast R.C.C lintels Ferro cement lintel Brick corbelling Brick Arches		
Flooring	Cow dung			Cement plaster over brick bats Burnt clay tiles over brick bats	Fly ash terrazzo tiles	

Among them also the popularity of these alternative options is not gaining that much acceptance as that of modern building practises, especially among the poor. It may be due to the easy availability of energy intensive building materials and the popularity and acceptance of modern building process. It can also be noticed that these alternative building materials are not being produced and made available on a scale comparable to that of the modern building materials (Gopikuttan, 2004).

5.3.4 Sustainable utilization of waste materials for building process

The supply of cost-effective durable building materials is one of the major problems of technology in providing housing in developing countries irrespective of rural or urban areas. The establishment of high technology building material industries in the model of developed countries can make only limited contribution to meet their immediate and future needs (UNCHS, 1988).

Locally available waste materials can be utilized for the development of sustainable building materials and contribute in solving this problem to certain extent. Fly ash, red mud and lime sludge are the major industrial wastes utilized for the building industry in India. Fly ash or pulverised fuel ash is a waste product from thermal power plants where pulverised coal is being used as fuel. Forty million tonnes of fly ash are produced annually in India. Disposal of this waste product causes severe environmental problems. At the same time the potential of this material as an alternative building material such as bricks, blocks, Portland pozzolana cement, tiles, lightweight aggregates and hollow blocks is excellent.

Red mud is an industrial waste produced during the production of aluminium. In India about four million tonnes of red mud are produced annually. The Building Materials and Technology Promotion Council (BMTPC) of India has developed different technologies for utilization of this waste material in the production of bricks, tiles, corrugated roofing sheets and as binder for several products like doors, panels etc. One of the greatest technological opportunities available to building material industries is their potential to incorporate the agricultural and industrial wastes either as raw materials or as fuel substitutes, thus simultaneously reducing pollution and the need for the extraction of new raw materials (UNCHS, 1993). Table 5.3 gives a list of alternative technologies from agricultural or industrial wastes which are available in India.

Even though there is an active intervention by the appropriate technology institutions in the state with strong support from the government to promote alternate building materials, none of these institutions are effectively making use of the available industrial or agricultural wastes in Kerala. Lime sludge is a waste product from sugar, paper and fertilizer industry. It can also be utilized for the production of building blocks and Portland pozzolana cement. Red mud and lime sludge are the main industrial wastes available in Kerala. Rice and coconut are the major crops in Kerala and hence rice husk, rice straw and coir pith are abundantly available as agricultural residues. Even though technologies are available for utilising these wastes in building process (coir fibre for fibre cement roofing sheets, wall panels) as building blocks (straw bale technology) and pozzolanic material (rice husk ash), they are not yet introduced or widely in practise in the state.

Table 5.3 Alternative building materials

Type Of Waste (Industrial/Agricultural)	Source	Building Material
Fly ash / Pulverized fuel ash	Thermal Power plant	Portland- Pozzolana cement, Fly ash bricks, Roofing tiles
Red Mud	Aluminium industry	Bricks, Tiles, Blended cement, Fibre-reinforced panel products.
Lime sludge	Sugar, Paper, Fertilizer industry	Pozzolana cement Building blocks
Rice husk	By product from rice processing	Pozzolana cement Building blocks
Coir Pith	Coir industry	Building blocks
Rice Straw	Rice cultivation	Building blocks

The housing situation of Kerala and the present building practises in the state urge an evaluation of the sustainability and affordability of prevailing technological options. Alternative technologies and materials were introduced in Kerala with the primary objective of finding affordable housing solutions. But the present housing situation in the state reveals that sustainability of those alternatives has to be given more significance than affordability alone, since none of the options can be affordable (in the present as well as in the future) without being sustainable. Traditional technology in Kerala, based on locally available materials like wood, laterite, thatch and mud has given way to modern technology based on cement, steel and burned brick in a comparably short period of time ranging from thirty to fifty years. Even though the modern materials are more expensive than traditional materials, their easy availability and popularity made the technology more popular even among the poor. This explains why the CEEF technology innovations in Kerala could not compete with the modern building process, even though they provided many options that were more affordable.

5.4 Selection of building alternatives

The selection of sustainable technological options has been done in two stages. The first stage employs the conceptual framework from chapter 2 for a comprehensive analysis. However, in the second stage, a grading of basic building materials and popular technological options based on embodied energy has been done. Basically the second phase of grading plays a crucial role only when two alternative score equal points in the first phase analysis in making the most appropriate choice.

5.4.1 Comprehensive analysis based on the conceptual framework

This section presents a comprehensive analysis using the conceptual framework for the selection of the suitable technological options according to the requirements of Kerala. Fig. 5.3 is an adaptive version of the same framework in the context of sustainable-affordable building process.

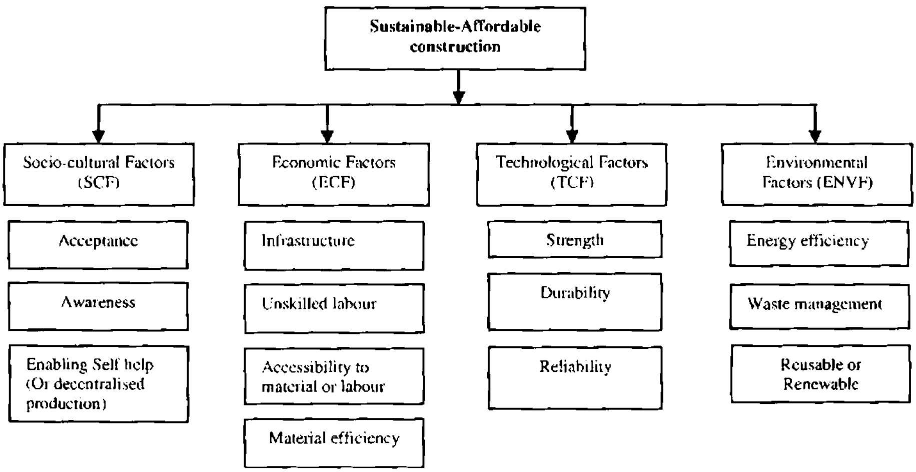


Figure 5.3 Conceptual framework: sustainable-affordable construction

As explained earlier (Chapter 2), all four aspects of sustainable-affordable habitat are closely interrelated to each other (refer Fig 2.3). In the context of sustainable housing development, sustainable construction can be considered as synonym to technological sustainability. 'Sustainable' refers to the general property of a material, building section or construction that indicates whether or not specific demands are met for affecting the air, water and soil qualities, for influencing the health and well being of living organisms, for use of raw materials and energy, and even for scenic and spatial aspects, as well as for creating waste and nuisance (Hendriks, 2001). This definition clearly indicates the relation between four aspects; such as- 'affecting the air, water and soil qualities' and 'scenic and spatial aspects, as well as for creating waste and nuisance' - refers to environmental factors (ENVF), 'influencing the health and well being of living organisms' refers to both socio-cultural (SCF) and economic (ECF) factors, and use of raw materials and energy implies technological (TCF) as well as environmental factors.

Socio-cultural Factors (SCF) - Technological innovations can be said to be sustainable only if they are accepted by the users and are beneficial to their well-being. Proper awareness of the technology is a factor which helps in making the technology acceptable. The materials or technology, those requiring decentralized production can help in enabling the users in self building and result in local level employment and income generation. This will improve the affordability of the technology and make it economically sustainable.

Economic Factors (ECF) - Technological options which demands minimum infrastructure, basic resources and unskilled labour requirements improves the affordability of sustainable constructions only if there is enough accessibility to material and labour.

Technological Factors (TCF) - The sustainability of technological options also depends on strength and durability aspects and are important criterions to be ensured particularly in the case of materials those are locally produced. Along with this, the reliability of technological innovations also adds to technological sustainability.

Environmental Factors (ENVF) - As explained through the definition of sustainable construction, environmental sustainability mainly refers to the quality of surrounding habitat. Technological innovations can be said to environmentally sustainable only if it either contributes to or maintain the quality of environment rather than degrading it by utilizing non-renewable resources or producing materials which are harmful to the environment.

This analysis adopts a methodology based on the assumption that all the four factors of sustainable-affordable construction are having equal importance and are interdependent to each other. Each technological alternative is given a score (two, one or zero) for each criterion (under the four factors of sustainable-affordable construction) based on a qualitative comparison among the different alternatives. The total sustainability score of various options are calculated as the sum of the four factors.

Tables 5.4 to 5.6 presents the analysis of prevailing building practices in the state based on this methodology. Different technology alternatives for walling, roofing, type of mortar and other miscellaneous practises currently in use in Kerala are analysed.

Walling alternatives - Table 5.4 gives an evaluation of the different walling alternatives prevailing in Kerala. Among the various alternatives, laterite wall masonry has the highest value of sustainability. Hence laterite can be suggested as the most sustainable option in places where they are locally available. Hollow and solid concrete block masonries also have fairly good scores next to laterite masonry. Even though the CEEF technology options like soil stabilized mud blocks and rubble filler block had maximum scores in technological and environmental factors, their total sustainability is comparatively low or nearly equal to that of hollow and solid concrete block masonry. This is attributed to their lower scores in socio-cultural factors as compared to other alternatives. In the same way, the lowest sustainability values of socio-cultural factors and economical factors of rat-trap bond masonry compared to other brick masonry options in Kerala making it unsustainable and unaffordable, even though it has many technological and environmental advantages over other options. These examples show that the economical sustainability of a technology or material is closely linked to the socio-cultural factors.

Table 5.4 Sustainability analysis of prevailing technology options for walling: Kerala

Technology options for Walling	Socio-cultural Factors (SCF)					Economic Factors (ECF)						Technological Factors (TCF)					Environmental Factors (ENVF)					Total score 100
	Acceptance	Awareness	Self Help	SCF	SCF (%)	Infrastructure	Unskilled labour	Accessibility to material or labour	Material efficiency	ECF	ECF (%)	Strength	Durability	Reliability	TCF	TCF (%)	Energy	Waste management	Reusable Renewable	ENVF	ENVF (%)	
Brick masonry English bond	2	2	2	6	**100**	2	2	2	0	6	**75**	2	2	2	**6**	**100**	0	1	1	2	**33**	77
Flemish bond	2	1	1	4	**68**	2	1	1	1	5	**63**	2	2	2	**6**	100	0	2	1	3	**50**	70
Rat trap bond	1	1	0	2	**34**	2	0	0	2	4	**50**	2	2	2	6	100	1	2	1	4	**67**	63
Laterite wall	2	2	2	6	**100**	2	2	2	1	7	**88**	2	2	2	**6**	100	2	2	2	6	**100**	**97**
Hollow concrete block masonry	2	2	2	6	**100**	1	2	2	2	7	**88**	2	2	2	**6**	**100**	1	2	1	4	**67**	89
Solid concrete block masonry	2	2	2	6	**100**	1	2	2	1	6	**75**	2	2	2	**6**	**100**	1	2	1	4	**67**	86
Adobe	1	1	2	4	**68**	1	2	2	2	7	**88**	1	2	1	4	**67**	2	2	2	6	**100**	81
Soil stabilized mud blocks (SMB)	1	1	2	4	**68**	1	2	2	2	7	**88**	2	2	2	6	100	1	2	2	5	**83**	85
Rubble filler block	1	1	2	4	**68**	1	2	2	2	7	**88**	2	2	2	6	100	1	2	2	5	**83**	85
Ferro cement	1	1	1	3	**68**	2	1	1	2	6	**75**	2	2	2	**6**	**100**	1	1	1	3	50	73

Roofing alternatives - Table 5.5 presents the evaluation of the different roofing alternatives. Mangalore pattern roofing tiles with wooden rafters has proved to be the most sustainable roofing option among the prevailing alternatives. The CEEF technology alternatives like filler slab and shell roofing has comparably lower sustainability values against their maximum scores in technological sustainability. This owes to the lower sustainability values in socio-cultural factors (compared to reinforced roofing slab), economic factors and environmental factors (compared to thatch and Mangalore pattern roofing tiles).

Table 5.5 Sustainability analysis of prevailing technology options for roofing: Kerala

Technology options for Roofing	Socio-cultural Factors (SCF)					Economic Factors (ECF)						Technological Factors (TCF)					Environmental Factors (ENVF)					Total score 100
	Acceptance	Awareness	Self Help	SCF	SCF (%)	Infrastructure	Unskilled labour	Accessibility in material or labour	Material efficiency	ECF	ECF (%)	Strength	Durability	Reliability	TCF	TCF (%)	Energy	Waste management	Reusable Renewable	ENVF	ENVF (%)	
Thatch / Palm leaves	0	2	2	4	67	2	2	2	2	8	100	0	0	0	0	0	2	2	2	6	100	67
Mangalore pattern tiles	1	2	2	5	83	1	2	2	1	6	75	1	1	1	3	50	1	2	1	4	67	**69**
Aluminium/ GI sheet	1	2	2	5	83	1	2	2	1	6	75	1	1	1	3	50	0	1	2	3	50	65
Reinforced cement concrete slab	2	2	1	5	83	1	1	2	0	4	50	2	2	2	6	100	0	1	0	1	17	63
Filler slab	2	1	1	4	67	1	1	1	1	4	50	2	2	2	6	100	1	1	0	2	33	63
Shell roofing	1	0	2	3	50	1	0	1	1	3	38	2	2	2	6	100	1	1	1	3	50	60

Table 5.6 presents an evaluation of miscellaneous building alternatives for the sustainable choice of mortars and other CEEF technology options in the building process.

Binder material - Mud is the traditional binding material from the age old days in India. Sustainability analysis also indicates it's potential as an excellent building material with a highest sustainability compared to the other prevailing options. Cement, the most popular building material has fairly good score for socio-cultural factors and maximum values for technological factors. But its cost and energy intensive production methods are making it least sustainable among the other alternatives.

Miscellaneous options - Exposed brick work with brick arches is a symbol of CEEF technology buildings in Kerala. Along with these two, the use of pre-cast reinforced concrete door and window frames and filler slab roofing is also a common feature of the

CEEF houses. The sustainability values in socio cultural factors for these alternatives give an indication of the popularity of CEEF technology in Kerala. Reinforced concrete door and window frames are widely popular in Kerala as an affordable alternative compared to conventional wooden frames. The possibility of decentralised production is also an added advantage making it affordable. At the same time, the difficulties in getting the expert labourers and proper know-how about the other technology alternatives over the prevailing technologies make them less acceptable and affordable to the users.

Table 5.6 Sustainability analysis of miscellaneous technology options: Kerala

Miscellaneous technology options	Socio-cultural Factors (SCF)					Economic Factors (ECF)						Technological Factors (TCF)					Environmental Factors (ENVF)					Total score 100
	Acceptance	Awareness	Self Help	SCF	SCF (%)	Infrastructure	Unskilled labour	Accessibility	Material efficiency	ECF	ECF (%)	Strength	Durability	Reliability	TCF	TCF (%)	Energy	Waste management	Reusable /Renewable	ENVF	ENVF (%)	
Different alternatives for binder material																						
Mud	0	1	2	3	50	2	2	2	2	8	100	1	1	1	3	50	2	2	2	6	100	75
Lime	1	2	2	5	83	1	2	2	1	6	75	2	2	2	6	100	1	1	0	2	33	73
Cement	2	2	0	4	67	0	2	2	0	4	50	2	2	2	6	100	0	1	0	2	33	63
Miscellaneous CEEF technology options																						
Brick arches	2	1	1	4	67	2	1	1	2	6	75	2	2	2	6	100	2	1	1	4	67	77
R.C.C door and window frames	1	1	1	3	50	1	2	2	2	7	88	2	2	2	6	100	0	1	2	3	50	72
Exposed brick work	1	1	1	3	50	2	1	1	2	6	75	2	2	1	5	83	2	1	2	5	83	73

5.4.2 Grading of building components based on embodied energy

This part of analysis makes a grading of basic building materials and popular technological options based on embodied energy. Sustainable housing development requires materials and technologies which have less impact on the environment. Human activity has increased the levels of certain greenhouse gases in the atmosphere resulting in global warming. Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, troposphere ozone and chlorofluorocarbons (CFCs). Of these gases CO_2 is the most important by-product of the building material industry. Several studies have been done to identify and solve the implications of building materials industry on the environment due to emission of carbon dioxide, dumping of waste materials and excessive energy utilization during the production, processing and transportation of building materials. Construction activity contributes 17% of the carbon dioxide emission in India (Tiwari, 2001). The major energy intensive building materials, namely steel and cement are readily available in all the corners of the state, even though they need to be transported over large distances from the place of their origin. Extensive use of these materials can deplete the non renewable resources and adversely affect the environment. At the same time it is difficult to meet the alarming housing needs by adopting energy efficient traditional materials alone. Hence there is a need for optimum utilization of available resources and raw materials to produce environmentally friendly sustainable affordable alternatives (Reddy, 2004). This necessitates the choice of building alternatives based on embodied energy.

The total energy use during the life cycle of a building is an important concern and the embodied energy forms a considerable part (40%) of the total energy use in low energy residential buildings (Thormark, 2002; Chen et al., 2001). It is the energy that is used to extract, process, manufacture and transport building materials and components, and can be taken as an important index on measuring the sustainability of building alternatives. But the value of embodied energy for different materials varies from one country to another depending on the source of energy used for manufacturing. The indirect energy use in a residential building through the energy content of the materials of construction in India is about 3-5 GJ/m^2 of floor area, whereas the same indicator for an office building in Japan is 8-10 GJ/m^2. The higher value in Japan can also be attributed to the use of more energy intensive mechanised construction activity (Debnath et al., 1995). Chani et al. (2003) has calculated the embodied energy rates (EER), i.e., the embodied energy needed per unit area of different walling elements in India. Their analysis shows that traditional bricks which are most widely used for walling in India prove to be the worst choice with respect to energy input. The study of Reddy and Jagadish (2001) on embodied energy of available building alternatives in India also gives an insight into the selection of different building alternatives.

Among the basic building materials, aluminium is the highest energy intensive material. Steel and cement, the most widely used building materials for house construction are also energy intensive in nature. Lime pozzolana can be a better alternative to replace cement in this respect (see Appendix 5.1, Table 1). All the renewable materials and waste products which are being used as building alternatives are the most sustainable choices with respect to energy (zero energy).

The environmental suitability study for walling materials in Sri Lanka conducted by Emmanuel says that environmental suitability is a relative phenomenon and hence it is only possible to say that one material is either better or worse than another material rather than finding the best material (Emmanuel, 2004). The principle of DCBA method for the evaluation of building materials is also the same. Here also a comparative analysis has been done to identify the sustainable building materials. The letters show how environmental friendly an alternative is. In this method D = the normal (current or conventional) situation, C = correct the environmental damage of the normal situation, B = Limit the environmental damage to a minimum, A = autonomous situation with little or no environmental damage (Duijvestein, 2001). The scope of DCBA method has now been extended to economic and social aspects of sustainability from the initial concern on environmental aspects. The principle of 'PAGE' analysis used in this research for grading different materials based on embodied energy is also similar to DCBA method.

- 'P' refers to Poor; for highly energy intensive materials,
- 'A' refers to Average; moderate energy,
- 'G' refers to Good; low energy, and
- 'E' refers to Excellent; for zero or minimum energy material (mostly renewable).

'PAGE' is only used as additional check in the comprehensive analysis using the framework and is only used in situations when two alternatives carry equal scores in the main analysis.

Table 5.7 to 5.9 shows a comparative grading of different building components based on embodied energy. The values of embodied energy used in this grading are taken from the works of Chani et al. (2003) and Reddy et al. (2001). It is disappointing to see that the most popularly used traditional brick masonry with cement mortar is the worst choice in terms of embodied energy (Table 5.7). Hollow concrete block masonry (40×20×20) is the most appropriate selection from the prevailing alternatives.

Table 5.7 PAGE' grading based on embodied energy of different walling elements

Walling elements with (Dimensions in cm)	**Embodied energy in MJ/ m²**		
	Cement mortar (1:6)	**Composite mortar** cement: lime: sand	
		1:1:6	**1:2:9**
Traditional Brick 22.9X11.4X7.6	615 **P**	638 **P**	621 **P**
Modular Brick 20X10X10	539 **P**	562 **P**	548 **P**
Hollow Concrete Block 40X20X10	348 **A**	365 **A**	353 **A**
Hollow Concrete Block 40X20X20	193 **G**	204 **G**	195 **G**
Solid Concrete Block 30X20X15	300 **G**	312 **A**	303 **A**

P (Poor) – 450 MJ/m² and above A (Average) – 300 to 450 MJ/m², G (Good) – 150 to 300 MJ/m²; E (Excellent)- Below 150 MJ/m²

Table 5.8 'PAGE' grading based on embodied energy of different roofing elements

Roofing elements	Embodied energy in MJ/ m^2 Energy / m^2 of plan area of roof	PAGE grading
Reinforced cement concrete slab	730	P
SMB filler slab roof	590	P
RC ribbed slab roof	491	P
Composite brick panel roof	560	P
Burnt clay brick masonry vault roof	575	P
SMB masonry vault roof	418	A
Mangalore tile roof	227	G
Ferro cement roof	158	G
P (Poor) – 450 MJ/m^2 and above; A (Average) – 300 to 450 MJ/m^2; G – 150 to 300 MJ/m^2, E (Excellent)- – Below 150 MJ/m^2		

Table 5.8 presents a list of different roofing elements with their PAGE grading. From the available options, Ferro cement roof (grade G) is the most sustainable option with the lowest embodied energy. Reinforced cement concrete slab is the most energy intensive choice (grade P). Unfortunately it is the popularly used roofing technology in Kerala. Among the other available alternatives Mangalore tile roofing (grade G) can be suggested as a sustainable alternative.

Table 5.9 'PAGE' grading based on embodied energy of different types of mortars

Type of Mortar	Embodied energy in MJ/m^3	PAGE grading
Cement mortar (1:6)	1268	P
Cement mortar (1:8)	1006	P
Cement soil mortar Cement :soil :sand (1:2:6)	849	A
Cement pozzolana mortar (1:6) [Cement :pozzolana– .8:0.2]	918	A
Cement pozzolana mortar (1:8) [Cement :pozzolana – 0.8:0.2]	736	G
Cement soil mortar Cement :soil :sand (1:2:8)	773	G
Lime pozzolana mortar (1:3) [Lime :pozzolana – 1:2]	732	G
P (Poor) - 1000 MJ/m^3 and above, A (Average) - 800 to 1000 MJ/m^3 G – 500 to 800 MJ/m^3 and E (Excellent)-- Below 500 MJ/m^3		

Cement mortar is the most widely accepted and popularly using technological alternative in Kerala among the other options of this kind. But in terms of embodied energy it is the most unsustainable choice. Table 5.10 presents a list of different types of mortars with their PAGE grading. Lime pozzolana mortar (grade G) is the sustainable alternative in terms of embodied energy.

5.5 Sustainable alternatives: specific considerations in the context of Kerala

The results of the sustainability analysis can be used as a guideline for the selection of suitable technological options according to the peculiarities and requirements of Kerala. The ensuing text discusses the various factors which contribute to the sustainability of technological options in the context of Kerala.

Acceptance, awareness and feasibility of technological options can be considered as the basic criteria for socio-cultural sustainability. The un-sustainability of rat-trap bond masonry among the other brick masonry options gives a clear understanding of the importance of socio-cultural factors in sustainable technology. Rat-trap bond masonry has several advantages compared to English bond (most popular brick masonry alternative in Kerala) masonry. But the unawareness of technology and the poor acceptance make it less preferable to the users. This is the same case with filler slab; an affordable alternative to roofing when compared with the popular reinforced cement concrete slab. This also gives an indication to the relation between economic factors and socio cultural factors. Both the above mentioned technologies are considered to be more cost effective than their present popular alternatives, but the un-sustainability in socio-cultural factors makes them less affordable in practice. Along with this the increasing popularity of a few other CEEF technology alternatives (hollow or solid concrete blocks, pre-cast door and window frames) show the significance of decentralised production in enabling self-help or mutual help to improve the feasibility.

The relation between socio-cultural factors and affordability of certain CEEF technology options was explained in the previous section. An exception to this can be seen in the case of locally available alternatives like thatch and mud. Even though they have poor acceptance and inferior image (for thatch roof), their local availability in Kerala make them economically sustainable. This is also true with reinforced concrete slab roofing. Filler slab roofing is considered to be more material efficient, comfortable and economical than reinforced concrete slab. But in practice the poor awareness on this technology and availability of skilled labours make it less affordable to the users.

Although most of the appropriate technology experts advocate labour intensive technologies as sustainable options in less developed economies, the situation in Kerala is different. This can be clear from the less affordability of rat-trap bond masonry. Even though there is a considerable saving in material usage, this technology is found to be economically unsustainable in Kerala due to its labour-intensive nature. Hence sustainable construction in Kerala demands minimum labour cost and infrastructure, unskilled labour and accessibility of resources. It also demands innovations in renewable resources to make locally available materials sustainable. This can be supported by the poor technological sustainability of thatch. Even though there are technologies available to improve the durability of thatch, none of them is popular or even known to the real users.

The evaluation of the prevailing technological alternatives in Kerala points to the importance of effective policies for the dissemination of technological innovations to the real users. Also the evaluation points towards the need for innovative technological options from renewable resources.

The following points can be taken as guidelines for the selection of new alternatives:

- Alternative technological options should be capable of being produced locally using decentralised production methods and with utilisation of local resources (materials and manpower).
- The alternative technological options should be able to prove their advantages over prevailing options within a reasonable time period. (This could help in improving their acceptance and popularity).
- Technologies which demand minimum infrastructure, local resources and know-how with unskilled and less labour intensive nature should be popularized.
- Locally produced environmentally friendly alternatives in the building process which utilize local waste materials, renewable or reusable materials and less energy intensive technology should be promoted.

5.5.1 *Choice of sustainable technology options*

The above discussion based on the results of sustainability analysis on the building options in Kerala suggests the utilization of locally available renewable materials in the building process. From the analysis in the previous section it became clear that laterite, the locally available material, is the only present sustainable option for walling. Although, laterite and lateritic soils cover around 60% of the total geographical area of Kerala, there are places where laterite is not available. Hollow concrete block is the obvious option in such places. A renewable building alternative from local resources as walling option can be a good choice for affordable housing. Suzuki et al. (1995) and Andrew et al. (1994) have studied the implications of building construction on environment in the context of Japan and New Zealand respectively. Both agree that construction of wooden houses has less impact on the environment than with any other type of house, since wood is a renewable resource.

The straw bale construction (SB) might be an appropriate alternative in the context of Kerala, where rice straw is available as a local waste in most of the places. Along with rice straw, rice husk is also a waste product from the paddy fields. The potential of rice husk ash (RHA) as a cement replacement material is excellent. Utilization of both SB and RHA in the building process will be more promising in another way if it can accelerate the paddy cultivation, as this is an immediate necessity in Kerala for the balancing of local ecosystem. Declining paddy cultivation is a growing concern in the state, as it results in many of the environmental problems. The area and production of rice which was steadily increasing till the mid seventies had to succumb to economic pressure due to the promotion of cash crops like rubber, banana, and tapioca and also due to the growth of the construction sector. These factors also support the necessity of finding out more value added products from paddy fields other than rice to retain the environmental balance and protect the natural ecosystem.

5.5.2 *Sustainability analysis for new technology options*

Since straw bale construction and rice husk ash pozzolana are pioneers in the building process of Kerala, the criteria used for socio-cultural factors and economic factors in the previous section cannot be employed directly. Among the criteria for socio-cultural factors, awareness of technology options can be taken as a measure only if the technology is known to the public, but these two are purely new technology in the context of Kerala. The same is the case with 'availability of labour' criteria in technological factors. Acceptance of technology is also a criterion that is connected with awareness. But in this analysis acceptance is measured as the ability of the technological options to prove their advantages over prevailing options within a reasonable time period.

Table 5.10 presents an evaluation of the two selected alternatives using the framework. This has been done using the same methodology as in the previous section. Comparative values were assigned with respect to the popular technological options (hollow block and cement) in Kerala.

The results establish the sustainability of these alternatives in the building process of Kerala. The two sustainable-affordable alternatives proposed for rural building applications in Kerala are:

Rice husk ash (RHA) Pozzolanas - Alternative option for cement
Straw bale (SB) construction - Alternative technique for walls

However, with respect to the behavior of straw bale walls in the climate of Kerala only limited knowledge is available. Kerala falls within the realm of tropical climate and dominant feature is monsoon with an average rainfall of 3100 mm. Even though the examples of the 1938 bale mansion in Huntsville, Alabama and a 1978 building near Rockport, Washington (an area reported to receive about 1900 mm of annual rain) supports the durability of SB walls in rainy seasons; it is necessary to prove the durability and gain reliability before introducing this technique to the public. Basic details on straw bale construction, its advantages and few examples of projects are presented at the Appendix 5.2 of this chapter.

Table 5.10 Sustainability analysis for new technology options: Kerala

Technological options	Straw bale construction	Rice Husk Ash Pozzolana
Socio-cultural Factors (SCF) Acceptance	2	2
Self help or decentralised production	2	2
Total score SCF	**4**	**4**
SCF in %	**100**	**100**
Economic Factors (ECF) Infrastructure	2	2
Unskilled labour	1	2
Local materials	2	2
Less labour intensive	2	2
Total score ECF	**7**	**8**
ECF in %	**88**	**100**
Technological Factors (TCF) Strength	1	1
Durability	1	1
Reliability	1	1
TCF	**3**	**3**
TCF in %	**50**	**50**
Environmental Factors(ENVF) Energy	2	2
Waste management	2	2
Utilisation of renewable resources	2	2
Total score ENVF	**6**	**6**
ENVF in %	**100**	**100**
Aggregate score (100)	**85**	**88**

5.6 Conclusion

The analysis of the major technological options in Kerala gives a better overview on the sustainability of the present building process in the state. Among the present technologies, traditional building technology with laterite walls, Mangalore pattern tile roofing and mud mortar is found to be the most sustainable technological option for affordable housing in Kerala, where laterite is locally available. Locally produced hollow concrete block masonry can be suggested as an alternative technological option to replace laterite in other places. This choice of building alternatives has been made from the prevailing popular technologies in Kerala. At the same time, we could not consider the potential of CEEF technology options like rat-trap bond masonry, adobe, soil stabilized mud blocks, rubble filler block, filler slab and shell roofing due to their comparatively poor scores in socio-cultural sustainability and economic sustainability.

None of the technological alternatives could be affordable in practice, if it has not enough support and acceptance from the society. Hence dissemination of technological innovations is a must to make it acceptable, feasible and there by affordable to the users. This can be attributed to the present inferior image of CEEF technology against modern or prevailing energy intensive building process in Kerala.

The evaluation of present building process in Kerala also point towards the need for alternative technological options utilizing locally available agricultural and industrial wastes to replace energy intensive technology. Locally available materials, especially wastes, significantly reduce the consumption of energy and secondary resources needed for extraction, processing, fabrication and transportation. Straw bale (SB) and rice husk ash (RHA) are promising in this regard. In Kerala, straw and rice husk are abundantly available as agricultural residues. Promoting these two alternatives in building industry can certainly contribute in realizing the dream of "shelter for all" and lead to sustainable future.

Appendix 5.1

Table 1 Embodied energy of basic building materials

Basic building materials	**Embodied energy MJ/Kg**
Aluminium	237
Structural Steel	42
Cement	5.85
Lime	5.63
Lime pozzolana	2.33
Bricks	1.4
Laterite	0
Sand	0
Rubble	0
Fly ash	0
Rice husk ash	0
Straw	0
Mud	0

Appendix 5.2

Straw bale (SB) construction: A sustainable walling option

This technique has not been introduced in Kerala so far. But the ecological and environmental significance of straw bale along with the plenty availability of rice straw in the state supports the sustainability of straw bale construction as an affordable option for housing in Kerala. Straw is a viable and renewable building alternative, plentiful and cheap. It is the plant structure between the root crown and the grain head. The internal structure of a single straw is tubular, tough and it contains cellulose, hemi-celluloses, lignin and silica. It has high tensile strength also.
Straw bale construction is basically a wall system in which bales of straw are stacked up, pinned together, capped by an assembly to bear and distribute the roof load and then plastered with cement, lime, mud, or other materials to protect the bales. Properly constructed and maintained, straw bale walls, with exterior and interior plaster, remain waterproof, fire resistant and pest free. Environmentally, economically and in terms of efficiency, straw bale houses offer many advantages. However, careful attention to details during and after construction is crucial in order to avoid moisture problems. Providing proper site drainage is the most important factor for longevity.

Type of bales

Bales are rectangular compressed blocks of straw, bound by strings or wires. Straw bales come in all shapes and sizes. Rectangular bales are the only bales suitable for building. Three string bales (585 × 405 × 1070 mm) common in western USA has an average weight of 29 kg. The two string bales (460 × 350 × 920 mm) which are common in the rest of USA and most of the world are easier to handle and has a weight ranging from 15 to 19 kg.

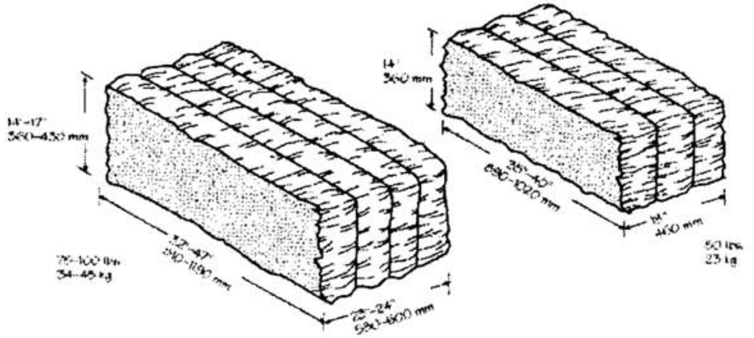


Figure 1 Three and two string bales (source:http://buildinggreen.com)

Besides these traditionally sized bales, big jumbo bales are also becoming popular. They are basically available in two sizes. The real jumbo is 1200x760x2400 mm and the mini-jumbo is 800 mm wide and available in various lengths and heights depending on the bailing machine used. The jumbo bales are appropriate for bigger industrial buildings where they show definite advantages due to their high load carrying capacity of up to 1000 kg /bale for the 1200 mm wide variety. Machine handling is only possible due to their weight. Greater stability and the bigger size of jumbo bales compared to the conventional bales favors rapid and easy construction.

SB building techniques

Basically there are two main construction methods:

- Load bearing bales
- Non-load bearing bales

Load bearing (structural) bales

Load bearing bale walls are most suited to smaller buildings not taller than two stories. The bales are stacked like bricks with the joints staggered. Traditionally the stacked bales are pinned by driving wooden or bamboo stakes vertically through the bales to increase stability during construction. Some form of pinning is still quite common but now mostly in a form of external bracing using wood or bamboo. A roof plate bond beam is placed on the topmost course of bales. This bond beam is tied down to the foundation using pre-inserted (under the foundation) packaging straps or heavy duty fencing wire. The straps are tightened down to pre-compress the bales (roughly 4%). The plaster adds significantly to the structural integrity of the wall system.

Figure 2 Structural bales

The straw bale wall is a structural sandwich where the plaster takes the load and the bales act as stiffener for the plaster. In the load bearing technique the bales function as a fully load bearing wall system. It is recommended to keep the openings for windows and doors less than fifty percent of the total surface area of the wall and the unsupported wall length less than 6m.

Post and Beam (P&B) or Non- structural bales

This technique is more appropriate for the construction of large structures. In this case, the structural loads are taken by the posts and beams of the framed structure and the straw bales act as in fill material only. Preferably the bale walls are either placed on the outside of the wooden P&B structure or within, thus simplifying the construction by avoiding complicated interfaces between the wooden structure and the bales. The bale walls are attached to the beams to create some form of rigidity. The bale walls with plaster finish only form the wall membrane and have to carry its self -weight only.

Figure 3 Non-Structural bales

Other building methods using straw

- Straw-clay building

Clay and water are stirred and mixed with loose chopped straw to form a straw reinforced clay matrix. This technique has been and is still in use in different countries especially in Europe but also in other continents. Depending on the country the technique has different names like cob (UK and India) and Leichtlehm (Germany, Austria) etc. Earlier the mixture was packed in to a double-sided wooden form between heavy posts and beams of timber frame buildings. The current practice is to use lightweight wooden ladder frames thus vastly reducing the amount of wood required.

- Mortared bales

Mortar made of Portland cement and sand is applied between the straw bales. This is plastered on the exterior and interior surfaces to protect the bales. This technique has now almost been discontinued because the mortar joints form cold bridges between the straw bales, result in condensation and leads to the decomposition of the straw bales.

- Pressed straw panels

Straw is compacted under controlled temperature and pressure. The resulting panels can be used for walls as well as roofs. These panels are not used for exterior applications but only for partition walls and for ceilings. The application is mainly due to the good acoustic property of the panels.'

Construction and Practical issues

Humidity and Moisture

SB buildings are capable of surviving humid climates, only if proper attention has been given in preventing condensation before and during construction. Following points should be noted.

- Moisture content in a bale should not exceed 15% of its dry weight.
- The tops of bale walls, exposed horizontal surfaces (e.g. window sills) and joints with wooden frames must be carefully sealed and designed to drain off moisture.
- Extra care should be given to store and protect the bales from the field of origin to the completion of building. Straw left in a moist, aerobic environment (above 20% moisture content) supports the growth of fungi leading to the decay of the straw. The stacking of bales should be carefully done to prevent this. Bales may be stacked near to the place of construction on palettes or lumber to keep them adequately raised by 15 to 20 cm above ground level. If the ground is wet, the bales must be protected from rising damp by a plastic cover directly on the ground leaving a well ventilated air gap between the bales and plastic. Make the bale stack tall and narrow rather than flat and wide to minimize the flat area exposed to sun and rain and increasing the ability for good ventilation. The top of the stack should be peaked or rounded to ease water run off.
- Ensuring the permeability of wall surfaces for preventing condensation is an important measure to avoid the decay of bales after it has been constructed.

The SB house built without foundation and without exterior plastering with bales placed over plastic put on the ground, near Tonasket, Washington in 1984 has no apparent deterioration of the bales. This indicates the importance of drying out of bales and breathing (Steen et al., 1994).

Fire

Plastered straw bale walls are less of a fire risk than traditional timber framed walls. The American Society for Testing and Materials fire tests conducted on plastered straw bale wall assemblies in Albuquerque and California shows a high resistance to flame spread and fire resistance. ASTM E-119 fire testing in New Mexico found that a plastered, 450 mm straw bale wall survived fire penetration in excess of two hours, after which the flame source was discontinued; even non-plastered wall survived for 34 minutes (EBN, 1995). The National Research Council of Canada also tested plastered straw bales for fire safety and found performance better than conventional building materials. It is found that the plastered surface withstood temperatures of about 1010° C for two hours before developing cracks. These findings are also supported by real life experiences in the field. Plastered straw bale structures have survived wild fires where wooden buildings burned to the ground and steel melted. The basis for this extraordinary performance is that straw bales hold enough air to provide good insulation value, but because they are compacted firmly, they do not hold enough air to permit combustion.

Stacking and pinning

Bales of load bearing walls must be laid flat and stacked in running bond with each bale overlapping the two bales beneath it. Whereas for non-load bearing walls bales are laid either flat or on edges. The first course of bales must be laid by impaling the bales on vertical stakes extending from the foundation. Only full-length bales may be used at corners of load bearing walls.

Advantages of Straw bale construction

Straw bale construction has several advantages over other conventional building practices. They are discussed below.

Significant savings in energy use

Straw bales as building materials enable a significant reduction in energy consumption. It can be achieved in two areas.

- Energy used to make it available as a building material (embodied energy) and
- Reducing residential energy consumption for either heating or cooling.

Based on the experience of the first attempt, a second building was constructed in the year 1998. Instead of casuarinas poles, steel rods were using for that building. Pre-compressed straw bales were used instead of hand pressed straw and chicken mesh. Reinforced concrete roof was constructed with 6 mm chips and straw bales were covered over the roof with chicken mesh and lime plastered.

Figure 5 Second SB building, Trichy, India

Both these SB buildings could effectively withstand a 1m high flood that lasted for 1.5 days with out any problem.

Examples from the Netherlands

In the Netherlands, the first Straw bale building was constructed during the period of 1944-45 by the architect W. Gubbels. The choice for straw bales was based on the limited availability of other building materials in the aftermath of Second World War.

Ouwerkerk - The first SB house built with a permit in the Netherlands was in the year 1998 at Ouwerkerk. It has got the following specifications.

- Non load bearing straw bales
- Lime plastering outside
- Inner walls made of adobe
- Wooden flooring

Figure 6 SB house Ouwerkerk

Warns - This is a residential building combined with a boat workshop with the following specifications.

- Strip foundation
- Non-load bearing straw bales
- Mud plaster

Figure 7 SB building in Warns (picture during construction in 2003 October)

6 RICE HUSK ASH POZZOLANA

6.1 Introduction

This chapter aims to identify a sustainable affordable alternative to replace (partially) cement for the primary building applications in rural areas. Rice husk contains large amounts of silica. Upon combustion of the husk, ashes consisting of amorphous silica are formed which are targeted as a supplementary cementing material on mixing with lime or cement. This chapter discusses the properties of rice husk ash samples produced from different types of field ovens to compare the performance of the ovens and to identify the most feasible method to produce reactive pozzolana. Different types of ashes are produced and long-term strength of rice husk ash pozzolanas with lime or cement is investigated. The strength of mortars produced from the rice husk ash samples from the field ovens and pozzolanic characteristics of the corresponding ashes are compared with those produced from the optimum conditions in the laboratory to make a worthwhile selection among the type of ovens.

There are various factors that govern the reactivity of rice husk ash (RHA) as a pozzolanic material. A detailed characterization of rice husk ash samples as a function of combustion conditions has been conducted to identify these factors, discuss the existing controversies on the formation of crystalline phases of silica during the incineration and hence to optimize the conditions for the production of a pozzolanically reactive ash from rice husk. The lab research has been actually done to judge the results of ash samples from the different field incineration arrangements.

Why to replace cement?

Conventional modern building materials are beyond the reach of the majority of the world population due to their poor affordability (UNCHS, 1993). Besides the escalation in the cost of building materials, rising environmental concerns due to the extensive exploitation of natural resources connected with construction and other housing development activities urge the search for alternative technological options. Cement, a vital material for construction activities, is a major contributor to global carbon dioxide emissions. Each tonne of Portland cement produced releases approximately the same quantity of carbon dioxide (Worrel et al., 2001). Environmental implications from cement industry can be grouped under excessive energy consumption, emission of greenhouse gases and dust pollution of the atmosphere besides the degradation of mined areas. The manufacturing process of cement is highly energy intensive and is one of the most energy engrossing sectors within the Indian economy. Therefore it is of particular interest in the context of both local and global environmental discussions. The energy consumption by the cement industry is estimated at about 2% of the global primary energy consumption, or almost 5% of the total global industrial energy consumption (World Energy Council, 1995).

Increased emission of greenhouse gases like methane and carbon dioxide is thus a major concern connected with the cement industry. 5% of global carbon dioxide emissions originate from cement production (Hendriks et al., 2004). According to the World Resource Institute 4% of the total CO_2 emission in India is from cement industries. Cement-related greenhouse gas emissions originate from fossil fuel combustion at cement manufacturing operations (about 40% of the industry's missions); transport activities (about 5%) and the combustion of fossil fuel that is required to make the electricity consumed during the production of cement (about 5%). But the major part of emission (about 50%) originates from the manufacturing process that converts limestone ($CaCO_3$) to calcium oxide (CaO), the primary component of cement (Humphreys et al., 2002). The dominant use of carbon intensive fuels like coal also adds to the increase in emissions of CO_2.

Dust emission is yet another problem related to cement manufacturing starting with quarrying of raw materials to the packing of finished products. The limestone mining area spread over 600 to 1000 acres of land is regularly subjected to various operations like drilling, blasting, crushing of limestone resulting in heavy dust emission, along with affecting the natural ecosystem. Besides the environmental problems, ordinary Portland cement is also expensive and unaffordable for a large section of the Indian population.

Rice husk ash pozzolana; A sustainable alternative for cement

About 50% of the Portland cement used in building construction is consumed for primary construction applications such as masonry and plastering. The strength requirements in such building processes are of the order of 4.0 MPa, while Portland cement is ideally suited for applications with strength requirements in excess of 15.0 MPa. According to Jagadish et al. (1988) pure Portland cement mortars are stiff and lack the plasticity that is very much needed in masonry construction. Lime-pozzolana cements can replace Portland cement in such cases with better performance. Pozzolanas are materials containing reactive silica and/or alumina, which although not cementitious by itself, will combine chemically with lime or cement in presence of water to form a strong cementing material. Granulated blast furnace slag, powdered bricks and tiles, burnt clay, furnace clinker, fly-ash and agricultural wastes (plant ashes) are the commonly used pozzolanas.

Plant ashes having high silica content are suitable as pozzolanas. Many plants during their growth take up silica from the earth. When plant residues are burned, organic material is broken down and disappears as carbon dioxide, water vapour etc. The remaining ash contains inorganic residues, notably the silica. Examples are rice husk ash, rice straw ash, bagasse ash etc. Of all plant residues, the ash of rice husks contains the highest proportion of silica.

Rice husk is an agricultural waste, which constitutes about one fifth of the 400 million tons of paddy produced annually world wide. India constitutes 22% of the world rice production. The percentage of rice husk from rice varies due to growing conditions such as season, temperature, methods of production, location and also on milling process. A small proportion of this waste material is used as a fuel, for chicken litter, or as cattle feed but generally it presents a big disposal problem in rice growing countries. But in Kerala rice husk is widely used as fuel for parboiling* operations in rice mills. Hence the usage of rice husk along with utilising its fuel value will be a more sustainable solution in Kerala.

Rice husk contains nearly 20% silica in hydrated amorphous form. On thermal treatment, the silica converts to cristobalite, the crystalline form and which is not at all reactive. However under controlled conditions, amorphous silica with high reactivity is produced (Mehta, 1978, Chandrasekhar, et al., 2003). RHA pozzolanas are produced by blending finely ground RHA with either lime or cement. Similar to ordinary Portland cement paste, calcium hydroxide ($Ca(OH)_2$) and calcium silicate hydrates (C-S-H) are the major hydration and reaction products in the RHA paste. Because of the presence of reactive silica available in RHA, the paste incorporating RHA had lower $Ca(OH)_2$ content than ordinary Portland cement paste (Zhang et al., 1996).

This research is an attempt to develop a sustainable affordable alternative from rice husk ash to replace (partially or fully) cement for the primary building applications in Kerala. However, the economical aspects for the bulk production of rice husk ash could not be considered. Along with bulk production, utilisation of the fuel value of rice husk can further improve the affordability of RHA pozzolana (Yogananda et al., 1988). It has been suggested as the next phase of this research. Succeeding sections deal with the details of laboratory research and field research.

6.2 Literature review

The use of RHA in concrete was patented in the year 1924 (Stroeven et al., 1999). In the conversion of rice husk to ash, the combustion process removes organic matter and leaves a silica rich residue. Several studies have been done on rice husk ash to identify the crystallization temperature and crystalline phases of silica (Ankara, 1976; Mehta, 1978; Yeoh et al., 1979; Ibrahim et al., 1980; Hamad et al., 1981; James et al., 1986; Hamdan et al., 1997; Paya et al., 2001; Chandrasekhar et al., 2003; Nehdi et al., 2003). The relative proportions of the forms of silica in the ash depend on both the temperature and the duration of burning. Along with this, the combustion method is also an important factor that governs the reactivity of rice husk ash.

There is a considerable controversy regarding the temperature and duration of burning at which the silica converts from amorphous form to crystalline during combustion of rice husk (Bui, 2001). Up to 1972, all the researches were concentrated to utilise ash derived from uncontrolled combustion. But Mehta (1978) established that a highly reactive ash can be produced by maintaining the combustion temperature below 500°C under oxidising conditions for a relatively prolonged period or up to 680°C provided the

* Parboiling is a hydrothermal treatment of paddy to separate rice grain.

high temperature exposure was less than one minute. Prolonged heating above this temperature may cause the material to convert (at least in part) first to cristobalite and then tridymite forms of crystalline silica. Chopra et al. (1981) have reported that for an incinerator temperature up to 700°C the silica was in amorphous form and silica crystals grew with time of incineration. The combustion environment also affects the specific surface area, so that time, temperature and environment also must be considered in the pyroprocessing of rice husks to produce ash of maximum reactivity (Ankara, 1976; Nehdi, 2003). James and Rao (1986) indicated that isothermal heating at a minimum of 675K (402°C) is required for complete destruction of organic matter from rice husk and to liberate silica. On combustion, the cellulose-lignin matrix burns away, leaving a porous silica skeleton. On grinding, this will give very fine particles with a large surface area. Parameters influencing the surface area of ash samples are temperature, duration of combustion and the treatment of rice husk before burning. The decrease in surface area can be attributed to crystalline growth and pore structure.

According to Hamad et al. (1981) ash prepared at a temperature of about 500-600°C consists of amorphous silica. Cristobalite was detected at 800°C and at 1150°C both cristobalite and tridymite were present. But Yeoh et al. (cited in Nehdi et al., 2003) reported that silica in RHA can remain in amorphous form at combustion temperatures of up to 900°C if the combustion time is less than one hour and crystalline silica is produced at 1000°C with combustion time greater than 5 minutes. Several researchers had reported that crystallisation of silica can take place at temperatures as low as 600°C (Cook et al., 1984; Shah et al., 1979 cited by Bui, 2001), 500°C (Dass, 1987 cited by Bui, 2001), or even at 350°C with 15 hours of exposure (Kapur, 1981, cited by Bui, 2001).

Yogananda and Jagadish from Indian Institute of Science (IISc), Bangalore (1983, 1988) did several studies on the pozzolanic properties of rice husk ashes produced by different field incinerators. They noticed that the long-term strength of RHA Pozzolanas produced from field arrangements in certain cases showed a decrease in strength after 28 days. This decrease in strength of RHA pozzolanas was a great concern for the popularity of RHA in building applications. This research is an attempt to verify this fact. The field ovens employed in this research are of the same type as that used by Yogananda et al., (1988) in their research.

Research approach

The research presented in this chapter has two main parts.

1. *Laboratory Research*

The first phase of this research addresses the optimization of RHA samples and discusses parameters, which influence the reactivity of the pozzolana from rice husk under controlled conditions in the laboratory. They are studied by detailed characterization of RHAs as a function of combustion conditions using X-ray diffraction (XRD), ^{29}Si magic-angle spinning (MAS) nuclear magnetic resonance (NMR), chemical analyses, conductivity measurements and microscopic analysis.

2. *Field Research*

The second phase presents a discussion on the comparison of RHA samples from different field ovens and recommends a feasible method to produce rice husk ash pozzolana in the normal conditions of rural environments. The initial phase of laboratory research is actually needed as a preliminary step to decide the quality of pozzolana from the field ovens. Lime reactivity test specified by IS standards (I.S 1727-1967), compressive strength test, particle size analysis are done to compare the properties. The results of the field tests will be judged against the findings of the lab research.

6.3 Laboratory research

6.3.1 Rice husk ash sample preparation

Rice husk samples were collected from Alleppey district of Kerala (India). Ash samples were prepared by burning 50 g of rice husk in a laboratory oven under the continuous supply of air for different durations of burning (15 minutes to 24 hours). An initial duration of two hours pre-heating was maintained in all cases to attain the desired temperature. Two ash samples were collected from each case. One sample was taken immediately after completion of the burning process (so called "quick cooling" (Q)).The second sample was collected after slowly cooling down inside the oven (so called "slow cooling" (S)). Testing conditions were maintained as follows.

- Temperature regimes (300°C, 500°C, 700°C, 900°C)
- Duration of burning (15 minutes, 6 hours, 12 hours, 24 hours)
- Nature of cooling (Quick cooling, Slow cooling)

The RHA samples produced from the laboratory under different testing conditions are represented with a unique designation throughout this chapter for convenience. For example RHA 500-6Q and RHA 500-6S designate the rice husk ash samples produced at a temperature of 500°C and a burning duration of six hours. Q and S indicate the nature of cooling. In order to find the parameters influencing the formation of reactive silica the samples collected from different regimes are subjected to chemical analyses, conductivity measurements, XRD, NMR and microscopic analysis.

6.3.2 Experimental methods

6.3.2.1 Chemical analysis for loss on ignition and total silica

All samples were subjected to chemical analysis after grinding them in an Agate mortar for ten minutes. ASTM C 311-00 standards were used for the determination of loss on ignition (LOI) and silica. The pre-weighed RHA sample is kept in an oven (800°C) and weighed again. The difference in weights is the weight of carbon that released as CO_2. The same sample (carbon removed) is taken and boiled in Nitric acid. It is then filtered through a weighed glass fibre filter and then washed with demineralised water. The filter is then dried in an oven at 105°C (whole night) and weighed again. The weight change is the weight of insoluble SiO_2 (Total silica, both crystalline and amorphous).

6.3.2.2 Soluble fraction of silica

Rice husk ash samples are taken, weighed in an analytical balance and boiled in 100 ml of 2.5 N (10%) NaOH. The solution is then filtered through a filter paper and washed with demineralised water. This filter is dried in an oven at 800°C (2 hours), cooled and weighed to get the weight of insoluble silica. Soluble silica remained as dissolved in the solution.

6.3.2.3 Pozzolanic activity

The variation of electrical conductivity of a saturated solution of calcium hydroxide on dispersing with the RHA samples can be taken as a measure of the pozzolanic activity of the samples (Luxan et al., 1989). Initially the conductivity of calcium hydroxide saturated solution (200 ml, 40°C) is measured. To this 5 g of RHA sample is added. The electrical conductivity is measured after two minutes of continuous stirring. The difference between the initial and final conductivities is calculated as a measure of pozzolanic activity. This is identified as a rapid method to evaluate the pozzolanic effect of rice husk ash (Bui, 2001, Feng et al., 2004, Goni et al., 2003).

6.3.2.4 X-ray diffraction (XRD) analysis

Two types of instruments were employed in this research for the XRD analysis of different RHA samples. They are (i) Philips PW 3710 X-ray diffraction system having a copper tube and a nickel filter and (ii) Bruker D8 Avance X-ray diffraction system operating with a 50 kV, 50 mA Cu radiation source and a Philips PW1820 diffractometer. This diffractometer uses a 40 kV, 50 mA Cu radiation source. When silica is truly amorphous, the characteristic X-ray diffraction peaks of crystalline forms of silica are absent.

6.3.2.5 Microscopic Analysis

XL 30 Philips ESEM and Jeol FESEM 6330F were used for the microstructure analysis of the RHA samples.

6.3.2.6 ^{29}Si Magnetic Angle Spinning (MAS), Nuclear Magnetic Resonance (NMR)

^{29}Si solid-state MAS NMR experiments were performed on a Chemagnetics Infinity 300 MHz (7.1T) and a Chemagnetics Infinity 600 MHz (14.1T) NMR spectrometer. On the 7.1 T spectrometer a Bruker 10 mm MAS HX probe head was employed, whereas a Chemagnetics 6 mm MAS HX Apex probe was used on the 14.1 T spectrometer. Spectra were obtained using single pulse excitation using a $\pi/2$ excitation pulse (5 μs, ν_1 = 50 kHz) and a relaxation delay of 600s. For a few selected samples, spin-lattice relaxation times T_1 were determined using a saturation-recovery experiment. In all cases the relaxation curves were strongly multi-exponential and in many cases full relaxation had not been reached after 600s. This means that some caution has to be taken into account with the quantitative interpretation of the spectra. Spinning speeds ranging from 3 kHz to 6 kHz were used in all cases fast enough to avoid spinning sidebands. Spectra are referenced with respect to TMS using the ^{29}Si resonance in Zeolite A (89.7 ppm) as a secondary standard. Spectra were processed and de-convoluted using the MatNMR processing software. De-convolution of the various Q-species in the spectrum was done assuming Gaussian line shapes in all cases.

6.3.3 Results and discussion

6.3.3.1 Chemical analysis

Fig. 6.1 and Fig. 6.2 show the variation of the loss on ignition, which is a measure for the residual carbon content, and the percentage soluble silica, which is considered to be related to reactivity, for the various RHA samples. The influence of different incineration times, temperatures and cooling regimes can be discussed based on the results of the chemical analyses.

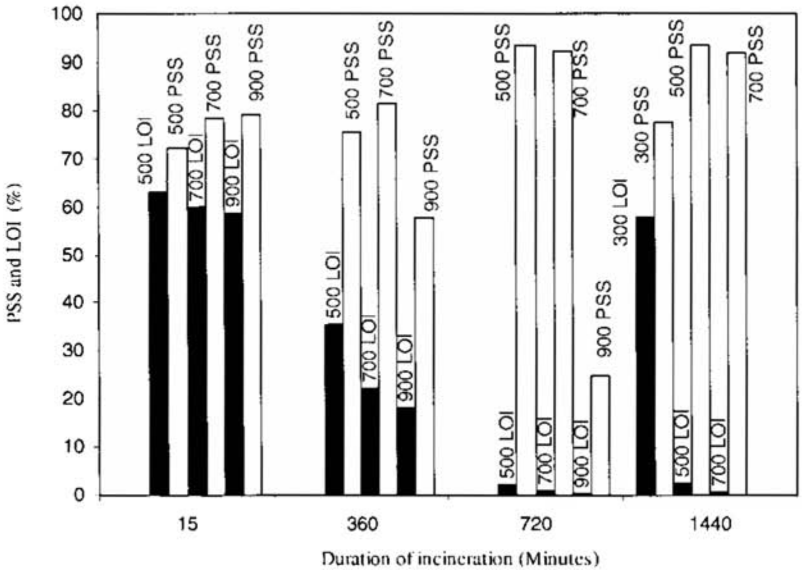


Figure 6.1 Percentage of soluble silica (PSS) and loss on ignition (LOI) in quick cooled RHA samples prepared using incineration temperatures of 300°C, 500°C, 700°C and 900°C for durations varying from of 15 to 1440 minutes (0.25 to 24 hours).

It is noticed that burning for a short duration (15 to 360 minutes) was insufficient at all temperatures to achieve complete incineration of rice husk to expel the carbon and to produce a reactive ash. At a burning temperature of 300°C this is still the case after incineration for 24 hours. However, both burning temperatures of 500°C and 700°C resulted in ash samples with low carbon content and high percentage of soluble silica at longer durations (12 hours to 24 hours) of incineration. Finally, the RHA900 samples showed a strong decrease in the percentage of soluble silica for longer durations. The loss on ignition was almost nil at a temperature of 900°C.

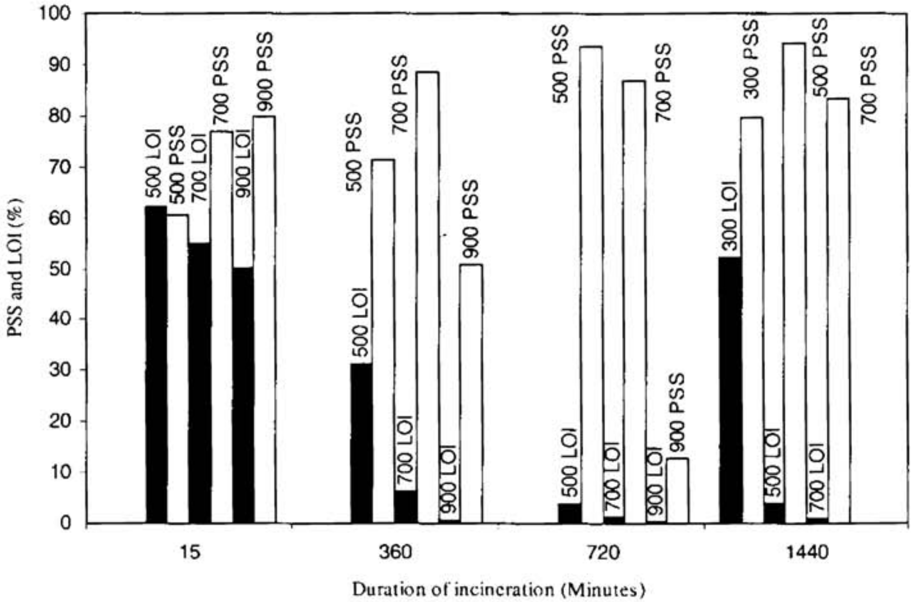


Figure 6.2 Percentage of soluble silica (PSS) and loss on ignition (LOI) in slow cooled RHA samples prepared using incineration temperatures of 300°C, 500°C, 700°C and 900°C for durations varying from of 15 to 1440 minutes (0.25 to 24 hours).

From this we can conclude that temperatures of 500°C and 700°C are favorable for producing reactive rice husk ashes. They showed very similar results for the percentage of soluble silica at all durations of incineration and cooling regimes. The percentage of carbon for these samples is somewhat lower in the slow cooling regime as compared to the quick cooling regime; in all cases these quantities are negligible however.

6.3.3.2 Pozzolanic activity

Chemical analysis could not discriminate between RHA 500 and RHA 700 samples in terms of optimal incineration conditions in relation to pozzolanic activity. The pozzolanic activity test, using the decrease in electrical conductivity when adding a defined amount of RHA to a saturated calcium hydroxide solution, can provide further insight. This test is a quick measure of the reactivity of the ash based on the presence of amorphous silica. A large change in conductivity is interpreted as a high pozzolanic activity (Luxan et al., 1989).

Table 6.1 Difference in the electrical conductivity (Δ mS/cm) of a saturated solution of calcium hydroxide on adding a defined amount of the respective RHA sample.

Samples S - slow cooling; Q - quick cooling	Variation of pozzolanic activity
700 – 12 S	3.2
700 -12 Q	3.6
700 - 24 S	3.0
700 - 24 Q	3.5
500 - 12 S	5.3
500 - 12 Q	5.4
500 - 24 S	5.2
500 -24 Q	5.2

As shown in Table 6.1 both RHA 500 and RHA 700 samples gave large conductivity changes which can be interpreted as good values for pozzolanic activity. RHA 500 samples consistently showed higher values than the RHA 700 samples and demonstrates their overall higher reactivity. On the basis of these experiments, all samples qualify as good* pozzolanas. RHA 500-12Q clearly shows the highest activity.

6.3.3.3 XRD analysis

Since the above-discussed tests could not identify differences in the formation of amorphous or crystalline silica for different cooling regimes, XRD analyses were performed for selected samples for further characterization. An indication of the crystallinity of the samples can be obtained from the intensity of the narrow reflections as compared to the broad band around 22 degrees (2θ).

The broad peak of RHA500 samples (Fig. 6.3) indicates the amorphous nature of silica at different testing conditions for this temperature. Similar results were obtained for the RHA 700 samples (Fig. 6.4) again showing hardly any crystalline reflections. For the

* According to Luxan et al., (1989) variation in electrical conductivity more than 1.2 is referred as good pozzolana

RHA 900-6Q (Fig. 6.5) some reasonably sharp and intense reflections start to show up on top of the broad amorphous background, evidencing that at these temperatures crystalline cristobalite starts to form. Only after incineration at 1100°C the material becomes highly crystalline. This is evident from Fig. 6.6. The XRD pattern of a RHA 1100 sample shows sharp reflections and that can be assigned to cristobalite and tridymite.

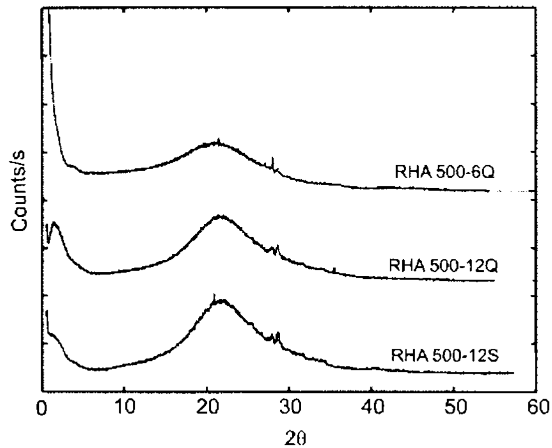


Figure 6.3 XRD patterns of RHA 500-6Q, RHA 500-12Q and RHA 500-12S samples. The broad and intense line centred at 2θ = 22° indicates that all samples are amorphous.

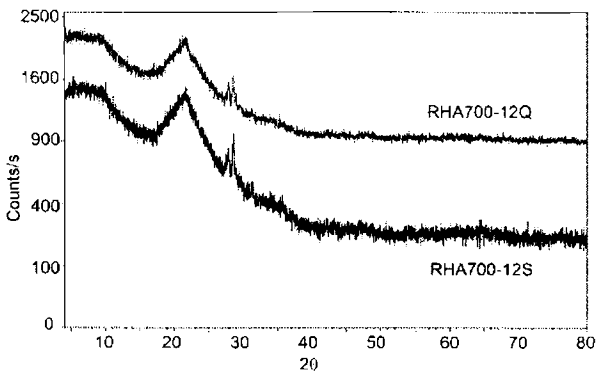


Figure 6.4 XRD patterns of RHA 700-12Q and RHA 700-12S samples, which are still dominated by a broad background indicating that the sample is amorphous

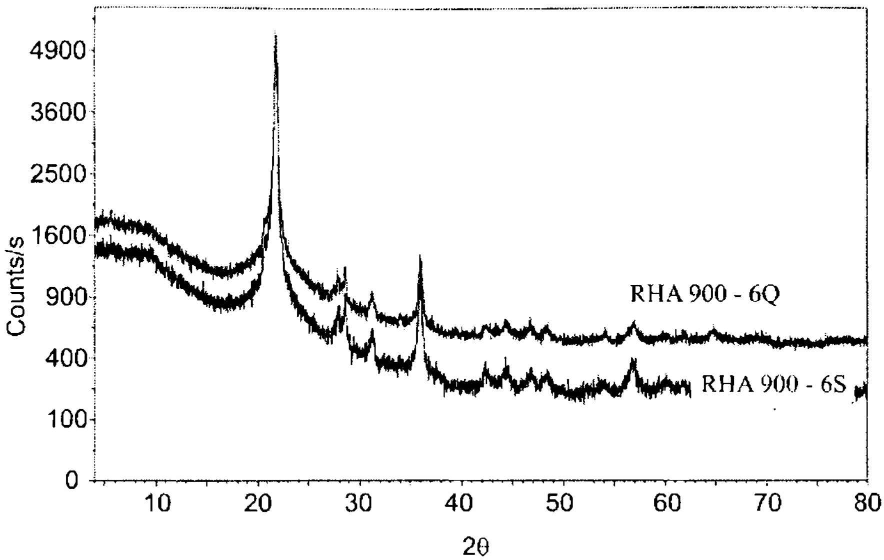


Figure 6.5 XRD patterns of RHA 900-6Q and RHA 900-6S samples. Sharp peeks indicate the presence of a major crystalline fraction in the samples.

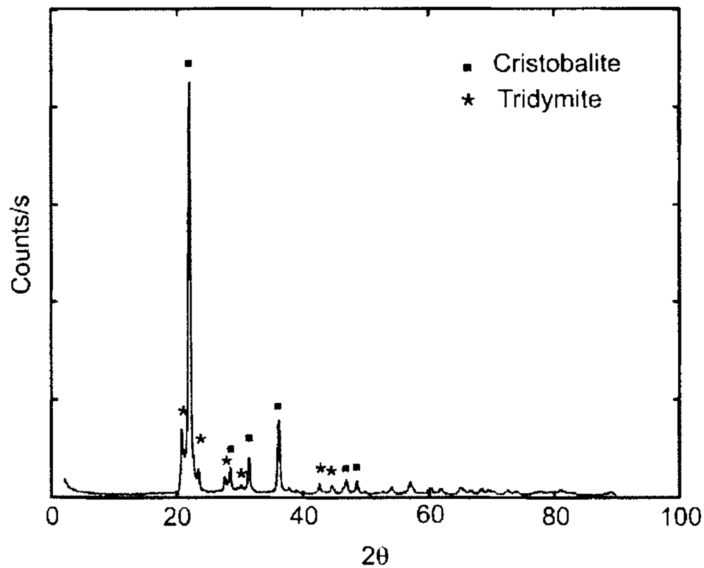


Figure 6.6 XRD pattern of an RHA1100 sample showing sharp lines and without broad background indicating the crystalline nature of the sample. Two phases could be identified being cristobalite and tridymite.

6.3.3.4 Microscopic analysis

Fig. 6.7 shows the morphology of different RHA 500 samples produced from controlled conditions in the lab. The difference in the morphology between RHA 500-12Q and RHA 500-12S shows that the particle size increases significantly in the slow cooling regime as compared to quick cooling.

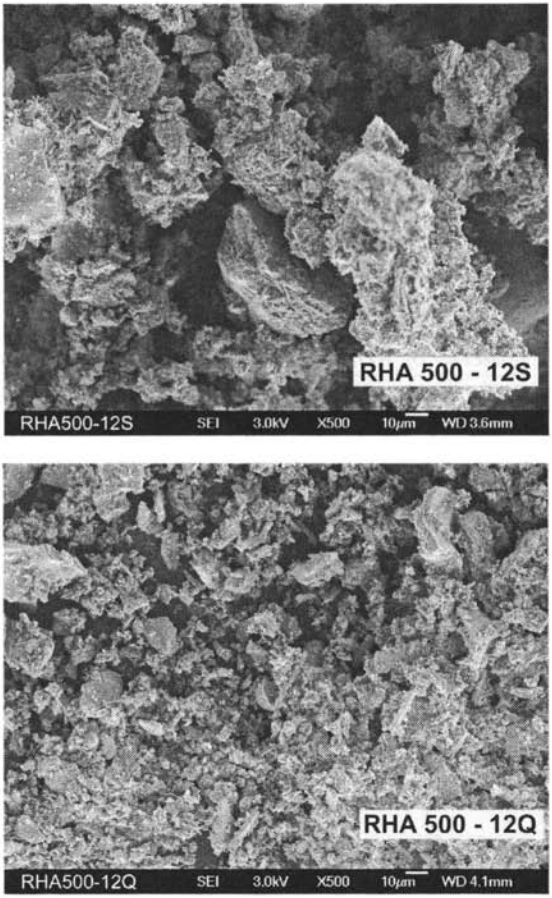


Figure 6.7 FESEM (Field Emission Scanning Electron Microscopy) images for RHA samples burnt at 500°C but differing in cooling procedure. Slow cooling samples were left in the oven to cool down whereas quickly cooled samples were directly removed from the oven. Slow cooling clearly leads to larger particle size indicating a more condensed structure.

Care has to be taken in interpreting particle size in terms of reactive surface. It cannot be interpreted in terms of crystallinity, however. In fact we do not observe particles with a specific morphology that could be related to certain crystalline fractions. The same was true for the RHA 700 samples. During incineration expelling the carbon fraction and silica condensation are competing processes which lead to the formation of porous particles which can have very high internal surfaces.

6.3.3.5 ^{29}Si MAS NMR

Although XRD and FESEM give some insight in the crystallinity of the samples, they cannot provide information about the composition and reactivity of the amorphous fraction of the RHAs. ^{29}Si Solid-state NMR is well suited to provide this insight as it probes the local structure of a silicon atom and does not rely on long-range order in the samples. In silica, ^{29}Si chemical shifts depend on the degree of condensation of the SiO_4 tetrahedral in the material. Assignment of the spectra of silicates is done on the basis of the second coordination sphere of silicon (Engelhardt et al., 1987) using the Q^n nomenclature. Here 'n' designates the number of siloxane bonds a certain silicon atom is participating in. Through these siloxane bonds a silicon atom can be bonded to a maximum of four other silicon nuclei. As each of the Q^n species have a distinctive chemical shift ^{29}Si NMR can give information about the degree of condensation of a silica network.

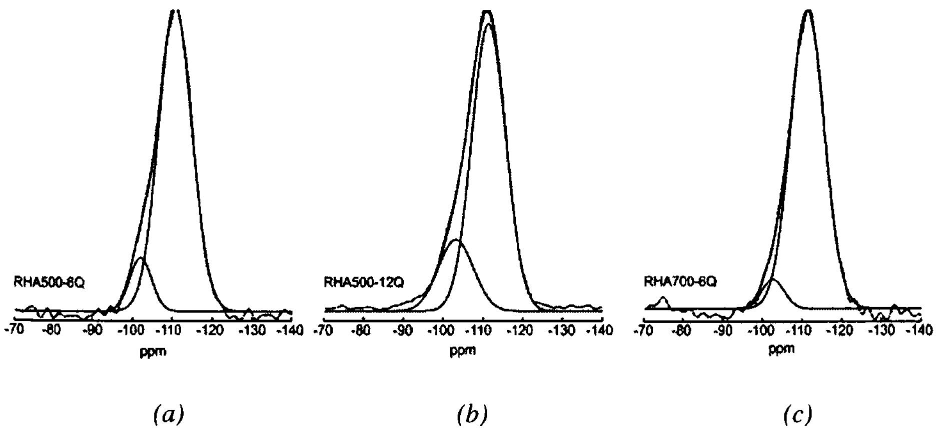


Figure 6.8 ^{29}Si MAS NMR spectra for RHA samples burnt at different temperatures for varying time. a) RHA sample burnt at 500°C for 6 hours and cooled quickly (RHA 500-6Q). b) RHA 500-12Q and c) RHA 700-6Q. All spectra are dominated by a strong and broad resonance at -111 ppm assigned to Q4 branches in condensed amorphous silica. A shoulder is present at -102 ppm indicating the presence of silanol Q^3 sites. For the RHA 500-12Q samples the largest amount of silanol sites are found which are related to the reactivity of the samples.

Within each Q species the exact chemical shift value depends on the Si-O-Si bond angles. This also allows one to get insight in the crystallinity of the materials. Crystalline samples are characterized by well-defined bond angles which are reflected in narrow NMR resonances, whereas amorphous samples are characterized by distributions in bond angles in general leading to broad Gaussian line shapes (Dupree et al., 2000; Pettifer et al., 1988).

Fig. 6.8 shows the ^{29}Si MAS NMR spectra of RHA 500-6Q, RHA 500-12Q and RHA 700-6Q samples. The spectra of the samples prepared at 500°C and 700°C are all dominated by a peak at approximately −111 ppm with a small shoulder at −102 ppm. From this we conclude that we have a very dense silicate network mostly consisting of Q^4 branches with a small amount (varying between 3% and 21%) of Q^3 sites from terminating silanol groups. These silanol groups are the only reactive groups in the silica and can thus be held responsible for the pozzolanic activity of the materials if they are accessible. The lines have very broad Gaussian line shapes with a width of approximately 10 ppm for the Q^4 sites and about 6 ppm for the Q^3 sites, indicating that the network is mostly amorphous with a large variation in Si-O-Si bond angles (Dupree et al., 2000; Pettifer et al., 1988).

None of the spectra of the samples burnt at 500°C or 700°C show the presence of any significant amount of crystalline material in line with the XRD observations and an early study of rice husk ashes by Hamdan et al. (1997). The situation changes at a temperature of 900°C, for these samples a relatively narrow line (FWHH ~3 ppm) appears at -111 ppm, on top of the broad amorphous resonances, that is assigned to the formation of cristobalite on the basis of the XRD data. Treatment at an even higher temperature of 1100°C significantly changes the spectrum (Fig. 6.9) with narrow lines (FWHH 1 ppm) at -110 ppm and -112 ppm (FWHH 3.5 ppm) indicating that the sample mostly consists of a mixture of cristobalite and tridymite (Dupree et al., 2000), in line with the XRD observations.

Table 6.2 summarizes the results of the spectral deconvolution of the various ^{29}Si MAS NMR of a series of RHA samples. The line shape was assumed to be purely Gaussian for all resonances in the amorphous phase. Of particular interest is the fraction of silanol species (Q^3) present in the amorphous material as this is thought to be related to the reactivity of the samples and their pozzolanic properties. The percentage of Q^3 sites in the RHA 500-6Q and RHA 500-6S samples is 10% and 6% respectively. This indicates that the condensation reactions in the ashes are progressing during the cooling process leading to a more condensed network with less surface sites for the slowly cooling samples. An intriguing observation is that the amount of silanol groups increases by increasing the incineration time to 12 hours to 21% and 12% for the samples RHA 500-12Q and RHA 500-12S respectively. This is in line with an earlier investigation of Ibrahim and Hemaly (1988) who reported a continuous increase in the specific surface area and pore volume in RHA samples produced at 500°C with increasing burning duration up to 12 hours. Almost constant values of BET surface area and pore volume were reported when the duration was increased from 12 hours to 24 hours. From saturation-recovery experiments the slowest relaxing component in these materials is estimated to have a T_1 of ~200s showing that a quantitative analysis of the spectra is valid in this case.

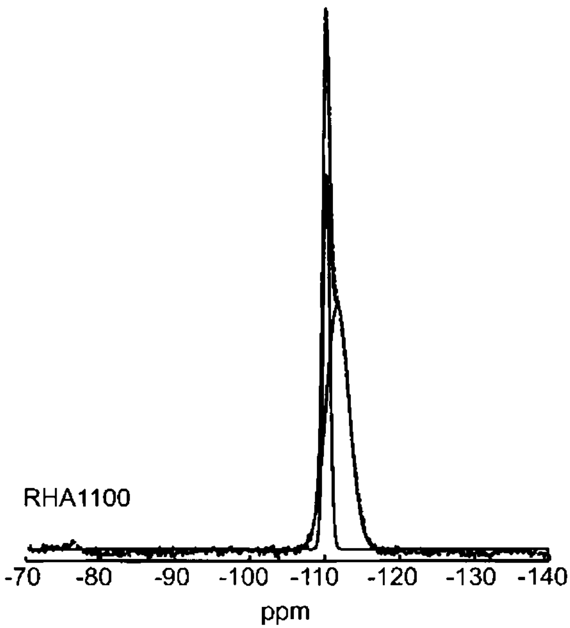


Figure 6.9 ^{29}*Si MAS NMR spectrum of RHA 1100. The relatively narrow lines at -110 and -112 ppm indicates the presence of crystalline cristobalite and trydimite (Dupree et al., 2000)*

Moving to a higher burning temperature of 700°C the amount of silanol species goes down to 6% and 3% for the RHA 700-6Q and RHA 700-6S samples respectively. This is in line with the expectation that a higher burning temperature leads to faster condensation and therefore a denser network with less surface sites. Again a slow cooling process leads to a further reduction of the silanol sites. It should be noted that we observed a significant increase in the spin-lattice relaxation time for these samples to a point that quantitative evaluation of the spectra is no longer fully warranted. Due to the mobility and coupling to protons, the relaxation time of the silanol groups is expected to be shorter than for the Q^4 sites in the core of a particle. This means that the amount of Q^3 sites could actually be lower than the estimations on the basis of the spectral de-convolution. Most likely the Q^4 sites in the core of the particles will relax through spin-diffusion to the surface where silanol groups and possible paramagnetic impurities act as a relaxation sink. So the increase in effective T_1 indicates that at higher temperature the inner and/or outer surface of the silica particles are reduced with less fast relaxing sites in the vicinity of many Q^4 species.

Table 6.2 Details of de-convolution showing the peak position in ppm relative to TMS, the integrated peak area (in arbitrary units–a.u), and the Full Width at Half Height (FWHH) in ppm for the Q^3 and Q^4 resonances observed in the ^{29}Si MAS NMR spectra of various RHA samples. For the RHA 900 a second Q^4 resonance is observed assigned to the appearance of crystalline material.

RHA Samples	500-6Q	500-6S	500-12Q	500-12S	700-6Q	700-6S	900-6Q	900-6S
Q^3								
Peak Pos. (ppm)	-102.1	-101	-103.2	-102.4	-102.6	-101.7	-103.5	-103.1
Peak Area (a.u.)	7.6	4.7	40.4	21.0	3.0	2.4	2.5	0.3
FWHH (ppm)	6.5	6	10.4	7.5	6.7	5.6	6.6	7.4
Q^4								
Peak Pos. (ppm)	-110.9	-110.2	-111.5	-111.1	-111.4	-111.2	-111.8	-112.2
Peak Area (a.u.)	65.4	75.0	156.1	156.4	45.5	76.3	32.8	28.5
FWHH (ppm)	9.8	10.6	10	10	10	11.7	8.3	8.9
Q^3 (%)	10	6	21	12	6	3	7	1
Q^4								
Peak Pos. (ppm)							-111.1	-111.3
Peak Area (a.u.)							6.4	12.7
FWHH (ppm)							2.5	3.1

Going to even higher burning temperature of 900°C we observe the first formation of crystalline material, although the majority of the material is still amorphous. In the RHA 900-6Q sample there is still a reasonable amount (upper limit 7%) of Q^3 species present in the amorphous fraction of the sample. Again it should be noted that this amount is an estimated upper limit in this case as the spin-lattice relaxation times of this condensed material becomes prohibitively long to obtain fully quantitative data.

In summary, the NMR data give direct access to identification of the reactive sites in the RHA samples. Spectral de-convolution of the spectra clearly identifies the RHA 500-

12Q sample as having the highest amount of silanol groups present in the sample making it the favorable sample as pozzolanic cement additive.

The optimization of RHA samples at different controlled laboratory environments was done in order to compare the properties of the ash samples from a rather uncontrolled environment in the field. The results of the investigations in the first phase indicated the reactivity of samples burnt at 500°C or 700°C. This insight helped in the second phase of further research on field ovens.

6.4 Field research: Investigation on performance of field ovens[†]

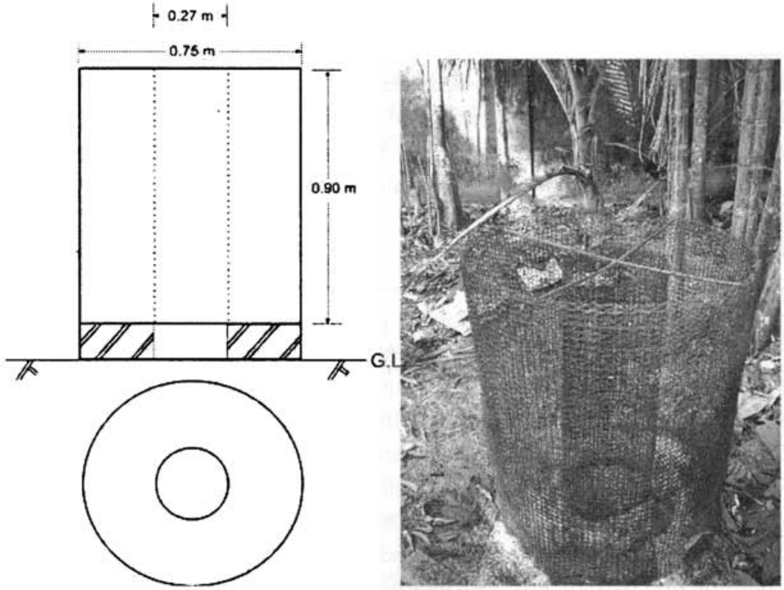
For rural building applications, sophisticated ovens and techniques are not feasible and affordable to maintain the controlled conditions in the lab. This part of the experimental technical research was carried out to identify an affordable incinerator to produce reactive pozzolana for rural building applications in Kerala. It deals with the production and analysis of rice husk ash samples from different types of field ovens. Ash samples are subjected to various tests to determine the parameters (amorphous silica content, loss on ignition and particle size distribution) ,which decide the pozzolanic activity. The long-term strength of the lime/cement pozzolana mortar produced from these samples are compared with that of a reference sample produced at optimised conditions in the lab and also with the pozzolana mortar of waste ash from parboiling operation of paddy.

6.4.1 Types of field ovens

The performance of three types of field ovens viz. (A) the annular kiln enclosure, (B) the rectangular brick oven and (C) the pit oven were investigated. The rice husk ashes produced are indicated as RHA A, RHA B and RHA C.

A. Annular oven - An annular enclosure with a height of 0.9 m, consisting of two co-axial hollow cylinders (open at the top) are made with weld meshes (Fig. 6.10). The inner cylinder has a diameter of 0.27 m and an outer cylinder with a diameter of 0.75 m. The base and exterior of this arrangement is protected with an extra layer of chicken mesh to prevent the escape of ash samples. Rice husk is filled in the annular portion between the two cylinders. This arrangement can be kept elevated from the ground using bricks so as to apply heat from the bottom. Temperature is measured at different parts of the sample using a temperature probe. It took almost nine hours for complete burning. RHA samples were collected (RHA A) after the complete cooling of ash samples.

[†] Nair, D.G., Jagadish, K.S., Fraaij, A., 2006. Reactive pozzolanas from rice husk ash: An alternative to cement for rural housing, Cement and Concrete Research, **36** (6), pp. 1062-71.



(i) (ii)

Figure 6.10 Plan, section (i) and picture (ii) of annular kiln enclosure for burning rice husk

Figure 6.11 Brick kiln enclosure for burning rice husk

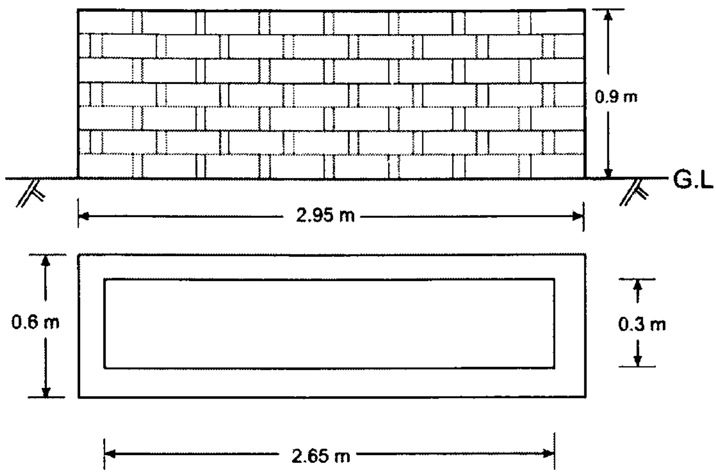


Figure 6.12 Plan and front elevation of the brick kiln enclosure for burning rice husk

B. Rectangular brick oven- A rectangular enclosure (2.95 m × 0.6 m × 0.9 m) as shown in the picture (Fig. 6.11, Fig. 6.12) is built with bricks having a number of small openings in the body of the enclosure to allow a smooth flow of air. It is filled with rice husk and burning of the sample is started from the top, slowly progressing towards the bottom. The burning process was slow compared to the annular enclosure and it took almost three days for complete burning. The ash samples collected from this oven is denoted as RHA B.

C. Pit burning- A pit of 1 m diameter and depth is dug in the ground (Fig. 6.13) and filled with rice husk. The burning of rice husk was allowed to take place from the

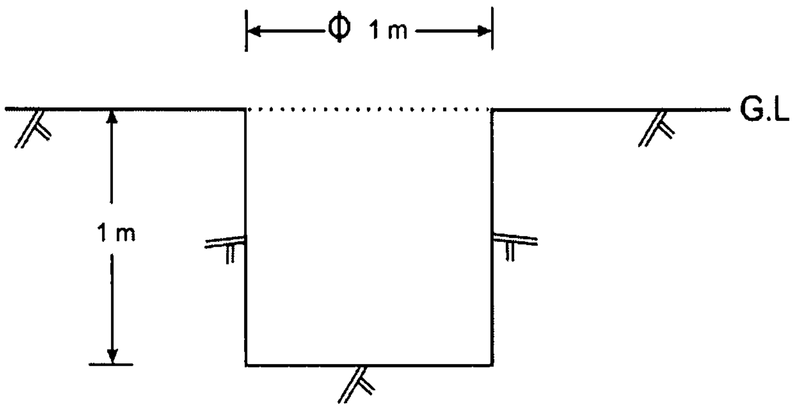


Figure 6.13 Arrangement for pit burning

top surface in the same manner as in the rectangular enclosure. Burning proceeded from the top surface slowly downwards. It took almost one week for the complete burning and simultaneous cooling of the sample. The ash samples collected from this burning arrangement is denoted as RHA C.

The ash samples were checked with a temperature probe during the burning process to for identifying the maximum temperature and it was found to varying from 500 to 600°C in all the cases. Also the three RHA samples were collected after one week from the initial date of burning to keep consistency. The performance of the three rice husk ashes A, B and C were compared with ashes produced in the laboratory (reference RHA D) and waste ash obtained from parboiling operation of paddy (RHA E).

D. Laboratory oven - RHA D is the reference sample (RHA-12S) made at controlled conditions in the lab using a muffle furnace with continuous supply of air. Ash samples of 500 g were used for each burning operation. After keeping the rice husk in a porcelain container, the oven was switched on and an initial duration of two hours was given to reach the desired temperature of 500°C. The oven was then maintained at this temperature for 12 hours. After 12 hours of heating, the oven was switched off (maintaining the air supply) and kept closed for another 24 hours and samples were collected (after complete cooling).

E. RHA E- This is the waste ash collected from a rice factory where rice husk is being used as the fuel for the parboiling operation of paddy.

The ash samples collected from different sources (A to E) were subjected to grinding in a ball mill for sixty minutes and the powder thus obtained was used for further tests. As these ashes are supposed to be produced in the rural environments for practical applications, no limits of fineness were prescribed for final samples and instead the duration of grinding was maintained constant for all the samples for keeping uniformity in the procedure.

6.4.2 *Experimental methods*

6.4.2.1 Chemical analysis for loss on ignition and soluble fraction of silica

The different RHA samples were subjected to chemical analysis for amorphous silica and loss on ignition in the same manner as that of the samples from the laboratory studies. The results are compared in Table 6.3 and Fig. 6.14.

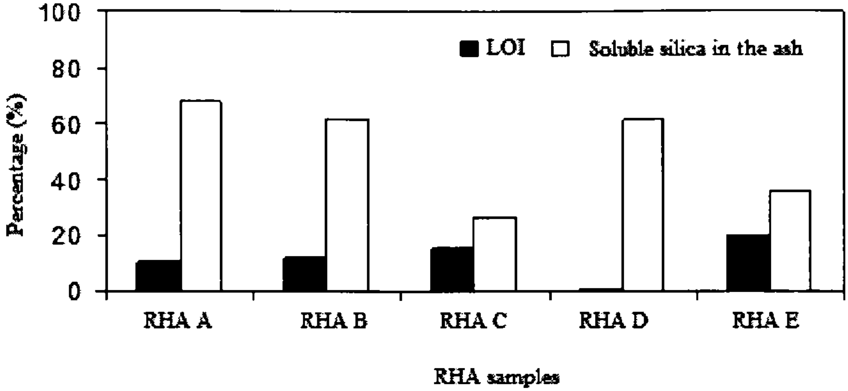


Figure 6.14 Percentage of soluble silica fraction and loss of ignition in different RHA samples

RHA A from the annular kiln enclosure has the highest percentage of soluble fraction of silica compared to the other samples. But the reference sample (RHA D) has the lowest carbon content.

Table 6.3 Properties of different rice husk ash samples from the field ovens

Samples	Type of oven or source of sample	Colour	LOI %	SiO_2 Total %	Percentage of soluble Silica in ash %	Percentage of soluble silica in total Si O_2 %	Variation in Electrical Conductivity (Pozzolanicity) mS/cm
RHA A	Annular oven	Light Grey	10.8	82	67.7	82.6	2.6
RHA B	Brick oven	Light Grey	12.1	85	61.8	72.7	2.6
RHA C	Pit burning	Grey	15.3	82	27	32.9	2.1
RHA D	Laboratory oven	Light grey	0.8	88.5	61.1	69	3.9
RHA E	Waste ash from parboiling	Black	20.5	76.7	35.9	46.8	1

6.4.2.2 Pozzolanic activity

Table 6.3 gives the pozzolanic activity of different RHA samples. The reference sample (RHA D) has the highest value of pozzolanic activity and waste ash (RHA E) has the lowest value. Among the field samples RHA A has the highest value.

6.4.2.3 XRD *analysis*

Fig. 6.15 to Fig. 6.17 show the XRD patterns of different rice husk ash samples RHA A, B, C, D and E.

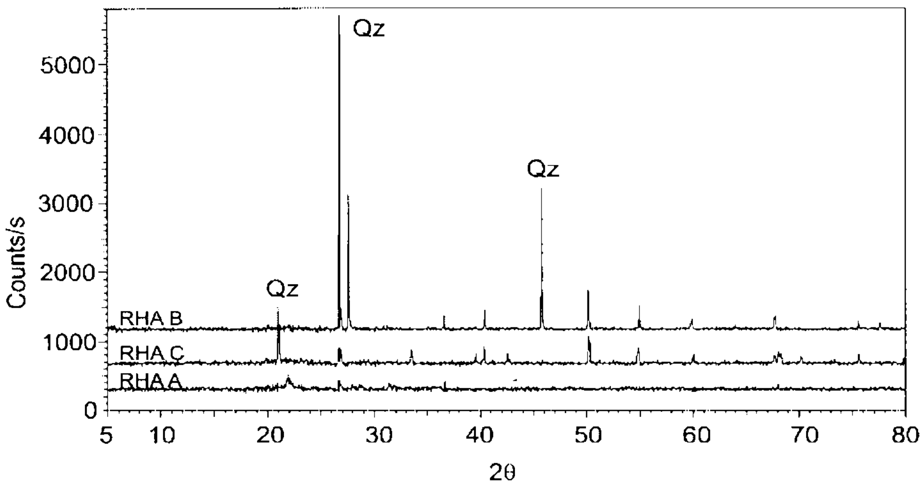


Figure 6.15 XRD of RHA A, RHA B and RHA C (Field samples). Peaks of crystalline fractions in the XRD pattern of RHA B and RHA C is visible. RHA A is purely amorphous. (Absence of amorphous humps and difference of this XRD pattern from other pictures is due to the background subtraction of the data)

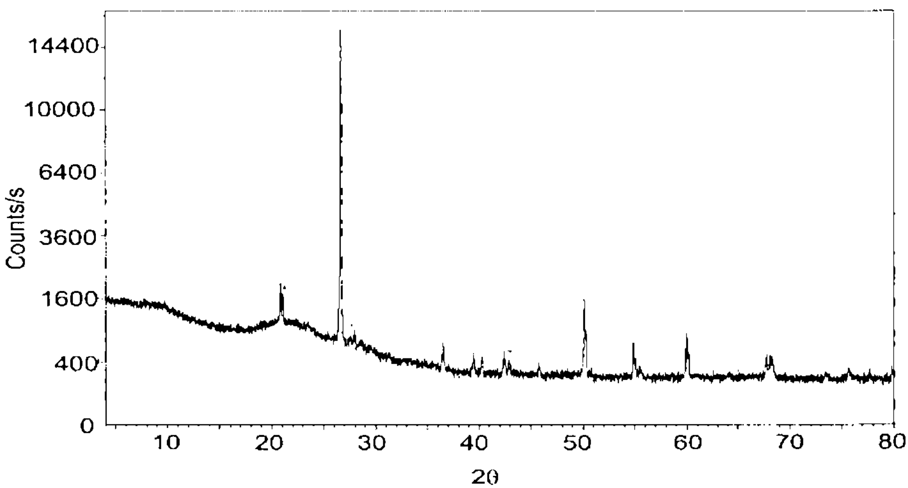


Figure 6.16 XRD of the reference sample, RHA 500-12 S (RHA D)

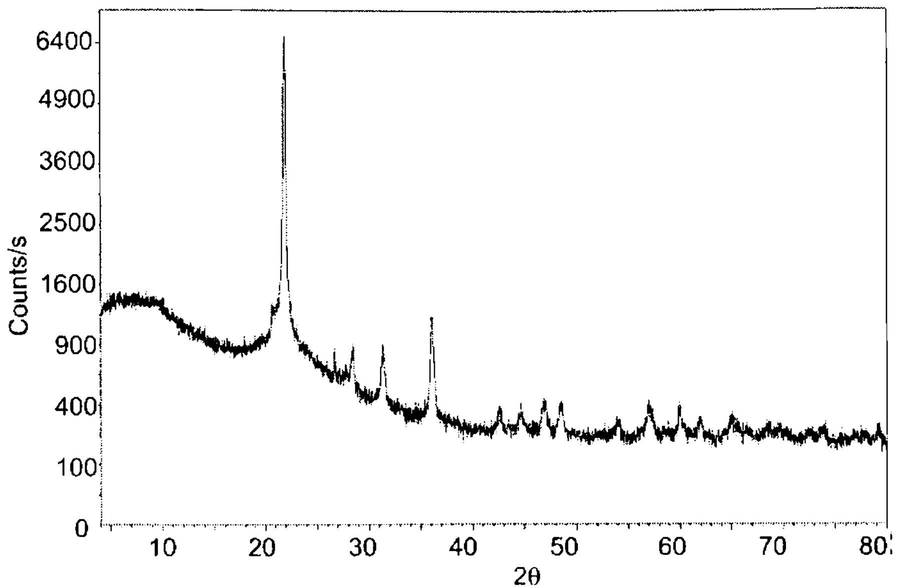


Figure 6.17 XRD of RHA E (Fuel waste), sharp peaks showing the crystalline nature of the sample

Only cristobalite could be detected in RHA A. The XRD analysis of RHA B, C, D and E showed the peaks of quartz also. Also the XRD pattern of RHA C and E indicate the presence of crystalline silica in excess of other RHA samples.

6.4.2.4 Particle size analysis

Table 6.4 and Fig. 6.18 give the details of particle size analysis. These measurements were done by Laser diffraction with the Malvern Mastersizer S, 300RF lens and a sample presentation unit.

Table 6.4 Particle size distribution (in μm) of different RHA samples

RHA Samples	Type of oven or source of sample	D10	D50	D90
RHA.A	Annular oven	7.3	40.9	152
RHA.B	Brick oven	9.1	47.3	171
RHA.C	Pit burning	7.1	44.5	320
RHA.D	Laboratory oven	3.7	18.9	60.7

The ash samples were made wet with a non-ionic surfactant and dispersed in demineralised water. They stayed stable for several minutes. When ultrasonic effect is applied, the distribution became much smaller. The percentage of large particles was less in RHA D compared to A and B, whereas RHA C showed higher percentage of coarse particles (with D 90 = 320 μm, i.e. 90% of particles smaller than 320 μm).

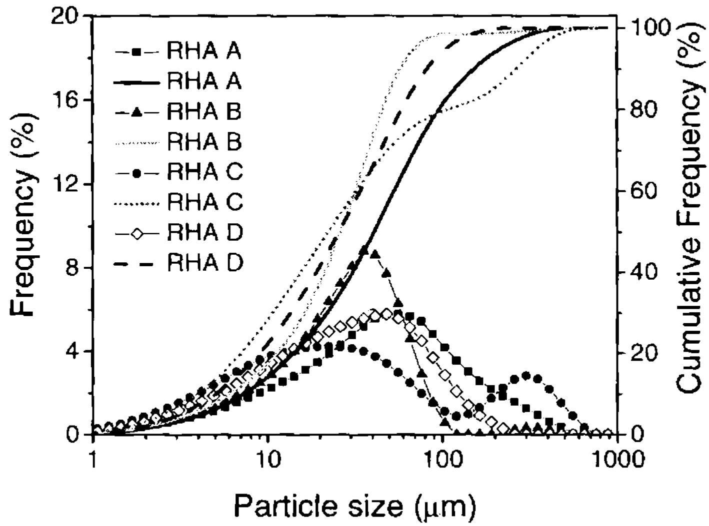


Figure 6.18 Particle size distributions of different RHA samples

The unimodal distribution of A, B and D samples (Fig. 6.18) corresponds to the homogeneity of ashes whereas the bimodal distribution of RHA C shows the heterogeneous nature of RHA C. Among the four samples subjected for particle size analysis RHA D showed a higher percentage of finer particles. Within the field samples, rice husk ash samples from the annular oven showed the finest particles and those from the pit arrangement were with coarse particles.

6.4.2.5 Determination of specific surface area

The specific surface areas of the RHA samples were determined by nitrogen adsorption using the Quanta chrome Autosorb-6B analyzer. The BET (Brunauer, Emmett and Teller) method provides a combined surface area value for both inter-particle area (surface inside pores) and intra-particle area (the structure and outer surface of the particles). Table 6.5 shows the specific surface area of different RHA samples. The reference sample (D) has a higher surface area than the field burnt samples.

Table 6.5 BET surface area of different RHA samples

RHA Samples	Type of oven or source of sample	BET surface area (m^2/g)
RHA.A	Annular oven	63 ± 1
RHA.B	Brick oven	65 ± 1
RHA.C	Pit burning	43 ± 1
RHA.D	Laboratory oven	115 ± 1

6.4.2.6 Lime reactivity test

This test has been recognised as a standard method by I.S.1727-1967 for determining the reactivity of the pozzolanic material (RHA) with hydrated lime. Lime reactivity is represented by the compressive strength of standard mortar test cubes prepared and tested under specific conditions. The dry materials of standard test mortar of lime-pozzolana-sand in the different proportions (by weight) is tested. Lime and ash is weighed and inter-ground in a ball mill (for 60 minutes) just before making the mortar. Cube specimens of 40 mm size* are moulded according to I.S 1727-1967 specifications. After covering the surface of the specimen in the mould with a smooth and greased glass plate, it is kept in a moist room at a temperature of 21°C for 48 hours. Then the specimens are removed from the mould and cured at 90% to 100% relative humidity for a period of 8 days at 50 ± 2°C in an incubator. After curing for eight days, the specimens were taken out of the oven and tested for compressive strength. Since the specimens were kept exposed to the air only for a short duration, risk of carbonation can be neglected.

* The test specimens used are 40 mm cubes instead of the 50 mm cubes as specified by I.S.1727-1967

Table 6.6 Lime reactivity of different RHA samples expressed by eight days average compressive strength

Sample	Type of oven or source of sample	Mix* Lime-Ash-Sand	Average compressive strength in eight days (N/mm^2)
RHA A	Annular oven	1:3:12	11.0
RHA B	Brick oven	1:3:12	7.8
RHA C	Pit burning	1:3:12	5.4
RHA D	Laboratory oven	1:3:12	13.4

6.4.2.7 Long term compressive strength

Lime-RHA and cement-RHA mortars in 1:3 proportions (by weight) were prepared for different proportions of lime-RHA and cement-RHA combinations. 40 mm cube specimens were prepared in the same manner as that of lime reactivity test and compressive strength was measured after a curing period of seven days to one year according to ASTM C 311- 00 standards.

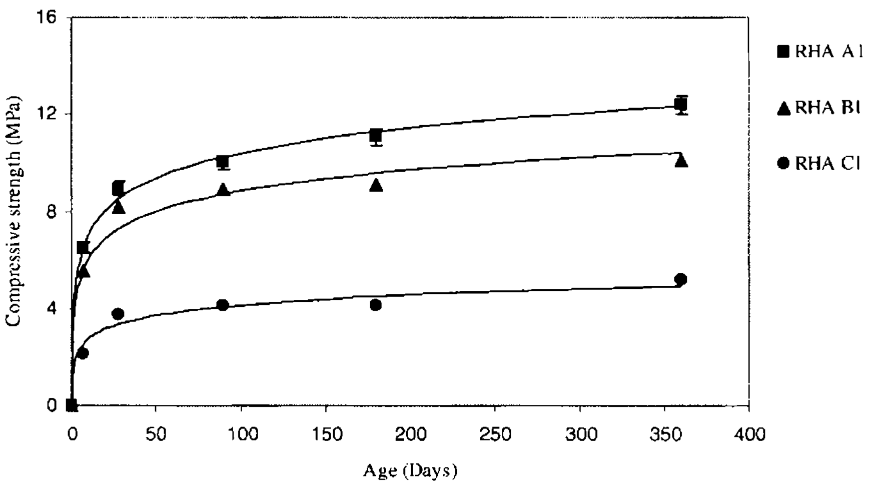


Figure 6.19 Long-term compressive strength of lime - RHA - sand mortars (1:1:6)

* Water content in percentage by weight of lime and ash is 0.76

X_1, X_2, X_3 and X_4 series corresponds to 1:1:6, 1:3:12, 3:1:12 and 2:1:9 proportions of lime or cement: RHA: sand and the letter 'X' denotes to different RHA samples. Fig. 6.19 and Fig. 6.20 show the evolution of the compressive strength of different Lime-RHA mortars during a period of one year. In all the mortars, a gain in strength with time can be seen (Appendix 6.1).

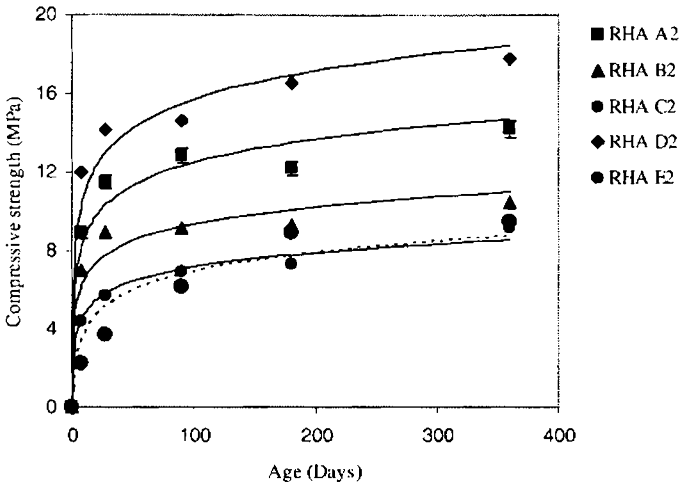


Figure 6.20 Long-term compressive strength of lime -RHA- sand mortar (1:3:12)

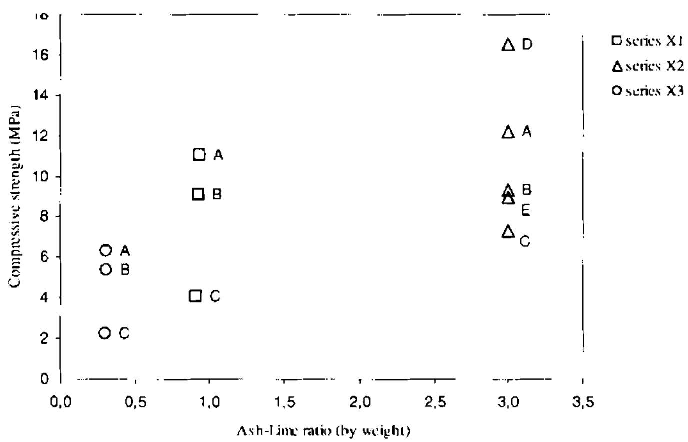


Figure 6.21 Influence of ash content on the compressive strength (180 days) of lime-RHA mortars of different proportions

The percentage of rice husk ash in the total powder (ash + lime or cement) has also a significant influence in the strength of the mortar. Fig. 6.21 illustrates this. It can be seen that the series X_2 (1:3:12) with the highest ash-lime ratio is having the highest compressive strength.

6.4.3 Results and Discussion

6.4.3.1 Chemical analysis

Table 6.3 and Fig. 6.14 give the variation of soluble silica and carbon content in different RHA samples. The influence of different heating arrangements and burning duration can be discussed on the basis of the results of chemical analysis.

Among the field samples RHA A from the annular oven gave better results with minimum carbon content (LOI) and maximum percentage of soluble silica. LOI was ranging from RHA A to RHA C in the order of RHA A < RHA B < RHA C and soluble silica as RHA A > RHA B > RHA C. In both cases RHA C, the ash sample from the pit burning gave inferior results compared to RHA A and B. This variation in soluble silica and carbon content can be due to the longer duration of burning and limited air flow in the case of pit burning compared to the other two arrangements.

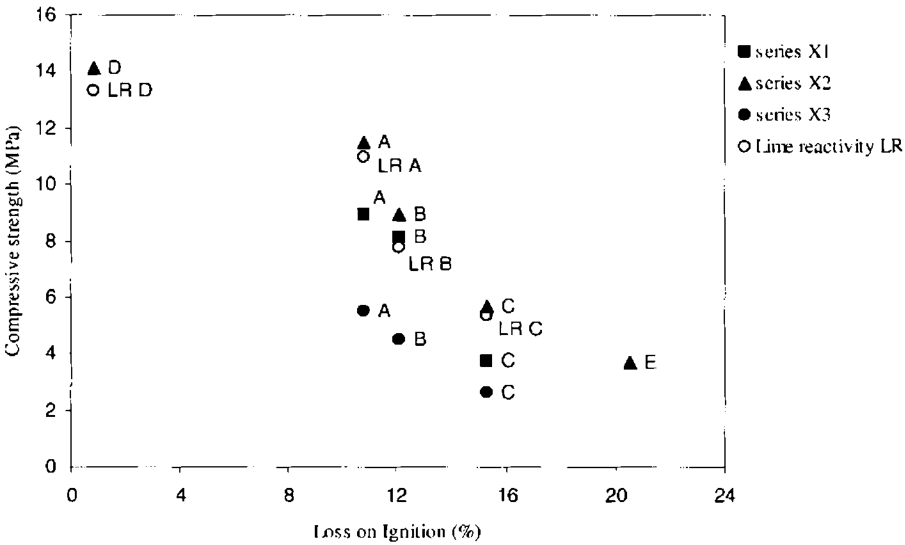


Figure 6.22 Influence of carbon on the 28 day compressive strength of different Lime-RHA mortars

Fig. 6.22 and Fig. 6.23 show the variation in compressive strength of different Lime-RHA samples (with the water-binder ratio of 0.76) with loss on ignition and total silica in the ash. It confirms the negative influence of carbon in the compressive strength of corresponding mortars for three different mix compositions of the field samples.

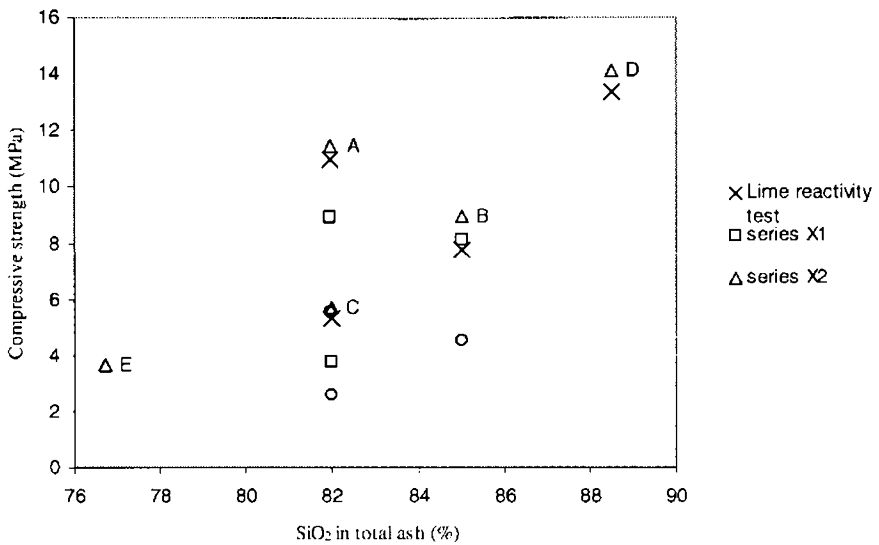


Figure 6.23 Influence of soluble silica in the ash in the 28 day compressive strength of different Lime - RHA mortars

The quick burning and plenty air flow in the case of annular enclosure due to its peculiar shape and bottom firing favored better results of RHA A. This factor can be confirmed from the case of RHA E with uncontrolled burning. It had a lower percentage of soluble silica and highest percentage of LOI. But the reference sample RHA D, produced from the controlled conditions in the lab showed the results of least carbon content among the samples and higher percentage of amorphous silica compared to RHA C and E. The color of the samples also gives an indication of carbon content.

6.4.3.2 Pozzolanic activity

The variation in electrical conductivity of saturated calcium hydroxide solution on adding the pozzolanic material can be taken as a quick measure of the pozzolanic activity of RHA samples. It is based on the concept that the active constituents of the pozzolanic material will react with calcium hydroxide leading to a decrease in concentration of Ca^{2+} and hence to a decrease in electrical conductivity. Table 6.3 gives the different properties of RHA samples. Among the tested RHA samples, pozzolanic activity decreases from the reference sample (RHA D) to the fuel ash (RHA E) in the order RHA D > RHA A > RHA B > RHA C > RHA E, in the same order as the loss on ignition (Fig. 6.24).

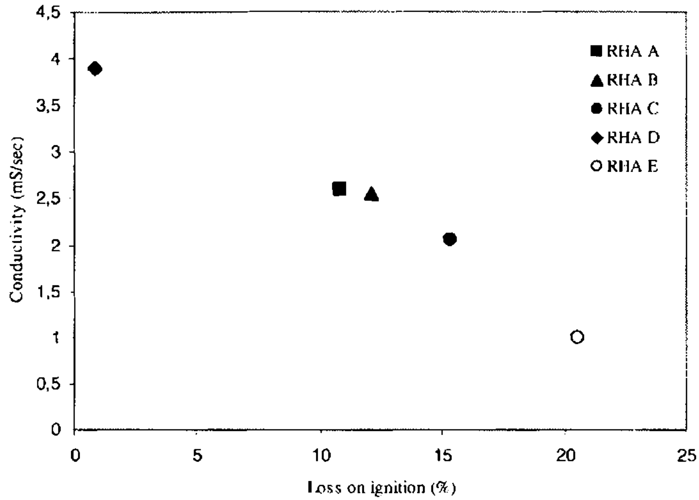


Figure 6.24 Influence of loss on ignition on the pozzolanic activity of different RHA samples, pozzolanic activity expressed as a variation in electrical conductivity

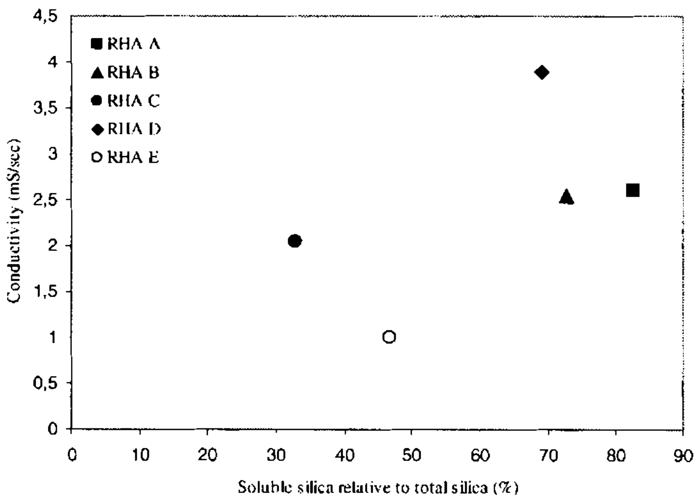


Figure 6.25 Influence of soluble silica in the pozzolanic activity of different RHA samples

The field samples showed a variation in the reactivity in the same order as that of soluble silica and LOI from RHA A to RHA C. However, RHA D showed a higher value of pozzolanic activity than RHA A and RHA B, even though it had a lower percentage of soluble silica (Fig. 6.25). This can be attributed to the extremely low value of the loss on ignition for RHA D. The same influence could also be noticed in the cases of RHA C and E. Even though both soluble silica and carbon content are deciding factors on the reactivity of RHA pozzolana, these results show the significance of carbon content in the pozzolanic activity.

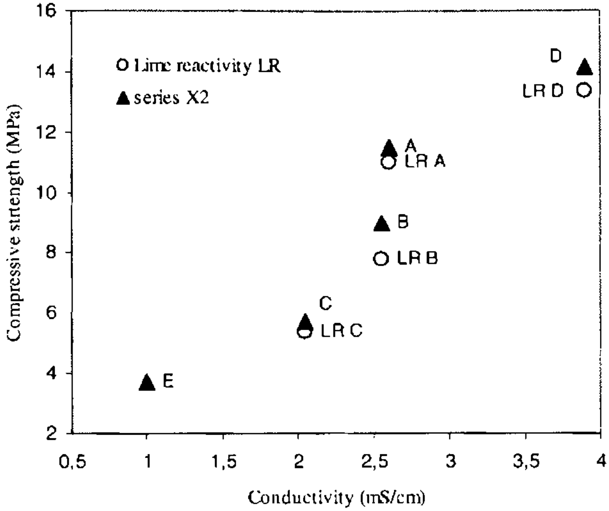


Figure 6.26 Relation between conductivity and compressive strength of different RHA mortars

As illustrated by Fig. 6.26, the pozzolanic activity of different RHA samples explained by the changes in the electrical conductivity gives a clear indication of the variation in compressive strength of different mortars in accordance with the pozzolanicity of corresponding ashes.

6.4.3.3 XRD analysis

XRD analysis also shows consistent results with the chemical analysis. XRD patterns of RHA A and RHA B shows the amorphous nature of samples, whereas the peaks of quartz could be detected in the other samples. The presence of quartz in RHA C can be due to the longer duration of burning or can also be attributed to the contamination of sand particles from the pit. The uncontrolled burning of waste ash contributed to the crystalline property of silica in RHA E.

6.4.3.4 Particle size analysis

Table 6.4 gives the percentage of different sizes of particles in the tested RHA samples. It shows the same variation as that of pozzolanic activity from RHA D to C with RHA

D having the higher percentage of smaller particles. Fig. 6.18 shows the particle size distribution of different samples. It clarifies the presence of coarse particles (D 90 = 320 μm) in RHA C compared to RHA B (D 90 = 171 μm) and RHA A (D 90 = 152μm). Higher concentration of comparatively smaller particles in RHA D (D 90 = 60.7 μm) explains the higher reactivity of the reference sample. Also the field samples showed consistent results in the particle size with the reactivity of ash samples. These results also confirm the excellence of annular enclosure (RHA A) compared to the other two field arrangements.

6.4.3.5 BET analysis for surface area

The BET results of all the samples vary in the same order as that of pozzolanic activity, as expected. Fig. 6.27 shows the influence of specific surface area on the 180 day compressive strength of different Lime-RHA samples with the same water-powder ratio (0.76). RHA D, having the higher specific surface area, gave the highest compressive strength in 1:3:12 proportion of lime - RHA mortar.

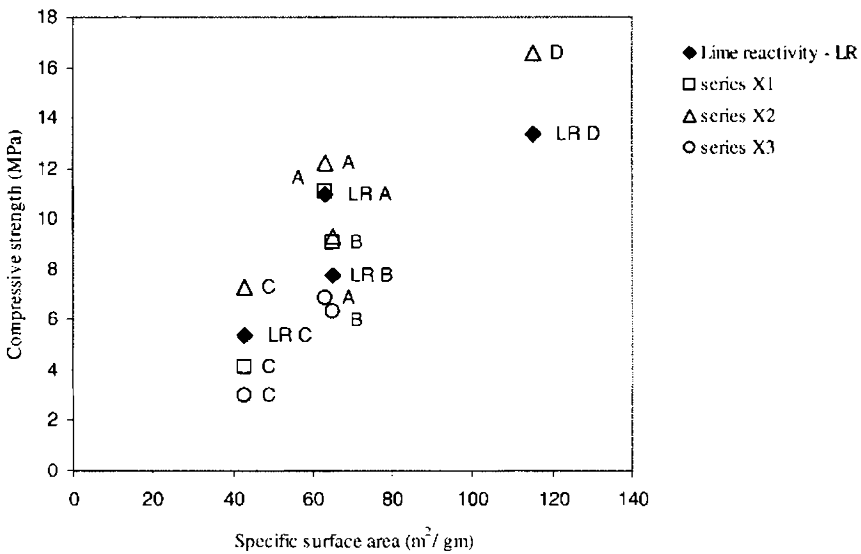


Figure 6.27 Influence of Specific surface area in the Long term (180 day) compressive strength of different lime - RHA mortars

Compressive strength of mortars from other RHA samples also showed a variation in the same way with respect to the specific surface area. Since all the samples are subjected to grinding with the same conditions, the higher specific surface area of the reference sample (RHA D) can be attributed to the controlled conditions of burning. The higher surface area of RHA increases its pozzolanic activity (Feng et al., 2004). Hence the higher surface area of the RHA D compared to other samples can also be attributed to the higher strength gain. According to James and Rao temperature and duration of incineration are important parameters which influence the specific surface area (James and Rao, 1986). The annular oven took only a comparatively short duration of burning and cooling compared to the other two field arrangements. This supports the variation in specific surface area of the field samples and the corresponding variation in the compressive strength of mortars (Fig. 6.27). Hence the grinding efficiency is apparently not the same for different ashes with different particle size and surface area (Table 6.4 and Table 6.5). Also the specific surface area of rice husk ash is mainly controlled by pore structure and hence collapse of the pores will result in a decrease in surface area. Therefore, grinding of RHA will not influence the BET values, until it reaches certain fineness (Bui, 2001).

6.4.3.6 Lime reactivity and compressive strength

The lime reactivity test is considered as a quick measure of the reactivity of RHA pozzolanas. The tested RHA samples were showing a decrease in strength from RHA D to RHA C as shown in Fig. 6.28. Similar variation could also be noticed in the compressive strength of RHA-lime mortar.

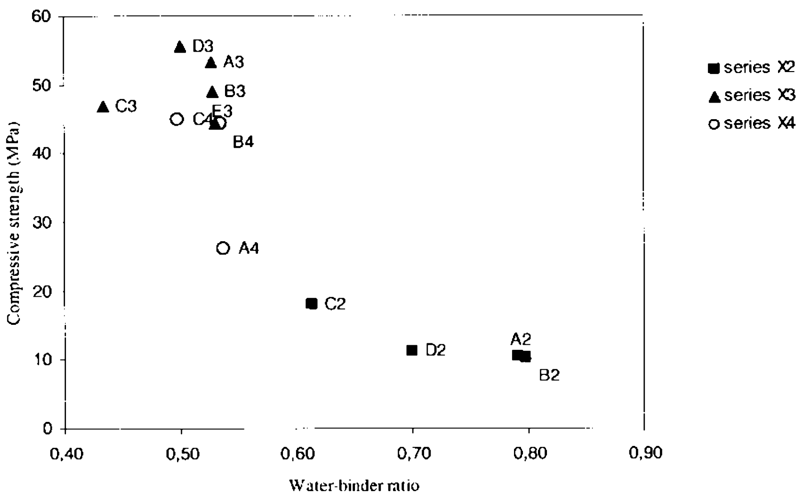


Figure 6.28 Influence of water-binder (water-powder) ratio on the compressive strength (28 day) of different Cement- RHA mortars

According to Paya et al. (2001) the reactivity of RHA with lime depends on a combination of two factors, i.e. its non crystalline silica content and specific surface area. But the variation in compressive strength of RHA–lime pozzolanas in different proportions also confirms the influence of carbon content (with RHA D giving higher strength) along with the other two parameters. All the mixes showed a strength gain during the period of one year. Field burnt samples showed a decrease in strength from mortars with RHA A to RHA C with lime mortar.

However the variation in the compressive strengths of cement-RHA mortars from different ashes was not that consistent as in lime-RHA mortars. This can be mainly due to the different water-powder ratios. This variation in water content in different mortars was guided by the loss on ignition of the corresponding RHA samples and ash content. The influence of water-powder ratio in the compressive strength of cement-RHA mortar can be well explained by Fig. 6.28. The coarse nature of large sized particles of RHA C provided a satisfactory gradation of fine particles and lead to a dense mix. The filler effect of smaller particles in the mix dominates the pozzolanic effects in this case (Gemma Rodrý´guez de Sensale, 2006).

From the analysis of different RHA samples, it is confirmed that ash samples produced at controlled conditions in the lab resulted in more pozzolanically reactive ash than the field samples. This can be attributed to the minimum loss on ignition and higher surface area of the samples from the controlled conditions. Presence of un-burnt carbon can adversely affect the reactivity of ash even though it is rich in amorphous silica. Ensuring ample supply of air is hence necessary for reducing the carbon content of ashes. Hence the duration and type of incineration are important parameters, influencing the performance of field ovens. The comparisons on the properties of field ashes confirm the significance of annular enclosure over the other two field ovens.

6.5 Conclusions

This experimental technical research was an investigation for identifying an affordable and feasible method to produce a pozzolanically reactive RHA for building applications in rural areas. The first phase of this research gave an insight into the optimized conditions for getting the most reactive ash from the laboratory environment. Since these controlled conditions are not feasible utilizing the limited infrastructure of rural environments, three types of field burning arrangements were tried in the latter phase to get a pozzolanically reactive ash. The properties of ash samples from these field burning arrangements were investigated and compared with a reference sample from the lab environment. We came to the following conclusions.

I. Rice husk ash from optimized conditions in the lab

An in-depth characterization of rice husk ashes has been conducted to identify the optimum conditions for producing a reactive ash from rice husk. The amount of soluble silica and loss on ignition in the different RHA samples showed that incineration at 300°C is unsuitable, as not all carbon is expelled from the samples. It furthermore indicated the reactivity of samples burnt at 500°C to 700°C. This agrees with the earlier investigations of Mehta (1978) and Hamad et al. (1981) who have identified the temperature range of 500 to 700°C as optimum for reactive ash formation. And disagrees with other investigations (cited by Bui, 2001) regarding the formation of crystalline silica at lower temperatures. The lower temperatures reported for the crystallisation of silica in rice husk ash could be attributed to contamination of husk with quartz.

Pozzolanic activity tests verified the good pozzolanic activity of the RHA 500 and RHA 700 samples, with uniformly higher values for the samples incinerated at 500°C. XRD and microscopic analysis confirmed the amorphous character of both the RHA 500 and RHA 700 samples with the first crystalline material appearing at processing temperatures of 900°C and higher.

To get insight about the formation of reactive material on a molecular level, a detailed analysis has been carried out using ^{29}Si solid-state NMR. The broad Gaussian line shapes in the spectra of the different RHA samples supports the amorphous nature of the silica in samples burnt at temperatures of 500°C and 700°C. At higher temperatures a gradual conversion to crystalline material was observed, in agreement with the XRD results. The amount of Q^3 sites in the amorphous phase of the RHAs varied with a clear maximum for RHA 500-12Q with a Q^4:Q^3 ratio of 4:1. This sample also showed the highest conductivity drop in the pozzolanic activity test. So we can conclude the most reactive rice husk ash is produced after incineration for 12 hours at 500°C and subsequently quickly cooling the sample down by directly removing it from the oven.

II. Rice husk ash from different field burning arrangements

A selection of field burnt samples has been done by comparing their properties with the reference sample (RHA 12S) prepared from the controlled conditions in the lab. We came to the following conclusions.

- RHA samples from the annular enclosure (RHA A) produced comparable results in the compressive strength of mortars with that of the reference sample (RHA D) in all the mix compositions. Therefore the annular type of oven can be suggested as an affordable and simple option for the small-scale production of RHA in rural areas. A modification of the annular enclosure with bricks instead of weld meshes can be suggested as a long-term solution considering the limited life span of weld meshes.
- Rice husk ash pozzolanas from the brick ovens (RHA B) also gave reasonably good strengths with lime and cement in different proportions even though those were inferior in strength compared to that from the annular kiln enclosure.
- The lower strength values of mortars with the ashes from the pit burning compared to the other samples can be due to longer period of incineration and slow cooling rate. Reducing the depth of the pit can modify this arrangement to ease air supply and result in better ash.
- Type of kindling can also affect the duration of incineration. Rice husk ash samples from the brick ovens were produced by firing the oven from the bottom, whereas in

other two cases, husk samples were fired from the top. Bottom kindling can accelerate the burning process and ease natural cooling.

- Analysis of fuel waste ash (RHA E) from the parboiling operations supports the possibility of reusing it as RHA pozzolanas of lower strengths.
- The long-term compressive strength of mortars from all the tested RHA samples showed a progressive increase in the strength against the earlier investigations of Yogananda et al., (1988), and proved the potential of rice husk ash as a sustainable replacement (see section 5.5.3, chapter 5) to cement in building applications.

Thus, this research has contributed in

- Identifying the optimum conditions for producing the most pozzolonically reactive RHA sample in the controlled conditions in the lab and
- Suggesting an affordable and feasible method to produce pozzolanically reactive rice husk ash in the field environments.
- Establishing the long-term of strength of RHA pozzolans

Appendix 6.1

Compressive strength of different RHA pozzolanas

Table 1 Compressive strength of lime - RHA mortar

Lime – RHA mortar	Water-powder ratio (percentage by weight of lime and ash)	Compressive strength for different durations in MPa				
		7 days	28 days	3 months	6 months	1 year
RHA A1(1:1:6)	0.76	6.5	8.9	10	11.1	12.4
RHHA B1	0.76	5.6	8.2	8.9	9.1	10.1
RHA C1	0.76	2.1	3.8	4.1	4.1	5.2
RHAA2 (1:3:12)	0.76	8.9	11.5	12.8	12.2	14.2
RHHA B2	0.76	7.0	9.0	9.2	9.3	10.5
RHA C2	0.76	4.4	5.7	7.0	7.3	9.2
RHA D2	0.76	12	14.1	14.6	16.6	
RHA E2	0.76	2.2	3.7	6.2	9.0	
RHAA3 (3:1:12)	0.76	2.6	5.5	6.2	5.4	7.5
RHHA B3	0.76	2.8	4.5	5.4	6.2	7.2
RHA C3	0.76	1.2	2.6	2.6	2.3	3.4

Table 2 Compressive strength of cement-RHA Mortar

Cement -RHA mortar	Water powder ratio (percentage by weight of lime and ash)	Compressive strength for different durations in MPa				
		7 days	28 days	3 months	6 months	1 year
RHAA2 (1:3:12)	0.79	7.9	10.4	12.7	12.7	14.7
RHHA B2	0.80	10.1	10.2	11.4	14.6	16.2
RHA C2	0.61	7.6	18.1	20	20.5	24.4
RHA D2	0.70	9.6	11.2	13.8	15.0	
RHAA3 (3:1:12)	0.53	33.4	53.2	49.2	53.4	68.5
RHHA B3	0.53	37.7	48.9	51.6	59.3	80.8
RHA C3	0.43	37.9	46.8	52.5	65.8	70.52
RHA D3	0.50	41.2	55.5	61.6	64.6	
RHA E3	0.53	29.7	44.3	46.2	61.8	
RHA A4 (2:1:9)	0.53	23.3	26.1	51.9	60.2	-
RHHA B4	0.54	25.3	44.8	53.1	55.4	68.8
RHA C4	0.50	30.2	44.4	42.6	64.1	70.0

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This chapter deals with the general conclusions and recommendations of this research. Section 7.2 presents a comprehensive review of the results achieved. This is followed by a number of recommendations (section 7.3) for the practical implementation of policies to contribute to sustainable-affordable housing development in Kerala. The final section highlights the scope for further research.

7.2 Achievements of this research

The prime objective of this research was to gain a better understanding of the concept of sustainable-affordable housing for developing countries, in order to come up with improved strategies to meet the needs of economically weaker sections of population. A conceptual framework has been developed on integrating the four equally significant and interdependent objectives of sustainability, concerning socio-cultural, economic, technological and environmental factors. This framework has been adopted and tested in the context of Kerala (India). It has been applied in both the socio-political evaluation of low income housing programmes and in the technological evaluation of the building process in Kerala. In addition to this, the thesis has contributed to technological innovations of the building process by improving understanding of potential use of rice husk ash as a pozzolanic material to replace (partially) cement. This would greatly reduce the environmental pollution by the disposal of rice husk, and create less expensive and more sustainable cement for building construction. This has been done by (i) addressing and discussing the long standing disagreement on the condensation of the silica network in rice husk ash (which determines its pozzolanic properties) during the incineration process of rice husk and (ii) identifying an affordable incinerator to the rural environments, requiring minimum infrastructure to produce rice husk ash pozzolana. The succeeding paragraphs presents the results achieved.

7.2.1 The conceptual framework

A major achievement of this research is the development of the conceptual framework and its application on various aspects of housing, creating a comprehensive approach encompassing the different objectives of sustainable-affordable housing. This framework includes (a) a conceptual model and (b) an objectives hierarchy model for sustainable-affordable housing.

a. Conceptual model and significance of interrelation between four aspects of sustainability in sustainable-affordable housing

Figure 2.3 (chapter 2) sketches the conceptual model for sustainable-affordable housing. It is represented by four overlapping circles with each circle symbolizing one of the four aspects of (socio-cultural, economic, technological and environmental) sustainability. Socio-cultural needs and practices of the households and communities influence the primary requirements of housing. Sustainable housing should respond to these needs and requirements. Affordability or economic capacity of an individual plays a significant role in achieving his housing requirements. Thus sustainable-affordable housing for the poor can be defined as "housing which is accessible and affordable to satisfy the housing needs of people whose income does not enable them to afford housing suitable for their needs in the regular housing market". In this definition, the term 'accessible' refers to the feasibility to fulfil those present and future needs. The basic housing need of an individual is often a reflection of his or her socio-cultural needs. In that way sustainable-affordable housing is related to *socio-cultural* (basic needs) and *environmental* aspects (present and future needs) of sustainability. The term 'affordable' in the definition mainly implies the affordability by the individual in fulfilling these needs. Innovative technological options are necessary for affordable housing solutions. In this sense it is connected to the *economic sustainability* and affordability of sustainable *technological* options. Developments in the economy and social changes should be able to sustain ecology and improve potential resources for future generations. In the context of global population growth and the Earth's finite resources, the way in which human beings are accommodated or sheltered is a major and integral part of the imperative to maintain a global environmental equilibrium. Hence sustainable building processes should be able to put emphasis on environmentally friendly technologies utilizing locally available waste materials and renewable resources. Therefore this framework assigns equal importance to all these four aspects of sustainability in sustainable housing and accepts their dependencies on each other.

b. The objectives hierarchy model (CF_1) for sustainable-affordable housing

The objectives hierarchy model (Fig. 2.9) integrates both the perspective of the households (users) and the concepts of sustainability in housing development. It enlists the different objectives of sustainable-affordable housing under the four aspects of sustainability and analyses the housing issues based on the specified criteria. This model can be applied as a general tool for addressing housing problems and for modifying policies in any of the less developed economies. An adaptive version of this model is also developed and applied in this research for the evaluation of the building process.

The conceptual framework for sustainable-affordable housing (Fig. 2.10) is a combination of objectives (CF_1) and strategies (CF_2) for sustainable-affordable housing. The second part (CF_2) helps in the formulation of strategies based on the evaluation using the objectives hierarchy model.

7.2.2 *Application of the conceptual framework in the evaluation of housing schemes in Kerala*

The conceptual framework for sustainable-affordable housing has been applied and tested in the context of economically weaker section housing in Kerala. The outcomes of these analyses had brought out valuable insights both in the housing situation of the low income households in Kerala and as well as in the significance of the correlation between different sustainability aspects in the housing programmes. Three types of analysis have been done.

1. Analysis I. Evaluation of the goals of several government programs (Chapter 3, section 3.3)
2. Analysis II. Evaluation of government programs from the perspective of an observer (Chapter 3, section 3.3)
3. Analysis III. Evaluation of several government programs from the perspective of the beneficiary households (Chapter 4)

The outcomes of these evaluations can be summarized under the following headings:

I. Problems of low-income housing in Kerala and strategies for sustainable-affordable housing
II. Significance of correlation between different sustainability aspects

Ad. I: Problems of low-income housing in Kerala and strategies for sustainable-affordable housing

The comparative evaluation from different perspectives identifies a mismatch between the objectives and instruments of government policies and the real situation of beneficiary households. It underlines the failure of different housing policies (Box 7.1) with respect to sustainable housing development and understands that changes in policies over the years 1970 to 2000 have not led to significantly different outcomes. The results of the evaluation and recommendations for strategic measures are briefly discussed here under different aspects of sustainability, i.e. (a) socio-cultural, (b) economic, (c) technological and (d) environmental sustainability.

Box 7.1

The overlooking of socio-cultural and environmental factors in the housing programme poor accessibility to resources, improper awareness on building process and innovati technological options, and insufficient basic services are identified as the main problems the poor households in Kerala.

a. Socio-cultural sustainability

Socio-cultural sustainability of housing programmes has the least significant role in the total sustainability of selected housing programmes. This explains the poor acceptability of the housing programmes among the users. The main aspects could be identified as

- lack of flexibility or little adaptability of houses to the future requirements of households (One Lakh Housing Scheme-OLHS).
- increased dependency of households on government support.
- poor involvement of both the households (OLHS) and community (Indira Awaas Yojana-IAY and Total Housing Scheme-THS) in the building process.
- poor integration of amenities and services (IAY and THS).

Policy measures for achieving socio-cultural sustainability in housing should explain the importance of

- stimulating participatory housing through involvement of households and with the support of community.
- promotion of core housing concepts instead of rigid type designs.
- fostering equality between citizens through careful neighbourhood planning of the houses in such a way as to allow the mixing up of different income levels of the society in the same locality and to ensure adequate infrastructure facilities and community services.

b. Economic sustainability

The financial ability of the households in all the cases is found to play a significant role in the economic sustainability of the housing programmes. This shows the importance of strategies to empower the poor for housing themselves. The economic unsustainability of housing schemes in Kerala was clear from the following observations:

- the poor housing conditions of beneficiary households
- problems connected with land ownership and incomplete houses (IAY and THS)
- insufficient housing facilities (OLHS) and
- poor accessibility of the households to basic resources for housing (IAY and THS).

Economic sustainability of housing programmes can be ensured by improving the strategies for

- ensuring consistent income for the poor households by
    - empowering them in the different activities of the building process, like production of building materials and other skilled labour training.
    - integrating the housing schemes for the economically weaker sections with poverty alleviation programmes.
- ensuring accessibility to resources such as land tenure, supplementary loans, building materials, labour and infrastructure facilities. Accessibility to credit services can be improved by promoting micro-finance institutions and by flexibility in loan services depending on the needs of the household and their ability to make repayments.
- ensuring minimum housing facilities for the so-called completed houses.

c. Technological sustainability

The household surveys and case studies confirm the concern about the following factors of the technological sustainability of housing programmes in Kerala. They are

- scarcity of affordable materials and availability of skilled labor
- feasibility and affordability of technological options
- lack of technical guidance or supervision in the building process
- poor know-how of the building process
- poor know-how of cost effective alternatives
- excessive use of energy-intensive materials

The poor correlation (as found by SPSS analysis) between the socio-cultural and the technological factors in the housing programmes clearly illustrates the un-sustainability of the present building process in Kerala in terms of acceptability and feasibility of technological solutions. Strategies for technological sustainability should include measures for

- ensuring timely guidance and technical supervision in the building process
- ensuring the availability of materials and skilled labour
- empowering the beneficiaries to acquire minimum skills for the building process
- promotion of technological innovations
- promotion of the use of renewable and local materials

d. Environmental sustainability

Environmental sustainability of housing schemes in Kerala raises greater concern over other aspects of sustainability, as it has not received the desired attention, neither in the conceptualization stage nor in the perception of beneficiaries in real situations. The topics, which need immediate attention, are

- insufficient basic services
- excessive conversion of agricultural land for housing and
- poor concern over the utilization of non-renewable resources

The little importance given to environmental factors, as revealed from the analysis, can be considered as one of the main reasons for the development of slum-like human settlements in the rural areas of Kerala. Policies should be improved to

- integrate basic infrastructure facilities as vital component of housing
- adopt proper regulatory measures for conservation of agricultural land and against uncontrolled land reclamation for clay mining, housing and other development activities.
- ensure conservation of resources through energy efficiency in household activities, alternate solutions for renewable energy and by integrating rainwater harvesting methods.

Ad II: Significance of correlation between different sustainability aspects

The results of statistical analysis (Analysis III, chapter 4) confirm the inter-relations between the four aspects of sustainability as suggested in the conceptual model. Although the statistical relevance of this finding is somewhat limited due to the limited size of the sample and to the consequent choice for 90% evidence to prove the validity of the framework, the relevance of the correlations between the factors gives an indication of its reliability. This finding is corroborated and supported by the findings of the individual case studies described in section 4.2. These results also give a satisfactory indication on the validity and usefulness of this framework for further applications in similar situations. Significant findings can be listed as follows:

- the evaluation of public housing schemes in Kerala points towards the failure of implementation strategies because of the lack of integration of the four main aspects of sustainable-affordable housing, namely socio-cultural, economic, technological, and environment factors.
- the evaluation of different housing programmes reveals the excessive dependency of the sustainability of housing programmes on the economic status of the households (to afford and maintain the houses) over the policy initiatives of the government. This confirms the failure of enabling strategies and shows the poor correlation between socio-cultural factors and economic factors in housing.
- the insignificance of correlation between socio-cultural sustainability and technological sustainability in all the housing schemes verifies the un-sustainability of the present building process in Kerala. It points towards the poor knowledge of the households of building processes, improper utilization of resources and difficulties in accessing innovative technology.

- technological sustainability in all the cases had a strong correlation with economic sustainability. This indicates the importance of the affordability of technological options.
- the insignificant correlation of socio-cultural sustainability and environmental sustainability gives an indication of the insufficient basic infrastructure facilities and poor concern in the Kerala district about the non-renewable resources.
- the meagre correlation between socio-cultural sustainability and economic sustainability shows the poor affordability of the housing schemes, especially in providing the basic shelter needs.

7.2.3 *Application of the conceptual framework in the evaluation of present building process in Kerala*

A selection of sustainable building alternatives suitable to the requirements of Kerala has been carried out in two stages (chapter 5). The first stage employs the conceptual framework from Chapter 2 for a comprehensive analysis. However, in the second stage, a grading of basic building materials and popular technological options based on embodied energy has been done. Basically the second phase of grading plays a crucial role only when two alternative score equal points in the first phase analysis in making the most appropriate choice. The outcomes of this evaluation acknowledge the traditional building technology with laterite walls, Mangalore pattern tile roofing, and mud mortar as the most sustainable technological option for affordable housing in Kerala, where laterite is locally available. Locally produced hollow concrete block masonry can be suggested as an alternative technological option to replace laterite in other places. These findings point at the failure of Cost-Effective and Environmentally Friendly (CEEF) technological options in Kerala against the modern or prevailing energy intensive building process. This has led us to the conclusion that none of the technological alternatives can be feasible in practice if they do not have enough support and acceptance from society. The evaluation of the building process in Kerala underlines the need for

- popularization of the cost-effective and environmentally friendly technology alternatives and dissemination of technological innovations through proper strategies
- demonstration of technological innovations to the public so that they can experience the advantages.
- formulation of stakeholder groups including the technical experts to deliver the new technology and post delivery services as to ensure proper implementation and usage of new innovations.
- innovative technology options which require unskilled labor, renewable resources and decentralized production and
- popularizing affordable, environmentally friendly building materials suitable to the requirements of Kerala.

7.2.4 *Rice husk ash pozzolana as a partial replacement for cement*

The search for new environmentally friendly affordable materials has led to the experimental research on the pozzolanic activities of rice husk ash (chapter 6). This has been done to explore the possibilities of the production of a reactive pozzolana in rural environments with minimum infrastructure and utilizing the limited skills of poor households. Both experimental studies in the laboratory (a) and field studies on oven technology (b) were carried out.

a. Lab research for reference sample from optimized conditions

An experimental study was carried out in order to find the optimal temperature regime for the formation of crystalline silica from rice husk that can be used successfully as replacement for Portland cement. In literature contradictory findings on this point have been presented (Bui, 2001; Mehta, 1978; Hamad et al, 1981). From an in-depth study of the amount of soluble silica and loss on ignition of different rice husk ash samples that were produced under different thermal condition is was found that incineration at 300°C is unsuitable as not all carbon is expelled from the samples. The studies furthermore revealed substantial reactivity of samples burnt at 500°C or 700°C. This agrees with the earlier investigations of Mehta (1978) and Hamad et al. (1981), who had identified the temperature range of 500 to 700°C as optimum for reactive ash formation. Electrical conductivity test verified the good pozzolanic activity of the RHA samples at 500 and 700°C, with systematic higher values for the samples incinerated at 500°C. XRD and microscopic analysis confirmed the amorphous character of both the RHA 500 and RHA 700 samples with the first crystalline material appearing at processing temperatures of 900°C and higher. To get insight about the formation of reactive material on a molecular level, a detailed analysis has been carried out using ^{29}Si solid-state NMR. The broad Gaussian line shapes in the spectra of the different RHA samples supports the amorphous nature of the silica in samples burnt at temperatures of 500°C and 700°C. At higher temperatures a gradual conversion to crystalline material was observed, in agreement with the XRD results. The amount of Q^3 sites in the amorphous phase of the RHAs varied with a clear maximum for RHA 500-12Q with a Q^4:Q^3 ratio of 4:1. This sample also showed the highest conductivity drop in the pozzolanic activity test. So we came to the conclusion that the most reactive rice husk ash is produced after incineration for 12 hours at 500°C and subsequently quickly cooling the sample down by directly removing it from the oven.

b. Field ovens for rice husk ash production

For rural building applications, sophisticated ovens and techniques are not feasible and affordable to maintain the controlled conditions in the lab. The second part of the experimental technical research was carried out to identify an affordable incinerator to produce reactive pozzolana for rural building applications in Kerala. Rice husk ash samples from three different types of field ovens, i.e. an annular kiln enclosure, a brick oven and a pit oven, were examined. We came to the following conclusions:

- rice husk ash samples from the annular kiln enclosure (RHA A) produced better results (higher mortar strength) in all the mix compositions compared with those from other field ovens. Therefore the annular type of oven can be suggested as an affordable and simple option for the small-scale production of rice husk ash in rural areas. A modification of the annular enclosure with bricks instead of weld meshes is suggested as a long-term solution considering the limited life span of weld meshes.
- rice husk ash pozzolanas from the brick ovens (RHA B) also gave reasonably good strengths with lime and cement in different proportions though those were inferior in strength compared to that from the annular kiln enclosure.
- the lower strength values of mortars with the ashes from the pit burning (RHA C) compared to the other samples can be due to longer period of incineration and slow cooling rate. Reducing the depth of the pit can modify this arrangement to ease air supply and result in better ash.

7.2.5 Conclusion and Reflection

This thesis integrates different perspectives to understand the housing problems in low-income countries, and to develop improved strategies to lead to sustainable-affordable housing. These perspectives combine a technological outlook, mainly concentrating on building materials, with non-technical aspects such as the socio-cultural outlook of the beneficiaries, the economic aspects of the building process, and the political aspects as seen from the government perspective. By integrating these perspectives in one conceptual model, this thesis claims to improve our understanding on sustainable-affordable housing. Moreover, the conceptual framework proposed by this research has proved successful in functioning as a practical tool, both for evaluating the effectiveness of various policy approaches by the state government of Kerala, and the (lack of) outcomes of these policies as seen through the eyes of the beneficiaries. Another integration of technical an non-technical aspects has been achieved by evaluating the potentials of rice husk ash as a partial replacement to cement, by combining the technical evaluation with various non-technical aspects such as affordability, availability of local materials, and know-how by unskilled people. Although the viability of these ovens for rice husk ash production has not been tested under field conditions in Kerala or elsewhere in India, this research points into a clear direction for sustainable-affordable housing utilizing renewable and less energy intensive building materials suiting to the requirements of households and as well as on the concepts of sustainability. This research thus combines conceptual analysis, tool development, technical analysis and innovation in such a way that it has both theoretical and practical relevance.

7.3 Recommendations for implementation

The evaluation of public housing schemes in Kerala urges the need for efficient and effective implementation strategies, suitable for the socio-economic and cultural specifications of the state. This section proposes some recommendations for the practical implementation of sustainable-affordable housing in Kerala.

a. Integrated approach

The evaluation of public housing schemes in Kerala identifies the integration of the four aspects of sustainability as the crucial element for sustainable-affordable housing. The involvement of all stakeholders in the building process including beneficiary households, the local community, non-governmental organizations, and the local government can strengthen the integration of these aspects. Therefore, the overall process requires the support from a strong network of different stakeholders and institutions to achieve its objectives.

b. Formulation of support mechanism

The findings of this research strongly argue in favor of formulating a support mechanism ("Housing Support Organizations" similar to that of People's Housing Process of South Africa) for capacity building and for enabling people to address their own housing needs. Inaccessibility to resources (including land, finance and technology) is one of the main obstacles for the poor households in Kerala in achieving their shelter needs. Hence the enabling strategies should merge with sustainable solutions to overcome this. Support mechanisms in the form of "Housing Support Organizations" can help the households in securing subsidies, obtaining land ownership and accessing technical, financial, logistic and administrative support related to housing activities.

c. Ensuring the affordability of households

Ensuring consistent income by empowerment or facilitating income-generating activities should be considered as the initial step for sustainable-affordable housing. The principle of micro financing as developed by the Grameen Bank (Bangladesh) is a fruitful solution for achieving economic sustainability in housing.

d. Ensuring the technological sustainability in the building process

The present Building Centers or other technology organizations could probably act in a role to ensure the sustainability of the building process. Enabling the households in the building activities, production and supply of building materials, arranging skilled labor, and dissemination of technological innovations should be their prime concern. All beneficiary households should be given a preliminary awareness and basic know-how on the building process. Further, extensive training should be given for interested households on different activities related to the building process such as building material production and other construction activities. These Centers should also be made responsible for popularizing and improving the innovative technological alternatives (CEEF technology) according to the requirements of the locality and making it feasible to the public. Locally available waste materials from agricultural and industrial processes, which are less energy intensive and require unskilled labor, should be identified and promoted. For example, the field burning arrangements developed in this research can be popularized through these organizations by enabling the households in the production process and making them aware on the advantages.

e. Ensuring basic infrastructure facilities and conservation of resources

Ensuring physical infrastructure needs special concern in the case of individual households. Specific guidelines should be adopted for ensuring basic services such as water, sanitation and waste management. Provision of toilets and drainage facilities should be made an integral part of housing.

7.4 Scope for further research

The following themes could be considered for further research.

a. Application of conceptual framework in other developing countries

The proposed conceptual framework can be applied to other developing countries for sustainable housing solutions. Testing and further application of this framework is suggested for other countries.

b. Further experimental research on rice husk ash pozzolana

Further researches on rice husk ask as replacement for Portland cement should include:

- Bulk production of rice husk ash
- Environmental problems on rice husk ash production and
- Exploration of the potential of rice husk ashes from the rice mills after utilising its fuel value.

The field ovens proposed in this research are suitable for small-scale production of rice husk ash pozzolana. Further research is necessary for improving the affordability of this material through bulk production to make it readily available through a somewhat centralized outlet (such as Building Centre) in the rural areas. Utilization of the fuel value of RHA can further improve the economic value of this waste material. Hence more advanced research is suggested to explore the potential of rice husk ashes directly obtained from the places where it is being used as fuel.

c. *Experimental research to check the suitability of straw bale technology in the environmental condition of Kerala*

Even though straw bale technology is proposed as an alternative sustainable option for buildings, its compatibility with the environmental conditions of Kerala is yet to be investigated. This is purely a new concept to the building process in Kerala and has never been introduced. Hence prior monitoring and practical applications are necessary to investigate their structural performance and sustainability to gain acceptance.

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Summary

The persistence and growth of poor shelter conditions, particularly in the developing countries, is a worldwide stumbling block to socio-political stability and economic development (UNCHS, 1990). The causes and nature of these problems differ from country to country, depending on local social, economic and political contexts. The multidimensional nature of this issue has been the focus of this research and addresses the following main question within the context of Kerala (India).

How to develop an integrated framework to analyze (both for the evaluation of policy and building process) the housing problems of the poor (from their own perspective), and which sustainable materials or technological options could be suggested along with policy recommendations to achieve sustainable-affordable housing in Kerala?

This thesis integrates different perspectives to understand the housing problems in low-income countries, and to develop improved strategies leading to sustainable-affordable housing. These perspectives combine a technological view, mainly concentrating on building materials, with non-technical aspects such as the socio-cultural view of the beneficiaries, the economic aspects of the building process, and policy aspects as seen from a government perspective. This research combines conceptual analysis, tool development, technical analysis and innovation in such a way that it has both theoretical and practical relevance.

These objectives have been approached and achieved by addressing a number of sub questions. The succeeding sections summarize this under five heads.

1. Housing issues: a framework for conceptualization

How can the housing problems be evaluated from the perspective of the users, in such a way as to contribute to sustainable development?

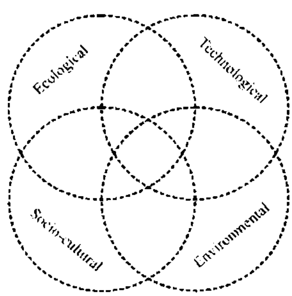


Figure 1 Basic concept for sustainable-affordable housing

Sustainable-affordable housing development has been conceptualized as a combination of four equally significant aspects of sustainability, namely socio-cultural, economic, technological and environmental (Fig. 1).

Social and cultural factors determine the primary requirements of housing. The financial capacity or affordability by an individual or family has the immediate effect of transforming this need or requirement into a sound reality. Technology acts as a catalyst to help realizing this, by providing affordable options suiting individual requirements and changing circumstances. The environment is the carrier of the above and should be sustained for future generations as well as accomplishing present demands. This framework is a modification of the three pillar concept of sustainable development (UN) incorporating an additional technology factor. Sustainable-affordable housing for the poor can thus be defined as "housing which is accessible and affordable to satisfy the housing needs of people whose income does not enable them to afford their housing suitable to their needs in the formal housing market, having a minimal impact on the environment".

A hard-core policy framework is inevitable for the efficient working of implementation systems, optimizing limited resources and integrating the demands and requirements of various actors in accordance with changing circumstances. It is also essential to create a 'pull' from the side of beneficiaries rather than being a 'push' from the authorities in achieving the development of sustainable housing. The conceptual framework for sustainable-affordable housing developed in this thesis is a combination of these objectives and strategies for sustainable-affordable housing.

The 'objectives for sustainable-affordable housing' have been defined using a methodology resembling that of Value Focused Thinking (VFT). It helps in identifying the needs of the households from the perspective of households based on the principles of sustainable development. The objectives were used to construct an evaluation framework, which have been applied and tested within the context of Kerala for the evaluation of housing issues. Based on the analysis and evaluation of the Kerala cases, strategies are formulated in accordance with the requirements of sustainable-affordable housing.

2. Evaluation of public housing schemes: Kerala

What were the various policy approaches in the previous years in India (Kerala) addressing the shelter problems of the poor and how far have the different schemes been successful in achieving sustainable housing development and what is the real housing situation of the poor households in Kerala?

The housing situation in Kerala is quite different from other parts of India. Despite the positive trend (diminishing quantitative housing deficits) in the housing conditions, a close analysis shows that the poor and lower segments in society often do not get the necessary assistance for the actual construction and completion of houses. Visible slum-like areas occur in human settlements in rural parts of the state, with many inhabitants still deprived of basic facilities like drinking water and sanitation. Though the poor manage to get support, government sponsored projects often fail to meet the initial goals.

The review of the evolution of the present housing policy in Kerala reveals a reflection of global policy changes during the corresponding periods, but with minor modifications to cope with the interests of political leaders and policies of the respective governments. State government intervention in public housing was pioneered by the launching of the so-called One Lakh Housing Scheme (OLHS), with the role of the government partially as a 'provider' of public housing (Phase I). Even though by that time (1970s) the International agencies that were constantly advocating public housing had already shifted their focus from this approach, the government of Kerala promoted this with a few modifications.

The housing schemes implemented during the Fifth Five Year Plan (1974-79) addressed the issue of rural housing. The basic principle of shelter provision under this scheme can be said to be one of 'aided self-help' (Phase II), whereby the government selects the potential users (beneficiaries), arranges for financing and administrative procedures, and the users provide the entire or part of the labor input. This, new shift in policy was in line with the international policies based on aided self-help and mutual help marking the second phase.

The 1990s witnessed significant changes in housing policy. The National Housing and Habitat Policy of 1998 addressed the issues of sustainable development, infrastructure and strong public private partnership for shelter delivery. This was a true mirror image of the whole sector development concept of UN and World Bank (Phase III). In 1996, with the decentralization movement, local governments started getting involved in different development activities in Kerala. The 'Total Housing Scheme' (1998) was introduced during this period with the concept of whole sector development with the local or self government as the implementing agencies.

Three government housing schemes [One Lakh Housing Scheme (OLHS), Indira Awaas Yojana (IAY) and Total Housing Scheme (THS)] were identified for detailed evaluation on the basis of their representative nature in policies with those of the international agencies, their uniqueness in implementing agencies and other particular characteristics (Table 3.3, chapter 3).

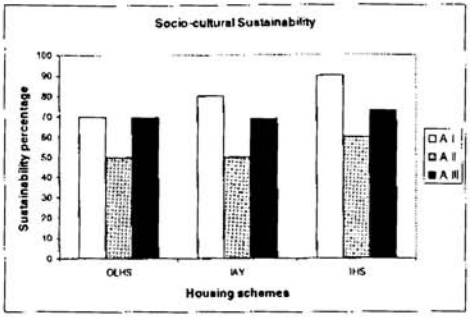


Fig. 2a

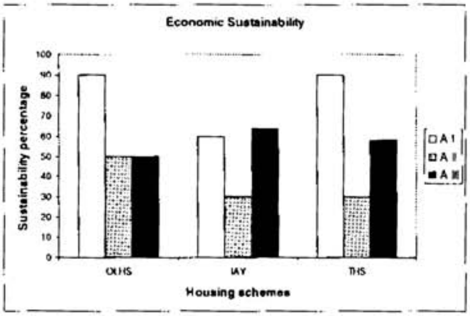


Fig. 2b

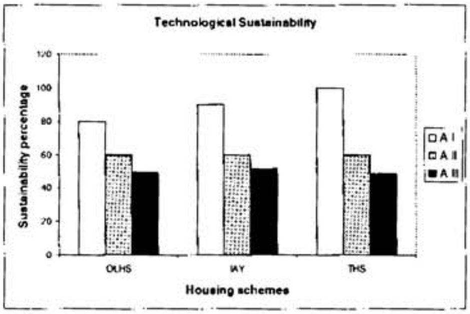


Fig. 2c

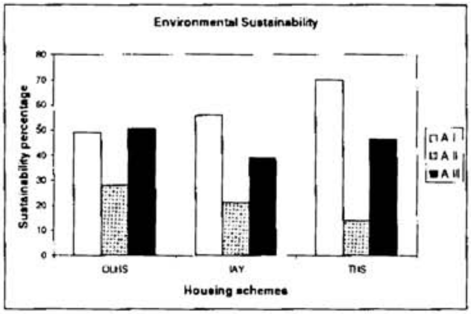


Fig. 2d

Figure 2 Comparison of different aspects of sustainability according different housing schemes, i.e. socio-cultural, economical, technological and environmental, from the perspectives of the government (A I) and users (A II and A III).

The sustainability analysis has been carried out in three stages (from different perspectives) using the criteria derived from the conceptual framework. The first stage of analysis (Analysis I) has been done to evaluate the goals of the government programs and the second as well as the third stages (Analysis II and III) to assess the real situation of the beneficiary households. Analysis I is based on information provided by government reports and government officials. Analysis II has been done based on the researcher's observations from the field, and Analysis III based on information from household surveys. Fig. 2 (a to d) presents the results on various aspects of sustainability of the selected schemes based on the analysis. Irrespective of the different policies of the government, the representative schemes selected for evaluation from each phase of policy do not show significant differences between the end results, and all of them seem to have partially failed in achieving their goal of sustainable housing.

The mismatch between the perceptions (goals) of government and the real situation of the beneficiary households (results) is clear from the evaluation. This shows the ineffectiveness of the different policies and need for effective policies for proper implementation.

In general the evaluations show that Analysis I (from the perspective of government) is systematically more positive than the evaluations by the researcher and the beneficiaries (Analysis II and III). The evaluations show the lack of integration of the four main aspects of sustainable-affordable housing, namely socio-cultural, economic, technological, and environment factors and how it has contributed towards the failure of implementation strategies. The overlooking of socio-cultural and environmental factors in the housing programmes, poor accessibility to resources, improper awareness of the building process as well as the availability of innovative technological options, and insufficient basic services are identified as the main obstacles for the poor households in Kerala. The low affordability by the households and lack of consistent income further added to their problems.

3. Evaluation of present building process: Kerala

Does the present building process in Kerala contribute to sustainable housing? If not what are the recommendations for modifying it?

An evaluation of a selection of sustainable building alternatives suitable to the requirements of Kerala was carried out using the conceptual framework. A grading of basic building materials and popular technological options based on embodied energy was also done to add a semi-quantitative refinement. Basically this grading only plays a decisive role when two alternatives score equal points in the comprehensive analysis to make the most appropriate choice. The outcomes of this evaluation acknowledge the traditional building technology with laterite walls, Mangalore pattern tile roofing, and mud mortar as the most sustainable technological options for affordable housing in Kerala, where laterite is locally available. Locally produced hollow concrete block masonry is suggested as an alternative technological option to replace laterite in other places. These findings illustrate the sad failure in implementing cost-effective and environmentally friendly (CEEF) technological options in Kerala compared to the market success of the prevailing 'modern' energy-intensive building process. It leads us to the conclusion that none of the technological alternatives can be feasible in practice, if they have not enough support and acceptance from society.

The evaluation of the building process in Kerala underlines the need for

- the popularization of the cost-effective and environmentally friendly technology alternatives and dissemination of technological innovations through proper strategies.
- the demonstration of technological innovations to the public so that they can experience the advantages.
- the formation of stakeholder groups including technical experts to deliver environmentally friendly technology and post delivery services to ensure proper implementation and usage of new innovations.
- innovative technology options, which demand unskilled, labor, renewable resources and decentralized production.

4. Rice husk ash pozzolana as a sustainable alternative to cement

How can rice husk ash pozzolana be developed locally as a sustainable alternative to replace cement for the primary building applications in Kerala?

The search for new environmentally-friendly affordable materials has led to the experimental research on the pozzolanic activities of rice husk ash (chapter 6). It has been done to explore the possibilities in the production of a reactive pozzolana in rural environments with minimum infrastructure and utilizing the limited skills of poor households. An in-depth characterization of rice husk ashes has been conducted as the first phase of this experimental technical research to identify the optimum conditions for producing a reactive ash from rice husk. The rice husk ash produced after an incineration for 12 hours at 500°C and subsequent quick cooling by directly removing it from the oven is identified as the most reactive sample. This is in agreement with earlier investigations by Mehta (1978) and Hamad et al. (1981) who have identified the temperature range of 500°C to 700°C as optimum for reactive ash formation. At the same time, these findings disagree with a few other investigations (cited by Bui, 2001) regarding the formation of crystalline silica at lower temperatures. The present research thus makes a contribution in solving the dispute regarding the crystallization temperature of silica during the incineration of rice husk.

The second part of this experimental technical research was carried out to identify an affordable incinerator to produce reactive pozzolana for rural building applications in Kerala. Rice husk ash samples from three different types of field ovens were examined. We came to the following conclusions:

- rice husk ash samples from the annular kiln enclosure (RHA A) produced better results (higher mortar strength) in all the mix compositions compared with those from other field ovens. Therefore the annular type of oven is suggested as an affordable and simple option for the small-scale production of rice husk ash in rural areas. A modification of the annular enclosure with bricks instead of weld meshes

is suggested as a long-term solution considering the limited life span of weld meshes.
- rice husk ash pozzolanas from the brick ovens (RHA B) also gave reasonably good strengths with lime and cement in different proportions though those were inferior in strength compared to that from the annular kiln enclosure.
- the lower strength values of mortars with the ashes from the pit burning (RHA C) compared to the other samples can be due to a longer period of incineration and slow cooling rate. Reducing the depth of the pit can modify this arrangement to ease air supply and result in better ash.

5. Strategies and Recommendations for sustainable-affordable housing in Kerala

What policy recommendations can be proposed (particularly for the economically weaker sections) for sustainable-affordable housing so as to contribute to sustainable development?

Based on the evaluation, a number of strategies for the development of sustainable-affordable housing are proposed:

Policy measures for achieving socio-cultural sustainability:
- Stimulate participatory housing through involvement of households and with community support.
- Promotion of core housing concepts (basic units adaptable to changes according to future requirements) instead of rigid type designs.
- Fostering equality between citizens through careful neighborhood planning to allow the mixing up of different income levels of society in the same locality, and to ensure adequate infrastructure facilities and community services.

Strategies for economic sustainability should include measures to
- ensure steady income for poor households
- ensure accessibility to resources such as land tenure, supplementary loans, building materials, labor and infrastructure facilities.
- improve accessibility to credit services by promoting micro-finance institutions and flexibility in loan services depending on the needs of the household and their ability to make repayments.
- ensure a minimum level of housing facilities.

Strategies for technological sustainability should include measures to
- ensure timely guidance and technical supervision in the building process
- ensure the availability of materials and skilled labor
- empower the beneficiaries to acquire minimum skills for the building process
- promote technological innovations

- promote the use of renewable and local materials

Strategies for environmental sustainability should include measures to
- integrate basic infrastructure facilities as vital component of housing
- adopt proper regulatory measures for the conservation of agricultural land and against uncontrolled land reclamation, for clay mining, housing and other development activities.
- ensure conservation of resources through energy efficiency in household activities, alternate solutions for renewable energy, and by integrating rainwater harvesting methods.

The evaluation of public housing schemes in Kerala urges the need for efficient and effective implementation strategies, suitable for the socio-economic and cultural specifications of the state. It identifies the integration of the four aspects of sustainability as crucial for achieving sustainable-affordable housing. The involvement of all stakeholders in the building process including beneficiary households, the local community, non-governmental organizations, and the local government can strengthen the integration between these aspects.

Recommendations proposed are:
- *an integrated approach* in the overall process with support from a strong network of all the different stakeholders and institutions to achieve the objectives of sustainable-affordable housing.
- *the formulation of a support mechanism* ("Housing Support Organizations" similar to that of People's Housing Process of South Africa) for capacity building and to enable people to address their own housing needs.
- *to improving the affordability for households*, by ensuring a consistent income through empowerment or through facilitating income-generating activities.
- *to ensure the technological sustainability in the building process*
- *to ensure basic infrastructure facilities and the conservation of resources*

SAMENVATTING

De hardnekkigheid en de groei van slechte huisvestingcondities, voornamelijk in ontwikkelingslanden, vormen een struikelblok voor sociaal-politieke stabiliteit en voor economische ontwikkeling (UNCHS, 1990). De oorzaken en de aard van deze problemen verschillen van land tot land, en zijn afhankelijk van de lokale sociale, economische en politieke contexten. Het multidimensionale karakter van dit probleem heeft de focus gevormd voor dit onderzoek en heeft geleid tot de volgende hoofdvraag in de context van Kerala (India):

Hoe kan een geïntegreerd raamwerk worden ontwikkeld om het huisvestingsprobleem van de armen (vanuit hun eigen perspectief) te analyseren (zowel wat betreft het beleid als het bouwproces) en welke duurzame materialen of technologieën kunnen samen met beleidsaanbevelingen worden voorgesteld om duurzame en betaalbare huisvesting in Kerala te bewerkstelligen?

Dit proefschrift integreert verschillende perspectieven om het huisvestingsprobleem in ontwikkelingslanden te kunnen begrijpen, en om verbeterde strategieën te ontwikkelen die kunnen leiden tot duurzame en betaalbare huisvesting. Deze perspectieven combineren een technologische invalshoek, die vooral concentreert op bouwmaterialen, met niet-technische aspecten zoals de socio-culturele invalshoek van de begunstigden, de economische aspecten van het bouwproces, en de beleidsaspecten vanuit het perspectief van de overheid. Het onderzoek combineert conceptuele analyse, methodiekontwikkeling, technische analyse, en innovatie op een manier die zowel theoretische als praktische relevantie heeft.

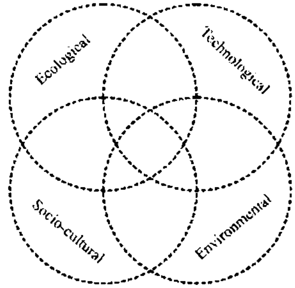
Dit doel kon bereikt worden door een aantal subvragen te stellen, waarvan de beantwoording noodzakelijk was voor het verkrijgen van inzicht in de totaalproblematiek. De vijf onderdelen van deze samenvatting vatten deze deelvragen samen.

1. Huisvestingskwesties: Een raamwerk voor conceptualisering

Hoe kunnen huisvestingsproblemen zodanig worden geëvalueerd vanuit het perspectief van de gebruikers dat dit kan bijdragen tot duurzame ontwikkeling?

Duurzame en betaalbare huisvestingsontwikkeling is geconceptualiseerd als een combinatie van vier even belangrijke aspecten van duurzaamheid, namelijk sociaal-culturele, economische, technologische en ecologische duurzaamheid (Figuur 1).

De sociale en culturele factoren bepalen de belangrijkste te stellen eisen aan huisvesting. De financiële positie of draagkracht van een individu of een familie heeft een



Figuur 1 Basisconcept voor duurzame en betaalbare huisvesting.

direct effect op het omzetten van de behoefte of noodzaak in een concrete realiteit. Technologie treedt op als katalysator om dit te realiseren, door betaalbare opties te leveren die passen bij individuele eisen en veranderende omstandigheden. Het milieu is de drager van het bovenstaande en moet worden ontzien om een draagvlak te creëren voor toekomstige generaties, en tevens te voldoen aan de behoeften van de huidige generatie. Dit raamwerk is een aanpassing van het "3-P" concept ("People, Planet, Prosperity") voor duurzame ontwikkeling (VN) met toevoeging van de technologische factor. Duurzame en betaalbare huisvesting voor de armen kan dus gedefinieerd worden als "huisvesting die bereikbaar en betaalbaar is zodat in de huisvestingsbehoefte wordt voorzien van mensen wier inkomen het niet toelaat om via de reguliere markt een huis te betrekken dat bij hun eisen past, en die een minimaal effect heeft op het milieu".

Een duidelijk beleidsraamwerk is onvermijdelijk voor efficiënte implementatiesystemen, die de beperkte middelen kunnen optimaliseren en de verschillende behoeften en wensen van diverse actoren onder veranderende omstandigheden kunnen integreren. Ook is het essentieel om op het gebied van duurzame huisvestingsontwikkeling een "trekkracht" te creëren vanaf de kant van de doelgroep in plaats van een "stuwing" vanaf te kant van de autoriteiten. Het conceptuele raamwerk voor duurzame en betaalbare huisvesting dat in dit proefschrift is ontwikkeld is een combinatie van deze doelen en strategieën voor duurzame en betaalbare huisvesting.

De "doelen voor duurzame en betaalbare huisvesting" zijn gedefinieerd door een methodologie te gebruiken die lijkt op "Value Focused Thinking" (VFT). Het helpt bij het identificeren van de behoeften van de huishoudens vanuit het perspectief van de huishoudens en is gebaseerd op de principes van duurzame ontwikkeling. De doelen zijn gebruikt om een evaluatiekader te ontwerpen dat is toegepast en getest in de context van Kerala voor de evaluatie van huisvestingsvraagstukken. Op basis van de analyse van de cases in Kerala zijn er strategieën geformuleerd die in overeenstemming zijn met de eisen voor duurzame en betaalbare huisvesting.

2. Evaluatie van de programma's voor publieke huisvesting: Kerala

Wat waren de verschillende beleidsbenaderingen in voorgaande jaren in India (Kerala) voor de huisvestingsproblemen van de armen, en in hoeverre zijn de verschillende programma's succesvol geweest in het bereiken van duurzame huisvestingsontwikkeling, en wat is de daadwerkelijke huisvestingssituatie van de arme huishoudens in Kerala?

De huisvestingssituatie in Kerala verschilt sterk van die in andere delen van India. Ondanks de positieve trend in de huisvestingssituatie (de kwantitatieve huisvestingstekorten nemen af) laat nadere analyse zien dat de arme en lagere segmenten van de samenleving zeer vaak niet de nodige hulp krijgen voor de daadwerkelijk constructie en voltooiing van huizen. Er zijn zichtbare sloppenwijkachtige gebieden in landelijke delen van de staat, waar veel inwoners nog steeds niet voorzien zijn van basisfaciliteiten zoals drinkwater en sanitaire voorzieningen. Hoewel de armen het klaarspelen om steun te krijgen, falen overheidsgefinancierde projecten vaak.

Een overzicht van de ontwikkeling van het huidige huisvestingsbeleid in Kerala laat zien dat de wereldpolitieke veranderingen zich weerspiegelen in de corresponderende perioden, maar met kleine aanpassingen aan de belangen van politieke leiders en het beleid van de verschillende overheden. Met de introductie van het "One Lakh Housing Scheme" (OLHS) (1 Lakh is honderdduizend) werd er geëxperimenteerd met interventie vanuit de staatsoverheid in publieke huisvesting, waarbij de rol van de overheid deels die van verschaffer van publieke huisvesting was (Fase 1). Hoewel in die periode (jaren 70) de internationale organisaties die constant publieke huisvesting hadden gepromoot zich hadden verwijderd van deze benadering, promootte de regering van Kerala dit met enkele kleine modificaties.

De huisvestingsprogramma's die tijdens het vijfde vijfjarenplan (1974-1979) geïmplementeerd werden, richtten zich op het probleem van huisvesting in de landelijke gebieden. Het basisprincipe van huisvesting binnen dit programma kan beschouwd worden als 'zelfvoorziening met hulp' (Fase 2), waarbij de overheid de potentiële gebruikers (begunstigden) selecteert en zowel de financiering als de administratieve processen regelt, terwijl de gebruikers zelf geheel of gedeeltelijk de noodzakelijke arbeidskracht leveren. Deze nieuwe verschuiving van het beleid lag in lijn met het internationale beleid dat was gebaseerd op zelfvoorziening met hulp en onderlinge hulp dat de tweede fase kenmerkte.

In de jaren '90 traden er significante veranderingen op in het huisvestingsbeleid. Het nationale huisvestings- en leefgebiedbeleid van 1998 (National Housing and Habitat Policy) richtte zich op de kwesties duurzame ontwikkeling, infrastructuur en sterke publiek-private samenwerking voor huisvesting. Dit was duidelijk een weerspiegeling van het concept van integrale sectorontwikkeling van de VN en de Wereldbank (Fase 3). Met de decentralisatiebeweging begonnen lokale overheden in 1996 betrokken te raken bij de verschillende ontwikkelingsactiviteiten in Kerala. In deze periode werd het integrale huisvestingsprogramma (Total Housing Scheme, 1998) geïntroduceerd vanuit het idee van integrale sectorontwikkeling met de lokale overheid of locaal zelfbestuur als implementerend orgaan.

Drie huisvestingsprogramma's van de overheid [One Lakh Housing Scheme (OLHS), Indira Awas Yojana (IAY) en Total Housing Scheme (THS)] zijn uit de verschillende fasen geselecteerd voor een gedetailleerde evaluatie op basis van hun representativiteit op het gebied van beleid in vergelijking met het beleid van de internationale organisaties, hun eenmaligheid wat betreft implementerende organisaties en andere typerende eigenschappen (zie hoofdstuk 3).

De duurzaamheidanalyse is uitgevoerd in drie fasen (vanuit verschillende perspectieven), met gebruikmaking van de criteria die zijn afgeleid van het conceptuele raamwerk. In de eerste fase van de analyse (Analyse I) zijn de doelen van de overheidsprogramma's geëvalueerd. In de tweede en de derde fase (Analyse II en Analyse III) is de werkelijke situatie van de begunstigde huishoudens bepaald. Analyse II is gebaseerd op de veldwaarnemingen van de onderzoeker en Analyse III is gebaseerd op de informatie uit de enquêtes onder de huishoudens.

De figuren 2(a) tot en met 2(d) laten de resultaten van de analyse zien, waarbij de verschillende aspecten van duurzaamheid van de geselecteerde programma's aan de orde komen. Ongeacht de verschillen in beleidsaanpak van de overheden tonen de representatieve schema's die geselecteerd zijn uit iedere fase in de beleidsuitvoering niet veel verschil in het eindresultaat. Het lijkt erop dat alle programma's deels gefaald hebben in het bereiken van hun doel, namelijk duurzame huisvesting.

De evaluatie maakt het verschil tussen de doelen van de overheid en de werkelijke situatie van de begunstigde huishoudens (het resultaat) duidelijk. Dit laat zien dat de verschillende projecten ineffectief zijn, en maakt de behoefte aan een meer effectief beleid voor een goede implementatie duidelijk.

In het algemeen tonen de evaluaties dat Analyse I (vanuit het perspectief van de overheid) systematisch positiever is dan de evaluaties van de onderzoeker en van leden van de doelgroep (Analyses II en III). De evaluaties tonen het gebrek aan integratie van de vier belangrijkste aspecten van duurzame en betaalbare huisvesting, namelijk sociaal-culturele, economische, technologische en ecologische factoren, en hoe dat heeft geleid tot het falen van implementatiestrategieën. Het over het hoofd zien van sociaal-culturele en milieufactoren in de huisvestingsprogramma's, de slechte toegankelijkheid

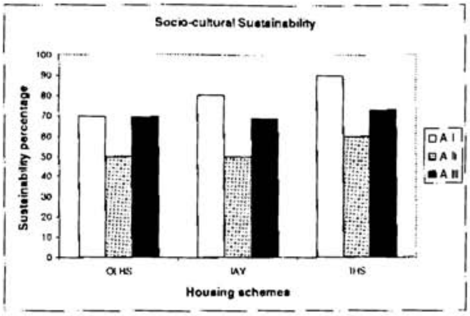


Fig. 2a

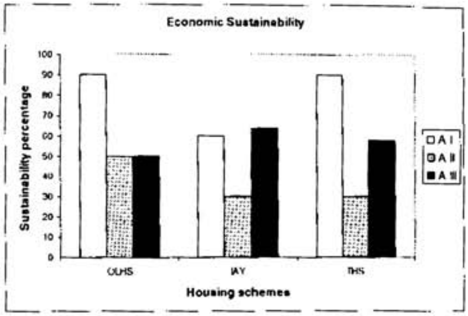


Fig. 2b

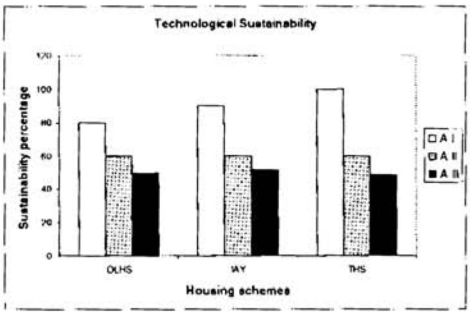


Fig. 2c

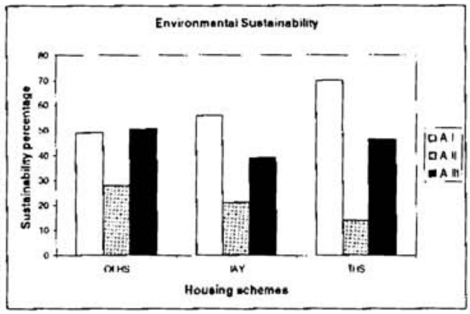


Fig. 2d

Figuur 2 Vergelijking van de verschillende aspecten van duurzaamheid, t.w. sociaal-culturele, economische, technologische en milieu-aspecten, in verschillende huisvestingprogramma's, gezien vanuit de perspectieven van de overheid (AI) en de gebruikers (AII en AIII).

tot de hulpmiddelen, de oneigenlijke kennis van zowel het bouwproces als van innovatieve technologische opties, en het gebrek aan basisvoorzieningen zijn geïdentificeerd als de belangrijkste obstakels voor de arme huishoudens in Kerala. De lage economische draagkracht van de huishoudens en het gebrek aan een consistent inkomen dragen verder bij aan de problemen.

3. Evaluatie van het huidige bouwproces: Kerala

Draagt het huidige bouwproces in Kerala bij aan duurzame huisvesting? Zo niet, welke aanpassingen kunnen dan aanbevolen worden?

Met behulp van het conceptuele raamwerk is er een selectie uitgevoerd van duurzame bouwalternatieven die aan de specifieke eisen in Kerala voldoen. Ook is er een waardebepaling uitgevoerd van gangbare bouwmaterialen en populaire technologische mogelijkheden. Deze waardebepaling was gebaseerd op "energie-inhoud" en voegt een semi-kwantitatieve verfijning toe. In feite speelt deze waardering alleen een cruciale rol indien een geschikte keuze moet worden gemaakt tussen twee alternatieven die een gelijke score behalen in de uitgebreide analyse. De uitkomsten van deze evaluatie geven aan dat de traditionele bouwtechnologie met laterietmuren, dakpannen in het Mangalore patroon, en mortel van leem de meest duurzame technologische optie is voor betaalbare huisvesting in Kerala, waar lateriet locaal beschikbaar is. Voor andere locaties wordt metselwerk met lokaal geproduceerde holle betonblokken geadviseerd als alternatieve technologische optie die lateriet kan vervangen. Deze bevindingen illustreren het falen van kosteffectieve en milieuvriendelijke (CEEF) technologische opties in Kerala tegenover het marktsucces van het overheersende moderne energie-intensieve bouwproces. Dit leidt ons tot de conclusie dat geen van de technologische alternatieven in de praktijk haalbaar is als ze niet op genoeg draagvlak en acceptatie van de maatschappij kunnen rekenen.

De evaluatie van het bouwproces in Kerala onderstreept de behoefte aan:

- Popularisatie van kosteffectieve en milieuvriendelijke technologische alternatieven en verspreiding van technologische innovaties door middel van geschikte strategieën.
- Demonstratie van technologische innovaties aan het publiek zodat het de voordelen ervan kan ervaren.
- Het formeren van groepen stakeholders, inclusief technische experts, zodat de nieuwe technologie geleverd kan worden, samen met de begeleiding die na de levering nodig is zodat een goede toepassing en correct gebruik van innovaties gewaarborgd kan worden.
- Innovatieve technologische opties die gebruik maken van ongeschoolde arbeid, vernieuwbare grondstoffen en gedecentraliseerde productie.

4. Puzzolane rijstkaf-as als een duurzaam alternatief voor cement

Hoe kan puzzolane rijstkaf-as lokaal ontwikkeld worden als duurzaam alternatief voor cement voor de primaire bouwtoepassingen in Kerala?

De zoektocht naar nieuwe milieuvriendelijke en betaalbare materialen heeft geleid tot experimenteel onderzoek naar de puzzolane activiteit van rijstkaf-as (hoofdstuk 6). Dit is gedaan om de mogelijkheden te onderzoeken voor de productie van een reactieve puzzolaan in een landelijke omgeving met een minimale infrastructuur met gebruikmaking van de beperkte vaardigheden van de arme huishoudens. Als eerste fase van dit experimentele technische onderzoek is een diepgaande karakterisering van rijstkaf-as uitgevoerd om de optimale condities voor het produceren van een reactieve as van rijstkaf te identificeren. Het meest reactieve monster dat gevonden is, is een rijstkaf-as dat geproduceerd is door een verbranding van 12 uur bij 500°C en vervolgens een snelle koeling direct nadat het uit de oven gehaald is. Dit stemt overeen met eerdere onderzoeken van Mehta (1978) en Hamad e.a. (1981), die het temperatuurgebied van 500 tot 700°C hebben gevonden als optimaal voor de productie van reactieve as. Tegelijkertijd komen deze bevindingen niet overeen met een aantal andere onderzoeken (geciteerd door Bui, 2001) met betrekking tot de formatie van kristallijn silicium bij lagere temperaturen. Dit onderzoek heeft dus bijgedragen aan een oplossing van een wetenschappelijke onenigheid met betrekking tot de kristallisatietemperatuur van de siliciumdioxide gedurende de verbranding van de rijstkaf.

Het tweede deel van dit experimentele technische onderzoek had ten doel om een betaalbare oven te vinden die de reactieve puzzolaan kan produceren voor landelijke bouwtoepassingen in Kerala. Monsters rijstkaf-as van drie verschillende typen veldovens zijn onderzocht. De volgende conclusies konden worden getrokken.

- Vergeleken met de monsters uit andere veldovens, waren de resultaten van de ringvormig omsloten pottenbakkersoven (RHA A) beter qua mortelsterkte (van alle geselecteerde testmortels met rijstkaf-as monsters in alle mixcomposities). Daarom kan het ringvormige oventype aanbevolen worden als een betaalbare en simpele optie voor de productie van rijstkaf-as op kleine schaal in een landelijke omgeving. Het wordt aanbevolen om de ringvormige omsluiting uit te voeren in baksteen in plaats van gelaste mazen, omdat de gelaste mazen een beperkte levensduur hebben.
- Rijstkaf-as van de stenen ovens (RHA B) gaven ook redelijk goede sterkten in combinatie met verschillende proporties kalk en cement, hoewel deze resultaten minder goed waren dan die van de ringvormig omsloten pottenbakkersoven.
- De gevonden lagere sterktewaarden van mortels die de as bevatten van kuilverbranding (RHA C) kunnen worden verklaard door de langere periode van verbranding en de lage koelsnelheid. Door de diepte van de kuil te verminderen zou de luchttoevoer vergemakkelijkt kunnen worden en dit kan leiden tot betere resultaten.

5. Strategieën en aanbevelingen voor duurzame en betaalbare huisvesting in Kerala

Welke beleidsaanbevelingen kunnen worden aangedragen (voornamelijk voor de economisch zwakkere sectoren) met betrekking tot duurzame en betaalbare huisvesting zodat er bijgedragen kan worden aan duurzame ontwikkeling?

Gebaseerd op de evaluatie kan er een aantal strategieën worden voorgesteld voor de ontwikkeling van duurzame en betaalbare huisvesting voor de verschillende aspecten van duurzaamheid.

Beleidsmaatregelen voor het bereiken van sociaal-culturele duurzaamheid:
- Het stimuleren van participatie in het huisvestingsprobleem door de huishoudens erbij te betrekken met steun van de gemeenschap.
- De promotie van basisconcepten ("core housing concepts"; basiseenheden die aanpasbaar zijn aan toekomstige omstandigheden) in plaats van voorgeschreven ontwerpen ("rigid type designs").
- Het nastreven van de gelijkwaardigheid tussen burgers door zorgvuldige wijkplanning, zodat verschillende inkomensniveaus in dezelfde buurt met elkaar gemengd kunnen worden, en door het verzorgen van een adequate infrastructuur en goede gemeenschapsvoorzieningen.

Strategieën voor economische duurzaamheid dienen de volgende maatregelen te bevatten:
- De garantie van een constant inkomen voor de arme huishoudens
- De garantie dat middelen als landbezit, aanvullende leningen, bouwmaterialen, arbeid en infrastructuur toegankelijk zijn.
- Verbeteren van de toegankelijkheid tot leningen door microfinanciële instellingen te promoten en door flexibel te zijn in het verstrekken van leningen, afhankelijk van de behoeften van het huishouden en hun vermogen tot terugbetaling.
- De garantie van minimale faciliteiten voor de huishoudens.

Strategieën voor technologische duurzaamheid dienen de volgende maatregelen te bevatten:
- De garantie van tijdige begeleiding en technisch toezicht op het bouwproces
- De garantie van de beschikbaarheid van materialen en geschoolde arbeid
- Het in staat stellen van de begunstigden om minimale vaardigheden voor het bouwproces te verwerven.
- Het promoten van technologische innovaties
- Het promoten van het gebruik van vernieuwbare en lokale materialen

Strategieën voor ecologische duurzaamheid dienen de volgende maatregelen te bevatten:
- De integratie van basisinfrastructuur als vitaal component van huisvesting
- Het nemen van goede regulerende maatregelen opdat landbouwgrond behouden blijft en ongecontroleerde landwinning voor kleiproductie, huisvesting en andere ontwikkelingsactiviteiten voorkomen wordt.
- De garantie voor conservering van grondstoffen door huisvesting energie-efficiënt te maken, door oplossingen met alternatieve energiebronnen en door integratie van methoden van regenwateropvang.

De evaluatie van publieke huisvestingsprogramma's in Kerala vraagt om efficiënte en effectieve implementatiestrategieën die geschikt zijn voor de sociaal-economische en culturele kenmerken van de staat. De evaluatie laat zien dat de integratie van de vier aspecten van duurzaamheid een cruciaal element vormt van duurzame en betaalbare huisvesting. Door alle belanghebbenden te betrekken in het bouwproces, zoals de begunstigde huishoudens, de locale gemeenschap, non-gouvernementele organisaties en de lokale overheid kan de integratie tussen deze aspecten versterkt worden.

Voorgestel-de aanbevelingen zijn:

- *Een geïntegreerde aanpak* in het gehele proces met behulp van een sterk netwerk van verschillende belanghebbenden en instituties opdat de doelen van duurzame en betaalbare huisvesting bereikt kunnen worden.
- *Formulering van ondersteunende mechanismen* ("Housing Support Organisations" zoals het 'People's Housing Process' in Zuid-Afrika) om genoeg capaciteit te creëren en om de mensen hun eigen huisvestingsbehoefte aan te laten geven.
- *De betaalbaarheid voor huishoudens verbeteren,* door een consistent inkomen te garanderen door 'empowerment' of door het faciliteren van inkomensgenererende activiteiten.
- *Het verzekeren van technologische duurzaamheid in het bouwproces*
- *Het verzekeren van een basisinfrastructuur en het behoud van grondstoffen.*

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ABOUT THE AUTHOR

Deepa G Nair was born as the eldest daughter of Prof. C. Gopalakrishnan Nair and Mrs. N. Indira Devi on 30 May 1970 in Alleppey district of Kerala, India.

She received her Bachelor degree of Technology in Civil Engineering from Kerala University in 1992. Thereafter in 1993, she started her career as a volunteer Engineer trainee with Kerala State Nirmithi Kendra, the major semi-governmental organization in Kerala, actively involved in the propagation of Cost Effective and Environmentally Friendly (CEEF) building technology. During this period, she got the opportunity to do the Master of Science in Habitat Technology from Birla Institute of Technology and Science, Pilani, (India) and graduated in 1995. Later on she continued her service in Nirmithi Kendra, Cochin as a Habitat Engineer till 1999. During her career with Kerala State Nirmithi Kendra, she was fortunate to get involved with the projects relating to housing the poor and experience their genuine problems related to shelter. In November 1999 she joined in Cochin University of Science and Technology (CUSAT) as a faculty member of School of Engineering. From 2002 to 2006, she has worked as a PhD researcher at the faculty of Civil Engineering and Geosciences at Delft University of Technology, The Netherlands, which resulted in this thesis entitled "Sustainable-affordable housing for the poor in Kerala".

Deepa is married to Mr. K.R Rajendran and is a proud mother of two boys Achyuth (Achu) and Ashwin (Moni).