U07TT703

TECHNICAL TEXTILES

CLASS NOTES

B.Tech-7th Semester

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Syllabus

U07TT703 **TECHNICAL TEXTILES** **3 0 0 100**

UNIT I **9**

Technical Textiles – An Overview: Definition and scope of technical textiles, Milestones in the development of technical textiles, Textile processes, applications, Classification of technical textiles, Future of the technical textiles industry.

Technical Fibres: Introduction, High strength and high modulus organic fibres, High chemical- and combustion-resistant organic fibres, High performance inorganic fibres, Ultra-fine and novelty fibres, Fibres used in Civil and agricultural engineering, Automotive and aeronautics, Medical and hygiene applications, Protection and defence applications.

UNIT II (Agrotech & Filtech) **9**

Agro Textiles: Construction details –Properties and applications.

Textiles in Filtration: Introduction, Dust collection, Fabric construction, Finishing treatments, Yarn types and fabric constructions, Fabric constructions and properties, Production equipment, Finishing treatments, Fabric test procedures.

UNIT III (Buildtech, Geotech & Meditech) **9**

Textiles in Civil Engineering: Geosynthetics, Geotextiles, Essential properties of geotextiles, engineering properties of geotextiles, Geotextile structure, Frictional resistance of geotextiles.
Medical Textiles: Introduction, Fibres used Non-implantable materials, Extra-corporeal devices, Implantable materials, and Healthcare / hygiene products.

UNIT IV - (Protech) **9**
Textiles in Defence: Introduction, Historical background, Criteria for modern military textile materials, Textiles for environmental protection, Thermal insulation materials, Water vapour permeable and waterproof materials, Military combat clothing systems, Camouflage concealment and deception, Flame-retardant, heat protective textiles, Ballistic protective materials, Biological and chemical warfare protection.

UNIT V (Transportech) **9**

Textiles in Transportation: Introduction, Textiles in road vehicles, Rail applications, Textiles in aircraft, Marine applications, Future prospects for transportation textiles.
Belts, Tyre cords, Hoses: Introduction, Construction particulars, Fibres and yarns used.

TOTAL: 45Hrs

TEXT BOOKS

1. A.R. Horrocks & S.C. Anand (Edrs.), Handbook of Technical Textiles, The Textile Institute, Manchester, U.K., 2000, Woodhead Publishing Ltd., Cambridge, England.
2. S. Adanur "Wellington Sears Handbook of Industrial Textiles", Technomic Publishing Co. Inc., Lancaster, Pennsylvania, ISBN: 1-56676-340-1, 1995.

REFERENCES

1. N.W.M. John, "Geotextiles", Blackie, London, ISBN: 0-216-91995-9, 1987.
2. S. Anand, "Medical Textiles", Textile Institute, 1996, ISBN: 185573317X.
3. Textiles in Automotive Engineering by Walter Fung and Mike Hardcastle, Woodhead publishing.
4.

UNIT-I –TECHNICAL TEXTILES-INTRODUCTION

Total Hours: 9 hours

Technical Textiles – An Overview: Definition and scope of technical textiles, Milestones in the development of technical textiles, Textile processes, applications, Classification of technical textiles, Future of the technical textiles industry.

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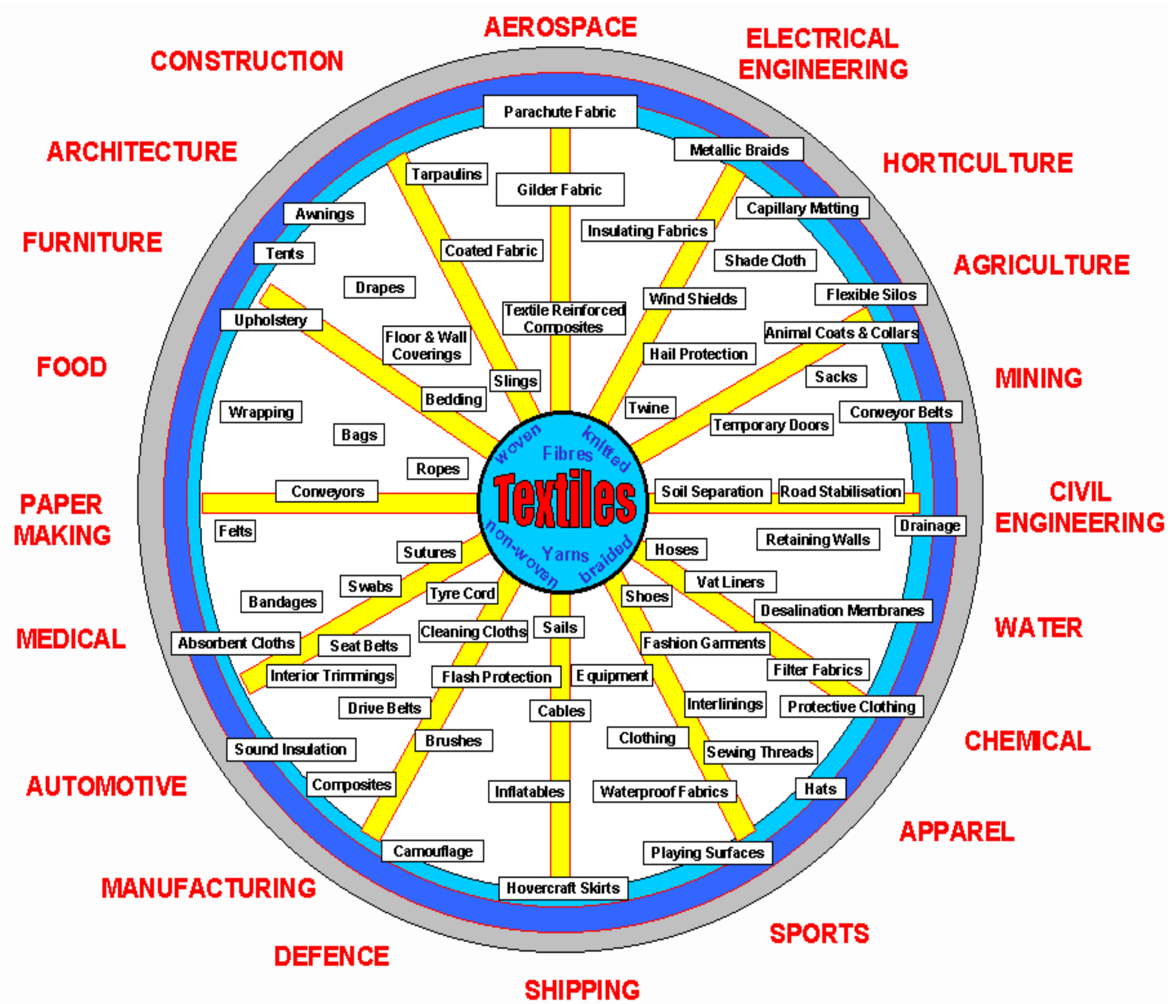


1.0 **Technical Textiles - Definition:**

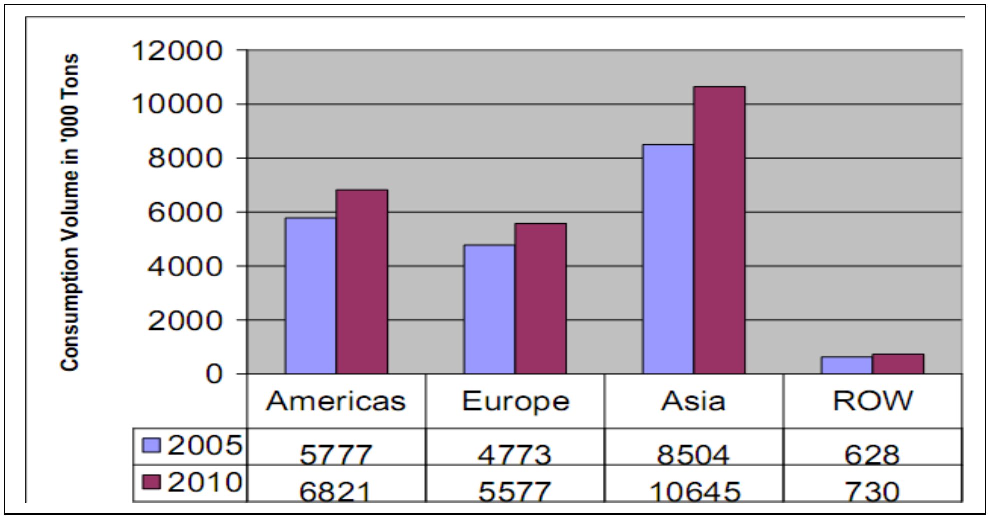
Textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics are termed as Technical Textiles.

1.1 Scope of Technical Textiles:

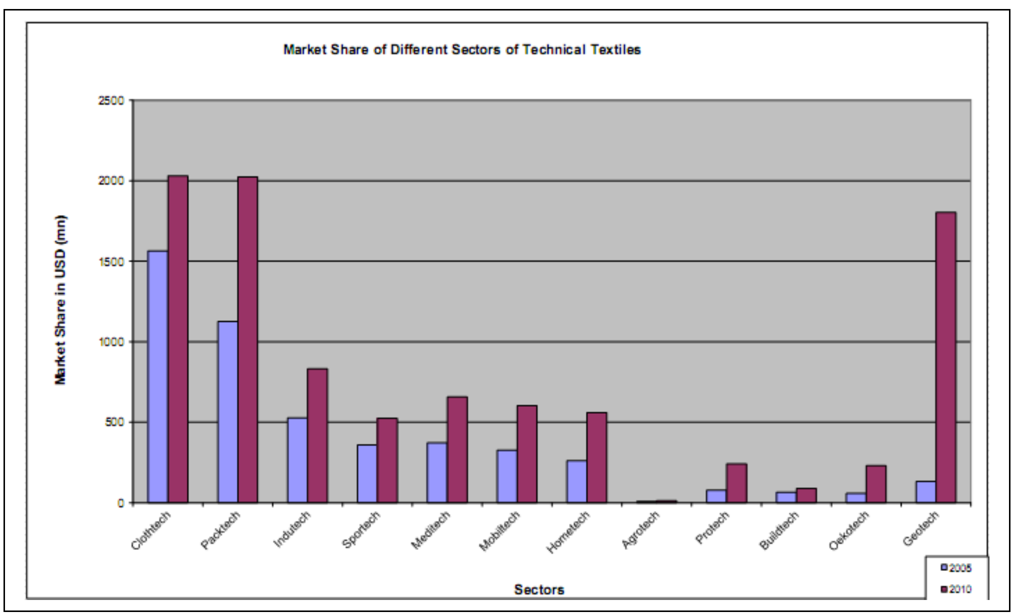
1. Recognized as one of the most dynamic and promising area for the future of the textiles industry.
2. Advances in polymers, fibres, yarns, chemical technology and fabric/web forming technologies have spearheaded the development of technical textiles.
3. Driving force behind the developments:
   - Ever increasing applications for fibrous material in non-conventional sectors.
   - Demands on good performance and functional properties.
4. The usage of technical textile materials in the industries around the world is growing substantially, offering a lucrative business opportunity.
5. In many developed countries like USA and Japan, technical textiles account for over 35 per cent of the textile industry output.

Year	**2005**	**2010**
Global Consumption	Rs. 480,000 Cr (US $ 106 Billion)	Rs. 570,000 Cr (US $ 127 Billion)
India's Consumption	Rs. 24000 Cr (US $ 5 Billion)	Rs. 44200 Cr (US $ 9.6 Billion)
India's existing share in global market	4.7 %	7.6 %

1.2 World Consumption of Technical Textiles by Region:



1.3 Market Size of various Technical Textiles Sector:



1.4 Milestones in the development of Technical textiles:

Although the development of technical and industrial applications for textiles can be traced back many years, a number of more recent milestones have marked the emergence of technical textiles as we know them today. Very largely, these have centred upon new materials, new processes and new applications.

1.4.1 Developments in fibre materials – natural fibres

Until early in the 20th century, the major fibres available for technical and industrial use were cotton and various coarser vegetable fibres such as flax, jute and sisal. They were typically used to manufacture heavy canvas-type products, ropes and twines, and were characterized by relatively heavy weight, limited resistance to water and microbial/fungal attack as well as poor flame retardancy. Wool proved far less versatile and economic for most industrial applications although it is still valued for its insulating and flame retardency properties and finds use in several high temperature and protective clothing applications. Silk is an even more exotic fibre, rarely used in technical applications other than for highly specialized uses such as surgical suture thread.

1.4.2 Viscose rayon

The first commercially available synthetic fibre, viscose rayon, was used as reinforcement material for tyres and, subsequently, other mechanical rubber goods such as drive belts, conveyors and hoses. Its relatively high uniformity, tenacity and modulus (at least when kept dry within a rubber casing), combined with good temperature resistance, proved ideal for the fast emerging automotive and industrial equipment markets. At a much later stage of its lifecycle, other properties of viscose such as its good absorbency and suitability for processing by paper industry-type wet laying techniques contributed to its role as one of the earliest and most successful fibres used for nonwoven processing, especially in disposable cleaning and hygiene end-uses.

1.4.3 Polyamide and polyester

Polyamide (nylon) fibre provided high strength and abrasion resistance, good elasticity and uniformity as well as resistance to moisture. Its excellent energy absorbing properties proved invaluable in a range of end-uses from climbing ropes to parachute fabrics and spinnaker sails. Carpet backing and cover stock are more likely to use polyester in Asia largely because of the greater availability and better economics of fibre supplies in those regions.

1.4.4 Polyolefins:

The development of polyolefin (mostly polypropylene but also some polyethylene) fibres as well as tape and film yarns was another milestone in the development of technical textiles. The low cost and easy processability of this fibre, combined with its low density and good abrasion and moisture-resistant properties, have allowed its rapid introduction into a range of applications such as sacks, bags and packaging, carpet backings and furniture linings as well as ropes and netting. Initially used in conjunction with viscose to permit thermal bonding, polypropylene has now benefited from a growing appreciation of the important role that moisture wicking (as opposed to absorption) can play in hygiene applications such as cover stock for diapers (nappies).

1.4.5 High performance fibres

The above 'conventional' fibre types, both chemical and natural, still account for over 95% of all organic fibre technical textiles in use (i.e. excluding glass, mineral and metal fibres). Many of them have been modified and tailored to highly specific end-uses by adjustment of their tenacity, length, decitex, surface profile, finish and even by their combination into hybrid and bicomponent products.

First and foremost of these high performance fibre group are the aramids, both the highly temperature resistant meta-aramids (widely used in protective clothing and similar applications) and the high strength and modulus para-aramids (used in a host of applications ranging from bulletproof vests to reinforcement of tyres, hoses, friction materials, ropes and advanced composites).

At long last, carbon fibres appear to be emerging from the doldrums, with the appearance not only of important new civil aerospace markets but also of high technology sporting goods and industrial applications such as wind generator turbine blades and reinforced fuel tanks.

The introduction of other high performance fibres proliferated, particularly during the late 1980s, and in the wake of the aramids.These included a range of heat and flameproof materials suitable for protective clothing and similar applications (such as phenolic fibres and PBI, polybenzimidazole), ultra-strong high modulus polyethylene (HMPE) for ballistic protection and rope manufacture, and chemically stable polymers such as polytetrafluoroethylene (PTFE), polyphenylene sulphide (PPS) and polyethyletherketone (PEEK) for use in filtration and other chemically aggressive environments.

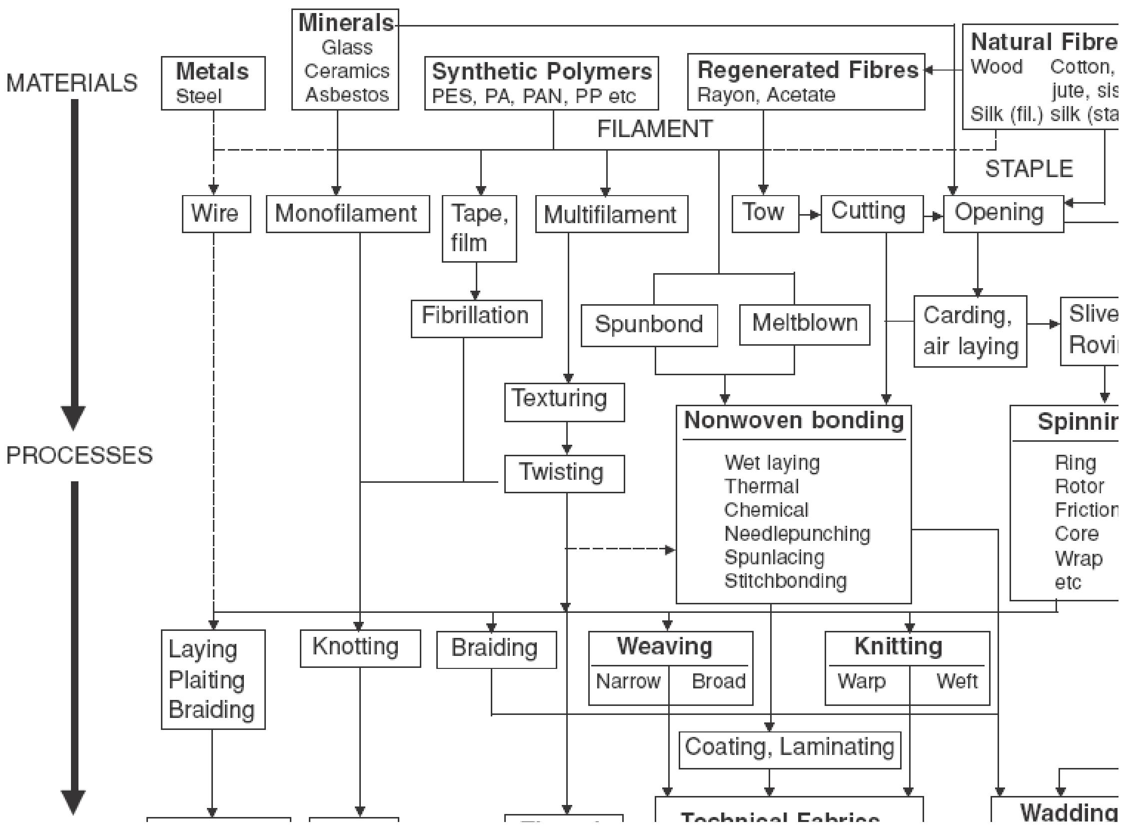
1.4.6 Glass and ceramics

Glass has, for many years, been one of the most underrated technical fibres. Used for many years as a cheap insulating material as well as reinforcement for relatively low performance plastics (fibre glass) and (especially in the USA) roofing materials, glass is increasingly being recognized as a sophisticated engineering material with excellent fire and heat-resistant properties. It is now widely used in a variety of higher performance composite applications, including sealing materials and rubber reinforcement, as well as filtration, protective clothing and packaging.

The potential adoption of high volume glass-reinforced composite manufacturing techniques by the automotive industry as a replacement for metal body parts and components, as well as by manufacturing industry in general for all sorts of industrial and domestic equipment, promises major new markets.

Various higher performance ceramic fibres have been developed but are restricted to relatively specialized applications by their high cost and limited mechanical properties.

1.5 Textile Processes and applications:



1.5.1 Technical Textiles – Consumption:

Table 1.2 Worldwide consumption of technical textiles by product type, 2000–2005

	10^3 tonnes			$ million		
	2000	2005	Growth (% pa)	2000	2005	Gr (%
Fabrics	3760	4100	1.7%	26710	29870	2.2
Nonwovens	3300	4300	5.4%	14640	19250	5.6
Composites	1970	2580	5.5%	6960	9160	5.6
Other textiles[a]	2290	2710	3.4%	11950	14060	3.3
All textile products	11320	13690	3.9%	60260	72340	3.7

1.6 Classification and applications of Technical textiles:

1.6.1 Agriculture, horticulture and fishing:

Textiles have always been used extensively in the course of food production, most notably by the fishing industry in the form of nets, ropes and lines but also by agriculture and horticulture for a variety of covering, protection and containment applications. Although future volume growth rates appear to be relatively modest, this is partly due to the replacement of heavier weight traditional textiles, including jute and sisal sacking and twine, by lighter, longer lasting synthetic substitutes, especially polypropylene. Lightweight spun bonded fleeces are now used for shading, thermal insulation and weed suppression. Heavier nonwoven, knitted and woven constructions are employed for wind and hail protection. Fibrillated and extruded nets are replacing traditional baler twine for wrapping modern circular bales. Capillary nonwoven matting is used in horticulture to distribute moisture to growing plants. The bulk storage and transport of fertilizer and agricultural products is increasingly undertaken using woven polypropylene FIBCs (flexible intermediate bulk containers – big bags) in place of jute, paper or plastic sacks. At sea, fish farming is a growing industry which uses specialized netting and other textile products. High performance fibres such as HMPE (e.g. Dyneema and Spectra) are finding their way into the fishing industry for the manufacture of lightweight, ultra-strong lines and nets.

1.6.2 Construction-building and roofing:

Textiles are employed in many ways in the construction of buildings, both permanent and temporary, dams, bridges, tunnels and roads. A closely related but distinct area of use is in geotextiles by the civil engineering sector. Temporary structures such as tents, marquees and awnings are some of the most obvious and visible applications of textiles where these used to be exclusively made from proofed heavy cotton, a variety of lighter, stronger, rot-, sunlight- and weatherproof (also often fireproof) synthetic materials are now increasingly required. Nonwoven glass and polyester fabrics are already widely used in roofing applications while other textiles are used as breathable membranes to prevent moisture penetration of walls. Fibres and textiles also have a major role to play in building and equipment insulation. Glass fibres are almost universally used in place of asbestos now. Double wall spacer fabrics can be filled with suitable materials to provide sound and thermal insulation or serve as lightweight cores for composite materials. Composites generally have a bright future in building and construction. Existing applications of glass-reinforced materials include wall panels, septic tanks and sanitary fittings. Glass, polypropylene and acrylic fibres and textiles are all used to prevent cracking of concrete, plaster and other building materials. More innovative use is now being made of glass in bridge construction.

1.6.3 Home textiles:

By far the largest area of use for other textiles as defined above, that is other than fabrics, nonwovens and composite reinforcements, over 35% of the total weight of fibres and textiles in that category, lies in the field of household textiles and furnishing and especially in the use of loose fibres in wadding and fiberfill applications. Hollow fibres with excellent insulating properties are widely used in bedding and sleeping bags. Other types of fibre are increasingly being used to replace foams in furniture because of concern over the fire and health hazards posed by such materials.

Woven fabrics are still used to a significant extent as carpet and furniture backings and in some smaller, more specialized areas such as curtain header tapes. However, nonwovens such as spun bonded have made significant inroads into these larger markets while various dry laid and hydro-entangled products are now widely used in household cleaning applications in place of traditional mops and dusters.

1.6.4 Medical and hygiene textiles:

The largest use of textiles is for hygiene applications such as wipes, babies' diapers (nappies) and adult sanitary and incontinence products. Nonwovens dominate these applications which account for over 23% of all nonwoven use, the largest proportion of any of the 12 major markets for technical textiles. The other side of the medical and hygiene market is a rather smaller but higher value market for medical and surgical products such as operating gowns and drapes, sterilization packs, dressings, sutures and orthopaedic pads. At the highest value end of this segment are relatively tiny volumes of extremely sophisticated textiles for uses such as artificial ligaments, veins and arteries, skin replacement, hollow fibres for dialysis machines and so on.

1.6.5 Geotextiles in civil engineering:

The economic and environmental advantages of using textiles to reinforce, stabilise, separate, drain and filter are already well proven. Geotextiles allow the building of railway and road cuttings and embankments with steeper sides, reducing the land required and disturbance to the local environment. Revegetation of these embankments or of the banks of rivers and waterways can also be promoted using appropriate materials.

1.6.6 Transportation textiles:

Transport applications (cars, Lorries, buses, trains, ships and aerospace) represent the largest single end-use area for technical textiles, accounting for some 20% of the total. Products range from carpeting and seating (regarded as technical rather than furnishing textiles because of the very stringent performance characteristics which they must fulfil), through tyre, belt and hose reinforcement, safety belts and air bags, to composite reinforcements for automotive bodies, civil and military aircraft bodies, wings and engine components, and many other uses.

1.6.7 Packaging and containment:

Important uses of textiles include the manufacturing of bags and sacks, traditionally. An even faster growing segment of the packaging market uses lighter weight nonwovens and knitted structures for a variety of wrapping and protection applications, especially in the food industry. Tea and coffee bags use wet-laid nonwovens. Meats, vegetables and fruits are now frequently packed with a nonwovens insert to absorb liquids. Other fruits and vegetable products are supplied in knitted net packaging from cotton, flax and jute but increasingly from polypropylene. Strong, lightweight spun bonded and equivalent nonwoven paper-like materials are particularly useful for courier envelopes while adhesive tapes, often reinforced with fibres, yarns and fabrics, are increasingly used in place of traditional twine. Woven strapping are less dangerous to cut than the metal bands and wires traditionally used with densely packed bales.

1.6.8 Protective and safety clothing and textiles:

Textiles for protective clothing and other related applications are another important growth area which has attracted attention and interest somewhat out of proportion to the size and value of the existing market. The variety of protective functions that needs to be provided by different textile products is considerable and diverse. It includes protection against cuts, abrasion, ballistic and other types of severe impact including stab wounds and explosions, fire and extreme heat, hazardous dust and particles, nuclear, biological and chemical hazards, high voltages and static electricity, foul weather, extreme cold and poor visibility.

1.6.9 Sports textiles :

Applications are diverse and range from artificial turf used in sports surfaces through to advanced carbon fibre composites for racquet frames, fishing rods, golf clubs and cycle frames. Other highly visible uses are balloon fabrics, parachute and paraglider fabrics and sailcloth.

1.6.10 Ecological protection textiles

The final category of technical textile markets, as defined by Techtextil, is technical textiles for protection of the environment and ecology. This is not a well defined segment yet, although it overlaps with several other areas, including industrial textiles (filtration media), geotextiles (erosion protection and sealing of toxic waste) and agricultural textiles (e.g. minimizing water loss from the land and reducing the need for use of herbicides by providing mulch to plants).

1.7 Future of the technical textiles industry:

The future of technical textiles embraces a much wider economic sphere of activity than just the direct manufacturing and processing of textiles. The industry's suppliers include raw materials producers (both natural and artificial), machinery and equipment manufacturers, information and management technology providers, R&D services, testing and certification bodies, consultants, education and training organizations. The new millennium promises even fiercer international competition which will see manufacturers striving to engineer costs downwards and develop global economies of scale in production and product development. Technical textiles will become better ‘value for money’ than ever before and this should open the way towards further applications as existing end-uses mature.

1.8 Technical Fibres:

1.8.1 High strength and high modulus organic fibres:

Ultra-high molecular weight polyethylene (UHMWPE) fibres, Dyneema or Spectra, are today the strongest fibres known, with tensile moduli in excess of 70GNm^2.This fibre is claimed to be 15 times stronger than steel and twice as strong as aromatic polyamides such as Kevlar. It is also low in density, chemically inert and abrasion resistant. It, however, melts at around 150 °C and thermally degrades at 350 °C which restrict its use to low temperature applications.

One successful approach eventually led to the advent of liquid crystalline polymers. These are based on polymerization of long stiff molecules such as *para*-phenylene terephthalamide achieving molecular weights averaging to around 20000.The influence of the stiff aromatic rings, together with hydrogen-bonding cross links, combines the best features of both the polyamides and the polyesters in an extended-chain configuration. Molecular orientation of these fibres is brought about by capillary shear along the flow of the polymer as it exits from the spinneret thus overriding the need for subsequent drawing. Kevlar by DuPont and Twaron by Akzo (now Acordis) were the first of such fibres to appear in the early 1970s. There now exists a series of first, second and third generations of *para*-aramids. Kevlar HT for instance, which has 20% higher tenacity and Kevlar HM which has 40% higher modulus than the original Kevlar 29 are largely utilized in the composite and the aerospace industries. *Para*aramids generally have high glass transition temperatures nearing 370 °C and do not melt or burn easily, but carbonise at and above 425°C. All aramid fibres are however prone to photodegradation and need protection against the sun when used out of doors. Other high tenacity and high modulus fibres include the isotropically spun Technora (Teijin) and Supara, based upon *para*-

aramid copolymers, with slightly lower maximum strength and modulus values than Kevlar.

1.8.2 High chemical- and combustion-resistant organic fibres:

The fibres discussed in the previous section were developed following earlier observations that aromatic polymer backbones yielded improved tensile and heat resistance compared with conventional fibres.However, if the polymer chains have lower symmetry and order, then polymer tractability and textile fibre characteristics are improved. Solvent-spun Nomex and Conex were the first so-called *meta*-aramids made from poly (meta-phenylene isophthalamide) and were produced by DuPont in 1962 and by Teijin in 1972, respectively.

Nomex is particularly well known for its resistance to combustion, high decomposition temperature prior to melting and high limited oxygen index (LOI), the minimum amount of oxygen required to induce ignition.

Table 2.2 LOI and tenacity range of some high chemica and combustion-resistant organic fibres

Fibres brand name	Manufacturer	LOI (%)	Tenacit (GPa)
Nomex	Du Pont	29	0.67
Conex	Conex	29	0.61
Kermel	Rhone-Poulenc	31	0.53
Inidex	Courtaulds	43	0.12
PBI	Hoechst-Celanese	41	0.39
PAN-OX	RK Textiles	55	0.25
PEEK		42	
PEK			
PPS	Phillips	34	0.54

Melt-spinnable aromatic fibres with chains containing paraphenylene rings, like polyether ether ketone (PEEK), polyether ketone (PEK) and poly (*p*-phenylene sulphide) (PPS), also have high melting points but, since their melting points occur prior to their decomposition temperature, they are unsuitable for fire-retardant applications. However, their good chemical resistance renders them suitable for low temperature filtration and other corrosive environments.

The polyheterocyclic fibre, polybenzimidazole or PBI, produced by Hoechst- Celanese has an even higher LOI than the aramids. It has excellent resistance to both heat and chemical agents but remains rather expensive. P84, initially produced by Lenzing and now produced by Inspec Fibres, USA, comprises polyimide groups that yield reasonably high resistance to fire and chemical attack. The acrylic copolymer-based fibre produced by Acordis known as Inidex (although now no longer produced) unlike many aramid fibres has high resistance to UV (ultraviolet) radiation and a fairly high LOI at the expense of much reduced tenacity and rather low long-term exposure resistance to heat.

1.8.3 High performance inorganic fibres

Any fibre that consists of organic chemical units, where carbon is linked to hydrogen and possibly also to other elements, will decompose below about 500°C and cease to have long-term stability at considerably lower temperatures. For use at high temperatures it is therefore necessary to turn to inorganic fibres and fibres that consist essentially of carbon. Glass, asbestos and more recently carbon are three well-known inorganic fibres that have been extensively used for many of their unique characteristics. Glass-reinforced boat hulls and car bodies, to name but two application areas of such composites, reduce overall weight and cost of fabrication as well as eliminating the traditional problems of rotting wood and rusting metals associated with traditional materials. Their good resistance to heat and very high melting points has also enabled them to be used as effective insulating materials.

Asbestos is a generic name for a variety of crystalline silicates that occur naturally in some rocks. The fibres that are extracted have all the textile-like properties of fineness, strength, flexibility and more importantly, unlike conventional fibres, good resistance to heat with high decomposition temperatures of around 550°C.

High purity, pyrolysed acrylic-based fibres are classified as carbon fibres. The removal of impurities enhances carbon content and prevents the nucleation and growth of graphite crystals which are responsible for loss of strength in these fibres. Carbon fibres with different structures are also made from mesophase pitch. The graphite planes in PAN-based fibres are arranged parallel to the fibre axis rather than perpendicular as is the case with pitch-based carbon fibres. Their high strength and modulus combined with relatively low extensibility means that they are best utilized in association with epoxy or melt-spinnable aromatic resins as composites.

Aluminosilicate compounds are mixtures of aluminium oxide (Al2O) and silicon oxide (SiO2); their resistance to temperature depends on the mixing ratio of the two oxides. High aluminium oxide content increases their temperature tolerance from a low of 1250°C to a maximum of 1400°C. However, despite their high temperature resistance, these fibres are not used in high stress applications owing to their tendency to creep at high temperatures. Their prime applications are in insulation of furnaces and replacement of asbestos fibres in friction materials, gaskets and packings. Both aluminium oxide or alumina fibres and silicon oxide or silica fibres are also produced. Pure boron fibres are too brittle to handle but they can be coated on tungsten or carbon cores. Their complex manufacturing process makes them rather expensive. Their prime application is in lightweight, high strength and high modulus composites such as racket frames and aircraft parts. Boron fibre use is limited by their thickness (about 16mm), their relatively poor stability in metal matrices and their gradual loss of strength with increasing temperature. Boron nitrides (BN) are primarily used in the electronic industry where they perform both as electrical insulators and thermal conductors.

The most outstanding property of silicon carbide (SiC) is the ability to function in oxidizing conditions up to 1800 °C with little loss of mechanical properties. Silicon carbide exceeds carbon fibre in its greater resistance to oxidation at high temperatures, its higher compressive strength and better electrical resistance. SiC fibres containing carbon, however, lose some tensile properties at the expense of gaining better electrical conductivity.

1.8.4 Ultra-fine and novelty fibres

Ultra-fine or microfibres were developed partly because of improved precision in engineering techniques and better production controls, and partly because of the need for lightweight, soft waterproof fabrics that eliminate the more conventional coating or lamination processes. As yet there are no universal definitions of microfibres. *Textile Terms and Definitions* simply describes them as fibres or filaments with linear densities of approximately 1.0 dtex or less.

The Japanese first introduced microfibres in an attempt to reproduce silk-like properties with the addition of enhanced durability. They are produced by at least three established methods including island-in-sea, split process and melt spinning techniques and appear under brand names such as Mitrelle, Setila, Micrell, Tactel and so on. Microfibres are also used to make bacteria barrier fabrics in the medical industries. Their combined effect of low diameter and compact packing also allows efficient and more economical dyeing and finishing.

For example, Solar-Aloha, developed by Descente and Unitika in Japan, absorbs light of less than 2mm wavelength and converts it to heat owing to its zirconium carbide content. Winter sports equipment made from these materials use the cold winter sun to capture more than 90% of this incident energy to keep the wearer warm. Another interesting material gives rise to thermochromic fabrics made by Toray which have a uniform coating of microcapsules containing heat sensitive dyes that change colour at 5 °C intervals over a temperature range of -40°C to 80 °C creating ‘fun’ and special effects.

Cripy 65 is a scented fibre produced by Mitsubishi Rayon (R) who have enclosed a fragrant essence in isolated cavities along the length of hollow polyester fibres. The scent is gradually released to give a consistent and pleasant aroma. Pillows and bed linen made from these materials are claimed to improve sleep and sleeping disorders. The effect can also be achieved by printing or padding microcapsules containing perfumes into fabrics which subsequently burst and release the perfume. Infrared-emitting and bacteria-repelling fibres are some of the other emerging novel fibres.

1.9 Fibres Used in Technical Textiles:

1.9.1 Civil and agricultural engineering:

Natural fibres such as flax, jute and ramie can be used for most temporary applications where, for instance, soil erosion is the problem. The geotextiles made from these natural polymers help to prevent the erosion of soils by allowing vegetative growth and their subsequent root establishment.

In most medium to long term applications however, where physical and chemical durability and dimensional stabilities are of prime concern, synthetic fibres are preferred.

There are currently at least six synthetic polymers considered suitable for this purpose; they include:

- Polypropylene
- Polyester
- Polyethylene
- Polyvinyl chloride
- Polyamide
- Aramids.

Polypropylene is by far the most utilized geotextile, followed by polyester, the other three trailing behind with polyamide as the least used synthetic polymer. *Para*aramids are only used where very high creep resistance and tolerance to prolonged heating are required.

At least three main degrading mechanisms have been identified that ultimately determine the durability and life of the contending polymer; they include:

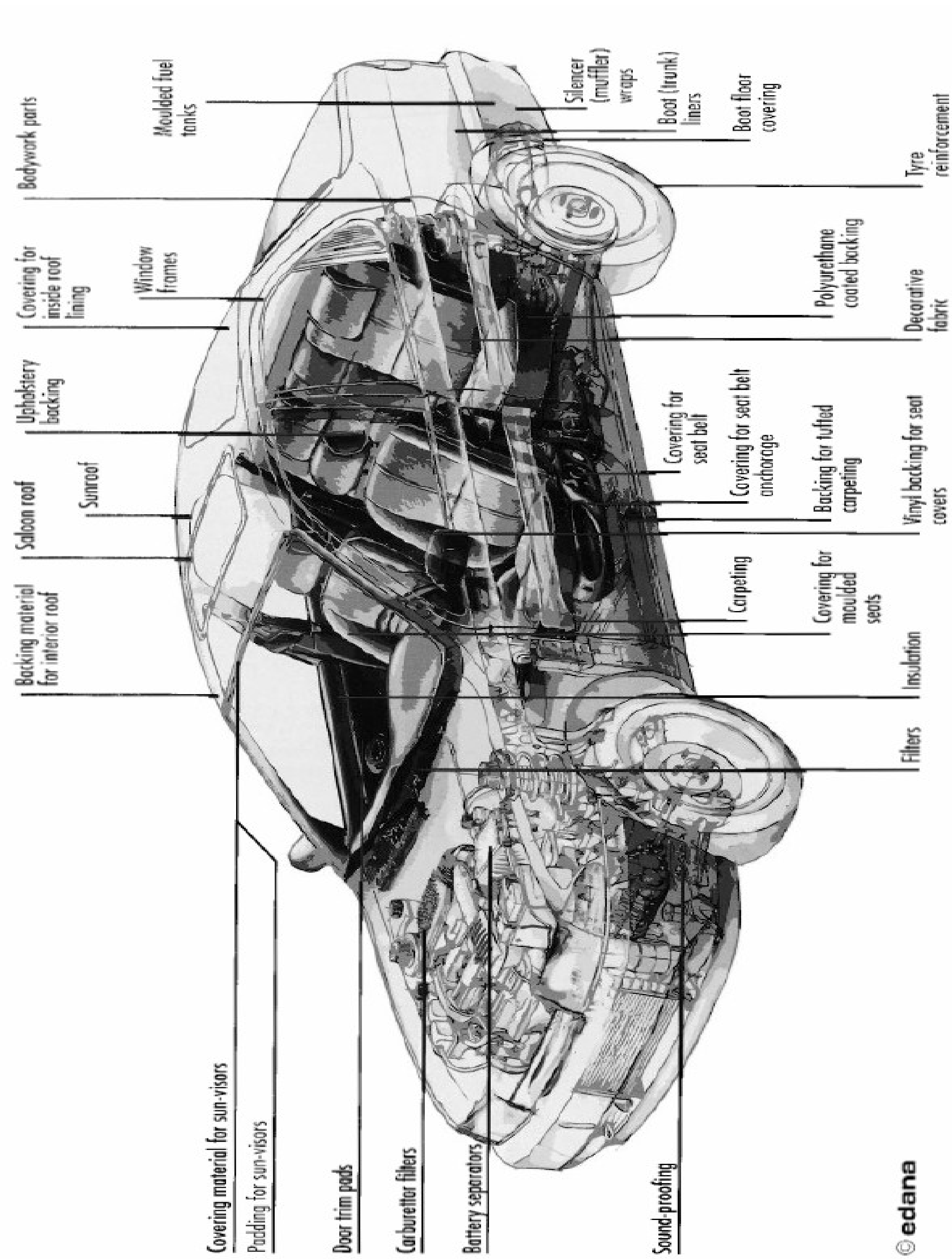
Physical degradation is usually sustained during transport or installation in one form or another. Initiation of cracks is normally followed by their subsequent propagation under environmental or normal stress. In the first instance, polymer susceptibility to physical degradation depends on such factors as the weight of the geotextile; generally lightweight or thin geotextiles suffer larger strength losses than thick and heavy materials.

Chemical degradation is the next mechanism by which chemical agencies, often in combination with ultraviolet light or/and heat, attack the polymer whilst in use or being stored. Ultraviolet radiation normally attacks the surface of the polymer and initiates chain breakage or scission which leads to embrittlement and eventual failure of the polymer. Generally, chemical degradation is a function of polymer type, thickness and availability of stabilizers. Polyolefins are particularly susceptible to ultraviolet degradation and need protection using light-stabilizing additives.

Biological degradation can result from at least three types of microbiological attack: direct enzymatic attack, chemical production by microorganisms which may react destructively with the polymer, and attack on the additives within the polymer.

1.9.2 Automotive and Aeronautics:

Component	Decorative cover face material	Intermediate or soft touch	Carrier or rigid structure
Seats	Polyester fabric (woven/knitted), Wool, Wool/polyester blends (woven), Leather	Polyurethane foam, Polyester non-woven	Cushion/squab, polyurethane fo Metal frame



The high technical requirements that the automotive industry places on all items which go into vehicles has ensured that many of the old established methods of producing fibres, yarns and fabrics proved to be at best extremely difficult and at worst virtually impossible for many reasons, among the most important of these are; Abrasion, Fastness to light and UV degradation, Tensile strength, Pilling, Flammability, Seam strength.

1.9.3 Medical and Hygiene textiles:

Degradable Fibres:

Absorbed by the body within two to three months. Example: Natural fibres such as alginate, chitin, chitosan, collagen, cotton and viscose.

Non-degradable Fibres:

Take more than six months to degrade and absorbed by the body. Example: Polyester, polyamide, polypropylene and polytetrafluoroethylene (PTFE).

Resorbable Fibres:

Fully degradable and completely absorbed by the body. Example: Fibres obtained from polydioxanone, polyglycolic acid and polylactic acid.

Fibres Used in Non-implantable Medical Devices :

Fibre Type	Applications
Cotton, viscose, lyocell	Absorbent pad
Alginate fibre, chitosan, silk, viscose, lyocell, cotton	Wound-contact layer
Viscose, lyocell, plastics film	Base material
Cotton, viscose, lyocell, polyamide fibre, elastomeric-fibre yarns	Simple non-elastic and elastic bandages
Cotton, viscose, lyocell, elastomeric-fibre yarns,	High-support bandages
Cotton, viscose, lyocell, elastomeric-fibre yarns,	Compression bandages
Cotton, viscose, lyocell, polyester fibre, polypropylene fibre, polyurethane foam	Orthopaedic bandages
Cotton, viscose, plastics film, polyester fibre, glass fibre, polypropylene fibre,	Plasters
Cotton, viscose, lyocell, alginate fibre, chitosan	Gauze dressing
Cotton	Lint

Viscose, cotton linters, wood pulp,	Wadding
Polylactide fibre, polyglycolide fibre, carbon	Scaffold

Fibres Used in Implantable Materials:

Fibre Type	Application
Collagen, catgut, polyglycolide fibre, polylactide fibre	Biodegradable sutures
Polyester fibre, polyamide fibre, PTFE fibre, polypropylene fibre, polyethylene fibre	Non-biodegradable sutures
PTFE fibre, polyester fibre, silk, collagen, polyethylene fibre, polyamide fibre	Artificial tendon
Polyester fibre, carbon fibre, collagen	Artificial ligament
Low-density polyethylene fibre	Artificial cartilage
Chitin	Artificial skin
Poly (methyl methacrylate) fibre, silicon fibre, collagen,	Eye-contact lenses and artificial cornea
Silicone, polyacetyl fibre, polyethylene fibre	Artificial joints/bones
PTFE fibre, polyester fibre	Vascular grafts
Polyester fibre	Heart valves

Fibres Used in Extracorporeal Devices Materials:

Type Fibre	Application	Function
Hollow polyester fibre, hollow viscose	Artificial kidney	Remove waste products from patients' blood
Hollow viscose	Artificial liver	Separate and dispose of patients' plasma and supply fresh plasma

Hollow polypropylene fibre, hollow silicone membrane	Mechanical lung	Remove carbon dioxide from patients' blood and supply fresh oxygen

Fibres Used in Healthcare and Hygiene Textiles:

Fibre Type	Application
Cotton, polyester fibre, polypropylene fibre,	Surgical gowns
Viscose	Surgical caps
Viscose, polyester fibre, glass fibre	Surgical masks
Polyester fibre, polyethylene fibre,	Surgical drapes, cloths
Cotton, polyester fibre, polyamide fibre, elastomeric-fibre yarns	Surgical hosiery
Cotton, polyester fibre	Blankets
Cotton	Sheets, pillowcases
Cotton, polyester fibre	Uniforms
Polyester fibre, polypropylene fibre	Protective clothing, incontinence, diaper/sheet, cover stock
Super absorbent fibres, wood fluff,	Absorbent layer
Polyethylene fibre,	Outer layer
Viscose, lyocell	Cloths/wipes

1.9.4 Protection and Defence Textiles:

Requirements of Protective and defence clothing:

Property	Comments
Water Repellant, Water Proof Wind Proof, Snow Shedding	For exterior materials exposed to cold/wet weather
Water vapour permeable	For clothing and personal equipments (tents)
Thermally insulating	For Cold climates

Rot-resistant	For tents, covers, nets etc.
UV light resistant	For environments with strong sunlight
Air permeable.	For hot tropical climates
Biodegradable	If discarded or buried

In the early days, leather and metal mesh garments were used to protect the body against sword and spear attacks, but with the passage of time development of new materials occurred. In these garments, Kevlar or Twaron continuous filament yarns are woven into tight structures and assembled in a multilayer form to provide maximum protection. Their high tenacity and good energy. UHMWPE, commercially known as Dyneema (DSM) and in composite form as Spectra Shield by Allied Signal, is now used to make cut-resistant gloves and helmets, as well as a wide range of protective garments. However, unlike Kevlar, with a fairly low melting temperature of 150°C, it is best suited to low temperature applications.

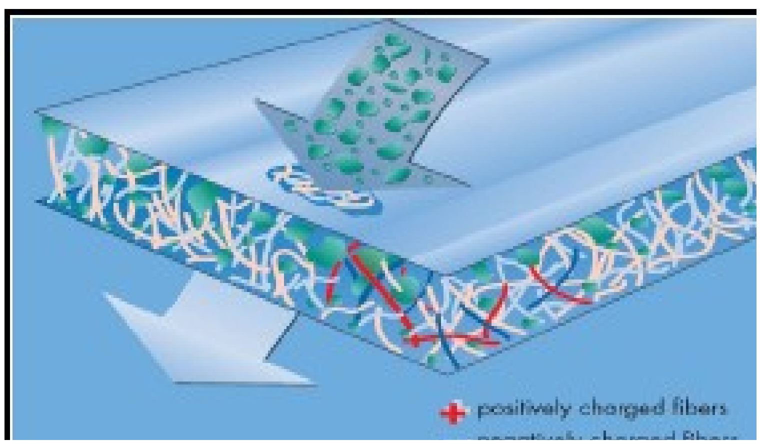
UNIT-II – AGROTEXTILES AND FILTRATION TEXTILES

Total Hours: 9 Hours

Agro Textiles: Construction details – Properties and applications.

Textiles in Filtration:

Introduction, Dust collection, Fabric construction, Finishing treatments, Yarn types and fabric constructions, Fabric constructions and properties, Production equipment, Finishing treatments, Fabric test procedures.



2.0 Agro Textiles:

2.1 Introduction:

Agriculture and textiles are the largest industries in the world providing basic needs such as food and clothing. Agro textiles are now days extensively being used in horticulture, farming and other agricultural activities. The usage of agro textiles will be benefited in terms of products with enhanced quality, higher yields fewer damages and bearable losses. It also permits as to use lower quantities of weed killers and pesticides.

2.1.1 Agro textiles - Fabric Forms:

There are different forms of agro textiles are available such as Nets, Sheets, Woven, Nonwoven, Knitted and Coated. A comprehensive range of woven and knitted fabrics, nets and meshes for landscaping, horticulture and agriculture, protective textiles it is mainly used.

2.1.2 Agro textiles - Fibers Used:

There is use of synthetics as well as natural fibers in agro textiles. Fibers used in agro textiles are as follows: -

- Nylon
- Polyester
- Polyethylene
- Polyolefin
- Polypropylene
- Jute
- Wool

Among all these fibers the Polyolefin is extensively used where as among natural jute and wool is used it not only serve the purpose but also after some year it degrades and act as the natural fertilizer.

2.1.3 General Property Requirement of Agrotextiles:

The properties required for agro textiles are:

- Weather resistance- It must work effectively in cold as well as hot climatic conditions

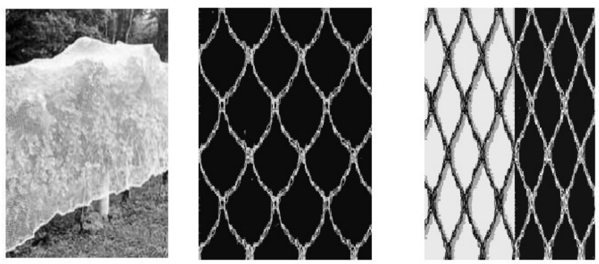
• Resistance to microorganisms-it must resistant to microorganism to protect the living being

• Stable construction- the construction must be such that it must be stable for any application

• Lightweight- the weight of the fabric should be such that it will bare by the plant.

2.2 Construction Details:

2.2.1 Hail protection: Hail protection fabrics helps shield vines from the fruit damage and defoliation associated with hail yet still lets through plenty of sunlight.



Constructional Details:

- Fibre : UV stabilized Polyethylene
- Diameter of Monofilament : 0.25 to 0.3 mm
- Mesh Width : 10 x 4 mm
- Weave : Leno
- Knitted Design : Raschel Warp diamond design

Properties:

- Long lasting, tear resistant, rip resistant.
- High ultraviolet stabilization for long life
- Service life: 15-20 years

2.2.2 Wind protection Fabrics: Trees that are protected from wind are generally healthier, reach full growth more rapidly, and have higher yield. Wind Break Fabrics protect crops from wind and, in some cases, orchard temperatures can be increased by reducing wind speed.

Construction Details:

UV stabilized fabric from UV stabilized polyethylene monofilaments both woven and knitted form.

Properties:

- Strong, long lasting.
- UV resistance
- High tear resistance.

2.2.3 Soil Covers or landscape Covers or Weed protection fabrics:

The relevant parameters for an agro textile, used as soil cover, will be determined based on laboratory tests and field experiments.

The relevant parameters for soil cover fabric features:

• Woven polypropylene fabric

• Controls weed growth for agricultural settings

• Permeable (allows water to pass through)

• Colored stripes every 12" make for easy plant alignment

• Ideal for greenhouses or outdoors where weeds need to be controlled

• UV stabilized for extended life.

- 100 % Polypropylene with 80, 90, 100, 110, 130, 150 g/m²

2.2.4 Shade Fabrics:

Shade fabric absorbing 90% of sunlight.

- It is made from 100% polypropylene monofilament strands.
- It is UV stabilized to hold up under the most extreme solar conditions.
- It can be used for a variety of applications: wind and privacy screen, shading for sports and recreation.
- Knitted Sunshade cloth is made from 100% UV stabilized polyethylene.
- Its unique lock stitch construction allows customers the ability to cut the fabric with scissors without further unraveling.

2.2.5 Insect Repellent Fabrics:

Various pests like Whitefly, scale insects attack some ornamental plants and vegetables frequently. The fabrics of such kind are stretched across the open-air plantations so that the pests can no longer get to the plants and also the climate will not be disturbed in any way.

Constructional Details:

- Weave : Linen
- Material: Polyethylene monofilament yarns
- Yarn Diameter : 0.25 mm
- Cloth Density : 24 epcm x 11 ppcm

2.2.6 Temperature Controlled Fabrics:

- Temperature Control fabric is a nonwoven, spun bonded polyester fabric designed to protect crops from cold, frost, insects and a variety of adverse environmental factors.
- Temperature Control fabric helps captures heat on sunny days and retains heat radiating from the ground at night.
- This aids in protecting sensitive ornamentals, nursery stock and foliage 24 hours a day.

2.2.7 Harvesting aids:

- Harvesting nets are used to collect the fruits falling from a tree.
- This helps to keep the cost of cultivation low by eliminating additional labor associated with harvesting.
- Harvesting nets are predominantly grip structures which can be developed using warp knitting technology.

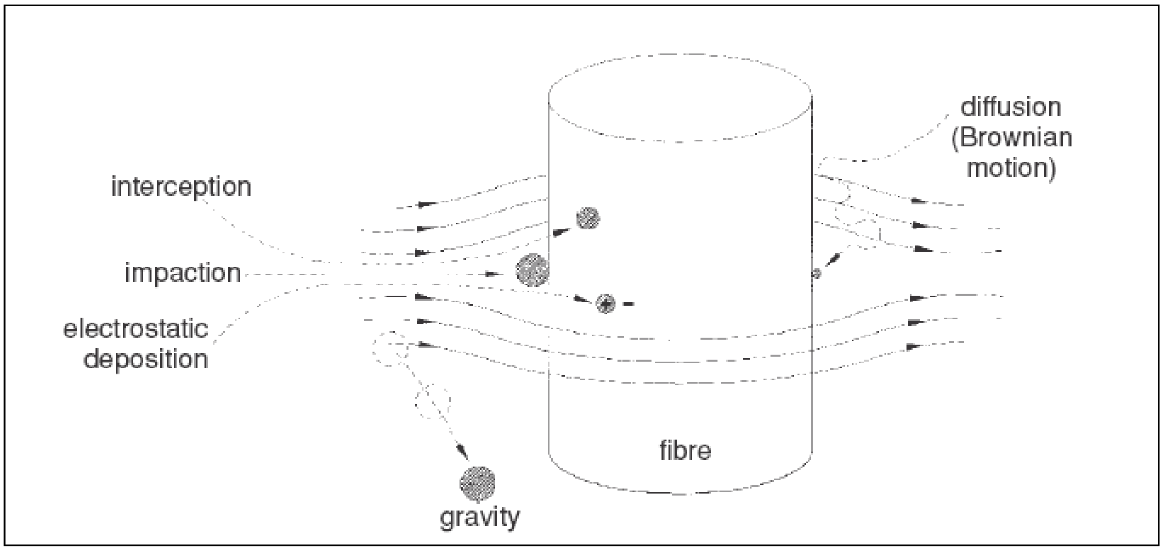
3.0 Textiles in Filtration:

3.1 Introduction:

The separation of solids from liquids or gases by textile filter media is an essential part of countless industrial processes, contributing to purity of product, savings in energy, and improvements in process efficiency, recovery of precious materials and general improvements in pollution control. In fulfilling their tasks, the media may be expected to operate for quite lengthy periods, frequently in the most arduous of physical and chemical conditions.

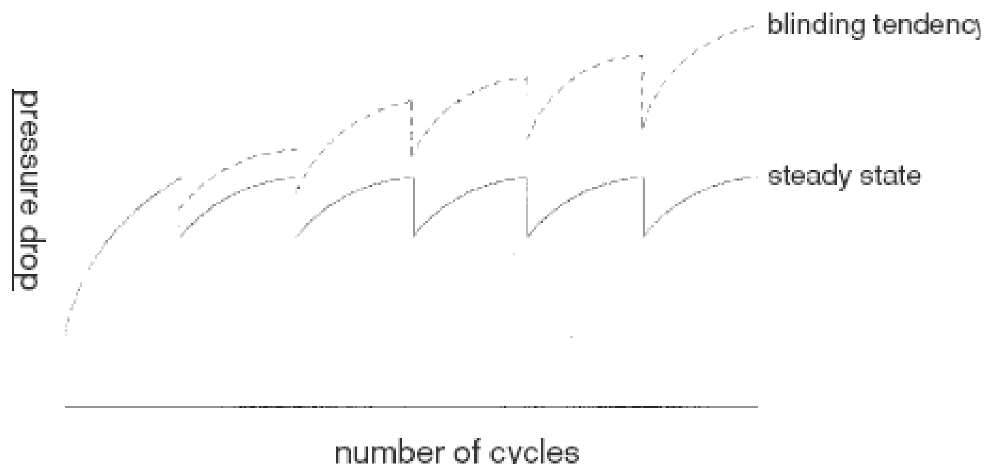
3.2 Dust Collection:

Much has been written on the various mechanisms by which particles are arrested by unused filter media. These are normally explained in terms of the effect of a spherical particle on a single fibre and may be summarized as gravitational, impaction, interception, diffusion (Brownian motion) and electrostatic.



As the gas passes through the fabric, the particles in the gas stream are retained, leading to the formation of a layer of dust on the surface. This is normally referred to as a ‘dust cake’.

After a period of time, the accumulated dust leads to a reduction in the permeability of the material, and creates an increased pressure drop on the outlet side of the fabric. Consequently the fabric must be cleaned at appropriate intervals to return the pressure drop to a more acceptable level. Dust is then again collected and the filter continues through cycles of dust accumulation and cleaning. This mechanism is shown graphically in below figure.



From the graph it will be observed that, after cleaning, the pressure drop does not return to the original level. This is because the fabric still retains a fraction of dust that actually assists in filtration by forming a porous structure that bridges the apertures in the fabric. It is this bridged structure that determines the filtration efficiency for subsequent filtration periods. The graph also shows that the pressure drop after each cleaning cycle continues to rise until a steady state condition develops. Were this not to occur (broken lines), the pressure drop would continue to rise to the point where more power would be required to pull the gas through the system than the fan can produce. This would result in a reduction in flow rate, possible fabric damage and ultimately system shut down.

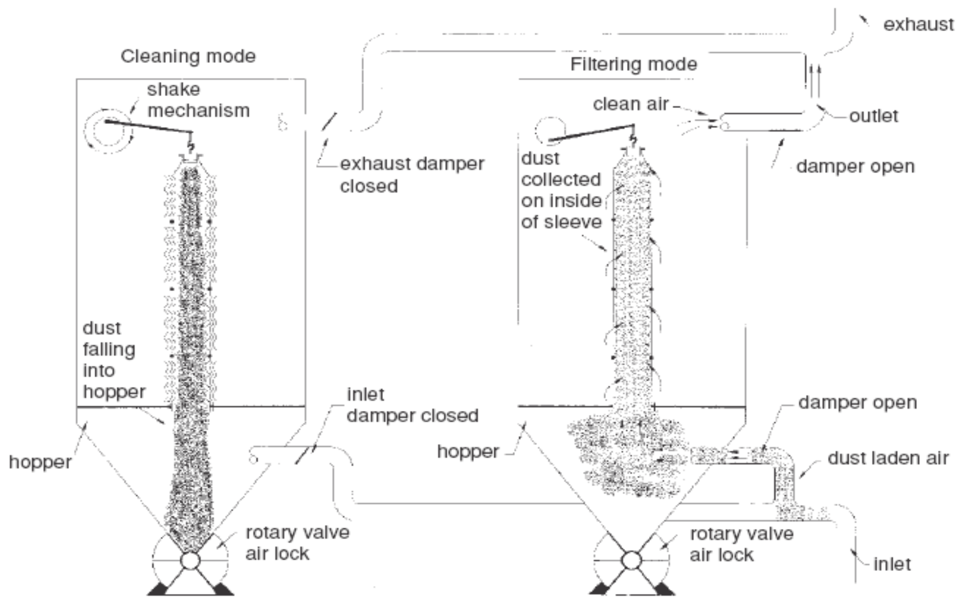
It follows from the above that, in steady state conditions, the amount of dust that is removed during cleaning is virtually equal to the amount that accumulates in the filtration phase. In reality a small, almost imperceptible increase in pressure drop may take place, resulting in a condition that will ultimately necessitate fabric removal.

3.3 Cleaning Mechanism:

Fabric dust collectors are usually classified according to their cleaning mechanism, these being shake, reverse air and jet pulse.

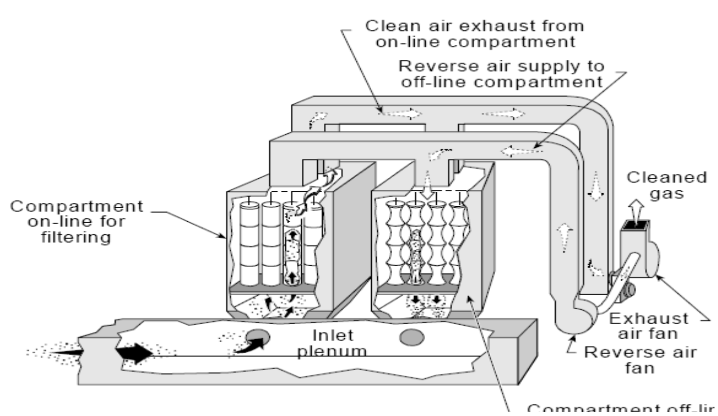
Shake cleaning:

Shake cleaning, as the name implies, involves switching off the exhaust fan and flexing the filter elements (or sleeves) with the aid of a shaking mechanism, either manually, as



in traditional units, or automatically. In both cases the effect is to release the dust, which then falls into a hopper for collection and removal. In this type of collector the filter sleeves, which may be up to 10 m in length, are suspended under controlled tension from the arm of a flexing mechanism which effects the cleaning action.

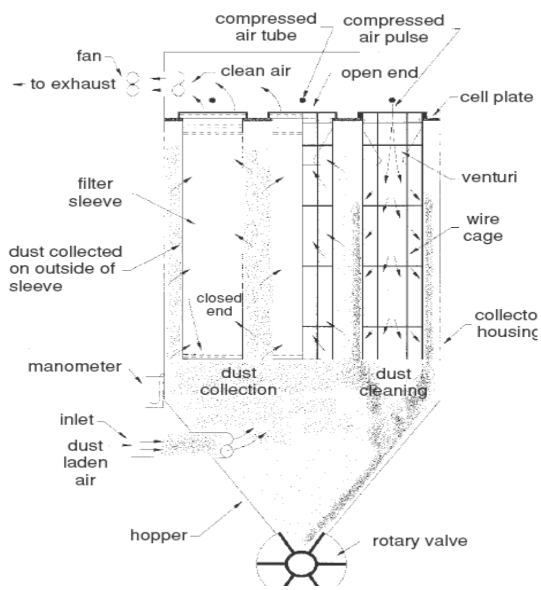
Reverse air cleaning:



With this mechanism, cleaning is achieved again by switching off the exhaust fan but this time followed by reversing the airflow from outside to inside of the sleeves. There are two basic styles of reverse air collector. The first causes the sleeve to inflate during the collection phase and partially collapse during low pressure reverse air cleaning, whereas in the second, involving a higher cleaning pressure, the sleeves are prevented from total collapse by means of a number of metal rings inserted at strategic intervals along the length of the sleeve during fabrication. In some cases, reverse air cleaning may also be combined with a shake mechanism for enhanced performance.

Pulse jet cleaning:

Compared with the mechanisms described so far, which normally involve dust collection on the inside of the sleeves, pulse jet collectors operate by collecting dust on the outside. On this occasion the sleeves, typically 3m in length and 120–160mm in diameter, are mounted on wire cages. In operation, removal of the collected dust is effected by a short



pulse of compressed air, approximately 8–14 litres in volume and 6 bar pressure, which is injected into a venturi tube located at the opening of the elements. This transmits a shock pulse that is sufficient to overcome the force of the exhaust fan and also to cause a rapid expansion of the filter sleeves. The dust is thus made to fall from the sleeves and to be collected in the hopper

3.4 Fabric design or selection considerations

The primary factors which determine the selection of a fabric for a particular application may be summarized as:

- thermal and chemical conditions
- filtration requirements
- equipment considerations, and
- Cost.

Thermal and chemical conditions

The thermal and chemical nature of the gas stream effectively determines which type of fibre is to be used.

Generic type	Examples	Max working temperature (°C)	Abrasion resistance	Acid resistance	Alkali resistance	Some damaging agents
Polyester	Dacron Trevira	150	VG	G	P	Quicklime, conc. mineral acids, steam hydr
Polyaramid	Nomex Conex	200	VG	P	VG	Oxalic acid, mineral acids, acid salts
Polyimide	P84	260	VG	P	VG	Oxalic acid, mineral acids, acid salts
Cellulose	Cotton Viscose	100	G	P	VG	Copper sulphate, mineral acids, acid salts, bacteria
Silicate	Fibreglass	260	P	F	F	Calcium chloride, sodium chloride, strong
Homopolymer acrylic	Dolanit Zefran Ricem	140	G	G	F	Zinc and ferric chloride, ammonium sulpha thiocyanates
Copolymer acrylic	Dralon Orlon	120	G	G	F	As above for homopolymer
Polypropylene	Moplefan (Trol)	90 (125)	G	E	E	Aluminium sulphate, oxidising agents, e.g. salts, nitric acid
PTFE	Teflon Rastex	260	F	E	E	Fluorine
Polyamide	Nylons	100	E	P	E	Calcium chloride, zinc chloride, mineral aci
Polypeptide	Wool	110	G	G	P	Alkalis, bacteria
Polyphenylene-Sulphide	Ryton Procon	190	G	VG	E	Strong oxidising agents
PEEK	Zyex	250	VG	G	G	Nitric acid

Depending on the duration of exposure, high temperatures may have several effects on the fibre, the most obvious of which are loss in tenacity due to oxidation and less effective cleaning due to cloth shrinkage.

The presence of moisture in the gas stream, which above 100 °C will be present in the form of superheated steam, will also cause rapid degradation of many fibres through hydrolysis, the rate of which is dependent on the actual gas temperature and its moisture content. Similarly, traces of acids in the gas stream can pose very serious risks to the filter fabric.

Polyaramid fibres are particularly sensitive to acid hydrolysis and, in situations where such an attack may occur, more hydrolysis-resistant fibres, such as produced from polyphenylenesulphide (PPS), would be preferred. On the debit side, PPS fibres cannot sustain continuous exposure to temperatures greater than 190 °C (and atmospheres with more than 15% oxygen) and, were a major constraint, consideration would have to be given to more costly materials such as polytetrafluoroethylene (PTFE).

Because a high proportion of fabric dust collectors are not faced with such thermal or chemical constraints, the most commonly used fibre in dust collection is of polyester origin, this being capable of continuous operation at a reasonably high temperature (150 °C) and is also competitively priced.

Filtration requirements:

The fabric is designed to capture the maximum number of particles present. The particle size and size distribution will be of great importance to the media manufacturer since these will determine the construction of the fabric. If the particles are extremely fine this could lead to penetration into (and possibly through) the body of the fabric, plugging of the fabric pores, ineffective cleaning and a prematurely high pressure drop. The fabric would become ‘blind’. The skill therefore will be to select or design a fabric, which will facilitate the formation of a suitable dust pore structure on or near the surface and will sustain an acceptable pressure drop over a long period.

The particles may also present a challenge according to their abrasive nature, this giving rise to internal abrasion that will be further aggravated by the flexing actions to which the sleeve will be subjected.

Conversely, by constructing the filter medium with a blend of fibres of widely contrasting triboelectric properties, it is claimed by a fibre manufacturer6 that superior collection efficiency can be obtained

Equipment considerations

Equipment considerations again focus on the cleaning mechanisms and in particular, the forces applied by them. In the case of shake collectors, the filter sleeves will be subjected to quite vigorous flexing, which could lead to the formation of creases and ultimately holes in the fabric through flex fatigue, a situation that, as stated previously, will be aggravated by the presence of abrasive particles in the gas stream. As a consequence, in addition to resisting stretch from the weight of the dust load, a filter fabric with superior flexibility – at least at the strategic flex points – will provide a longer life.

Cost

In spite of all the design considerations and performance guarantees that are frequently required of the media manufacturer, this is still a highly competitive industry. As a consequence every effort is made to reduce media manufacturing costs, either by judicious sourcing of raw materials, or more efficient manufacturing (including fabrication) techniques.

3.5 Fabric Construction:

Three basic types of construction are found in fabric dust collectors, viz., woven fabrics, needle felts and knitted structures. The first two are produced in flat form and will require (i) slitting to appropriate width and (ii) converting into tubular sleeves, whereas knitted fabrics may be produced directly in tubular form.

Woven fabrics

Used predominantly in shake collectors, this class of filter fabric may comprise twisted continuous filament yarns, short staple-fibre yarns (cotton or woollen spinning system) or perhaps a combination of both. Weave patterns may be in the form of elementary twills, for example 2/1, 2/2 or 3/1, or perhaps simple satin designs, the latter providing greater flexibility and hence superior resistance to flex fatigue and a smoother surface for superior cake release.Woven fabric area densities are typically in the range 200–500gm^{-2}.

Design requirements include resistance to stretch from the mass of the dust cake, resistance to flex fatigue from the shake cleaning mechanism, a surface that will facilitate efficient dust release and a construction that will effect maximum particle capture whilst at the same time providing minimum resistance to gas flow.

Needle felts

This type of construction, a cross-section view is by far the most widespread in dust collection processes, providing an infinitely larger number of pores and facilitating considerably higher filtration velocities than woven fabrics. The use of a woven scrim, whilst not employed in every case, provides the needle felt with stability and the necessary tensile characteristics to withstand the stresses imposed by the predominantly pulse cleaning mechanism, whereas the batt provides the necessary filtration efficiency and also a measure of protection for the base cloth from abrasion caused by constant flexing against the cage wires. Depending on the tensile specification of the finished needle felt, the area density of scrims is usually in the range 50–150 gm^{-2}

Needle felt area densities are typically in the range 300–640gm^{-2}, lighter qualities being used in reverse air and shake collectors and heavier qualities in pulse jet collectors. The majority of needle felts actually fall in the range 400–510 gm^{-2}, these facilitating generally higher filtration velocities. However, in the event that the dust is particularly abrasive, a longer life may be expected from felts in the 540–640gm^{-2} range.

Knitted fabrics:

Because they are capable of being produced in seamless tubular form, weft-knitted fabrics provide, in theory, an attractive and economic alternative to both woven and needled constructions. By inlaying appropriate yarns into the knitted structure, the elasticity which is normally associated with such fabrics can also be controlled and the same may be used to enhance the particle collection capability

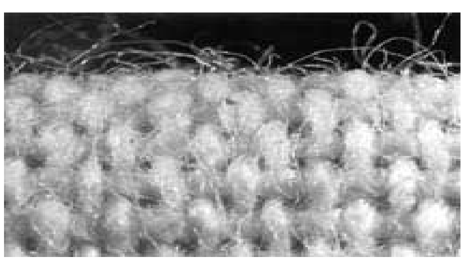
3.6 Finishing Treatments:

These are designed essentially to improve (i) fabric stability, (ii) filtration collection efficiency, (iii) dust release, and (iv) resistance to damage from moisture and chemical agents. A number of finishing processes are employed to achieve these goals, for example heat setting, singeing, raising, calendaring, 'special surface treatments' and chemical treatments.

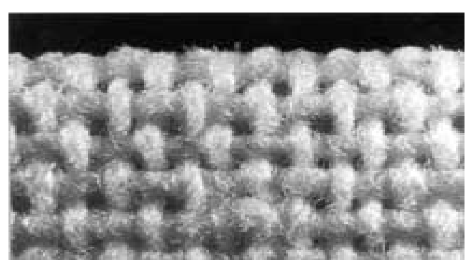
Heat setting:

Improved stability is essential in order to prevent shrinkage during use. Such shrinkage may be caused by the relaxation of tensions imposed on fibres and/or yarns during manufacture, or be due to the inherent shrinkage properties of the raw materials themselves. As heat is the primary cause of shrinkage, it is logical that fabric stability should be achieved by thermal means. Such an operation is normally referred to as heat setting, and may be carried out by surface contact techniques, 'through air' equipment, or by stentering, the latter two being preferred because they enable greater penetration of heat into the body of the structure. In addition to stabilising the fabric, the heat setting process will also effect an increase in the density of the structure through increased fibre consolidation. This in turn will further assist in achieving a higher level of filtration efficiency.

Singeing



Before Singeing

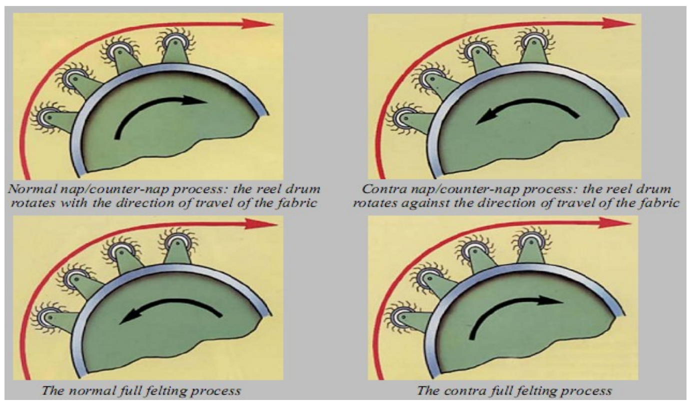


After Singeing

Filter fabrics, especially needle felts, which are produced from short staple fibres, invariably possess surfaces with protruding fibre ends. Since such protrusions may inhibit cake release by clinging to the dust, it is common practice to remove them. This is achieved by singeing, a process in which the fabric is passed, at relatively high speed, over a naked gas flame or, in another technique, over a heated copper plate. The heat of the flame causes the fibres to contract to the surface of the fabric where, in the case of thermoplastic fibres, they form small hard polymer beads

Raising

The raising process is designed actually to create a fibrous surface, normally on the outlet side of the filter sleeve, to enhance the fabric's dust collection capability. In operation the fabric is pulled over a series of rotating rollers termed 'pile' and 'counter pile', each of which is clothed with card wire and mounted concentrically on a large cylinder of approximately 1.5 m diameter.



As the cylinder rotates, the pile rollers raise the fibres proud of the surface whereas the counter pile rollers stroke them into a more orderly fashion. Raised fabrics may comprise 100% staple-fibre yarns or a combination of multifilament and staple-fibre yarns, the latter being woven in satin style in which the face side is predominantly multifilament and the reverse side predominantly staple. The smooth surface provided by the multifilament will aid cake release whilst the raised staple yarns on the reverse side will enhance particle collection efficiency.

Calendering:

The calendering operation fulfils two objectives, viz. to improve the fabric's surface smoothness and hence aid dust release, and to increase the fabric's filtration efficiency by regulation of its density and permeability. As a result of the latter, the yarns and fibres become more tightly packed, making it more difficult for particles to pass through or even into the body of the fabric.

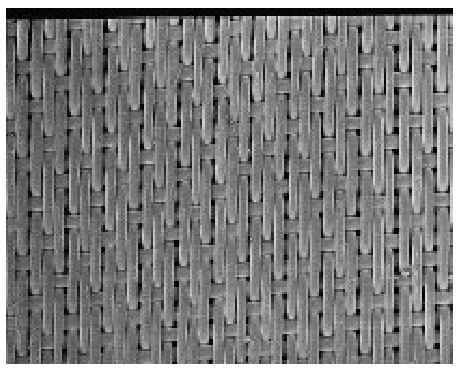
Chemical treatments

Chemical treatments are normally applied for one of two reasons, namely (i) to assist in dust release, especially where moist sticky dusts, possibly containing oil or water vapour are encountered, or (ii) to provide protection from chemically aggressive gases such as SO2 and SO3 referred to earlier.

3.7 Solid-Liquid Separation:

3.7.1 Yarn types:

Monofilaments:

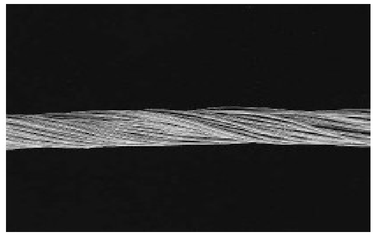


The diameters of the monofilaments used range from 0.1mm up to 1.0mm, the smaller diameters being used mainly in applications involving filter presses, pressure leaf and candle filters, rotary vacuum disc and rotary vacuum drum filters, whereas the larger diameters are used mainly in relatively coarse filtration applications involving heavy duty vacuum belt filters or multiroll filter presses.

The principal characteristics of monofilament fabrics may be summarized as (i) resistance to blinding, (ii) high filtrate throughput, and (iii) efficient cake release at the end of the filtration cycle. These characteristics are attributed to the smooth surface of the yarn and, in respect of cake release, weaving in a satin construction can further enhance this. For most filtration applications involving monofilaments, the majority of diameters used are in the range 0.15–0.35mm, yielding fabric area densities between 180 and

450gm^{-2}.Heavy-duty filter belt applications, on the other hand, usually employ diameters from 0.3–1.0 mm resulting in area densities from 500–1700 gm^{-2}.

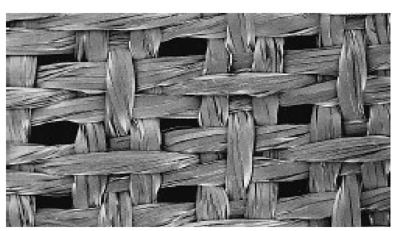
Multifilament:



The filament assemblies may be held together by air intermingling, texturising or twist, the latter being preferred for warp purposes owing to the abrasive forces that will impact on the filaments – especially during weaving where the yarn is under considerable tension – and that may otherwise lead to filament breakage.

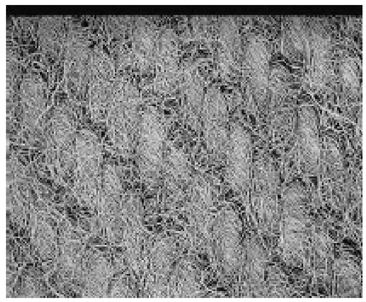
Multifilament fabrics are characterized by their high strength and resistance to stretch, these properties being enhanced as the tenacity of the yarn increases. Multifilament yarns are also more flexible than monofilaments, a property which facilitates weaving of the tightest and most efficient of all woven fabrics. This is used to particular advantage when filtering fine particles (<1mm) at very high filtration pressures, in some cases in excess of 100 bar. Fabric area densities in this category vary from as little as 100gm^{-2} to around 1000 gm^{-2}.The lighter fabrics, depending on the application, may require additional assistance in the form of a support or backing cloth.

Fibrillated tape ('split film') yarns:



As the title suggests, these yarns are produced by taking a narrow width polypropylene film then splitting it into a number of components and binding these together by twist. However, as they are considerably stiffer than the latter, they are not normally used in filter fabrics as such but rather in more open weave backing cloths. Therefore their function is to provide protection for the more delicate primary filter fabric from damaging surfaces, whilst at the same time permitting the free flow of filtrate from the filtration compartment.

Staple-fibre yarns:



In addition to particle collection efficiency, fabrics produced from woollen spun staple-fibre yarns are also characterized by their resistance to abrasive forces, such as may be found on rough, possibly chemically corroded cast iron filter plates. For this, and filtration purposes in general, the yarns are usually spun with 3.3 decitex fibres in relatively coarse linear densities, typically from 130–250 tex. Fabrics in this category are normally woven in area densities ranging from 350–800 gm^{-2}, the lighter and intermediate fabrics generally being used in pressure leaf and rotary vacuum drum filters and the heavier fabrics in filter presses.

Yarn combinations

By producing fabrics with different components in warp and weft it may be possible to create a structure that utilizes the best features of each. The most popular combinations in this respect comprise multifilament warp and staple-fibre weft yarns and monofilament warp and multifilament weft yarns. In both cases the ratio of warp to weft threads is at least 2 : 1 and usually considerably higher. This facilitates the production of fabrics with a smooth warp-faced surface for efficient cake release and also higher warps tensile properties for greater resistance to stretch from the mass of heavy cakes. In the case of the multifilament and staple combination, the inclusion of a staple-fibre weft yarn provides scope for improved resistance to mechanical damage whilst maintaining a high particle collection efficiency and an acceptable throughput. Similarly, the inclusion of a multifilament weft yarn in a monofilament and multifilament fabric will lead to an improvement in filtration efficiency, especially if it is suitably texturised.

3.7.2 Fabric constructions and properties:

Plain weave

This is the most basic weave of all woven structures that provides the framework for the tightest and most rigid of all single layer filter fabrics. Because of the sinusoidal path that the yarns follow, this weave is particularly suitable for flexible yarns of the multifilament and short staple-fibre types. The weave is also ideally suited to applications where thread displacement, due for example to high internal pressures, may otherwise be experienced.

Twill weaves

Usually produced in simple 2/2 or 2/1 style, twill weaves enable more weft threads per unit length to be crammed into the fabric than the preceding design (plain weave). As a consequence, this facilitates the production of fabrics of higher area density and hence greater bulk, features which are particularly suited to woollen spun yarns. Twill weave fabrics are also marginally more flexible than plain weave fabrics, which may be advantageous when fabricating cloths of complex make up or indeed when fitting the cloths on the filter itself, for example, caulking into grooves

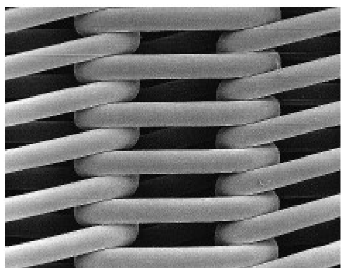
Satin weaves

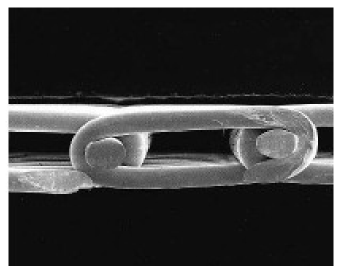
Both regular and irregular satin weaves are employed. The irregular weaves, such as the four-shaft construction, are frequently found in more densely sett high efficiency fabrics, often with two warp threads being woven as one. Although maximum separation may be the principal requirement here, the combination of weave pattern and a double multifilament thread arrangement also creates a smooth surface for superior cake release. By comparison, the regular satin weaves such as the eight-shaft and 16-shaft constructions are usually employed where efficient cake release and throughput are of greater importance. From this it will be appreciated that the weaves with the longer floats are normally used in conjunction with monofilament yarns.

Duplex and semi duplex weaves

These weaves are frequently, though not exclusively, found in belt filters, either of the vacuum, continuous multiroll press, or of the vertical automatic pressure type. Owing to the interlacing pattern of the threads, it is possible to create fabrics with a measure of a solidity and stability that are ideally suited to filters of the types identified. On the debit side, the cost of weaving such high density fabrics tends to preclude their use in all but a limited number of niche applications.

Link fabrics:





Link fabrics are produced by a novel technique in which polyester monofilaments are wound into spiral form then meshed with similar monofilaments, which are spiral wound in the opposite direction. The spirals are subsequently held together by a straight monofilament. By virtue of this form of construction it is possible to produce endless filter belts without the need for special joining techniques such as 'clipper' seams, which are often the weakest point in a filter belt.

Needle felts

Needle felts have found only limited use in liquid filtration because their thickness and density render them prone to blinding in many applications. One area where they have found some success, however, has been in the filtration of metal ore concentrates such as copper on horizontal vacuum belt filters. These applications tend to be very aggressive on the filter fabric, and hence a suitably designed and finished needle felt is often more cost effective than a considerably more expensive woven fabric, especially if required in lengths of around 80 m and widths up to 6m. The solids which are captured in such applications quickly form a cake on the surface and, should some penetration occur, as with woollen spun yarns, the bulky nature of the material provides scope for the particles to escape. For such arduous applications, needle felts are generally in the area density range 800–1000gm^{-2}.

3.7.3 Production equipment

Warping equipment:

From the preceding information, it will be appreciated that in the production of woven filter fabrics, which are predominant in solid–liquid separation processes, there is a demand for a wide range of qualities.

Weaving equipment:

In the majority of cases, filter fabrics are woven on either flexible or rigid rapier looms, which require a smaller shed for weft insertion than more traditional shuttle looms. In this respect they generally inflict less damage on the warp sheet. Even so, because filter fabrics are frequently quite densely sett, looms with beat-up forces of the order of 15kNm^{-1} in reed widths up to and in excess of 4m may be necessary to achieve the required pick spacing. High weft thread densities also demand high warp tensions and these in turn impose substantial stresses on let-off, shedding and take-up mechanisms. As a consequence, only weaving machines that are adequately reinforced in these areas will be suitable for long term performance. By comparison, heavy duty belt filters may require fabrics up to 8m in width. For these purposes the warps usually consist of a series of precision wound 'minibeams' or spools which, after preparation, are mounted on a common let-off shaft on the weaving machine.

3.7.4 Finishing treatments

Finishing treatments for fabrics employed in liquid filtration applications are designed for three basic reasons, namely (i) to ensure dimensional stability during use, (ii) to modify the surface for more efficient cake release, and (iii) to regulate the permeability of the fabric for more efficient particle collection.

Dimensional stability treatments

The application of heat will accelerate this recovery process and, similarly, the application of heat may also induce a measure of shrinkage, which is inherent in the fibre, or filament as received. This shrinkage, be it inherent in the fibre or due to a stress recovery phenomenon, may cause several problems during use. Examples include difficulties in actually fitting the cloth on to the filter, misalignment of holes in cloth and filter and, in extreme cases, partial by-pass of the filter cloth by unfiltered slurry. In most cases this is achieved by selection of yarns of appropriate tenacity but, in the case of filter fabrics designed for use on belt filters, additional assistance is necessary. For such applications the fabrics are subjected to a thermal stretching operation that, in addition to increasing the fabric's initial modulus, also eradicates any tension variations that will have been introduced during yarn preparation or weaving and that may otherwise cause lateral tracking problems on the filter.

Surface modifications

Surface modifications include singeing, which has already been discussed.

Special surface treatments

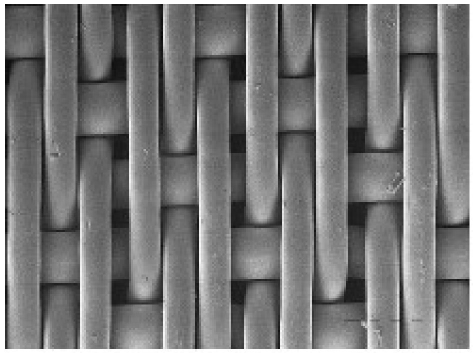
Although the surface of a fabric can be significantly enhanced by physical/thermal means such as singeing and calendering, the development of chemical coatings such as Madison Filter (formerly Scapa Filtration)'s Primapor has led to the production of still more efficient filter media.

3.7.5 Permeability regulation:

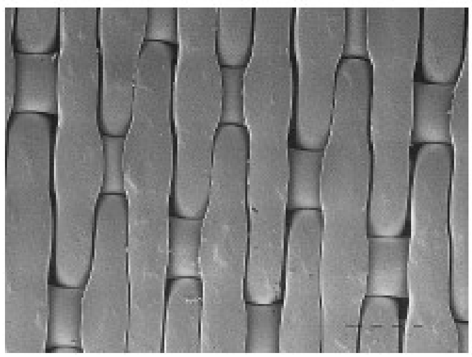
Calendering:

The calendering operation is able both to modify the surface and also to regulate the fabric's permeability by means of heat and pressure. A third variable, namely the speed at which the fabric is processed, will also have a controlling influence on the effectiveness of the operation.

In the case of needle felts, a reduction in pore size is achieved by compressing the fibres into a more dense structure (loads up to 300decaNm^{-1} may be necessary) and, by selection of the appropriate conditions, a more durable surface can also be obtained through partial fusion of the surface fibres.With woven fabrics, on the other hand, some deformation of the yarns may be necessary to achieve the optimum filtration properties.



! Scanning electron micrograph showing monofilament fabric before calender



3.7.6 Fabric test procedures:

General quality control tests:

The tests concerned primarily are area density, fabric sett, yarn types and linear densities, fabric structure, air permeability, thickness and density (principally needle felts), tensile properties and fabric stability.

The resistance to stretch is of particular interest with respect to tensile properties. Resistance to stretch at relatively low loads (e.g. less than 100N per 5cm) is therefore of particular importance from a control point of view. Furthermore, since this phenomenon is temperature related, the ability to carry out such measurements at elevated temperatures is also a useful asset.

Shrinkage tests take one of several forms depending on whether the application is wet or dry. For dust collection applications, measurement of the fabric's free shrinkage in an air circulating oven is the standard practice, the time of exposure and temperature varying according to the specific test procedure.

Although test procedures exist for measuring the liquid permeability of fabrics (e.g. by measurement of the time for a specified volume of water to pass through the fabric), either under gravity (falling column) or at a specified vacuum, it is normally more convenient to quantify the permeability of fabrics by air techniques.

Whichever technique is used, it is important to remember that, although permeability results are a useful pointer in characterizing the efficiency of a fabric, they must not be viewed in isolation but rather in conjunction with other fabric parameters such as thickness (needle felts), area density and threads per unit area (fabric sett).

Performance-related tests

In the case of large mesh monofilament screening fabrics, it is possible to calculate the aperture size simply by means of thread diameters and thread spacing. With much tighter constructions on the other hand an alternative approach has to be taken.

Measurement of 'equivalent pore size' by a bubble point procedure is perhaps the most well known and involves immersing the fabric in a suitable wetting fluid and then measuring the air pressure that is necessary to create a bubble on the surface.

The pore size can be calculated from the relationship $r = 2T \times 10^5/\sigma Pg$, where r is the pore radius (µm), T is the surface tension of the fluid (mNm^{-1}), σ is the density of water at the temperature of test (gcm^{-3}), P is the bubble pressure (mm H_2O) and $g = 981cms^{-2}$.

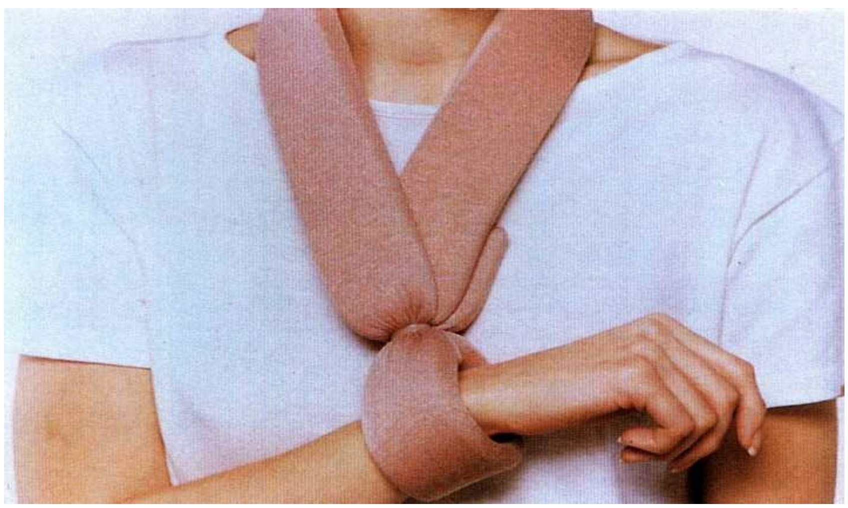
An arguably more relevant approach to assessment of filtration efficiency is proposed by Barlow in which a dilute suspension of fly ash in glycerol is pumped through the fabric. By measuring the particle size distribution with the aid of a Coulter counter before and after passage through the fabric – and before the formation of a filter cake – a measure of its filtration efficiency can be obtained.

UNIT -III - GEOTEXTILES AND MEDICAL TEXTILES

Total Hours: 9 hours

Textiles in Civil Engineering: Geosynthetics, Geotextiles, Essential properties of geotextiles, engineering properties of geotextiles, Geotextile structure, Frictional resistance of geotextiles.

Medical Textiles: Introduction, Fibres used Non-implantable materials, Extra-corporeal devices, Implantable materials, and Healthcare / hygiene products.



4.0 Textiles in Civil Engineering:

4.1 Introduction:

The application of textiles is prevalent in technical textiles area. Among those, textiles used in civil engineering applications such as road construction, river embankment, soil erosion protection, slit fencing, filtration and drainage are significantly important in world countries.

4.2 Need for Geosynthetics:

1. **Non-Uniform Consistency:**

Soils are made up of different types of particles such as gravel, sands, silt, clay and possibly organic materials. Many times, the consistency of the soil (types of particles) can vary throughout the length of the project. This can have a significant effect on such factors as drainage, settlement, frost heaves, etc., all of which can create problems.

2. Unstable Soils

In areas where soils consist of clays, silts and organics, especially in areas that drain poorly, the sub grade may be unstable. As a result, the unstable soil is not able to provide adequately support for a road or embankment.

3. Moisture problems

Depending upon the consistency of the soil, the presence of moisture can create such problems as loss of strength, swelling/shrinking, and frost heave.

4.3 Geosynthetics:

In the field of civil engineering, membranes used in contact with, or within the soil, are known generically as 'geosynthetics'.This term encompasses permeable textiles, plastic grids, continuous fibres, staple fibres and impermeable membranes.

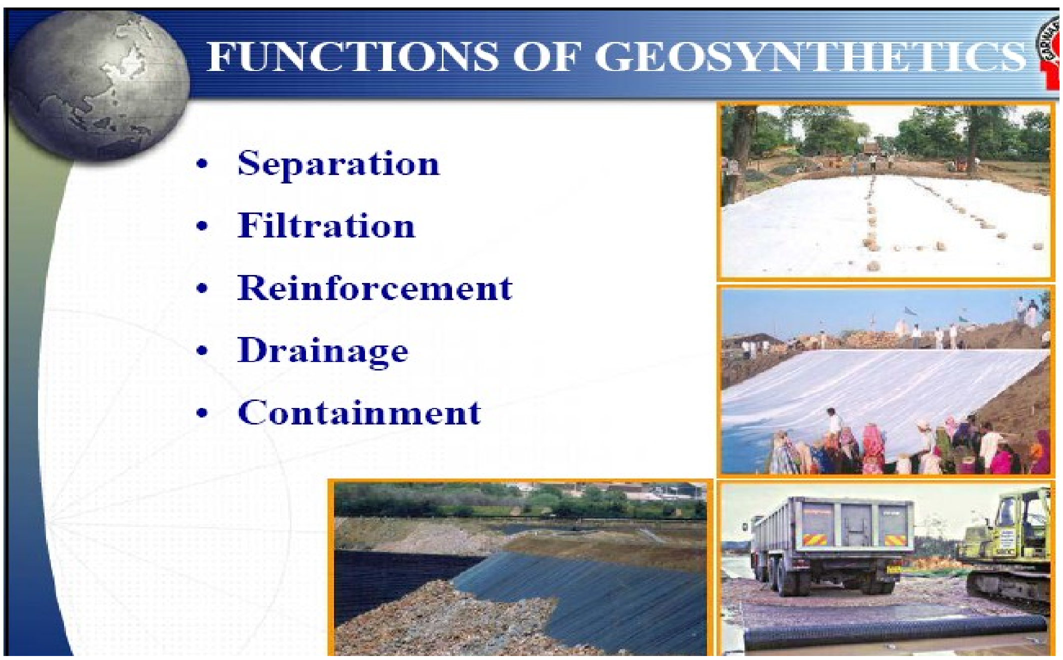
4.4 Types of Geosynthetics:

- A **Geotextiles** is a permeable textile structures made of polymeric materials and are used mainly in civil engineering applications in conjunction with soil, rock or water.
- **Geogrids** are plastic materials formed into a very open grid like configuration with very large apertures.
- **Geomembranes** are impervious sheets of rubber or plastics, used as a moisture or vapor barrier.
- **Geonets** are structures formed by continuous extrusion of polymeric ribs placed at acute angles to one another, which on opening will give net like configuration and used to convey fluids.

- **Geocomposites** are usually composed of two geosynthetics

4.5 Geosynthetics – Functions:

1. **Separation**
2. **Stabilization**
3. **Reinforcement**
4. **Filtration**
5. **Drainage**
6. **Erosion Control**



4.6 Geotextile – Fabric Forms:

Geotextiles basically fall into five categories – woven, heat-bonded nonwoven, and needle punched nonwoven, knitted and by fibre/soil mixing.

Woven fabrics:

They have a surprisingly wide range of applications and they are used in lighter weight form as soil separators, filters and erosion control textiles. In heavy weights, they are used for soil reinforcement in steep embankments and vertical soil walls; the heavier weight products also tend to be used for the support of embankments built over soft soils. The beneficial property of the woven structure in terms of reinforcement, is that stress can be absorbed by the warp and weft yarns and hence by fibres, without much mechanical elongation. This gives them a relatively high modulus or stiffness.

Heat-bonded nonwoven textiles:

They are generally made from continuous filament fine fibres that have been laid randomly onto a moving belt and passed between heated roller systems. These fabrics acquire their coherence and strength from the partial melting of fibres between the hot rollers, resulting in the formation of a relatively thin sheet of textile.

Needle punched nonwoven fabrics:

They are made from blended webs of continuous or staple filaments that are passed through banks of multiple reciprocating barbed needles. In the case of needle punched textiles, considerable thicknesses (up to more than 10 mm) and weights greater than 2000 gm^{-2} can be achieved, whereas the heat bonding process is limited in its efficacy as thickness increases.

Knitted fabrics:

They are used in the field of geotextiles, are restricted to warp-knitted textiles, generally specially produced for the purpose. Warp-knitting machines can produce fine filter fabrics, medium meshes and large diameter soil reinforcing grids.

4.7 Geotextile Polymers:

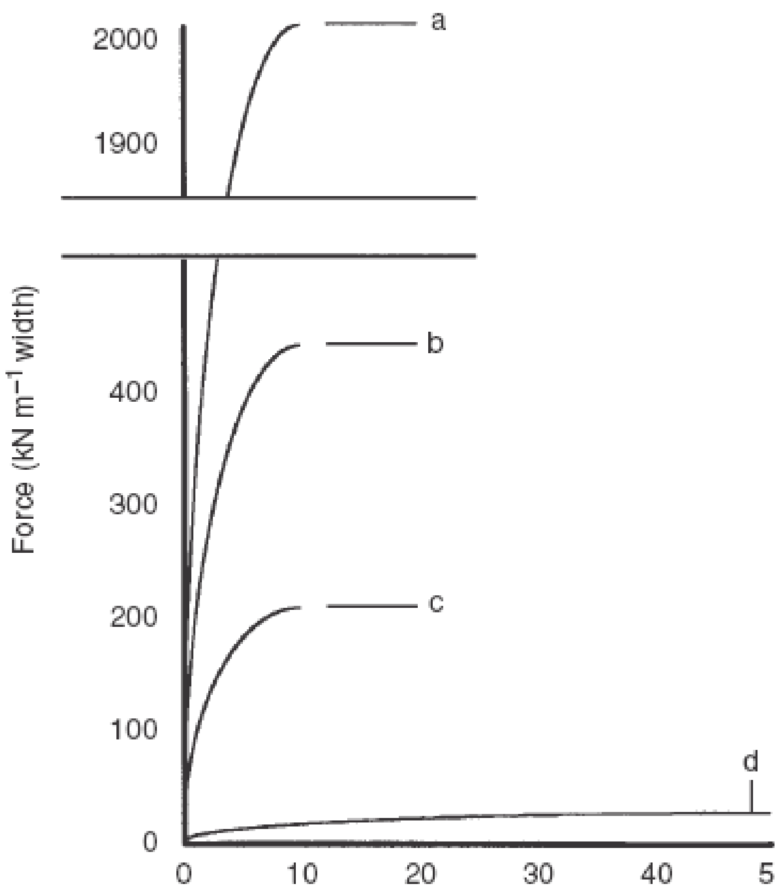
Almost all geotextiles available in the United States are manufactured from either polyester or polypropylene. Polypropylene is lighter than water (specific gravity of 0.9), strong and very durable. Polypropylene filaments and staple fibers are used in manufacturing woven yarns and nonwoven geotextiles. High tenacity polyester fibers and yarns are also used in the manufacturing of geotextiles. Polyester is heavier than water, has excellent strength and creep properties, and is compatible with most common soil environments.

Properties	Polyester	Polyamide	Polypropylene	Polyethylene
Strength	**H**	**M**	**L**	**L**
Elastic modulus	**H**	**M**	**L**	**L**
Strain at failure	**M**	**M**	**H**	**H**
Creep	**L**	**M**	**H**	**H**
Unit weight	**H**	**M**	**L**	**L**
Cost	**L**	**H**	**L**	**L**
Resistance to U.V. light	**H**	**M**	**H**	**H**
Alkalis	**L**	**H**	**H**	**H**
Fungus, vermin	**M**	**M**	**M**	**H**
Fuel	**M**	**M**	**L**	**L**
Detergents	**H**	**H**	**H**	**H**

H: High; M: Medium; L: Low

4.8 Essential properties of Geotxtiles:

The three main properties which are required and specified for a geotextile are its mechanical responses, filtration ability and chemical résistance. These are the properties that produce the required working effect. They are all developed from the combination of the physical form of the polymer fibres, their textile construction and the polymer chemical characteristics.



Typical ultimate stress–strain failure levels (a) of high strength and (b) of medium strength polyester woven geotextiles used for embankment support and soil reinforcement, (c) of geogrids and lower strength polyester woven geotextiles used for soil reinforcement and (d) of low strength, highly extensible nonwoven geotextiles used for separation and filtration. (c) represents the current maximum strength capacity of polyethylene geogrids.

Mechanical responses include the ability of a textile to perform work in a stressed environment and its ability to resist damage in an arduous environment. Usually the stressed environment is known in advance and the textile is selected on the basis of numerical criteria to cope with the expected imposed stresses and its ability to absorb those stresses over the proposed lifetime of the structure without straining more than a predetermined amount.

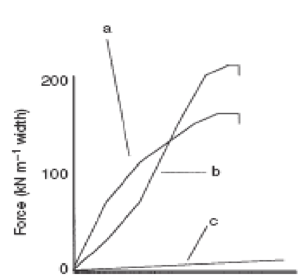
On the other hand, damage can be caused on site during the construction period e.g. accidental tracking from vehicles) or in situ during use (e.g. punching through geotextiles by overlying angular stone). Clearly, in both cases, damage is caused by an undesirable circumstance which is particularly difficult to remove by design.

The ability to perform work is fundamentally governed by the stiffness of the textile in tension and its ability to resist creep failure under any given load condition. The ability to resist damage is complex, clearly being a function of the fibre's ability to resist rupture and the construction of the fabric, which determines how stresses may be concentrated and relieved.

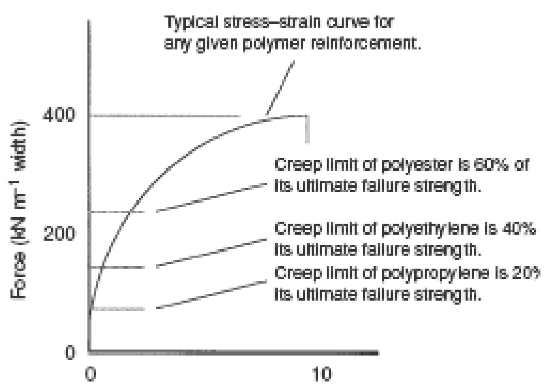
Geotextiles are rarely called upon to resist extremely aggressive chemical environments. Particular examples of where they are, however, include their use in the basal layers of chemical effluent containers or waste disposal sites. Ultraviolet light will tend to cause damage to most polymers, but the inclusion of additives, in the form of antioxidant chemicals and carbon black powder, can considerably reduce this effect.

4.8.1 Mechanical properties:

The weight or area density of the fabric is an indicator of mechanical performance only within specific groups of textiles, but not between one type of construction and another. For example, within the overall range of needle punched continuous filament polyester fabrics, weight will correlate with tensile stiffness. However, a woven fabric with a given area density will almost certainly be much stiffer than an equivalent weight needle punched structure.



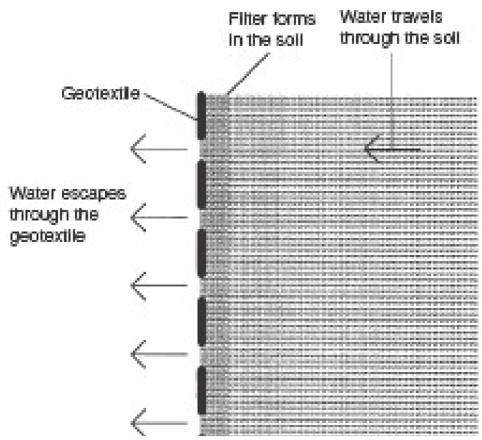
Different stress–strain curve shapes exhibited by the three main types of geosynthetic construction: (a) Geogrids absorb the imposed stresses immediately, giving a high initial modulus. Later, the curve flattens. (b) Woven fabrics exhibit initial straightening of warp fibres which produces a low initial modulus. Later the modulus increases as the straightened polymer fibres take the stress directly. (c) Nonwovens give a curvilinear curve, because extension is primarily resisted by straightening and realignment of the random fibre directions.
The breaking strength of a standard width of fabric or 'ultimate strip tensile failure strength' is universally quoted in the manufacturers' literature to describe the 'strength' of their textiles.
Creep can cause the physical failure of a geotextile if it is held under too high a mechanical stress. It has been found that in practical terms, both polyester and polyethylene will stabilize against creep if stress levels can be maintained at a sufficiently low level. Although polypropylene does not seem to stabilize at any stress level, its creep rate is so low at small stresses that a 'no creep' condition may be considered to exist in practice.



4.8.2 Filtration properties

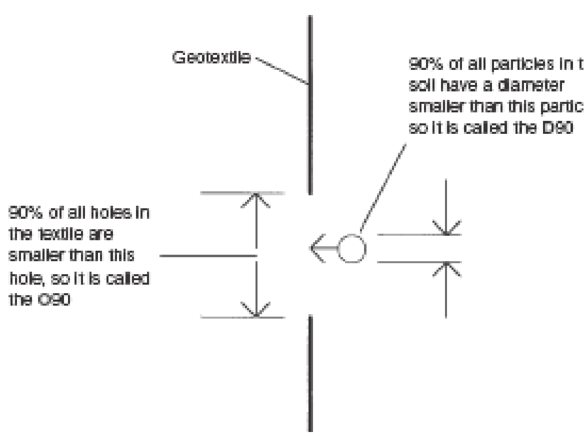
Filtration is one of the most important functions of textiles used in civil engineering earthworks. It is without doubt the largest application of textiles and includes their use in the lining of ditches, beneath roads, in waste disposal facilities, for building basement drainage and in many other ways

The permeability of geotextiles can vary immensely, depending upon the construction of the fabric. Various national and international standards have been set up for the measurement of permeability that is required, most often at right angles to the plane of the textile (cross flow), but also along the plane of the textile (in-plane flow, called transmissivity).



Internal soil filter zone generated by a geotextile

The filtration effect is achieved by placing the textile against the soil, in close contact, thus maintaining the physical integrity of the bare soil surface from which water is passing. Within the first few millimeters of soil, an internal filter is built up and after a short period of piping, stability should be achieved and filtration established



Relationship between O90 and D90

The procedure for matching a textile to the soil, in order to achieve stability under difficult hydraulic conditions, is to use a textile whose largest holes are equal in diameter to the largest particles of the soil (where O90 = D90).Where hydraulic conditions are less demanding, the diameter of the largest textile holes can be up to five times larger than the largest soil particles (O90 = 5D90). Particularly difficult hydraulic conditions exist in the soil (i) when under wave attack, (ii) where the soil is loosely packed (low bulk density), (iii) where the soil is of uniform particle size, or (iv)where the hydraulic gradients are high.

Even under ideal conditions, if the O90 pore size is bigger than 5D90, then so called piping will take place. The textile O90 pore size should be reduced from 5D90 towards D90 as the ground and hydraulic conditions deteriorate.

4.8.3 Chemical resistance

Although the chemical mechanisms involved in fibre degradation are complex, there are four main agents of deterioration: organic, inorganic, light exposure and time change within the textile fibres.

Organic agents include attack by micro- and macro faunas. This is not considered to be a major source of deterioration per se. Geotextiles may be damaged secondarily by animals, but not primarily. For example, few animals will eat them specifically, but in limited instances, when the textile is buried in the ground, it may be destroyed by animals burrowing through. Microorganisms may damage the textiles by living on or within the fibres and producing detrimental by-products.

Inorganic attack is generally restricted to extreme pH environments. Under most practical conditions, geotextile polymers are effectively inert. There are particular instances, such as polyester being attacked by pH levels greater than 11 (e.g. the byproducts of setting cement), but these are rare and identifiable.

Geotextiles can fail in their filtration function by virtue of organisms multiplying and blocking the pores, or by chemical precipitation from saturated mineral waters blocking the pores. Ultraviolet light will deteriorate geotextile fibres if exposed for significant periods of time, but laboratory testing has shown that fibres will deteriorate on their own with time, even if stored under dry dark cool conditions in a laboratory.

4.9 Engineering properties of geotextiles

The physical and mechanical properties of soil are virtually unaffected by the environment over substantial periods. The natural fibre geotextiles could be used where the life of the fabrics is designed to be short. The definition of a short-term timescale varies from site to site and application to application. It depends ultimately on a number of factors, such as the size of the job, the construction period, the time of the year (weather), and so on. With natural fibres the stalks/stems can be stripped away to leave just the fibre which can be adapted to suit many different purposes in numerous forms and shapes with a wide range of properties. The key to developing geotextiles from natural fibres is the concept of designing by function, that is, to identify the functions and characteristics required to overcome a given problem and then manufacture the product accordingly

4.9.1 Geotextile structure forms

There are eleven different types of geotextile structure and fibre type together with their standard properties.

Table 14.13 Total strain and creep strain of vegetable fibre yarns

Type of yarn	Max. load (kN)	Max. strain (%)	40% load (kN)	Strain at 40% load	20% load (kN)	Strain at 20% load	10% load (kN)	Strai 10%
Sisal	1.05	6.90	0.42	3.50	0.21	2.30	0.11	1.50
Abaca	1.04	3.19	0.42	1.40	0.21	0.80	0.10	0.50
Coir	0.35	26.71	0.14	3.70	0.07	1.50	0.04	0.70
Flax	0.68	4.02	0.27	2.30	0.14	1.50	0.07	0.90

Total strain for 10 min

Type of yarn	% of Max. load		
	40	20	10
Sisal	4.6	2.7	1.5
Abaca	1.8	1.3	0.6
Coir	5.1	2.0	1.7
Flax	2.4	1.5	0.9

Creep strain for 10 min

Type of yarn	% of Max. load		
	40	20	10
Sisal	1.1	0.4	0.0
Abaca	0.4	0.5	0.1
Coir	1.4	0.5	1.0
Flax	0.1	0.0	0.0

Total strain for 100 min

Type of yarn	% of Max. load		
	40	20	10
Sisal	4.6	2.8	1.6
Abaca	1.9	1.4	0.7
Coir	6.0	2.3	1.8
Flax	2.6	1.5	1.0

Creep strain for 100 min

Type of yarn	% of Max. load		
	40	20	10
Sisal	1.1	0.5	0.1
Abaca	0.5	0.6	0.2
Coir	2.3	0.8	1.1
Flax	0.3	0.0	0.1

Total strain for 1000 min

Type of yarn	% of Max. load		
	40	20	10
Sisal	4.8	3.0	1.8
Abaca	2.0	1.4	0.7
Coir	6.9	2.7	2.0
Flax	2.8	1.5	1.1

Creep strain for 1000 min

Type of yarn	% of Max. load		
	40	20	10
Sisal	1.3	0.7	0.3
Abaca	0.6	0.6	0.2
Coir	3.2	1.2	1.3
Flax	0.5	0.0	0.2

Total strain for 10 000 min

Type of yarn	% of Max. load		
	40	20	10
Sisal	5.0	3.2	2.0
Abaca	2.1	1.5	0.8
Coir	7.9	3.1	2.1
Flax	2.9	1.6	1.2

Creep strain for 10 000min

Type of yarn	% of Max. load		
	40	20	10
Sisal	1.5	0.9	0.5
Abaca	0.7	0.7	0.3
Coir	4.2	1.6	1.4
Flax	0.6	0.1	0.3

Total strain for 100 000 min

Type of yarn	% of Max. load		
	40	20	10
Sisal	5.2	3.3	2.1
Abaca	2.2	1.5	0.8

Creep strain for 100 000 min

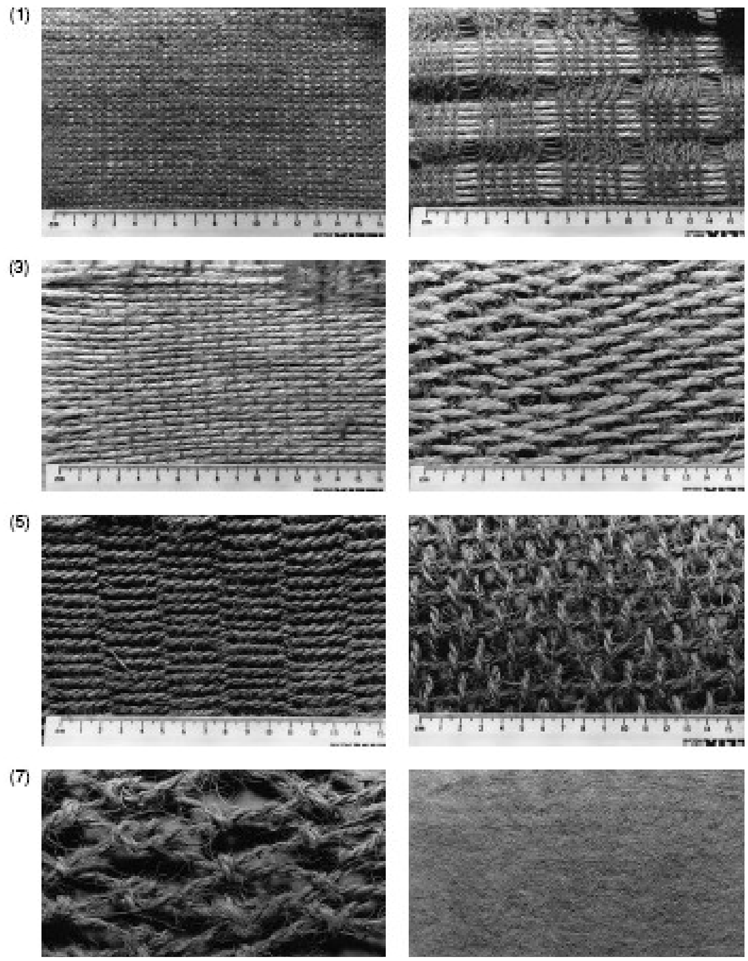
Type of yarn	% of Max. load		
	40	20	10
Sisal	–	1.0	0.6
Abaca	–	0.7	0.3

The creation of reinforcing geotextiles made from vegetable fibres introduces new manufacturing restraints, compared with the use of synthetic fibres and structures on existing textile machines.

They have been created with the fundamental properties required to form geotextiles to reinforce soil, in that they have been designed to provide:

- The highest possible strength in one direction, combined with ease of handling and laying on site

- Soil particle interlock with the fabric to such an extent that the soil/fabric interface exhibits greater shearing resistance than the surrounding soil, i.e. the soil/fabric coefficient of interaction (α) is greater than one
- A degree of protection to the high strength yarns during installation
- A tensile strength in the range of 100–200kNm-1.
- Ease of manufacture on conventional textile machines.



The knitted flax/sisal inlay number 1 has as many straight inlay yarns as possible in one direction which gives the geotextile its high strength, without introducing crimp into these yarns. Thus a fabric is produced which has low extensibility compared with conventional woven structures. The knitted loops hold the inlay yarn in a parallel configuration during transportation and laying on site; under site conditions it would be impractical to lay numerous individual sisal yarns straight onto the ground.

The knitted loops also provide some protection for the sisal inlay yarns during installation/backfilling. The most advantageous use of the knitted loops in this structure is that they form exactly the same surface on both sides of the fabric and the sand is in contact not only with the knitted loops but with the inlay yarns as well. Thus the shear stress from the sand is transmitted directly to both the inlay yarns and the knitted skeleton.

With the grid flax/sisal geotextile number 2, at predetermined intervals needles were omitted and the sisal inlay yarn left out, to produce large apertures in the geotextile. Structures 3 to 5 employed traditional woven patterns, but exploited combinations of different types of yarn and thickness to produce advantageous fabric properties for reinforcing geotextiles.

The plain weave sisal warp/flax weft geotextile number 3 allows the maximum possible number of the high strength sisal yarns to be laid in one direction, whilst the flax weft yarns hold the sisal yarns together during transportation and laying on site. By only using very thin weft yarns compared to the warp yarns no crimp is introduced in these warp yarns. This structure is not as stable as the knitted structures and the flax weft yarns offer no protection for the sisal warp yarns during installation.

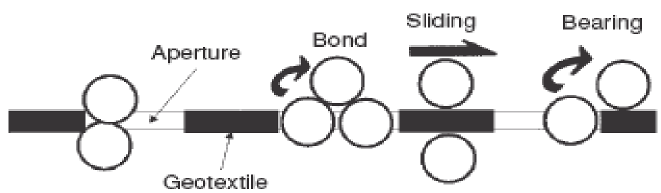
The plain weave sisal warp/coir weft geotextile number 4 provides the sisal strength yarn in one direction whilst using the coir weft yarn to form ridges in the structures caused by its coarseness, thus creating abutments which the soil has to shear around.

The woven 6 x 1 weft rib geotextile number 5 was designed to provide the ultimate protection for the high strength sisal yarns but without introducing any crimp. However, this structure has comparatively lower productivity because of the high weft cover factor and thus it is more costly.

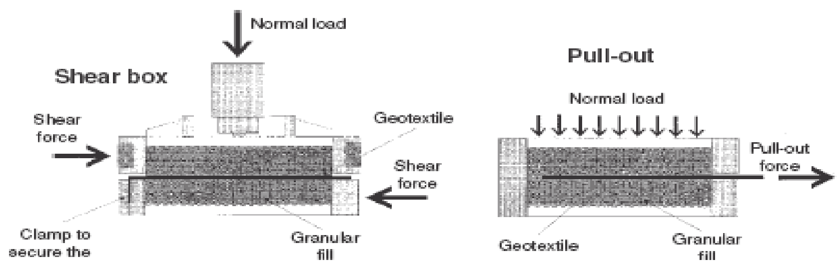
Numbers 6 to 11 are all commercially available geotextile products, with 6 to 9 being of a natural fibre origin. However, geotextiles 10 and 11 are of a synthetic origin from the midrange of synthetic products commercially available.

4.9.2 Frictional resistance of geotextiles

The frictional shearing resistance at the interface between the soil and the geotextile is of paramount importance since it enables the geotextile to resist pull-out failure and allows tensile forces to be carried by the soil/geotextile composite. The resistance offered by the fabric structure can be attributed to the surface roughness characteristics of the geotextile (soil sliding) and the ability of the soil to penetrate the fabric, that is, the aperture size of the geotextile in relation to the particle size of the soil, which affects bond and bearing resistance



14.19 Forms of shearing resistance; sliding, bond and bearing.



particles in the apertures to shear against ambient soil in close vicinity above and below the geotextile surface, whereas bearing resistance, which can only really be assessed by pull-out tests, is the effect of soil having to shear around abutments in the geotextiles, or at the end of the apertures, in the direction of shear. This mode of resistance is very similar to that encountered in reinforced anchors and is determined by relating the pull-out force to the sum of projected area of the transverse members in the geotextile.

The efficiency of geotextiles in developing shearing resistance at the soil–fabric interface is indicated by the coefficient of interaction (α) defined as the ratio of the friction coefficient between soil and fabric ($\tan \delta$) and the friction coefficient for soil sliding on soil ($\tan \varphi$).

5.0 Medical Textiles:

5.1 Introduction:

Medical textiles are an emerging sector of technical textiles industry and are fuelled due to constant improvements in healthcare as well as innovations in the textile field. Biomaterials - synthetic or natural which is intended to interface with biological systems to evaluate, treat, augment or replace any tissue or organ or function of the body. The healthcare industry in India is growing by 17% per annum.The use of disposables such as face mask, surgical head gears and shoe covers, surgical drapes and gowns is increasing in private hospitals .A recent survey conducted by Alhstorm, India, conducted among private hospitals in and around Chennai found that the usage of single-use fabrics is high as 40%.

5.2 Fibres Used:

Fibres used in medicine and surgery may be classified depending on whether the materials from which they are made are natural or synthetic, biodegradable or non-biodegradable. All fibres used in medical applications must be non-toxic, non-allergenic non-carcinogenic, and be able to be sterilized without imparting any change in the physical or chemical characteristics.

Commonly used natural fibres are cotton and silk but also included are the regenerated cellulosic fibres (viscose rayon); these are widely used in nonimplantable materials and healthcare/hygiene products.A wide variety of products and specific applications utilise the unique characteristics that synthetic fibres exhibit. Commonly used synthetic materials include polyester, polyamide, polytetrafluoroethylene (PTFE), polypropylene, carbon, glass, and so on. The second classification relates to the extent of fibre biodegradability. Biodegradable fibres are those which are absorbed by the body within 2–3 months after implantation and include cotton, viscose rayon, polyamide, polyurethane, collagen, and alginate. Fibres that are slowly absorbed within the body and take more than 6 months to degrade are considered nonbiodegradable and include polyester (e.g. Dacron), polypropylene, PTFE and carbon.

A variety of natural polymers such as collagen, alginate, chitin, chitosan, and so on, have been found to be essential materials for modern wound dressings. Collagen, which is obtained from bovine skin, is a protein available either in fibre or hydrogel (gelatin) form. Collagen fibres, used as sutures, are as strong as silk and are biodegradable. Calcium alginate fibres are produced from seaweed of the type Laminariae. The fibres possess healing properties, which have proved to be effective in the treatment of a wide variety of wounds, and dressings comprising calcium alginate are non-toxic, biodegradable and haemostatic.

Chitin, a polysaccharide that is obtained from crab and shrimp shells, has excellent antithrombogenic characteristics, and can be absorbed by the body and promote healing. Chitin nonwoven fabrics used as artificial skin adhere to the body stimulating new skin formation which accelerates the healing rate and reduces pain. Treatment of chitin with alkali yields chitosan that can be spun into filaments of similar strength to viscose rayon. Chitosan is now being developed for slow drug-release membranes.

Other fibres that have been developed include polycaprolactone (PCL) and polypropiolactone (PPL), which can be mixed with cellulosic fibres to produce highly flexible and inexpensive biodegradable nonwovens. Melt spun fibres made from lactic acid have similar strength and heat properties as nylon and are also biodegradable.

5.3 Non-implantable materials

Product application	Fibre type	Manufacture system
Woundcare		
absorbent pad	Cotton, viscose	Nonwoven
wound contact layer	Silk, polyamide, viscose, polyethylene	Knitted, woven, nonw
base material	Viscose, plastic film	Nonwoven, woven
Bandages		
simple inelastic/elastic	Cotton, viscose, polyamide, elastomeric yarns	Woven, knitted, nonw
light support	Cotton, viscose, elastomeric yarns	Woven, knitted, nonw
compression	Cotton, polyamide, elastomeric yarns	Woven, knitted
orthopaedic	Cotton, viscose, polyester polypropylene, polyurethane foam	Woven, nonwoven
Plasters	Viscose, plastic film, cotton, polyester, glass, polypropylene	Knitted, woven, nonw
Gauzes	Cotton, viscose	Woven, nonwoven
Lint	Cotton	Woven
Wadding	Viscose, cotton linters,	Nonwoven

5.3.1 Wound Care:

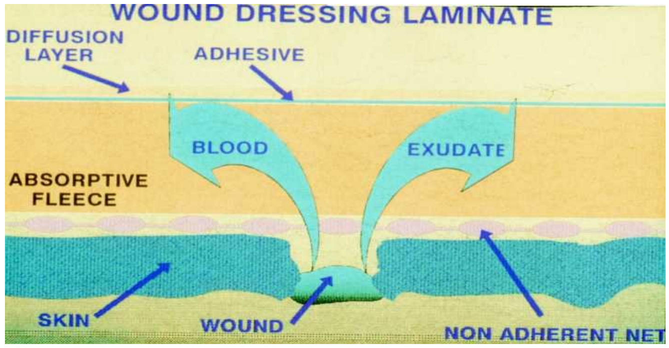
Requirement of an Ideal Wound Dressing:

- Provides a barrier against micro organisms, dirt and other foreign bodies
- Provides a moist environment at the wound surface.
- Possesses high absorption and retention of body fluids.
- Nonadherent

Wound Dressing:

A number of wound dressing types are available for a variety of medical and surgical applications. The functions of these materials are to provide protection against infection, absorb blood and exudate, promote healing and, in some instances, apply medication to the wound.

Common wound dressings are composite materials consisting of an absorbent layer held between a wound contact layer and a flexible base material.

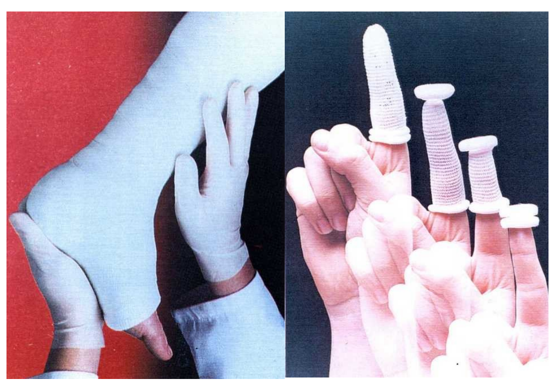


The absorbent pad absorbs blood or liquids and provides a cushioning effect to protect the wound. The wound contact layer should prevent adherence of the dressing to the wound and be easily removed without disturbing new tissue growth. The base materials are normally coated with an acrylic adhesive to provide the means by which the dressing is applied to the wound.

Other textile materials used for wound dressing applications include gauze, lint, and wadding. Gauze is an open weave, absorbent fabric that when coated with paraffin wax is used for the treatment of burns and scalds. In surgical applications gauze serves as an absorbent material when used in pad form (swabs).

5.3.2 Bandages

Bandages are designed to perform a whole variety of specific functions depending upon the final medical requirement. They can be woven, knitted, or nonwoven and are either elastic or non-elastic.



The most common application for bandages is to hold dressings in place over wounds. Such bandages include lightweight knitted or simple open weave fabrics made from cotton or viscose that are cut into strips then scoured, bleached, and sterilized. Elasticated yarns are incorporated into the fabric structure to impart support and conforming characteristics. Knitted bandages can be produced in tubular form in varying diameters on either warp or weft knitting machines.

Compression bandages are used for the treatment and prevention of deep vein thrombosis, leg ulceration, and varicose veins and are designed to exert a required amount of compression on the leg when applied at a constant tension. Compression bandages are classified by the amount of compression they can exert at the ankle and include extra-high, high, moderate, and light compression and can be either woven and contain cotton and elastomeric yarns or warp and weft knitted in both tubular or fully fashioned forms.

Orthopaedic cushion bandages are used under plaster casts and compression bandages to provide padding and prevent discomfort. Nonwoven orthopaedic cushion bandages may be produced from polyurethane foams, polyester, or polypropylene fibres and contain blends of natural or other synthetic fibres. Nonwoven bandages are lightly needle-punched to maintain bulk and loft.

5.4 Extracorporeal devices

Extracorporeal devices are mechanical organs that are used for blood purification and include the artificial kidney (dialyser), the artificial liver, and the mechanical lung. The function and performance of these devices benefit from fibre and textile technology.

Product application	Fibre type	Function
Artificial kidney	Hollow viscose, hollow polyester	Remove waste products from pat blood
Artificial liver	Hollow viscose	Separate and dispose patients pla and supply fresh plasma
Mechanical lung	Hollow polypropylene, hollow silicone, silicone membrane	Remove carbon dioxide from pat blood and supply fresh blood

The function of the artificial kidney is achieved by circulating the blood through a membrane, which may be either a flat sheet or a bundle of hollow regenerated cellulose fibres in the form of cellophane that retain the unwanted waste materials. Multilayer filters composed of numerous layers of needle punched fabrics with varying densities may also be used and are designed rapidly and efficiently to remove the waste materials. The artificial liver utilizes hollow fibres or membranes similar to those used for the artificial kidney to perform their function.

The microporous membranes of the mechanical lung possess high permeability to gases but low permeability to liquids and functions in the same manner as the natural lung allowing oxygen to come into contact with the patient's blood.

5.5 Implantable materials

These materials are used in effecting repair to the body whether it be wound closure (sutures) or replacement surgery (vascular grafts, artificial ligaments, etc.).

Product application	Fibre type	Manufacture system
Sutures		
biodegradable	Collagen, polylactide, polyglycolide	Monofilament, braided
non-biodegradable	Polyamide, polyester, PTFE, polypropylene, steel	Monofilament, braided
Soft-tissue implants		
artificial tendon	PTFE, polyester, polyamide, silk, polyethylene	Woven, braided
artificial ligament	Polyester, carbon	Braided
artificial cartilage	Low density polyethylene	Nonwoven
artificial skin	Chitin	
eye contact lenses/artificial cornea	Polymethyl methacrylate, silicone, collagen	
Orthopaedic implants		
artificial joints/bones	Silicone, polyacetal, polyethylene	
Cardiovascular implants		
vascular grafts	Polyester, PTFE	Knitted, woven
heart valves	Polyester	Woven, knitted

Biocompatibility is of prime importance if the textile material is to be accepted by the body and four key factors will determine how the body reacts to the implant. These are as follows:

- The most important factor is porosity which determines the rate at which human

tissue will grow and encapsulate the implant.

- Small circular fibres are better encapsulated with human tissue than larger fibres

with irregular cross-sections.

- Toxic substances must not be released by the fibre polymer, and the fibres should

be free from surface contaminants such as lubricants and sizing agents.

- The properties of the polymer will influence the success of the implantation in terms of its biodegradability.

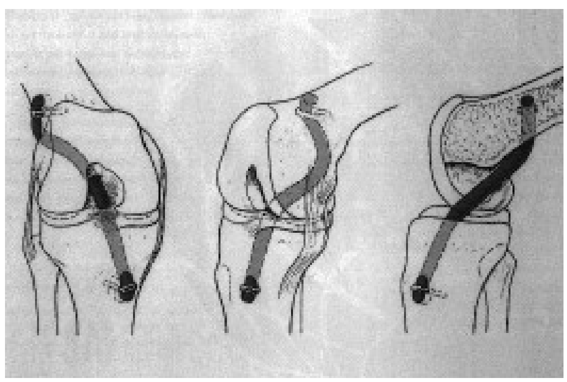
Polyamide is the most reactive material losing its overall strength after only two years as a result of biodegradation. PTFE is the least reactive with polypropylene and polyester in between.

5.5.1 Sutures

Sutures for wound closure are either monofilament or multifilament threads that are categorized as either biodegradable or nonbiodegradable. Biodegradable sutures are used mainly for internal wound closures and nonbiodegradable sutures are used to close exposed wounds and are removed when the wound is sufficiently healed.

5.5.2 Soft-tissue implants

The strength and flexibility characteristics of textile materials make them particularly suitable for soft-tissue implants. A number of surgical applications utilize these characteristics for the replacement of tendons, ligaments, and cartilage in both reconstructive and corrective surgery. Artificial tendons are woven or braided porous meshes or tapes surrounded by a silicone sheath.



Textile materials used to replace damaged knee ligaments (anterior cruciate ligaments) should not only possess biocompatibility properties but must also have the physical characteristics needed for such a demanding application. Braided polyester artificial ligaments are strong and exhibit resistance to creep from cyclic loads. Braided composite materials containing carbon and polyester filaments have also been found to be particularly suitable for knee ligament replacement.

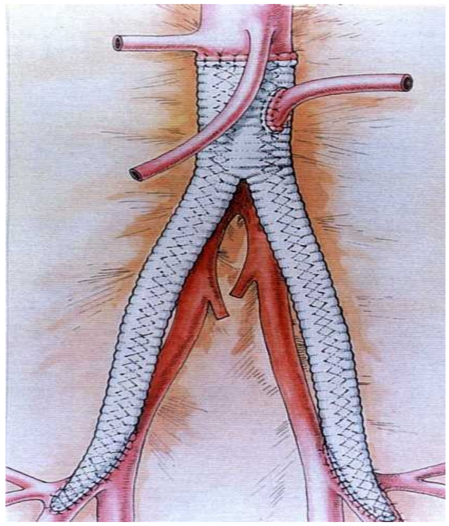
Low density polyethylene is used to replace facial, nose, ear, and throat cartilage; the material is particularly suitable for this application because it resembles natural cartilage in many ways. Carbon fibre reinforced composite structures are used to resurface the defective areas of articular cartilage within synovial joints (knee, etc.) as a result of osteoarthritis.

5.5.3 Orthopaedic implants

Orthopaedic implants are those materials that are used for hard tissue applications to replace bones and joints. Also included in this category are fixation plates that are implanted to stabilise fractured bones. Fibre-reinforced composite materials may be designed with the required high structural strength and biocompatibility properties needed for these applications and are now replacing metal implants for artificial joints and bones. To promote tissue in growth around the implant a nonwoven mat made from graphite and PTFE (e.g. Teflon) is used, which acts as an interface between the implant and the adjacent hard and soft tissue. Composite structures composed of poly (d, l-lactide urethane) and reinforced with polyglycolic acid have excellent physical properties. The composite can be formed into shape during surgery at a temperature of 60 °C and is used for both hard and soft tissue applications.28 Braided surgical cables composed of steel filaments ranging from 13–130mm are used to stabilise fractured bones or to secure orthopaedic implants to the skeleton.

5.5.4 Cardiovascular implants

Vascular grafts are used in surgery to replace damaged thick arteries or veins 6mm, 8mm, or 1 cm in diameter. Commercially available vascular grafts are produced from polyester (e.g. Dacron) or PTFE (e.g. Teflon) with either woven or knitted structures . Straight or branched grafts are possible by using either weft or warp knitting technology.



Polyester vascular grafts can be heat set into a crimped configuration that improves the handling characteristics. Knitted vascular grafts have a porous structure which allows the graft to become encapsulated with new tissue but the porosity can be disadvantageous since blood leakage (haemorrhage) can occur through the interstices directly after implantation.

Artificial blood vessels with an inner diameter of 1.5mm have been developed using porous PTFE tubes. The tube consists of an inner layer of collagen and heparin to prevent blood clot formation and an outer biocompatible layer of collagen with the tube itself providing strength. Artificial heart valves, which are caged ball valves with metal struts, are covered with polyester (e.g. Dacron) fabrics in order to provide a means of suturing the valve to the surrounding tissue.

5.6 Healthcare/hygiene products:

Healthcare and hygiene products are an important sector in the field of medicine and surgery. The range of products available is vast but typically they are used either in the operating theatre or on the hospital ward for the hygiene, care, and safety of staff and patients. Textile materials used in the operating theatre include surgeon's gowns, caps and masks, patient drapes, and cover cloths of various sizes.

Product application	Fibre type	Manufacture syst
Surgical clothing		
gowns	Cotton, polyester, polypropylene	Nonwoven, wove
caps	Viscose	Nonwoven
masks	Viscose, polyester, glass	Nonwoven
Surgical covers		
drapes	Polyester, polyethylene	Nonwoven, wove
cloths	Polyester, polyethylene	Nonwoven, wove
Bedding		
blankets	Cotton, polyester	Woven, knitted
sheets	Cotton	Woven
pillowcases	Cotton	Woven
Clothing		
uniforms	Cotton, polyester	Woven
protective clothing	Polyester, polypropylene	Nonwoven
Incontinence diaper/sheet		
coverstock	Polyester, polypropylene	Nonwoven
absorbent layer	Wood fluff, superabsorbents	Nonwoven
outer layer	Polyethylene	Nonwoven
Cloths/wipes	Viscose	Nonwoven
Surgical hosiery	Polyamide, polyester, cotton	Knitted

Surgical gowns should act as a barrier to prevent the release of pollutant particles into the air. Traditionally, surgical gowns are woven cotton goods that not only allow the release of particles from the surgeon but are also a source of contamination generating high levels of dust (lint). Disposable nonwoven surgical gowns have been adopted to prevent these sources of contamination to the patient.

Surgical masks consist of a very fine middle layer of extra fine glass fibres or synthetic microfibres covered on both sides by either an acrylic bonded parallel-laid or wet-laid nonwoven. The application requirements of such masks demand that they have a high filter capacity, high level of air permeability, are lightweight and non-allergenic. Disposable surgical caps are usually parallel-laid or spun-laid nonwoven materials based on cellulosic fibres. Surgical drapes and cover cloths are used in the operating theatre either to cover the patient (drapes) or to cover working areas around the patient (cover cloths).

Nonwoven materials are used extensively for drapes and cover cloths and are composed of films backed on either one or both sides with nonwoven fabrics. The film is completely impermeable to bacteria while the nonwoven backing is highly absorbent to both body perspiration and secretions from the wound. Hydrophobic finishes may also be applied to the material in order to achieve the required bacteria barrier characteristics.

The second category of textile materials used for healthcare and hygiene products are those commonly used on hospital wards for the care and hygiene of the patient and includes bedding, clothing ,mattress covers, incontinence products, cloths and wipes.

Incontinence products for the patient are available in both diaper and flat sheet forms with the latter used as bedding. The disposable diaper is a composite article consisting of an inner covering layer (cover stock), an absorbent layer, and an outer layer. The inner covering layer is either a longitudinally orientated polyester web treated with a hydrophilic finish, or a spun-laid polypropylene nonwoven material.

UNIT IV -PROTECTIVE TEXTILES

Total Hours: 9

Textiles in Defence: Introduction, Historical background, Criteria for modem military textile materials, Textiles for environmental protection, Thermal insulation materials, Water vapour permeable and waterproof materials, Military combat clothing systems, Camouflage concealment and deception, Flame-retardant, heat protective textiles, Ballistic protective materials, Biological and chemical warfare protection.

6.0 Textiles in Defence:

6.1 Introduction:

Defence forces on land, sea, or air throughout the world are heavily reliant on technical textiles of all types – whether woven, knitted, nonwoven, coated, laminated, or other composite forms. Technical textiles offer invaluable properties for military land forces in particular, who are required to move, live, survive and fight in hostile environments.

6.2 Historical background

Military textile science is not new, and one of the earliest documented studies can probably be credited to Count Rumford, or Benjamin Thompson. Rumford was an American army colonel and scientist who issued a paper in 1792 entitled 'Philosophical Transactions', which reported on the importance of internally trapped air in a range of textile fabrics to the thermal insulation provided by those fabrics. He was awarded the Copley Medal for his paper, as the significance of his discovery was recognized immediately. From the 1960s to the present day the military textiles, clothing and equipment of all major nations have become ever more sophisticated and diverse. They now utilize the most advanced textile fibres, fabrics and constructions available.

6.3 Criteria for modern military textile materials

The main functional criteria for military textiles are dealt with here under a range of headings. These include the physical, environmental, camouflage, specific battlefield threats, flames, heat and flash, and the economic considerations:

6.3.1 Physical Requirements:

Property	Comments
Light weight and Low bulk	Items have to be carried by individuals or vehicles with minimal space available
High durability and Dimensional stability	Must operate reliably in adverse conditions for long per of time without maintenance.
Cleanable	
Good handle and drape	Comfortable
Low noise emission	Tactically quiet – no rustle or swish
Antistatic	To avoid incendive or explosive sparks

6.3.2 Environmental Requirements:

Property	Comments
Water-repellent,	For exterior materials exposed to cold/wet we
Waterproof,	" "
Windproof and	" "
Snow-shedding	" "
Thermally insulating	For cold climates
Water vapour permeable	For clothing and personal equipment (tents e
Rot-resistant	For tents, covers, nets etc.
UV light resistant	For environments with strong sunlight
Air permeable.	For hot tropical climates
Biodegradable	If discarded or buried

6.3.3 Camouflage, concealment and deception requirements:

Property	Comments
Visual spectrum	Exposed materials match visual colours, texture and appearance natural backgrounds
Ultraviolet	To match optical properties of snow and ice
Near infrared	To match reflectance of background when viewed by image intensifiers and low light television
Far infrared	To minimise the heat signature emitted by humans and hot equipment. Detection by thermal imagers
Acoustic emissions	Rustle and swish noises emitted by certain textile materials Detected by aural means, unattended ground sensors and microphones
Radar spectrum	Detection of movement by Doppler radar

6.3.4 Requirements for flame, heat and flash protection:

Property	Comments
Flame retardance	Of outer layers exposed to flames and heat
Heat resistance	Avoid heat shrinkage and degradation
Melt resistance	For textiles in contact with the skin
Low smoke emission	To allow escape in confined spaces
Low toxicity	Of combustion products in confined spaces such as submarines, buildings, vehicles

6.3.5 Specific battlefield hazards:

Hazard	Comments
Ballistic fragments	From bombs, grenades, shells, warheads
Low velocity bullets	From hand guns, pistols, etc.
High velocity bullets	From small-arms rifled weapons from 5.56mm u 12.7mm calibre
Flechettes	Small, sharp, needle shaped projectiles
Chemical warfare agents	Including blood agents, nerve agents, vessicants
Biological agents	Bacteria, toxins, viruses
Nuclear radiation	Alpha, beta and gamma radiation
Directed energy weapons (DEW)	Includes laser rangefinders and target designator

6.3.6 Economic Considerations:

Property	Comments
Easy-care	Smart, non-iron, easily cleanable
Minimal maintenance	Maintenance facilities not available in the field
Long storage life	War stocks need to be stored for 10–20 years.
Repairable	Repairable by individuals or HQ workshops
Decontaminable or disposable	Against nuclear, biological or chemical contamina
Readily available	From competitive tendering in industry against a standard or specification
Minimal cost	Bought by taxpayers and other public funding

6.4 Textiles for environmental protection:

Military forces have to be prepared to operate in all parts of the globe from arctic, through temperate, to jungle and desert areas. As such they experience the widest range of climatic conditions possible, encountering rain, snow, fog, wind, lightning, sunlight, and dust. They have to survive the attendant heat, cold, wetness, UV light, wind chill and other discomforts on land, sea, and in the air. The environment is considered to have the highest priority where protection of the individual is considered.

6.4.1 Underwear materials

Textile materials used for next-to-skin clothing are primarily worn for hygiene reasons. The thermal insulation properties tend to be less important than the tactile properties and the way the material handles moisture (mainly perspiration) in order to remove it from the skin. Tactile properties are associated with fit, flexibility, roughness, and dermatitic skin reactions to remove it from the skin.

The perspiration and handling properties of knitted underwear materials are extremely critical for mobile land forces such as infantry soldiers, marines and special forces. Their activities range from rapid movement on foot carrying heavy loads, to total immobilization for long periods when lying in ambush or on covert reconnaissance operations in rural areas.

The buffering index (K_f) has values between 0 (no water transported) and 1 (all water transported).Values above 0.7 are indicative of 'good' performance.

Underwear fabric	Buffering index (Kf)	Ran
100% Cotton 1 × 1 rib (olive) (**13**)	0.644	5 =
100% Hollow polyester 1 × 1 rib (olive)	0.641	5 =
100% Quadralobal polyester 1 × 1 rib (olive)	0.720	4
70% Hollow polyester/30% cotton, 2-sided rib	0.731	3
67% Hollow polyester/33% cotton double jersey	0.765	1 =
64% Hollow polyester /36% cotton double jersey	0.764	1 =
72% Quadralobal polyester/28% cotton two-sided rib	0.645	5 =
63% Quadralobal polyester/37% cotton double jersey	0.635	8

The results show that a wide range of fabrics possess very similar buffering indices when exposed to large amounts of sweat. Values above 0.7 indicate that a fabric will have good wicking and drying properties. The best fabrics in these tests were blends of hollow polyester and cotton in a two-sided (bicomponent) double jersey construction. The 100% cotton military fabric, purported to be a poor fabric for performance underwear, actually performed better than a blend of a special quadralobal polyester and cotton, and equally as well as some of the high performance 100% polyester fabrics specifically developed for sports underwear. The main advantage of non-absorbent synthetic fibres is that they dry more rapidly on the body than cotton fabrics and minimise the cold 'cling' sensation.

6.5 Thermal insulation materials

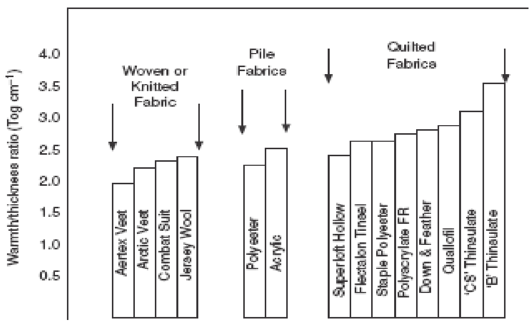
Military forces of many nations need to survive and fight in the most extreme conditions known on earth. The cold/wet regions tend to cause the most severe problems, as it is necessary to provide and maintain dry thermal insulation materials. The cold/dry areas, including the arctic, antarctic, and mountainous regions require the carriage and use of clothing, sleeping bags, and other personal equipment which possess high levels of thermal insulation. Military forces are prone to sacrificing thermal comfort for light weight and low bulk items.

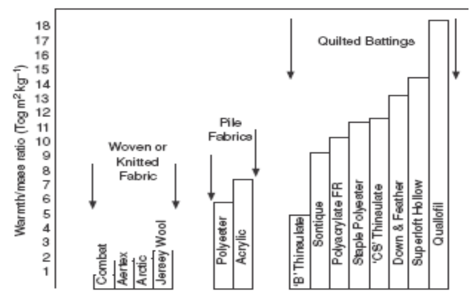
Any fibrous material will offer some resistance to the transmission of heat, because of the air enclosed between and on the surface of the fibres. What really determines the efficiency of the fibrous insulator is the ratio of fibre to air, and the way in which the fibres are arranged in the system. An efficient insulator will be composed of about 10–20% of fibre and 80–90% of air, the fibre merely acting as a large surface area medium to trap still air.

There is a secondary effect that is governed by the diameter of the fibres. Large numbers of fine fibres trap more still air, owing to the high specific surface area. However, fine fibres give a dense felt-like batting. There is a compromise between fineness and flexural rigidity which gives the fibre the ability to maintain a degree of 'loft', resilience and recovery from compression which is essential for clothing and sleeping bags. Finer fibre battings are more suitable for insulated footwear and hand wear, where low thickness is an important factor.

6.5.1 Insulation efficiency

The insulation efficiency of military clothing and equipment is critical, as we endeavour to achieve the highest insulation value at the lowest weight and thickness shows the warmth/thickness ratios in Tog per centimetre for a range of woven, knitted, pile and quilted textile assemblies. The Tog is the SI unit of thermal insulation, measured on a 'Togmeter'.19 The definition of the Tog unit is: 1 Tog = $m^2K/10$ Watts.





Woven and knitted fabrics offer poor insulation for their mass. The pile fabrics are intermediate in efficiency, but the quilted battings are the most efficient. Hollow fibres and down fillings are 13 to 17 times more efficient than polyester/ cotton woven fabric if insulation needs to be carried by the individual.

6.5.2 Effect of moisture on insulation

Any fibrous, porous insulation material is adversely affected by the presence of moisture, whether this is perspiration or rain. Replacing air of low thermal conductivity by water of high conductivity is the primary cause. Moreover, fibrous materials, particularly pile fabrics or quilted battings, have a high affinity for wicking and entrapping large amounts of moisture.

6.6 Water vapour permeable/waterproof materials:

One of the basic incompatibilities in technical textiles is that associated with providing waterproof materials which allow free passage of water vapour (perspiration). Without this facility, physiological problems can occur when impermeable clothing is worn by highly active soldiers, marines, and special forces.

Effects of wearing impermeable clothing in different conditions:

Conditions	Activity	Consequences
1. Cold/wet climate	Medium activity	Discomfort
2. Cold/wet climate in sweat-wetted clothing	High activity followed by low activity	Hypothermia (cold stre
3. Hot/moist climate and wearing protective clothing	High activity	Hyperthermia (heat str

6.6.4 Types of water vapour permeable barrier fabrics

There are three main categories of materials of this type:

1. **High density woven fabrics –** are typified by Ventile cotton fabric.There are also a range of fabrics based on woven microfibre polyester of Japanese origin such as Teijin Ellettes, Unitika Gymstar and Kanebo Savina. Ventile was originally developed for military use during World War II, and is still widely used by military and civilian forces.

2. **Microporous coatings and films** – are widely available in many variants. Such membranes are typified by having microporous voids of pore sizes from 0.1–5mm. The most well-known product, Gore-Tex®, utilises a microporous polytetrafluoroethylene (PTFE) membrane. There are also a range of products based upon polyurethane chemistry, with tradenames such as Cyclone®, Entrant®, and Aquatex®. Other products are based upon microporous acrylic, (Gelman Tufferyn®), and polyolefin (Celguard®). In some cases these membranes or coatings incorporate a top coat of a hydrophilic polymer to resist contamination of the pores by sweat residues, and penetration by low surface tension liquids.

3. **Hydrophilic solid coatings and films** – in contrast to microporous films, the hydrophilic products are continuous pore/free solid films. As such they have a high resistance to ingress of liquids. Diffusion of water vapour is achieved by the incorporation of hydrophilic functional groups into the polymer such as -O-, CO-, -OH, or -NH2 in a block copolymer. These can form reversible hydrogen bonds with the water molecules, which diffuse through the film by a stepwise action along the molecular chains.

6.6.5 Comparison of performance of water vapour permeable fabrics:

Type of barrier	Water vapour permeability	Liquid proofness	Cost	Comments
PTFE laminates	*****	*****	High	Market leade versatile, expensive
Microporous polyurethanes	** to *****	*** to *****	Medium to high	Widely used, reasonable durability
Hydrophilic polyurethanes and polyesters	** to ***	*** to *****	Low to medium	Cheap, widely available, s durability problems
High density woven fabrics	*****	*	Medium to high	Ventile is expensive, waterproof low
Impermeable coatings	–	** to *****	Low to medium	Uncomfortab

6.7 Military Combat Clothing:

Military usage of waterproof/vapour permeable textiles:

Water vapour permeable barrier	End item usage	Material specifica
PTFE Laminates	Waterproof suits, army, Royal Marines and Royal Air Force, camouflaged;	UK/SC/5444 PS/13/95
	MOD police anorak, black;	UK/SC/4978
	Arctic mittens;	UK/SC/4778
	Insock, boot liners;	PS/04/96
	Cover, sleeping bag, olive;	UK/SC/4978
	Tent, one man	UK/SC/4960
Microporous	Suit, waterproof, aerial erectors	UK/SC/5070
Polyurethane and hydrophilic polyurethane	Suit, foul weather, Royal Navy	PS/15/95
	Gaiter, snow, general service	UK/SC/5535
Ventile high density woven cotton	Coverall, immersion, aircrew, RAF;	
	Jacket, windproof, aircraft carrier deck;	
	Coveralls, swimmer canoeist	

6.7.1 Combat Soldier 95 clothing layers:

Layer	Material	Specifica
Underwear	100% Cotton knitted 1 × 1 rib, olive	UK/SC/4
Norwegian shirt	100% Cotton, knitted plush terry loop pile, olive	UK/SC/5
Lightweight combat suit	Cloth, twill, cotton/ polyester, camouflaged DPM, near IRR camouflaged	UK/SC/5
Windproof field jacket	Cloth, gaberdine, 100% cotton with nylon rip-stop, water-repellent, near IRR, DPM	UK/SC/5
Fleece pile jacket	Cloth, knitted, polyester, fleece pile, double-faced	UK/SC/5
Waterproof rain suit	Cloth, laminated, nylon/PTFE/nylon, waterproof/water vapour permeable, DPM, near IRR camouflaged	PS/13/95

6.7.2 Thermal and water vapour resistance data for combat clothing systems:

The water vapour permeability index (imt) is defined as S = Rct/Ret, where S = 60PaW^{-1}. The imt has values between 0 and 1.The thermal resistance (Rct) and vapour resistance (Ret) values for each layer are additive, which gives an indication of the total value for the clothing assembly, excluding air gaps, which can add significantly to both values.

Textile layer	Rct ($m^2 K W^{-1}$)	Ret ($m^2 Pa W^{-1}$)
Cotton underwear	0.03	5.1
Norwegian shirt	0.05	8.6
Polyester fleece	0.13	13.4
Lightweight combat suit	0.01	4.3
Windproof field jacket	0.005	4.8
'Breathable' rain suit	0.003	11.2
Total =	0.228	47.4

- **Class 1 materials** have Ret values greater than $150m2PaW^{-1}$, and are considered to be impermeable, i.e. they offer no perceivable comfort to the wearer.
- **Class 2 materials** have Ret values between 20 and $150m2PaW^{-1}$, and are rated as medium performance, offering some breathable performance. The majority of products on the market fit into this category.
- **Class 3 materials** have Ret values less than $20m2PaW^{-1}$ and have the best performance in terms of 'breathability'.

6.7.3 Vapour permeability of footwear

Leather military footwear for cold/wet climates can be fitted with a waterproof/vapour permeable liner or 'sock'. Its main purpose is to improve the waterproofness of leather boots.

- Sock liner: 23.9 m^2PaW^{-1}
- Boot leather: 80.2 m^2PaW^{-1}
- Combined boot + liner: 113.4 m^2PaW^{-1}

6.7.4 Vapour permeability of sleeping bags:

The heat and moisture transport properties of fibrous battings for temperate weight sleeping bags have been measured

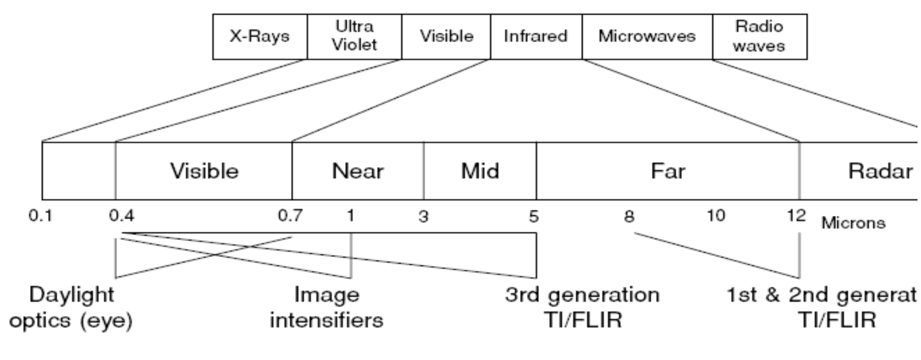
Sleeping bag filling type	Density (gm^{-2})	Water vapour resistance ($m^2 Pa W^{-1}$)	Thermal resist ($m^2 K W^{-1}$)
Polyester fibre	175	48.1	0.45
Polyester fibre	200	53.4	0.51
Polyester 4 hole fibre	200	54.5	0.52
Poly synthetic down	285	45.7	0.31
Mixed denier poly	300	49.6	0.39

6.8 Camouflage concealment and deception:

The word camouflage comes from the French word 'camoufler' (to disguise) and was first introduced by the French during World War I to define the concealment of objects and people by the imitation of their physical surroundings, in order to survive. Textiles are widely used as the camouflage medium, in the form of light flexible nets, covers, garnishing and clothing items.

6.8.1 Ultraviolet waveband

Only in the snow covered environment is UV observation of military importance. The threat is mainly from photographic systems which use quartz optics and blue/UV sensitive film emulsions.



Developments have seen the use of CCD video camera systems which can now operate in this short wavelength region. Snow has uniform high reflectance at all visible wavelengths, that is, it appears white, but it also continues to have a high reflectance in the UV region. The spectral curves for light, heavy, and melting snows vary somewhat, as the texture and crystal structures are different.

The detection problem occurs with white textiles or coatings, as the titanium dioxide pigment which is commonly used as a low-cost widely available treatment for artificial fibres is visually white, but has low reflectance in the UV. Luckily, other pigments such as barium sulphate are suitable and can be incorporated into textile coatings. Lightweight nylon or polyester filament fabrics coated with a pigmented acrylic coating are widely used for covers, nets and clothing.

6.8.2 Visible waveband

In this range we are trying to mimic natural or even artificial backgrounds, not just in terms of colour, but also patterns, gloss and texture. Colour can be measured in terms of tri-stimulus coordinates using a spectrophotometer in the laboratory. A tree or bush, for instance, will have a different appearance during different parts of the day as the quality of illumination changes. The leaves and bark also change appearance throughout the seasons of the year, deciduous vegetation showing the widest variation of colour, texture, and appearance from summer to winter.

Snow Camouflage net in use

Most textile fibres can be dyed to match the visual shades of a standard pattern. Nets, garnishing and covers for vehicle windscreens, machinery and large weapons are often made from lightweight polyurethane or acrylic-coated nylon which is pigmented to give the appropriate visual colours.

6.8.3 Visual decoys

Textile Decoy of a tornado aircraft

Textile materials are widely used to fabricate and simulate the outline of high value military targets such as aircraft, tanks, missile launchers, and other vehicles. These decoys vary in their complexity depending on the source of the potential attack. If surveillance and target acquisition is at short range, and with sufficient time to study detail, then the decoy has to be a realistic three-dimensional copy of the genuine item. Inflatable decoys made from neoprene or hypalon-coated nylon fabrics have been used to mimic armoured fighting vehicles (AFV), missile launcher/tracker modules, artillery, and other vulnerable equipment.

6.8.4 Near infrared camouflage

The NIR region of the spectrum covers the wavelength range from 0.7–2.0mm, although current camouflage requirements concentrate on the 0.7–1.2mm range. In this region objects are still 'seen' by reflection. The military camouflage threat is posed by imaging devices which amplify low levels of light, including moonlight and starlight, which go under the generic name of image intensifiers. These can be in the form of monoculars, binoculars, or low-light television systems.

Cellulosic fibres and blends thereof have been successfully dyed with a selected range of vat dyes which have large conjugated systems of aromatic rings. These have met NATO requirements for many years.

6.9 Flame-retardant, heat protective textiles:

There is a unique difference between civilian and military fire events. The majority of civilian fires are accidental events, whereas the majority of military fires are deliberate, planned events specifically intended to destroy equipment and installations, or to maim and kill human life.

The threat is such that defence forces have paid particular attention to the use of flame-retardant textiles for many applications. These specifically include:

• **Protective clothing** – for firefighters, bomb disposal (explosive ordnance disposal, EOD) crews, nuclear, biological and chemical (NBC) protection, AFV tank crews, naval forces aboard ships and submarines, aircrew, and special forces such as SAS (Special Air Service), SBS (Special Boat Service), and US navy seals.

• **Equipment** – such as tents, shelters, vehicle covers, and bedding.

6.9.1 Military flame and heat threat:

The threats to humans and equipment are as follows:

1. Open flames from burning textiles, wood, vegetation, furnishings and fuels
2. Radiant weapon flash – whether conventional or nuclear weapons
3. Exploding penetrating munitions, especially incendiary devices
4. Conducted or convected heat, including contact with hot objects
5. Toxic fumes generated in confined spaces
6. Smoke which hinders escape in confined spaces, and can damage other equipment
7. Molten, dripping polymers, which can injure clothed humans and spread fires in furnishings and interior fittings.

6.9.2 Criteria for protection of the individual:

We must consider the following criteria to protect forces exposed to the threats listed in :

1. Prevent the outer clothing and equipment catching fire by the use of flame retardant, self-extinguishing textiles. The material should still be intact and have a residual strength not less than 25% of the original. It should not shrink more than 10% after the attack.
2. Prevent conducted or radiated heat reaching the skin by providing several layers of thermal insulation or air gaps.

3. Minimise the evolution of toxic fumes and smoke in confined spaces by careful choice of materials. This is mainly a hazard posed by clothing and textiles in bulk storage. The submarine environment is a particularly hazardous problem, as it relies on a closed cycle air conditioning system. Some toxic fumes may not be scrubbed out by the air purification system.

4. Prevent clothing in contact with the skin melting, by avoiding thermoplastic fibres such as nylon, polyester, polyolefins, and polyvinylidene chloride (PVDC).

6.9.3 Flame-retardant textiles in military use

Although the range of flame-retardant products is large, the actual number of types used by military forces is quite small. Table 16.16 shows those which are used and the applications.The most widely used of these is Proban-treated cotton, a tetrakis hydroxymethyl phosphonium hydroxide product, bound to the fibre and cured in ammonia. Its advantage is its wide availability and low cost.

Fibre/fabric type	Treatment type	Cost	Military uses
Proban cotton	Chemical additive	Relatively cheap	Navy action dress Navy action coveral Anti-flash hood anc gloves Air maintenance coverall Welder's coverall
Aramid	Inherent fibre property	Expensive	Tank crew coverall Aircrew coverall Bomb disposal suit Submariner's clothi Arctic tent liners
Zirpro wool	Chemical additive	Medium/ high	Navy firefighters RAF firefighters Foundry workers
Modacrylic	Inherent fibre property	Medium/ low	Nuclear, biological, and chemical clot Tent liners
Flame-retardant viscose	Chemical additive	Medium	In blends with aran fibres only

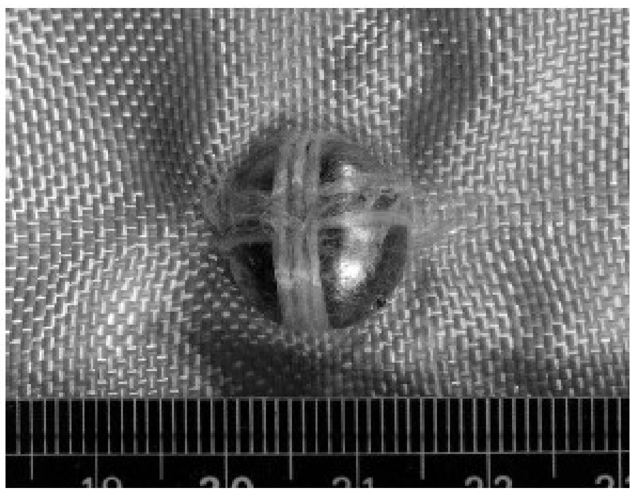
6.10 Ballistic protective materials

Most military casualties which are due to high speed ballistic projectiles are not caused by bullets. The main threat is from fragmenting devices. In combat, this means, in particular, grenades, mortars, artillery shells, mines, and improvised explosive devices (IEDs) used by terrorists. The main cause of injury to civilians (including police officers) has been bullets.

These can be classed as ‘low velocity’ bullets fired from hand guns (revolvers, pistols) at close range. ‘High velocity’ weapons, such as rifles and machine guns tend to be used at longer ranges. Generally speaking, the velocity itself is less important than the kinetic energy, bullet shape, or composition of the bullet

6.10.1 Textile materials for ballistic protection

Ballistic protection involves arresting the flight of projectiles in as short a distance as possible. This requires the use of high modulus textile fibres, that is those having very high strength and low elasticity. The low elasticity prevents indentation of the body and subsequent bruising and trauma caused by the protective pack after impact. Woven textiles are by far the most commonly used form, although nonwovens felts are also available.



One of the earliest materials used was woven silk, and work done in the USA has examined the use of genetically engineered spiders silk to provide protection. High modulus fibres based on aliphatic nylon 6-6 (ballistic nylon), have a high degree of crystallinity and low elongation, and are widely used in body armours and as the textile reinforcement in composite helmets.

Since the 1970s a range of aromatic polyamide fibres have been developed (paraaramids).These are typically based on poly-para benzamide, or poly-para phenyleneterephthalamide. Fibres with tradenames such as Kevlar® (Du Pont) and Twaron® (Enka) are available in a wide range of decitexes and finishes.

A range of ultra high modulus polyethylene (UHMPE) fibres have been developed.They are typically gel spun polyethylene (GSPE) fibres, with tradenames suchas Dyneema® (DSM) and Spectra® (Allied Signal). Fraglight® (DSM) is a needle felt fabric having chopped, randomly laid GSPE fibres.These GSPE fibres have the lowest density of all the ballistic fibres at about 0.97 gml^{-1}. The main disadvantage of these fibres is their relatively low melting point at about 150°C.

Property	Steel wire	Ballistic nylon	Kevlar 129	Dyne SK60
Tensile strength (MPa)	4000	2100	3400	2700
Modulus (MPa)	18	4.5	93	89
Elongation (%)	1.1	19.0	3.5	3.[illegible]
Density (gml^{-1})	7.86	1.14	1.44	0.[illegible]

6.10.2 Fabric types and compositions:

The majority of ballistic fabrics are of a coarse loose plain-woven construction. Continuous multifilament yarns with the minimum of producer twist tend to give the best results. The loose woven construction produces a light flexible fabric ideal for shaped clothing panels. However, with a loose sett there is a high probability of a projectile sliding between the individual filaments. In addition, a certain amount of bulk is necessary, as ballistic resistance increases with overall areal density. This necessitates the use of many layers, typically between 5 and 20, to produce a ballistic pack which will perform adequately. It is necessary to seal the ballistic vest inside a waterproof and light-tight cover, as the presence of moisture and UV light can reduce the ballistic performance.

6.11 Biological and chemical warfare protection

Biological and chemical warfare is a constant world threat. The toxic agents used are relatively easy to produce and their effects are emotionally and lethally horrific to the general population. They are weapons of insidious mass destruction.

6.11.1 Typical effects of toxic chemicals, microorganisms and toxins:

Toxic chemicals	
Nerve	affect nervous system, skin, eyes
Blood	prevent oxygen reaching body tissues
Blister	affect eyes, lungs, and skin
Choking	affect nose, throat, and especially lungs
Psycho-chemical	cause sleepiness
Irritant	cause eye, lung, and skin irritations
Vomiting	cause severe headache, nausea, vomiting
Tear	affect eyes and irriate skin
Microorganisms	
Anthrax	cause pulmonary complications
Plague	cause pneumonic problems (inflammation of the lung)
Tularemia	cause irregular fever lasting several weeks
Viral encephalitis	affect nervous system (inflammation of the brain)
Toxins	
Saxiloxin (STX)	cause shellfish poisoning – highly lethal
Botulinum A (BTA)	cause food poisoning – extremely lethal
Staphenterotoxin B	cause incapacitating effects

Source: *Jane's NBC Protection Equipment, 1990–91*

6.11.2 Chemical Biological Protective Clothing Materials:

- Classic CBD materials are based upon butyl rubber and activated carbon. Butyl rubber is a chemical-resistant impermeable elastomer; however, since butyl rubber is impermeable, it does not breathe and a soldier could overheat.
- Because of extremely high adsorptive properties, activated carbon is widely used in CBD systems to adsorb chemical vapors as well as odors.
- Activated carbon has an extremely large surface area, in some cases, in excess of 2000 m^2/g.

RELATIVE TOXICITY OF POISONOUS CHEMICALS

Compound	8-hour AEL/TWA (mg/m³)	Immediately dangerous to life and health (mg/m³)
Chlorine	3.0	30
Cyanogen chloride	0.6	not determined
Phosgene	0.4	8
Mustard gas	0.003	Carcinogen
Sarin	0.0001	0.2

- Activated carbon has a high adsorptive capacity for high boiling point gases (e.g. nerve agents), but a very low removal efficiency for low boiling point gases (e.g.

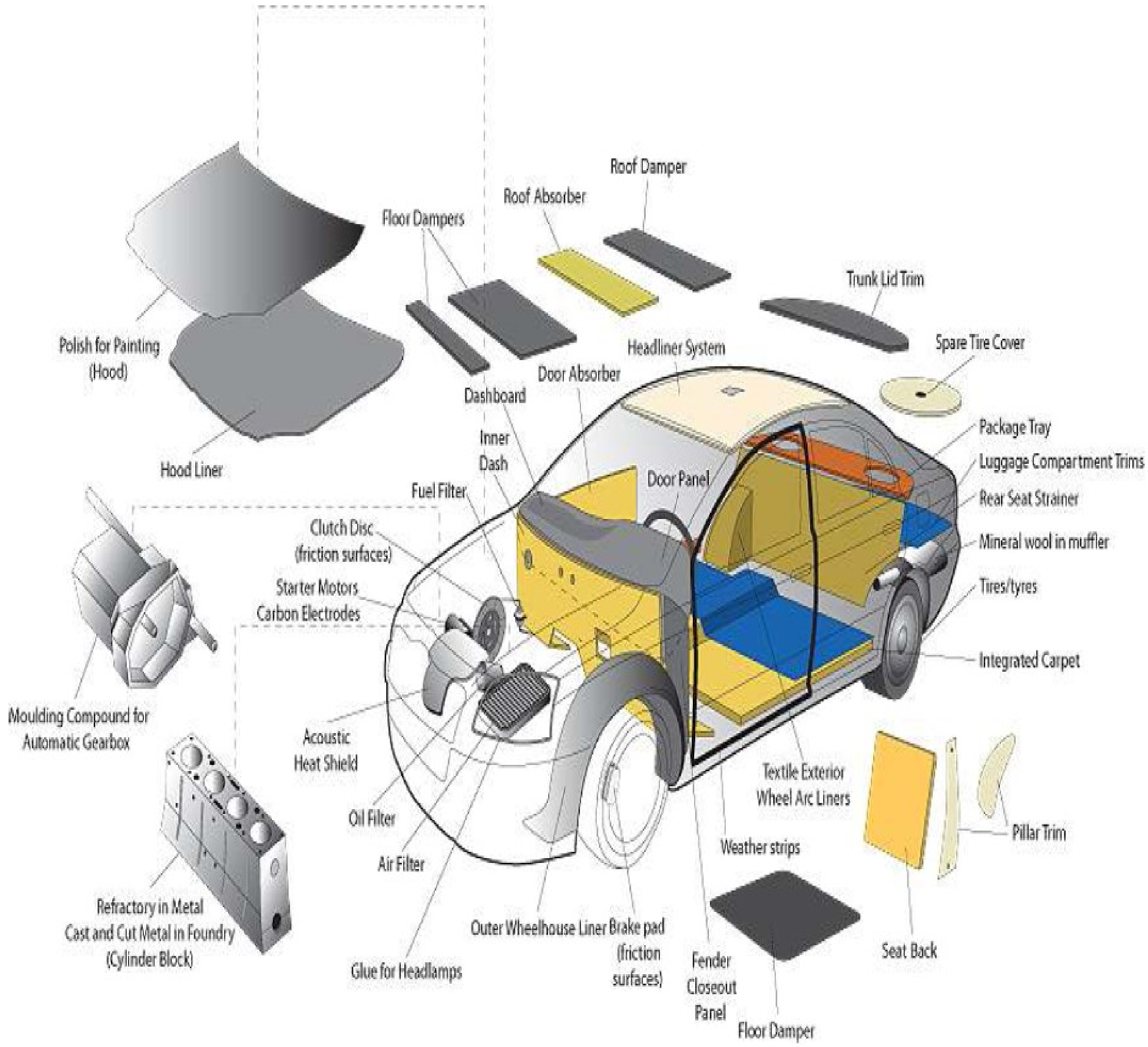
blood gases such as cyanogen chloride and hydrogen cyanide) and choking agents such as phosgene and chlorine.

- Activated carbon impregnated with heavy metals and triethylenediamine can effectively remove both high and low boiling point gases.

UNIT-V - TRANSPORTATION TEXTILES

Total Hours: 9

Textiles in Transportation: Introduction, Textiles in road vehicles, Rail applications, Textiles in aircraft, Marine applications, Future prospects for transportation textiles. Belts, Tyre cords, Hoses: Introduction, Construction particulars, Fibres and yarns used.



7.0 Introduction:

Transportation is the largest user of technical textiles. Textiles provide a means of decoration and a warm soft touch to surfaces that are necessary features for human well being and comfort, but textiles are also essential components of the more functional parts of all road vehicles, trains, aircraft and sea vessels.

7.1 Transportation Textiles –Break up:

S.No	Breakup of Transportation Textiles	Share %
1	Carpets (Including Car Mats)	33.3
2	Upholstery (Seating Fabric)	18
3	Pre-assembled interior components	14
4	Tyres	12.8
5	Safety Belts	8.8
6	Air Bags	3.7
7	Others	9.4
	Total	100

7.2 Fibres Used in Automotive Textiles:

Application	Fibres used
Seat covers	Nylon, polyester, pp, wool
Seat belt	Polyester
Carpet	Nylon, PET, PP
Air bags	Nylon 66,nylon 46
Tyre cords	Viscose rayon, nylon, Kevlar
Composites	Carbon, glass, armid

7.3 Properties of Fibres used in Automotive Textiles:

	Density ($g cm^{-3}$)	Melting point^{b} (°C)	Tenacity ($g den^{-1}$)	Stiffness (flexural rigidity) ($g den^{-1}$)	LO1 (% oxygen)	Abrasion resistance	Resista to sunl
Acrylic	1.12–1.19	150d^{b}	2.0–5.0	5.0–8.0	18	Moderate	Excelle
Modacrylic	1.37	150d^{b}	(HT)	3.8	27	Moderate	Excelle
Nylon 6	1.13	215	2.0–3.5 4.3–8.8	17–48	20	Very good	Poor–g (stabili
Nylon 6.6	1.14	260	(HT)	5.0–57	20	Very good	Poor–g (stabili
Polyester	1.40	260	4.3–8.8 (HT)	10–30	21	Very good	Good–excelle (stabili
Polypropylene	0.90	165	4.2–7.5 (HT) 4.0–8.5 (HT)	20–30	18	Good	Poor–g (stabili
Wool	1.15–1.30	132d^{b}	1.0–1.7	4.5	25–30 (Zirpro)	Moderate	Moder
Cotton	1.51	150d^{b}	3.2	60–70	18	Moderate	Moder
UHM							
Polyethylene	0.97	144	30	1400–2000	19		
Aramid	1.38–1.45	427–482d^{b}	5.3–22	500–1000	29–33		
Carbon	1.79–1.86	3500d^{b}	9.8–19.1+	350–1500	64+		
Glass	2.5–2.7	700	6.3–11.7	310–380	–		
PBI	1.30	450d^{b}	–	9–12	41		
Inidex	1.50	–	1.2	–	40		
Panox	1.40	200–900d^{b}	–	–	55		
Steel	7.90	1500	2.5–3.2	167–213	–	–	–
Aluminium	2.70	660	–	–	–	–	–

LOI, limiting oxygen index; HT, high tenacity; UHM, ultra high modulus; PBI, polybenzimidazole.

7.4 Fibre Requirements:

For seat coverings the main technical requirements are resistance to sunlight (both colour fading and fabric degradation by UV), abrasion resistance and, for public transport vehicles, reduced flammability. Seats frequently get damp from contact with wet clothing and, in the case of seats in public transport, subject to abuse by vandals and other irresponsible individuals.6The fabrics need to be resistant to mildew, hard wearing and strong with high tear strength. Soil resistance and easy cleanability are also necessary.

7.4.1 Resistance to sunlight and UV degradation:

Resistance to sunlight is perhaps the most important property a fabric must have. Choice of the wrong fabric can lead to breakdown of the seat cover within weeks, depending on the intensity and spectral distribution of the sunlight.

	Initial tenacity (g denier^{-1})	Outdoors (direct sunlight)		Behind glass	
		50% Loss	80% Loss	50% Loss	80% L
Acrylic semidull	2.1	13.6	36 (72%)[a]	19	36 (63
Polyester bright	4.2	3.7	7.9	24	36 (75
Polyester semidull	3.1 (spun)	4.0	9.1	36	36 (49
Polyester dull	4.2	3.6	8.0	20	36 (79
Nylon bright	5.3	9.5	17.0	10.3	20.7
Nylon semidull	5.4	3.2	6.5	4.5	8.2
Nylon dull	5.1	3.1	5.1	4.1	7.7
Rayon bright	1.6	2.6	6.3	3.0	14.2
Acetate bright	1.0	5.1	11.8	8.1	27
Cotton deltapine	1.8	2.9	5.8	4.9	14.0
Flax Irish	3.5	0.9	2.5	4.5	5.0
Wool worsted	0.7	2.3	3.2	4.5	7.6
Silk	4.2	–	–	0.8	3.9

Significant improvements in UV resistance can be obtained by addition of certain chemicals that are UV absorbers and these are used extensively with polyester, nylon and polypropylene for transportation applications. UV absorbers in nylon are usually added to delustred yarns which deactivate the sensitizing effects of the titanium dioxide present.

7.4.2 Abrasion resistance:

Seating fabric needs to be of the highest standard of abrasion resistance. Only polyester, nylon and polypropylene are generally acceptable, although wool is used in some more expensive vehicles because of its aesthetics and comfort. Wool has other specialist properties such as non-melting and reduced flammability which, as will be seen, make it suitable for aircraft seats. Fabric abrasion is influenced by yarn thickness, texture, cross-section and whether spun or continuous filament.

7.4.3 Reduced flammability:

For comfort, foam materials are used beneath the covering fabric.

Fabric	HRR ($kW m^{-2}$)	THRR ($kW min m^{-2}$)	T (s
Cotton/polyester	170	53	3
Wool	117	39	2
Modacrylic	83	28	2
Zirpro wool	64	24	2
Panox	27	15	3
Meta-aramid	13	6	4

Heat release rate (HRR), total heat release rate (THRR) and time to peak of heat release (Tp) for a variety of fabrics.

Fire blockers, first used on aircraft seats, are textile fabrics made from fibres with a very high level of inherent flame retardancy and heat stability, for example Panox (Lantor Universal Carbon Fibres), Inidex (Courtaulds) and aramid. They are being used increasingly on trains, buses and coaches.

7.5 Textiles in Passenger Cars:

Car interiors have become increasingly important for a variety of reasons.

7.5.1 General Requirements:

Yarn types

Fabrics are generally produced from bulked continuous filament (BCF) textured polyester yarns; false twist, knit de knit and air texturising are common, although the latter method is the most used. Staple spun yarns are less common because of their limited abrasion resistance in flat woven constructions. They are used, however, in woven velvets where the abrasion or wear is on the tips of the yarn rather than across its width.

Typical yarns for weaving are 167 dtex/48 filaments primary feedstock yarn which when quadrupled produces 668 dtex/192 filaments and 835 dtex/240 filaments yarn made from five ends of a primary yarn. Heavy duty yarns over 3000 dtex with 550 filaments are used for heavy goods vehicles (HGVs) or for special effects. Knitting yarns are lighter up to say 300 dtex.

Fabric structure:

The main fabric types with typical weight ranges are: flat woven fabric (200– 400 gsm), flat woven velvet (360–450 gsm), warp knit tricot (generally pile surface, 160–340 gsm), raschel double needle bar knitted (pile surface, 280–370gsm) and circular knits (generally pile surface, 160–230 gsm). Fabrics in nylon tend to be towards the lower weight range. Woven fabrics have been produced for many years using mechanical Jacquard systems and while they once offered the greatest design potential, knits have now caught up with them with the introduction of computer controlled knitting machines

Woven fabrics have limited stretch, which sometimes restricts their use in deep drawer moulding applications for door casings. Flat woven velvet fabrics are the most expensive to produce but are considered top of the range in quality. Knitted fabrics with raised surfaces are softer to the touch than flat wovens.

7.6 Belts and Hoses:

Belts:

High tensile strength, excellent flex resistance, excellent shock resistance and low extensibility are amongst the requirements for a long belt life. The V-belt is shaped for maximum friction grip as well as high strength with compactness and is composed of cord made from HT yarn such as the Trevira 700 series and rubber, usually chloroprene, covered with a fabric/rubber jacket. Textile-toothed belts have almost completely replaced chain drives in cars because they are quieter, weigh less, need no lubrication and allow a more compact design.

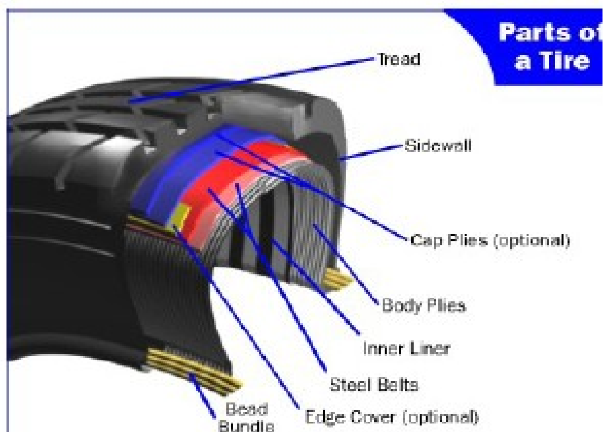
Hoses:

A variety of different fabric manufacturing techniques are used; knitting, circular weaving, wrapping, and for high-pressure uses, filament spiraling and braiding. Cotton was first used but this has been replaced with synthetic fibres, which provide higher strength, more durable flex and abrasion resistance and better rot resistance. High-tenacity yarns allow weight reductions and less bulk. For the highest performance of heat and strength, aramid fibres such as Nomex and Kevlar (both DuPont) are used.

Automotive hose products include fuel, oil, radiator heaters, hydraulic brakes, power steering, automatic transmission and air conditioning pipes. Nylon is not generally used in hoses because of its high extensibility but this specific property is useful in the expanding part of power steering hoses.

7.7 TyreCord:

The tyre is a complex technical component and must perform a variety of functions. It must cushion, dampen, assure good directional stability, and provide long-term service.



Most important of all, however, it must be capable of transmitting strong longitudinal and lateral forces (during braking, accelerating and cornering) in order to assure optimal and reliable road holding quality.

7.7.1 Function of TyreCord:

The cord which reinforcing the tyre performs dual functions:

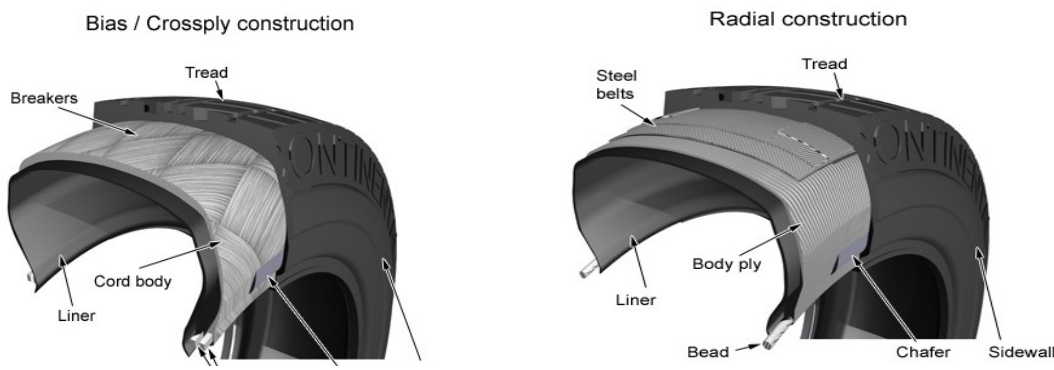
a) Tyre act as a pressure vessel and the cord keeps it dimensionally stable.

b) As tyre has contact between the vehicle and the road and thus steers the vehicle; the reinforcing textile cord monitors directional stability of the tyre.

The reinforcing function is influenced by:

- Properties of the textile cord.
- Mode of disposition of reinforcing material in the tyre.
- Adhesion between cord and rubber.

7.7.2 Various Tyrecord Cross section:



7.7.3 Essential property requirements of a Tyre cord:

- High Toughness
- Good flex fatigue resistance
- High tenacity (usually above 6 g/den).
- Good impact resistance.
- Good thermal stability.
- Capability of formation strong bond with the rubber.
- Low elongation and low moisture regain.

7.7.4 Relationship between Tyre performance and Tyre cord properties:

Tyre performance	Related property of tyre cord
Bursting strength	Tensile Strength
Tyre Endurance	Adhesion with Rubber
Power Loss	Viscoelastic Properties
Tread Wear	Modulus
Tyre Size & Shape	Modulus
Tyre Groove Cracking	Creep
Flat Spotting	Thermal Shrinkage
High Speed Endurance	Heat Resistance

7.7.5 Fibres Used:

- Nylon
- Polyester
- Steel is gaining popularity especially in the field of radial tyres.
- Aramid and glass fibres are also now in use

In India, nylon 6 tyre cord is most widely used for tyre manufacturing; it has the desirable properties of a tyre cord to good extent. Though nylon 66 and polyester tyre cords are widely used in Europe and America. Polyester is superior to nylon tyre cords in some respects e.g. less thermal shrinkage, less flat spotting tendency, but it suffers lack of bonding with rubber, of course this is overcome with special pretreatment. High strength, high modulus Kevlar though mainly used for composite, but now it is introduced in tyre manufacturing due to its excellent thermal stability and high strength

7.8 Other parts of the car interior:

Headliners used to be simple items in warp-knitted nylon, or PVC, sometimes 'slung' that is, held in place only at certain points. Modern headliners are multilayer materials that have become a structural part of the car roof supporting accessories, such as sun visors, interior lights, assist handles, electrical components and some even contain brake lights. They are engineered to give sound insulation and sound absorbing properties.

Warp knits have better abrasion and pilling resistance and mould better because of their superior stretch properties. However, nonwovens have the advantage of non-recovery after moulding. Nonwoven headliners are typically made from fine denier polyester or polypropylene fibre for maximum cover at low weight, about 200 gm^{-2}, with an anti abrasion finish.

Parcel trays, being just beneath the slanting rear window, demand the highest resistance to sunlight, for example 450 kJ compared to 150 kJ for a headliner. They are made by a press lamination technique or by direct pouring of the polymer on to the back of a polyester or polypropylene nonwoven.

7.8.1 Flocked fibre:

Surfaces such as window seals and dashboard components have textile flocked surfaces. The flock is usually polyester or nylon 6.6, but viscose and acrylic fibre are also used. Flock is useful in eliminating rattles and squeaks in the car as well as contributing to the overall aesthetics. Flocked yarns are sometimes used for seating and door panel fabric.

7.8.2 Seat belts:

Seat belts are multiple layer woven narrow fabrics in twill or satin construction from high tenacity polyester yarns, typically 320 ends of 1100dtex or 260 ends of 1670 dtex yarn. These constructions allow maximum yarn packing within a given area for maximum strength and the trend is to use coarser yarns for better abrasion resistance. For comfort they need to be softer and more flexible along the length, but rigidity is required across the width to enable them to slide easily between buckles and to retract smoothly into housings. Edges need to be scuff resistant but not unpleasantly hard and the fabric must be resistant to microorganisms. Nylon was used in some early seat belts but because of its better UV degradation resistance, polyester is now used almost exclusively worldwide.

7.8.2 Airbag:

Airbags are gas-inflated cushions built into the steering wheel, dashboard, door, roof, or seat of your car that use a crash sensor to trigger a rapid expansion to protect car driver from the impact of an accident. Airbags are typically made from high tenacity multifilament nylon 6.6 in yarn quality finenesses from 210, 420 to 840 denier although some polyester and even some nylon 6 is used.93 Nylon 6 is said to minimise skin abrasion because it is softer. Airbag fabric is not dyed but has to be scoured to remove impurities which could encourage mildew or cause other problems. It needs to have high tear strength, high antiseam slippage, controlled air permeability and be capable of being folded up into a confined space for over 10 years without deterioration. Some tests require 75% property retention after 4000 hours at 90–120°C, the equivalent of 10 years UV exposure and also cold crack resistance down to -40°C.

7.9 Future development in automotive textiles:

Car production is expected to remain generally static up to 2005 in the developed world, but is likely to expand considerably in the developing nations. Globally there are excellent opportunities for the multinational OEMs and their suppliers, especially those with the imagination and will to innovate new products and design features that will make car journeys more comfortable, safe and pleasant.

7.10 Textiles in other road vehicles:

7.10.1 Heavy goods vehicles (HGV):

More use of textiles is even being made in HGV interiors, which are becoming more comfortable with livelier colouring, softer more rounder shapes and surfaces. Composite materials are being used to replace bulky space dividers and doors to create more cab storage space. More cabs have sleeping quarters with beds, curtaining, carpets and textile wall coverings.

7.10.2 Tarpaulins:

HGVs are a major user of tarpaulins, which are made from PVC plasticol-coated nylon and polyester, usually Panama and plain woven from high tenacity yarns. Base fabrics vary from about 100 gsm to over 250 gsm and are coated with up to 600gsm or more of PVC plastisol applied in several layers. Tarpaulins must also pass flexing resistance, cold cracking, reduced flammability, coating adhesion, waterproofness and tear and tensile tests. They must be dimensionally stable over a wide range of temperatures and relative humidities and be resistant to common chemicals, oils and engine fuels. However, if the coating is damaged, microorganisms can migrate via moisture into the material. Tarpaulins are secured with high tenacity polyester narrow fabric which must also be tested carefully for strength and UV resistance.

7.10.3 Buses and coaches:

These vehicles cater for the general public and therefore require the highest standards of safety and durability. Seating fabric is typically 780gsm after coating with acrylic latex and is generally in conservative designs. The life of seating fabric varies from less than 6 years in some commuter public transport vehicles to 10 years or more in luxury coaches. High flammability performance requirements are becoming more stringent Textile-reinforced rigid composites are being used increasingly in buses and coaches to reduce weight and therefore conserve fuel.

7.11 Rail applications:

Interior decor and comfort are key factors in winning passengers away from other forms of transport. The decor of wall panels, seats and carpets cannot be changed every year and so designs must be neutral and not driven by fashion or fad. The major technical issue concerning textiles is reduced flammability. Seat upholstery, loose coverings, carpets curtains and bedding must all pass stringent tests. The materials must also have the correct aesthetics and durability must be in line with planned maintenance schedules

7.11.1 Seating

Woven moquette weighing about 800gsm in 85% wool/15% nylon has been the standard fabric for many years.161 To withstand high volumes of passengers, the fabric must satisfy high burst strength and breaking load tests and abrasion resistance must be in the order of 80 000 Martindale rubs. Polyesters, especially FR grades such as Trevira CS and FR have gained acceptance especially in Europe.

Fire blocker materials are being used increasingly for rail seats. Control of toxic fumes and smoke, which reduces visibility, is of especial importance for trains that pass through tunnels or are used in underground railways. Halogen containing materials, such as PVC, and any other materials that have high toxicity indices (modacrylic fibre) are excluded from passenger coaches

7.11.2 Other textiles uses

Sleeping car textiles, such as bed sheets and blankets, generally require high standards of performance and durability and some FR properties. Carpets are important in helping to create an attractive relaxing appearance, but they must be extremely hard wearing to cope with the volume of foot traffic sometimes for up to 20 hours a day. Wool and nylon are the fibres most used in FR qualities with smoke emission, toxicity of fumes and heat release carefully assessed.

7.12 Textiles in aircraft:

The main technical challenges for the textile technologist are safety (mainly with respect to flame retardancy) and weight saving. It is estimated that for every 1 kg of weight saved in an aircraft, £150 a year is saved in fuel costs, whilst a 100 kg lighter load can increase the range by 100km. Reduced flammability is vital and statistics show that fire accounts for over 25% of deaths in aircraft accidents.

- Furnishing fabrics include seat covers, curtaining, carpets and on long distance flights, blankets and pillows.
- The fabric itself is generally made from woven wool or wool/nylon blends (nylon in the warp) of 350–450gsm weight.
- Some woven polyester covers are now being used, giving saving in weight and improved easy care.
- The materials must therefore have soil-release properties and cleanability is evaluated by test staining with items such as lipstick, coffee, ball point ink, mayonnaise and other oils.
- FRP composites are largely used to reduce the weight of the flight by 20-30%

7.12.1 Furnishing fabrics

Furnishing fabrics include seat covers, curtaining, carpets and on long distance flights, blankets and pillows. Designs are generally in the livery colours of the particular airline, sometimes with company logos appearing in prominent positions. The article requiring most technical attention is the seat cover assembly on top of polyurethane foam. The fabric itself is generally made from woven wool or wool/nylon blends (nylon in the warp) of 350–450gsm weight.

7.12.2 Fibre-reinforced composites:

Fibre-reinforced composites are used extensively in all parts of the aircraft resulting in very significant savings in weight, for instance, about 1350 kg of composites are used in the Airbus A310 and approximately 690 kg are used in the Boeing 737-300 representing about 6% of the entire weight of the planes. Actual weight savings in the parts replaced by composite materials are between 20–30%.

7.13 Marine applications:

As in other areas of transportation, fibres are used in functional applications and more overtly in decorative applications. Again safety, like flame retardancy, is crucial and weight savings is also important requirements, especially in racing craft.

Carpets are especially important on passenger vessels because of their noise and vibration absorbing properties. They are more pleasant to walk upon than a hard surface and help to reduce physical stress and to provide a calmer and quieter atmosphere.

Coated fabrics are used for life rafts buoyancy tubes, canopies and life jackets. The base fabric for life rafts is generally woven polyamide with butyl or natural rubber, polychloroprene or thermoplastic polyurethane coatings. The total weight of the material varies from 230 gsm upto 685 gsm.Life jackets are generally made from woven polyamide coated with butyl or polychloroprene rubber to give total weights of about 230–290 gsm.Natural fibres in sails were first replaced by nylon and polyester, which are lighter, more rot resistant, have lower water absorption and, in the case of polyester, higher sunlight resistance.