MATERIALS FOR FISH NETS — THEIR PROPERTIES, SELECTION AND PRESERVATION

THESIS

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by

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Dedicated to my mother
Mrs. Mary Joseph

CONTENTS

C E R T I F I C A T E

This is to certify that this Thesis is an authentic record of research work carried out by Smt. P.J. CECILY, M.Sc. under the supervision of the late Shri. G.K. Kuriyan, former Director Central Institute of Fisheries Technology, Cochin and after his demise under my supervision and guidance and that no part of it has previously formed the basis for the award of any other degre in any University.

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CHAPTER I

INTRODUCTION

Fishing craft and gear play vital roles in the exploitation of the fishery resources. Fishing crafts include catamarans, dug-out canoes and small plank-built boats ranging in length from three to fifteen metres. The traditional fishing gears are drag nets, drift nets, gill nets, shore seines, boat seines, cast nets, hooks and lines and traps. Fishing methods like trawling, trolling and purse seining were introduced with the operation of mechanised boats. The materials for the fabrication of fishing gear play an important role in fisheries development.

Historical resumé:

At first, fibres of vegetable origin were the main materials used for fish net fabrication. Cotton, a seed fibre obtained from *Gossypium* spp. was most commonly used for fishing nets, while 'soft fibres', also known as 'bast fibres' obtained from the stalk of hemp (*Crotalaria juncea* and *Cannabis sativa*), jute (*Corchorus capsularis*), ramie (*Boehmeria nivea*) and flax (*Linum usitatissimum*) were also used for different types of fishing gear. The leaf fibres obtained from sisal (*Agave sisalana*) and manila (*Musa textilis*) and coir (*Cocos nucifera*) were extensively used all over the world for making trawls, set nets and ropes.

Prior to the introduction of synthetic twines, vegetable fibres were the materials used in India for the fabrication of indigenous fishing gears in the different maritime States of India. Hornell (1937), Mukerjee (1959), Kuriyan and Radhalakshmy (1960) and Kuriyan and Cecily (1962) have reported the use of different vegetable fibre twines for various types of fishing gears. Balasubramanyan et al (1960, 1961) reported the use of old pieces of sun hemp drift nets converted into bottom set gill nets for the capture of lobsters. Joseph and Narayanan (1965) indicated the use of sun hemp twines of diameters ranging from 1 to 2 mm for some of the bottom set gill nets in Brahmaputra river system. In Karnataka fisheries, 'rampani' net is still made of hemp twines and the best suited material for bottom set gill nets for dara fishery off the coast of Bombay is Italian hemp (Deshpande 1962). Miyamoto and Shariff (1959), George and Radhalakshmi (1962) and Kuriyan and Radhalakshmi (1962) have described the characteristics of sun-hemp twines used for various types of fish nets. George (1971) has described the various indigenous methods and gears prevalent in various systems of inland waters of India and given the details of specifications of vegetable fibre twines used for fabrication of lines, traps and different types of nets.

Kuriyan et al. (1962) mentioned that certain parts of indigenous 'thanguvala' known as 'adivala' and 'nervala' were made of hand-twisted single stranded cotton cords of 5 yarns belonging to 20 count yarn. Sathyanarayana and Sadanandan (1962) in their study on the encircling gill nets for sardines and mackerel of Kerala coast observed the use of hand-made single stranded cotton cords of 3 and 4 yarns. Deshpande and George (1962) reported the use of 6 and 7 yarns for 'aravala' and 'malmade' parts of the net while hand-made multistranded cotton twines of 20/4/3, and 20/7/3 were used for the 'vellayadi' part of 'Kolachivala', a two boat seine for gar fishes. Joseph and Narayanan (1965) in their survey on the fishing gear and methods of river Brahmaputra gave details of the use of single stranded cotton cords and multistranded cotton and hemp twines of various specifications used for the different types of indigenous gear operated in that area. Evaluations of the physical properties of cotton fish net twines by Kuriyan and Cecily (1959, 1960 and 1962) revealed the need for uniform twists and stability of twines by maintaining the correct ratios for inner and outer twists.

More information on the use of machine twisted three stranded cotton twines for commercial prawn trawling was provided by Satyanarayana et. al. (1962), Satyanarayana and Nair (1962), Nair and George (1964), Nair et al (1966) and Deshpande et al (1968). Early designs of trawl nets of two seam and four seam indicated a gradual increase in thickness of three stranded cotton twines from the wing and belly regions towards the throat and cod-end by selecting cotton twines of specifications 20/6/3, 20/7/3, 20/8/3, 20/9/3, 20/10/3 and 20/12/3. A deviation from the above design was used by Narayanappa (1968) in the catch efficiency studies of trawl nets in which only a single specifications of cotton twine of 20/8/3 was used from the wing to the throat region while the cod end was made of nylon 210/7/3. Again Nair (1969) mentioned the use of nylon 210/7/3, 210/9/3 and 210/12/3 for bottom trawls in place of cotton of specifications 20/7/3, 20/9/3 and 20/12/3. Earlier designs of gear for both marine and inland waters showed that the materials used for ropes were of vegetable origin, mainly sisal, manila and coir.

The problem of rotting was the main drawback of vegetable fibres which was overcome to a certain extent by treating the nets with indigenous preservatives at frequent intervals. The most popular method practised by fishermen all over the world is the application of tannin and its fixation by either ammoniacal copper sulphate solution or potassium dichromate and treatment with chemicals like Copper Sulphate, Copper naphthenate, coal tar and resins (Takayama and Shimozaki (1957). Miyamoto et al (1962) gave a comparative account of rotting resistance of netting twines of vegetable origin. Details of indigenous preservatives used in different maritime States of India along with the methods of treatment followed by local fishermen were given by Miyamoto (1959), Kuriyan and Nayar (1961) and Kuriyan et al (1962). Methods of preservation of cotton twines were also described by Nayar (1962), Kuriyan and Nayar (1962), Venaja (1963) and Cecily and Kunjappan (1971 and 1973). Miyamoto and Shariff (1959) and George and Radhalakshmi (1962) studied the efficacy of preservatives on hemp twines. Experiments on preservation of coir, manila and sisal were carried out by Nayar and Naidu (1960, Nayar et al. 1962), Nayar and Naidu 1962 and Nayar and Vanaja (1962). Cecily (1977) in her thesis submitted to the University of Cochin gave a detailed account of tanning materials, optimum concentration of tannin solution to get the maximum effectiveness, fixation of tannin, use of coal tar on tannin fixed twines and other chemical preservatives to retard the process of rotting of vegetable fibres.

Sandoz (1959) and Ruperti (1959) described acetylation and Arigal-C process by which vegetable fibres could be made rot-proof; but because of the complicated nature of their application and high cost, these methods of preservation did not gain popularity.

Innovation of man-made fibres was the answer to the serious problem of deterioration met with in vegetable fibres and as soon as they were made known, there were large demands for synthetic fibres from the fishing industry. The non-rotting character of synthetics is of great importance in so far as it can dispense with the laborious and expensive rot-proofing treatments required for vegetable fibres. The first synthetic material to be introduced in fishing belonged to polyvinyl chloride group and that was in the year 1936 for making traps (Brandt 1957). After the second world war many synthetic fibres were manufactured from polymers and it marked the beginning of a revolution leading to the use of synthetics in place of vegetable fibre twines in fishing industry.

Nylon became very popular amongst the man-made fibres and because of its strength, fineness, elasticity, durability and rot-proofness got an easy entry in the field of gill nets, set nets, seines and long line fisheries all over the world. Mugaas (1959) reported the use of nylon in Norway from the year 1951 onwards and found its catchability to be approximately twice that of conventional hemp nets. Amano (1959) observed that Salmon and trout gill nets made of amilan in Northern Pacific caught twice as much fish as ramie nets. Catch efficiency studies done by Saetersdal (1959) in Norwegian waters indicated the fishing power of artificial fibre to be 2.5 to 4.4 times for cod, 1.4 to 2.3 times for coal fish and 1.2 to 1.3 times for mackerel compared to cotton; whereas Brandt (1955) found only a 35% increase in catch in herring drift net made of perlon. Zaucha (1964) reported comparative studies on gill nets made of nylon, Kuralon and cotton in Polish waters and found the first one to be the strongest material for herring drift net, while kuralon nets equalled cotton nets in strength and efficiency. But Saetersdal (op. cit.) was of opinion that cods caught in nylon nets were inferior to those caught in cotton nets as the fish died more rapidly. Molin (1959) reported the fishing capacity of multifilament nylon in inland waters of Sweden to be twice and that of monofilament nylon seven times that of cotton net, the difference being attributed to the invisibility of monofilament nylon under water. Fishing trials in Japanese waters by Shimozaki (1964) showed the catch efficiency of monofilament gill net to be 1.2 to 2.3 times that of cotton nets while its performance was not found satisfactory due to difficulties involved in handling bedause of its bulk and knot-looseness. The use of nylon soon spread to the purse-seine fishery. In Japan when purse-seine was made of nylon, the boat and the crew could operate a much larger net. Nylon nets were widely employed in the tuna and bonito fisheries (Amano, 1959). The first menhaden seine made out of nylon proved to be more durable than nets previously used. The largest nylon purse-seine ever manufactured in U.S.A. was produced in 1956 for tuna-seining. Set nets made of nylon were rot and abrasion resistant and could be left in water for indefinite periods.

The uses of terylene for cod and coal fish and Japanese Kuralon for cod traps in Norwegian waters were investigated later. Molin (1959) was of opinion that kuralon or terylene could be used for parts which are destroyed by the ultra violet rays of the sun. Polyvinyl chloride was found equally efficient as nylon by Teikoku (1959) in Salmon and trout fisheries in Northern Sea and the fibre did not deteriorate even in the warmest season of the year. Krehalon, a vinylidene chloride fibre having high specific gravity and hence sinking faster was found suitable for set-nets, long lines and trawls. Kureha Kasei (1959) suggested that since this fibre is very sensitive to heat, the nets should be kept off from sandy beaches.

The next new fibre developed was courlene or polyethylene in monofilament form which was found suitable for lines, traps and ropes. According to Shimozaki (1964) the cost of synthetic fibre ropes worked out to be three times that of manila and their excessive elongation sometimes rendered them inefficient and even dangerous. According to Kloppenburg and Reuter (1964), the properties of polyethylene depend on the type and quality of polymer used for its production and the degree of stretch applied at the orientation stage and hence recommended only highly stretched monofilaments for rope-making. Twisted monofilaments of polyethylene slowly got introduced into trawl fisheries to replace cotton and manila and continued to be popular as trawl twine even after the acceptance of nylon and terylene in many of the fishing gears of the world. Owing to the buoyant nature of polyethylene fibre, Shimozaki (1964) recommended use of cotton or vinylon webbings for the under part of the trawl net and polyethylene for the other parts.

Polypropylene as monofilament then entered the fishing rope industry. Further researches resulted in the production of polypropylene multifilament (ulstron), the fibre possessing equal strength in dry and wet conditions, and resembling nylon multifilament but for its low specific gravity and elasticity. According to Carter and West (1964), polypropylene multifilament has got the outstanding properties of polyamide, polyester and polyethylene. Honda and

Osada (1964) worked out the catch ratio of gill nets made of ulstron and amilan twines of the same diameter. They did not observe any change in the mesh size after continued operations. But the material was found to be two to three times more voluminous than amilan and the number of tears were also more. Ulstron was also found suitable for seines and trawls. Since trawl efficiency depended to a large extent on the extensibility of the fibre, trawl twines were given relatively high twist factors (Klust 1964). In mid-water trawls, a stiffening or bonding agent was applied to enable the nets to retain their hydrodynamic shape. According to Carter and West (1964) the largest use of ulstron was in the production of ropes.

Side by side with the development of vegetable twines by improved methods of processing and preservation, synthetic twines, mainly nylon got into the Indian fishing industry. Even though the exact period of introduction of man-made fibres in India is not clearly known, the first consignment of nylon landed in the country in the year 1954 - 55 under the TCM aid (Radhalakshmi and Nayar, 1973). Later, with the establishment of the then Indo-Norwegian Project, Central Fisheries Technological Research Station and Off-shore Fishing Station, the suitability of synthetic materials like nylon, terylene, kuralon, saran, polyethylene and polypropylene in various forms was studied in the laboratory and field for various types of fishing gear. The country depended entirely on imports of synthetic gear material till indigenous production of nylon yarn was started in 1962 using imported Caprolactum. Now, polymerisation plants are available in various parts of the country and nylon as monofilament and multifilament yarns in various deniers are being manufactured for fisheries purposes. The salient features of nylon, especially its strength, pliability, elasticity and rot-proofness attracted even the traditional fishermen and the fishing industry came forward to accept it despite the high initial investment.

Field studies conducted on marine gill nets showed that twine sizes of 210/1/3 and 210/1/4 are suitable for sardine and mackerel (Satyanarayana and Sadanandan, 1962; Joseph and Sebastian, 1964) 210/2/3 for pomfret and Hilsa (Sulochanan and Krishna Rao (1967), Panicker et. al (1978) and 210/6/3 and 210/12/3 for Scomberomorus guttatus and Scomberomorus commersoni respectively, (Mathai et. al (1971), Sreekrishna et al (1972) and Sulochanan et al (1975). Satyanarayana and Sadanandan (1962) described a new design of bottom set gill net made of nylon for the capture of lobsters. The use of nylon was extensively experimented in Hirakud reservoir by Sulochanan et al (1968), Naidu and George (1972), George et. al (1973), Naidu et. al. (1976), George et al (1979) and Khan et al (1980). Investigations were also carried out using nylon monofilament and multifilament twines at Gandhisagar (Nayar et al, 1969) and Gobindsagar reservoirs (Mathai and George, 1972; Khan et al., 1975; George et al, 1977, and Khan et al., 1980) for the fabrication of various types of simple gill nets, viz. surface and column set nets, vertical line net, frame net and trammel nets for the capture of various species of fish and the efficacy of nylon nets in reservoir fisheries got well established. George *et al.* (1975) also carried out experiments on the catch efficiency and selective action of coloured gill nets in Gobindsagar reservoir and Narayanappa *et al.* (1977) in Hirakud reservoir.

The synthetic fibre produced in India after nylon was polyethylene in the form of continuous monofilaments which could be twisted into twines of varying thicknesses. These fibres because of their rigid nature, knot-firmness and cheapness were readily accepted as a trawl gear material in preference to cotton in small trawls and sisal and manila in deep water fishing (Kartha *et al.*, 1974). Simultaneously, braided monofilaments of polyethylene also appeared in the market. Polyethylene produced as flat tapes for the weaving industry also could be twisted to form fish net twines at less cost than monofilament twines and the material was tested successfully in the trawl fishery (Kartha *et al.*, 1977). A further development in this line is the fibrillation of tape yarns. Twines made out of these split fibres showed better pliability and smoothness than those made of flat tapes and the utility of this material in place of bast-fibres is yet to be established.

Polypropylene as monofilaments also entered the fishing industry soon; but because of its rigidity, it was used

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only for mounting ropes. Both polyethylene and polypropylene are largely consumed in the rope making industry, slowly replacing the vegetable fibre ropes. Production of polypropylene in multifilament form has been a recent development, the prospects of which are expected to be enormous as the material is quite pliable and resembles nylon in its physical properties except for the elasticity and density. The material is to be further tested in the laboratory and field.

The properties of synthetic fibres vary with the inherent physical characteristics of the basic raw material used, mode of preparation of yarns and method of construction of twines. Since the synthetic fibres are manufactured from polymers which are synthesised from simple chemical units, the qualities of man-made fibres can be influenced by the process of manufacture and certain modifications can even be introduced at the processing stage to meet any specific requirement to a certain extent. Hence, an elaborate study of the properties of fish net twines produced in India has been taken up with a view to determining their suitability for various types of fishing gear with particular reference to conditions prevailing in India.

CHAPTER II

VEGETABLE AND SYNTHETIC FIBRES

2.1 Vegetable fibres, their extraction and properties:

Cotton fibre is single-celled and originates from the epidermis of the seed coat of Gossypium species. Cotton fibres are classified as 'long staple', having a length of 2.54 - 5.08 cm. with fine, strong calibre (Egyptian and Sea island cotton); 'intermediate staple', having coarse texture and length 1.27 - 4.65 cm. (American upland) and 'short staple' of no lustre with a length of 0.95 - 2.54 cm. (Indian and Asiatic). Harris (1954) and Gulati (1957) studied the structure of cotton fibre in detail. Cotton fibre is an irregularly twisted, collapsed and flattened tube with a central lumen throughout its length except at extremities. The fibre consists of an outer cuticular layer and primary and secondary walls of cellulose. The physical features show convolutions which often reverse in direction. According to Balls (1928), Brown (1938), Anon (1956) and Meredith (1959), these convolutions are advantageous in spinning. The cell dimensions are : length - 10-50 mm and diameter 14-21 μ.

Bast fibres, often known as soft fibres, are schlerenchymatous multicellular filaments embedded in the stem of the plants and cemented together by a natural gum like substance. Examples are Linum usitatissimum (flax), Cannabis sativa (true hemp), Crotalaria juncea (Sun or sun-hemp), Corchorus capsularis (jute), and Boehmeria nivea (Ramie).

Mauersberger (1954) and Himmelfarb (1957) have studied in detail the structures of these cells. Flax or linen fibres are unusually broad with indistinct cell dimensions varying from 5 to 55 mm in length and from 13 to 41 μ in diameter. Cross sections of these fibres are polygonal. Hemp fibres are uneven in width showing fissures and cross markings. Cells of jute have heavy longitudinal striations and unevenly thick walls with broad irregular lumen and blunt ends. Cells in ramie are blunt, show many longitudinal striations, broad lumen irregular in outline, cell dimensions being 60-750 mm length, 17-64 μ diameter having a cross section of elongated polygon with rounded corners.

Leaf fibres or hard fibres occur in the outer surface of the leaves of Musa textilis (manila also known as abaca') and Agave sisalana (sisal). There is no bonding substance cementing the fibres to the parenchymatous tissue of the leaves. According to Himmelfarb (op. cit.), cells in abaca' are smooth, lustrous and relatively thin walled with long tapering ends. The lumen is large, distinct and rounded. The cell is oval, 10-32 μ in diameter and cross sections are irregularly round or oval. Sisal cells show no cross marking and they have wide prominent lumens and blunt ends which are forked. The lumen is often wider than the cell wall and circular in shape. The cross section is sharply polygonal. Fibres are stiff, 1.83 - 3.65 m. long, light, elastic, strong, durable and resistant to salt and water. Coir fibres obtained from Cocos nucifera (coconut) are mainly composed of schlerenchymatous cells, highly lignified, containing 20.6% moisture. The fibre is short, coarse, brown, harsh and springy.

Cordage fibres of plant origin are similar in chemical constitution, the main constituent being cellulose, the content of which varies from fibre to fibre and is found associated with vegetable matter, lignin and pectin in various measures as presented in table I.

Table I

Cotton fibres are separated from seeds and other extraneous matters and cleaned by mechanical processess known as ginning, carding and combing. The fibres are parallelised to form slivers and twisted into yarns. Bast and coir fibres are extracted by a process of retting [Pringle (1951), Mauersberger (op. cit), Anon (1956), Himmelfarb (op. cit)]. Water retting is carried out in dam, river or tank and dew retting by spreading the stalk exposed to weather. The fibres obtained by dew-retting are darker in colour and inferior in quality to those obtained by water retting. A double retting process is also reported by Pringle op. cit and Mauersberger (op. cit) in which the retting in water is allowed to proceed about half way through and the fibres further dried in sun. Retting is then continued and completed by gentle retting action yielding superior quality fibre. Depending on the

Table : 1 Composition of vegetable fibres

Sl. No.	Name of fibre	Cellulose (%)	Moisture (%)	Ash (%)	Lignin and pectin (%)	Extractives (%)
1	Cotton	90.00	8.00	1.00	0.50	0.50
2	Flax	76.00	9.00	1.00	10.50	3.50
3	Hemp	77.07	8.76	0.82	9.31	4.04
4	Sunn	80.40	9.60	0.60	6.40	3.00
5	Jute	63.24	9.93	0.68	24.41	1.42
6	Abaca	63.72	11.83	1.02	21.83	1.60
7	Sisal	77.20	6.20	1.00	14.50	1.10

temperature of water, condition of stalk and other related factors, water retting may take two to three weeks in the case of bast fibres and 6-10 months in coir fibres (Anon 1950). Retting is followed by stripping and washing by hand operation or using decorticating machines and the fibres are separated from the pith. The bast bundle is freed of bark and woody portions by a process called scutching. The 'line' fibre is then hackled by hand on coarse steel pins and graded according to colour, lustre, length and general appearance. The leaf fibres are extracted by mechanical scraping of the fresh leaves.

The utility of fibres depends on their physical and chemical properties. When the cellulose chains are nearly parallel to the fibre axis, they are said to be highly oriented and the closeness with which the cellulose chains bind one another is termed degree of crystallinity (Himmelfarb op. cit.). Both the factors conjointly exert a profound influence on the physical characteristics of the fibres such as tensile strength, stretch, elasticity, bending ability, abrasion and effect of wetting. The specific gravities of vegetable fibres are 1.54 for cotton, 1.51 for ramie, 1.50 for flax and 1.48 for hemp and jute.

Weindling (1947) studied the comparative physical properties of fibres and found that among soft fibres, ramie ranked first with respect to durability, tensile strength, length of fibre cells, fineness and colour, while flax showed the maximum cohesiveness, uniformity and pliability. Hemp stood second with respect to tensile strength followed by flax and jute. Among hard fibres, abaca' was found superior to sisal regarding durability, tensile strength, fineness, uniformity and pliability. Schiefer (1944) showed that hemp fibre had 72% of dry strength of abaca' and 87% of that of sisal. In his studies on the stretch properties of vegetable fibres, the superiority of hard fibres over soft ones was established. Stretch at rupture was found to be 2.8% for manila, 2.9% for sisal, 1.8% for hemp and 1.5% for jute. The flexing endurance worked out to be greater for sisal followed by abaca' and jute, while hemp registered half the value of those of abaca' and jute.

The ratio of wet strength to dry strength of the fibres as worked out by Schiefer (op. cit) were 0.79 for abaca', 0.89 for sisal, 0.83 for jute and 0.58 for hemp. The absorption of moisture by fibre as explained by Himmelfarb (op. cit) occurred by water molecules penetrating the fibre and forming an internal part of its molecular structure with consequent changes in properties and water is held mechanically in the interspaces between the cells. Natural cordage fibres absorb moisture resulting in swelling, pronounced increase in elongation and reduction in strength except in the case of cotton and ramie. According to Meredith (op. cit) the absorbed water penetrates the amorphous region and forms a hydrate resulting in an increase in volume. The water also acts as a lubricant releasing internal stresses causing swelling, which increases the fibre strength of cotton and ramie.

Robinson and Johnson (1953) determined the knot strength of vegetable fibres and found softer fibres to be less adversely affected by knotting, enabling them to withstand bending stresses better. Himmelfarb (op. cit), observed that hard fibres as a class are more resistant to abrasion than soft fibres.

Studies on the relationship of fibre properties with the spinning value of cotton confirmed the role of staple length and fibre fineness in assessing the quality of yarn. Balls (op. cit) and Gulati (op. cit), pointed out that yarn strength is dependent on fibre properties, their intrinsic strength, fineness and slipperiness, while there was no marked correlation between spinning value and fibre length. Spinning operation was done in early days by hand using a simple spindle consisting of a piece of wood carrying a weight or 'whorl' at the lower end (Springle, op. cit). Due to the momentum of the whorl, the fibres are drawn and spinning is continued. At present, drawing of fibres and spinning are done by machines. Depending upon the fineness of the yarns, the process of spinning is done on a ring flyer or gill spinning frame. For ramie, dry spinning is employed producing yarns of 56 to 60 lea, while yarn of 180 lea is also made. Ramie fibres are cut after degumming to adjust their lengths to suit the equipment. Flax is cottonised to be spun on cotton machinery (Pringle, op. cit). Mauersberger (op. cit) pointed out that treatment with hot water softened the gum holding individual fibres together in hemp facilitating their being spun into even and fine yarn. Himmelfarb (op. cit) reported that a softener or batching material like oil in water or water in oil is used for bast fibres to minimise possible damage to fibres during spinning.

During the spinning process, the sliver is attenuated by twisting, converting it to a continuous cylindrical form i.e. yarn. Twist plays an important role in the preparation of yarn. Since vegetable fibres are short, the twis t is given either in the clockwise or anti-clockwise direction (Gulati op. cit). The purpose of the twist is to bind the component fibres together transmitting stress from fibre to fibre along the length of the yarn. Himmelfarb (op. cit) found a corresponding increase in the strength of yarn with twist; while it decreased beyond an optimum twist and on further twisting breaking occurred due to local overtwisting. A rigid fibre is given less twist. Smoother fibres slide more readily against the contacting fibres and consequently a greater degree of twist is required to compress them adequately. Short fibres yield finer and softer yarns in comparison to coarser fibres. The process of twisting causes a certain amount of contraction which is proportional to the number of turns inserted in the yarn. Himmelfarb (op. cit) noted a 25% reduction in strength in case of hard fibre by spinning into yarn.

The quality of yarn is expressed in terms of its appearance, count, turns per unit length, strength, elasticity and moisture content. Evenness is a very important factor in grading of yarn which is determined in terms of diameter, weight per unit length, number of fibres in cross section and distribution of twist and strength.

2.2 Synthetic fibres, their preparation and properties

The development of synthetic fibres was started around 1920 by H. Staudinger and after a great deal of research for a period of 40 years, man-made fibres could be produced from simple natural products such as coal, lime oil, molasses, grain and common salt. Since second world war, synthetic fibres became very popular and large varieties of them having different physical properties were invented. Countries like U.S.A., Japan, Federal Republic of Germany, U.S.S.R., Great Britain, Italy and France started manufacturing these fibres on commercial basis. Hans Stutz (1959) made an elaborate classification of synthetic fibres based on their source, process of manufacture together with various trade names under which they are marketed. The chemical groups or classes of synthetic fibres used for making fishing nets are the following.

Polyamide (PA) :

Two types of nylons are used for fish nets viz, nylon 6 6 and nylon 6. The discovery of the former is credited to Dr. Wallace Hume Carothers of U.S.A. in the year 1935 and is prepared by heating hexamethylene diamine with adipic acid (Arzano, 1959). The latter is synthesised from a single monomer 'Caprolactam' and was developed by a chemist, P. Schlack of

Germany in the year 1937 - '38. Structurally both nylons consist of the same amide group but differently arranged to constitute a long chain molecule (Himmelfarb op. cit). From the fisheries point of view, there is not much difference between these two polyamides, as they possess practically similar mechanical properties.

Polyethylene (PE):

Polyethylene fibres are produced by a method developed by Ziegler of Germany in the year 1950. The monomer, the basic unit of polyethylene is obtained by cracking petroleum under low pressure in the presence of an organo-metal catalyst, aluminium aklyl. The fibre is prepared by polymerising ethylene at high pressure of 1500 psi. The fibre is known by trade names, 'polythene', 'courlene' and 'Hi-sex'.

Polypropylene (PP):

This fibre was developed by Professor Natta of Italy in the year 1954 by polymerisation of olefines using organo-metallic catalysts of Zeigler type. Polyethylene and polypropylene are collectively known as polyolefines. Because of their difference in physical properties, they are considered as two separate groups. 'Ulstron' is the trade name given to polypropylene fibre.

Polyester (PES) :

Polyester fibre was developed by J.R. Whinfield and

J.T. Dickson of United Kingdom in the year 1940-41 by the poly-condensation of terephthallic acid and ethylene glycol. The fibres are manufactured by the ester exchange of glycol and dimethyl terephthallate. The common trade names are 'terylene' and 'dacron'.

Polyvinyl chloride (PVC) :

This fibre was developed by F. Klatte and H. Hubert of Germany in the year 1934 from the monomer, vinyl chloride. It was the first synthetic material used for fishing gear under the trade name 'Pe Ce'.

Polyvinylidene chloride (PVD) :

This fibre was invented in 1939 in U.S.A. by co-polymerising a mixture of vinylidene chloride and vinyl chloride. The trade name of this composition is 'Saran'.

Polyvinyl alcohol (PVA) :

Polyvinyl alcohol fibre was produced in the year 1931 by W.O. Hermann and W. Haehnel. This fibre was further improved in Japan since 1938 and the product is known as 'Kuralon'.

The polyvinyl chloride, polyvinylidene chloride and polyvinyl alcohol fibres are not much used in fisheries except in Japan where they find application in various types of fishing gear. Another synthetic fibre, viz; polyacrylonitrile fibre, although important in the textile industry, is not popular for application in fish nets.

The finished polymer is cut into chips and converted into fibre form by melt spinning, i.e. squirting the molten substance through spinnerets which on emerging gets solidified by cooling in a current of air into ductile threads. The manufacture of filaments is done by drawing or stretching them to three to four times their original length according to Carrothers (op. cit); whereas Lohani (1961) recorded a stretch of four to five times. In case of nylon, according to Inderfurth (1953) cold drawing developed transparency and a high degree of lustre. Cold drawn filaments had a much higher tensile strength and elasticity than undrawn filament. They were sufficiently pliable and tough to be tied into hard knots, whereas undrawn filaments were inelastic and fragile. In the case of polyethylene the draw ratio is eight to ten times, the stretching being done in boiling water and wound up under constant tension. The degree of drawing influences the physical properties of the final product, mainly tenacity.

The properties of synthetic fibres vary from material to material and also depend on the mode of preparation of basic yarn. Detailed properties of manmade fibres are given by Carroll-Porczynski (1961). The characteristics of synthetic fibres commonly used all over the world for making fish net twines are presented in table 2.

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Table 2

The basic fibre types used in the fishing industry are of different types, viz; continuous monofilament and multifilament, staple fibre, tape and split fibre. In continuous filament the fibre length is infinite. Monofilament means a single filament which can either function as a twine as in nylon monofilament or made into finer forms and twisted or braided to form twines of suitable diameter as in polyethylene and polypropylene monofilament twines and braided cords. Multifilament consists of a number of smooth and silky filaments produced in different degrees of fineness, generally much thinner than 0.05 mm diameter. They are produced with or without twist. Staple fibres also known as spun fibres are discontinuous in nature. They are also prepared by cutting continuous filaments into suitable lengths and twisting into yarn by spinning. Yarn made of staple fibre has a rough surface due to the hairy projections of the numerous loose ends of the fibres. Nylon and terylene can be produced both as continuous filament as well as spun fibre; while polyvinyl alcohol fibres are made only in the staple form.

Flat tape of high density polyethylene is the basic raw material used in sack industry. Studies carried out by the candidate showed that these could be twisted into twines just as monofilaments and field trials conducted with this

Tables 2. Characteristics of synthetic fibres(filament) used for making fish net twines.

Sl. No.	Properties			Polyamide (PA 66)	Polyamide (PA 6)	Polyester (PES)	Polyethylene (PE)	Polypropylene (PP)	Polyvinyl chloride (PVC)	Polyvinylidene chloride (PVD)	Polyvinyl alcohol (PVA)
1	Fibre density			1.14	1.14	1.38	0.96	0.91	1.39	1.70	1.30
2	Tenacity (g/den)	dry	Normal tenacity	4.5-6.0	4.1-5.8	4.0-5.5	4.0-6.0	6.5-7.7	2.7-3.7	1.5-2.6	3.5-4.5
			high tenacity	6.5-8.5	6.5-8.0	6.0-7.0	..	..	..	..	7.7-9.2
3	Breaking Strength Wet(in % of dry)			85-95	85-95	100	110	100	100	100	77
4	Extension (%)	dry	normal tenacity	26-32	24-30	27-17	20-40	20.5	13-30	18-33	14-19
			high tenacity	15-20	16-24	15- 7	..	..	..	..	9-20
		wet	normal tenacity	30-37	27-34	27-17	20-40	20.5	13-30	18-33	14-22
			high tenacity	18-28	19-23	15- 7	..	..	..	..	12-22

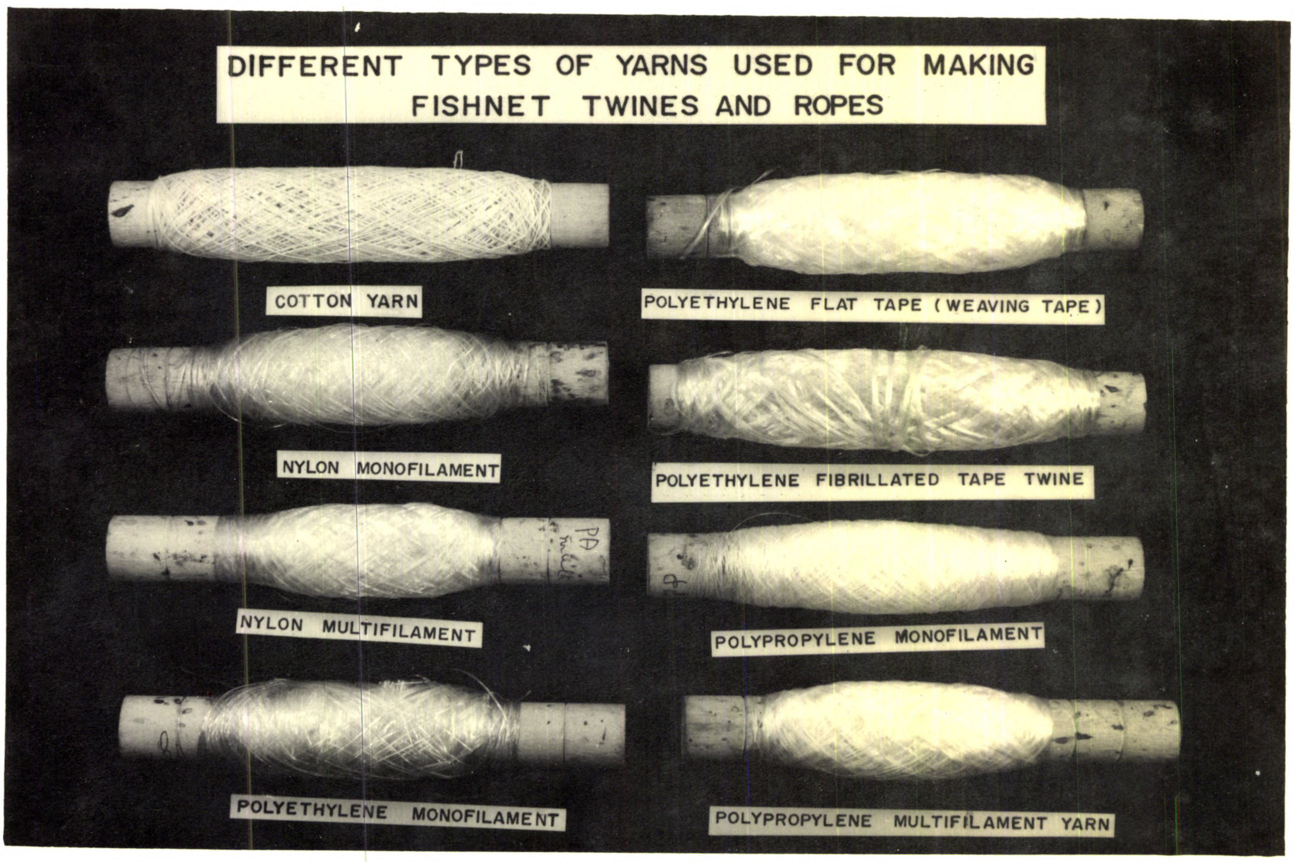
Contd.....

Table 2. Contd..

Sl. No.	Properties	Polyamide (PA 66)	Polyamide (PA 6)	Polyester (PES)	Polyethylene (PE)	Polypropylene (PP)	Polyvinyl chloride (PVC)	Polyvinylidene chloride (PVD)	Polyvinyl alcohol (PVA)
5	Knot strength (%)	85-90	85-90	70	..	72	70	70-80	75-80
6	Moisture regain(%) at 65%	4	4	0.4	0	0	0.3	0.4	5.0
7	Weight in water (in % of air dry wt.)	12	12	28	Buoyant	Buoyant	26-28	41	23
8	Softening point(C)	220-235	170-180	230-250	115-125	140-165	70-80	115-160	200
9	Melting point (C)	245-250	215-218	250-266	125-140	160-175	180-190	170-175	220-230
10	Resistance to Weather	medium	medium	high	medium	low medium	very high	high	high

material (Kartha et. al 1977) showed its suitability for fabrication of bottom trawl nets. The split fibres originate from oriented plastic tapes which are stretched during manufacture by such high draw ratios that the tapes split longitudinally when twisted under tension. A yarn made of such fibrillating tape consists of split fibres of irregular fineness similar to natural bast or hard fibres. Photograph I shows the different types of synthetic yarns used for the manufacture of fish net twines.

Photograph I



1. Different types of fish net yarns.

Yarns are produced in standard sizes and many numbering systems exist to denote their sizes, which fall under two prominent heads viz; the 'indirect system' and the 'direct system'. The former is followed generally for vegetable fibre yarn as well as spun synthetic yarns in which the weight is kept constant and the length varies; hence higher the number, the thinner would be the yarn. They include English Count (Ne), metric count (Nm), English Linen count (Lea) 'typ' system, and runnage (m/kg or yds/lb). In the direct system of numbering the length is kept constant and the weight varies. The 'denier system' is commonly used for continuous synthetic filaments as well as silk. The British Standards Institution has drawn up standards for textile yarn adopting the 'tex' system. The International Standards Organisation has recommended this system of numbering based on metric units for international adoption in place of various methods of numbering followed in different countries. The details of numbering systems are given in Chapter III under terminology on fibres, yarns and twines. For easy conversion of the different systems of numbering, the formula applied is

$$Tex = 0.1111 \times Td = \frac{1000}{Nm} = \frac{590.5}{Ne} = \frac{1000000}{m/kg} = \frac{496055}{yds/lb}$$

where Td = total denier number,

Nm = metric count; Ne = English cotton count (Klust 1964).

Nylon yarn is generally made of 210 denier size while those of 420, 630, 840, 1260 are also made for specific uses (Warenzeichenverband, 1959). He has indicated the use of nylon yarn of 140 denier having 68 filaments and Terylene yarn of 250 denier having 48 coarser filaments or 144fine filaments for salmon gill nets. Carrothers (1957) mentioned the use of terylene yarns made of 50, 75, 100, 125 and 250 denier sizes. Shimozaki (1959) has codified the properties of polyamide group of fibres of yarn size 60, 110, 210 and 250 denier and teviron of 300 denier. The different denier sizes described by Honda and Osada (1964) for polyamide is 210, polyester-210, polypropylene 180, saran 360 and teviron 300.

Nylon multifilament yarn comprises generally of 24 filaments. Carmody (1968) described the production of yarn with 6, 7, 12, 15, 18 and 24 filaments and opined that the yarns made of 6, 7 and 15 filaments were more suited for netting twines. In India, nylon yarns of 210 denier having 24 and 34 filaments are commonly used for the production of fish net twines (Nayar and Radhalakshmi, 1973). Monofilaments fall within the range of 100 - 4000 deniers, those used in fish twines falling in the 100 - 1000 range. The denier size of flat tape ranges from 750 to 1000.

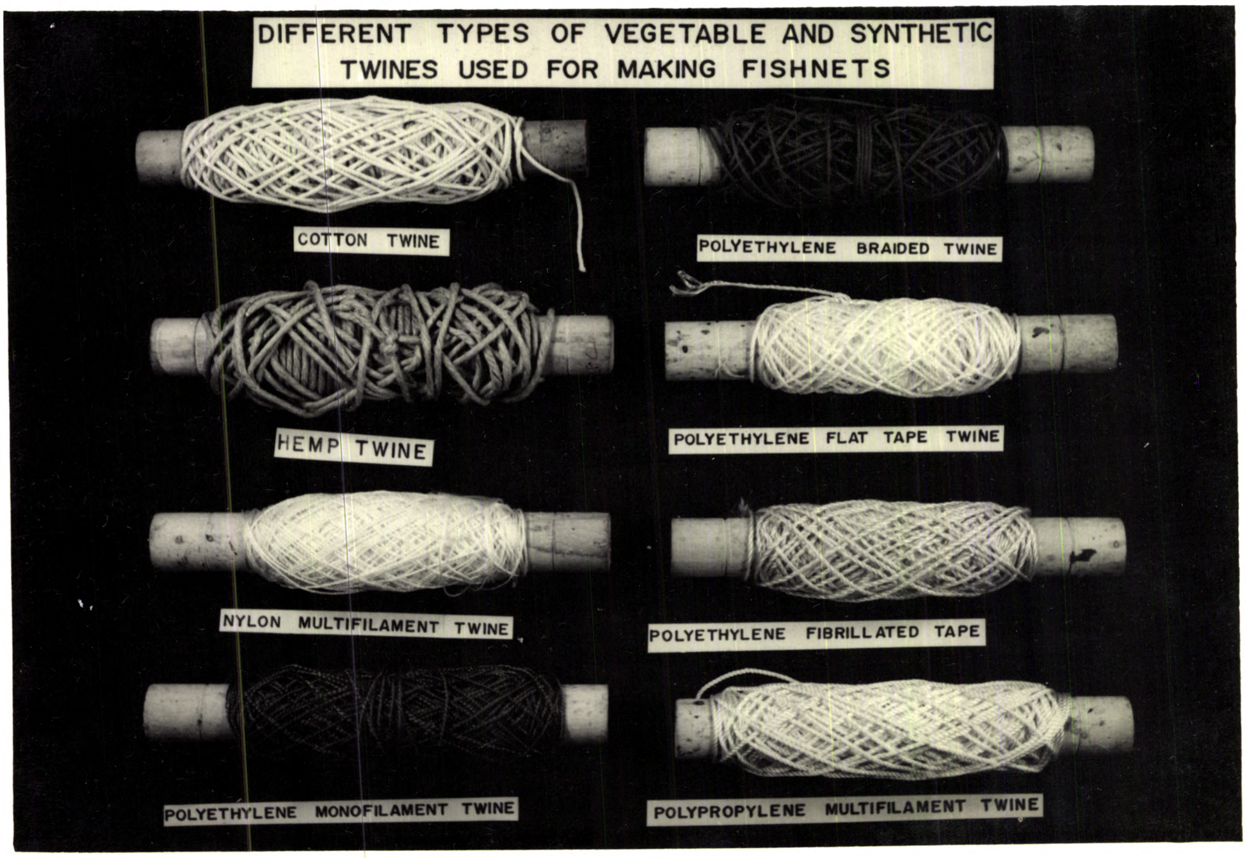
2.3 Construction of twines:

The methods followed for the manufacture of netting twines are twisting, plaiting or braiding. A twine is produced by two twisting operations. Two or more single yarns belonging to staple fibre type, monofilament, multifilament or tapes are twisted together in the direction of left hand or right hand to form a strand or ply and in the second twisting operation two, three or even four such strands are twisted in the direction opposite to the earlier operation to form the twine. In the preparation of cotton twines the yarns are drawn through water (wet spun), while nylon yarns are twisted in the dry state. Figure 1 shows the direction of twist and method of construction of twine.

Fig. 1

Photograph 2 presents the different types of twines used for fabrication of fishing nets.

Photograph 2



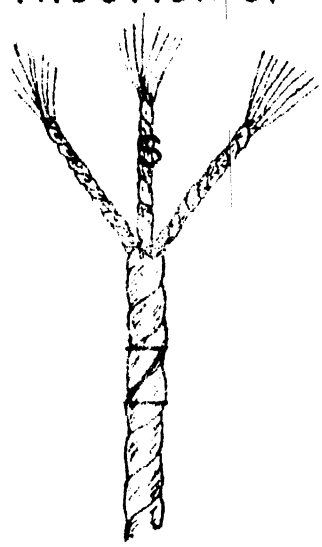
2. Different types of fish net twines.

The number of twists given to strands and twines are to be so adjusted that a twine in the free state does not show kinks or tendency to snarl or liveliness of cut ends. Proper ratio of inner and outer twists are to be maintained to produce balanced twines and the twist-factor followed by the firms for the manufacture of twines depends upon the type of material, thickness of twine and hardness required for the end use which would be discussed in chapter 5.3.

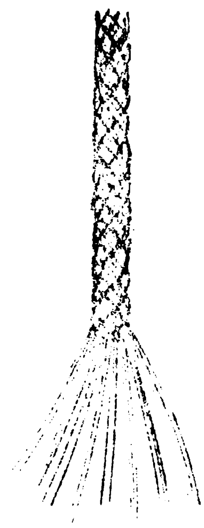
Braided twines are produced by interlacing a number of yarns and strands in such a way that they cross each other in diagonal direction to the edge (Klust 1973). Braids form a tube and the size of lumen depends upon the kind of braiding, number and kind of strand, core and structure of the braid; the compactness of the braid depending on the increase in the number of visible picks or stitches per unit length resulting in soft, medium or hard lay. The core is made of single yarn, folded yarns or monofilaments which fill the lumen of the braided tube or twisted continuous filament twine or straight monofilaments. Figure 2 shows the process of construction of braided twines.

Fig. 2

CONSTRUCTION OF TWINE Fig:1



BRAIDED TWINE Fig: 2



2.4 Designation of twines

The designation of a twine is done by different methods. The diameter of the twine was followed in many countries along with diameter of yarn with which it was made together with the number of yarns. Another method is by denoting the runnage of twine. Hayhurst and Robinson (1959) designated twines by giving the yarn size, number of yarns in a strand and number of strands in a twine. Accordingly, a cotton twine is designated by 20/5/3 and a nylon twine 210/5/3 having 5 yarns per strand, with three such strands and the thickness of twine was occasionally referred to in the trade by code number 5. This code system could be applied to twines of different thicknesses except for 210/1/2 and 210/2/2, the former is known as code no. ½ and the latter as code no. 1½. The twine having one yarn in each strand is known as code no. 1 and depending on the number of yarns in each strand, the twines are known by their code numbers.

Net makers often require the weight of twines. A rough way of calculation of weight of twine is by estimating the 'Nominal tex' by multiplying the yarn tex with the number of strands. An allowance of 10% is added to this value to compensate for the increase in the actual weight due to contraction by twisting operation for medium laid twines. The 'resultant tex' (Rtex) value is based on the actual weight of the twine per 1000 metre length which takes into account the increase in weight due to twist also. R-tex value holds good for designating twines of any twist hardness, for braided twines of complicated strudture and for twines of dissimilar components such as saran - nylon combination (Klust op. cit). But the resultant tex alone does not supply full indicating of netting twine as there is possibility of giving wrong information in such cases as a higher R-tex of one specification of hard lay can be the same as that of another specification of twine having more number of yarns but of soft lay. In order to avoid such a misinterpretation the count of single yarn and the number of strands constituting the twine are given along with R-tex values. This method of designation gives a clear picture of the specification of twines used in fishing industry.

According to the system developed by the CIFT and accepted as Indian Standard (IS 4640 - 1968) the method of designating twine is as follows.

i) linear density of single yarn in tex system

ii) The number of single yarns in one strand

iii) Number of strands forming the twine

iv) Resultant linear density expressed in the tex system

v) Twist directions in the various stages upto the finished product

vi) The composition of the yarn

1. The first three characteristics are joined to each other by a multiplication sign, the fourth characteristic is preceded by the letter R, fifth is indicated by the letter Z or S, for eg. 23 tex Z x 68 x 3Z; R 460 tex Z.

2. For netting twines composed of dissimilar materials and heavily twisted trawl twines complete designation would be complicated. In such cases the resultant linear density, the direction of twist, the composition of yarn and their percentage of combination will be useful; for eg. R 4000 tex S, nylon 75%, polyester 25%.

3. Twines obtained by braiding is designated by their resultant linear density, eg. braided twine R 4000 tex.

4. The International Standards Organisation has also recommended the above method for giving designation to the net twines. Klust (1964) advocated an almost similar method along with the incorporation of the number of twists inserted at the various stages of production of twines.

CHAPTER III

TERMINOLOGY ON FIBRES, YARNS AND TWINES

Abrasion	:	the wearing away of any part of a material by rubbing against another surface.
Absorption	:	a process in which one material (absorbent) takes in or absorbs another (the absorbate).
Braid	:	a process of interlacing three or more threads in such a way that they cross each other and are laid together in diagonal formation. This process is also known as plaiting.
Breaking strength (breaking load)	:	the maximum load (or force) applied to a specimen in a tensile test carried to rupture. The breaking strength is commonly expressed in gram(kilogram) force or more recently in Newton(N) (1 kgf = 9.80665 N)
Breaking stretch	:	increase in length at rupture of a specimen during a tension test expressed in units of length as a percentage of the original length.

Cabled netting twine	:	netting twine or folded yarn made by two or more twisting operations.
Carding	:	a process of untangling and partially straightening fibres by passing them between two closely spaced surface which are moving at different speeds, one of which is covered with sharp points.
Combing	:	a process of straightening of fibres and extraction of short, broken fibres, neps and foreign matter.
Constant rate of extension tensile testing machine	:	a tensile strength testing machine in which the rate of increase of specimen length is uniform with time.
Constant rate of load tensile testing machine	:	a tensile strength testing machine in which the rate of increase of load being applied to a specimen is uniform with time.
Constant rate of traverse testing machine	:	a tensile strength testing machine in which the pulling clamp moves at a uniform rate and the load is applied through the other clamp which moves appreciably to actuate

a weighing mechanism, so the rate of increase of load or elongation is dependent upon the extension characteristic of the specimen.

Cord	:	a term applied to a variety of textile strands including plied yarns, cabled yarn or structures made by plaiting or braiding.
Core	:	a filament or strand that serves as an extended axis around which other filaments can be wound.
Count	:	the size or the number of yarn based on the relation between length and weight of yarn. Yarn count may be based on the number of fixed length per standard weight (direct system) or the number of fixed weights per standard length (indirect system)
Deformation	:	a change in the shape of a specimen caused by the application of a tensile load or force.
Denier	:	a unit of fineness, the yarn having a weight of 0.05 gram per 450 metre length. It is numerically equal to the number of grams per 9000 metres.

Density	:	mass per unit volume expressed in grams per cubic centimetre(g/cm^3)
Density, linear	:	mass per unit length; the quotient obtained by dividing the mass of a fibre or yarn by its length.
Draw ratio	:	the ratio of the speeds of the first and second pull-roll strands used to orient the filaments during manufacture.
Elasticity	:	that property of a material by which it redovers its original size and shape immediately after removal of the stress causing deformation.
Elongation	:	increase in length in the direction of load at breaking point caused by a tensile force expressed as a percentage of the original length.
Energy	:	the area under the load-elongation curve ie. the product of force and distance or work.
Extension	:	the longitudinal strain in a tensile test which is expressed as a fraction of the initial length.

Fatigue : the phenomenon wherein a material ruptures or changes one or more of its properties permanently after a measured fatigue time.

Fibre, man made : a class name for various genera of fibres produced from fibre forming substances which may be polymers synthesised by man from simple chemical compounds.

Fibre, natural : a class name for various genera of fibres of animal, mineral or vegetable origin.

Fibre number : the linear density of a fibre expressed in suitable units as tex, denier, millitex, etc.

Fibre, soft or bast : flexible elongated fibres from the inner bark of various plants used chiefly in twine, nets and woven fabrics.

Fibrillated tape : a synthetic yarn containing split fibres of irregular fineness.

Flat tape : basic material used in the weaving of sacks and mat made of polyethylene and polypropylene films.

Flexibility : that property of a material by virtue of which it may be flexed or bowed repeatedly without causing rupture.

Flexural stiffness : the resistance of twine to laterial or bending deformation

Hairiness : the condition of the yarn when there are numerous loose ends of cocoon filaments projecting from the surface

Humidity : the condition of the atmosphere with respect to water vapour which may be expressed on an absolute basis or on a relative basis.

Initial modulus : the slope of the initial straight portion of a load-elongation or stress-strain curve.

Jute : a multicellular soft fibre creamy white to brown in colour obtained from the bast of Corchorus capsularis.

Knot efficiency : the ratio of dry knot strength to dry twine strength or wet knot strength to wet twine strength expressed as percentage of the straight twine strength which is retained in the knotted structure.

Knot breaking strength : the breaking strength of a twine with a knot tied in the portion of a specimen between the clamps.

Knot stability (knot-fastness or knot-slip resistance)	:	the ability of the knots to retain their original shape by resisting the inversion into another form without slip or loosening
lea	:	a unit of length (300 yards used to determine the number of linen yarn.
Load-elongation curve (stress-strain behaviour)	:	the values of load (kg) plotted on a graph against elongation (percent). This curve shows the relationship of stress-strain behaviour of netting twines.
Mass	:	quantity of matter in a body.
Modulus of elasticity	:	the load required to stretch a specimen of unit cross-sectional area expressed in dynes per square centimetre.
Modulus, Young's	:	the ratio of change in stress to change in strain within the elastic limits of the material.
Moisture content	:	the amount of moisture in a material determined under prescribed conditions and expressed as percentage of the mass of the moist specimen.
Monofilament	:	a single continuous filament wiry

		and stiff, having a circular cross section and diameter between 0.1 and 1.0 mm or more. Monofilaments of oval or flat cross sections are also manufactured which form the basic yarn used for twisting into strands and twines in the case of polyethylene; while monofilaments of nylon as such are used for fine gill nets.
Multifilament	:	fibres of indefinite length produced in different degrees of fineness having more than the normal number of individula filaments.
Netting yarn	:	standard term for all textile material which is suitable for the manufacture of fish net twines.
Netting twine	:	netting twine or folded yarn is made of two or more single yarns or monofilaments by twisting operations.
Newton	:	the unit of breaking load in the International system (1 kgf = 9.80665 N)

Nylon	:	a synthetic polyamide fibre of extrme toughness and elasticity.
Nylon 66	:	a polyamide condensation polymer of hexamethylene diamine with adipic acid.
Nylon 6	:	is a polyamide from caprolactam.
Ply	:	a number of single yarns twisted together.
Polyacrylonitrile	:	obtained by polymerisation of acrylonitrile, CH2 : CHCN, the basic unit of acrylic fibres.
Polyethylene	:	polymerised ethylene produced by polymerisation at high pressures and temperatures.
Polyester	:	a long chain synthetic polymer generally produced from the reaction of ethylene glycol and terephthalic acid or its derivatives.
Polyamide	:	compounds formed by polymerisation of amino acids or by the condensation of diamines with dicarboxylic acids.
Polyvinyl alcohol	:	a group of colourless water soluble resins made by the acidic

		or basic hydrolysis of a polyvinyl ester usually the acetate.
Polyvinyl chloride	:	obtained by polymerisation of vinyl chloride
Rough	:	a condition in which the surface resembles sand paper.
Runnage	:	the length of final product in metres per kilogram or yards per pound. Runnage is the reciprocal of linear density.
Resultant linear density (R-tex)	:	the linear density of the final product resulting from twisting, folding or cabling operations.
Shrinkage	:	a decrease in length, area or volume calculated as a percentage of the original.
Single yarn	:	the simplest thread composed of fibres which may be spun yarn, filament yarn, monofilament or split fibre yarn. Single yarns are the components of netting twine.
Sisal	:	a hard fibre obtained from sword like leaves of sisal plant, *Agave sisalana*.
Sliver	:	a continuous strand of loosely assembled fibres which is approximately

uniform in cross sectional area and without twist.

Specification : a precise statement of a set of requirements to be satisfied by a material indicating wherever appropriate, the procedure by means of which it may be determined whether the specified requirements have been met.

Spinneret : a metallic cap or jet with microscopic holes in the flat surface through which spinning solutions are forced which emerge as fine filaments into a coagulating medium.

Spinning : a process of making yarns from fibres

Standard tension : it is the tension applied to straighten the test specimen. All measurements of length and elongation are carried out under a well defined pre-tension using a weight equal to 500 metre length of twine.

Staple : fibres having short length as cotton or wool in the case of natural fibres and continuous multifilament cut into suitable lengths of yarn

		(40mm to 120mm) for spinning in the case of synthetics.
Staple fibre, man-made	:	fibres of spinnable length manufactured directly or by cutting filaments
Staple length	:	the length of a staple fibre without stretching or disturbing the crimp of the fibre.
Strain	:	the relative length of deformation exhibited by a specimen subjected to a tensile force.
Strand	:	an ordered assemblage of textile fibres having a high ratio of length to diameter.
Strength	:	the ability of a material to resist strain or rupture induced by external force.
Stress	:	the resistance to deformation developed within a specimen subjected to an external force.
Take-up, twist	:	the change in length of a yarn caused by twisting, expressed by percentage of the original untwisted length.
Tenacity	:	tensile stress expressed as force per unit linear density of the unstrained specimen expressed as grams per denier or grams per tex.

Tensile strength : the maximum tensile stress expressed in force per unit cross-sectional area of the unstrained specimen expressed as kilograms per square millimeter.

Tex : a unit for expressing linear density equal to the mass in grams of one kilometre of yarn, filament or fibre.

Tex, nominal : is the number obtained by multiplying the weight of a single yarn by the number of yarns multiplied number of strands. This method gives an approximate linear density of the twine as the thickness in mass due to twisting or braiding is not taken into consideration.

Twine : an aggregate of fibres or yarns composed into a partially or completely balanced twisted structure of indefinite length. Plied twine is generally twisted in reverse direction to the component yarns.

Twist : the number of turns about its axis, per unit length, noted in a fibre, yarn or twine. It is expressed in turns per inch, turns per metre or by the helix angle in a structure of known diameter.

Twist, balanced : an arrangement of twist ina plied yarn or cord which will not cause twisting on itself when the yarn or cord is held in the form of an open loop.

Twist, cable : the construction of cable yarn cord or rope in which each successive twist is in the opposite direction to the preceding twist an SZS or ZSZ construction.

Twist-coefficient : a measure of hardness of yarn determined by multiplying the turns per unit length by the square root of the count in a direct system.

Twist counter : an instrument used to determine the amount of twist per unit length in all types of yarns.

Twist direction : the direction of twist is indicated by the letters S and Z. The product has an S or Z twist when the spirals or helices formed by the fibres or filaments around its axis incline in the direction of the letter S or Z.

Twist, hard	:	an amount of twist in yarn in excess of the usual number of turns causing the yarn to become hard.
Twist-factor	:	the product obtained when the twist expressed in turns per centimetre is multiplied by the square root of the yarn number expressed in tex.
Twist, inner(middle twist)	:	the twists applied to yarns to bind them in the form of a strand or ply, the direction of twist may be the same or opposite to that of yarn.
Twist, outer (upper twist)	:	the twists given to the strands in the direction opposite to that of inner twist while preparing twines.
Twist setting	:	done in boiling water or at atmospheric pressure in steam boxes, the schedule of time and termperature is adjusted according to the yarn and intended use.
Twist-on-twist	:	two fold yarn in which the twist is in the same direction as that of the single yarn; for instance S-S or Z-Z.
Twist against twist	:	two fold yarns in which the twist is in the opposite direction as that of the single yarn, for eg. SZ or ZS.

Vegetable fibres : all textile fibres of vegetable origin, cotton, flax, ramie, jute, hemp, abaca, henegium, sisal, pine apple, et.

Weight : the force exerted on a body by gravit

Yarn : a continuous strand of textile fibres filaments or material suitable for knitting, weaving or twining.

Yarn, number : a measure of fineness of size of yarn expressed either as mass per unit length or length per unit mass depending upon the yarn numbering syste

Yarn numbering : numbering systems to measure the fineness of the yarn-the indirect system of numbering and the direct system of numbering. The numbering systems are as follows:

I. Indirect system : a numbering system indicating the length of yarn for a constant weight higher the number the thinner would be the yarn. Examples are British count, Metric count and spindle.

i) British count (Ne) or cotton (continental) the number of system hanks each of length 840 yards weigh one English pound. This system is used in Great Britain, U.S.A., Japan, Canada and other countries to denote the size of cotton yarn and synthetic staple yarn.

ii) Metric count : the number in kilometres of single yarn weighing one kilogram. This system is used for cotton, hemp and synthetic fibres in some countries.

iii) English linen count (lea) : the number of hanks each of length 300 yards weighing of one English pound. This system is used for ramie and flax.

iv) Spindle : the number of hanks of 14,400 yards per pound.

v) Typ system : the number of one thousand yards of yarn per one pound.

vi) Rope yarn number: In some European countries rope yarn number as metres per Kilogram or yards per pound is used for measuring trawl twines made of manila, sisal and synthetic filaments. This system is followed in Great Britain and Canada for denoting the size of trawl twines and seine twines.

II. Direct system of numbering : a numbering system indicating the weight of yarn for a constant standard length, higher the number, the thicker would the yarn examples are International denier system and tex system

i) Denier system : based on the weight in grams of 9000 metres of single yarn.

ii) Tex system : based on the weight in grams 1000 metre of single yarn, higher the tex value, the heavier the yarn.

Yield point : fibres obey Hooke's law ie. strain is proportional to the stress, only upto certain limit beyond which the fibre exhibits a plastic flow which point is known as yield paint.

Weathering : deterioration of net materials when exposed to weather conditions.

Weight : the force exerted on a body by gravity

CHAPTER IV

EXPERIMENTAL PROCEDURE

Japan Chemical Association (1959), Van Wijngaarden (1959), Carrothers (1959), Klust (1964), Von Brandt and Carrothers (1964) have reported test methods for fishing gear materials. The methods described by Indian Standards Institution (IS: 5815, part I, II and III 1970 and part IV 1971) were followed for the evaluation of physical properties viz. thickness, linear density, twist and breaking load. Details of the test methods are given below.

4.1 The standard atmosphere for testing is 27 ± 2°C and 65 ± 2% R.H.

4.2 The standard tension is equal to the weight of 500 m. length of twine.

4.3 A standard tension is applied to one end of the twine after fixing the other end to a hook, lengths of one metre marked using a scale and test specimens cut off. The mass of the twine is determined by a torsion balance shown in photograph 3.

Photograph 3

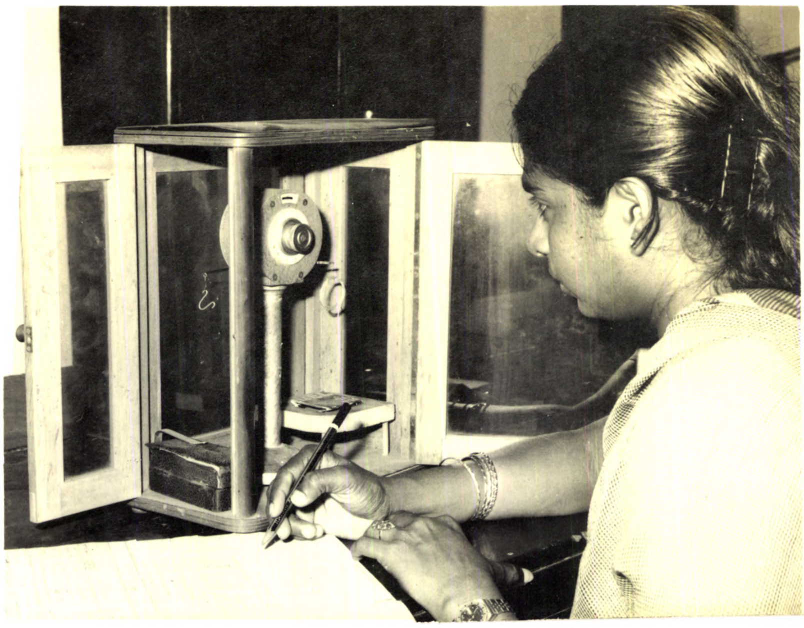
The wet weight is determined by immersing the test pieces in distilled water for a period of 24 hours and noting the wet weight after allowing the adhering water to drain off.

The underwater weights of the test pieces are determined by suspending the previously wet material underwater using a thin plastic filament. Materials which are buoyant are kept immersed in water by using additional weights and finding the difference in weight after removing the test samples.

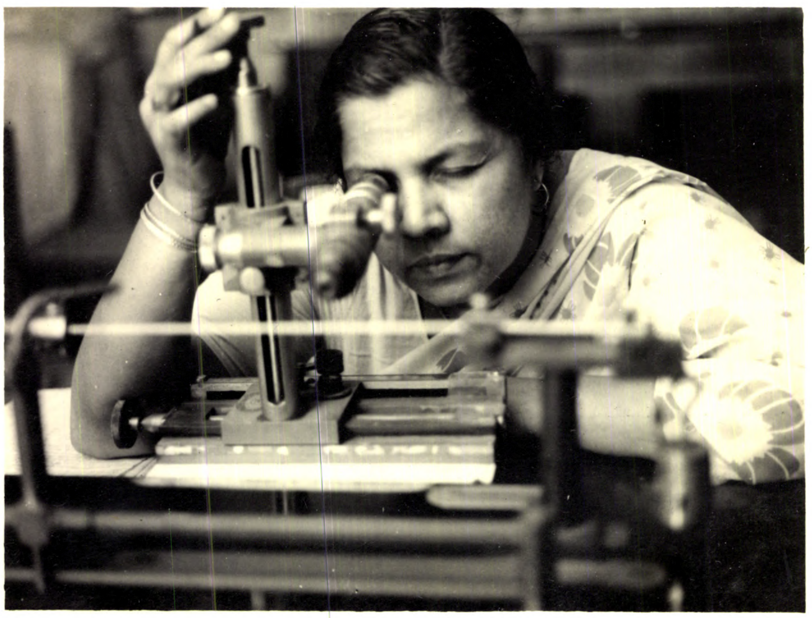
4.4 The diameter is determined by the use of a travelling microscope shown in photograph 4. The twine is kept taut by

Photograph 4

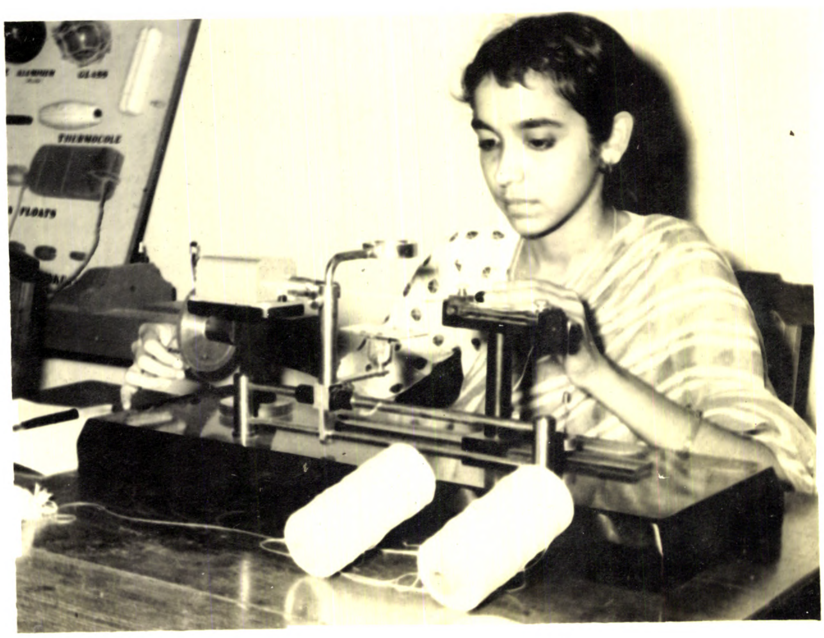
applying a standard tension. The pin head of the travelling microscope is rotated so that one of the cross wires kept in the eye-piece of the microscope touches the upper edge of the twine. The readings on the main scale and vernier scale are noted. The pinhead is again rotated so that one of the cross bar wires touches the lower edge of the twine and the readings on the scale are noted. The difference between the two readings gives the diameter of the twine



3. Torsion balance.



4. Travelling microscope.



5. Twist counter.

in mm.

4.5 The twist is determined using a twist counter shown in photograph 5. The movable part of the twist counter is

Photograph 5

drawn so as to give a length of 25 cm. After applying a standard tension, the twine is fixed on the twist tester. The handle is rotated in the direction opposite to that of twist given to the twine till the strands are separated. The twists recorded in the counter give the outer twist (To) of the twine. Keeping one of the strands in fixed position, the other strands are cut off and the handle rotated in the opposite direction so that the reverse twists given to the strands while untwisting the twine are neutralised and the counter reads zero. The extra length of strand measured by applying one third standard tension gives an indication of the contraction in length of strand while twisting into twine. The remaining twists in the strand are noted by the untwisting method until the yarns get parallelised, the number of twists recorded give the inner twists balancing with the outer twists. Since the outer twist is always opposite to that of inner twist, for twist specification studies the number of inner twists given to the strand is the sum of inner and outer twists . The twist is expressed as number of turns per metre length of twine.

4.6 The breaking strength and stretch are determined by using a tensile strength tester or dynamometer, working on the principle of constant rate of traverse of 300 mm/mt. shown in photograph 6. The specimens are fixed by applying

photograph 6

a standard tension and strained, the test length being 200 mm. When the test piece breaks at the centre, the breaking strength and stretch are noted simultaneously on the respective scales. The strength is recorded in kilograms and stretch in millimetres. The breaking stretch is expressed as percentage of the test length of the specimen. The breaking strength and stretch in wet condition are noted by immersing the test-pieces in distilled water for a period of 24 hours and noting the strength and elongation at the breaking point.

4.7 The stress-strain property of the twine is determined by a tensile strength tester by noting the elongation at equal intervals of load till the breaking point. The percentage elongation of the twines plotted against the loads gives the load-elongation curve and the area under the curve is noted for calculating the energy and Young's modulus of the samples tested.

bent in such a way as to form a loop and the ends are fixed in the metal clamp. A light cellphane vessel of about 3 gm weight is suspended from the loop. Water is led into the vessel from a burette adjusted in such a way that the flow of water-drops gradually draws the loop of the twine together. The opening of the loop at its widest point is observed with the assistance of a gauge and the flow of water is stopped as soon as the opening is decreased to 5 mm. The weight of the vessel and the quantity of water dropped into it as read from the burette is used as a measure in grams of the stiffness of the material tested.

4.10 The resistance of abrasion of net materials is determined by using an abrasion tester as shown in photograph 7.

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photograph 7

One end of the twine is fixed on a hook and a standard tension is applied on the other end which is kept free to move over a pulley. The twine is allowed to rub on an oilstone abradant which is allowed to move to and fro. The number of rubbings are noted in the counter fixed on the abrasion tester. After applying certain number of frictions, the abraded portion of the test specimen is subjected to breaking strength test and the comparative resistance to abrasion is noted.

4.8 The knot strength is determined by noting the strength at break of a twine on which either an overhand knot, a single knot (reef or trawl), knot and a half, double knot or lock knot is tied at the centre of the twine as shown in Figure 3. The reduction of breaking strength by tying of knot is expressed as percentage with respect to unknotted twine. When two twines are involved in forming a knot, the linear strength is doubled to find out the reduction in strength due to the tying of knot.

Figure 3

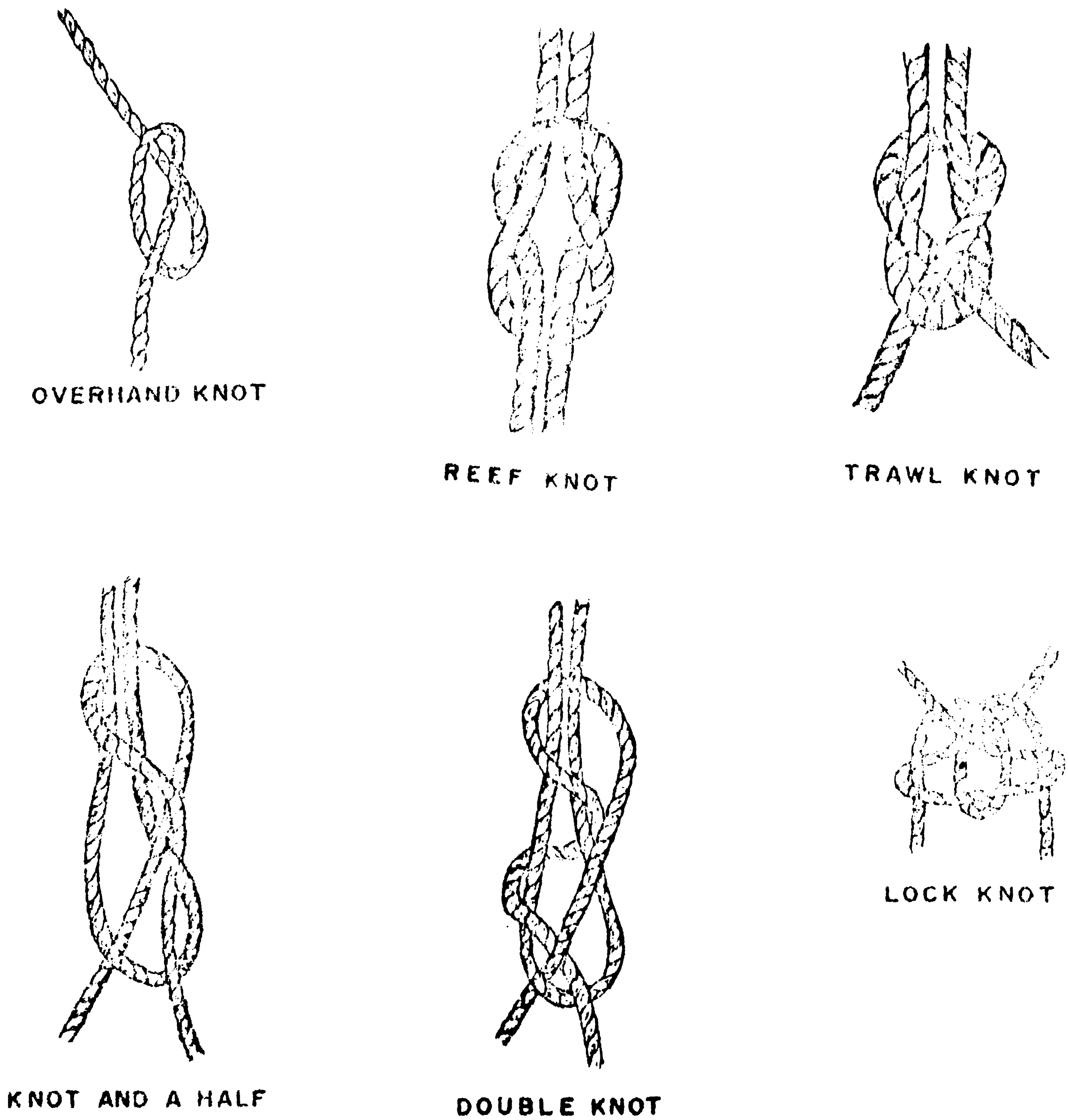
The mesh strength was studied by noting the strength of mesh at break using a tensile strength tester. The meshes are stretched in between the grips provided separately for conducting strength of meshes (IS : 5815 Part V, 1971

The knot firmness is tested by cutting one of the limbs of a knot and testing its strength till the twine breaks or loosens.

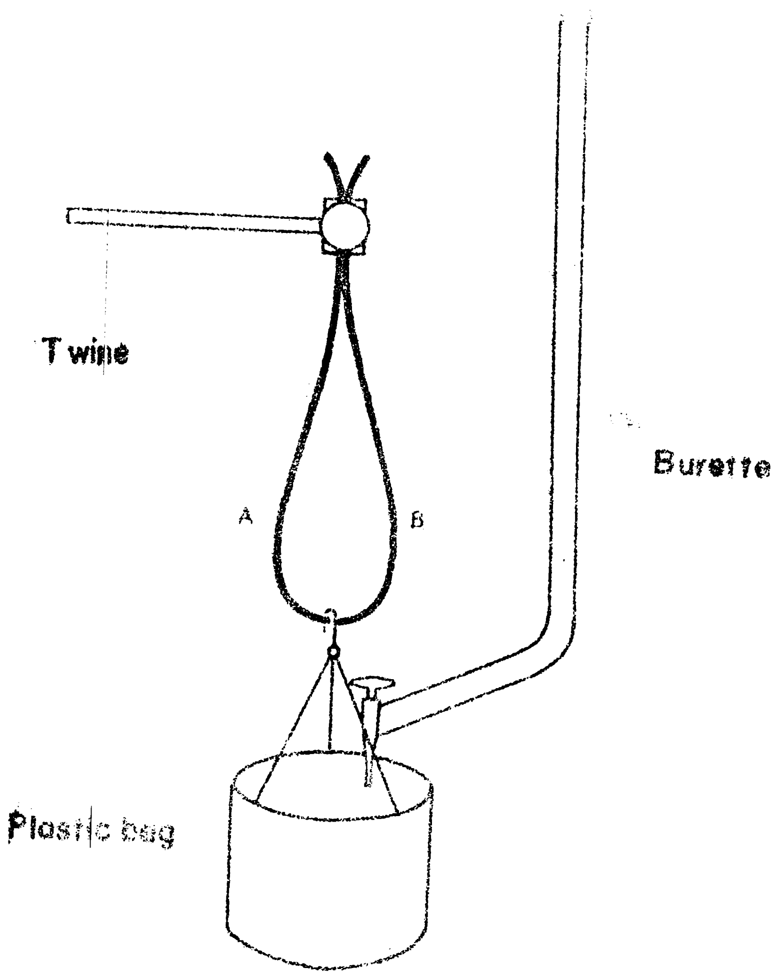
4.9 The flexural stiffness is noted by a device as shown in figure 4. Twenty cm/ length of the specimen is

Figure 4

DIFFERENT TYPES OF KNOTS Fig: 3



FLEXIBILITY TESTING DEVICE - Fig. 4.



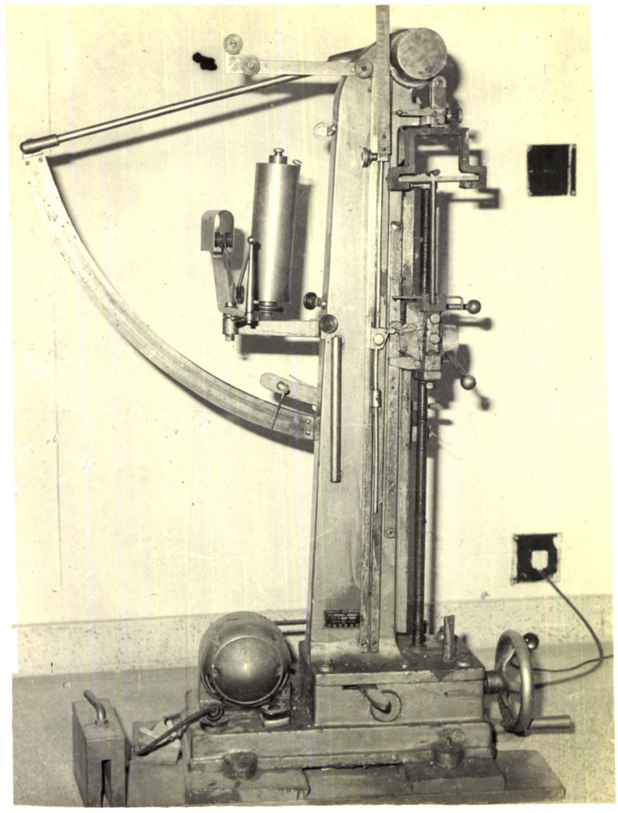
In the case of wet tests the samples soaked in distilled water for a period of 24 hours are subjected to abrasion tests while keeping them moist throughout the experiment by dripping water from a tank fitted above the moving portion of the tester. The number of frictions required to break the specimen or the difference in the breaking strength of the samples before and after the experiment are noted.

4.11 The resistance to static loading is determined by hanging different loads from one end of the twine, the other end being tied to a hook at the top shown in photograph 8. The period of loading is kept as 4, 8, 12 and 24 hours. The difference in the stress-strain property or the breaking strength and stretch before and after the experiment gives the effect of static loading. The extension of material due to

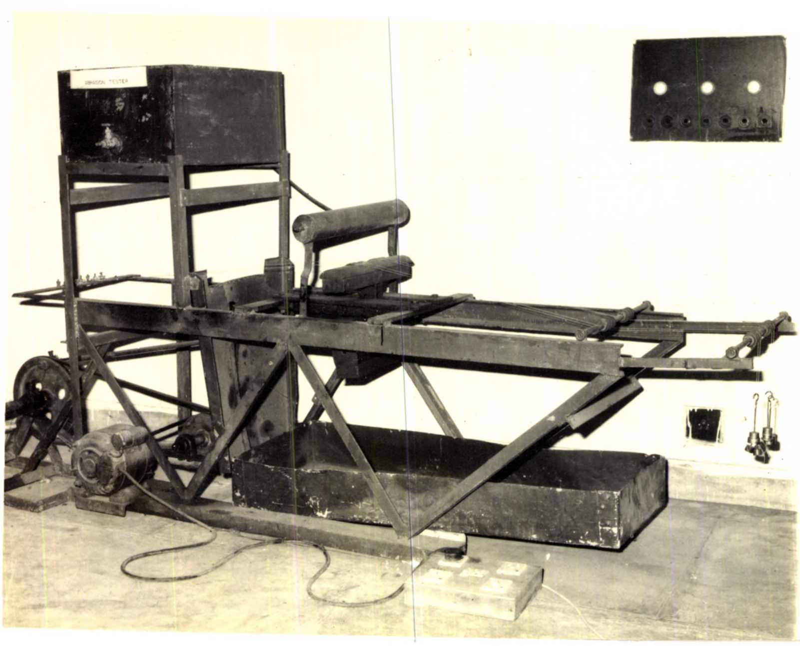
Photograph 8

fatigue is noted by finding the increase in the length of twine using a standard tension before and after loading tests.

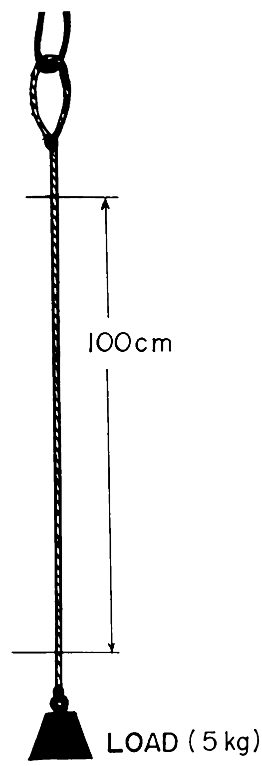
4.12 The weathering experiment is carried out by exposing the test samples of one metre length on a wooden frame to the action of weather. After periodic intervals the retention of strength is determined using a tensile strength tester.



6. Tensile strength tester.



7. Abrasion Tester.



8. Static load test.

4.13 The deterioration of fish net twines under continuous immersion in backwaters was studied by keeping bunches of twines of 50 cm length knotted at the free end under the surface of the water and periodically determining their retention of strength.

4.14 The effect of chemicals is determined by treating the twines with chemicals and noting the strength and strete before and after the treatments. The action of heat was studied by exposing the twines to varying temperatures.

CHAPTER V

PHYSICAL PROPERTIES OF NETTING TWINES

The physical properties of single stranded and multi-stranded hand-made cotton twines used by fishermen for indigenous nets in the different maritime States of India prior to the introduction of synthetic twines are presented in tables 3, 4 and 5. The physical properties of machine twisted cotton twines of soft and hard lay used for fabrication of gill nets and trawl nets are presented in tables 6 and 7. The physical properties of bast fibre twines such as sunhemp and Italian hemp commonly used for certain types of fishing gear are presented in tables 8 and 9 and those of coir twines used for certain parts of nets and ropes are given in table 10. A comparative account of the physical properties of vegetable fibre twines is presented in table 11.

Tables: 3,4,5,6,7,8,9,10 and 11

The data collected on the physical properties of synthetic twines such as polyamide multifilament, polyethylene twisted monofilaments, polyethylene monofilaments braided, polyethylene flat tape twines, polyethylene fibrillated tape twines and polypropylene multifilament twines are presented in tables 12,13,14,15,16 and 17.

Tables: 12,13,14,15,16 and 17.

Table: 3 Properties of single stranded hand-made cotton twines used for indigenous gill nets

Sl. No.	Name of State and Fishing Centre	Specification	Diameter (mm)	Mass per metre (g)	Twist per metre	Breaking strength (kg) dry	Breaking strength (kg) wet	Breaking stretch (%) dry	Breaking stretch (%) wet
	KERALA								
1	Vizingham	20/ 3/1	0.382	0.094	878	0.93	1.80	6.6	8.7
2	"	20/ 4/1	0.483	0.138	732	1.33	1.54	9.4	10.9
3	"	20/ 5/1	0.522	0.181	507	1.78	2.09	9.0	11.4
4	"	20/ 6/1	0.565	0.241	692	2.40	2.50	12.3	10.8
5	"	40/ 3/1	0.320	0.045	606	0.40	0.42	5.5	7.9
6	"	40/ 4/1	0.375	0.074	626	0.59	0.62	7.7	8.8
7	Alleppey	20/ 4/1	0.519	0.126	736	1.80	2.30	8.3	11.7
8	"	40/ 5/1	0.455	0.081	819	1.20	1.50	6.9	9.9
9	Cochin	20/ 4/1	0.417	0.144	838	1.40	1.50	10.9	11.0
10	"	20/ 6/1	0.498	0.297	602	2.10	2.70	8.0	11.1
11	"	40/ 6/1	0.380	0.197	756	1.20	1.40	9.0	10.2
12	Madras	20/ 5/1	0.654	0.187	646	1.90	2.50	15.1	15.3
13	Rameswaram	20/ 5/1	0.616	0.195	760	1.70	2.10	15.2	14.4
	ANDHRA PRADESH								
14	Kakinada	20/ 5/1	0.539	0.183	803	1.70	2.10	10.1	13.1
15	"	40/10/1	0.540	0.170	677	[illegible]	[illegible]	[illegible]	[illegible]

Table: 4 Physical properties of single stranded hand-made cotton twines used for indigenous seine nets

Sl. No.	Name of State and fishing village	Specification	Diameter (mm)	Mass per metre (g)	Twist per metre	Breaking strength (kg)		Breaking stretch (%)	
						dry	wet	dry	wet
KERALA									
1	Vizingham	20/ 2/1	0.433	0.051	492	0.42	0.53	3.81	5.00
2	"	20/ 3/1	0.505	0.084	610	0.87	0.98	4.50	6.50
3	"	20/ 5/1	0.700	0.200	500	2.50	3.10	5.07	6.95
4	"	20/ 6/1	0.710	0.215	583	2.27	3.00	6.22	7.55
5	"	20/ 7/1	0.737	0.228	433	2.59	5.30	5.62	7.42
6	"	20/10/1	0.935	0.344	339	4.50	6.60	5.31	6.93
7	"	10/ 8/1	1.340	0.688	282	6.15	7.55	7.70	7.85
8	"	10/10/1	1.384	0.715	195	6.56	8.50	7.02	8.05

Table: 5 Physical properties of multi-stranded cotton twines used for indigenous nets.

Sl. No.	Name of State and fishing centre	Specification	Diameter (mm)	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Breaking strength (kg) dry	Breaking strength (kg) wet	Breaking stretch (%) dry	Breaking stretch (%) wet
	ANDHRA PRADESH									
1	Visaghpatinam	20/5/3	1.024	0.536	319	815	5.4	6.6	14.7	22.5
	MAHARASHTRA									
2	Bombay	10/5/3	1.041	0.619	264	480	9.4	10.3	16.3	25.0
3	"	20/7/3	1.223	0.804	280	811	10.2	12.4	21.2	27.6
4	"	20/8/3	1.293	0.[illegible]	252	654	11.4	12.0	19.7	30.1
5	"	20/9/3	1.424	0.999	232	622	13.4	14.0	21.0	28.0
	GUJARAT									
6	Gujarat	6/9/4	2.943	5.841	126	559	35.5	38.1	35.2	40.4
7	Jamnagar	14/8/3	1.637	1.386	268	906	12.4	13.4	37.1	42.1
	TAMIL NADU									
8	Madras	20/4/3	0.913	0.412	299	850	5.5	6.4	11.6	18.4
9	Rameswaram	20/6/2	0.873	0.369	543	661	4.1	5.0	17.0	19.0
10	Karwar	20/2/3	0.632	0.198	480	681	2.1	2.7	14.2	19.7
	FORMER FRENCH POSSESSION									
11	Pondicherry	20/7/2	1.000	0.475	346	760	2.7	3.1	11.6	22.3

Table: 6 Physical properties of machine-made soft-twisted cotton twines.

Sl. No.	Speci-fication	Dia-meter (mm)	Mass per metre (g)	Twist per metre		Breaking strength (kg)		Breaking stretch (%)	
				outer	inner	dry	wet	dry	wet
1	20/ 4/3	1.00	0.37	323	646	5.6	6.6	12.0	16.0
2	20/ 9/3	1.20	0.90	228	520	13.6	15.7	16.7	30.0
3	20/12/3	1.40	1.10	189	354	16.8	19.2	19.5	28.8
4	20/15/3	1.70	1.60	177	331	21.6	24.2	22.1	32.8
5	20/18/3	2.00	2.10	217	390	26.6	30.2	25.0	33.0
6	20/22/3	2.10	2.40	165	260	31.7	34.3	24.5	31.0
7	20/32/3	2.60	3.60	138	213	46.7	53.5	24.5	33.5
8	30/ 4/3	0.63	0.23	402	795	3.7	4.0	11.0	14.7
9	30/ 6/3	0.79	0.39	378	583	5.8	6.5	20.3	24.0
10	30/ 9/3	0.93	0.56	260	543	8.5	10.9	14.6	26.1
11	40/ 4/3	0.61	0.18	350	610	3.3	3.7	12.2	18.3
12	40/ 6/3	0.74	0.29	331	520	4.5	5.4	18.5	21.1
13	40/ 9/3	0.84	0.43	260	370	6.8	7.4	14.2	23.3

Table: 7 Physical properties of machine-made hard-twisted cotton twines.

Sl. No.	Specification	Diameter (mm)	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Breaking strength (kg) dry	Breaking strength (kg) wet	Breaking stretch (%) dry	Breaking stretch (%) wet
1	20/ 3/3	0.72	0.30	398	1640	4.2	4.8	14.5	27.2
2	20/ 4/3	0.87	0.47	358	1365	5.2	6.3	17.2	33.8
3	20/ 5/3	0.95	0.63	291	1280	6.1	7.3	24.2	30.7
4	20/ 6/3	1.04	0.76	299	1167	8.7	9.7	21.9	30.0
5	20/ 7/3	1.09	0.87	291	987	10.5	11.6	18.8	30.3
6	20/ 8/3	1.15	0.98	291	961	11.2	11.6	21.9	29.8
7	20/ 9/3	1.25	1.22	236	846	12.5	13.2	25.7	34.5
8	20/10/3	1.28	1.25	236	874	14.1	14.9	21.8	30.8
9	20/12/3	1.39	1.39	197	661	16.6	17.2	21.6	32.5
10	20/14/3	1.54	1.86	205	555	17.7	18.7	26.6	37.2
11	20/16/3	1.67	2.12	205	608	20.8	22.8	26.7	36.5
12	20/18/3	1.78	2.37	201	601	23.7	24.5	26.0	32.5
13	20/20/3	1.88	2.67	189	631	25.9	27.4	26.4	35.2
14	20/21/3	1.97	2.66	189	524	27.6	28.4	28.6	36.2

Table 17 Contd.

Sl. No.	Speci-fication	Dia-meter (mm)	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Breaking strength (kg) dry	Breaking strength (kg) wet	Breaking stretch (%) dry	Breaking stretch (%) wet
15	20/23/3	1.99	2.77	185	504	28.5	30.6	30.4	30.0
16	20/24/3	2.06	3.07	189	508	30.6	35.2	2822	32.0
17	20/25/3	2.17	3.10	181	500	30.6	32.5	32.5	23.7
18	20/26/3	2.18	3.17	185	496	31.8	34.4	29.4	35.9
19	20/27/3	2.19	3.23	177	484	31.7	32.5	23.3	32.2
20	20/29/3	2.25	3.67	165	504	35.5	36.4	23.3	34.8
21	20/30/3	2.29	3.86	169	484	36.1	37.5	30.1	36.3

Table: 8 Physical properties of sun hemp twines used by fishermen.

Sl. No.	Area where used	Type of net	Specification (no. of yarns)	Diameter (mm)	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Br. Strength (kg) dry	Br. Strength (kg) wet	Br. stretch (%) dry	Br. stretch (%) wet
1	KERALA	drift and	2	0.95	0.80	298	236	7.4	8.0	4.4	9.8
	Quilon	bottom set	3	1.19	0.12	230	181	12.2	17.4	5.3	10.0
	Vishingham	gill nets	4	1.68	2.11	177	198	20.9	25.7	6.5	11.2
2	TAMIL NADU	drift and	3	1.25	0.97	190	..	11.3	13.2	6.8	9.9
	Madras	set gill nets	4	1.50	1.32	181	..	18.2	18.0	6.7	8.8
	Ratnagiri	seines and	5	1.61	1.63	170	..	19.0	21.1	6.7	10.8
		stake nets	6	1.95	2.10	157	..	20.2	21.7	6.7	9.7
			7	2.10	2.14	147	..	19.5	23.9	6.7	12.6
			8	2.15	2.56	142	..	27.1	30.5	5.5	11.9
			9	2.34	2.98	131	..	39.6	40.8	6.8	15.0
			10	2.50	3.32	118	..	32.8	37.5	7.0	16.1
3	KARNATAKA	drift net and	2	0.57	0.27	398	405	4.5	4.9	5.7	7.0
	Karwar	shore seines	2	0.83	0.29	344	280	5.8	5.8	4.9	7.5
4	ORISSA										
	Hanabad	bag net and	6	2.34	2.93	108	206	23.5	30.0	8.6	9.8
		gill nets	9	3.03	4.59	59	203	29.2	38.8	8.3	11.6
5	MAHARASHTRA										
	Bombay	bag net	3	1.00	0.78	374	339	9.6	8.8	9.6	12.5

Table 9 contd. Physical properties of Sun hemp twines obtained from traders.

Sl. No.	Specifications (no. of yarns)		Diameter (mm)	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Breaking Strength (Kg) dry	Breaking Strength (Kg) wet	Breaking Stretch (%) dry	Breaking Stretch (%) wet
1	Firm A	3	1.88	2.03	219	..	19.3	27.0	5.4	7.5
		2	2.11	2.81	258	214	26.4	29.5	4.9	7.3
		4	2.24	3.51	131	168	26.4	31.9	6.3	10.2
2	Firm B	3	1.66	2.12	194	139	21.3	25.5	8.4	8.5
		4	2.28	4.00	139	227	31.5	34.7	7.6	10.9
3	Firm C	2	0.98	0.72	299	189	12.0	12.2	5.1	7.5
		3	1.85	2.55	174	140	19.8	24.3	7.6	11.2
		4	2.42	4.61	152	190	23.2	38.8	7.0	11.1
4	Firm D	2	1.37	1.42	187	122	11.4	10.8	7.3	7.7
5	Firm E	3	0.72	0.42	313	259	8.5	10.5	6.5	7.8
		4	1.39	1.65	226	455	26.9	27.6	8.9	18.8
		4	2.17	3.55	143	304	74.8	69.9	11.9	22.9

Table: 9 Characteristics of Italian hemp twines.

Sl. No.	Diameter (mm)	Mass per metre (g)	Twist per metre	Breaking strength (kg)		Breaking stretch (%)	
				dry	wet	dry	wet
1	0.596	0.274	337	7.6	8.2	6.7	9.8
2	0.631	0.331	325	7.9	8.4	6.6	11.4
3	0.766	0.490	230	11.2	11.7	7.7	9.5
4	0.910	0.689	264	13.2	13.5	8.3	10.8
5	2.080	3.390	531	67.5	69.5	7.5	11.9

Table: 10 Physical properties of coir twines.

Sl. No.	Diameter (mm)	Mass per metre	Breaking strength (kg)		Breaking stretch (%)	
			dry	wet	dry	wet
1	3.41	4.08	13.1	15.4	34.7	19.3
2	3.68	4.48	20.7	16.4	34.5	38.3
3	4.12	6.25	24.0	22.0	37.4	43.5
4	4.41	5.44	30.9	24.6	29.8	33.9
5	4.42	7.32	40.1	30.3	32.3	32.5

Table: 11 Comparative/physical properties of vegetable fibre twines.

Sl. No.	Material	Diameter (mm)		Mass per metre (g)		Breaking strength (kg) dry		Breaking strength (kg) wet		Breaking stretch (%) dry		Breaking stretch (%) wet	
		x	σ	x	σ	x	σ	x	σ	x	σ	x	σ
1	Sun hemp	2.26	0.2	3.31	0.3	32.7	3.5	37.3	3.7	5.8	0.9	11.6	1.0
2	Italian hemp	2.08	0.1	3.90	0.2	67.5	4.8	69.4	5.4	8.0	0.5	16.0	1.3
3	Flax	2.21	0.1	2.93	0.3	44.6	5.6	50.9	5.6	8.8	0.9	16.6	1.2
4	Sisal	2.38	0.1	3.28	0.3	36.0	5.4	38.9	5.7	9.6	0.9	14.5	1.3
5	Manila	2.66	0.2	3.90	0.4	50.2	6.4	53.7	5.6	9.1	0.9	15.9	1.2
6	Cotton	2.21	0.1	2.34	0.1	27.0	1.7	30.7	2.2	21.1	1.7	26.7	1.0
7	Coir	2.57	0.2	2.04	0.4	9.1	2.0	8.4	2.1	21.2	4.0	25.9	4.2

x = arithmetic mean

σ = Standard deviation

Table: 12 Physical properties of polyamide multifilament (nylon) twines.

Sl. No.	Specification	Code No.	Diameter (mm)	Mass per metre (g)	Runnage (m/kg)	Twist per metre outer	Twist per metre inner	Breaking strength (kg) dry	Breaking strength (kg) wet	Breaking strength ([illegible]) dry	Breaking strength ([illegible]) wet	Knot strength (kg) wet
1	210/ 1/2		0.370	0.053	18870	662	1272	3.1	2.8	28.5	26.2	1.7
2	210/ 2/2		0.500	0.106	9400	384	604	6.2	6.1	23.7	27.4	3.8
3	210/ 2/3		0.628	0.155	6450	316	588	8.7	8.6	26.6	29.6	5.3
4	210/ 3/3		0.760	0.232	4320	275	473	13.6	12.4	23.9	27.4	7.3
5	210/ 4/3		0.854	0.312	3210	233	440	18.6	14.4	25.7	22.7	10.2
6	210/ 5/3		0.990	0.395	2350	228	390	21.2	20.0	25.4	22.3	13.0
7	210/ 6/3		1.041	0.482	2070	212	383	25.5	24.0	23.9	24.5	14.8
8	210/ 7/3		1.196	0.566	1770	221	354	28.7	26.7	26.6	24.2	16.2
9	210/ 8/3		1.210	0.651	1536	189	352	34.3	29.6	27.4	23.6	18.1
10	210/ 9/3		1.307	0.725	1380	176	321	38.0	34.1	26.8	23.6	21.0
11	210/12/3		1.540	0.983	1020	178	245	49.5	43.2	23.1	26.3	25.0
12	210/15/3		1.700	1.241	810	152	308	59.9	53.8	28.2	27.4	33.1
13	210/18/3		1.813	1.486	670	143	264	69.9	62.6	24.7	24.5	36.1
14	210/24/3		2.188	1.965	510	116	184	90.7	81.1	25.7	24.8	46.5

Table: 13 Physical properties of polyethylene monofilament twines

Sl. No.	Specification	Diameter (mm)	Mass per metre (g)	Runnage (m/kg)	Twist per metre outer	Twist per metre inner	Breaking strength (kg) dry	Breaking strength (kg) wet	Breaking stretch (%) dry	Breaking stretch (%) wet	Knot strength (kg)
1	2 x 3	0.788	0.209	4784	272	210	5.0	5.6	41.6	31.8	3.7
2	3 x 3	0.988	0.338	2958	199	198	8.0	8.8	33.3	27.8	4.1
3	4 x 3	1.007	0.446	2242	144	67	11.5	13.2	34.0	24.6	11.6
4	5 x 3	1.205	0.566	1766	140	40	14.5	15.6	46.6	37.4	13.7
5	6 x 3	1.361	0.679	1473	130	50	17.3	18.7	48.0	37.9	15.9
6	8 x 3	1.526	0.917	1091	178	49	21.2	24.2	45.8	31.9	20.1
7	10 x 3	1.588	1.332	750	138	87	37.8	41.7	33.0	24.5	30.9
8	12 x 3	1.700	1.389	719	98	104	39.3	41.4	24.8	20.3	32.7
9	15 x 3	2.151	1.796	556	98	100	46.7	50.2	23.0	22.4	41.2
10	16 x 3	2.109	2.185	458	125	100	54.6	56.1	29.7	25.6	42.1
11	20 x 3	2.419	2.743	365	115	96	58.6	65.7	33.5	32.0	47.0
12	21 x 3	2.341	2.412	415	124	45	55.9	71.2	54.0	32.8	56.7
13	23 x 3	2.560	3.060	325	90	62	93.6	95.8	24.4	23.4	74.2
14	24 x 3	2.520	2.778	360	93	10	76.5	87.3	34.4	32.4	63.7
15	30 x 3	2.709	3.142	320	114	59	76.8	82.8	40.9	32.6	64.2

Table 13 Contd.

Sl. no.	Speci- fication	Dia- meter (mm)	Mass per metre (g)	Run- nage (m/kg)	Twist per metre, outer	Twist per metre, inner	Breaking stre- ngth (kg) dry	Breaking stre- ngth (kg) wet	Breaking stre- tch (%) dry	Breaking stre- tch (%) wet	Knot strength (kg) wet
16	32 x 3	3.098	4.374	220	97	62	116.6	120.3	24.5	24.6	93.2
17	45 x 3	3.540	5.320	185	91	84	99.4	114.5	45.0	40.8	88.6
18	48 x 3	3.210	4.580	218	94	20	91.7	104.6	42.3	46.1	85.9
19	60 x 3	4.140	8.103	123	53	46	189.1	176.6	29.6	36.3	163.2
20	63 x 3	4.380	8.953	110	52	42	200.7	193.5	31.3	35.3	178.0
21	72 x 3	4.060	7.520	132	83	59	142.0	149.3	43.2	35.6	119.4

Table: 14 Physical properties of polyethylene monofilament braided twines.

Sl. No.	Diameter (mm)	Mass per metre (g)	Runnage (m/kg)	Breaking strength (kg) dry	Breaking strength (kg) wet	Knot strength (kg) wet	Breaking stretch (%) dry	Breaking stretch (%) wet
1	0.75	0.437	2248	10.00	11.75	9.5	50.2	49.8
2	1.00	0.664	1506	14.40	14.10	10.6	97.9	84.0
3	1.15	0.768	1302	16.08	18.00	16.2	72.3	40.8
4	1.25	0.962	1040	20.84	24.47	19.9	60.3	42.1
5	1.35	1.113	898	26.30	29.05	26.2	81.0	44.8
6	1.50	1.286	780	24.37	26.25	21.2	92.3	45.9

Table: 15 Physical properties of high density polyethylene flat tape(weaving tape) twines.

Sl. No.	Diameter (mm)	Mass per metre (g)	Runnage (m/kg)	Twist per metre		Breaking strength (kg)		Breaking stretch (%)		Knot strength (kg)
				outer	inner	dry	wet	dry	wet	wet
1	1.35	0.668	1500	174	291	17.8	20.1	27.0	22.8	14.7
2	1.79	1.489	670	172	347	34.1	39.3	25.6	25.6	25.5
3	2.10	2.049	490	173	338	43.2	48.5	33.6	29.8	36.8
4	2.80	3.146	315	122	259	68.6	69.8	32.2	28.7	53.2
5	3.50	4.774	144	100	225	98.2	105.5	33.9	33.3	79.1

Table: 16 Physical properties of polyethylene fibrillated tape twines.

Sl. No.	Dia-meter (mm)	Mass per metre (g)	Runnage (m/kg)	Twist per metre		Breaking strength (kg)		Breaking stretch (%)		Knot strength (kg) wet
				outer	inner	dry	wet	dry	wet	
1	0.86	0.340	2940	251.2	195.8	10.3	11.2	25.1	21.5	8.9
2	1.15	0.635	1575	167.8	206.0	18.3	20.6	27.5	24.6	16.2
3	1.50	1.071	935	132.0	191.4	28.8	32.8	31.7	25.8	25.9
4	1.92	1.425	700	110.8	174.4	36.6	41.3	34.3	29.0	32.8
5	2.08	1.824	548	135.0	307.2	42.0	46.8	44.6	29.3	35.8
6	2.10	2.193	455	124.6	278.4	49.8	55.9	45.5	30.3	43.0

Table: 17 Physical properties of polypropylene multifilament twines.

Sl. No.	Specification	Diameter (mm)	Mass per metre (g)	Runnage (m/kg)	Twist per metre		Breaking strength (kg)		Breaking stretch (%)		Knot strength (kg) wet
					outer	inner	dry	wet	dry	wet	
1	190/1/2	0.377	0.0464	21550	575.2	887.6	2.53	2.54	26.6	27.6	1.5
2	190/1/3	0.416	0.070	14285	393.0	733.0	4.04	4.08	23.2	20.8	2.3
3	190/2/3	0.659	0.142	7040	289.0	582.2	7.81	8.42	24.5	24.8	4.6
4	190/3/3	0.785	0.207	4830	254.6	552.0	12.2	12.98	28.2	25.3	7.1
5	190/4/3	0.876	0.249	4016	261.0	527.0	16.1	14.4	27.4	22.9	8.2
6	210/1/2	0.388	0.051	19605	524.0	877.2	2.65	2.85	25.3	27.6	1.8
7	210/1/3	0.454	0.084	11948	282.4	619.2	4.21	4.85	25.2	25.2	2.9
8	210/2/3	0.705	0.177	5650	272.4	562.2	8.9	8.15	27.8	25.4	4.9

5.1 Linear density:

The mass of twine is an important factor to be reckoned while designing a net (Reuter 1959). Apart from economic considerations, the mass of twine helps to determine the total weight of the gear which in turn indicates the buoyancy and gravitational forces necessary to keep the net in the proper fishing position. Radhalakshmi (1964) has worked out an empirical formula for the estimation of the weight of webbing based on the mass of twine, its count number and the stretched mesh size. The mass of the twine depends on its thickness as is evident from the above tables 3 to 17 in the case of different specifications of vegetable and synthetic twines. Kuriyan and Cecily (1959, 1960), Nayar (1960)and Kuriyan and Radhalakshmi (1960) have proved that the mass is directly proportional to the square of diameter of twines, which in turn is directly proportional to the total number of yarns, the count number of the single yarn remaining the same. The data on mass and diameter of various specifications of twines of vegetable and synthetic origin were analysed using the relationship $W = Kn$ and $W = K\ D$ where, W is the mass (g) per metre length of twine, n is the total number of yarns constituting the twine, D is the diameter of twine (mm) and K is the constant of proportionality in both the equations. Table 18 shows the values of constants worked out for vegetable fibre twines for the above relationships.

Table 18

The variation in the value of K in the relationship W = Kn ie. the weight of a single yarn of 20 count yarn of cotton twines shows that irrespective of whether the twines are single stranded or multistranded, the K values depend on the degree of twist, a soft twisted twine showing less weight when compared to a hard twisted one. When the number of twist per unit length is relatively greater, the shrinkage of the yarns is more, resulting in the use of more material for making the twines and consequently the mass per unit length of twine is therefore relatively higher than that of a soft twisted twine. The constants worked out for soft twisted cotton twines made of different count numbers show that apart from the degree of twists applied to strands and twines, the size of the yarn with which the twines are made exert profound influence on the linear density.

The values of K in the relationship $W = KD^2$ show the mass of twine in grams per diameter square serve as an index to denote the relative mass of different materials. This relationship also shows higher value of K in the case of hard twisted cotton twines. Among the other vegetable fibre twines, Italian hemp is heavier than the other materials of the same thickness with sun hemp, flax, sisal, manila and

Table 18 Relationship of mass, total number of yarns and diameter of vegetable fibre twines.

Materials	Value of K in the relationship	
	$W = Kn$	$W = KD^2$
1. Cotton		
hand made single stranded	0.035	0.62
" multistranded	0.037	0.47
machine made soft twisted 20 count	0.036	0.55
" 30 "	0.020	0.60
" 40 "	0.015	0.54
hard twisted 20 "	0.044	0.75
2. Sunhemp	-	0.65
3. Italian hemp	-	0.78
4. Flax	-	0.60
5. Sisal	-	0.58
6. Manila	-	0.56
7. Coir	-	0.31

W = mass/metre; n = total no. of yarns; D =diameter, K = constant coir following the order. Coir is the lightest among the materials compared.

In the case of synthetic fibre twines the data collected on mass and diameter were statistically analysed. Highly significant positive correlation ($p = 0.01$) between mass and diameter square was observed which indicates that the mass of the twine increases with the increase in diameter square. Regression equations of mass on diameter square were worked out for each type of twine. The equations are presented below.

Material	Regression equations
1. PE braided twines	$Y = 0.64\ X$
2. PE fibrillated twines	$Y = 0.46\ X$
3. PA multifilament	$Y = 0.45\ X$
4. PE monofilament twisted twines	$Y = 0.44\ X$
5. PE flat tape twisted twines	$Y = 0.41\ X$
6. PP multifilament twines	$Y = 0.35\ X$

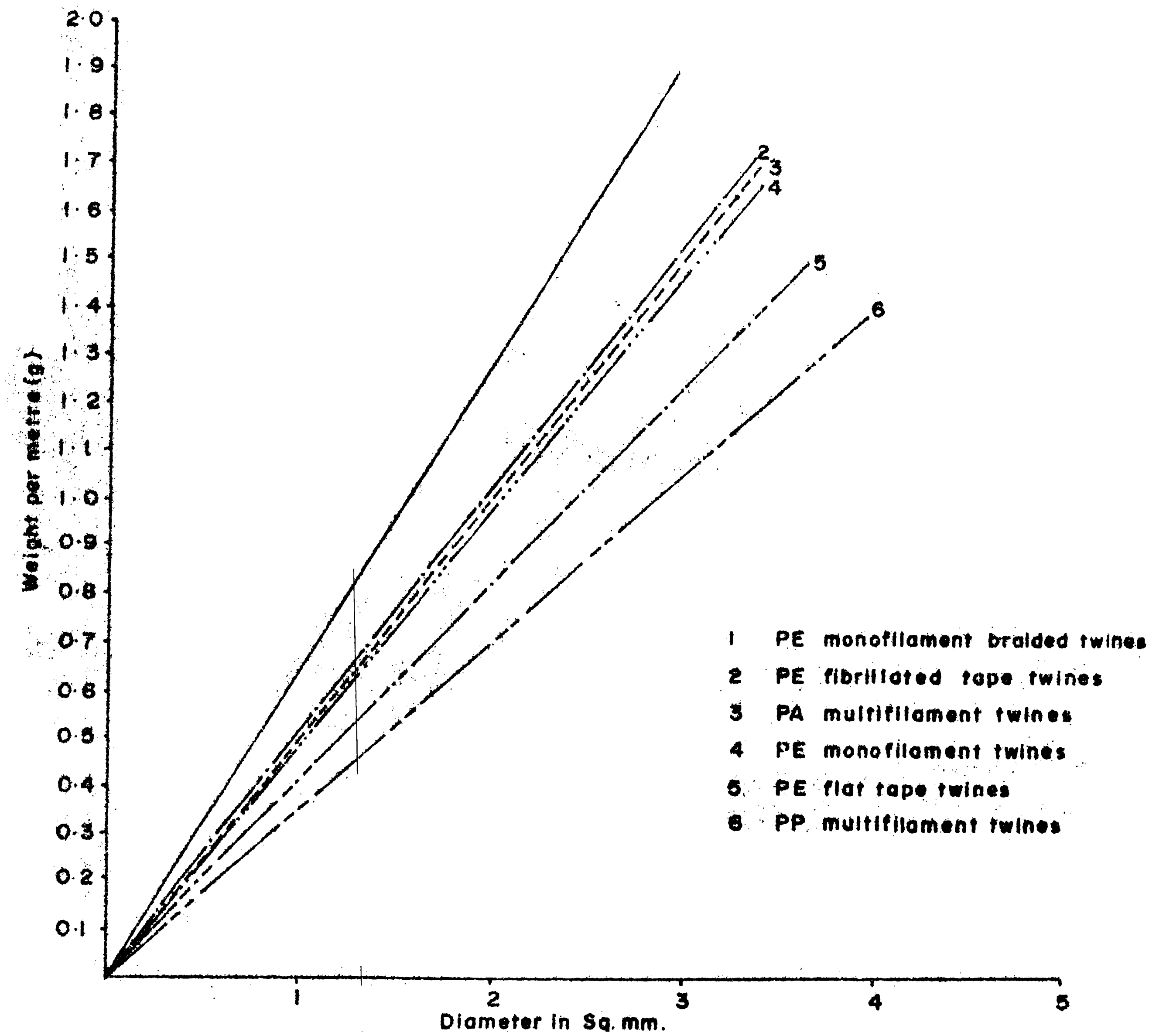
Where Y is the dependent variable (mass in grams per metre) and X is the independent variable (diameter square in mm). The constant K is worked out by using the relation $K = \frac{Y}{\frac{\Sigma X}{n}}$ where 'n' is the number of observations.

The graphical representation of the equations worked out

Figure 5

are given in the figure 5. ...

RELATIONSHIP BETWEEN WEIGHT AND DIAMETER Fig: 5



K values in the above equations show that the PE monofilament braided twine is the heaviest, followed by PE fibrillated twines, PA multifilament, PE monofilament twines, PE flat tape and PP multifilament. As observed in the graph, PE fibrillated, PE monofilament and PA multifilament are more or less of the same weight, while PP multifilament twines have the least weight amongst the synthetic fibre twines tested. By using the above regression equations the weight for any given diameter of twine can be estimated.

In a similar way, if the mass per metre of any twine is given, the diameter can be obtained by the following regression equations of the diameter square on mass per unit length.

Materials	Regression equations.
1. PP multifilament	Y = 2.86 X
2. PE flat tape	Y = 2.42 X
3. PA multifilament	Y = 2.40 X
4. PE monofilament	Y = 2.27 X
5. PE fibrillated	Y = 2.22 X
6. PE braided	Y = 1.59 X

Where Y is the diameter square (mm) and X is the mass in grams per metre.

The density and specific volume are inversely proportional and hence the thickness of twine on equal weight per metre increases with decreasing density of fibres. From the above equation it is evident that the PP multifilament shows higher diameter for a given mass when compared to PA multifilament twines. This is attributed to the lesser density of PP multifilament twine in comparison with PA multifilament twines. Here comparison is made between multifilament twines of two different polymers but the type of yarn and construction are the same.

With regard to polyethylene, four constructionally different samples of the same polymer are compared. Fibrillated tape and monofilament twisted twines are having almost the same diameter and they are found to be thinner than flat tape twines. PE braided twines showed the least diameter among the others when samples of equal mass are compared. Although monofilaments are used as the basic yarn for both twisted and braided forms, the variations of the values of K in the above regression equations is attributed to the constructional difference ie. twisting versus braiding resulting in the lower diameter values on equal mass in the case of braided twines compared to monofilament twisted twines.

5.2 Diameter

The diameter of the twine is an important characteristic in determining the effect of current on a given piece of webbing, the pull on the net by the moving fish and the power required or speed attained in the case of towed gear (Carrothers 1959). Andreev (1962) followed the formula $D = K\sqrt{\frac{n}{Nm}}$ for determining the diameter D of twine where n is the number of yarns, Nm, the count number in the metric system and K, the constant in the relationship which was worked out as 1.3, 1.5-1.6 and 1.4 for cotton, kapron and hemp respectively. The selection of twines of proper diameter for a particular fishing gear is made by experience. The thinner the twine, the lower is the resistance, which in most cases is advantageous for the catching efficiency as it reduces water turbulence which in turn minimises the frightening effect on fish. The importance of diameter of twine in the case of gill nets has been reported by von Brandt and Liepolt (1955), Mohr (1961), Gulbadamov(1962), Steinberg (1964), Znamensky (1963), Nayar et. al (1967) and Sulochanan and Krishna Rao (1964).

The relation between mass and diameter has been already discussed earlier (5.1). The influence of diameter on other properties such as twist, strength and knot strength of twines will be discussed under the respective topics. Klust (1973) stated that PA netting twines become thinner in wet condition compared to those of polyester, polyethylene, polypropylene and polyvinyl chloride diameter of which remained practically unchanged.

5.3 Twist

The method of twisting of twines from single yarns of monofilament, multifilament and staple yarns and the process of braiding have already been discussed under chapter II (Figures 1 and 2). The twist data presented in tables 3 to 11 show that before the introduction of synthetic twines, Indian fishermen were using vegetable materials like cotton and hemp, either single-stranded or multi-stranded with two, three or four strands. Hayhurst and Robinson (1959) are of opinion that in two stranded twines the interstices and the angle of lay are wide so that the twines do not have a round shape although they have the advantage that the strands cannot ride over one another. They contend that the three stranded construction is more stable and free from distortion than the other types, the reasons being that the cross section is in the form of a triangle which is not easily pushed out of shape; the angle of lay is more acute and the interstices are narrow. Although the twines with four strands give exceptionally round formation, the lay gets easily distorted causing uneven stresses.

Tauti (1929) in his studies on strength of cord in relation to twist observed that the balance between the primary twist for making strands from yarns and the secondary twist to make the twine from strand is very important, since an increased twist augments the tensile strength upto an optimum point, beyond which it produces an opposite effect. Kondo

(1938), Koizumi (1954) and Shimozaki (1957) mention that among cotton and synthetic twines with varying twists used for fishing gear in Japan, there is a difference of about 15 to 20% in tensile strength since an overtwisted and weaker twine may be found side by side with a correctly twisted stronger one. Hayhurst and Robinson (1959) stated that additional twists reduced the breaking strength and length per unit weight and improved the extension at break and resistance to abrasion and general wear.

When the strands are twisted, each strand makes a helix and the angle between this helix and the axis of the twine is commonly termed the 'angle of twist' (Figure 6).

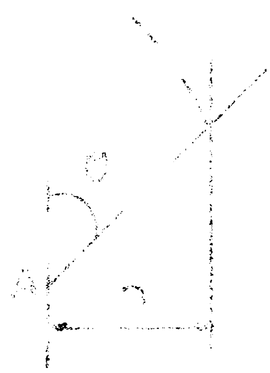


Fig. 6 Angle of twist of twine.

The degree of twist of a twine is represented by this angle. The greater the angle of twist, the harder is the twine. Twist can, therefore, be expressed by their number per unit length.

If AB represents the pitch of helix (length of twist), AC the length of helix, D the diameter and T the number of twist per unit length of twine, then, BC (circumference of twine) = πD

$$AB = \frac{1}{T}$$

$$\tan = \frac{BC}{AB} = \frac{\pi D}{\frac{1}{T}} = \pi DT$$

Accordingly, $T = \frac{\tan\theta}{D}$

or $D = \frac{\tan\theta}{T}$

The above formulae lead to the conclusion that when the diameter of the twine is constant, the number of twists per unit length is proportional to the angle of twist and when the angle of twist remains constant, the number of twists per unit length is inversely proportional to the diameter.

If, therefore, n and n_1 denote the total number of yarns constituting each twine, D and D_1 their respective diameters and W the mass of a thread of length L, then,

$$L \times \frac{\pi}{4} D^2 : L \times \frac{\pi}{4} D_1^2 = n W : n_1 W$$

Therefore $D^2 : D_1^2 = n : n_1$

ie. $D : D_1 = \sqrt{n} : \sqrt{n_1}$

If the angle of twist ' ' is constant in both the twines,

$$T : T_1 = D_1 : D$$

$$\text{or } T : T_1 = \sqrt{n_1} : \sqrt{n}$$

...

The number of twists therefore is inversely proportional to the diameter of twines and also to the square root of number of yarns, the size of the component yarn remaining the same. The twist data on different specifications of twines belonging to both vegetable and synthetic origin presented in tables 3 to 17 depict the above relationships.

The obvious difficulty in twisting a multistrandded twine is to give the appropriate outer twist in relation to the inner twist of the strand. If the proper ratio is not maintained between the inner and outer twists, the twine will be unstable and suceptible to twist in the direction of outer or inner twist whicever is more. Klust (op. cit) mentions that fish net twines can be made as soft, medium, hard and extra-hard as per requirements of various types of fishing gear and it may not be possible to specify the degrees of hardness by numerical values. Since twist is an important factor in the selection of material for different kinds of nets, an attempt has been made to find out the proper ratio between inner and outer twists and to evolve the twist-factors to produce twines having varying degrees of twists. Basic yarn of cotton of count number 20 was selected for this study. Using a hand-driven twine twisting machine shown in photograph 9, cotton twines of varying degrees of twists were prepared in two different directions viz. ZSZ and ZZS. Tables 19 and 20 present the number of inner and outer twists for soft, medium, hard and extra-hard twines of cotton made in

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Tables 19 and 20

ZSZ and ZZS directions.

The constant for the degrees of twists were worked out incorporating the total number and count number of yarns as,

$$T_o = K\sqrt{\frac{Ne}{n}}$$; where T_o is the outer twist per metre length of twine, n is the total number of yarns, Ne is the count number of yarn in the British system and K, the twist-factor depicting the 'degree of twist'. The K values found out for the different degrees of twists for cotton twines are as follows:

	ZSZ	ZZS
Soft	185	225
Medium	230	275
Hard	275	320
Extra-hard	315	355

By substituting the K values, total number and count number of yarns, the outer twist for different degrees of hardness for any specification of cotton twine can be estimated. The inner twist can be worked out from the relationship,

$T_o = KT_i$ where T_o is the outer twist, T is the inner twist. The constant K was found to be 0.28 for ZSZ direction and 0.54 for ZZS direction.

Table: 19. Twist specifications (twist/m) for cotton twines twisted in ZSZ direction with different twist factors.

Sl. No.		Soft		Medium		Hard		Extra-hard	
		outer	inner	outer	inner	outer	inner	outer	inner
1	20/ 2/3	323	1157	431	1543	502	1799	523	2047
2	20/ 3/3	263	941	351	1260	409	1468	468	1677
3	20/ 4/3	227	815	303	1087	354	1268	405	1453
4	20/ 5/3	204	728	272	972	318	1138	363	1299
5	20/ 6/3	185	661	247	882	283	1031	330	1181
6	20/ 7/3	172	614	229	819	268	957	306	1094
7	20/ 8/3	161	575	214	766	250	894	286	1024
8	20/ 9/3	154	539	202	730	236	842	270	964
9	20/10/3	144	515	193	687	225	803	257	921
10	20/11/3	137	488	183	653	213	762	244	874
11	20/12/3	131	468	175	626	205	732	234	835

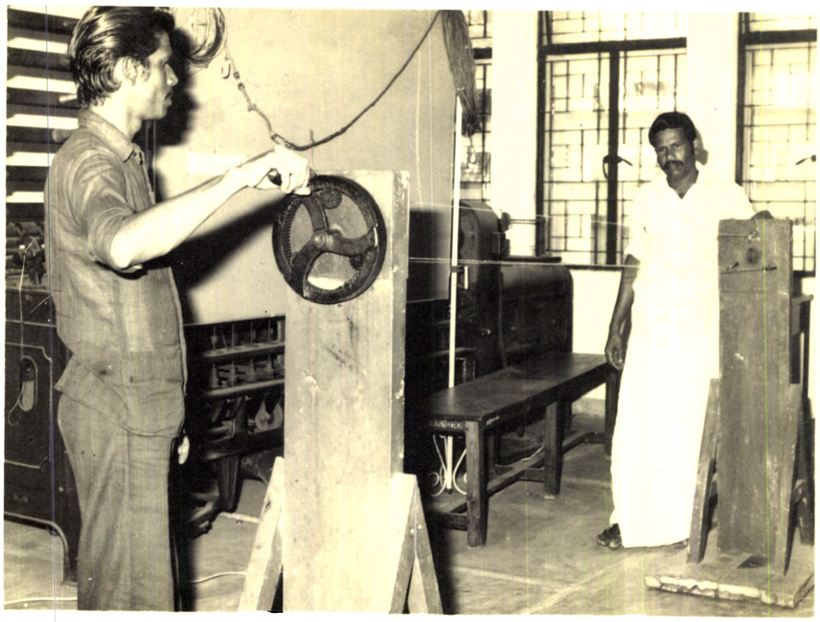
Table: 20 Twist specifications (twist/m) for cotton twines twisted in ZZS direction with different twist factors.

Sl. No.	Specification	Soft		Medium		Hard		Extra-hard	
		outer	inner	outer	inner	outer	inner	outer	inner
1	20/ 2/3	395	1200	502	1480	573	1665	646	1358
2	20/ 3/3	321	1004	409	1236	466	1389	525	1539
3	20/ 4/3	278	890	354	1090	405	1228	455	1437
4	20/ 5/3	250	815	318	996	363	1118	407	1232
5	20/ 6/3	227	752	288	913	330	1027	371	1138
6	20/ 7/3	211	709	268	862	306	961	344	1067
7	20/ 8/3	197	673	250	815	286	909	322	1008
8	20/ 9/3	185	642	236	775	270	866	303	957
9	20/10/3	177	620	225	748	257	835	289	917
10	20/11/3	168	596	213	716	244	799	274	878
11	20/12/3	161	579	205	695	234	772	263	846

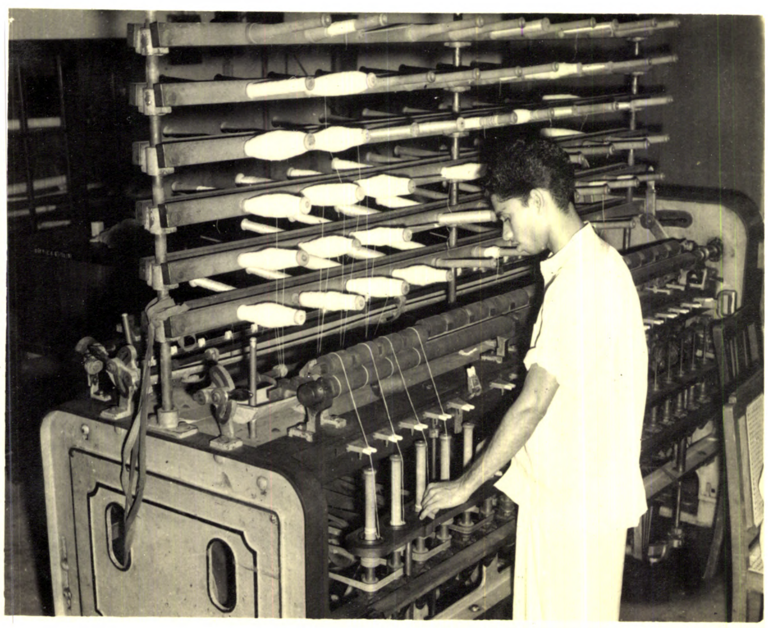
The suitability of the above twist factors tested using ring-type twisting machine (photograph 10) showed that cotton twines of soft and medium twists in the directions ZSZ and soft twines in ZZS could be made according to the suggested twist specifications, whereas in the case of twines with higher degrees of hardness kinks were formed in the strands. The reason for kink formation during strand twisting was investigated. Since the direction of outer twist was opposite to that of the twist of strand, a number equal to outer twist got untwisted from the strands during twine twisting operation. There was no provision in the case of ring type twisting machine to add inner twist during the latter operation to compensate the loss of inner twist by the change of direction of twist as in the case of hand-driven twine twisting machine. A further probe on the limitatión of the ring type machine showed that the higher the degree of hardness the greater was the contraction in length of yarn as shown in table 21 and 22.

Table 21 and 22

The above studies also indicated that the twist on twist (ZZ) in strand making operation required more of contraction in length of yarn than twist against twist (ZS). The experiments confirmed that twines which need greater contraction of length of yarn could be twisted according to the suggested standards in hand-driven twine twisting device where the twisting gear on the opposite side is fixed on



9. Hand driven twine twisting machine.



10. Ring type twine twisting machine.

Table: 2.1 Contraction (%) in length of cotton yarn during twine twisting operation using hand driven twine twisting device.

Degree of twists	Percentage contraction in length of cotton yarn by twisting	
	ZZS	ZSZ
Soft	18.5	10.4
Medium	25.1	18.3
Hard	38.2	25.9
Extra-hard	41.0	27.1

Table: 22. Contraction of yarns during twine twisting operations in ring type twisting machine. (Specification : cotton 20/5/3).

Sl. No.	Direction of twist: ZSZ — Twist per metre: outer	ZSZ — Twist per metre: inner	ZSZ — contraction observed (%): outer twisting	ZSZ — contraction observed (%): inner twisting (total contra-ction)	Direction of twist: ZZS — Twist per metre: outer	ZZS — Twist per metre: inner	ZZS — contraction observed (%): outer twisting	ZZS — contraction observed (%): inner twisting (total contra-ction)
1	100	460	4.8	5.3	193	323	6.5	8.2
2	205	547	5.5	7.4	189	401	6.2	9.1
3	201	582	5.1	7.4	208	500	7.0	13.3
4	318	795	10.6	14.4	260	657	9.1	16.1
5	362	885	13.3	17.9	315	780	12.3	21.0
6	389	996	16.0	20.8	394	975	17.6	27.2
7	421	1146	17.3	24.5				

wheels and can be drawn closer so as to provide for the required contraction in length of yarn during the twisting process.

The twist data on synthetic twines presented in table 12 to 17 were analysed. The K values showing the relation of inner to outer twist per metre length of twine show that the outer twist is about 58% of the inner twist in the case of polyamide multifilament twines, 52% in polypropylene multifilament twines and 50% in polyethylene flat tape twines. In the case of polyethylene twisted monofilaments and polyethylene fibrillated tape twine, this relationship is found to be erratic. Samples of polyamide multifilament and polyethylene monofilament twines procured from different traders were subjected to analysis of physical properties to note the twist-factors. Tables 23 and 24 present the properties of similar specifications of twines made of PA multifilaments and PE monofilament twines. It is evident from

Table 23 | Table 24

these tables that the traders are not following any set pattern in selecting the twist-factors for the production of twines and the physical properties of twines are affected to a certain extent by adopting different twist specifications.

Table:23 Physical properties of similar specifications of nylon twines obtained from different traders

Firm	Specification	Diameter (mm)	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Breaking Strength (Kg) dry	Breaking Strength (Kg) wet	Breaking Stretch (%) dry	Breaking Stretch (%) wet	Tenacity (g/den) dry	Tenacity (g/den) wet
A	210x2x3	0.56	0.15	296	292	7.1	6.4	28.0	32.0	4.9	4.5
B	210x2x3	0.61	0.16	278	304	8.1	6.7	26.0	25.4	5.8	4.9
C	210x2x3	0.60	0.11	367	259	4.4	3.9	31.4	33.3	4.6	4.0
A	210x3x3	0.71	0.23	298	240	11.1	10.5	26.8	33.4	5.2	4.9
B	210x3x3	0.72	0.24	246	234	13.3	11.0	30.6	27.8	6.4	5.3
C	210x3x3	0.76	0.24	263	513	10.8	10.4	30.4	31.6	6.1	6.0
A	210x4x3	0.86	0.31E	214	216	15.2	13.9	29.0	35.0	5.3	4.8
B	210x4x3	0.77	0.32	199	226	17.9	14.4	29.8	27.8	6.4	5.2
C	210x4x3	0.99	0.34	265	267	13.0	11.9	40.0	43.6	4.3	3.9
A	210x5x3	1.10	0.42	242	258	19.2	17.6	38.0	48.5	5.1	4.7
B	210x5x3	0.96	0.41	190	242	21.8	18.4	31.4	32.4	6.0	5.1
C	210x5x3	0.95	0.40	198	214	19.5	16.9	29.2	33.8	5.3	4.6
A	210x6x3	1.08	0.52	222	302	21.5	20.5	40.5	47.0	4.5	4.3
B	210x6x3	1.12	0.53	226	268	24.0	19.1	38.4	40.0	5.1	4.1
C	210x6x3	1.16	0.51	236	256	22.5	20.5	38.0	40.2	4.9	5.5

Table: 24 Physical properties of similar specifications of polyethylene monofilament twines obtained from different traders.

Firm	Specification	Diameter (mm)	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Breaking Strength (Kg) dry	Breaking Strength (Kg) wet	Breaking Stretch (%) dry	Breaking Stretch (%) wet	Tenacity (g/den) dry	Tenacity (g/den) wet
A	2 x 3	0.661	0.211	323	88	7.3	7.4	24.0	23.8	3.8	3.9
B	2 x 3	0.788	0.299	272	210	5.0	5.6	41.6	31.8	2.7	3.0
C	2 x 3	0.708	0.215	257	121	7.3	7.5	24.8	22.8	3.8	3.9
A	3 x 3	0.904	0.386	289	60	12.9	13.3	27.3	28.8	3.7	3.8
B	3 x 3	0.988	0.338	199	188	8.1	8.8	33.3	27.8	2.6	2.9
C	3 x 3	1.075	0.346	208	101	13.4	14.0	26.8	27.8	4.3	4.5
D	3 x 3	1.040	0.513	291	115	12.5	14.6	39.7	37.0	2.7	3.2
A	4 x 3	1.007	0.446	144	67	11.5	13.2	34.0	24.6	2.9	3.0
B	4 x 3	1.119	0.520	196	156	8.0	8.6	91.3	72.0	1.7	1.8
C	4 x 3	0.940	0.181	120	93	8.9	10.3	41.4	31.8	2.7	3.2
A	5 x 3	1.191	0.620	273	68	20.3	20.9	30.8	30.3	3.6	3.7
B	5 x 3	1.317	0.639	168	25	13.7	15.9	41.8	27.4	2.4	2.8
C	5 x 3	1.200	0.569	180	147	18.7	19.0	30.8	30.3	3.6	3.7
D	5 x 3	1.205	0.566	140	40	14.5	15.6	46.6	37.4	2.8	3.1
A	6 x 3	1.361	0.679	130	50	17.3	18.7	48.0	37.9	2.9	3.1
B	6 x 3	1.349	0.815	240	28	23.9	24.6	33.3	32.4	3.2	3.3
C	6 x 3	1.420	0.732	171	130	21.4	21.5	26.3	23.6	3.2	3.3

Experimental twisting was carried out in the laboratory using hand-driven twine twisting machine and different specifications of synthetic twines were made from nylon multifilament yarn of 210 denier, polyethylene monofilament of 250 denier, polyethylene flat tape and fibrillated tape twines of 1000 denier. Since wide variations in the degree of twists are not used among the different synthetic twines as in the case of cotton twines, suitable twist-factors were worked out for soft and hard twisted nylon and medium twisted twines of polyethylene monofilament, flat tape and fibrillated tape.

Tables 25, 26, 27, 28 and 29 present the twist specifications and strength of balanced twines of PA multifilament of 'soft' and 'hard' twists and PE monofilament, PE flat tape, PE fibrillated tape of medium twist.

Tables 25, 26, 27, 28 & 29

However, the synthetic twines can be made by different twist-factors and even if the inner and outer twists are not balanced, the twist can be set by post twisting stabilising treatments such as thermosetting and application of bonding agents. The twist specifications prescribed here can be used as guidelines for making balanced twines of polyamide multifilament, polyethylene monofilaments, flat tape and fibrillated tape twines without any twist-setting process. From the above twist specifications the relationship between outer twist and inner twist, total number and denier number of yarns were

Table: 25 Specifications for soft twisted polyamide multifilament(nylon) twines.

Sl. No.	Specification	Mass per metre (g)	Runnage m/kg	Twist per metre outer	Twist per metre inner	Breaking Strength Min. (Kg) dry	Breaking Strength Min. (Kg) wet
1	210x 2x3	0.16	6200	310	560	6.3	5.4
2	210x 3x3	0.24	4200	250	450	9.5	8.1
3	210x 4x3	0.33	3000	230	410	12.6	11.7
4	210x 5x3	0.41	2400	210	380	15.7	13.4
5	210x 6x3	0.51	1950	255	460	18.9	16.1
6	210x 7x3	0.59	1700	225	420	22.0	18.7
7	210x 8x3	0.65	1550	200	360	25.2	21.4
8	210x 9x3	0.77	1300	170	310	28.2	24.2
9	210x12x3	1.00	1000	155	305	37.8	32.2
10	210x15x3	1.28	780	145	270	46.5	40.0
11	210x18x3	1.51	660	135	250	56.5	48.0

Table: 26 Specifications for hard twisted polyamide multifilament (nylon) twines.

Sl. No.	Specification	Mass per metre (g)	Runnage (m/kg)	Twist per metre outer	Twist per metre inner	Breaking Strength Min. (Kg) dry	Breaking Strength Min. (Kg) wet
1	210x 2x3	0.17	6000	490	870	6.1	5.1
2	210x 3x3	0.25	4000	395	720	9.2	7.6
3	210x 4x3	0.36	2800	360	630	12.2	10.0
4	210x 5x3	0.43	2300	300	550	15.3	12.6
5	210x 6x3	0.54	1850	285	510	18.3	15.2
6	210x 7x3	0.62	1600	265	475	21.4	17.5
7	210x 8x3	0.70	1420	250	450	24.4	20.2
8	210x 9x3	0.82	1220	230	420	27.6	22.2
9	210x12x3	1.06	940	200	365	36.8	30.2
10	210x15x3	1.35	740	180	328	46.0	37.8
11	210x18x3	1.59	630	164	296	55.0	45.0

Table: 2.7 Specifications for polyethylene monofilament twines. (yarn diameter 0.2mm)

Sl. No.	Speci-fication	Mass per metre (g)	Runnage (m/Kg)	Twist per metre outer	Twist per metre inner	Breaking Strength Min. (Kg) dry
1	2x3	0.23	4400	260	410	6.0
2	3x3	0.33	3000	220	360	8.0
3	5x3	0.62	1600	170	280	15.5
4	6x3	0.77	1300	155	250	19.0
5	9x3	1.18	850	130	220	29.0
6	15x3	1.82	550	120	200	40.0
7	24x3	3.08	325	90	155	65.0
8	30x3	4.35	230	80	140	90.0
9	45x3	6.67	150	75	125	140.0
10	60x3	8.00	125	70	120	170.0

Table 28 : Specification for twines made of PE flat tape.

Sl. no.	Speci-fication	Diameter (mm)	Runnage (m/kg)	Twist per metre Outer	Twist per metre Inner	Breaking Strength (Kg)
1	2 x 3	1.0	500	175	290	17
2	4 x 3	1.5	570	170	285	34
3	5 x 3	2.0	490	165	272	43
4	8 x 3	2.5	315	120	260	65
5	12 x 3	3.0	210	100	225	98

Table: 29 Specifications for twines made of Polyethylene(HDPE) fibrillated tape.

Sl. No.	Speci-fication	Mass per metre (g)	Dia-meter (mm)	Runnage (ms/Kg)	Twist per metre outer	Twist per metre inner	Breaking Strength Min.(Kg) dry
1	1000x1x3	0.34	0.75	2900	200	390	8.5
2	1000x2x3	0.64	1.00	1550	170	350	15.5
3	1000x3x3	1.05	1.50	950	150	310	25.0
4	1000x4x3	1.43	1.75	700	135	300	32.4
5	1000x5x3	1.82	2.00	550	130	290	40.0
6	1000x6x3	2.22	2.20	450	125	275	49.1
7	2000x1x3	0.71	1.25	1400	170	295	17.5
8	2000x2x3	1.44	2.00	695	130	260	31.5
9	2000x3x3	2.22	2.25	450	115	230	52.4
10	2000x4x3	3.08	2.50	325	105	210	65.0
11	2000x5x3	3.70	2.75	270	95	200	80.0

worked out and the K values are presented in table 30.

Table 30

By substituting the respective K values for different types of materials, the approximate outer and inner twists of synthetic twines of any specification can be estimated.

The guidelines given in table 25 and 26 for twisting nylon twines were tested by some of the twine twisting factories in India and the twines showed stability of inner and outer twists and expected strength and related properties. Field studies conducted at Central Institute of Fisheries Technology also showed suitability of soft twisted nylon twine for gill nets in marine and inland waters, while hard twisted twines were better suited for trawl nets, purse seine, and other types of nets which require high sinking speed. Polyethylene monofilament twines of different specifications were made by many firms in India as per guidelines given in Table 27 and the products tested in the field successfully for fishing gear like trawls, stake nets, dip nets, traps, etc. Since the material is light proper rigging attachments were provided to keep the nets in the concerned fishing positions. Due to the rigidity and buoyant nature, the material is unsuitable for gill net fishery where pliability is a criterion for selection. Because of the cheapness of the fibre, polyethylene monofilaments are extensively used for making ropes. Braided twines made of polyethylene monofilaments

Table:30 The relationship between outer twist, inner twist, total number of yarns and count number of yarn

Sl. No.	Materials	The values of constants (k) in the relationship To = KTi	To = K	To = K
1.	PA multifilament soft twisted twines	0.55	900	15670
2.	PA multifilament hard twisted twines	0.55	1200	17600
3.	PE monofilament twines	0.60	740	12300
4.	PE flat tape twines	0.60	575	18200
5.	PE fibrillated tape twines	0.47	450	14700
6.	PP multifilament twines	0.52	720	10000

have also been introduced recently in Indian fishing industry. However the utility of this material for trawls, traps and lines are to be tested by conducting field trials. The polyethylene flat tape twines made by a firm according to the guidelines given in table 28 were found to be more or less like polyethylene monofilament twines and suitable for nets where rigidity is a criterion for selection. The twines produced by a firm according to the suggested standards were tested for their utility in fabrication of trawl nets. Comparative studies of trawl nets made of different materials proved the utility and cheapness of flat tape twines for bottom trawl nets (Kartha et al 1977). The standards given in table 29 were tested for production of fibrillated tape twines in a firm. The twines manufactured were found to be more flexible than twines made of polyethylene monofilaments and flat tape and resemble those made of bast fibres. Apart from utilising the fibrillated tape twines for trawls, stake nets, dip nets and similar types of fishing gear, it is expected that these twines can also be used as a substitute material for hemp twines in gill net fishery with proper rigging attachments since the density of the material is less than that of water. Field trials on this material are yet to be carried out to find out its suitability for different types of fishing gear.

5.4 BREAKING STRENGTH

The breaking strength of a twine depends on the inherent properties of the basic raw material such as the kind of fibre, mode of preparation of yarn and methods of construction of twines. The inherent properties of vegetable and synthetic fibres are given in tables 1 and 2. It is evident from table 2 that the polyamide, polyester and polypropylene multifilament fibres possess higher strength than other groups of polymers. It is reported by Arzano (op. cit) that polyamide, polyester and polyvinyl alcohol filaments can be made into normal and high tenacity fibres by increasing the draw ratio, by which the strength per denier shows a substantial increase of 40-45% in the case of high tenacity fibres. Klust (op. cit) mentions that the polyvinyl alcohol fibre was first introduced in fishing industry as staple fibres which were further modified as continuous fibres having considerably high breaking strengths. Polyvinyl chloride and polyvinylidene chloride fibres have lower strengths compared to polyvinyl alcohol. Since polyvinyl chloride was cheaper the material was consumed in large quantities for fishing purposes; but it was gradually displaced by polyethylene which has got comparatively better properties than polyvinyl chloride.

The effect of twist on the strength of twines, the balance between the inner and outer twists, the degree of twist, and the methods of construction of twines have already been discussed earlier. Lonsdale (1959) found the ratio of twine strength to aggregate yarn strength to be 95% in case of nylon. Honda (1956) has reported about the influence of the length of test-piece on the breaking strength of twines; the longer the piece, the stronger they are. Between twines of the same material and thinner than 60 yarns of C-20 equivalent, the difference in breaking strength was not conspicuous. Warenzeichenverband (op. cit) observed that the specific tenacity of monofilaments decreases with increasing diameter, for example it is 70 - 80% for 0.1 to 0.3 mm diameter, 60 - 70% for 0.35 - 0.70 mm and 50 - 60% for monofilaments above 0.7 mm. He also found that a high degree of stretching of fibres resulted in considerable increase in strength of twines. Imperial Chemical Industries (1959) give a comparative account of strengths of terylene, amilan and nylon twines of different specifications which shows that the strength of terylene is unaffected by wetting whereas amilan and nylon lose strength in wet state. With regard to the difference in the wet and dry strengths of twines, Shimozaki (1959) found that natural fibre twine is about 10 - 20% stronger in wet condition than dry; but it is the other way with amilan and kurelon. With teviron, saran and kuralon the wet twines were found to be 3.5% stronger than dry ones (Shimozaki 1951).

It has already been proved by Kuriyan and Cecily (op. cit) that breaking strength is directly proportional to the square of the diameter of twines and the total number of threads constituting the twine when the count number of yarn is the same. Table 31 presents the constants worked out in the case of vegetable fibre twines for the relationships $S = Kn$ and $S = KD^2$; where S is the breaking strength of twines in kilograms, n is the total number of yarns, D is the diameter (mm) and K, the constant of proportionality.

Table 31

It would be seen that K in the equation $S = Kn$ stands for the strength per yarn of the twine which is found to be higher in the case of soft twisted cotton twines when compared to hard-twisted ones. This finding is in conformation with the earlier observation that harder the twist, the lower the breaking strength. The constants obtained for twines made of yarns of different count numbers show that the breaking strength of a single thread is inversely proportional to the count number of yarns (indirect system) as can be seen from the above table. In the case of vegetable fibre twines other than cotton, this relationship could not be worked out as the size of yarn is not discernable. Hence the relationship of strength and diameter square was worked out in the case of Sunhemp, Italian hemp, flax, sisal, manila and coir. A comparison of the K values in the above relationships shows that Italian hemp is more than twice as strong as Sunhemp. Strength decreases in the order flax, manila, Sunhemp and sisal. Coir twines exhibited poor strength when compared to other materials

Table 31 Relationship of strength, number of yarns and diameter of vegetable fibre twines.

Materials			Value of K in the relationship $S = Kn$ Dry	$S = Kn$ wet	$S = KD^2$ dry	$S = KD^2$ wet
1. Cotton-Handmade						
	6	count	0.98	1.06	4.1	4.4
	10	"	0.71	0.89	3.4	4.3
	14	"	0.52	0.56	4.6	5.0
	20	"	0.35	0.46	4.2	6.0
	40	"	0.16	0.19	4.0	4.3
machinemade						
soft twisted	20	"	0.49	0.55	7.1	8.2
	30	"	0.31	0.38	9.5	11.3
	40	"	0.24	0.28	9.1	10.2
hard twisted	20	"	0.45	0.52	7.3	8.6
			$S = KW$		$S = KD^2$	
2. Sunhemp			9.90	11.3	6.4	7.4
3. Italian hemp			20.20	20.6	15.6	16.1
4. Flax			15.20	17.3	9.1	10.4
5. Sisal			11.00	11.9	6.3	6.9
6. Manila			12.80	13.7	7.2	7.6
7. Coir			4.40	4.1	1.2	1.1

S = Breaking strength (Kg)

n = Total no. of yarns

D = Diameter

W = Mass/metre

K = Constant.

tested. The increase of strength in wet condition were 16.1% in the case of sunhemp, 14.2% in flax, 13.5% in cotton, 8.1% in sisal and 6.9% in manila. The increase in strength of Italian hemp by wetting was only 2.9%, while coir showed a reduction in strength of 7.5% in the wet state.

The correlations (r) between the diameter square and breaking strength in dry and wet conditions of different synthetic materials are as follows:

Materials	'r' values	
	Dry	Wet
PA multifilament twines	0.996	0.996
PE monofilament twines	0.974	0.980
PE monofilament braided	0.940	0.916
PE flat tape twine	0.996	0.994
PE fibrillated twine	0.980	0.978
PP multifilament twine	0.992	0.984

In all these cases the 'r' values are positive and highly significant (p 0.01) which proves the linear relationship between the two. The regression equations of breaking strength (Y) on diameter square (X) are given below:

Materials	Dry	Wet
PA multifilament twines	Y=22.24 X	Y=20.13 X
PE monofilament twines	Y=10.62 X	Y=12.30 X
PE monofilament braided	Y=13.82 X	Y=15.31 X
PE flat tape twine	Y= 9.39 X	Y=10.36 X

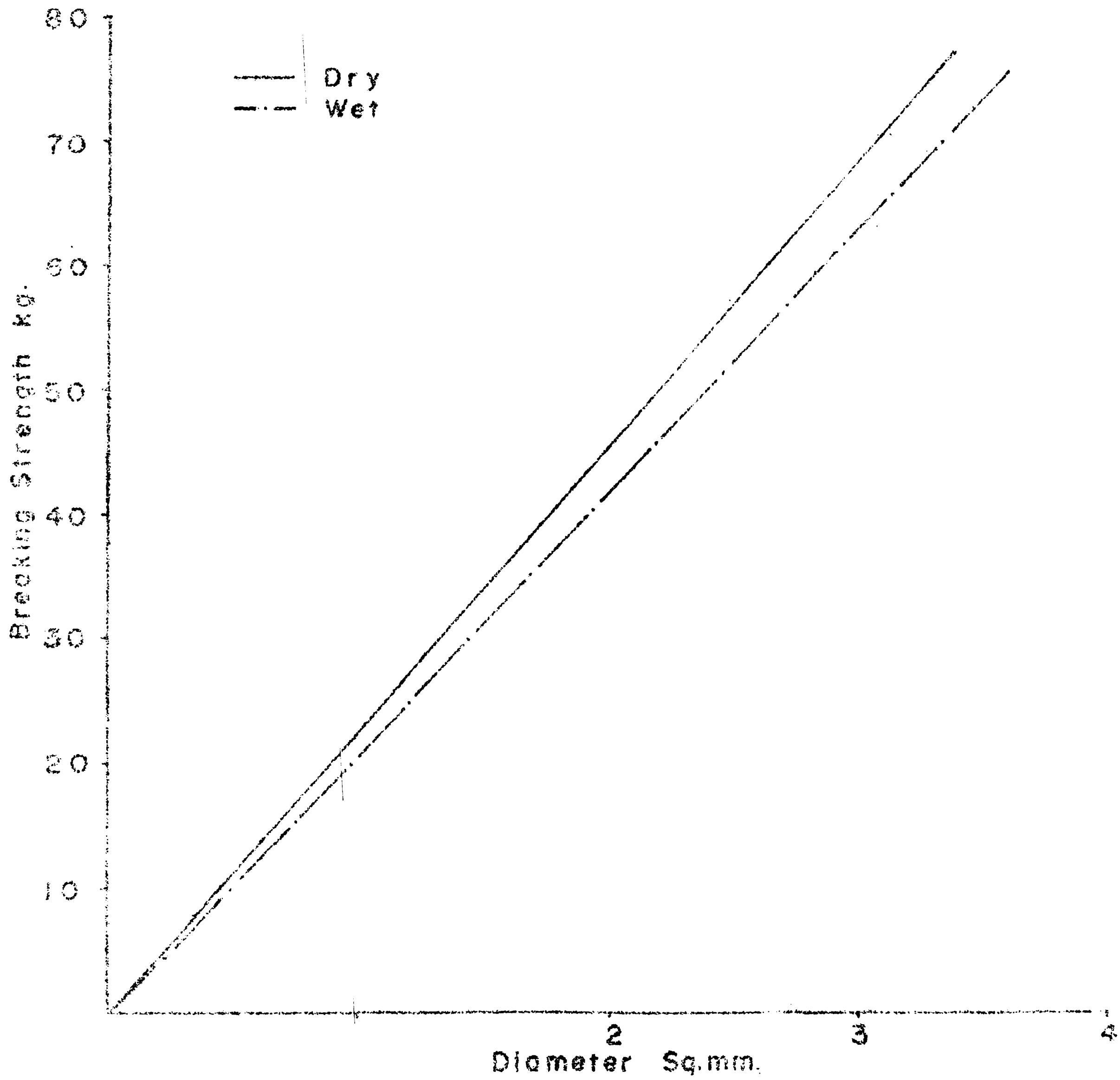
PE fibrillated twine	Y=11.92 X	Y=13.33 X
PP multifilament twine	Y=19.48 X	Y=19.94 X

From the above equation it may be seen that PA multifilament has got the maximum strength followed by PP multifilament, PE braided, PE fibrillated, PE monofilament twines and PE flat tape twines in the descending order.

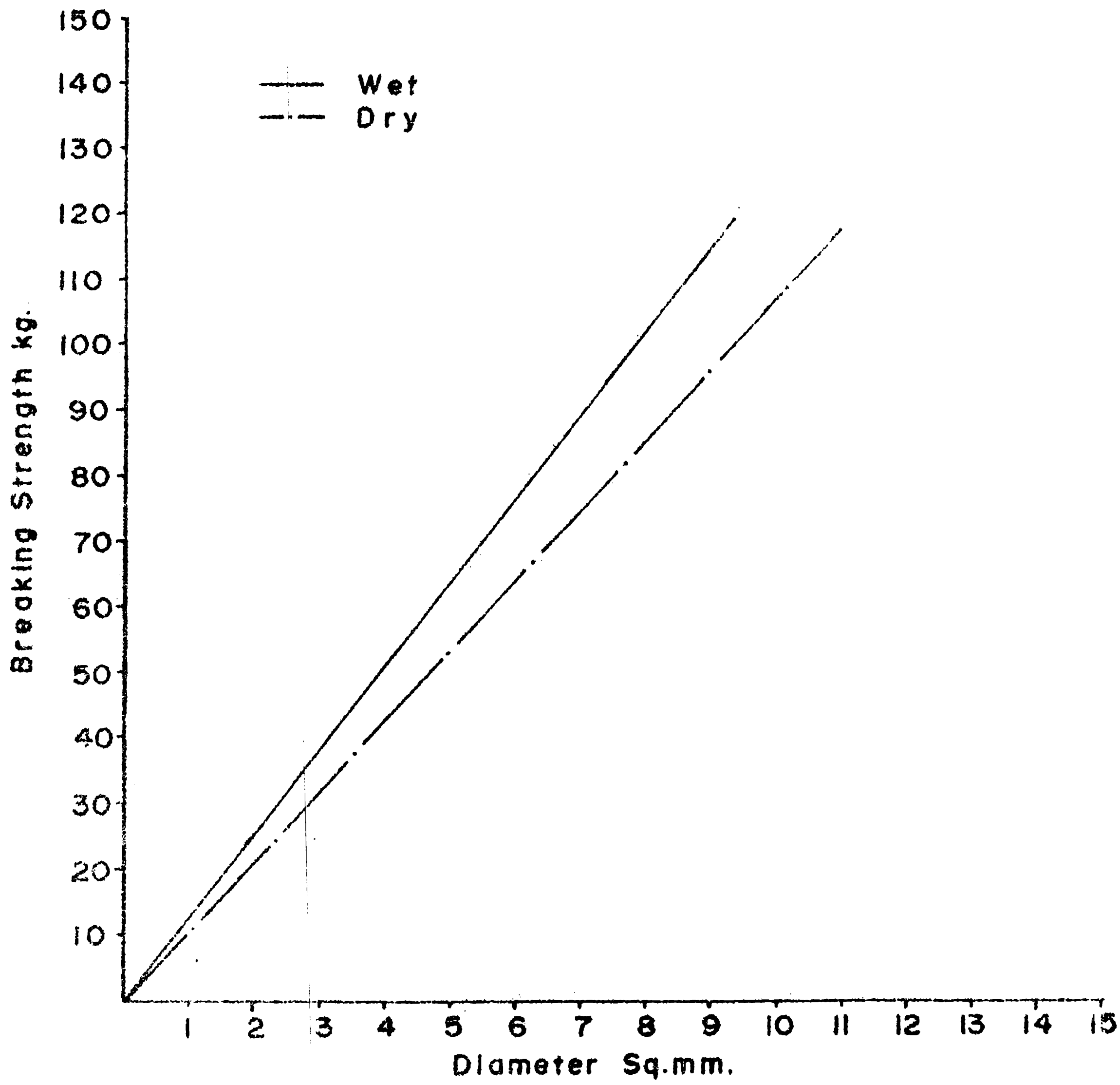
By applying paired 't' test, dry and wet strengths were compared. There is highly significant (p 0.001) reduction in strength (-10.2%) in the case of nylon twines in the wet state as can be seen from figure 7. In the case of PE monofilament twines, the strength improved by wetting by 15.8% (figure 8). Braided twines showed an increase of strength of 10.9% in the wet state as can be seen from figure 9. The rate of increase in strength in case of flat tape twines is 10.3% and that of fibrillated twine is 11.8% as is evident in figures 10 and 11. From the above figures it can be concluded that polyethylene twines, whatever be the form of yarn for making twines show improvement of strength by wetting. In the case of polypropylene multifilament twines, the difference in strength in dry and wet conditions was not significant as it is more or less constant. In this case, both dry and wet strength were combined to get a common regression line ie. Y=19.71 X as presented in figure 12.

Figures 7, 8, 9, 10, 11 and 12

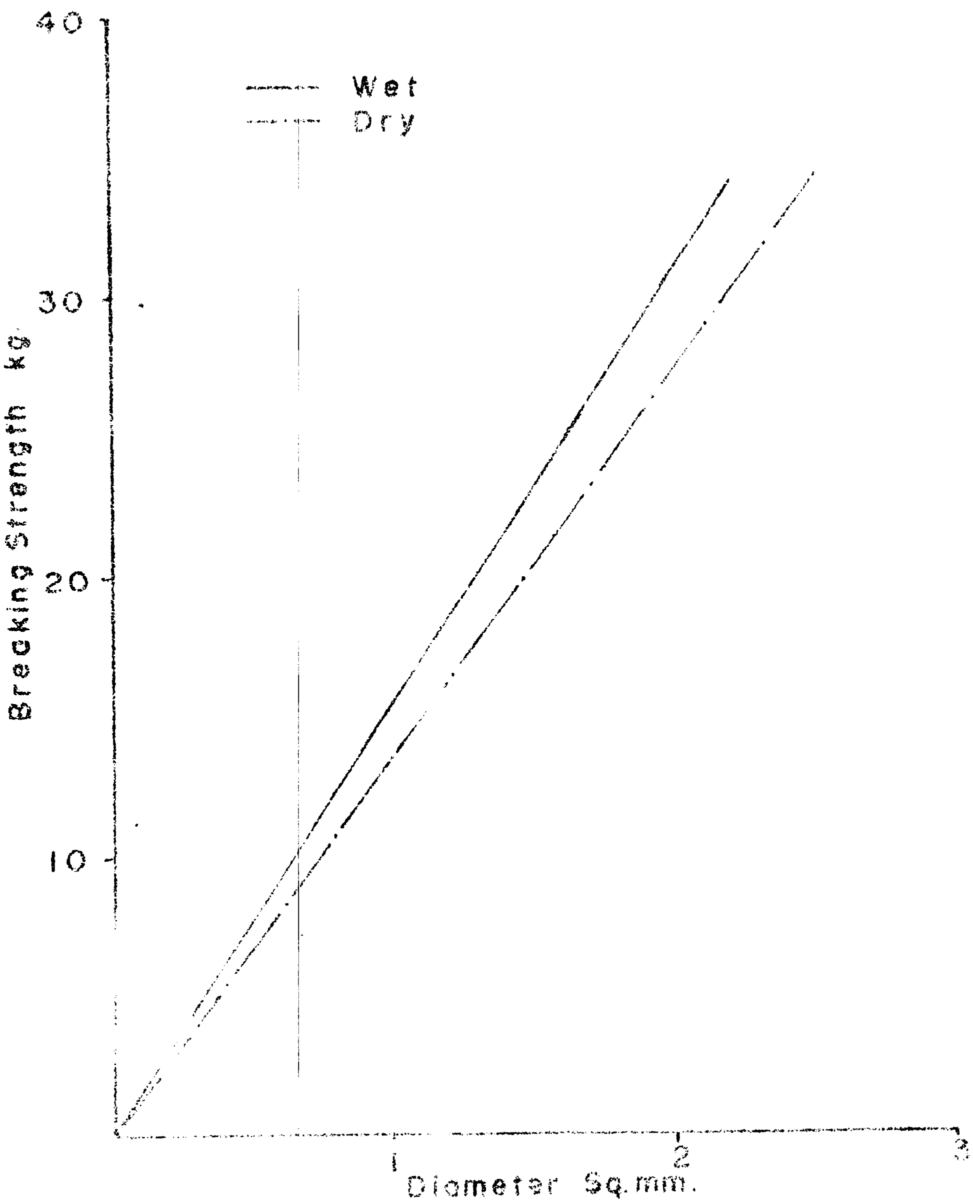
RELATIONSHIP BETWEEN BREAKING STRENGTH AND DIAMETER - PA Multifilament twines Fig: 7



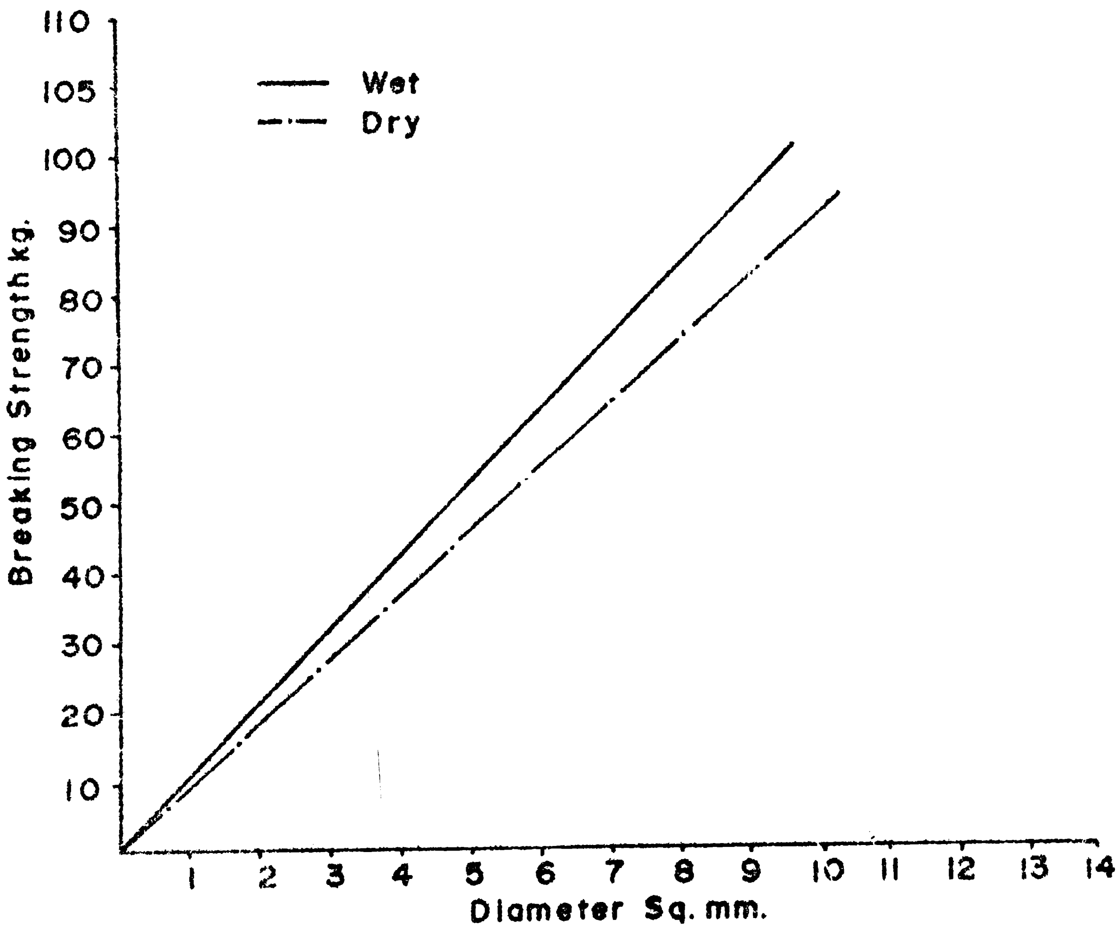
RELATIONSHIP BETWEEN BREAKING STRENGTH AND DIAMETER - PE Monofilament twines Fig: 8



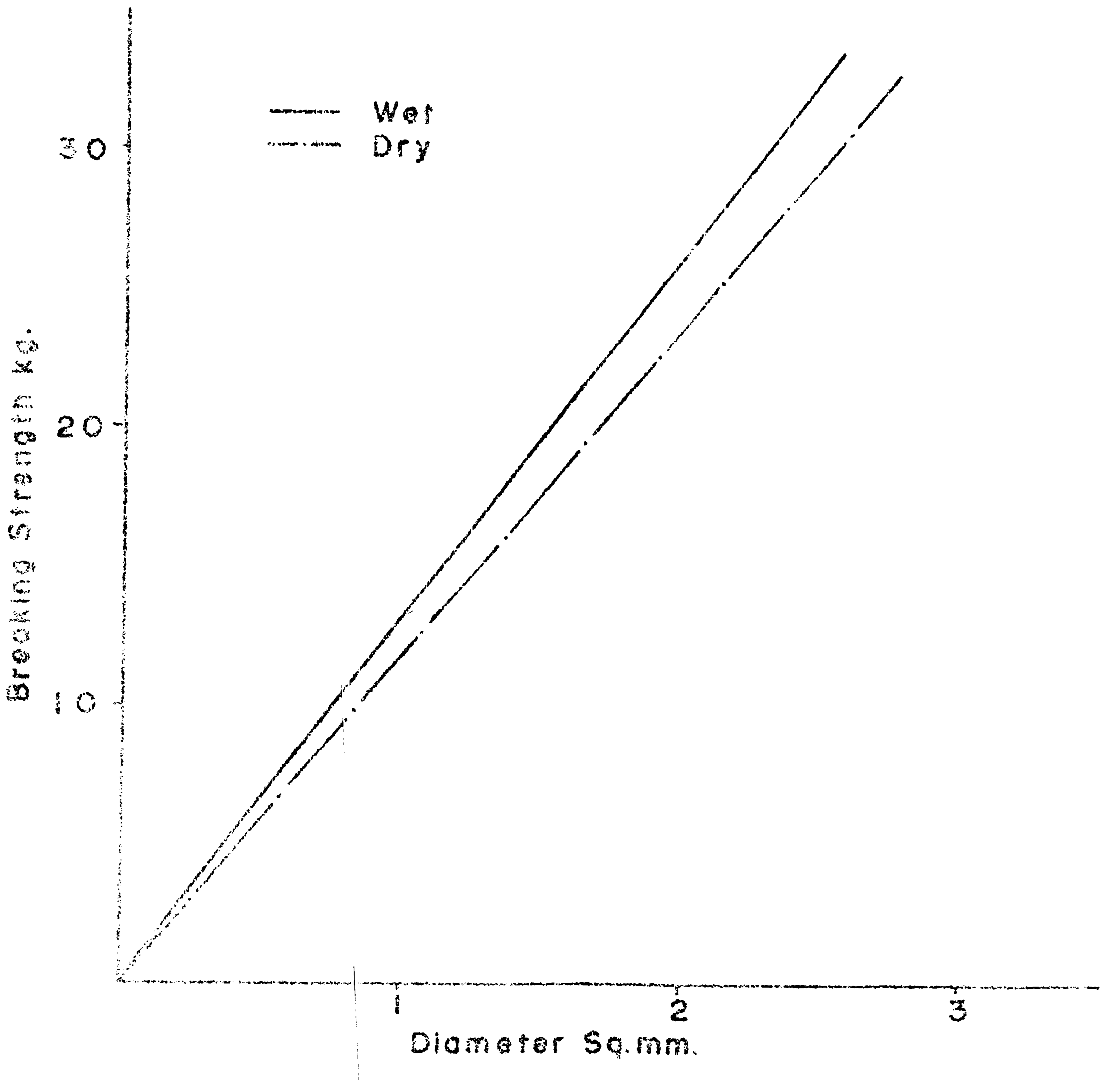
RELATIONSHIP BETWEEN BREAKING STRENGTH AND DIAMETER - PE Monofilament braided twines Fig:9



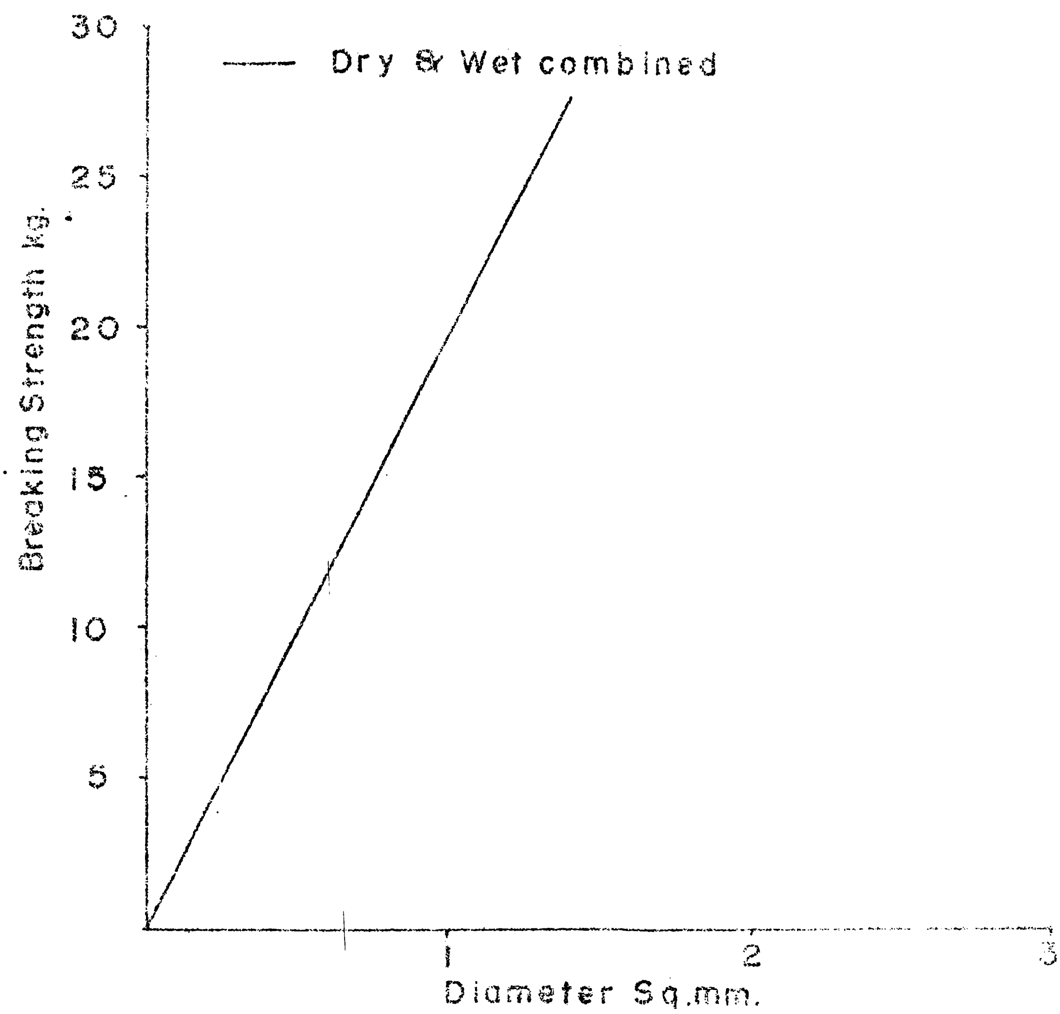
RELATIONSHIP BETWEEN BREAKING STRENGTH AND DIAMETER— PE Flat tape twines. Fig: 10



RELATIONSHIP BETWEEN BREAKING STRENGTH AND DIAMETER - PE Fibrillated tape twines Fig: II



RELATIONSHIP BETWEEN BREAKING STRENGTH AND DIAMETER - PP Multifilament twines Fig:12



5.5 Elongation

As in the case of strength, the extensibility of fish net twines depends on several factors such as kind of fibre, its inherent qualities, fibre processing and method of preparation of yarn and twines. ICI (op. cit) records that the extensibility is more for polyamide group of fibres and comparatively small for polyester. Under the same group of fibres, the extensibility depends on whether the fibre is a multifilament, monofilament or staple. Arzano (op. cit) has reported that twines made of staple yarns produce higher degree of stretch than continuous filament twines. He has also indicated that pre-stretching in the preparation of polyamide and polyester fibres of continuous filament and polyvinyl alcohol fibres of both continuous filament staple yarns results in considerable decreases in the breaking extension when compared to normal tenacity yarns.

The breaking stretch values of various specifications of single and multistranded cotton twines soft and hard twisted cotton twines, sunhemp, Italian hemp and coir twines are presented in tables 3 to 10 and the comparative stretch properties of vegetable fibre twines are included in table 11. It is evident that the breaking stretch is more in hard twisted cotton twines than soft twisted ones. Reuter (1959) observed that the total extension at break of manila rope was more with normal lay than hard and soft laid ropes in dry condition. Contrary to this, in the wet condition he observed higher total extension at break in case of manila ropes with hard and soft lay than with normal lay. The twist specification studies on nylon twines of soft and hard lay also indicated higher breaking stretch values for hard laid nylon twines than their soft counter parts.

Regarding the comparative breaking stretch values of different vegetable fibre twines, it would be evident from table 11 that the extensibility of sunhemp is lower than Italian hemp and flax. Sisal and manila twines exhibited almost the same breaking stretch, while cotton and coir showed comparatively greater elongation when compared to other vegetable fibre twines. In all the vegetable fibre twines tested, the breaking stretch was found to be more in wet condition than in dry.

Data collected in the breaking strength of different types of synthetic fibre twines showed the correlation between diameter and dry and wet breaking stretch to be non-significant in all types of twines tested. One of the possible explanations is that the stretches of twines are independent of thickness. This is an important finding since in gill nets, the stretch of twine is an important factor for the capture of suitable species, as an increase in the mesh size may become responsible for the escape of gilled fish. Based on this finding, allowance need be given only to the inherent stretching property of the fibre and the method of construction of twines. Klust (op. cit) has reported that most of the synthetic twine. are hydrophobic in general and their dry and wet elongations are nearly identical. But he has noted slight increase in elongation in the case of polyamide twines as the material can absorb sufficient moisture to affect not only the breaking strength but also the elongation. Observations on the effects of wetting on synthetic twines showed a marginal decrease of stretch in wet condition compared to dry stretch in case of nylon twines (table 12). The percentage breaking stretch of polyamide multifilament in the dry state was in the range (23, 29). In polyethylene monofilament twines, the percentage breaking stretch in the dry condition was observed to be in the range (23, 48). The decrease of stretch from dry to wet condition in the case of polyethylene monofilament was found to be highly significant. In wet state the breaking stretch was mostly in the range (28, 38). As regards polyethylene monofilament braided twines the decrease in stretch in the wet state was significant at 5% level. Braided twines registered a very high breaking stretch ranging from 50 to 98% in the dry state and decreased to 40 to 84% in wet condition. The variation of stretch values observed in the case of polyethylene twisted monofilament and braided twines is attributed to the variation in the stretching property of the different samples. Polypropylene multifilament twine is found to have the minimum breaking stretch of 23 to 29% in the dry condition and the difference between dry and wet

...

breaking stretch the difference was non-significant.

It can also be stated that the stretching property of polyamide multifilament and polypropylene multifilament follow a similar pattern. Both were having the minimum breaking stretch among the materials tested and the breaking stretch was unaffected by wetting.

5.6 STRESS-STRAIN BEHAVIOUR OF FISH NET TWINES:

In textile industry much importance is attached to the tenacity of the fibre; but for fishing purposes extensibility is an equally important property especially the behaviour of the fibre when stressed to a degree not reaching the breaking point. The elastic behaviour of a fibre is referred to as 'Young's modulus'. The textile fibres do not obey Hooke's law which states that strain is proportional to stress. They obey this law only upto a stage called 'yield point', beyond which the fibres exhibit a plastic flow. Where Hooke's law is applicable, the 'Young's modulii' of different fibres are comparable. Arzano (op. cit) stated that deformation caused by strain consists of two components, an elastic extension which is recoverable on release of stress and a permanent elongation which is not recoverable. The former is of great importance for several end uses. According to him the area under the load-elongation curve depicts the ability of the twine to absorb energy which may be the same for low tenacity and high tenacity fibres, as in the former case the strength is low and the extension is high and vice versa in the latter. The knowledge of the stress-strain behaviour of twines on the different parts of the net is therefore needed to counteract the deformation that the nets undergo during fishing operations.

The shape of the load-elongation curve is different for the various types of fish net twines as it depends on the inherent stretching properties of fibre at increasing loads as well as on the manufacturing pattern to a certain extent. The trawls, especially cod ends made of hard fibres like manila and sisal, withstand sudden shock loads, but because of their very small extension properties, they are not able to absorb the kinetic energy. The net in operation is not only subjected to dead loads, but the tension that plays on the net is dragged against the current and the force exerted by struggling fish may have to be absorbed by the net. If the net can absorb the energy inflicted on it, the material selection can be considered to be proper.

Carrothers (op. cit) suggested that salmon nylon nets need not be so strong as linen gill nets to hold the same gravity of fish due to the high degree of elastic extension shown by the former. Warenzeichenverband (op. cit) has shown the load-extension curve of perlon climb at a more obtuse angle than that of natural fibres which show greater working capacity enabling it to absorb shocks like spring. Stretched nylon recovers its original length very soon except for the permanent elongation which is approximately 10%. He found that immediately after the application of load, a high degree of extension ensured which regained its equilibrium within the next 15 to 20 minutes. As indicated earlier the extension was found to be proportional to the increase in the load which was relatively greater at low and medium loads than at high loads. Hans Stutz (op. cit) compared the load-extension properties of different twines in dry and wet conditions. Perlon and trevira were tested in continuous and spun forms and differences in behaviour were observed under small to medium loads, which are very significant for practical purposes. In polyester the load-elongation curve is relatively steep at low load, which is advantageous to certain types of nets. Klust (1973) observed that perlon continuous filaments have higher tenacity and lower extension than those of spun yarn. Comparing perlon and trevira twines of similar thickness showed much better wet tenacity in the latter. He observed that twines of staple fibres are more extensible than those of continuous filament.

The stress-strain behaviour of different netting twines are presented in Figures 13 to 19. The load (kg) is plotted on the ordinate and elongation (%) on the abscissa.

It would be evident that each kind of fibre has not only a specific degree of elongation but also a typical form of load-elongation curve. It is also observed that at equal loads the elongation reduces with the size of twines irrespective of the kind of fibre as thicker the twine more force is required to obtain the elongation.

In the case of cotton twines it is observed that the degree of twist influences the stress-strain properties; higher the twist, more is the elongation at equal loads and the breaking strength is affected to a certain extent. The load-elongation curve seems to incline towards the x - axis with increase in the degree of twist(Figure 13). However the area under the load-elongation curve seems to

Fig. 13

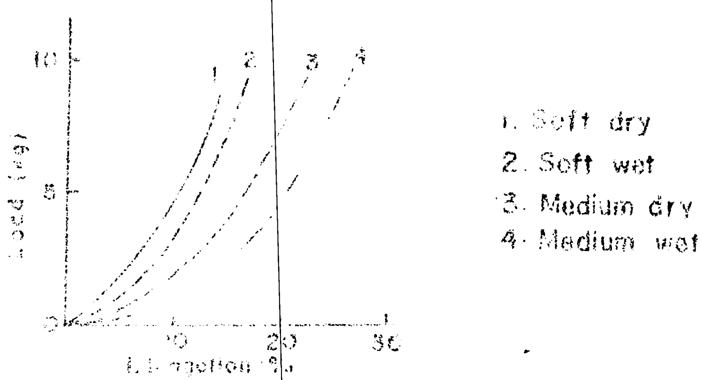
be not much affected since the decrease in strength due to increase in the number of twists is compensated by enhanced elongation values. It is also observed that cotton twines improve both strength and extension in the wet condition.

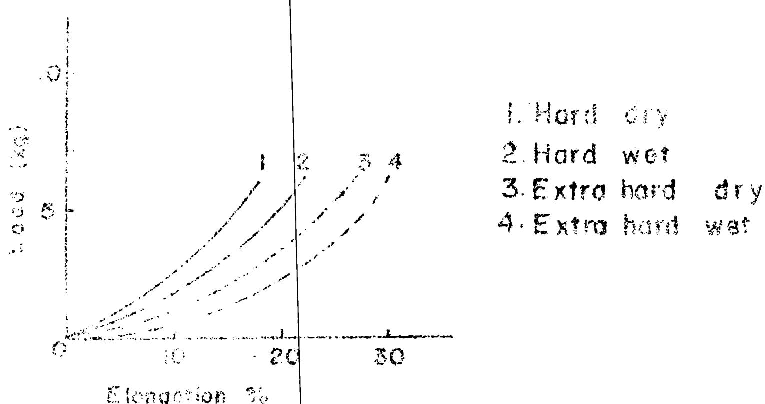
In the case of PA multifilament twines elongation was found to be more at low loads than at higher loads. In the wet state the strength of nylon twine is considerably reduced while the extension is slightly improved as is evident in Figure 14a and b.

Figs. 14 and 15

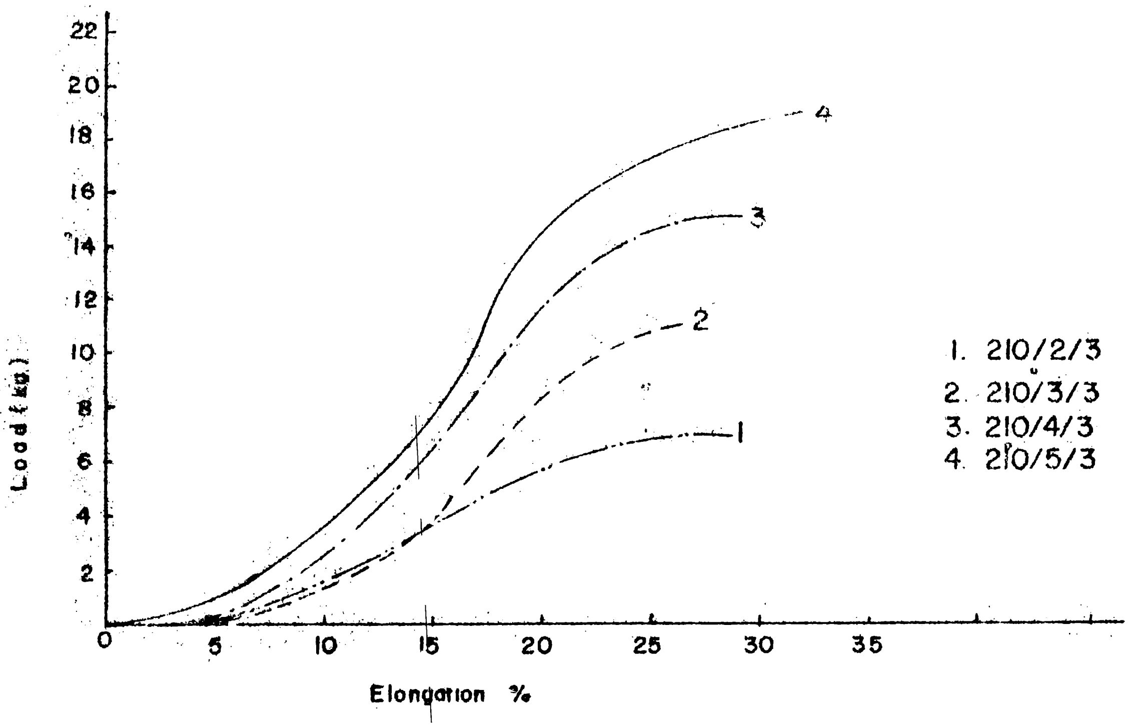
PE monofilament twines show increased stretch in the dry state at increasing loads bringing the load-elongation curves towards the ordinate (Figure 15). The breaking strength is improved by wetting while the extension is considerably reduced. In the case of PE monofilament braided

STRESS - STRAIN BEHAVIOUR OF COTTON TWINES (20/6/3) WITH SOFT, MEDIUM, HARD AND EXTRA HARD TWISTS – Fig 13

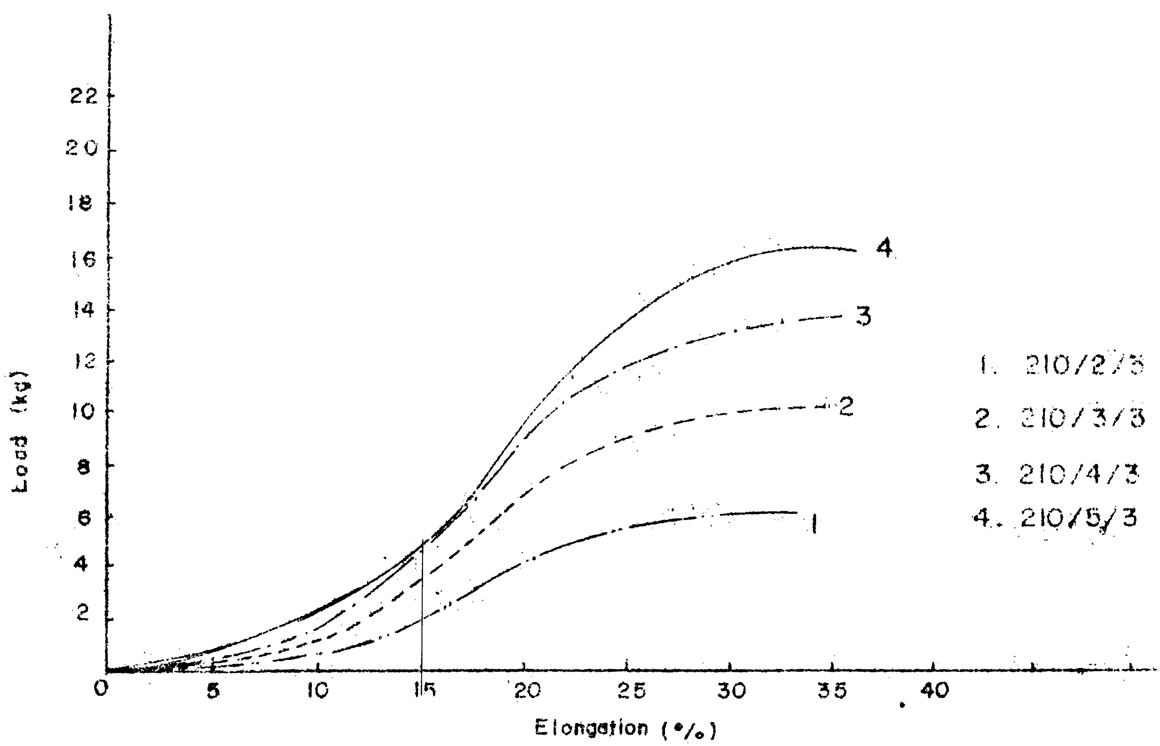




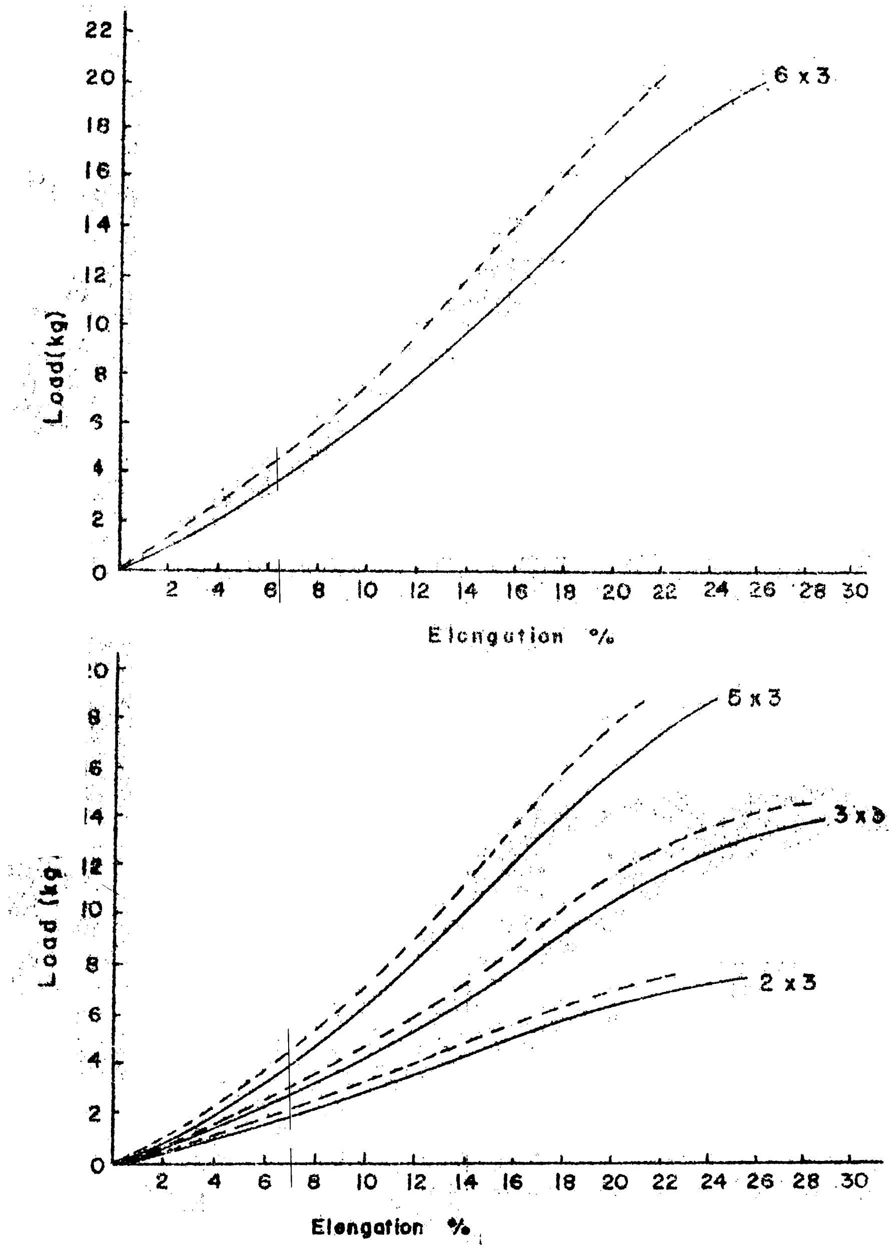
STRESS-STRAIN BEHAVIOUR - P A MULTIFILAMENT TWINE (DRY) Fig: 14 a.



STRESS - STRAIN BEHAVIOUR - PA MULTIFILAMENT TWINES (WET) Fig.



STRESS - STRAIN BEHAVIOUR PE MONOFILAMENT TWINES (DRY & WET) Fig : 15



twines also a similar trend is observed. However a deviation in the stretching property is observed as the elongation is found to be less during the initial stages of loading and on reaching the breaking point a plastic flow of extension could be noticed which enables the material to cover a large area under the load-elongation curve in the dry state. This stretch at the'yield point' is considerably reduced in the wet condition as is evident in figure 16.

Fig. 16

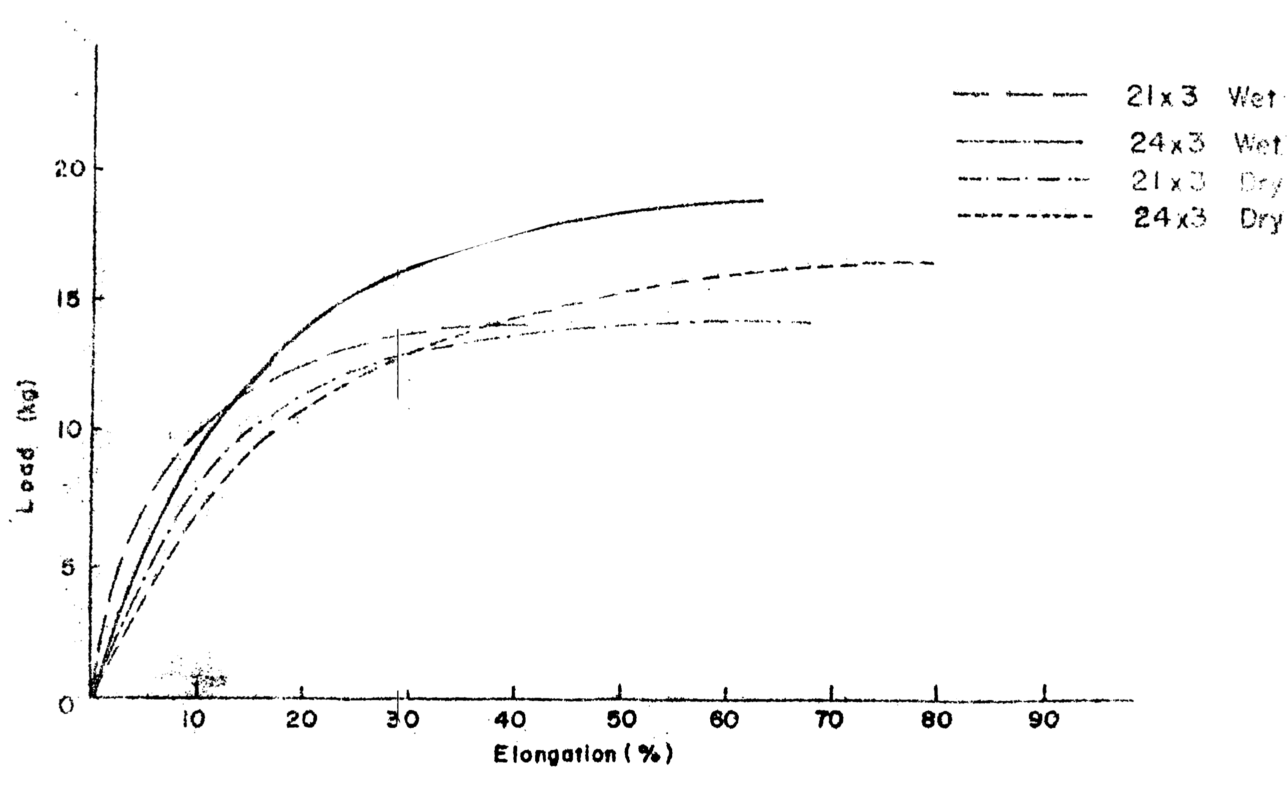
PE flat tape twines show low stretch when compared to both PE monofilament twisted and braided products. In the wet state the strength is improved and the stretch is reduced as shown in figure 17.

Fig. 17

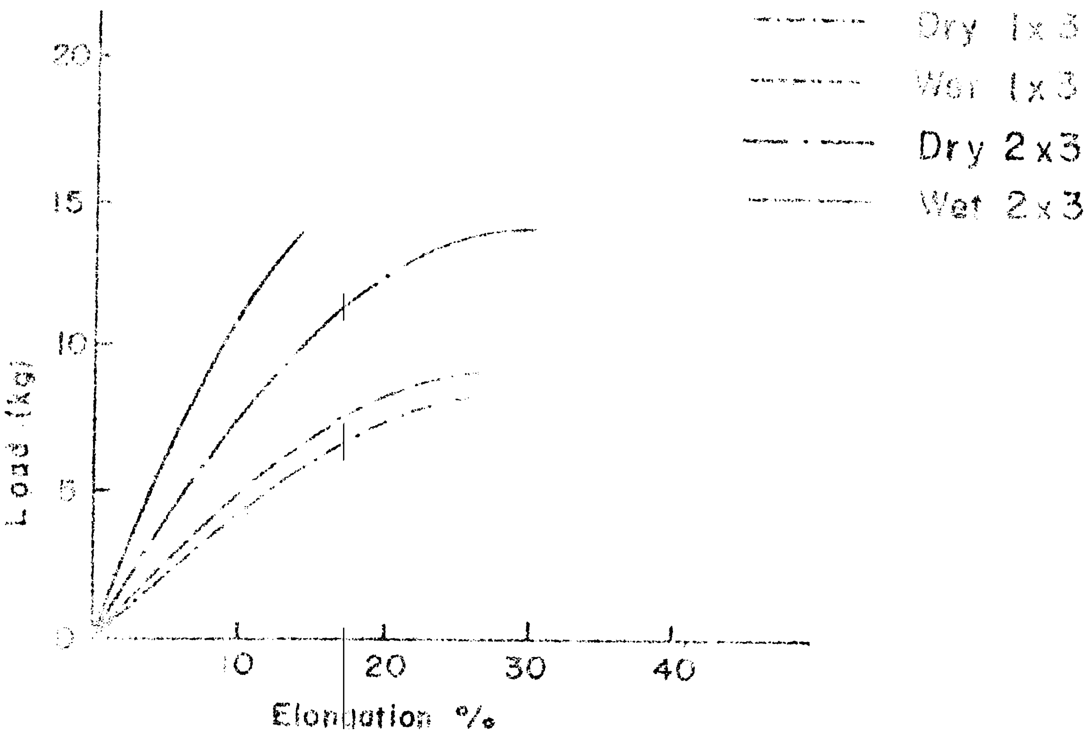
PE fibrillated tape twines show more extension than PE flat tape twines in the dry state. In the wet state the stretching tendency is considerably reduced (Figure 18).

Fig. 18

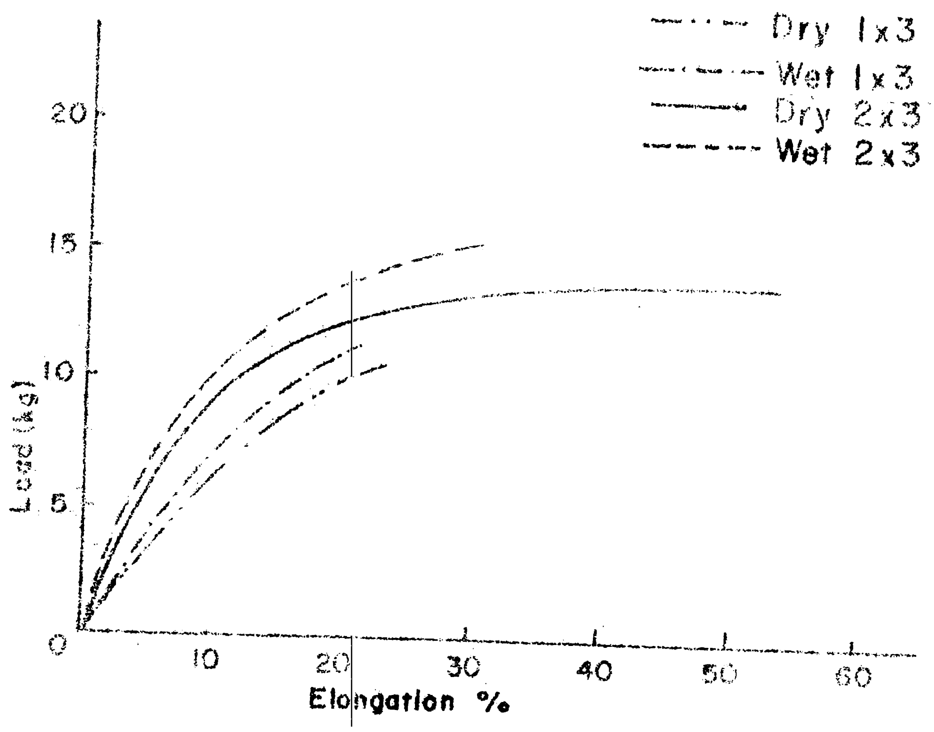
STRESS-STRAIN BEHAVIOUR-PE MONOFILAMENT BRAIDED TWINES - Fig : 16



STRESS - STRAIN BEHAVIOUR - PE FLAT TAPE - Fig : 17



STRESS-STRAIN BEHAVIOUR - PE FIBRILLATED TAPE Fig: 18

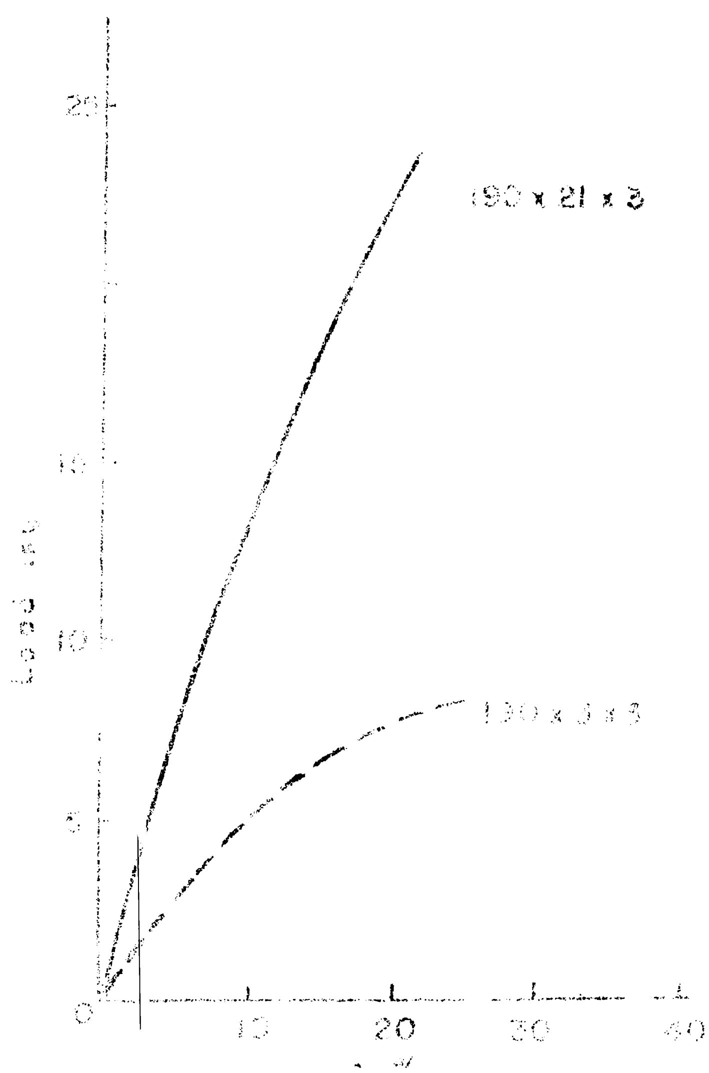


The stress-strain behaviour of different forms of polyethylene twines shows that all the varieties registered improved strength followed by a decrease in stretch at different loads in the wet condition which reduce the area under the load-elongation curves observed in the dry state.

In polypropylene multifilament twines no difference in the stress-strain values could be observed between dry and wet states as is evident in figure 19.

Fig. 19

STRESS - STRAIN BEHAVIOUR
PP MULTIFILAMENT - Fig



5.7 KNOT STRENGTH

Azzano (op. cit) stated that the knotting test may give an idea of the effect of bending due to knotting. Lonsdale (op. cit) reported that when a knot is tied it constitutes a spot of weakness and reduces the effective strength of the twine. According to him the knotting efficiency of nets made of nylon 66 yarn is of the order of 40 to 50% for single knots and 50 to 60% for double knots; the difference in the configuration of knots being responsible for the variations in the knotting efficiency. Imperial Chemical Industries (op.cit) while determining the knot strength of terylene twines also observed that a twine with double knot showed a knot strength about 10% higher than single knotted twines. Shimozaki (1959) reported that the breaking strength of knotted twine can be regarded as nearly proportional to the total number of yarns and could not find any difference between the double knot and lock knot in nylon twines. HansStutz (1959 b) studied the lateral strength and knot firmness of synthetic twines for fishing purposes and indicated that the knot strength in wet condition is the decisive factor in juding the usefulness of the material in nets, as high normal tensile strength need not give equally good knot strength. This fact is borne out by the lower knot strength values of continuous filament twines which possess higher tensile strength compared to twines made of spun material. HansStutz (op. cit) is of opinion that net twines made of spun yarn (staple) show sufficient firmness of knots which is directly attributable to the rougher surface produced by the projecting ends and the position of capillary fibres. This finding is in agreement with the views of Himmelfarb(op.cit) that when the strand surfaces are smooth, the frictional forces in binding are reduced and the knot breaks more rapidly. Carrother's (op. cit) studies on the staple and continuous filament nylon twines revealed that although the former is only half as strong as the latter, it is about 4/5th as strong when knotted. Klust (op. cit) found that with polyamide and polypropylene continuous filament netting yarn, the finer the twine, the lower is the loss in strength at knot. Although polyethylene monofilament twine has low dry breaking strength, this disadvantage is partially compensated by the fact that they are not affected by water and their loss in strength by knotting is low. Hans Stutz (op. cit) also observed that the twines wetted for 24 hours and then dried showed a better knot firmness than dry samples. Klust (op. cit) tested the weavers' knot in AB - CD and AC - BD directions of pull ie. the normal (N) direction or top mesh and the transverse (T) direction or side mesh respectively and found the knot breaking load tested in top mesh direction as superior to side mesh. He is of opinion that the top mesh direction is appropriate as it is closer to the common position in the nets.

The knot strengths of vegetable fibre twines in different direction of pull are presented in table 32.

Table 32

It was found that although sunhemp possesses a lower linear strength compared to Italian hemp, it shows better knot-efficiency than the latter. Among the two varieties of sunhemp, the one having a rougher surface shows superior efficiency than that having a smooth surface.

Of the different kinds of knots used in the fabrication of nets, the English knot or trawl knot and the reef knot or square knot are most commonly used. Since continuous filaments are having smooth surfaces, the knots are unstable and susceptible to slip, resulting in unequal shape and size of mesh. This is undesirable for gill nets where the catch depends on certain specific opening of the mesh. Knot stability is necessary for many other types of gear such as trawls as well to maintain the correct hanging of netting to lines. For these reasons, manufacturers improve the resistance against knot slippage by using knot and a half or double knot, in place of single knots which give the net sufficient knot-stability (Tran-Van-Tri and Ha-Khac-chu 1964). Compared to the normal single weaver's knot, these knots have the disadvantage of increased weight due to the difference in length of twine and size of knot which adversely affects the invisibility of gill nets.

Table 32. Knot strength of vegetabl fibre twines.

Type of knot and directions of pull	% Retained Strength							
	Cotton		Sunhemp (rough)		Sunhemp (smooth)		Italian hemp	
	dry	wet	dry	wet	dry	wet	dry	wet
Reef knot								
AB-CD	86.2	89.8	97.0	91.8	71.3	71.9	68.6	79.7
CA-DB	75.6	70.0	89.6	85.8	58.8	69.5	55.7	69.2
B-D	78.3	80.2	97.3	82.4	52.4	47.1	64.1	59.6
Trawl knot								
AB-CD	66.8	83.1	96.7	95.7	70.0	77.2	54.8	75.3
CA-DB	82.9	88.2	81.7	83.8	67.9	72.7	68.9	74.9
B-D	63.1	74.9	97.7	81.8	50.1	53.0	54.2	70.1
A-D	57.1	72.5	78.7	70.9	51.8	47.8	59.3	55.2
B-C	67.9	85.1	75.7	83.3	51.4	54.3	61.7	53.9

Heat treatment methods either dry or wet heat is mo...., used by net manufacturers for setting the knots(Tani I weo 1964).

Klust (op. cit) opines that the breaking strength of a knot decreases with the angle into which the loops of the netting yarns are forced by the knot and it increases with the number of loops in the knot. According to him an overhand and reef knot have a somewhat lower breaking strength than weaver's knot and double weaver's knot is the strongest. The knot strength of nylon twines when different types of knots are tied are presented below.

Types of Knots	% Retained strength Top-mesh	Side-mesh
Reef knot	73.3	72.0
Trawl knot	61.4	72.6
Knot and a half	63.4	60.0
Double knot	61.8	58.0
Lock knot	65.0	69.5

The data on knot strength of different synthetic twines presented in tables 12 to 17 were subjected to statistical analysis to find the relation of knot strength Y(Kg) in the wet state and diameter square X(mm). The above relationship is connected by the regression equations as,

PA multifilament	Y = 12.37 X
PE monofilament twines	Y = 9.46 X
PE monofilament braided	Y = 12.69 X
PE flat tape twines	Y = 7.53 X
PE fibrillated twines	Y = 10.45 X
PP multifilament twines	Y = 11.67 X

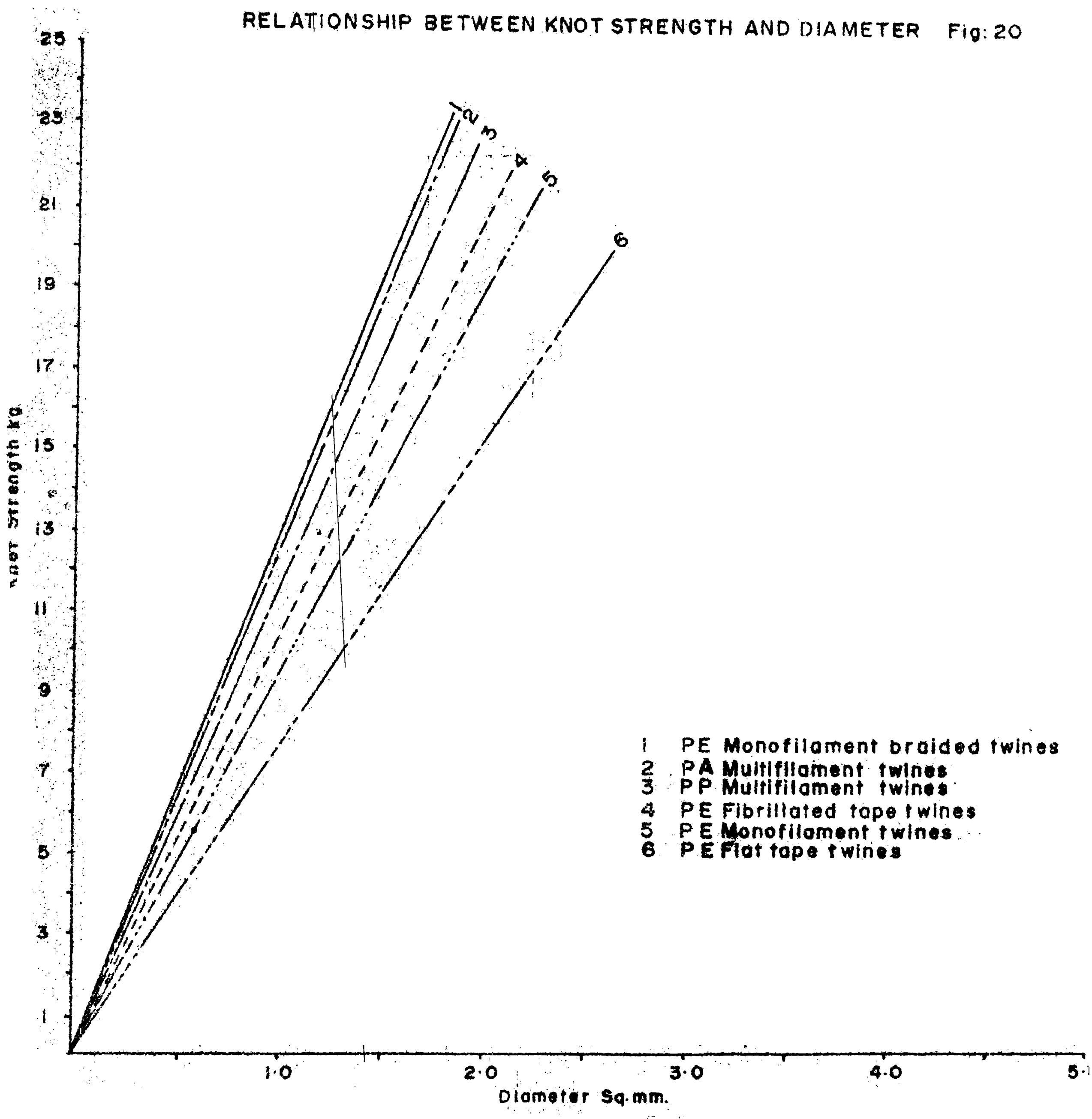
The graphical representation of the regression equations is given in Figure 20.

Fig. 20

It is evident that the PE braided twines have the highest knot strength followed by PA multifilament, PP multifilament, PE fibrillated, PE monofilament and PE flat tape. A study of the confidence intervals suggests that know efficiency based on the thickness of twines show that PE monofilament braided and PP multifilament have wider ranges and that knot efficiency relationships are different among the other materials.

Materials	r values	95% confidence interval	
PA multifilament twines	0.993	(12.22	12.52)
PE monofilament twines	0.979	(9.42	9.50)
PE monofilament braided	0.871	(7.65	17.73)
PE flat tape twines	0.996	(7.42	7.64)
PE fibrillated tape twines	0.977	(9.81	11.09)
PP multifilament twines	0.989	(8.69	14.67)

RELATIONSHIP BETWEEN KNOT STRENGTH AND DIAMETER Fig: 20

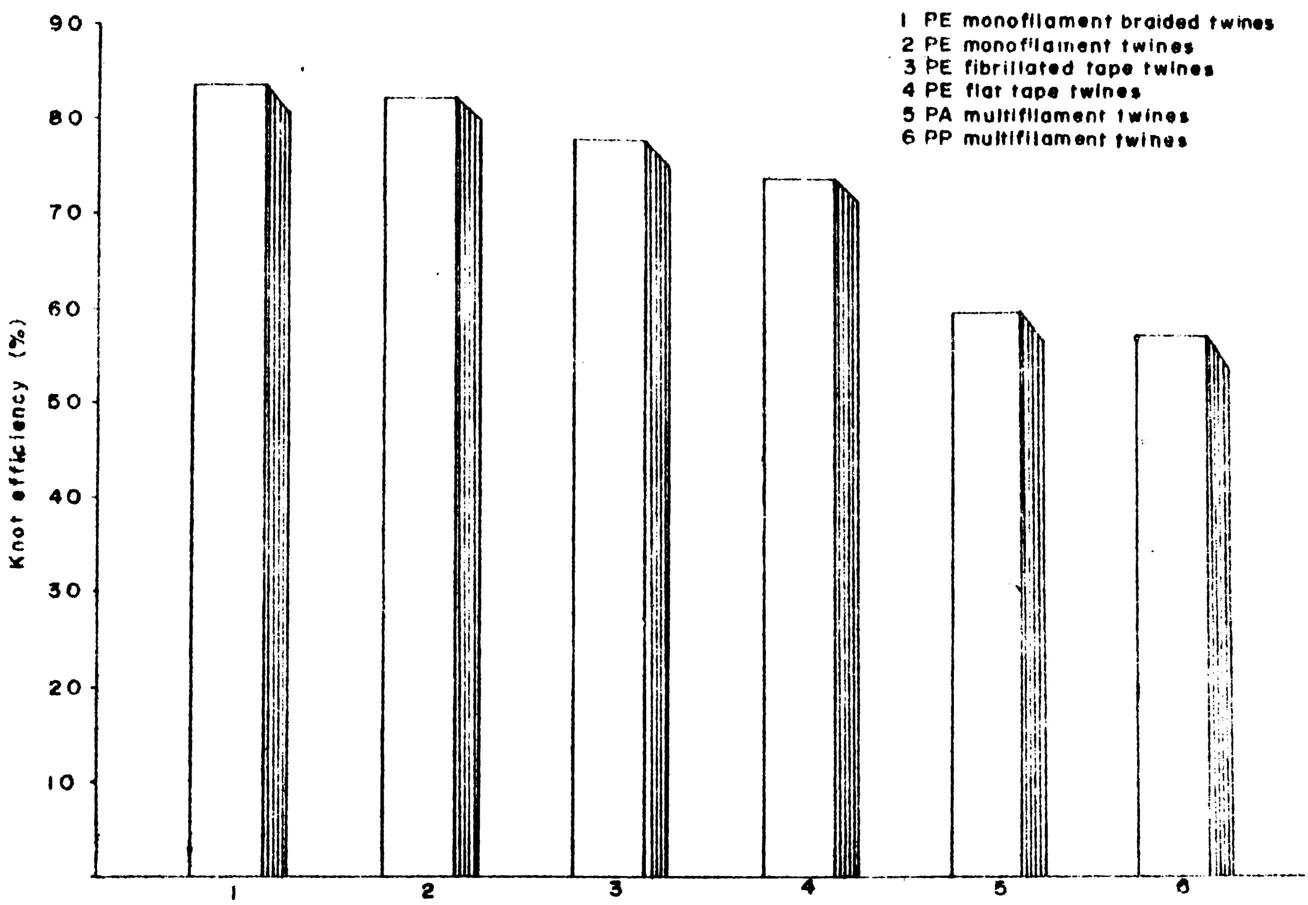


The weighted average percentage knot efficiency by taking original wet breaking strength as weight are presented in Figure 21.

Fig. 21

It may be noted that PE braided twines have the maximum (83.7%) and PP multifilament the minimum 57.4% knot efficiency. Between PE monofilaments (82.16%) and PE braided twines the variation is not much pronounced. The higher knot efficiency of the characteristic rough surface of the monofilaments and the process of making twines either by twisting or braiding do not affect the knot efficiency. The other forms of polyethylene such as fibrillated tape and flat tape registered knot efficiencies of 77% and 73.9% respectively and PA multifilaments showed only 60%.

KNOT EFFICIENCY OF DIFFERENT SYNTHETIC FISH NET TWINES Fig: 21



CHAPTER VI

CAUSES OF DETERIORATION OF FISH NET TWINES

6.1 Rotting:

Rotting is a phenomenon due to which vegetable fibres deteriorate by the combined action of bacteria, fungi and other cellulolytic organisms. de Bary (1886), Hutchinson and Clayton (1919), Burns (1925), Winogradsky (1929), Smith (1938), Barghoorn (1942), Stanier (1942) and Gupta (1947) studied the causes of deterioration of vegetable fibres resulted in large scale destruction. Nishiyama and Yamazoe (1914) found that cotton twines kept in an aqueous medium, fresh or saline, but devoid of bacteria did not loose their original strength for one year. Kawai(1914) and Terada (1914) recorded that rotting of netting twine in water is related its temperature and that the higher the temperature the quicker was the rotting. Burns (1925) observed that the rate of decay was more in areas of high temperature, dampness and rain. Whiteleather and Brown (1945) pointed out that in tropics the deterioration of fishing gear proceeds more rapidly because of high temperature high organic and bacterial count of medium. According to Farrar (1950) deterioration of nets is much faster in brackish water than in sea water. Brandt (1954) studied deterioration of netting yarns in different waters and confirmed that eutrophic lakes have a greater deteriorating effect on fishing nets than oligotrophic lakes and that flowing water increases the degree of deterioration.

The common method followed in different countries for preservation of net materials is the application of indigenous preservatives like twigs, barks, leaves, fruits and seed coats of certain tannin yielding trees and plants. /Villadolid and Sulit (1932), Clague and Datingaling (1950), Kuriyan and Nayar (1961)/. Cutch is the extract obtained from the plant Acacia catechu which grows in India and Burma. Detailed studies on tannin bath using various barks of tannin yielding trees to get the maximum effectiveness of preservation, use of fixatives like copper sulphate and potassium dichromate on tannin treated twines and tar treatment on both tannin treated and tannin fixed vegetable fibre twines were carried out by Cecily (1977). The present investigation has been restricted to the rotting medium and the factors influencing the deterioration of fishing nets.

Klust (1952) in his studies on degradation of net materials in Cuxhaven harbour established the influence of water temperature on rotting process. Koura (1963) reported the results of comparative studies of rotting medium at Alexandria in Egypt, subtropical region in Cuxhaven, the estuary of River Elbe in the temperate zone found that the rotting rate depends on temperature of the medium. Radhalakshmi and Kuriyan (1969) working on the evaluation of preservatives at tropical and temperate zones found that the physical factors of the test sites influenced the rotting action. The treated twines underwent deterioration at a quicker or slower rates according to the location of the sites and they found it to be greater at Cochin than at Cuxhaven. Miyamoto et. al (1962) studied the rotting resistance properties of fishing gear materials and found that the coefficient of rotting differs with the nature of fibre with which the twines are made of and correlated the rotting resistance to the diameter of the twines. They also mentioned that since the hydrographical factors of the test site change due to the two monsoons, it is probable that these factors would also have effect on the rotting of twines.

Samples of cotton, jute, sisal, manila and coir were subjected to continuous immersion in Cochin backwaters. The hydrographical factors such as temperature of the surface water, salinity, oxygen, phosphate, nitrate and rainfall were noted at definite intervals for a period of one year from January to December. Deterioration due to rotting was measured in terms of loss in breaking strength of the exposed materials at periodic intervals. Rotting value for the month was obtained by finding the loss in strength on the last day of the month as per method suggested by Brandt (1959) and Brandt and Carrothers (1964). Samples whose breaking strength decreased by ¾th of their original value were replaced by fresh samples and the total loss of strength was noted as the rotting value for that particular month. Tables and present the

Table 33 The hydrographical factors during the different months of the year.

Months of the year	Rainfall mm	Salinity %	Water temp	Oxygen content	Phosphate mg/l	Nitrite mg/l	pH
January	2.5	27.72	28.2	2.33	0.50	0.018	7.0
February	6.4	35.21	29.1	2.60	0.52	0	7.1
March	23.3	32.83	30.6	2.34	0.30	0.023	7.2
April	160.9	30.95	31.4	3.96	0.70	0.003	7.3
May	484.9	21.92	29.8	2.07	0.65	0.01	7.2
June	273.1	7.61	29.6	2.72	0.89	0.03	7.1
July	932.8	2.39	27.9	3.11	0.37	0.053	7.0
August	455.0	1.38	28.2	2.83	0.50	0.06	7.0
September	336.3	7.47	28.2	2.30	0.36	0	7.0
October	117.7	7.57	27.8	2.80	0.26	0.01	7.0
November	183.0	20.03	28.3	3.01	0.30	0.09	7.0
December	nil	28.96	28.4	2.80	0.27	0.0	7.0

Table 34 The rotting values per day for the different months of the year.

Months	Cotton	Jute	Sisal	Manila	Coir
January	3.14	2.9	2.45	1.745	0.535
February	3.93	3.4	2.80	2.35	0.936
March	3.49	3.16	2.61	2.07	0.04
April	3.14	3.34	2.37	2.84	1.355
May	4.12	3.11	2.93	2.53	1.11
June	3.02	2.34	2.83	3.06	1.05
July	4.15	2.18	2.8	3.24	1.60
August	4.65	2.67	2.57	2.83	1.21
September	4.72	2.45	2.85	2.83	1.14
October	4.02	2.55	2.12	3.09	1.05
November	4.25	2.8	2.32	2.26	1.02
December	4.38	2.56	2.30	2.69	1.10

hydrographical conditions of the test site and the rotting per day values observed for different vegetable fibre twines under continuous immersion during the different months of the year.

Tables: 33 and 34

To find out the factors influencing rotting a correlation analysis of the data on the measurement of the environmental parametres and rotting value was made. For the sake of distinguishing the correlation coefficients conveniently, the following alphabets are used to denote the measurements of the factor indicated against each.

a	-	cotton	f	-	salinity
b	-	jute	g	-	water temperature
c	-	sisal	h	-	oxygen content
d	-	manila	i	-	phosphate
e	-	coir and	j	-	nitrite

The simple correlation coefficients between rotting and environmental parametres are given in the first 5 rows and the correlation matrix among the factors, in the rest of the rows.

Simple Correlation Coefficients

Material	Salinity (f)	Water temp. (g)	02 content (h)	Phosphate (i)	Nitrite (j)
Cotton(a)	-0.4057	-0.5822*	-0.2043	-0.5703	0.2931
Jute (b)	** 0.8169	0.6559*	0.0344	0.1823	-0.3850
Sisal (c)	-0.1593	0.1576	-0.4410	0.4599	-0.2218
Manila(d)	*-0.6992	-0.1461	0.4196	0.1436	0.0160
Coir (e)	-0.5304	-0.2492	0.5271	0.1900	0.1608

	Water temp.	02 content	Phosphate	Nitrite
Salinity	0.5599	-0.0145	-0.0035	-0.3359
Water temperature		0.2554	0.5186	-0.3787
02 content			0.1319	0.2119
Phosphate				-0.2628

* Significant at 5% level

** Significant at 1% level.

Because of the interrelationship between salinity and temperature as can be seen from an almost significant correlation coefficient (0.5599) partial co-relation coefficients which are necessary to find out whether a factor is actually influencing the rotting or not are presented below.

Partial correlation coefficients obtained when the effects of one or two environmental factors are kept constant. (The letter given after the dot indicate the factor/factors whose effects are held fixed).

Cotton	Jute	Sisal	Manila	Coir
$r_{af.g}$ = −0.1213	$r_{bf.g}$ =0.7207	$r_{ef.g}$ =0.3008	$r_{df.g}$ =0.7516	$r_{ef.g}$ =0.413
$r_{ag.f}$ =−0.6179*	$r_{bg.f}$ =0.4209	$r_{cg.f}$ =0.3000	$r_{dg.f}$ =0.4084	$r_{eg.f}$ =0.064

Judged from the simple correlation coefficient, rotting of cotton shows inverse correlation with water temperature. The significant negative partial correlation coefficient shows that this inverse relationship is actual and not an apparent one caused by the inter-connection between salinity and temperature. However, it is also possible that the direct relationship may not be with water temperature but with some other factor which is correlated with water temperature. Though somewhat high correlation with phosphate and rotting of cotton is observed, (−0.5703) more observations are necessary to draw a conclusion as the computed value and tabulated value for significance almost coincide.

The significant value of $r_{bf.g}$ shows that rotting of jute and salinity are actually correlated. Though there is significant correlation between the rotting and water temperature, non-significance of $r_{bg.f}$ shows that they are not actually correlated. The apparent relationship between these can be attributed to the inter-relationship between salinity and temperature.

Variations in salinity and temperature do not seem to affect rotting of sisal as $r_{cg.f}$ are not significant.

An inverse relationship with salinity is observed in manila as shown by a significant negative $r_{df.g}$. The simple correlation coefficient also showed a significant negative value.

Variations in salinity and temperature do not seem to affect the rotting of coir, the respective partial correlation coefficients being insignificant.

The following conclusions could be derived.

i) Rotting of cotton seems to decrease with increase in water temperature or some other factor which has direct relationship with water temperature.

ii) Increases in salinity tends to increase rotting of jute.

iii) Increases in salinity tend to decrease rotting of manila.

iv) Rotting of coir does not seem to be affected by the variations in any of the factors considered.

v) Oxygen content and nitrite do not seem to affect the rotting of vegetable fibres.

Table 35. Resistance to continuous immersion of synthetic twines.

Exposure period (months)	Salinity (‰)	Temperature (°C)	Retained Strength (Kg) of materials exposed to continuous immersion						
			PA monofilament	PA multifil	PA Staple	PES multifil	PE monofil twines	PP multifil.	PVA Staple
Original Wet	-	-	13.1	13.5	13.3	15.4	18.4	16.4	13.1
1	30.3	31.1	14.8	15.9	13.3	13.7	20.2	14.1	12.9
2	32.2	31.3	13.4	13.4	12.0	13.7	19.9	14.9	12.2
3	30.7	31.4	12.3	12.7	11.0	13.6	20.7	14.5	11.2
4	21.2	29.6	14.7	14.2	13.0	13.2	20.1	14.7	11.3
5	4.5	28.5	12.2	11.8	10.5	12.9	18.6	14.3	10.7
6	2.1	28.3	12.7	13.2	11.7	13.5	19.8	14.4	11.3
8	7.2	28.4	14.1	14.6	11.9	14.1	21.1	14.4	9.6
9	12.5	29.5	13.6	13.0	8.8	12.4	19.4	15.4	10.6
10	22.4	28.9	14.4	12.5	11.4	12.1	18.6	10.0	7.0

Seven sets of synthetic twines viz. polyamide monofilament, multifilament and staple twines; polyester multifilament, polyethylene monofilament, polypropylene multifilament and polyvinyl alcohol were exposed in Cochin backwaters for continuous immersion tests. The hydrographical conditions of the test site along with the original breaking strengths and retained breaking strengths observed at specific interval upto a period of 10 months are presented in Table 35.

Table 35

Whether the breaking strength decreases with the duration of immersion was investigated by checking up the possibility of an inverse relationship between the numbers of days of immersion and the corresponding breaking strength. The correlation coefficient (r), the regression coefficient (b) and the standard error of the regression coefficient (s_b) for the seven materials are shown below.

The correlation coefficient(r), regression coefficient (b) and standard error of 'b' for a regression of breaking strength on duration of immersion.

Material	r	b	s_b
1) Polyamide monofilament	0.0776	0.0246	0.1194
2) Polyamide multi-filament twines	0.3926	-0.1542	0.1365
3) Polyamide staple twines	0.5620	-0.2392	0.1331
4) Polyester multi-filament	-0.6071	-0.1267	0.0627
5) Polyethylene mono-filament twines	-0.3607	-0.0971	0.0949
6) Polypropylene multi-filament twines	-0.4472	-0.229	0.1685
7) Polyvinyl alcohol	**-0.8559	-0.4583**	0.1047

"**" indicates significance at 1% level.

The departure of the regression coefficient from zero was tested using the appropriate t-test. Only for polyvinyl alcohol, the regression coefficient was found to be significantly different from zero. Thus this material showed a linear reduction in breaking strength with the duration of immersion. For the other six materials no linear reduction in breaking strength with the duration of immersion was observed, as the regression coefficients were not significantly different from zero.

Whether there was difference in the mean breaking strength after immersion from the breaking strength before immersion was also tested by t-test. The breaking strength before immersion and the mean breaking strength after immersion are presented below.

<u>The breaking strength before immersion and the mean breaking strength after immersion.</u>

Materials	Breaking strength before immersion.	Mean breaking strength after immersion.
1) Polyamide monofilament	13.1	13.6
2) Polyamide multifilament	13.5	13.5
3) Polyamide staple	13.3	11.51**
4) Polyester	15.4	13.2***
5) Polyethylene	18.4	19.8**
6) Polypropylene	16.4	14.1**
7) Polyvinyl alcohol	13.1	10.7**

"**" indicates significance at 1% level on the basis of t-test.

"***" indicates significance at 0.1% level on the basis of t-test.

For nylon cart and Nylon monofilament, no sigﬁficant change in the breaking strength was noticed as judged from the t-test. For the other five materials, t-test showed differences in the mean strength after immersion. For polyamide staple and multifilament twines of polyester and polypropylene and polyvinyl alcohol, a decrease in mean breaking strength after immersion is noticed. Though not significant, somewhat large negative correlation coefficients were noted for these materials. This also suggests a decreasing trend in the breaking strength. Although syntheti twines are considered to be rot-proof, this decreasing trend in strength on continuous immersion for a long period is attributable to friction caused by the flow of water and adherence and cutting of filaments of twines by animals and plants living in water.

6.2 Weathering of Fish Net Twines.

The term 'weathering' is used to denote the combined effect of sunlight, rain, wind, smoke and gases of the atmosphere on the properties of fish net materials. It is rather not possible to study in isolation the effect of each of these factors; but it can be taken for granted that worst deterioration is caused by the ultraviolet rays of the sun. Owing to the seasonal and locational variations in the intensity of sunlight, the degree of damage done to fibrous materials may differ and in general exceed that caused by immersion in water. Both natural and synthetic fibres are weakened by exposure to sunlight. Fels (1960) conducted investigations on the photodegradation of textile yarns at three different places at Kan in Nigeria, Didcot in England and Kanpur in India and found considerable variations with respect to places, although some of the results in Nigeria had been in agreement with those in Didcot and

Kanpur. Himmelfarb (op. cit) stated that hard fibre cordage withstood weathering better than soft-fibre cordage and treatment with lubricant improved resistance to microbial deterioration. He made a comparison of weather deterioration of nylon as monofilament, multifilament and staple yarn and found that the first one was more resistant to weather than the other two. The above findings have been corroborated by Klust (1955), Koura (1963) and Radhalakshmy and Kuriyan (1969). On comparing the weather resistance of polyethylene monofilament and polypropylene monofilament, Ede and Henstead (1964) found the latter to be less resistant compared to the former. Klust (1959a) expressed the view that resistance to weather varied only slightly in the different vegetable fibre twines, whereas synthetics showed great variations from fibre to fibre. According to him terylene polyester shows better resistance to weathering than polyamides and resembles the best of natural fibres, although polyvinyl alcohol fibre was found to be better. Klust (1959 b) also stated that delustered fibre has considerably lower resistance against weathering than the normal (lustrous) one of the same kind and therefore considers such a fibre as unsuitable for fish nets. Shimozaki (1959) conducted weathering tests with amilan, kuralon, saran, teviron and cotton twines treated with cutch and found that the strength decreased by 16% in amilan, 24% in kuralon, 10% in saran, 6% in teviron and 8% in cutch treated cotton. The synthetic twines treated with tar did not give any protection against weathering.

Warenzeichenverband (op. cit) reported that monofil displayed a higher degree of resistance to sunlight and weather conditions than vegetable fibre twines which equalled the immunity shown by polyacrylonitrile fibres. He also observed that with increase in the diameter, photodegradation was less noticeable. According to him twines made of polyamide filament or staple fibre were relatively less resistant to weathering than those made of cotton. Imperial Chemical Institution (op. cit) reported that exposure of terylene and nylon to weathering resulted in 46% loss in breaking strength in the former and 64% in the latter in the course of 10 months. Radhalakshmi and Kuriyan (1969) have reported the weathering tests on fish net twines conducted at two different stations viz., tropical site (Cochin) and temperate region (Cuxhaven). Results indicated that while at Cochin both perlon monofilament and the polyvinyl alcohol showed high resistance to weathering, at Hamburg best results were obtained with monofilaments of perlon and polyethylene. Polypropylene showed only less resistance to weather at both test sites. Taking the polyamide group as a whole, the order of preference with respect to weather resistance was monofilament, continuous filament and staple fibre and the effect was found to be identical at both tropical and temperate test sites. Molin (op. cit) observed that in certain types of fishing tackle such as bow nets and set nets the sensitivity of nylon necessitated frequent replacement of the damaged parts and suggested the use of saran, kuralon or terylene which are less sensitive to ultraviolet rays for the upper parts.

Various measures have been suggested by different authors to retard the process of weathering. Sulit and Panganibhan (1954) and Brandt (1957) advocated the use of cutch and subsequent treatment with coal tar to protect the net materials from the adverse effect of weathering. Burdon (1957) held the view that chemical preservatives, particularly of copper compounds, have a deleterious effect on the influence of sunlight. Warenzeichenverband (op. cit) reported that colouring with Perliton dyes showed remarkable fastness in water. But Robinson (1959) is of opinion that dyeing of synthetics has no effect at all on photodegradation. Shimozaki (op. cit) indicated that the samples treated with tar alone did not give much protection in case of amilan, saran, teviron except kuralon and when tar mixed with an emulsion of alkaline soap water was applied, synthetic twines improved their weather resistance. Radhalakshmi and Kuriyan (1969) showed that retention of strength of cotton twines after 37 months of exposure was good when treated with cutch fixed by : 1) potassium dichromate and carboleneum, 2) copper sulphate and 3)a combination of cutch, testalin and carboleneum.

The rates of deterioration of various kinds of fibres on exposure to light and weather vary considerably. The resistance of fish net twines to weathering is measured in terms of decrease in the breaking strength. It is, however, impossible to determine precisely the behaviour of each fibre towards weathering, because the results vary with different places and seasons and also depend upon the properties of fibres produced by different manufacturers. Coal tar derivatives, bitumen, black varnish or similar agents used to increase stiffness, sinking speed, abrasion resistance and knot stability of netting considerably influence their weather resistance. Sun's radiations are partly reflected by the water surface and partly absorbed by the water. Even in absolutely clear water, only 47% of the sun's radiations penetrate to a depth of 1 m. (Klust 1973). The violet and ultraviolet parts of sunlight which cause the deterioration of textiles undergo maximum absorption in water. The deteriorative effect of sunlight is therefore much lower in water than in air. Incorporation of antioxidants and radiation-absorbers into the polymer improves the weather resistance property of synthetic twines. Polyethylene and polypropylene are difficult to dye by normal methods and hence spin-dyeing is followed by incorporating pigment in the polymer before the filament is formed.

The results of weathering tests conducted are summarised below.

6.21 <u>Comparative weather resistance of different vegetable fibre twines.</u>

Vegetable fibre twines such as cotton, Sunhemp, Italian hemp, sisal, manila and coir were exposed to weather continuously for a period of six months and the retention of strengths were noted at periodic intervals. The results are presented in table 36. The percentage retention of

Table 36

strength of the materials were plotted against the number of days exposed to weather (Figure 22).

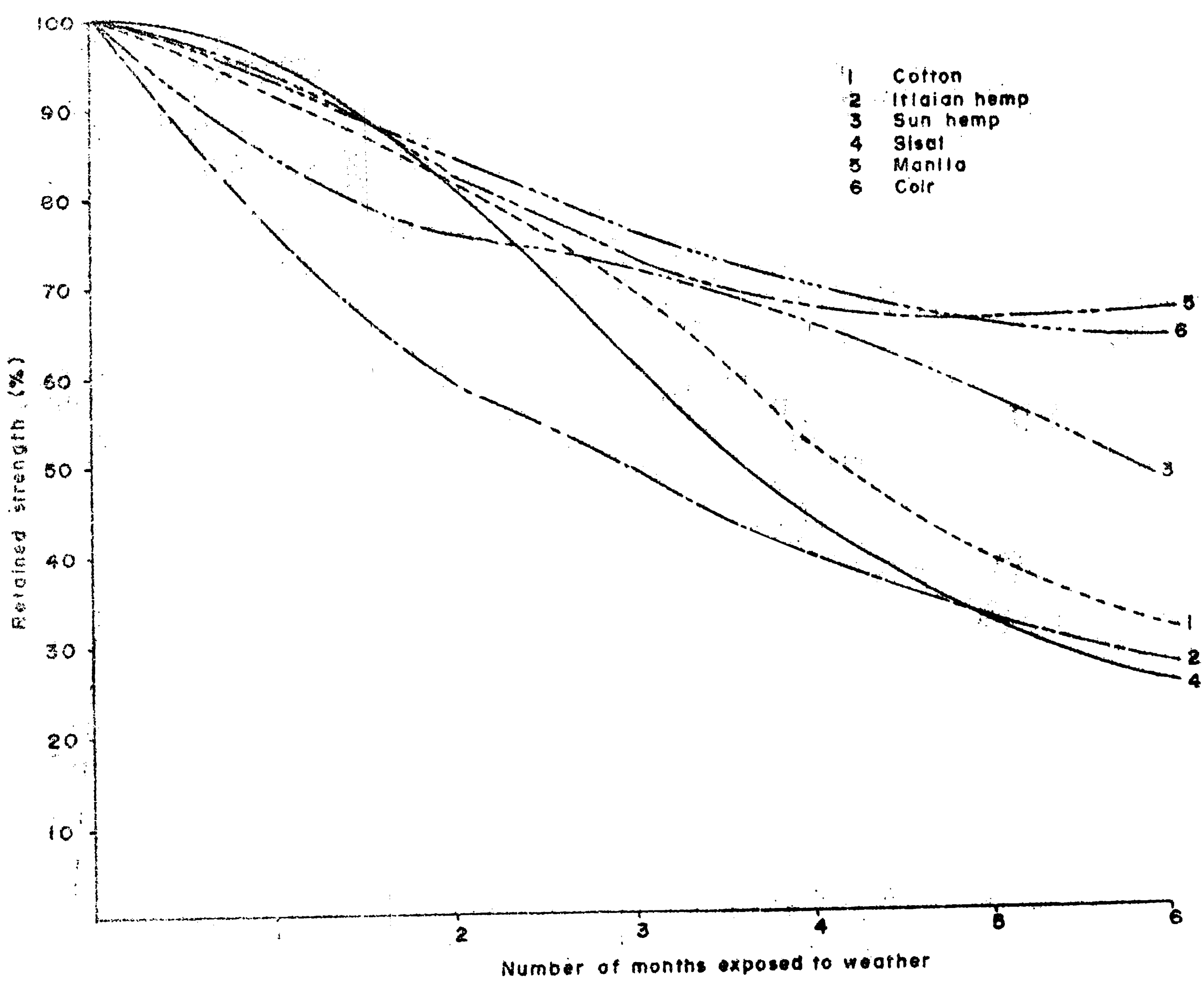
Fig. 22

It may be observed that the difference in percentages of retained strength between materials and between periods of exposure to weather were highly significant (p 0.01). In order to identify the materials having significant weather resistance, critical difference among mean strength at 5% level was worked out. It was observed that there is no significant difference between cotton and sisal; and manila and coir, whereas the percentage of retained strengths are significantly different among groups cotton-sisal; sunhemp;

Table 36 Comparative weather resistance of vegetable fibre twines.

Sl. no.	Name of material	Dia-meter (mm)	Ori-ginal breaking strength (kg)	Breaking strength (kg) after exposure to weather for					
				30 days	60 days	90 days	120 days	150 days	180 days
1	Cotton	0.99	5.7	5.2	4.5	3.9	2.9	2.2	1.7
2	Sun hemp	1.02	8.6	7.3	6.5	6.4	5.7	4.9	4.2
3	Italian hemp	0.91	13.5	10.2	7.9	6.7	5.3	4.2	3.7
4	Sisal	3.30	63.1	60.4	51.3	38.7	27.3	19.4	15.7
5	Manila	2.70	43.7	40.9	36.1	32.1	29.3	29.0	29.4
6	Coir	4.40	26.5	24.6	22.6	20.1	18.7	17.2	17.0

WEATHER RESISTANCE OF VEGETABLE FIBRE TWINES Fig:22



Italian hemp; and manila-coir. It was also observed that manila and coir exhibited higher degree of resistance to weather than other vegetable fibre twines tested. The lowest resistance was found in Italian hemp although the material possessed very high breaking strength.

6.22 Effect of cutch and coal tar on the weather resistance of vegetable fibre twines.

Cotton, Sunhemp and Italian hemp were treated with cutch and coal tar separately and tested to find the effectiveness of the preservative treatment by exposing to weather continuously for a period of six months. The data collected are presented in table 37. To compare the retention of strength by twines with treatments and with the period of exposure the data were subjected to statistical analysis using the three way analysis of variance technique. The model used for this study is:

$$Y_{ijk} = \mu + a_i + b_j + c_k + \alpha_{ij} + B_{jk} + Y_{jk} + E_{ijk}$$

where μ = the overall effect

a_i = i^{th} treatment effect i = 1,2,3

b_j = j^{th} material effect, j = 1,2,3

c_k = k^{th} month effect, K = 1,2,3,4,5,6

α_{ij} = The interaction effect on i^{th} treatment with j^{th} material.

B_{jk} = the interaction effect of j^{th} treatment with K^{th} month.

...

Table 37

r_{ik} = the interaction effect of i^{th} treatment with K^{th} month.

and ε_{ijk} = random error. Both treatments were compared with control and the analysis of the results are presented in table 38.

Table 38

It was observed that the percentage of retained strengths were highly significant ($p < 0.01$) between treatments, between periods of exposure and between materials. Also, the interactions treatment X material was highly significant. The treatment X period of exposure was significant only at 5% level, whereas the material X period of exposure was found to be not significant. The course of weathering of control and treated samples are presented in figures 23, 24, & 25.

Figs. 23, 24 and 25.

Cotton and Sunhemp were seen to be almost equally efficient when treated with cutch and coal tar, the more effective being the latter. Since coal tar treatment increases the weight of the net, its use is restricted to submerged nets. There is a steep decrease in retained strength in the first month of exposure for cotton treated with both preservatives

Table 37 Weather resistance of vegetable twines treated with cutch and coal tar.

No. of days exposed to weather	Breaking strength (Kg) before and after treatments					
	Treated with cutch			Treated with coal tar		
	Cotton	Sun hemp	Italian hemp	cotton	Sun hemp	Italian hemp
original	6.1	7.9	9.0	6.0	6.9	11.7
after 30 days	5.5	7.2	8.3	5.3	5.9	10.5
" 60 "	5.2	6.6	7.5	4.9	5.6	9.0
" 90 "	5.1	6.3	7.3	4.9	6.1	7.8
" 120 "	4.9	5.9	6.8	4.8	6.0	6.6
" 150 "	4.7	5.7	5.8	5.1	5.7	5.9
" 180 "	4.6	5.6	5.3	5.4	5.5	5.4

TABLE 38

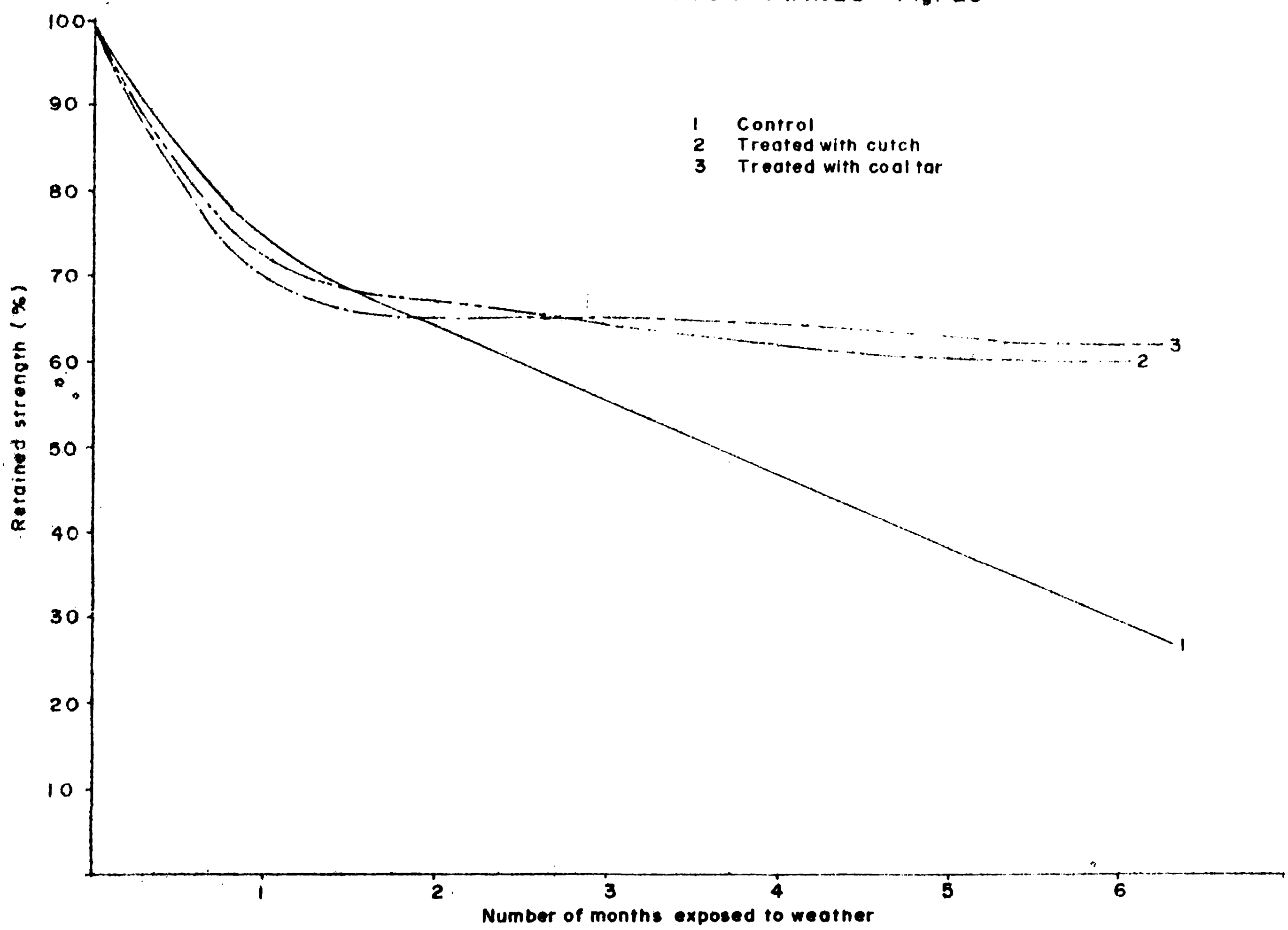
A NOVA

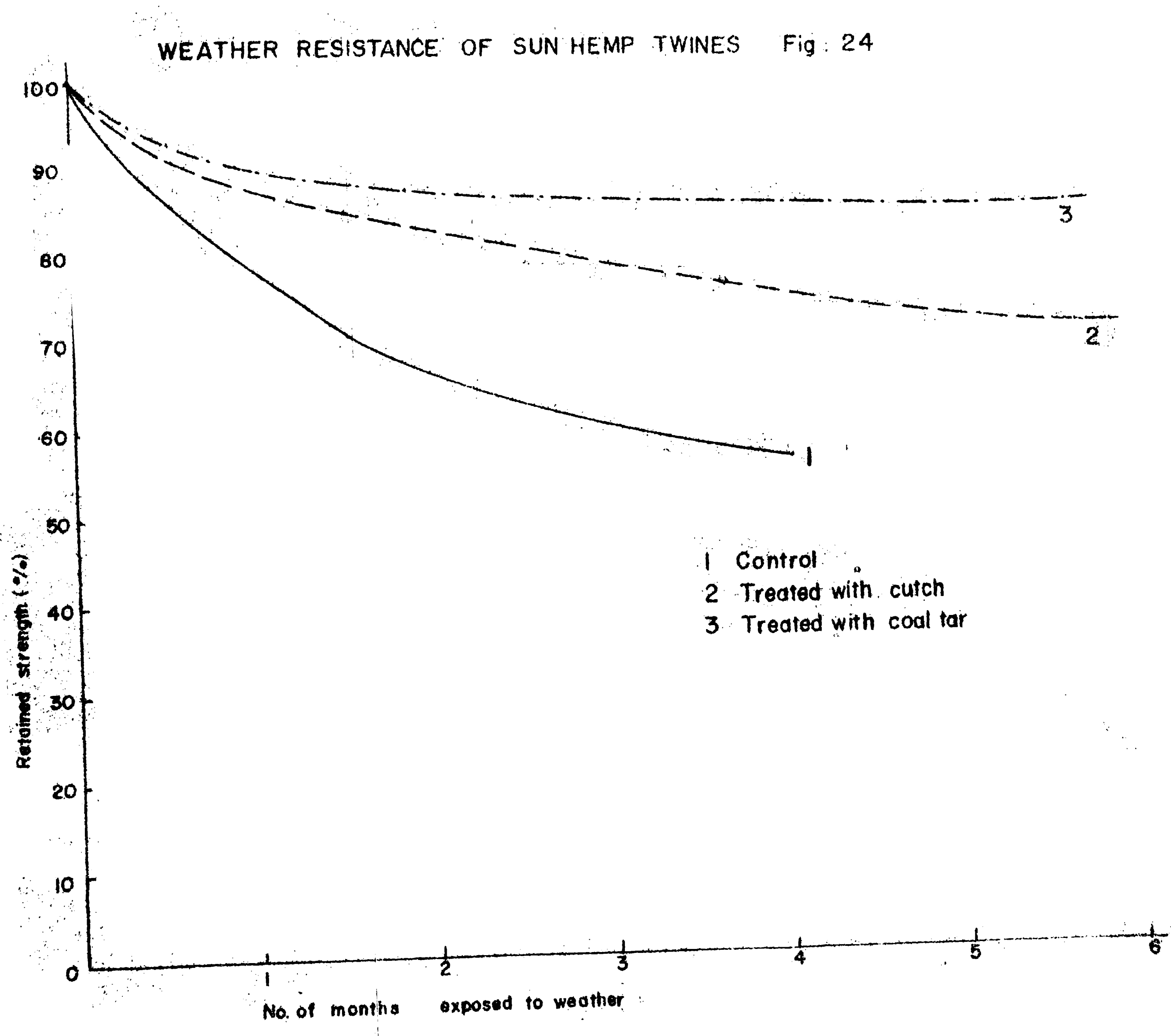
Source of variation	S.S	df	M.S	F	
Bet. treatments	4743.2026	2	2371.60	47.17	**
Bet. periods	5238.2793	5	1047.66	20.84	**
Bet. (materials)	2268.8015	2	1134.40	22.56	**
TR x PRD	1325.1707	10	132.5171	2.6354*	
TR x VR	688.1618	4	172.0405	3.4215	**
VR x PR	493.7018	10	49.3702	< 1	
Error	1005.6549	20	50.2827		
Total	15762.9726	53			

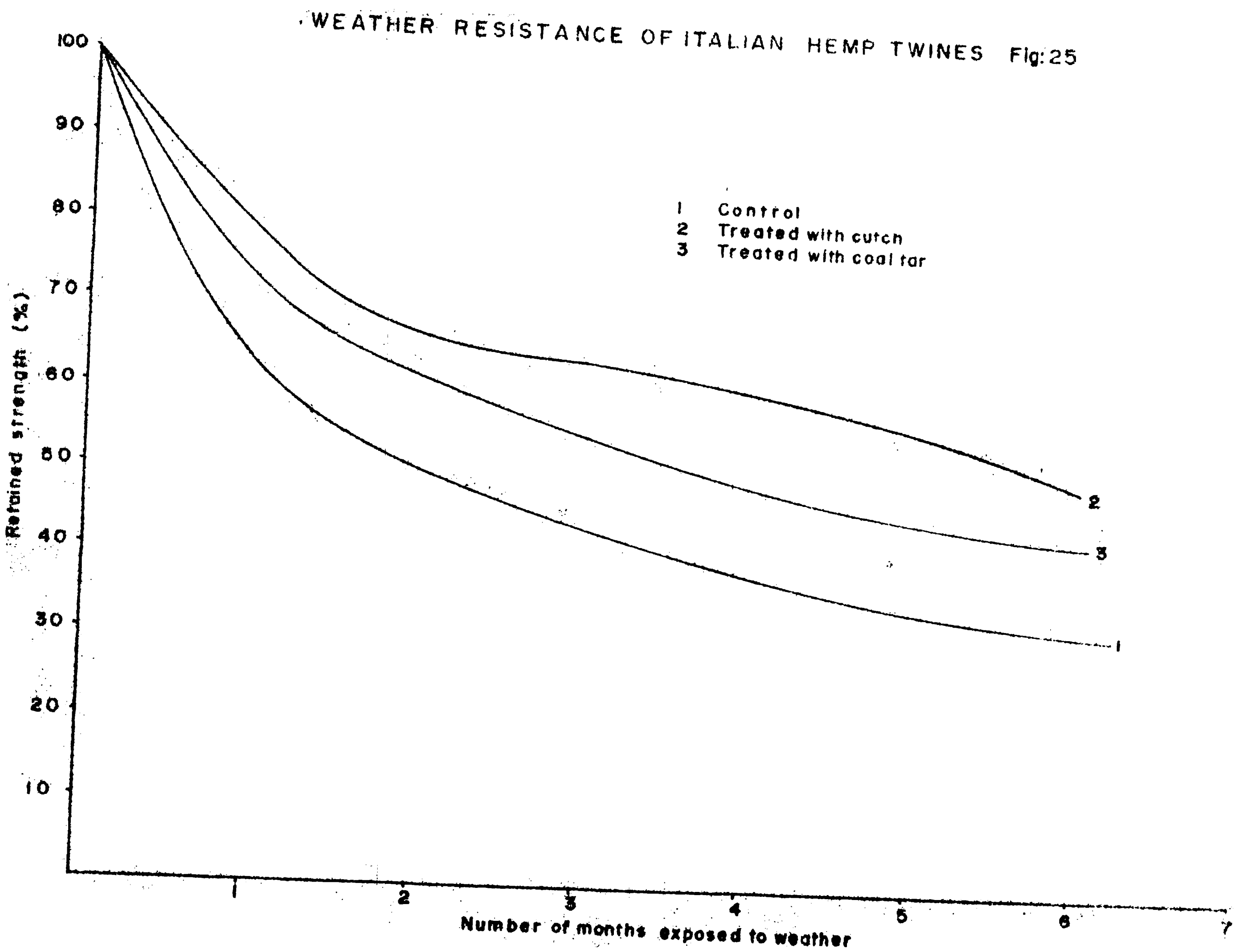
* $P \leq 0.05$

** $P \leq 0.01$

WEATHER RESISTANCE OF COTTON TWINES Fig: 23




WEATHER RESISTANCE OF SUN HEMP TWINES Fig : 24
100
90
80
70
60
50
40
30
20
10
0
Retained strength (%)
1
2
3
4
5
6
No. of months exposed to weather
1 Control
2 Treated with cutch
3 Treated with coal tar
1
2
3



WEATHER RESISTANCE OF ITALIAN HEMP TWINES Fig:25
1 Control
2 Treated with cutch
3 Treated with coal tar
Retained strength (%)
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
Number of months exposed to weather

and thereafter the reduction in strength was only marginal. In the case of Italian hemp, treatment with cutch was more efficient than that with coal tar. In all cases the treated samples were found to be stronger than the control.

6.23 <u>Comparative weather resistance of different synthetic yarns:</u>

Synthetic yarns belonging to different polymers and different types of yarns of the same polymer were tested by exposing the yarns to weather conditions. Polyamide multifilament and monofilament; polyethylene monofilament and flat tape; and polypropylene monofilament were exposed to weather and the data on the retention of strength are presented in table 39.

Table 38

The coeff. of correlation between the number of days of exposure and the percentage retention of strength was found to be negative and highly significant in all the cases indicating a steady decrease in strength as the period of exposure increased. The percentage of retained strengths observed at periodic intervals were plotted against number of days of exposure and presented in figure 26.

Fig. 26

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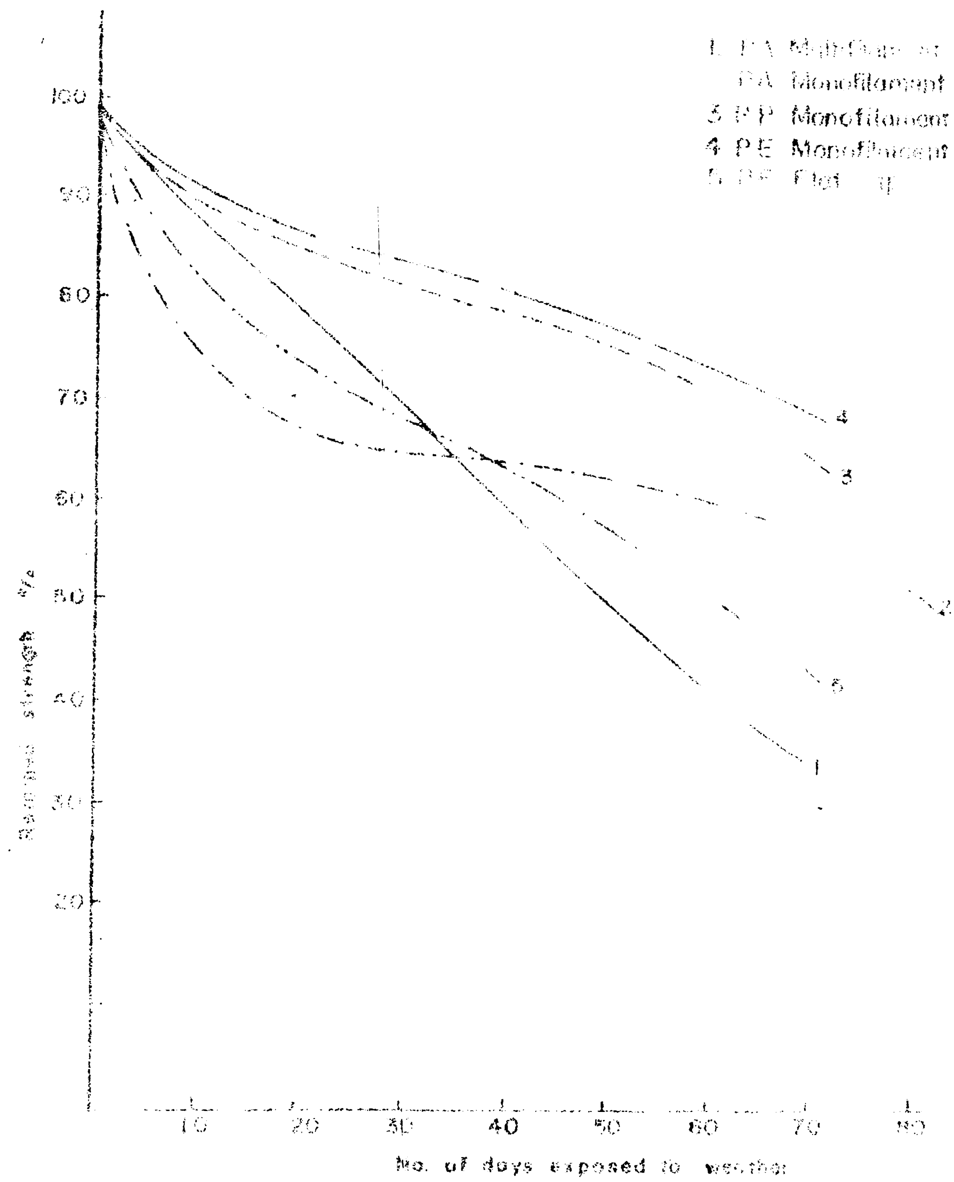
Table: 39. Comparative weather resistance of different synthetic yarns.

No. of days exposed to weather	Percentage Retention of strength after exposure to weather				
	PA multi-filament	PA mono-filament	PP mono-filament	PE mono-filament	HDPE flat tape
10	86.5	68.5	84.0	87.5	85.0
20	85.4	67.5	83.5	83.0	70.5
30	68.0	66.5	82.0	87.5	69.5
40	62.0	65.5	77.0	76.0	65.5
50	53.5	67.5	78.0	79.5	66.5
60	38.5	59.0	72.0	79.5	49.5
70	36.0	58.0	64.0	72.5	41.5

COMPARATIVE WEATHER RESISTANCE OF DIFFERENT SYNTHETIC YARNS Fig: 26



Polyethylene monofilament was found to be the most resistant material amongst the yarns exposed to weather, followed by polypropylene monofilament. Among polyamide multifilament and monofilament yarns, reduction in strength is rapid in the case of the former, reaching 50% after 50 days exposure to weather while in the latter case there was steady decrease in first 10 days, upto 68.5%, and thereafter the reduction was comparatively slow. Comparing polyethylene monofilament and polyethylene flat tape yarn, monofilament was found to be more resistant.

6.24 Comparative weather resistance of different synthetic twines:-

The retained strengths of seven different types of synthetic twines, viz. polyamide monofilament, multifilament and staple twines, multifilament twines of polyester and polypropylene, polyethylene monofilament twines and polyvinyl alcohol staple fibre twines exposed to weather conditions continuously for a period of 10 months are presented in table 40. The corresponding retention of stre-

Table 40

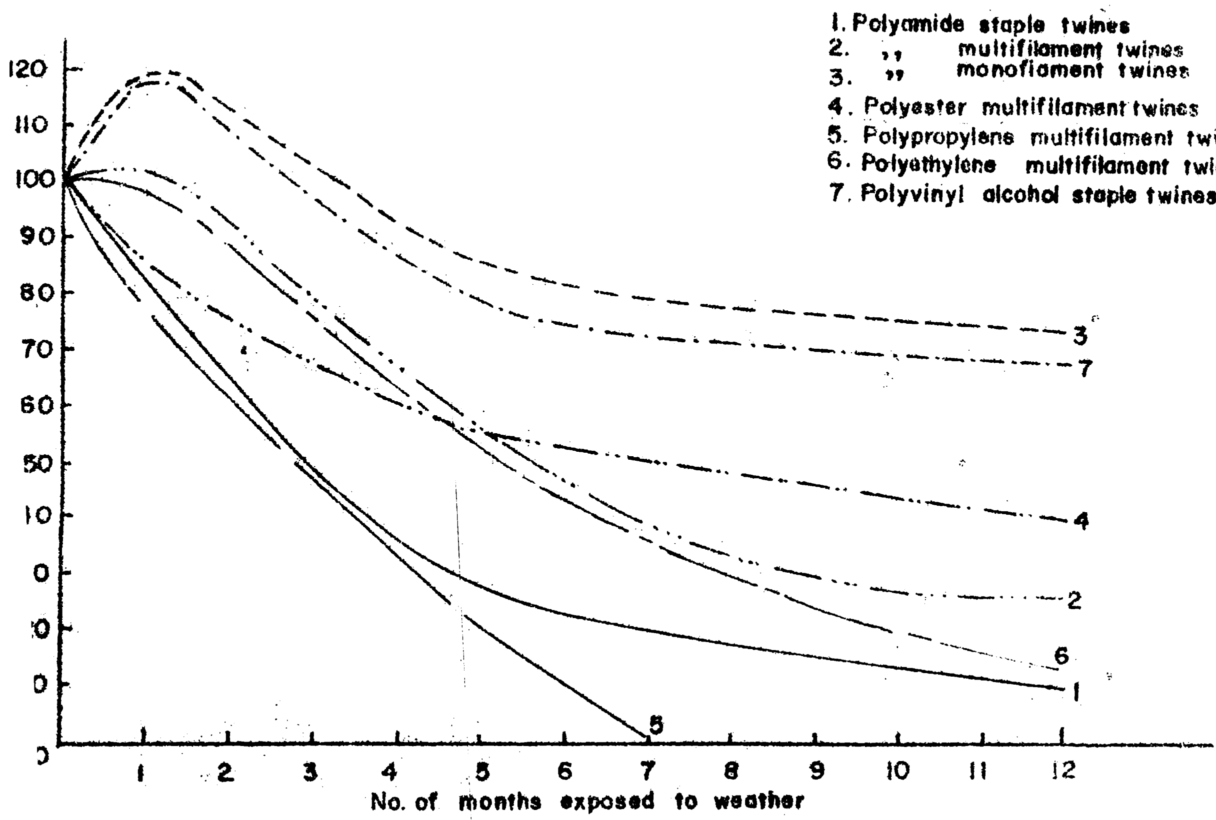
ngths in each type of twine at periodic intervals were plotted as shown in figure 27.

Fig. 27

Table 40 **Weather resistance of different synthetic fibre twines**

Sl.No	Twines exposed	Breaking strength original (kg)	Retained Breaking strength(kg)after exposure						
			1 month	2 months	3 months	5 months	7 months	9 months	12 months
1.	Polyamide staple	15.3	12.65	9.65	7.90	4.25	3.2	1.95	1.65
2.	Polyamide multifilament	17.2	17.85	17.15	13.0	9.45	6.75	6.15	4.85
3.	Polyamide monofilament	17.6	21.3	20.85	19.3	15.05	15.35	13.85	13.05
4.	Polyester multifilament	17.1	14.45	12.70	11.5	10.1	9.15	8.0	6.85
5.	Polypropylene multifilament	15.6	14.45	11.4	7.65	2.9	0.35	r o t	t e n
6.	Polyethylene monofilament twisted	19.1	18.95	15.75	14.6	9.1	6.45	4.8	2.45
7.	Plywiyl alcohol staple	14.1	17.25	14.85	14.45	10.95	11.2	10.5	9.55

WEATHER RESISTANCE OF DIFFERENT SYNTHETIC TWINES. Fig: 27



The polyamide monofilament and polyvinyl alcohol twines showed better resistance than the others. Both registered an increase in the breaking strength during the first month and then gradually decreased. Even after 10 months of exposure to weather polyamide monofilament and polyvinyl alcohol twines retained 74% and 68% breaking strength respectively. Polyamide staple and polypropylene multifilament reached 50% strength level in aperiod of 3 months of exposure. In both cases there was a steep decrease from the date of exposure. Polyethylene monofilament twines took 5 months to reach 50% level of strength, compared to 5 to in polyamide multifilament and 7 to 8 months in terylene multifilament.

6.25 Weather resistance of synthetic twines of different diameters

Polyamide multifilament and polyethylene twisted monofilaments and flat tape twines of different diameters were exposed to weather conditions to study the effect of thickness of twines on the resistance to weather. The data collected are presented in table 44. The relation between retention of strength and number of days exposed is presented in figure 28.

Table 44

Fig. 28

Table: 41 Comparative weather resistance of synthetic twines of different diameters

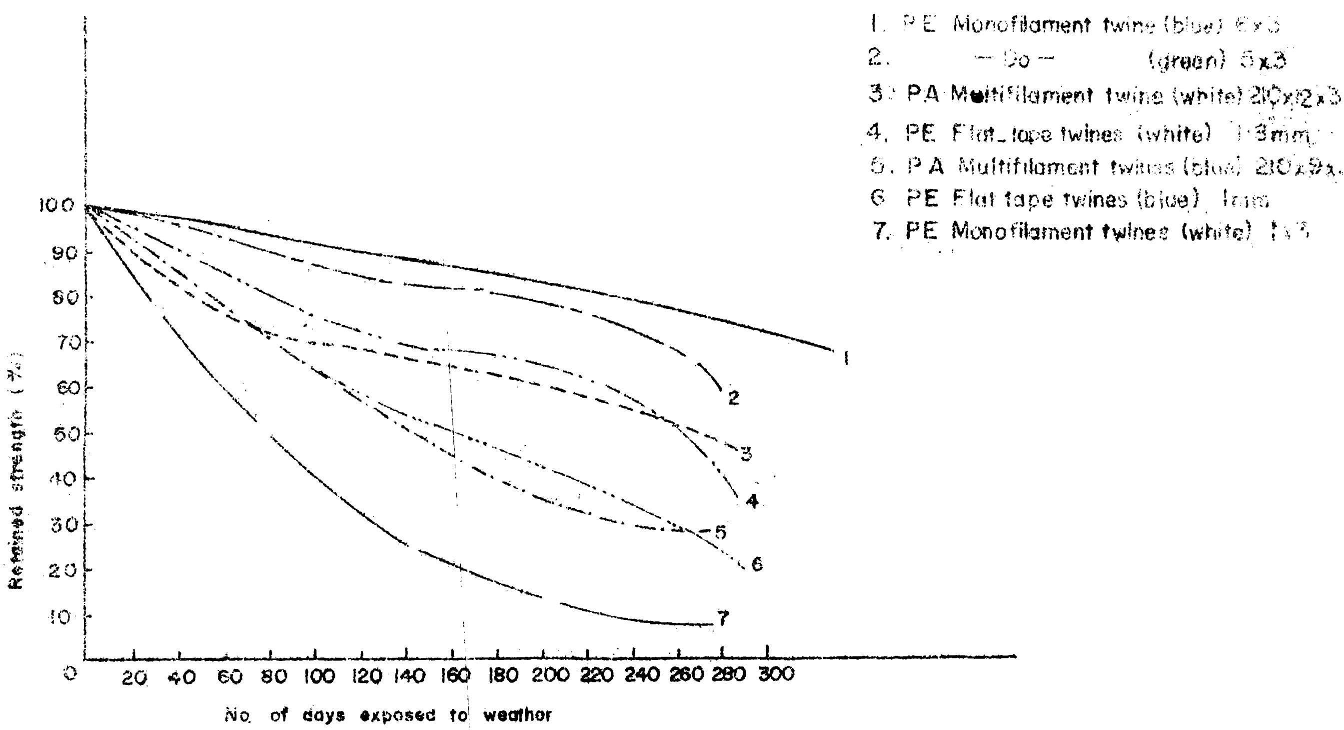
No. of days exposed to weather	Percentage retention of strength						
	PA multifilament twine		PE twisted monofilament			High density polyethylene flat tape	
	210x9x3 blue	210x12x3 white	1 x 3 white	5 x 3 green	6 x 3 blue	1 mm blue	1.8 mm white
1	2	3	4	5	6	7	8
19	79.5	84.5	98.5	98.5	99.0	79.5	84.5
31	74.5	81.5	82.5	98.5	101.0	74.5	81.5
52	75.0	80.5	62.0	95.5	98.5	75.0	80.5
62	73.0	80.0	67.0	92.5	95.5	73.0	80.0
77	62.0	74.0	47.0	91.0	94.5	62.0	74.0
95	58.5	72.5	36.0	89.0	94.0	58.5	72.5
110	49.0	71.5	37.8	85.0	90.5	49.0	71.5
125	50.0	71.0	32.0	50.5	85.5	50.0	71.0

Contd......

Table 41 Contd.

1	2	3	4	5	6	7	8
146	51.0	61.5	26.4	84.5	88.5	51.0	61.5
164	48.0	63.0	18.0	80.5	88.0	48.0	63.0
185	46.0	63.0	23.2	81.5	88.0	46.0	63.0
201	48.5	65.0	15.7	79.0	86.5	48.5	65.0
215	43.0	62.0	13.5	79.0	83.5	43.0	62.0
230	37.5	56.0	15.7	78.5	80.0	37.5	56.0
245	34.6	55.0	..	76.5	79.0	34.6	55.0
262	34.0	54.0	..	73.0	78.0	34.0	54.0
275	29.6	47.5	..	73.0	72.5	29.6	47.5

COMPARATIVE WEATHER RESISTANCE OF SYNTHETIC TWINES OF DIFFERENT DIAMETERS – Fig: 28



The sample of nylon twine 210/9/3 coloured in blue reached 50% strength in a period of 140 days, whereas white nylon 210/12/3 took 280 days of exposure to weather to reach the same strength level. In the case of PE monofilament twines, 1 x 3 white reached 50% strength in 80 days' time while 5 x 3 coloured in green retained 60% strength and 6 x 3 coloured in blue retained 70% strength after exposure to weather continuously for a period of 300 days. In the case of tape twines, 1 mm diameter twine reached 50% strength by exposure to weather for 150 days and 1.8 mm diameter twine after 260 days.

It is evident from the figure that the diameter has got definite influence on the weather resistance in all the cases. This finding corroborates results of Klust (op. cit) that the thicker the twine, the better the protection given by the outermost covering to the inner layers when subjected to weathering. Regarding the effect colour of twines on weather degradation it cannot be confirmed by this experiment since the diameter of twines are different. However, it seems that the colour has no deteriorative effect in the case of polyethylene twines.

6.26 Effect of colour and chemicals on the weather resistance of nylon twines

Nylon twines of 210/9/3 dyed in different colours in the laboratory were exposed to weather along with control for a period of 150 days. The data collected for different periods of weathering are presented in table 42. The data

Table 42

were analysed by using the analysis of variance technique. It was observed that the difference between treatments was highly significant (P 0.01). The critical difference was worked out and the mean breaking strength values were grouped. The breaking strength of undyed sample (white) and sample dyed in yellow colour showed similar resistance to weathering, whereas group consisting of blue, grey, orange and brown behaved similarly showing a slightly lower resistance compared to the first group. Nylon twines dyed in green and red colour showed very poor resistance to weather.

From the results it is clear that dyeing has not improved the resistance to weather of nylon twines. On the other hand dyeing with most of the colours showed only adverse effect.

Table: 42 Weather resistance of nylon twines dyed in different shades, and those treated in Chemisol and coal tar.

No. of days exposed to weather	Breaking Strength values (Kg) polyamide multifilament twines dyed								treated with	
	white	blue	green	yellow	grey	orange	red	brown	Chemisol	coal tar
original strength(dry)	21.5	20.4	20.5	20.5	20.5	20.8	20.6	20.7	21.8	21.8
30 days	18.1	17.6	15.7	19.3	17.0	17.6	15.6	17.9	19.8	16.6
60 "	17.5	16.2	15.0	18.1	16.3	16.5	10.6	15.5	17.9	14.2
90 "	16.0	13.4	11.8	15.4	13.6	13.0	8.1	14.1	16.9	13.7
120 "	13.7	11.5	8.3	12.4	12.1	9.8	4.8	11.3	14.9	10.8
150 "	14.2	10.9	7.6	11.5	11.2	8.3	4.4	10.6	14.6	11.8

Nylon twines of the same specification as those treated with colours were also treated with chemisol, a weather retardi preservative and coal tar and subjected to exposure tests along with the coloured nylon twines (table 42). It was observed that the chemisol treated twines exhibited resistance equal to the first group i.e. without colour and yellow coloured nylon twines; while the resistance of coal tar treated twines was similar to the second group comprising of blue, grey, orange and brown. Hence it can be concluded that both treatments did not show extraprotection to nylon twines against weathering.

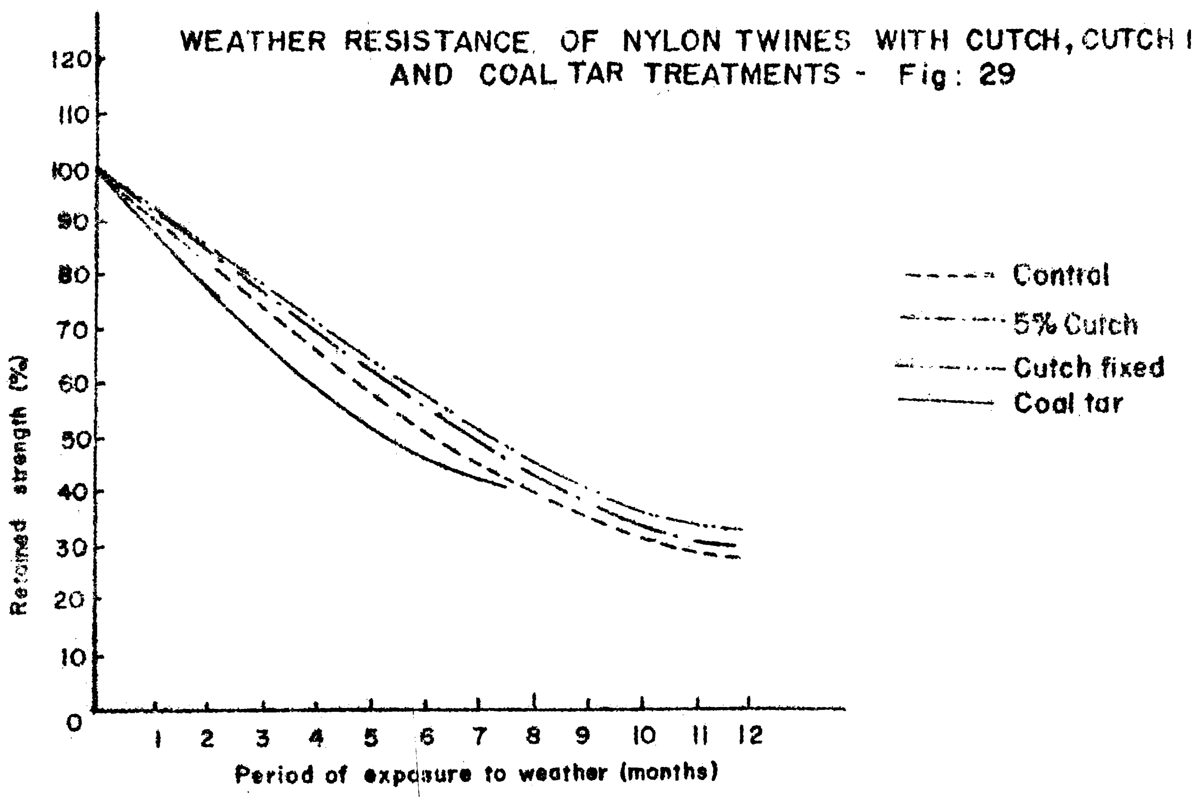
Another set of nylon twines (210/4/3) treated with 5% cutch, cutch fixed by ammoniacal copper sulphate solution and coal tar were exposed to weather along with untreated twines. The retained strength at periodic interval are presented in table 43. From a plot of the number of months of exposure to weather on the retained strength (figure 29) an exponential decay relation of the form $Y = AB^{-X}$ was observed.

Table 43

Fig 29

TABLE 43 WEATHER RESISTANCE OF NYLON TWINES(210/4/3) TREATED WITH CUTCH, CUTCH FIXED AND COAL TAR

Sl. No.	Treatments	Breaking strength (Kg)		Retention of strength (kg) after exposure to weather for different periods(months)					
		Before treatment	After treatment	2	4	6	8	10	12
1.	untreated	14.2	14.2	10.6	9.7	7.6	6.0	4.5	4.0
2.	treated with 5% cutch	14.2	15.4	12.0	10.6	7.6	6.3	4.8	4.8
3.	cutch fixed by ammoniacal copper sulphate	14.2	15.1	11.6	11.1	8.6	7.3	5.1	4.4
4.	Coal tar	14.2	15.4	10.9	8.9	6.7	6.4	5.0	5.1


WEATHER RESISTANCE OF NYLON TWINES WITH CUTCH, CUTCH I
AND COAL TAR TREATMENTS - Fig: 29
120
110
100
90
80
70
60
50
40
30
20
10
0
Retained strength (%)
1 2 3 4 5 6 7 8 9 10 11 12
Period of exposure to weather (months)
Control
5% Cutch
Cutch fixed
Coal tar

Therefore between logariths of retained strength and the number of months of exposure a linear relationship is expected. This was confirmed by the highly significant correlation coefficients between logariths of retained strength and number of months of exposure (Table 44). Whether the rate of decay is the same for all the four types of treatments was tested by using analysis of covariance method as given in table 44.

Table 44

As shown by the 'F-tests', there is no significant difference in the rate of deterioration due to different treatments and also there is no significant difference in the initial breaking strength corresponding to different treatments. Thus a common relation between the retained strength and the months of exposure, regardless of the four treatments can be expressed as

$$\log(\text{retained strength}) = 1.1603 - 0.0442(\text{months of exposure})$$

or as in the exponential decay relation

$$Y = 14.46\ (1.11)$$

Table : 44 Comparison of regression lines - log Retained strength on number of months of exposure to weather.

	d.f	x^2	xy	y^2	Reg Coeff.	Deviations from regression d.f	S.S.	M S
L within								
1 untreated	6	112	-5.2070	0.2447	-0.0465	5	0.00269	0.00053(s)
2 5% cutch	6	112	-5.0816	0.2368	-0.0454	5	0.00598	0.00119
3 Cutch fixed	6	112	-5.0046	0.2287	-0.447	5	0.00503	0.00101
4 Coal tar	6	112	-4.5200	0.1946	-0.0403	5	0.01220	0.00244
5						20	0.02590	0.00129
6 Pooled, W	24	448	-19.8132	0.9045	-0.0442	23	0.02824	0.00123

Table 44. Contd.

7			Difference between slopes			3	0.00234	0.00078
8	Between, B	3	0	-0.0002	0.0104			
9	W + B	27	448	-19.8134	0.9149	26	0.03863	0.00149
10			Between adjusted means			3	0.01039	0.00346

Comparison of slopes : $F = \frac{0.00078}{0.00123} = 0.63$ (d.f = 3,20) N.S

Comparison of elevations : $F = \frac{0.000346}{0.00123} = 2.81$ (d.f = 3,23) N.S

x^2 , y^2 and xy are the corrected sums of squares and cross products.

- G 3504 -

Where Y is the retained strength and X is the number of months of exposure, 14.46 and 1.11 being estimates of the constants A and B.

The regression lines for the four treatments and the combined regression line along with the plot of log retained strength on the number of months of exposure are presented in figure 30

Fig. 30

The figure shows that the straight lines corresponding to the different treatments are very close to the combined line. The following conclusions are drawn.

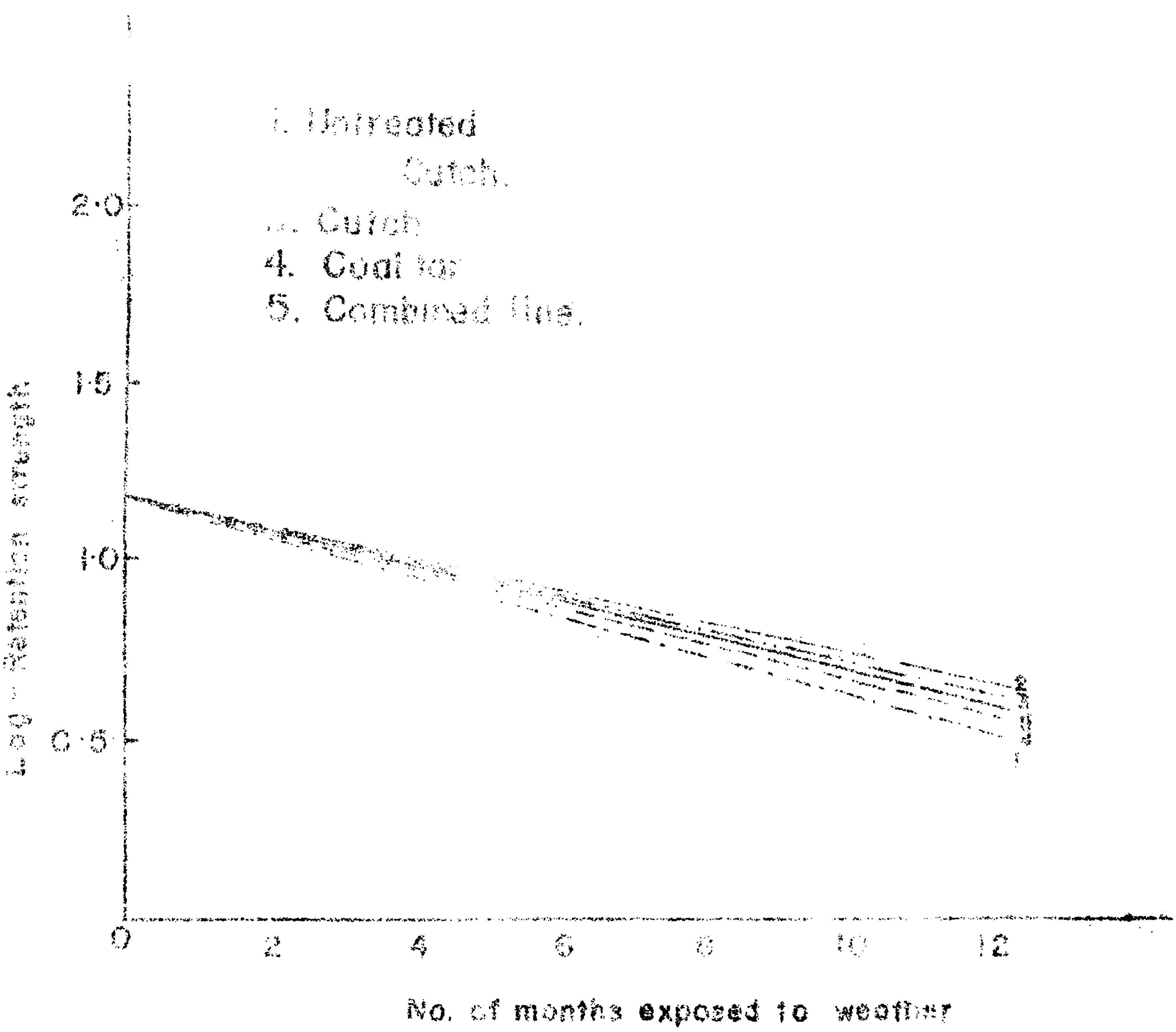
1. The relationship between retained strength and number of months of exposure is found to follow the exponential decay law

$$Y = AB^{-X}$$

2. There is no significant difference between the rates of deterioration for the four treatments considered.

3. There is no significant difference in the initial breaking strength corresponding to different treatments.

WEATHER RESISTANCE OF NYLON -
REGRESSION LINES - Fig: 30



6.3 FATIGUE DUE TO STATIC LOADING:

Honda (1965) carried out experiments on fatigue on netting twines with various static loads for about a week and found that polyethylene, polypropylene and cremona twines are unable to recover the elongation caused by fatigue compared to amilan and tetron. It was also noted that fatigue by smaller loads does not affect the strength of twines and when greater loads were applied, the strength loss was rapid.

Different samples of fish net twines were subjected to fatigue due to static loading test (photograph 8) by suspending a load of 5 kg. for varying periods such as 4 hours, 18 hours, 24 hours and 48 hours. The elongation of the samples was noted and they were tested for stress-strain behaviour. Figures 31 to 37 show the results of load-elongation of cotton twines, PE monofilament twines, PE braided twines, PP fibrillated twines, PE flat tape twines and PP multifilament twines before and after the static loading tests for different periods. Table 45 shows the elongation caused by static loading, the breaking strength and stretch of the different materials.

Figures 31, 32, 33, 34, 35, 36 and 37

Table : 45

FATIGUE DUE TO STATIC LOAD (5kg)
COTTON - Fig - 31

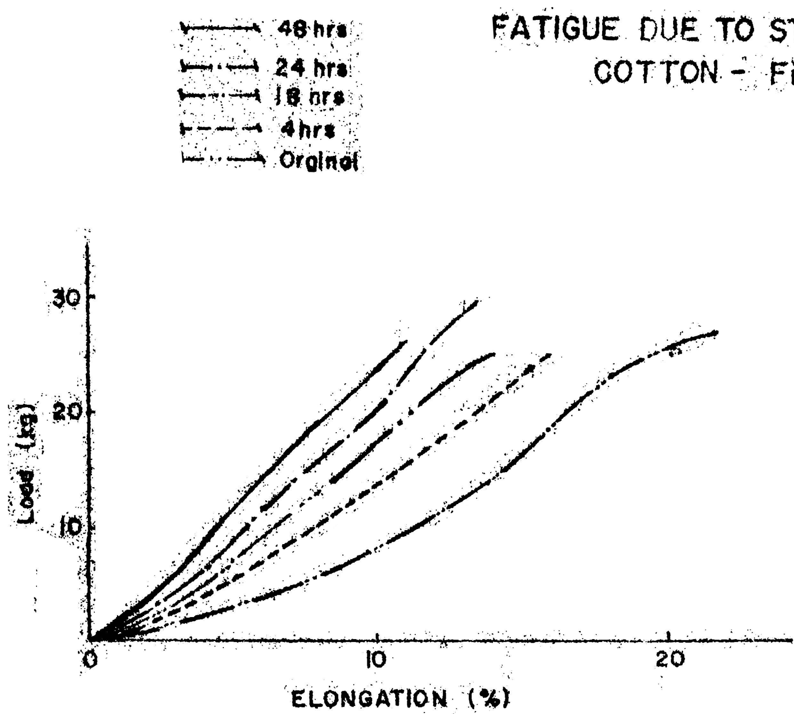
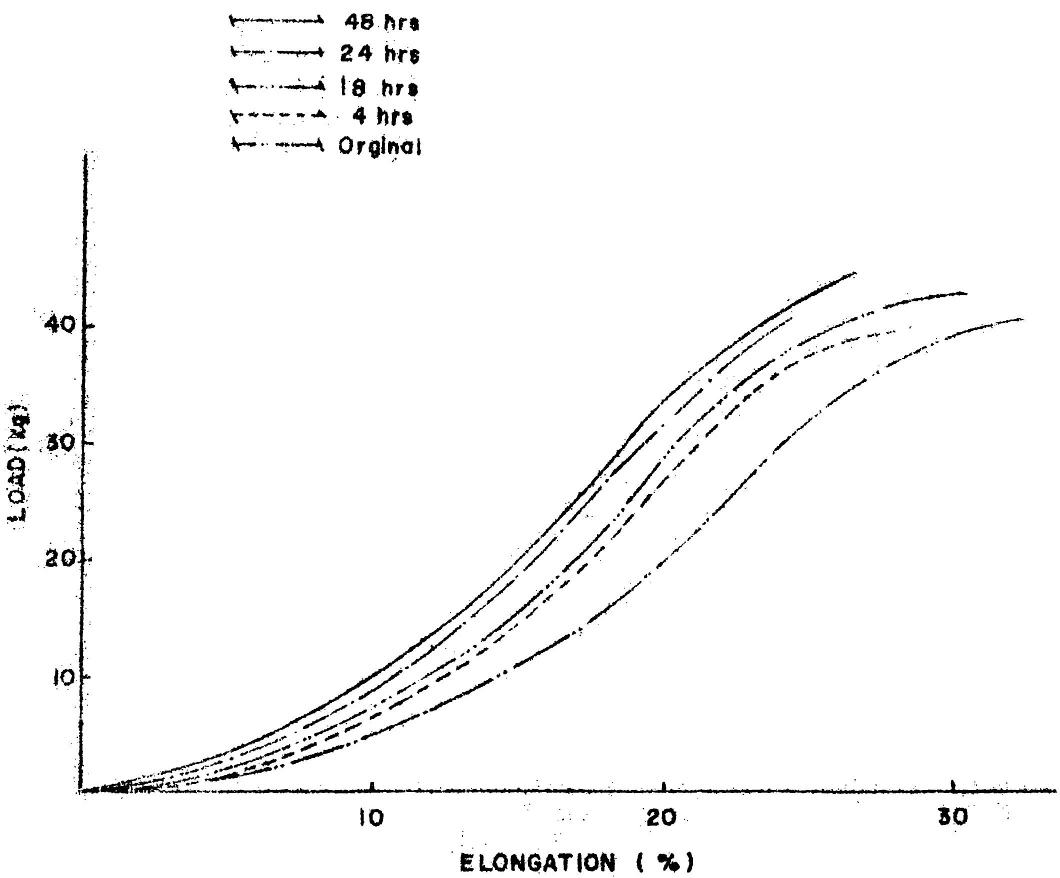
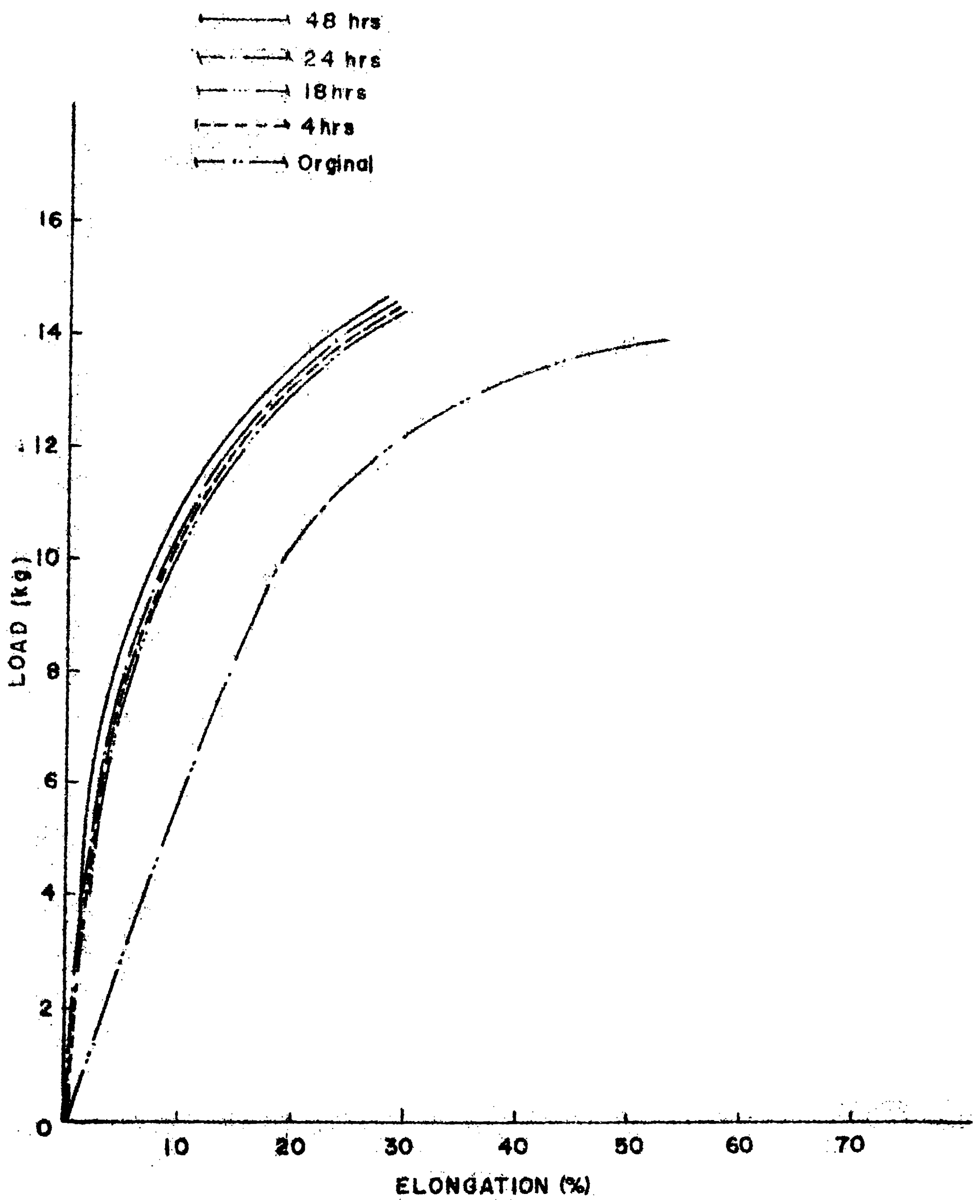


Fig. STRESS - STRAIN BEHAVIOUR OF NETTING TWINES AFTER FATIGUE DUE TO STATIC LOADING.

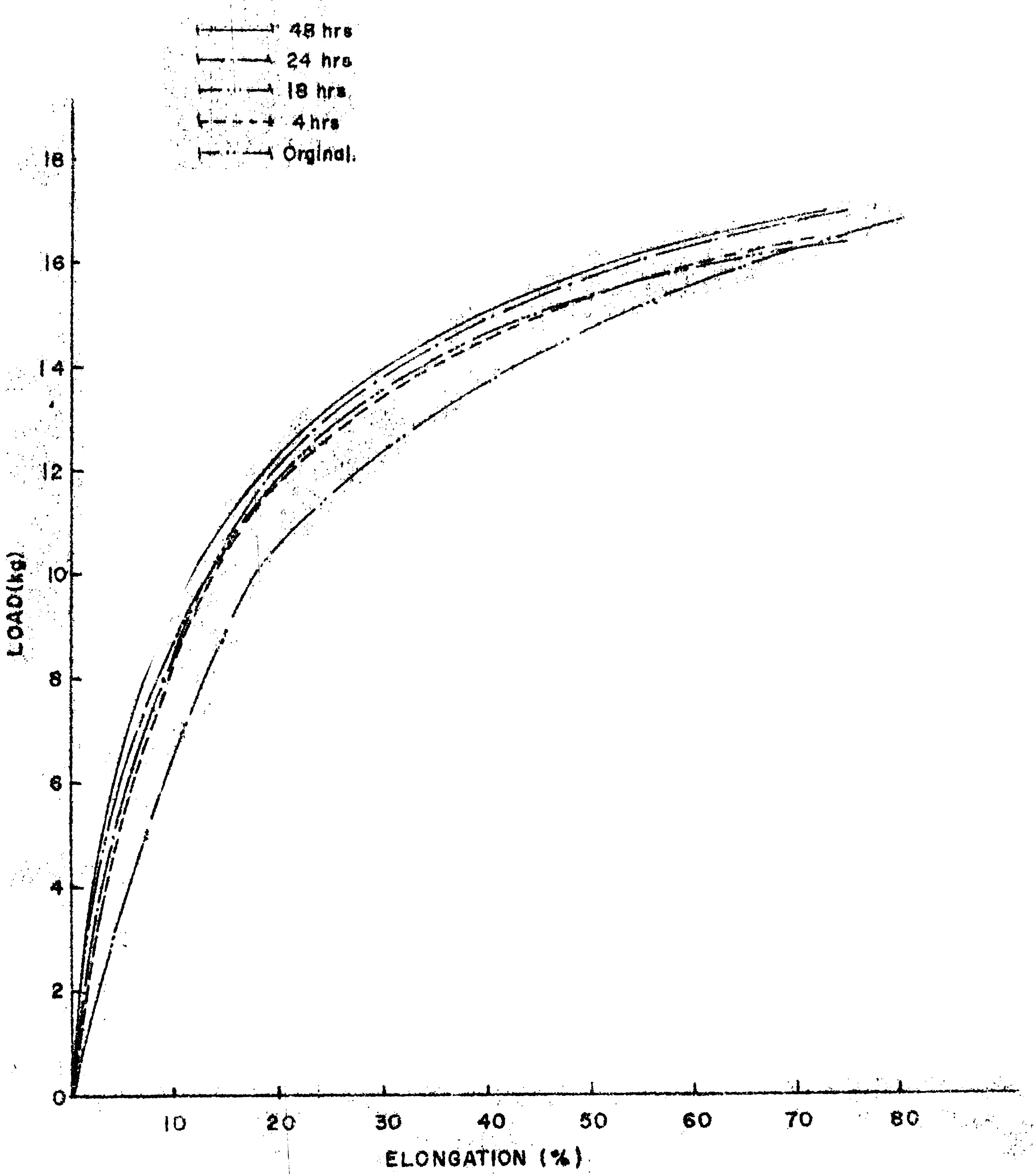
FATIGUE DUE TO STATIC LOAD (5 kg) - P A MULTIFILAMENT TWINES - Fig:32



FATIGUE DUE TO STATIC LOAD (5kg) - PE MONOFILAMENT TWINES. Fig. 33

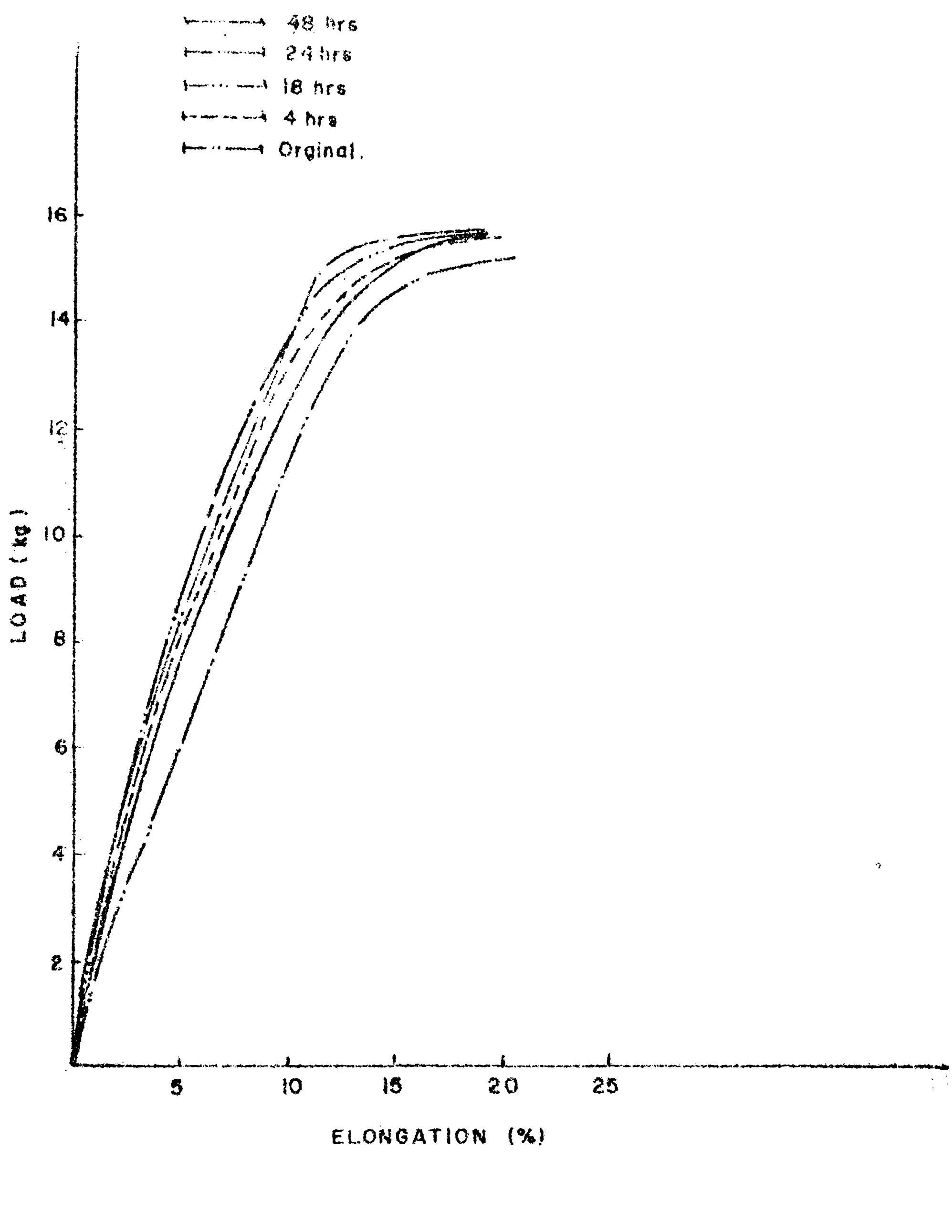


FATIGUE DUE TO STATIC LOADING (5 kg) PE MONOFILAMENT BRAIDED TWINES - Fig 34

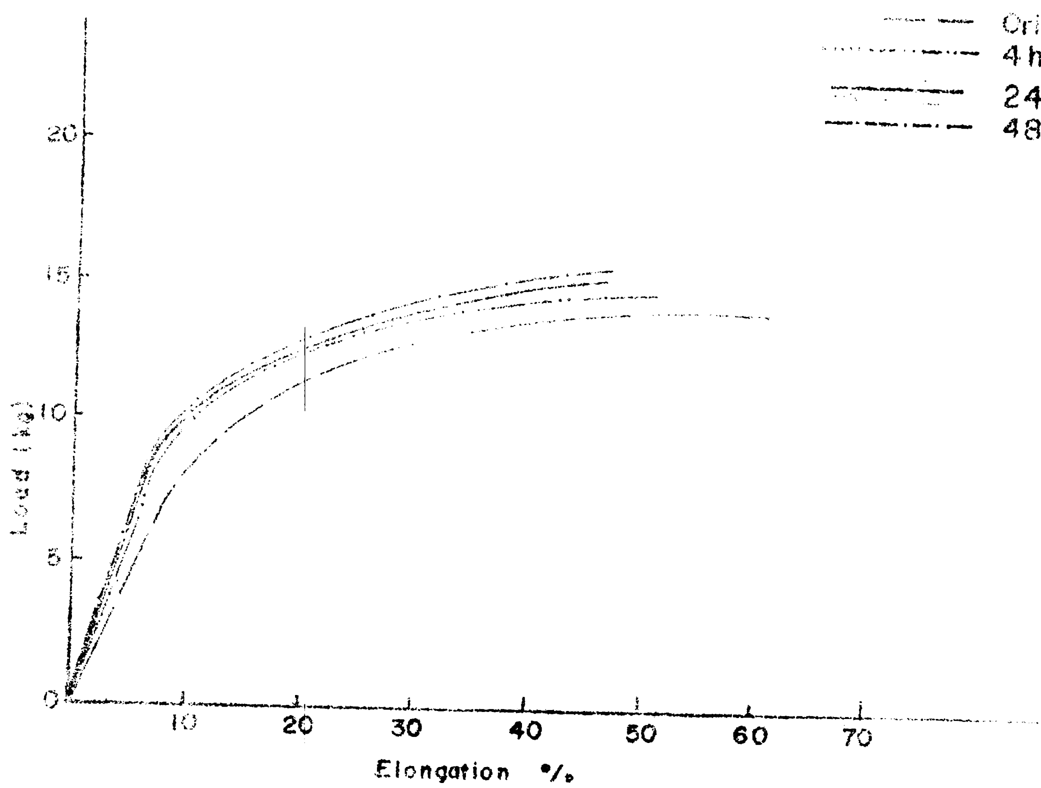


FATIGUE DUE TO STATIC LOAD (5 kg) - P E FLAT TAPE

Fig: 35



FATIGUE DUE TO STATIC LOADING (5 kg) - PE FIBRILLATED TAPE Fig : 36



FATIGUE DUE TO STATIC LOAD (5 kg) – P P MULTIFILAMENT TWINES – Fig: 37

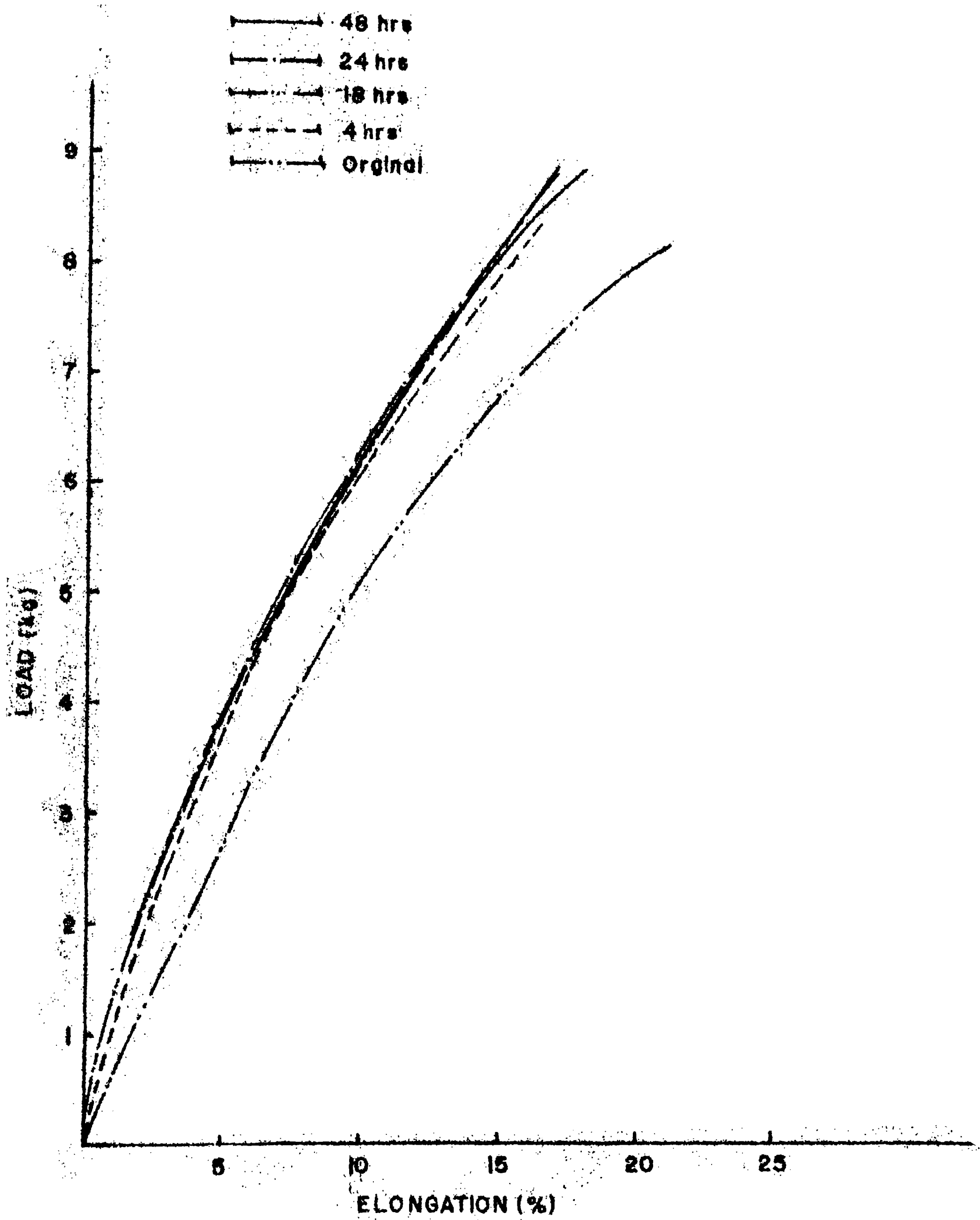


Table 145 Elongation, breaking strength and stretch on fatigue due to static loading for different periods.

Materials	Time of fatigue	Elongation (%)	Breaking Strength (Kg)	Stretch (%)
Cotton	original	-	25.2	21.6
"	4 hours	9.5	24.4	15.8
"	18 "	11.5	27.5	14.0
"	24 "	12.0	27.0	13.8
"	48 "	12.3	26.0	11.6
PA multifilament	original	-	40.0	36.0
	4 hours	6.8	43.0	27.6
	18 "	7.0	44.5	24.4
	24 "	8.4	39.0	30.5
	48 "	9.7	44.0	26.5
PE monofilament	original	-	14.0	53.1
	4 "	11.0	14.7	42.0
	18 "	11.3	14.2	29.8
	24 "	16.1	14.5	29.8
	48 "	16.9	14.8	28.1
PE braided	original	-	16.8	80.0
	4 hours	2.2	16.6	72.3
	18 "	2.3	16.4	75.0
	24 "	3.2	17.1	80.5
	48 "	4.0	17.0	74.5

Table : 45. Contd.

PE flat tape	original	-	15.2	21.0
	4 hours	3.2	15.6	20.0
	18 "	3.6	15.6	19.6
	24 "	3.7	15.8	18.6
	48 "	4.5	15.7	20.1
PE fibrillated tape	original	-	14.2	30.1
	4 "	2.0	14.5	2[illegible].2
	18 "	4.5	14.6	24.0
	24 "	5.0	15.0	25.0
	48 "	5.0	14.3	25.0
PP multifilament	original	-	8.2	21.2
	4 hours	4.5	8.2	16.0
	18 "	4.5	9.0	19.1
	24 "	4.7	8.8	16.8
	48 "	6.0	8.7	17.8

It would be seen that different materials react differently under the fatigue tests. The stress-strain behaviour shows that the original stretch of twines is affected by static loading for different periods. The load-elongation curves of different materials take up a course towards the ordinate depending upon the fatigue time in the case of cotton twines while the others follow a similar course with increase in the duration of fatigue time.

The effect of fatigue on the elongation of twines depends upon the inherent quality of the fibre. However irrespective of the material, it would be evident from the figures that the elongation is affected, while the strength of twine is not reduced by static loading. In fact, the strengths of the fatigued samples were found to be a little higher than those of the unfatigued. The decrease in the breaking stretch is attributed to the increase in the extension of net materials by static loading which is time-dependent.

6.4 ABRASION :

The wearing away of any part of a material by rubbing against another surface is known as abrasion. Vegetable fibres are mostly destroyed by rotting rather than abrasion and so fishermen did not pay much attention to this problem before the introduction of synthetics. Resistance to wear is an important property deciding the durability of the material. The nets come into contact with abrasive surfaces of different kinds such as wood, rusty metal, mechanically driven blocks, sharp edges, nails, rivets and others on the vessel and sand, gravel, shell, sponge, rock and other obstacles at the bottom of the sea. Internal abrasion is caused by the friction of fibres against each other. Rubbing of netting yarns against each other also causes abrasion to a lesser degree. Fyke nets ort rap nets used in stagnant waters are not subjected to considerable abrasive wear nor to strong stress, whereas trawls, particularly bottom trawls are exposed to intensive wear and tear. Damage caused to midwater trawl net is mainly attributable to the chafing of the net when it is hauled up over the ramp of a stern trawler. Shimozaki (op. cit) is of opinion that it is not feasible to compare the abrasive resistance of one type of fishing net with another that has different characteristics. However, for general purposes, comparison between various net twines having the same twist range can be made under identical conditions. He has also pointed out that results of laboratory tests cannot be taken as conclusive for judging the abrasion resistance of net materials and the only reliable test of this property is actual endurance in commercial fishing operations.

Studies conducted by Bombeke (1964) showed the resistance to abrasion of cabled nylon was seven times higher than that of manila and sisal in the dry state, but only slightly more resistant than sisal in the wet state. Warenzeichenverband (op. cit) tested the comparative abrasion resistance of twines made of vegetable fibres such as hemp and manila and synthetic fibre, perlon. With increase in the thickness of these twines the abrasion resistance in the wet state increased. According to him staple fibres showed a lower resistance than those made of continuous filament. The breaking strength showed 62% loss in the case of manila cord compared with 19% in the braided perlon cord. Klust (1959) studied the comparative abrasion resistance of both vegetable and synthetic fibres and found the latter to be superior to the former. Further, he found that the abrasion resistance decreased with the loss in breaking load caused by rotting of vegetable twines. When the loss in breaking load by rotting was 50%, the loss of abrasion resistance was found to be 23% and 15% for hemp and manila respectively. Between staple and continuous filament twines in case of both polyamide as well as polyvinyl alcohol Klust (1973) observed the abrasion resistance to be almost double in the case of filamentous type compared to staple twines. The comparative abrasion properties as studied by him have shown that the resistance to abrasion was more for synthetics than vegetable twines. Between polyester and polyamide continuous fibre twines, the resistance of polyester was found to be 50% of that of polyamide twines. The finer twines of other synthetic materials like polyvinyl chloride, polyvinyl alcohol and polyacrylonitrile showed only lesser abrasion resistance than cotton. Regarding the hardness of twines and the abrasion resistance, Klust found that hard twisted twines of polyamide had less abrasion resistance than soft twisted twines. The same trend was observed in the case of braided type of construction. Contrary to this observation, Shimozaki (op. cit) found that the twists of strands play an important role in increasing the rigidity of the twines in parts of nets which causes friction against hard objects. He suggested that the number of twists applied to strands should not be too much as to sacrifice tensile strength for improving abrasion resistance. Miyamoto and Mori (1957) observed that rubbing of hard synthetic twines against each other resulted in quick snapping of both twines, while a hard twine rubbed against a soft one broke the latter first. When both the twines were soft, the resistance to abrasion was found to improve. Shimozaki (op. cit) has shown that when cotton and kuralon were rubbed against each other, cotton withstood 260 rubbings while Kuralon withstood 530. But when Kuralon was rubbed against saran, it could withstand only 60 rubs.

The abrasion tests were conducted in the laboratory using an abrasion tester shown in photograph 7.........

One end of the twine is fixed on hook and the other end carries standard tension. The twines were set on pulleys enabling the twines to touch the moving oilstone abradant. The number of to and fro motions of the abradant (cycles) are noted on the counter. The twines subjected to abrasion were tested for breaking strength and stretch.

Nylon twines of different thicknesses were tested for resistance to abrasion. The breaking strength of the samples are given below.

No. of cycles	Breaking strength(Kg) of abraded nylon twines		
	210/3/3	210/6/3	210/9/3
5000	6.9	13.9	17.9
10000	5.6	10.8	13.1
12000	2.7	7.2	13.1

The data reveal that the breaking strength reduced considerably with increase in the number of frictions. It is also noted that with increase in thickness of twines the resistance to abrasion was more. It was noticed that strength of 210/3/3 twine reduced to 39% after 12000, while in the case of twines of 210/6/3 and 210/9/3 the reductions were 52% and 73% respectively.

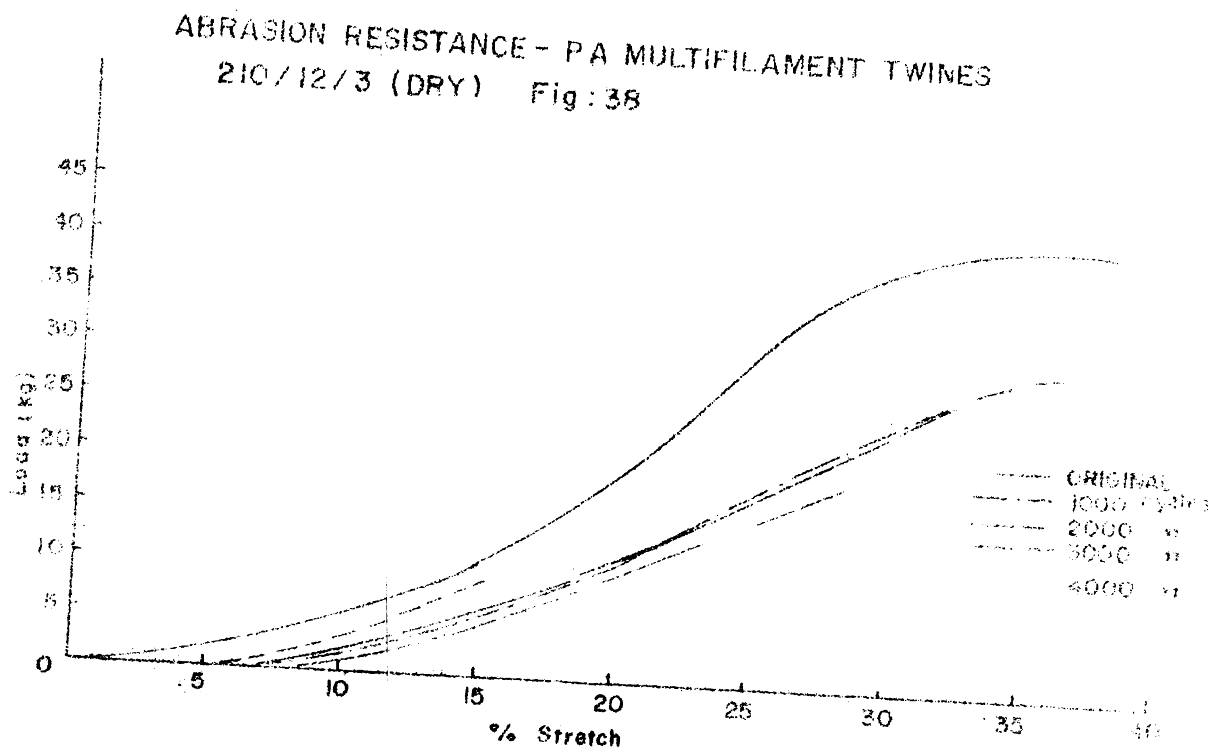
The stress-strain behaviour of nylon twines before and after abrasion tests is presented in Figure

Figs. 38 and 39

It is evident that the area under the load-elongation graph is considerably affected by increase in the number of frictions both in dry and wet conditions.

A comparison of the abrasion resistance of nylon and terylene is given in table 46

Table 46


ABRASION RESISTANCE - PA MULTIFILAMENT TWINES
210/12/3 (DRY) Fig: 38
Load (kg)
% Stretch
ORIGINAL
1000 cycles
2000 "
3000 "
4000 "

ABRASION RESISTANCE PA MULTIFILAMENT TWINES
210/12/ (WET) Fig: 39

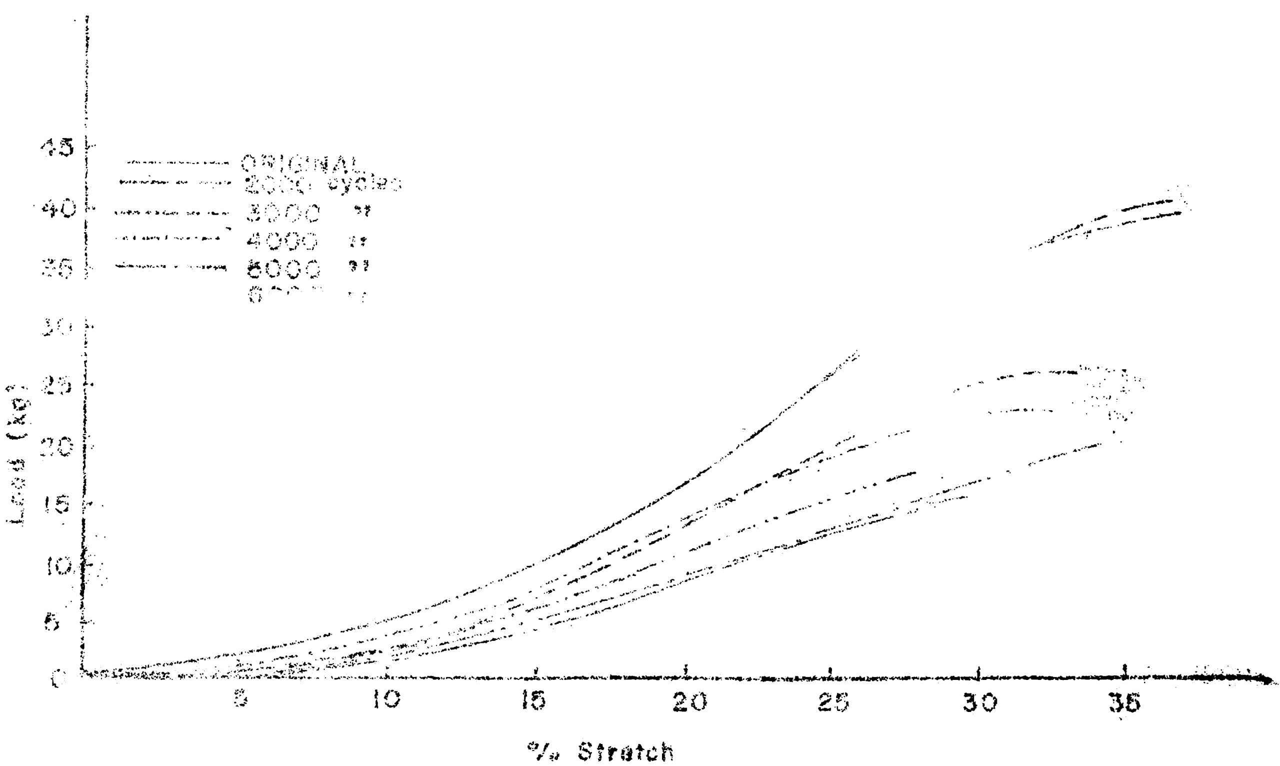


Table 46 Comparison of abrasion resistance of nylon and terylene twines

	Nylon 210/12/3 Dry Cycles	Br. Strength (kg)	Br.Stretch (%)	Wet Cycles	B.Strength (kg)	Br.Stretch (%)	Terylene 210/10/3 Dry Cycles	Br.Strength (kg)	Br.Stretch (%)	Wet Cycles	Br.Strength (kg)	Br.Stretch (%)
Original		42.5	38.0		39.6	37.1		32.8	14.5		35.5	16.2
	1000	31.5	37.3	2000	25.8	33.6	500	30.9	13.1	200	29.1	15.2
	2000	25.5	23.3	3000	23.1	32.1	1000	23.0	13.4	600	20.3	10.5
	3000	19.4	28.2	4000	19.7	34.4	1500	20.7	13.2	800	12.5	8.5
	4000	9.0	15.1	5000	17.4	28.2	2000	8.0	7.6	1000	7.6	7.4
				6000	17.1	28.0				1200	6.5	6.2
				7000	15.1	29.6						
No.of cycles upto break		4890			16318			4154			1858	

Both nylon and terylene twines showed decreasing strength and stretch values with increasing number of frictions. It is evident from the table that nylon exhibits better abrasion resistance in the wet state than in dry which is further confirmed by the number of frictions observed upto break. On the contrary, terylene twines showed better resistance in the dry state. Between the two samples studied, nylon possessed superior abrasion resistance especially in the wet condition.

The number of cycles observed for breaking samples of PE monofilament twines, PA multifilament (210/9/3), PE flat tape (2x3) and cotton twines of 210/12/3 are given below.

Materials	No. of cycles upto break	
	Dry	Wet
PE monofilament	44,745	27,312
PE flat tape	1,15,880	28,974
PA multifilament	22,258	32,194
Cotton	16,443	9,683

Although PE monofilament twines and flat tape twines show very high resistance to abrasion in the dry state, nylon twines seem to exhibit better resistance in the wet state than all the other materials tested.

A comparative account of the abrasion tests conducted on the different materials such as cotton, PA multifilament, PE monofilament twines, PE braided twines, PE flat tape twines, PE fibrillated tape and PP multifilament twines is presented in table 47. The to and fro movements (cycle) of the oilstone

Table: 4.7 Breaking strength and stretch of different net materials subjected to abrasion test.

Sl. no.	Materials	Original Strength (Kg) dry	Original Strength (Kg) wet	Samples abraded for 1 hr at the rate of 180 cycles per minute: Breaking Strength (Kg) Dry	Breaking Strength (Kg) wet	Breaking stretch (%) Dry	Breaking stretch (%) wet
@1	Cotton	14.5	15.1	2.6	4.2	15.6	21.5
2	PA multifilament	12.5	11.6	8.4	5.0	34.0	26.0
3	PE monofilament	16.0	17.2	12.0	9.6	24.0	16.3
4	PE braided	14.5	14.9	10.2	7.6	23.0	14.0
5	PE flat tape	9.1	9.8	5.5	3.3	14.5	12.0
6	PE fibrillated tape	10.5	11.3	8.1	7.2	15.0	14.0
*7	PP multifilament	12.7	12.5	9.0	4.7	20.0	10.0

@ abraded for 20 minutes

* abraded for 10 minutes.

abradant were noted as 110 per minute. The materials were

Table 47

put to abrasion continuously for a period of one ~~your~~ YEAR in dry and wet conditions and their breaking strength and stretch were noted before and after the tests. Since polypropylene multifilament twines and cotton twines could not withstand the test for one hour the time of abrasion was reduced to 10 minutes and 20 minutes respectively.

It would be evident from the table that the resistance to abrasion is more in the dry state when compared to wet in case of all the materials studied. Of the materials PE monofilament twines exhibited good resistance to abrasion both in dry and wet states. PE monofilament braided twines although exhibited good resistance in the dry state, poor performance was noticed in the wet condition. Flat tape twines showed lesser resistance than fibrillated tape twines. Fibrillated tape twines exhibited higher resistance to abrasion than nylon. Among the synthetic fibres polypropylene multifilament twines showed poor resistance to abrasion.

6.5 ACTION OF HEAT AND CHEMICALS :

Concentrated nitric acid, hydrochloric acid and sulphuric acid cause rapid disintegration of nylon fibre. Phosphoric acid degrades the net materials at elevated temperature and formic acid above 80% dissolve the fibre (Klust

1973) Japan Chemical Fibres Association (1959) reported the effect of heat, effects acids and alkalis and organic solvents on vinylon, nylon, vinylidene and polyvinyl chloride fibre. It is reported that polyester has got high level of resistance to chemical attacks like those of oxidising agents and organic solvents while phenols dissolve the fibre. Polyvinyl chloride is resistant to acids and concentrated caustic soda, while the fibre dissolves or swells in some aromatics, chlorinated hydrocarbon, ketones etc. Vinylidene chloride is affected by sunlight but unaffected by most acids. Alkalis like ammonium and sodium hydroxide affect the strength of twines while they showed good resistance to other chemicals and inert to organic solvents. Remarkable resistance to attack by alkali, acids, solvents and organic salts by polyethylene is reported while the twines flex at a temperature of 70 C. Vinyl alcohol cause decomposition or swelling in concentrated nitric acid, hydrochloric and formic acids. Strong alkalis cause yellowing but do not affect the strength; good resistance to organic solvents and oils is reported.

Since the effects of most of the chemicals have already been reported, experiments are restricted to assess the effect of fish net twines by dry andwet heat at different temperatures, action of grease, diesel oil and detergents with which the nets often come into contact on the boat deck. Table 48 presents the breaking strength and stretch of

Table: 48 Action of heat and chemicals on fish net twines.

Sl. no.	Action of heat and chemicals	Retained breaking strength (Kg)						
		Cotton	PA multi-filament	PE mono-filament	PE mono-braided	PE flat tape	PE fibri-llated	PP multi-filament
1	0 C	14.5	12.3	8.2	14.0	9.4	10.4	12.0
2	Dry heat 50	14.2	11.8	8.0	14.2	9.2	10.2	12.0
3	" 70 C	14.5	12.1	7.9	14.3	9.0	10.5	12.1
4	" 100 C	14.3	12.4	8.6	14.1	9.2	10.4	10.6
5	Wet heat 50 C	14.7	11.7	8.3	14.2	8.9	10.9	12.2
6	" 70 C	14.8	11.4	8.7	13.4	9.3	10.4	12.0
7	" 100 C	14.9	11.3	9.2	14.4	9.1	10.8	12.5
8	Room temp Dry	14.5	12.8	8.5	14.5	9.1	10.5	12.7
9	" wet	15.1	11.6	9.6	14.9	9.8	11.3	12.5
10	Diesel oil-cold	13.9	12.4	7.9	13.9	8.8	10.3	12.1
11	Chlorine water (1000 ppm)	15.0	11.5	8.5	14.2	8.4	10.7	12.2
12	Grease	15.1	12.0	8.4	14.1	8.6	10.2	12.3

different kinds of net materials on action of dry and wet heat, grease, diesel and chlorine water.

Table 48

It would be evident that the strength and stretch of common net materials are not affected by dry and wet hea upto 100 C. The results corroborates the earlier observati by Kuriyan and Cecily (1961). It is also noted that chemicals that come in contact with the deck surfaces do not affect the properties of fish net twines.

CHAPTER VII

MIXING OF SYNTHETIC FIBRES FOR FISH NETS :

Klust (1973) reported mixing of soft continuous filament material with split fibre or monofilaments results in an increase in stiffness could be obtained. The fliexibility indices observed in the combinations reported by him are as follows.

Proportion of mixture	Flexibility
PA cont. fil. 50% + PP fil. 50% braided	24
PA cont. fil.78% + P P split 22%	49
PP cont. fil. 50% + PP split 50%	91
PES cont. fil. 75% + PP split 25%	61
PA cont. fil. 66% + PE Monofil. twisted	12

Combination twines for fishing gears which consist of two synthetic components produced in Japan are the following.

Trade name	Combination
Kyokurin	PA fil + Saran
Livlon	PA fil + Saran
Marlon A	PA fil + PVA staple
Marlon B	PA fil + Saran
Marlon C	PA + PVC fil.

Mamoi Fishing Net MFG. Co. (1959) also mentioned a method to improve the specific gravity of nylon for use in deep water gill nets and seines by hanging a strip of vinylidene net 360d/30 ply on a ratio of 4:1 of nylon and vinylidene under the nylon. This method was not entirely satisfactory. Later nylon and vinylidene fibres were combined during manufacture of yarn and twine. This product is known as Livlon and possesses which had considerable advantage for deep water gill netting operations. The seine to be pursed should sink within two minutes to catch the entire school, i.e. the sinking must be at the rate of 1 fathom per second which is difficult to accomplish with ordinary material. However, Livlon seine netting of smaller diameter twine manufactured with a special twisting method was found to be equal in specific gravity to cotton and hence is able to meet the requirements. Marlon netting was first put to commercial use in 1951. Its most notable characteristics are derived from the combination of the best features of nylon and vinylon fibres. The advantages of such combinations are increased specific gravity, maintenance of strength by the predominance of nylon fibre and decreased knot slippage. Marlon and other combination synthetic twines are recommended for purse seines, beach seines, lamparas and trap nets.

ICI (op. cit) reported mixing of high tenacity terylene filament and spun acetate netting twines for pilchard nets. The net was quite suitable and did not bruise or damage the fish. The knots were also found to be stable. Terylene core spun cotton yarns also were tried for similar reasons, but because of the presence of cotton, the twines could not be rot-resistant as the mixed twines made with spun acetate yarn. Arzano (op. cit) has mentioned about blend with man-made fibre with viscose staple and acetate staple and blends with viscose staple with nylon and wool. Du Pont De Nemours (1959) mention about the combination of twines made of nylon and spun acetate used for trap netting.

As synthetic fibres are man-made they can be tailored to produce the required properties. A programme on mixing of synthetic fibres was therefore tried in the laboratory the results of which are indicated below.

7.1 Mixing of monofilaments of polyamide, polyethylene and polypropylene :

The monofilaments of size 0.20, 0.15 and 0.20 of polyethylene, polyamide and polypropylene were twisted in the ratio of 1:1:1 and the resultant twines were subjected to analysis of physical properties. In order to study the merits and demerits of blending twines were made exclusively with each of the components. Tables 49, 50, 51 and 52 present the physical properties of twines prepared in the above manner.

Tables 49, 50, 51 and 52

The average strength per denier of different specifications of polyamide monofilamenttwines were worked out to be 2.9 (g) in the dry state and 2.5 (g) in the wet state. A reduction in strength of 13.2% was observed by wetting.

In the case of polypropylene twines the average strength per denier in the dry and wet states was 4.2 (g) and

Table 4.9 Physical properties of PE monofilament twines (size of monofilament 0.2 mm)

Sl. no.	Specification	Mass per metre (g)	Twist per metre		Breaking Strength (Kg)		Breaking Stretch (%)		Knot strength (kg)
			outer	inner	dry	wet	dry	wet	wet
1	3 x 3	0.40	210	142	18.6	18.7	43.8	40.2	16.9
2	6 x 3	0.81	126	130	34.8	35.4	38.6	36.6	19.4
3	9 x 3	1.24	100	62	50.6	48.4	40.6	42.6	24.5
4	12 x 3	1.68	136	64	60.5	63.1	41.2	41.6	31.1
5	15 x 3	2.14	106	84	76.1	75.0	42.8	41.4	41.1
6	18 x 3	2.58	104	56	86.9	87.4	40.0	40.0	47.1

Table: 50 Physical properties of polyamide monofilament twines (size of monofilament: 0.2 mm dia.)

Sl. No.	Specification	Mass per metre (g)	Twist per metre		Breaking Strength (kg)		Breaking Stretch (%)		Knot strength (kg)
			outer	inner	dry	wet	dry	wet	wet
1	6 x 3	0.63	187	160	16.0	14.0	61.6	65.6	9.8
2	9 x 3	0.94	192	134	25.9	21.9	69.6	69.6	15.3
3	12 x 3	1.31	172	116	37.0	30.6	74.6	67.8	21.4
4	15 x 3	1.72	143	98	46.2	41.4	86.6	71.0	28.9
5	18 x 3	2.13	96	70	53.8	49.0	80.1	75.3	34.3
6	30 x 3	3.48	100	92	84.8	74.0	92.4	80.2	51.8
7	45 x 3	4.71	96	84	115.0	94.5	108.0	85.2	66.1

Table: 5 (Physical properties of polypropylene monofilament twines (size of monofilament : 0.15 mm dia.)

Sl. No.	Specification	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Breaking Strength (kg) dry	Breaking Strength (kg) wet	Breaking Stretch (%) dry	Breaking Stretch (%) wet	Knot strength (kg) [illegible]
1	3 x 3	0.21	292	130	9.6	9.6	49.4	48.0	11.0
2	6 x 3	0.42	236	128	15.7	15.9	50.0	49.3	16.7
3	9 x 3	0.61	176	92	23.7	24.4	53.2	47.4	26.4
4	12 x 3	0.83	150	88	32.4	32.7	52.2	49.0	34.4
5	15 x 3	1.03	130	84	39.4	41.2	52.2	46.2	43.0
6	18 x 3	1.21	120	54	46.4	45.9	49.4	44.0	48.6
7	30 x 3	2.08	102	58	62.2	63.4	53.4	48.4	63.8

Table: 52 Physical properties of combination twine made of monofilaments of polyethylene, polypropylene and polyamide in the ratio 1:1:1

Sl. No.	Specification	Mass per metre (g)	Twist per metre outer	Twist per metre inner	Breaking Strength (kg) dry	Breaking Strength (kg) wet	Breaking Stretch (%) dry	Breaking Stretch (%) wet	Knot strength (kg) wet
1	3 x 3	0.35	595	535	13.5	13.6	39.5	39.9	8.0
2	6 x 3	0.79	161	245	24.5	24.3	42.4	40.0	18.3
3	9 x 3	1.12	153	285	34.5	34.7	40.8	45.8	25.0
4	12 x 3	1.52	129	102	45.4	45.0	45.2	43.4	36.0
5	15 x 3	1.96	136	114	54.8	52.4	50.8	49.2	40.0
6	18 x 3	2.39	138	122	66.2	68.8	54.8	55.6	46.0
7	30 x 3	3.67	88	60	99.5	110.0	53.5	51.4	81.4

and 4.5 (g) respectively showing a slight improvement in strength in the wet condition. Plyethlene monofilaments twisted exclusively showed a tenacity value of 2.5 - 3.5 g/d with no reduction in strength in the wet condition. Differe specifications of combination twines made with PE, PP and PA monofilaments showed improvement in strength in both dry and wet conditions when compared to PA monofilaments twisted alone. The method of preparation of combination twines improves the specific gravity of material as one of the components is polyamide. Since monofilaments are widely used in the preparation of ropes, the method of mixing of monofila ments is expected to bring out added properties to the resultant product.

7.2 Mixing of multifilaments of Polyamide and Polyprophylene:

Multifilaments of 210 denier polypropylene were combined to product different specifications of mixed twines as shown in photograph 11

photograph 11

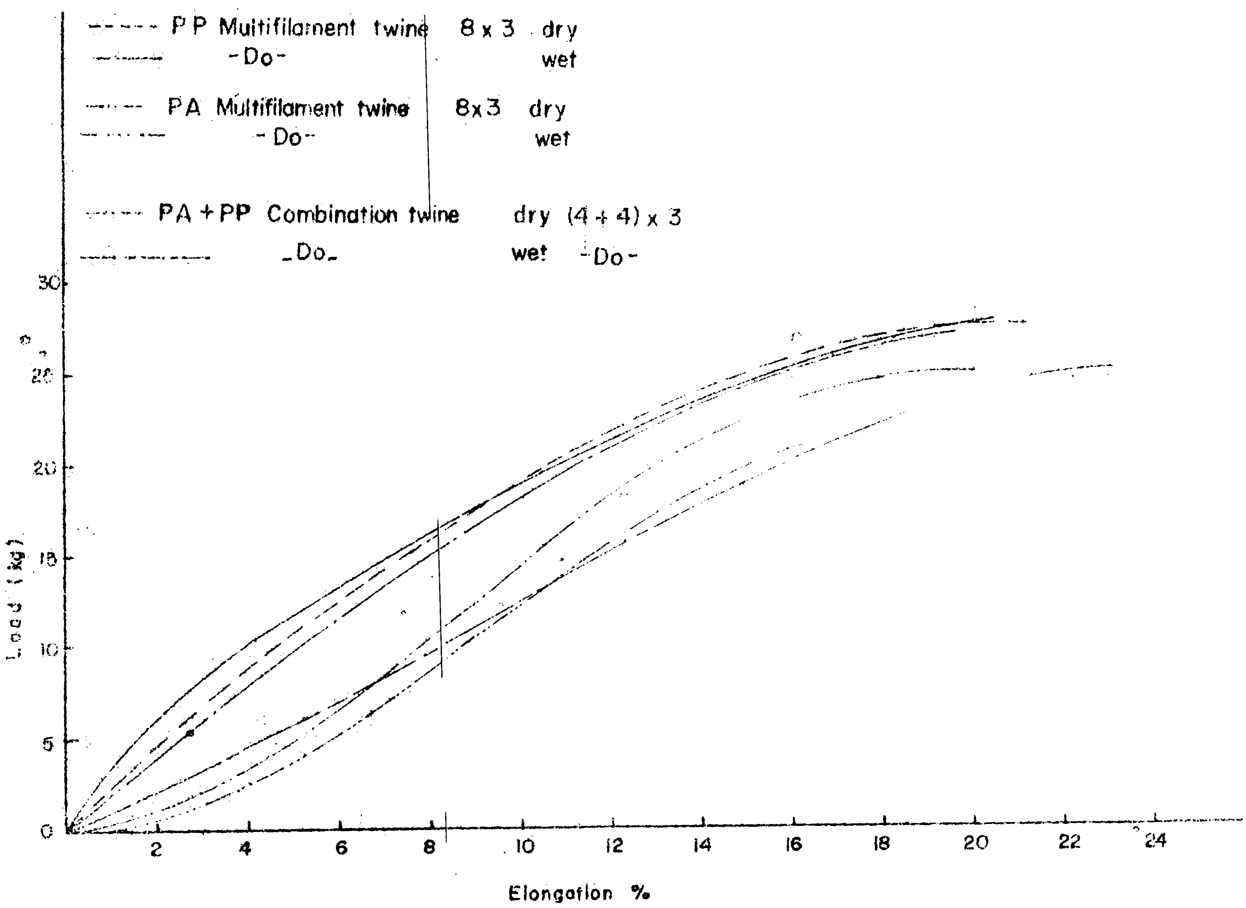
Earlier studies have proved that polyamide multifilaments loses strength in the wet state, while polypropylene twines gain in strength. Nylon is highly elastic possessing good stretching properties, while the extension in the case of polypropylene twines is low when compared to other net materials. Mixed twines prepared in the above manner were analysed for physical properties. The stress-strain readings were plotted and are presented in figure 40

Fig.40

The area under the curves, breaking strength and breaking stretch in dry and wet conditions are as follows.

Sl. No.	Twines prepared	Area under the curve (sq.cm.)		Breaking strength (kg)		Breaking stretch %	
		dry	wt.	dry	wet	dry	wet
1	PA multifilament 210x8x3	109	62	25.2	21.0	20.0	16.2
2	PP multifilament 190x8x3	153	148	27.6	28.2	21.2	20.5
3	Combination of PA and PP multifilaments 210x4x3+ 190x4x3	125	129	27.2	25.4	19.5	23.2

STRESS-STRAIN BEHAVIOUR OF PA MULTIFILAMENT, PP MULTIFILAMENT AND COMBINATION OF PA AND PP MULTIFILAMENT TWINES. Fig. 40



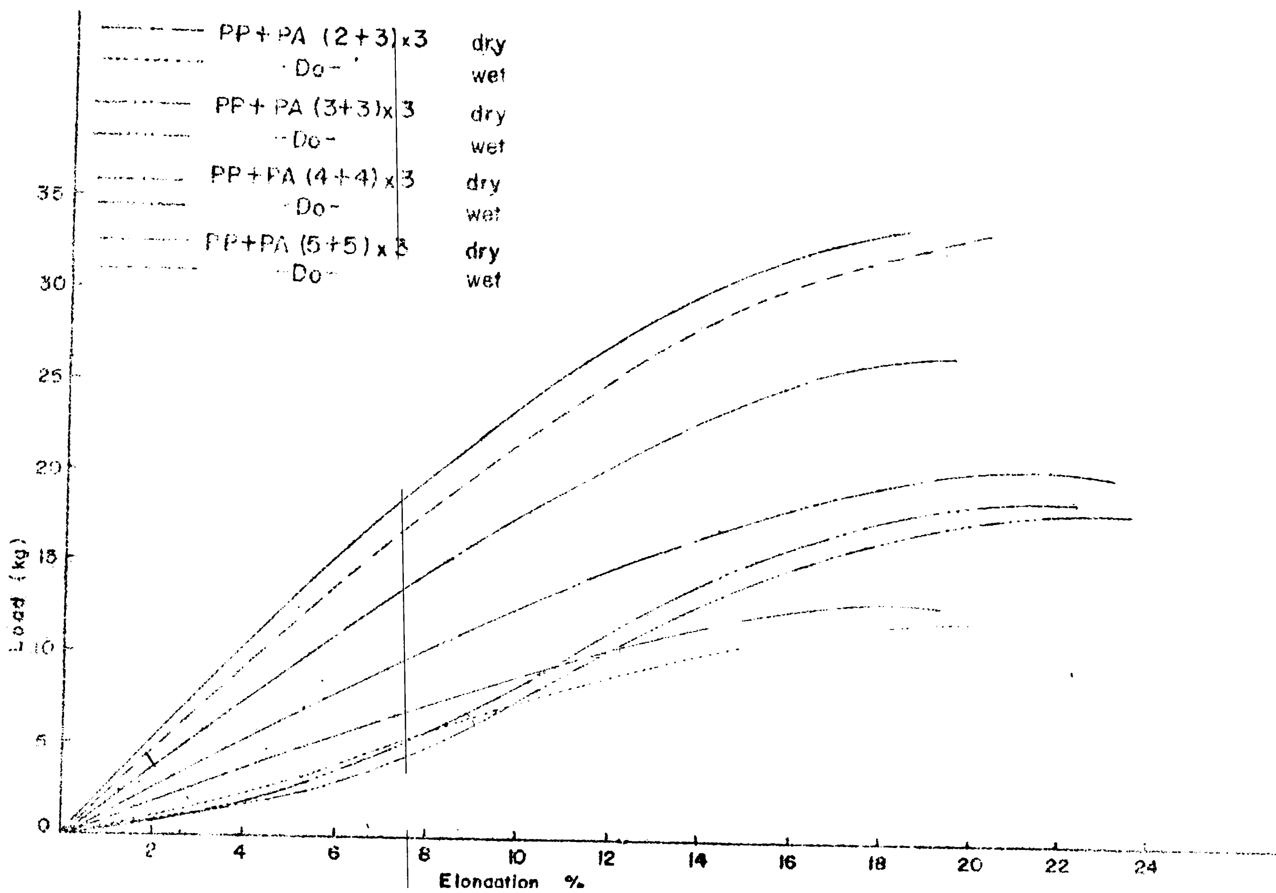
In PA multifilaments the breaking strength in wet condition is reduced while PP multifilaments improve strength in the wet slate. Combination twines show better strength in dry and wet conditions when compared to PA multifilaments twisted alone.

Different specifications of combination twines made of multifilaments of polyamide and polypropylene by experimental twisting in the laboratory were subjected to analysis of stress-strain behaviour and the same is presented in figure 41

Fig. 41

The combination twines made of PA and PP multifilaments were found to be quite flexible when compared to twines made of PP multifilaments alone. The specific gravity of the mixed twines was found to increase when compared to twines made of PP multifilaments alone as the former sink in water while the latter float. It is expected that the blending of PA and PP multifilaments may offer a new material to the fishing industry especially for gill nets where the requirements of pliability, strength and stretch are covered by this new product. By mixing of these fibres in the above

STRESS - STRAIN BEHAVIOUR OF DIFFERENT THICKNESSES OF COMBINATION TWINES MADE OF POLYPROPYLENE AND POLYAMIDE MULTIFILAMENT YARNS Fig. 41



manner the cost of nylon can be brought down by the inclusion of cheap polypropylene fibres.

1.3 Mixing of polyamide multifilament with polyethlene fibrillated tape yarns

The mixing process is similar to the one discussed earlier. Polyamide multifilaments and polyethyene fibrillated tape were twisted in the laboratory using hand driven twine twisting machine. Photograph 12 shows the combination twines prepared in this manner.

Photograph 12

Since the denier number of polyethylene fibrillated tape is 1000, nylon multifilaments of 840 denier were selected for this study.

Twines prepared	Br.strength (kg)		Breaking stretch %	
	dry	wet	dry	wet
1. PA multifilament 840x4x3	64.5	63.0	24.2	26.0
2. PE fibrillated tape 1000x1x3	6.7	7.2	45.0	35.0
3. Combination twine of PA and PE 840x1x3+1000x1x3	24.8	24.0	21.0	21.3
4. Combination twine of PA and PE 840x1x3+1000x2x3	30.3	29.7	23.1	21.3

The strength per denier of combination twines worked out to be .35 grams. It is also evident that by combining polyamide fibres with polyethylene fibrillated tape, the strength of the resultant product in the wet condition is observed to be the same as that of dry state which is also a positive sign when compared to twines made exclusively with polyamide fibres. Again the twines of this combination improved the specific gravity of polyethylene fibrillated twines which otherwise float in water.

It is expected that this material would be a substitute for Italian hemp used for Dara fishery as well as in place of sun hemp twines used in rampani nets where bast fibres have established their utility and so far no synthetic material could be selected as a substitute. The combination of PA multifilaments with PE fibrillated tape can also be tried for deep watdr gill nets for the capture of seer and sharks, apart from using this combination twine for other types of nets. The inclusion of cheap polyethylene fibres brings down the cost of preparation of mixed twines when compared to twines made of nylon alone.

7.4 Mixing of polyamide multifilament polyethylene fibrillated tape and polypropylene multifilaments

The twines prepared by mixing multi filaments of polyamide and polypropylene with those of polyethylene Fibrillated tape yarns are shown in photograph 13

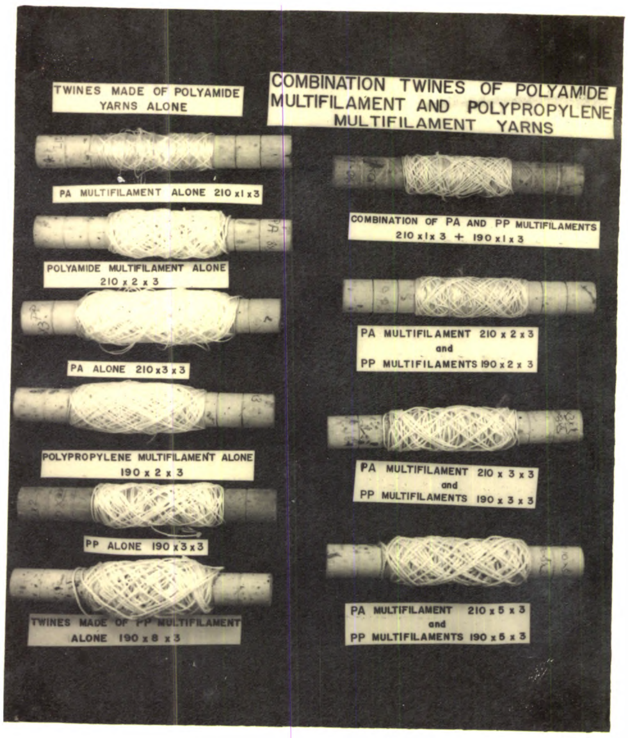
Photograph 13

The strength and stretch values observed in the case of combination twines prepared are as follows:

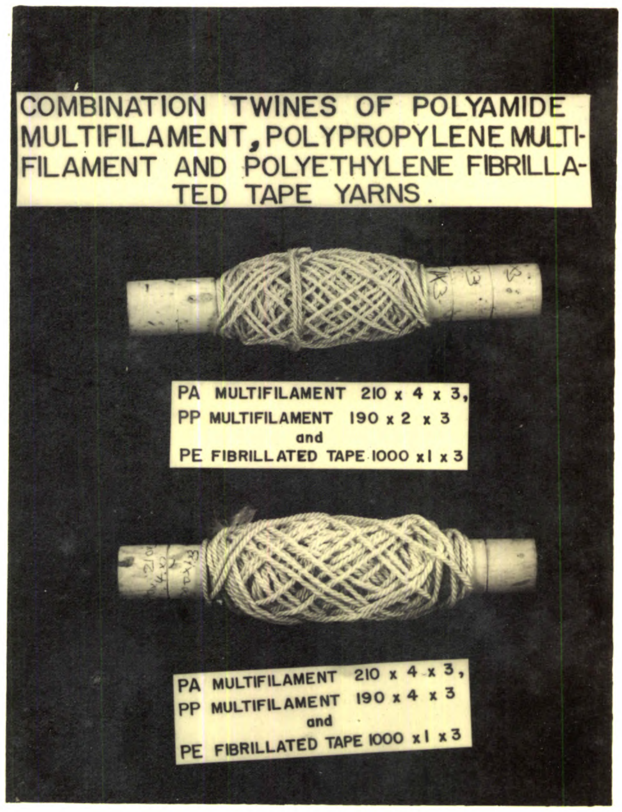
Specification of Combination twine		(210x4x3+ 190x2x3+ 1000x1x3)
Br.strength kg	dry	24.2
	wet	23.2
Br.stretch wet	dry	44.6
	wet	50.5

The strength per denier worked out to be 2.8 and 2.7 in the dry and wet condition respectively.

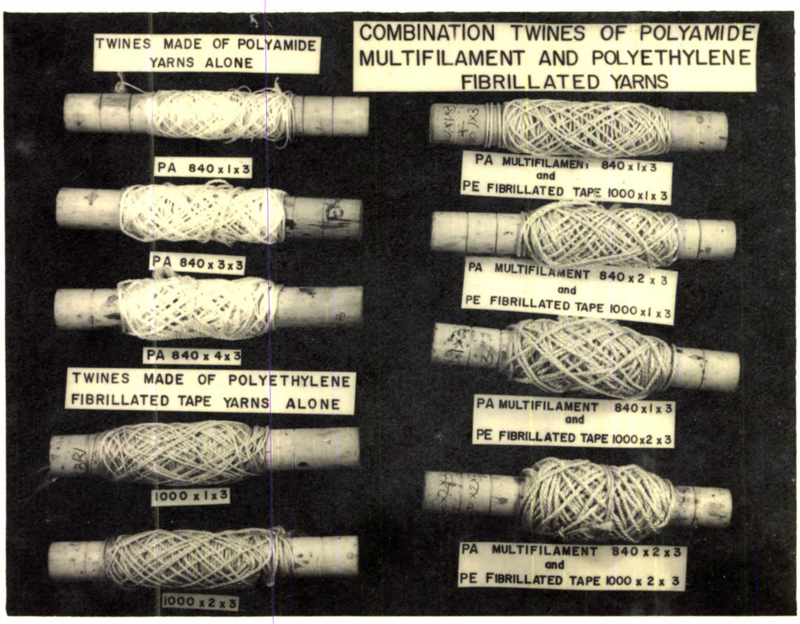
Twines made of polyethylene and polypropylene float in water since the specific gravity of the material is less than water. Hence nets made of these material are rigged with suitable weights to keep the net at concerned fishing positions. Although the production cost of polyethylene and polypropylene is cheap when compared to nylon the material is out of use in such type of nets where a high sinking speed


TWINES MADE OF POLYAMIDE YARNS ALONE
COMBINATION TWINES OF POLYAMIDE MULTIFILAMENT AND POLYPROPYLENE MULTIFILAMENT YARNS
PA MULTIFILAMENT ALONE 210 x 1 x 3
COMBINATION OF PA AND PP MULTIFILAMENTS 210 x 1 x 3 + 190 x 1 x 3
POLYAMIDE MULTIFILAMENT ALONE 210 x 2 x 3
PA MULTIFILAMENT 210 x 2 x 3 and PP MULTIFILAMENTS 190 x 2 x 3
PA ALONE 210 x 3 x 3
POLYPROPYLENE MULTIFILAMENT ALONE 190 x 2 x 3
PA MULTIFILAMENT 210 x 3 x 3 and PP MULTIFILAMENTS 190 x 3 x 3
PP ALONE 190 x 3 x 3
PA MULTIFILAMENT 210 x 5 x 3 and PP MULTIFILAMENTS 190 x 5 x 3
TWINES MADE OF PP MULTIFILAMENT ALONE 190 x 6 x 3

11


COMBINATION TWINES OF POLYAMIDE MULTIFILAMENT, POLYPROPYLENE MULTIFILAMENT AND POLYETHYLENE FIBRILLATED TAPE YARNS.
PA MULTIFILAMENT 210 x 4 x 3, PP MULTIFILAMENT 190 x 2 x 3 and PE FIBRILLATED TAPE 1000 x 1 x 3
PA MULTIFILAMENT 210 x 4 x 3, PP MULTIFILAMENT 190 x 4 x 3 and PE FIBRILLATED TAPE 1000 x 1 x 3

13


TWINES MADE OF POLYAMIDE YARNS ALONE
COMBINATION TWINES OF POLYAMIDE MULTIFILAMENT AND POLYETHYLENE FIBRILLATED YARNS
PA 840 x 1 x 3
PA MULTIFILAMENT 840 x 1 x 3 and PE FIBRILLATED TAPE 1000 x 1 x 3
PA 840 x 3 x 3
PA MULTIFILAMENT 840 x 2 x 3 and PE FIBRILLATED TAPE 1000 x 1 x 3
PA 840 x 4 x 3
TWINES MADE OF POLYETHYLENE FIBRILLATED TAPE YARNS ALONE
PA MULTIFILAMENT 840 x 1 x 3 and PE FIBRILLATED TAPE 1000 x 2 x 3
1000 x 1 x 3
PA MULTIFILAMENT 840 x 2 x 3 and PE FIBRILLATED TAPE 1000 x 2 x 3
1000 x 2 x 3

12

is required. The present studies tend to show that these material can be consumed in large scale by suitably mixing with nylon multifilaments so that the negative features of each of the components can be improved. However the present investigation will be complete only after testing the material in the filed conditons. The introduction of mixed twines for fish nets is expected to be a new venture and in Indian fishing industry and this study on the production of combination of twines by making use of multifilaments of polypropylene, polyethylene fibrillated tape yarns and polyamide multifilament not only increase the potential use of polyolefins but also reduces the investment onfishing gear.

CHAPTER VIII

SELECTION OF NET MATERIALS FOR FISHING GEAR AND RECOMMENDATIONS

Klust (1959) categorised the fishing nets into three major groups viz. nets of low strain like gill nets; nets of medium strain such as drift nets, box net, stake net, dip net, lift net, falling net and seines and nets of heavy strain like gape nets and trawls. Gill nets are passive gears into which the fish swim by accident and become gilled in their meshes. Twines of small diameter having sufficient breaking strength depending on the species of fish to be captured are to be selected for gill nets. During gilling the live fishes struggle to escape and the twines should yield to the pressure exerted by the fish. Retaining the correct mesh size is an important factor in gill nets, as alterations caused by looseness of knot or extension of twine may cause the escape of the gilled fish. Cotton, ramie and hemp were the materials used for fabrication of fish nets prior to the introduction of synthetic twines. Mugaas (1959) reported that in Norwegian fisheries cotton and hemp were completely replaced by nylon 66 and 6 and terylene for cod and coal fish gill nets. While replacing cotton with synthetic material, he has suggested that wet knot strength should be the main criterion as wetting and knotting are likely to affect the strength of synthetic materials (Robinson 1959). Warncke (1959) suggested replacement by 25% lighter synthetic material for coarser twines and the same running length as the natural fibre twines in the case of finer twines to avoid extra strong and heavy twines, while Mugaas (1959) suggested 50% more runnage than cotton so that a satisfactory wet knot strength could be obtained. Firth (1950) mentioned that one of the first commercial application of nylon is for the construction of gill nets. The use of perlon monofilament for hand lines and gill nets and perlon continuous filaments for tuna long lines and whale tow warps has been cited by Klust (1952). Amano (op. cit) reported the capture of salmons and trouts in Northern Pacific using amilan gill nets and found the material to be economical even though the price of nylon was twice as that of ramie. Contrary to this observation, Saetersdal (1959) found cod caught in nylon net inferior to those caught in cotton nets as the fish died quickly in the former. Gundry (1959) observed manmade fibres used for herring net to be not satisfactory as the fish got so deeply enmeshed that they could be extracted only with a great amount of labour. In the case of bottom set gill nets, the rocky sea bottom is likely to tear and pull loose an expensive synthetic net and hence he advocated the use of vegetable twines as they were more serviceable as long as the nets were maintained in the proper way. Experiment conducted with nylon gill nets in marine and inland waters in India showed their superiority over cotton nets mainly in matters of strength, elasticity, pliability and rot-proofness So a complete change over could be effected in Indian fisheri in the case of gill nets even by the traditional fishermen both for marine and inland waters.

Nylon is produced in India in the form of monofilaments continuous filaments and staple fibres of which the last one finds utility only in textiles. The translucent monofilament is almost invisible under water and this property helps to increase the catches.

Monofilaments of size group 0.20 to 0.25 mm are suitable for gill nets, beyond which the flexibility of the material is considerably affected. Kuriyan (1973) and Khan et. al (1975) found monofilament gill net more effective in Gobindsagar reservoir than multifilament nylon nets. IS(1975) present the guidelines for the preparation of monofilament nylon. However, bulkiness and knot looseness were the main problems met with in monofilament gill nets and hence multifilament twines have taken the place of monofilament as suitable material for gill nets. Polyamide continuous filament is the softest of all synthetic materials in the wet state, but since its natural white colour is far too visible in clear water, the material is dyed in green, blue, grey and brownish colours in commercial fisheries (Klust 1973). Experiments in India too showed the varying effect of colour on the capture of certain species of fishes. Klust advocated the use of soft twisted multifilament nylon for gill nets, as the hardness increases the elongation at increasing low loads which is undesirable for the functioning of gill nets.

IS; (1967, 1976, 1981) give the guidelines for the specifications of soft twisted polyamide multifilament twines for gill nets. Polyamide continuous filament twines are used for stronger or fine gill nets. Plaited twines of continuous filament perlon are specially strong and suited for large stow nets in river fishery. When lowest possible extension is called for as in pound nets, lift nets, gill nets and trammel nets, polyamide and polyester are the two groups of chemical fibres of choice (Klust 1960).

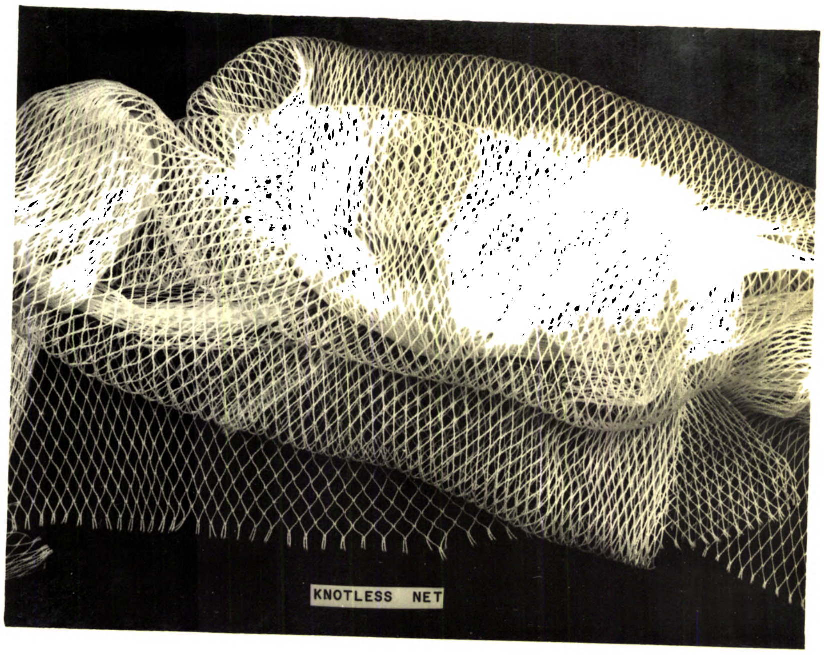
When lowest possible extension is required as in the case of pound nets and lift nets, twines of polyester are preferred. Klust (op. cit) described the use of polyamide staple fibre twines for lines, scoop net, fyke net, cast net, drift net, river stow net and drag net.

Klust (op. cit) is of opinion that medium strain fishing gear do not require very strong and costly material like polyamide while in the case of purse seines, the important properties to be looked for are good sinking speed, high breaking strength and low resistance to water flow. According to Klust (1973), high specific gravity, smooth surface and small diameter of netting accelerate the sinking speed and reduce resistance to water flow. The material used in India for indigenous two beat seine (Kolachivala) for gar fishes and single beat seine (thanguvala) of kerala was hand twisted cotton twines (Deshpande and George, 1962 and Kuriyan et.al;

1962). The only suitable synthetic material available in India at present is polyamide multifilament, although synthetic materials of higher specific gravity than nylon are available in other countries. In India knotless nets are being introduced recently. The performance of a smaller purse seine designed by Central Institute of Fisheries Technology and operated from indigenous 'Thanguvallams' was quite satisfactory. (Photographs 14 & 15).

Photographs 14 and 15

Going to heavy strain nets, cotton was the material used for fabrication of smaller trawl nets and sisal and manila for deep water trawls as indicated already. Trawl net material requires high wet knot strength; high extensibility, small diameter and high abrasion resistance. Lower towing resistance in such nets results in a reduction in towing power with consequent savings in fuel for increased towing speed, enabling the use of larger net by which the catch efficiency is increased (Klust 1973). The high elongation, elasticity and wet knot breaking load of polyamide continuous filament twine enable the net to withstand rough treatment during fishing and to haul in larger catches safely. Nylon in staple and continuous fibres was found to be a suitable material for German bottom trawls for herring and round fish and large gape nets of German rivers. Lusyne(1959)



14

15. Thanguvala operation.

recorded that the strain in the net should be spread across the knots and the twine should be strong enough to withstand the complex stress-strain reactions acting upon the webbing. While reviewing the properties of a particular type of synthetic twine, its application and suitability or otherwise to different classes of nets like purse seines, trawls, gill nets, ring nets, mid water trawls, drag nets etc. have been stressed by various authors (Anon 1957, Toikek Rayon Co. 1959, Anon 1959, Carrothers and West 1964). Ruggerio (1960) mentioned that trawls made wholly of 4.76 mm braided cords were used in bottom trawling in place of natural fibres in Gulf of Mexico. Eventhough synthetics are widely used for gill nets, their use for the fabrication of trawls is of a restricted nature. In experiments conducted in India on trawl nets for capture of prawns, the soft twisted nylon twines were found not suitable while the hard twisted twines had a better abrasion resistance, total elongation and toughness index in spite of reduced breaking strength due to twist hardness. IS:(1967) present the guidelines for the preparation of hard twisted nylon twines suitable for trawl nets. Du Pont De Nemours (1959) mentioned that larger trawl nets may be either lost or badly torn and the extra cost spent on nylon may not be justifiable and hence cheaper material is recommended for trawl gear. But for cod ends of trawl nets, Klust recommends polyamide or polyester filament or staple as ideal material to absorb the kinetic energy. In such cases the unloading of cod end need be done in fewer operations.

The use of perlon monofilament for hand lines and perlon continuous filaments for tuna long lines and whale tow warps has been cited by Klust (1952). Rankovic (1957) described nylon as serviceable for eel long lines in lake Scutary. Examples of whale runners and purse lines for encircling nets with nylon are cited by Klust (1958). Cotton was the material used traditionally in India for hand lines and long lines by fishermen of India (Balasubramanyan 1964). Deshpande et. al (1970) and Kartha et. al (1973) carried out shark long line experiments and bottom drift long lines for sharks, rays and eel using cotton lines. Further, Deshpande and Sivan (1969) Sivan et. al. (1969) and Subramania Pillai et al (1970 and 1972) have done troll-line experiments successfully with nylon lines. The suitable material for lines is hard twisted nylon.

The material introduced in Indian fishing industry after nylon for preparation of twines was polyethylene in monofilament form which had been fully accepted as a trawl gear material in Japan and other advanced countries. The main advantage is its lower price compared to nylon as it can be manufactured by simple inexpensive techniques. The extrusion and orientation can be done in a single 'in-line' unit or two separate units. Kloppenburg and Reuter (1964) mentioned that the processes of extrusion and orientation have a significant effect on the properties of the filament. Monofilaments of polyethylene can be twisted into twines of varying thicknesses for utilisation in fishing nets and ropes. Physical properties of twines made out of them have already been discussed in the earlier chapter.

The buoyant nature of the material coupled with rigidity makes polyethylene unsuitable for gill nets and purse seines, where the main properties required are flexibility and sinking speed. However, the material is suited for trawl nets and other types or dragged and stationery gear. The lower specific gravity helps in reducing the number of floats and consequent reduction in drag. These nets are easier to handle and clean. With proper rigging and weighting on the lower side of both bottom and midwater trawls, they can be maintained at the required fishing position. Studies conducted on the utility of this material for trawl fishery and ropes at the Central Institute of fisheries Technology, Integrated Fisheries Project and Exploratory Fisheries Project clearly proved that it can be used for medium and large trawl nets (Subramania Pillai et al., 1978, Kunjipalu et al., 1979, Subramania Pillai et al., 1979 and Kartha 1980). Experiments conducted by Kartha et al. (1974) with three types of similar designs of nets made of cotton, polyethylene and a combination of these two for the lower and upper parts of the net showed no significant difference in the catch rate of prawns in three nets, while the total catch were more in the exclusive polyethylene net and combination net than in cotton net. IS: (1971) give guidelines for the preparation of polyethylene monofilament twines in different specifications.

Polyethylene as flat tapes for the weaving industry has already been introduced. These flat tapes were twisted into different thicknesses in the laboratory and subjected to physical tests, the results of which have already been discussed earlier. Since the material possessed properties comparable to twisted monofilaments, it was tested in the field. Comparative efficiency studies of identical designs of trawls made of nylon, polyethylene monofilament and polyethylene flat tape twines owed highest catch in the tape net followed by monofilament and nylon nets (Kartha et al., 1977) proving the suitability of weaving tape as a trawl gear material. IS (1973) give the guidelines for the preparation of different specifications of flat tape twines.

Fibrillation of the flat tape was the next development in polyethylene and the twines made out of this were found to be more pliable than flat tape twisted twines, the properties of which have already been discussed earlier. Although field trials have not been conducted so far, it is expected that the twines can be utilised for nets in the place of bast fibres for rampani net of Karnataka or dara nets of Gujarat. The only drawback in utilising this material in gill nets is its lightness which may have to be overcome by adjustment in the rigging methods. Since polyethylene fibrillated tape is in the initial stage of production the material has to be tested under field. However, it is expected that these twines would be more suitable for trawl nets, dip nets, lift nets, stake nets and trap nets than other varieties of polyethylene twines. IS(1977) present guidelines for the preparation of different specifications of fibrillated tape twines.

Polypropylene belonging to polyolefin group is the next material to be introduced for fish nets in India. This is also in the initial stages of production and the samples in the form of monofilament and multifilament have been analysed for physical properties, the details of which have been already discussed earlier. The twines can be made in the same way as other synthetic materials and lower liveliness of twists was observed compared to nylon. This new material has many characteristics of polyethylene which is now well established as trawl twine material and certain characteristics of polyamide twines such as flexibility and strength. Polypropylene has the lowest density of all materials used for twine manufacture and the same strength in dry and wet conditions as indicated already. A remarkable difference from nylon is extensibility being relatively more in polyamide and comparatively small for polypropylene. Trials with polypropylene eode gill nets carried out by Norwegian fishermen showed that the nets are 10% lighter and lost less strength during fishing than nylon nets, with about equal catching efficiency.

Trawls made with polypropylene on top wing s, top belly and square was compared with trawl entirely made of manilla twines showed increased catch of 57% fish in polypropylene equipped net compared to 43% with all manila net. It also gave easier handling, lower water resistance and easier towing. Experiments conducted with salmon gill nets by these authors showed that polypropylene net could catch more of fish swimming near the surface. Cod gill nets made of polypropylene and nylon showed no significant difference in catching power. Although slightly thicker than equivalent nylon, Ulstron did not show any detrimental effect on shark gill nets. Danish seine and ring nets for herrings in Scotland, performed well in spite of the buoyancy of polypropylene. It is likely, therefore that with proper rigging and weighting it will be possible to produce purse seines in polypropylene which may effect reduction in weight, cost less price and be handled easily.

Carter and West (1964) recommended polypropylene for bottom trawls. As in the case of polyethylene, lower drag and reduction in the number of floats on the head lines are favourable points. These authors observed 50% advantage over manila trawls on a price-life basis. It is easier to handle because of the low moisture absorption. For midwater trawls, the fuel consumption was found to be less than that for heavier materials. In India the prospects of this material may be outstanding, considering the lower price, flexibility and equal strength in dry and wet conditions and availability of raw materials.

CHAPTER IX

SUMMARY AND CONCLUSIONS

Chapter I gives an introduction to the study of the materials for fish nets, their properties, selection and preservation along with a historical resume of the use of fish net materials all over the world with special reference to India. Cotton, hemp ramie, flax and jute are the vegetable fibre materials used for the fabrication of fishing nets by fishermen in the different maritime states of India. Manila, sisal and coir are extensively used for making set nets and ropes. The problem of rotting is the main draw back of vegetable fibres which is overcome to a certain extent by treating the nets at frequent intervals with preservatives containing tannin and chemical substances like copper sulphate, copper naphthenate, coal tar and resin. Since these treatments did not give a permanent protection against rotting, acetylation and 'arigal-C' processes were developed in foreign countries by which the vegetable fibres could be rendered rot-proof. But because of their complicated nature of application together with high costs, these methods did not gain much popularity with fishermen. Utilisation of man-made fibres was answer to the serious problem of deterioration of vegetable fibres and as soon as they were made known, there was a growing demand for synthetic fibres from the fishing industry. After the second world war, many synthetic fibres started being manufactured from different polymers and it was the beginning of a revolution leading to the use of synthetics in place of vegetable fibre twines in fishing industry on a global level. Nylon became very popular amongst the man-made fibres and because of its strength, fineness, elasticity and durability vis-a-vis rot-proofness got an easy entry in the field of gill nets followed by set nets, seines and long line fisheries all over the world. The variety of man-made fibres used in the fishing industry include polyamide, polyethylene, polypropylene, polyester, polyvinyl chloride, polyvinylidene chloride, and polyvinyl alcohol. Among these, polymerisation plants have been set up in India for production of nylon and polyethylene only. Until such time synthetic twines were imported to meet the requirements of the fishing industry.

The manufacture of polypropylene has been just taken up in the country and the products are under laboratory tests. Other fibres such as terylene, kuralon and saran have not yet be produced in India, though they are extensively used in many other parts of the world.

Chapter II presents the details of different vegetable and synthetic fibre twines, their extracts on manufacture and properties. Yarns of nylon are produced in several types like monofilament, multifilament and staple; polyethylene as monofilament, flat tape and fibrillated tape and polypropylene in the form of monofilament and recently in multifilament forms in the country to meet the requirements of synthetic fibres for the manufacture of fish net twines and ropes. The construction of twines by the process of twisting and braiding have been described with special reference to the numbering systems of yarns and designation of twines.

Chapter III gives the terminology as applied to fibres, yarns and twines. Chapter IV presents the experimental procedure for the evaluation of the data collected on the physical properties of fish net twines used by indigenous fishermen in the different maritime states of India prior to introduction of synthetic fibre and those of synthetic fibre twines used in the Indian fishing industry. The physical tests undertaken were linear density, diameter, twist, breaking strength, breaking stretch, stress-strain behaviour and knot strength on different specifications of fish net twines.

While determining the linear density of netting materials it was found that among the vegetable fibres, Italian hemp is heavier than other materials of the same thickness with sunhemp, flax, sisal, manila and coir following in the order, coir being the lightest among the materials tested. In the case of synthetic twines PE monofilament braided twine was found to be the heaviest, followed by PE fibrillated twine, PA multifilament, PE monofilament, PE flat tape and PP multifilament twines. PE fibrillated, PE monofilament and PA multifilament twines shared more or less the same linear densities, while PP multifilament twines had the least value amongst the synthetic twines tested. Since the density and specific volume are inversely proportional, the thickness of twine on equal weight per metre increases with decreasing density of fibres. It was shown that PP multifilament had higher diameter for a given mass when compared to PA multifilament twines. Polyethylene fibrillated tape and monofilament twines showed almost the same diameter and are thinner than PE flat tape twines. PE braided twines showed the least diameter among others when sample of equal mass were compared.

Evaluations of physical properties of vegetable and synthetic twines used for indigenous nets revealed the need for uniform twists and stability of twines by maintaining the correct ratios for inner and outer twists. The formulae for the angle of twist led to the conclusion that when the diameter of the twine is constant, the number of twists per unit length is proportional to the angle of twist and when the angle of twist remains constant, number of twists per unit length is inversely proportional to the diameter. Using a hand driven twine twisting machine, the optimum twists required to produce the maximum strength were worked out for cotton twines of two directions of twists viz. ZSZ and ZZS. The relations between inner to outer twists and outer twist and total number of yarns were also studied. Based on these studies, the twist factors for soft, medium, hard and extra hard cotton twines were found out incorporating the total number of yarns and count number of yarns. Similarly twist specifications were worked out for nylon twines of soft and hard lay and medium twisted twines made of polyethylene monofilaments. The twist specifications prescribed here can be used as guidelines for the manufacture of balanced twines of multifilament nylon and polyethylene monoflament twines without any twist setting process. Soft twisted nylon finds utility in gill nets while hard twisted nylon and polyethylene twines are widely used as trawl net material, the latter being more commonly used due to the cheapness of the material. High density polyethylene flat tape (weaving tape) used mainly for sack and carpet backing was twisted in the laboratory into twines of different specifications. The product was found to be more or less like polyethylene monofilament twines and quite suitable for nets where pliability is not a criterion for selection. Comparative studies of trawl nets made of different materials including PE monofilament and PE flat tape twines proved the utility and cheapness of these materials for bottom trawls.

As a next step, fibrillated yarn was used as the basic material for making fish net twines. Twines of fibrillated tape were found to be more flexible than twines made of twisted monofilaments and flat tape twines and resemble twines made of bast fibres. These twines can be tried as a substitute for hemp twines with proper rigging attachments, since the density of the material is less than that of water.

Regarding the strength property of netting twines, a comparative study showed that among vegetable fibres, Italian hemp is more than twice as strong as sunhemp. The strength decreased in the order of flax, manila, sun-hemp and sisal. Coir twines exhibited poor strength compared to other materials. The increases in strength in wet condition were 16.6% in the case of sun-hemp, 14.2% in flax, 13.5% in cotton, 8.1% in sisal and 6.9% in manila. The increase in strength of Italian hemp by wetting was only 2.9% while coir showed a reduction in strength of 7.5% in the wet state. In the case of synthetic twines, PA multifilament showed the maximum strength followed by PP multifilament, PE braided, PE fibrillated, PE monofilament twines and PE flat tape twines in the descending order. The wet strength of nylon twines showed highly significant reduction(-10.2%) while PE monofilament showed improved strength by wetting by 15.8%. PE braided twines also showed an increase of 10.9% in strength in the wet state. The rate of increase in strength in the case of flat tape twines was 10.3% and that in fibrillated twine 11.8%. It is evident that polyethylene twines, whatever be the form of yarn used for making twines show improvement of strength by wetting. In the case of polypropylene multifilament, no reduction in strength could be noticed in the wet state.

Regarding the comparative breaking stretch values of different vegetable fibre twines, it was evident that the extensibility of sunhemp was lower than those of Italian hemp and flax. Sisal and manila twines exhibited almost the same breaking stretch, while cotton and coir showed greater elongation as compared to other vegetable fibre twines. In all the vegetable fibres tested, the breaking stretches were found to be more in wet condition that in dry condition. In the case of synthetic twines, the correlation between diameter and dry and wet breaking stretch was found to be non-significant in all types of twines tested. One possible explanation is that the stretches of twines are independent of thickness. This is an important finding since in gill nets, the stretch of twine is an important factor for the capture of suitable species. Based on this finding, allowance need be given only to the inherent stretching property of the fibre and the method of construction of twines. Observations on the effect of wetting on synthetic twines showed a marginal decrease in stretch in wet condition compared to dry stretch in the case of nylon twines. The percentage breaking stretch of polyamide multifilament in the dry state was in the range (23%, 29%). In polyethylene monofilament twines, the percentage breaking stretch in the dry condition was observed to be in the range (23%, 48%). The decrease of stretch from dry to wet condition in the case of polyethylene monofilament was found to be highly significant. In wet state, the breaking stretch was mostly in the range 28% - 38%. As regards polyethylene monofilament braided twines, the decrease in stretch in the wet state was significant at 5% level. The braided twines registered a very high breaking stretch ranging from 50 to 98% in the dry state which decreased to 40 to 84% in wet condition. Great variations of stretch were observed in case of polyethylene twisted monofilament and braided twines which were attributable to the stretching tendency of samples at the yield point, which was found to vary considerably among samples. The polypropylene multifilament twine is found to have the minimum breaking stretch of 23 to 29% in the dry condition and the difference between dry and wet breaking stretches was non-significant.

The strength at knot in wet condition is an important property of a net material while selecting netting twines for fishing gear. PE braided twines showed the highest knot efficiency (83.7%) and PP multifilament the minimum (57.4%) among the materials tested. The knot efficiency of PE monofilament twines showed 82.2%, PE fibrillated 77.0%, and PE flat tape 73.9%. The knot efficiency of nylon multifilament was found to be 60%.

In Chapter VI, the causes of deterioration of fish net twines such as abrasion, weathering, rotting, fatigue and action of chemicals have been studied in detail with particular reference to conditions prevailing in India.

Chapter VII describes the mixing of synthetic fibres such as polyamide multifilament and polyethylene fibrillated tape yarns; polyamide multifilament and polypropylene multifilament yarns and lastly polyamide multifilament, polypropylene multifilament and polyethylene fibrillated tape yarns for the manufacture of fish net twines. This study is very important since mixing of yarns in the above lines has not been reported earlier elsewhere for fish net twines although in Japan combination twines of saran - nylon and nylon filament and kuralon staple have been tried. It was found that by mixing of yarns it is possible to produce a new yarn which has got a different property from that of the component yarns. Polyethylene and polypropylene are comparatively cheaper than polyamide twines and mixing of these fibres with nylon reduces the consumption of nylon, which is a costly material. Polyethylene and polypropylene are light materials, float in water due to their low specific gravity and as such are unsuitable for nets which require a higher sinking speed. Combination of these yarns with nylon yarns make it sink in water with added specific gravity. It has already been shown that nylon loses strength in wet state, while polyethylene gains it in wet condition, while polypropylene does not show any change in strength by wetting. Hence combination of characteristics of individual yarns yield twines with mixed properties of the component fibres and combinations tried in varying ratios help their utilisation in different types of fishing gears.

Monofilaments of polyamide, polypropylene and polyethylene were mixed and the combination twines proved to be a better product and it is expected that the mixed monofilaments can be used for lines and ropes.

Chapter VIII describes the selection of net materials for use in different types of fishing gear, although it is possible to broadly classify net materials, it is difficult to recommend a type of material as suitable for use in a particular type of fishing gear. The reason is that selection of material depends not only on the inherent properties of the fibre but also to a large extent on the processing techniques for the preparation of fibres, yarns and twines. It is concluded that by suitable adjustments, a material can be tailored to suit the requirement of any specific gear for which more intensive research work is needed.

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III. Thesis :

1. Rotting of fish net twines and its prevention. Submitted to the University of Cochin for the award of M.Sc Degree.