# Review of Literature

# 2. REVIEW OF LITERATURE

The review of literature pertaining to the research work entitled **"Development of nonwoven fabrics using *Sansevieria roxburghiana* and *Agave vera-cruz Mill* fibres for selected automobile acoustic applications"** was presented in the following sections.

**2.1. Textile Fibres**

2.1.1. History of Textile Fibres

2.1.2. Classification

**2.2. Natural Fibres**

2.2.1. Classification of Natural Fibres

**2.2.2. Leaf Fibres**

2.2.2.1. *Sansevieria roxburghiana*

i) Properties of *Sansevieria* Species

ii) Uses of *Sansevieria* Species

2.2.2.2. *Agave vera cruz – Mill*

i) Properties of *Agave* Species

ii) Uses of *Agave* Species

**2.2.3. Fruit Fibres**

2.2.3.1. Coir

i) Properties of Coir

ii) Uses of Coir

2.2.4. Fibre Extraction Methods

**2.3. Man-made Fibres**

2.3.1. Classification of Man-made Fibres

2.3.2. PET Fibre

i) Properties of PET Fibre

ii) Uses of PET Fibre

2.3.3. Polypropylene Fibre

i) Properties of Polypropylene Fibre

ii) Uses of Polypropylene Fibre

**2.4. Fibre Evaluation**

**2.5. Fibre Blending**

**2.6. Nonwoven**

## 2.1. Textile Fibres

The term textiles include the manufacture of fibres, yarns, fabrics and apparel discusses Woodings (2001). Fibres are fine hair like structure of animals, vegetables and mineral origin which are considered as the basic unit in making fabrics opines Pitambar (2003). Textile fibres are produced from a wide range of polymers suggest Sawyer etal. (2008). Polymers are long chain like molecules which are formed by chemically joining the monomers and the process is known as polymerization referred Thorpe and Thorpe (2009).

Commercially available fibres have diameters ranging from less than 0.004mm (0.00015in) to 0.2mm (0.008in) and they come in several forms. Fibres in general may be short fibre (known as staple or chopped), continuous single fibres (monofilament) untwisted bundles of continuous filaments (tow) and twisted bundles of continuous filaments (yarn) remarks Thomas (2006). The fibre is generally defined as a flexible homogeneous body having a high length to width ratio and a small cross section says Marwaha (2006).

According to Wiley-VCH (2008); Brameshuber (2006) there are many fibre structures available in nature but it is only textile fibres which can be spun into yarns suitable for weaving or knitting. Patra and Chakraborty (2009) reveal that fibres can be used as a component for composite materials. They can also be matted into sheets to make products such as paper or felt.

### 2.1.1. History of Textile Fibres

Archeological evidence indicates that textiles were used before thousands of years remarks Kothari (2000). Textile fibre history starts from about 500AD, the recorded oldest indication of fibre usage comes with the discovery of flax and wool fabric at excavation sites of the Swiss inhabitants in the $6^{th}$ and $7^{th}$ century BC. Different vegetables fibres and hair have been used by the ancient civilization suggest Nandhini and Jayalakshmi (2009).

According to Mwaikambo (2006) the use of these naturally occurring cellulose fibres can be traced back more than 10,000 years. About 8,000 B.C. in the Middle East China the cellulose fibres were used for textiles. Samuel (2010) describes that the discovery of various man made fibres began with the development of Rayon in France during 1890. Until 1920's the natural fibres enjoyed an absolutely dominant position in the textile market. But in the late 1990's the proportional of natural fibres in the world production of textiles dwindled to about 50 per cent regards Muzyczek (2000).

### 2.1.2. Fibre Classification

The textile industry uses many fibres as its raw materials. As a result of the development of new fibres, difficulties arise in the textile industry in terms of identification and classification. Hence, classification of textile fibres was compounded by the trained manufacturers to identify each of the fibres with the different trademarks. Textile fibres are classified according to the source and the length of the fibres (www.fibre2fashion.com). For convenience, fibres are generally classified as being either natural or manmade reveals Mahapatras (2009). Verma (2009) classifies fibres on their utility value. They include textile fibres, brush fibres, plaiting and rough weaving fibres, natural fibres and paper-making fibres.

## 2.2. Natural Fibres

Natural fibres are those found naturally from both plants and animals remark Seng etal. (2002). The wide range of natural fibres includes cotton, wool, jute, flax, silk, sisal, coir and many others. They are used in clothing and other consumer goods, as well as in industrial application says Mahapatras (2009).

Sayed and Marwaha (2006) state that natural fibres are the essential alternative on the ever expanding horizon of textile fibres. Saravanan (2006) opines that though synthetic fibres shows superior properties and performances compared to many of the natural fibres the latter has still strong acceptance in many applications. This may perhaps be due to their renewable characteristics, acceptable specific strength properties, low cost, enhanced energy recovery, biodegradability and ease of availability in many regions discuss Ramakrishnan (2008); Maniruzzaman etal. (2006). Cellulose fibres also include high toughness, reduced tool wear, comfort and feel reveal Doke and Sivakumar (2003).

No matter which climatic zone humans settled they were able to utilize the fibres of native species to make products such as clothes, buildings and cordage. The natural fibre kingdom is vast and among organic fibre sources, plant fibres occupy a significant place describe Chauhan and Deshmukh (2009).

According to Kanoongo and Adivarekar (2009), there are a number of fibre giving plants, abundantly available in rural areas. Many of these plant fibres hold immense potential for utilization as raw material for non-traditional applications opine Chattopadhyay etal. (2006). The natural fibres make today about 48 per cent of total fibre production world wide. About 80 per cent of this volume is cotton and remaining 20 per cent is shared by wool, jute, hemp, flax, silk, ramie and sisal reveal Kaniewski etal. (2000).

**Merits**

- Easily renewable materials
- No increase in $CO_2$ emission after burning (carbon neutral)
- Low density i.e. high specific strength and stiffness
- Low cost
- Easy processing
- Harmless to human skin

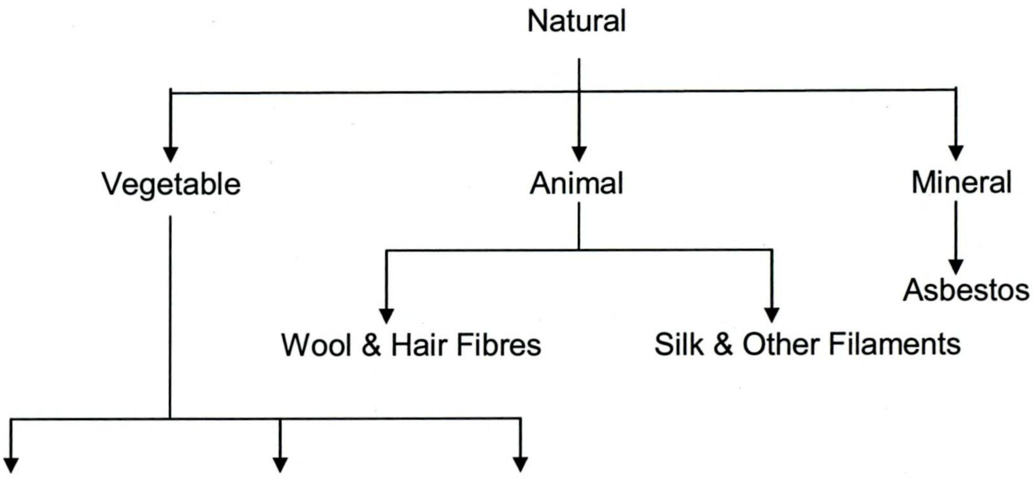
**Demerits**

- Low strength
- The effect of humidity and water (swelling)
- Easy to burn (poor fire resistance)

### 2.2.1. Classification of Natural Fibres

According to Stott etal. (2007) natural fibres are classified into three groups depending on their origin as follows:

**Classification of Natural Fibres**




| Seed/Fruit | Leaf | Bast |
|---|---|---|
| Mallow | Agave | Flax |
| Bombax | Banana | Lime |
| Milkweed | Lily | Mallow |
| Palm | Narcissus | Milkweed |
| Cotton | Palm | Mulberry |
| | Pineapple | Nettle |
| | | Pea |
| | | Serculia |

Natural fibres depending on their origin and structure have been divided into three groups as follows says Reddy etal. (2003).

- Soft, stem or bast fibres – these are sclerenchyma fibres usually associated with secondary phloem or the pericycle.
- Hard, leaf, or structural fibres – they are found in the monocotyledonous plant's supportive and conductive strands. Hard fibres also consist of xylem and phloem so they are called fibrovascular bundles remarks Pooja (2005).

- Surface fibres – these fibres are produced on the surface of stems, leaves, seeds, fruits, etc.

### 2.2.2. Leaf Fibres

Human ingenuity has created the ability to make textiles from plant leaves since early history. There are many plant species and varieties that have proved capable of being used as raw material for fibre extraction. Most of the leaf fibres commercially used includes sisal, abaca, and henequen, which account for eighty per cent of World production of leaf fibres opine Prance and Nesbitt (2005). Leaf fibres, very often referred to as hard fibres, can be obtained from the leaf, stem or the shoot axis view Stevens and Verhe (2004).

Botanically leaf fibres consist of xylem cells, phloem cells and fibres that are clustered together in a leaf of monocot plants. Leaf fibres, which are less durable than bast fibres, are not as important as bast fibres in making fabrics. However, leaf fibres are important as a cordage fibre (for rope making) reveals Berg (2008).

#### 2.2.2.1. *Sansevieria roxburghiana*

World wide there are more than 12 *Sansevieria* species present in different continents refers Seidemann (2005). The English name of *Sansevieria roxburghiana Schult* is Indian bowstring hemp. In Hindi it is known by various names such as murahri, marul, marva, etc. *Sansevieria roxburghiana* is native to east India and Myanmar (http://en.hortipedia.com). It is an herb occurring wild on the eastern coast of India from West Bengal to Tamilnadu in south says Vardhana (2006).

*Sansevieria roxburghiana* occurs rarely in open forests. It belongs to the family Liliaceae and is a stout, fleshy, perennial shrub with creeping root stock point out Khan and Khanum (2005). The leaves are found in tufts of 8 or 9 numbers. The flowers appear from the month of August-December in pale green tinged with violet colour. It appears in fascicles of 3-6 on 30-60cm long racemes. The fruit is a globose berry with 1-3 seeds ripening outside the pericarp reveal Pullaiah etal. (2000).

**i) Properties of *Sansevieria* Species**

Fibre from *Sansevieria* is of higher quality than other leaf fibres suggest Borah and Kalita (2003). It is creamy white in colour, coarse, has high strength, low elongation, good lustre and resistance to alkali point out Borah and Kalita

(2004); Goel and Nishkam (2003). The average density of *Sansevieria* fibre is 0.915g/cm$^3$. They are semi crystalline with cellulose $I_\beta$ in its structure report Sreenivasan etal. (2011). This fibre takes on different dyes readily. These fibres can also be bleached to improve its whiteness as well as aesthetic appeal remark Goel and Nishkam (2003).

**ii) Uses of *Sansevieria* Species**

The *Sansevieria* fibres are ideal for making bowstring and fine threads for ornamental purposes reveal Pandey and Gupta (2003). *Sansevieria* fibres are mainly used for making twines, ropes, cords, mats, etc. It can also be used for paper making regards Sambamurty (2005). It could be used for preparation of various households, decorative and furnishing articles remark Goel and Nishkam (2003).

The whole plant is traditionally used as a cardiotonic, expectorant, purgative, tonic in glandular enlargement and rheumatism view Roy etal. (2012). The roots are used as a febrifuge in snake bite and hemorrhoids opine Haldar etal. (2010). Rhizome juice also called Nadagamani or Sarpapola is prescribed for long prolonged coughs find out Prakash etal. (2008). The juice extracted from the leaves is used as nasal drops thrice in a period of two hours and leaf paste is also applied over the body for Vaidyas remark Reddy etal. (2006). Leaf juice is mixed with molasses and taken twice daily for 8 days to treat fever discuss Rahmatullah etal. (2009).

**2.2.2.2. *Agave vera-cruz Mill***

According to Debnath etal. (2010), there are over 200 varieties of *Agave*. Some of the common *Agaves* are *Agave americana, Agave angustifolia, Agave cantala, Agave fourcroydes, Agave sisalana, Agave vera-cruz Mill,* etc.

*Agave vera-cruz Mill* also known as blue elephant aloe or Kuwarbuti is native to Mexico says Vardhana (2006). *Agave vera-cruz Mill* belongs to the family *Agavaceae* express Mali and Bhadane (2011). It is a short stemmed, half woody plant having long, erect, fleshy leaves with sharp teeth on the edges and fierce spines on the tips which yields a valuable fibre describes Burke (2005). This plant is mostly found in India along waste places, roadsides and railway embankments point Khan etal. (2011).

*Agave vera-cruz Mill* plant flower in an optimum environment condition only after 20 to 30 years of vegetative growth and produces few stolons per year say Tejavathi etal. (2007). The leaves were many 1-2m long, broad and wide, linear – oblong. It has stout stem, broadened bases frequently covering much of the stem, margin liberally, regularly spaced at about 1-1.5cm distance with black or dark – coloured, patent or recurved prickles. Terminal spine up to 2.5cm long, dark – brown, scarcely decurrent. Inflorescence trichotomous in main branches, branches curved, flattened. Flowers usually paired with laterally developing subsidiary bud. Perianth – lobes pale green to pale amber coloured, linear – lanceolate. Ovary mostly longer than perianth – lobes, narrowly cylindrical. Stamens much exserted, anthers 1.2cm long, linear. Style slightly, obscurely lobed. Capsule oblong – cylindric, rounded at apex. Seeds black, shiny regards Dassanayake and Clayton (2000).

**i) Properties of *Agave* Species**

According to Nugent (2006) the fibres obtained from the leaves of the *Agave* family are stiffer, strong, creamy white, coarse, long and lustrous. Its length ranges from 100-125cm and diameter ranges between 0.2-0.4cm points out Pilla (2011). It also has the ability to stretch, affinity for certain dye stuffs, durable and it is resistant to deterioration in saltwater opines Ashby (2012).

**ii) Uses of *Agave* Species**

The fibres of *Agave* species are mainly used for producing rope. It is used to produce many different products such as nets, carpet pads, baskets, sandals, clothing, paper pulp, construction material, brushes and brooms says Khan (2001). It was also used as binding twine for grain harvesting machines in Western World remark Elzebroek and Wind (2008).

Flower buds and young flowers are eaten raw and also made into chutney. Flowers are even used as vegetables suggest Prabha etal. (2010). Compresses for wounds have been made from *Agave* pulp, juices from the leaves and roots were used in tonics. The roasted, sugar rich *Agave* hearts have been an important food for numerous Native American groups. Juice from the mature plants is consumed both fresh and fermented find out Phillips and Comus (2000).

**2.2.3. Fruit Fibres**

The seeds and fruits of plants are often attached to hairs or fibres or encased in a husk that may be fibrous (www.textileschool.com). The husks which protect the fruit for development can be processed and utilized as fibres. After removing the fruit, the husk can be extracted, retted and processed suggests Mishra (2000).

**2.2.3.1. Coir**

Bhatia and Smith (2008) say that over the last 25 years, India has generally been the leading producer of coir fibre in the world. Coconut fibre is also called as palm peat, coco peat, cocos, kokos and more commonly, coir views Weller (2005). Vijayakumar and Vittopa (2006) state that coir is a lignocellulosic fibre extracted from the exocarp of the fruit of the coconut palm, Cocos nucifera (Linn) by dehusking.

According to Black etal. (2006); Gupta (2005) there are three types of coir. The longest fibres, made from immature (green) coconut which is retted, are called 'mattress or white fibre'. The other two types of fibre made from dried coconut ('brown fibre') which is unretted are called very coarse and short staple fibre.

**i) Properties of Coir**

Coir is a multicellular fibre with the length varying from 50-150mm and the diameter varying from 12-24microns. Among all the natural fibre coir has the highest tensile strength and it retains much of the tensile strength under wet conditions. It contains 30-300 or more cells in its cross-section. The cross-section of fibre is polygonal to round. The fibre is mainly composed of cellulose and lignin along with hemicellulose, ash and pectin remark Mahish and Nayak (2007). Coir is relatively water- proof and is the only natural fibre resistant to damage by salt water point out Mwasha (2009). It's biodegradable, durable, moth and rot resistant, an excellent insulator of heat as well as sound and good water retention referred Alexander etal. (1999).

**ii) Uses of Coir**

According to Kwatra (2008) coir fibre has been traditionally used to make carpets, furniture, building insulation, yarn, rope, floor coverings like mats, as filling for mattresses, for sediment control and in textiles. It has also been used as eco-friendly substitute in different applications for erosion control, reinforcement and stabilization of soil. Bond (2005) remarks that coir yarn can be woven into a number of different designs such as boucle, panama, herringbone and brush matting.

### 2.2.4 Fibre Extraction Methods

Extraction of fibres means separation of fibres from the cemmenting substances such as pectins or lignin, wax resins, fat and other carbohydrates report Pardeshi etal. (2012). The fibre extraction procedure depends on the type of plant and portion thereof from which the fibres are derived. Fibre bearing plants have very different anatomy so the processing will differ indicates Xanthos (2005). Fibre extraction can be performed using several processes namely natural retting in the fields, chemical retting, enzymatic retting and by mechanical processing through decortication. Mechanical systems are generally preferred due to the reduced time for fibre extraction opines Lo (2006).

According to Ooi (2004) the extraction of fibre can be done either by hand stripping or by using stripping machines. The old method used was hand stripping using a knife blade. It was only in the 1920s and 1930s the properly functioning fibre extracting machine called a decorticator was introduced. In the **decortication** process the leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibres remain leaving the tissues (www.fibre2fashion.com). The decorticating machines process between 150-250Kg of dry fibre per day and produce fibre waste of around 20–30 per cent of the fibres contained in the leaves. They are highly mobile and are moved from the field to field opines Kunaka (2011).

**Retting** is the operation in which the technical fibres are loosened from the surrounding stem tissue by enzymes secreted by microorganisms. These enzymes degrade the non cellulosic substances, mainly pectins, which are in abundance in the surrounding tissue regards Tucker and Johnson (2004). Thus the fibres are extracted from plants by a natural microbial retting process. In running water retting, the plant stalks are bundled into crates weighted with stones and then placed in a river or creek for 10–20 days (the time period depends on plant type and water temperature) views Stein (2008).

In stagnant water retting, the plant bundles are placed in clean stagnant water weighed down by stones after covering with straw. It takes around 2–4 weeks for the bacteria in the water to hydrolyse the gummy substance. Some drawbacks of this process are that the product can become dirty owing to the stagnant water. There are chances of over retting which can damage the fibres. A strong odour is also produced remarks Sekhri (2011).

Due to acute shortage of water for retting and the environmental pollution created from conventional systems of retting, a new method of retting has been launched which has been recognized as ribbon retting. In ribbon retting barks are removed mechanically or manually in the form of ribbon. The ribbon are coiled and then allowed for retting in water with or without microbial inoculum reports Banik etal. (2007).

According to Bajpai (2011) dew retting is the oldest method of retting. The leaves are spread in uniform and thin, non overlapping swaths and left in the field where the moisture and temperature encourage colonization and partial degradation of pulp primarily by saprophytic fungi. The retting period generally lasts between 25 to 30 days in summer and between 50 and 100 days in winter. The retting may be either extended or reduced until moulds and fungal decomposition loosened the fibre bundles opine Netherton and Owen-Crocker (2008).

In enzymatic retting rather than enzymes secreted by microorganisms being responsible for the retting action, commercially prepared enzymes are used. In this method the retting time was drastically reduced say Tucker and Johnson (2004). Several enzyme products comprising mixtures of different enzymes such as pectinases, hemicellulases and cellulases have been used in enzymatic retting. Removal of pectin which acts as the binder between cells is important in retting. Hence pectinases have been the most effective enzymes in the retting process discuss Miettinen-Oinonen (2007).

According to Aggarwal (2011) in chemical retting the fibre yielding portion of the plant is first scraped out and cut into pieces and kept in containers containing different concentrates of NaoH and HCl solution in such a manner, so that they are completely immersed in the solution and kept for ten hours. After that each of them are boiled for 30minutes. Soda ash, oxalic soda and caustic soda in warm water or in boiling dilute $H_2SO_4$ solution are the chemicals commonly used. After retting they are washed thoroughly with cold water to separate the fibres and then dried to prevent further fermentation.

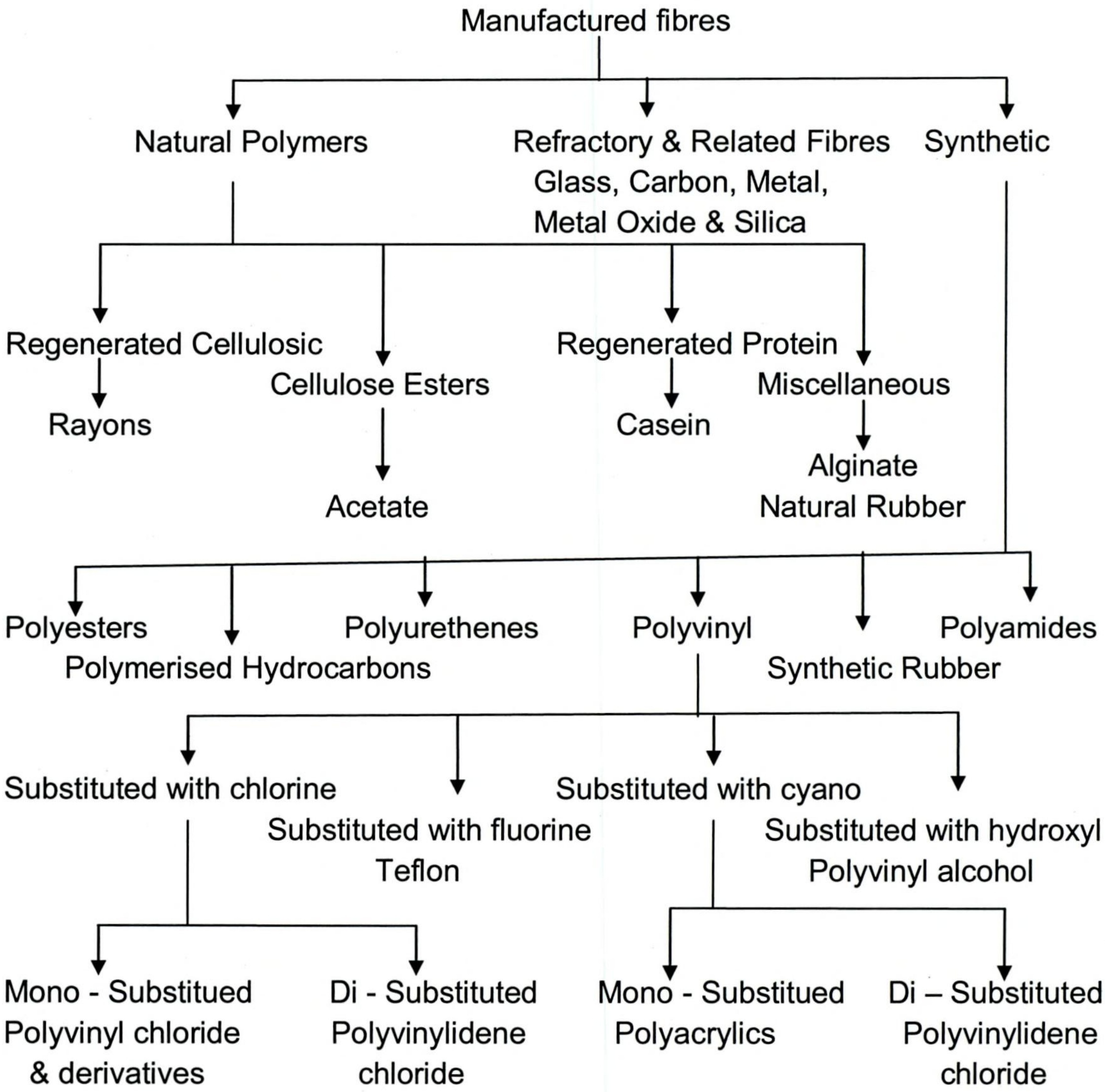
**2.3. Man-made Fibre**

A synthetic or man-made fibre generally comes from synthetic materials such as petrochemicals. But some types of synthetic fibres are manufactured from natural cellulose including rayon, modal and the more recently developed

Lyocell. Cellulose based fibres are of two types, regenerated or pure cellulose such as from the cupro - ammonium process and modified or derivitized cellulose such as the cellulose acetates (www.textilelearner.com). According to Sekhri (2011) manufactured fibres are created by technologists under controlled conditions. They are extruded as filaments. Filament fibres are long and may be cut into staple lengths if required.

**2.3.1 Classification of Man-made Fibre**

Manufactured fibres are broadly divided into three groups as follows says Choudhury (2006).




**2.3.2 PET Fibre**

PET (polyethylene terephthalate) is by far the largest volume thermoplastic polyester in production today. It was first synthesized by J.R.Winfield in the UK during the 1940s and its first commercial application was as a textile fibre. PET is one of the few materials that has a steady supply of recycled polymer opine Scheirs and Long (2003).

PET is manufactured by a stage wise melt polymerization process, which consists of (trans) esterification, prepolymerization and finishing polymerization steps remark Webb and Roe (2007). Fletcher (2008) expresses that the main chemical used in the Production of PET includes terephthalic acid (TA) or dimethyl terephthalate, which are reacted with ethylene glycol (EG). The resulting diglycole terephthalate (DGT) with parts of ternary and similar intermediate products is polycondensated in a second step with the help of a catalyst and possibly a stabilizer at 270 ... = 300°C under vacuum; this will split off EG. The PET can either be produced as chips or directly to fibres remarks Fourne (1999).

PET fibres composed of at least 85 per cent by weight of an ester of a substituted aromatic (or aliphatic) carboxylic acid are termed polyesters. In comparison with other synthetic fibres, PET belongs to the stronger and stiffer fibres remark Cavaco-Paulo and Gubitz (2003). PET can be depolymerized to give virgin PET. The main depolymerization process which is commercially used are glycolysis and methanolysis suggest Agrawal and Jaiswal (2011).

The most common polyester is Dacron, the polymer of terephthalic acid with ethylene glycol. This polymer is made by mixing the diacid with the glycol and heating the mixture to drive off water. Better product will be obtained using a transesterification process. In this process the dimethyl ester of terephthalic acid is heated to about 150°C with ethylene glycol. Methanol gas is evolved during the completion of the reaction describe Wade and Singh (2008). Recycled PET was obtained from washed, used beverage bottles that were chopped into flakes varying from 1-15mm say Bogdal and Prociak (2007).

**i) Properties of PET Fibre**

The properties of PET fibres depend strongly on the development of the microstructures during the fibre forming process where the transformation from molten to solid state occurs. Therefore, the physical properties of PET fibres vary depending on their processing conditions and thermal history. The main physical properties of PET fibres that influence their surface characteristics are thermal and a light property explains Hsieh (2001). Liu (2007); Kardas etal. (2009) suggest that PET is characterized by hydrophobicity, resistance to hydrolysis, high strength, toughness, low surface energy and limited reactivity.

PET has excellent transparency and mechanical properties. PET has good barrier properties, especially for odours and flavours reports Abdel-bary (2003). According to Mantia (2002) thermal degradation of PET occurs in the temperature range from 290-310°C.

**ii) Uses of PET Fibre**

According to Chatterjee and Gupta (2002); Kent (2003) polyester fibres are extremely versatile and are used extensively in a variety of apparel, household and industrial applications such as conveyor belts, tires, composites, etc. PET fibres are used in home furnishing such as carpets, draperies, sheets, pillows, wall coverings, upholstery, other uses include hoses, ropes, nets and cords define Thomas and Visakh (2011).

**2.3.3. Polypropylene Fibre**

Polypropylene fibres belong to the newest generation of large scale, manufactured chemical fibres. Polypropylene (PP) is the second most common linear thermoplastic of the polyolefin family. It is manufactured using conventional melt spinning process. Synthesis of polypropylene polymer involves stereo-regular polymerization processes to obtain highly regular chain structures. The commercially most important form of PP is isotactic PP. This polymer is produced by low pressure polymerization using Ziegler - Natta catalysts referred Gupta (2008); Mantia (2002). PP staple fibre is made by melting polypropylene chips in an extruder and forcing the melted plastic through spinning plates containing thousands of tiny holes. The resulting strands of molten plastic are cooled, stretched and cut into staple fibres (nonwoventools.com).

**i) Properties of Polypropylene Fibre**

Paul (2009) opines that polypropylene fibre has good mechanical properties, excellent chemical resistance, easily processable, relatively low cost and possesses poor adhesive properties. It is an inert fibre with good resistance against acid, alkali, insect and moisture, strong, relatively rigid and has a high performance ratio remark Debnath and Madhusoothanan (2011).

**ii) Uses of Polypropylene Fibre**

Polypropylene offers a number of applications because of its low price, high toughness and low density. It has successfully bridged the gap between the commodity polypropylene composites and the engineering thermoplastics suggest Anandjiwala etal. (2007). It can be made into ropes and cordage, primary and secondary carpet backing, carpet face yarns, upholstery fabrics, geotextiles, filtration materials, horticulture/agriculture materials, automotive fabrics, spill-cleanup materials, disposable diapers, hospital/medical care materials, and protective clothing (www.engr.utk.edu).

**2.4. Fibre Evaluation**

The structure and chemical composition of natural fibres varies greatly and depends on the source and many processing variables opines Clemons (2010). The performance of a given fibre depends on several factors including chemical composition, physical properties, mechanical properties, etc. In order to expand the use of natural fibres it is essential to know about fibre characteristics and the factors which affect the performance of that fibre says Bledzki (2002).

**2.5. Fibre blending**

Fibre blending is a process which involves an efficient mixing of various lots of fibres thus bringing together two or more fibres for reasons such as to maximize their performance, enhance their aesthetic qualities, improve market value and to decrease the cost of an expensive fibre remark Garrison (2002); Brown (2004); Nielson (2007). According to Kaplan (2002) fibre blending also facilitates further processing and improves fabric properties. Nowadays blends of natural fibres, natural with manufactured fibres and blends of different manufactured fibres based on the combination filament principle are the dominant factors in the fabric producing industries express Jackman etal. (2003).

**2.6. Nonwoven**

Nonwovens have taken on an important position in the textile world in the last few years. This applies not only in terms of quantities, but also to the increasing number and type of application regard Albrecht etal. (2002). Ratner and Bankman (2009) express that nonwoven is a textile structure produced directly from fibres without the intermediate step of yarn production. Das and Raghav (2009) define nonwoven fabrics as web structures made by bonding or interlocking fibres or filaments using mechanical, thermal, chemical or solvent methods.

Nonwoven fabrics have different properties from woven and knitted structures. They are often stiffer because there are no yarns that are free to move within the structure and many of their other performance properties are affected by the method of bonding the fibres together regard Collier and Epps (1999).

### 2.6.1. Classification of Nonwoven

Nonwovens are best classified by process, because each process produces a unique class of nonwovens utilizing different raw materials or different forms of the same raw materials and/or different forms of the same raw materials explains Hutten (2007). The formation of nonwovens consists of two basic steps namely web formation and bonding. The web formation in nonwoven production is a critical contributor of the end user product performance. Three basic methods are used to form a web formation namely dry laid, wet laid and polymer laid. A web has little strength when they are formed and must therefore be consolidated or bonded in some way states Yadav (2011).

Nonwoven bonding processes can be mechanical, chemical (including latent bonding using solvents) or thermal. Hydrogen bonding is also important in bonding cellulose webs. In chemical bonding binders are applied to a web which when dried bond the individual fibres to form a coherent sheet views Operah (2006). In the thermal bonding process the web will contain a portion of thermoplastic fibre which melt and act as a binder for the body fibres upon the application of heat state Smith and Cothren (1999). Mechanical bonding processes include needling, wet laying, felting and air or water jet techniques express Moody and Needles (2004). In the needle punching process, also known as needle felting, a batt of fibres is drawn through a needle loom. Fibres are mechanically entangled by reciprocating barbed needles suggests Wilson (2010).

### 2.6.2. Properties of Nonwoven Fabrics

Nonwoven fabrics may have a limited life, single use fabric or a very durable fabric. Nonwoven fabrics provide specific functions such as absorbency, liquid repellency, resilience, stretch, softness, strength, flame retardancy, washability, cushioning, filtering, bacterial barriers and sterility. These properties are often combined to create fabrics suited for specific jobs while achieving a good balance between product use-life and cost. They can mimic the appearance, texture and strength of a woven fabric and can be as bulky as the thickest paddings (www.inda.org).

### 2.6.3. Uses of Nonwoven Fabrics

Today nonwoven fabrics have emerged as an alternative to woven in most of the industrial applications. The reason is due to the increased awareness about nonwoven fabrics point out Bala etal. (2009). Among the textiles, the noise reduction of nonwovens for use as soundproofing has received more attention than other soundproof materials especially in some applications such as an interior noise reduction in automobiles and the internal walls of airplanes report Honarvar etal. (2010).

Pal (2009) stresses that nonwoven fabrics are used to make automotive parts from trunk liners and carpets to air and fuel filters. General nonwoven offers both PP and PET based fabrics for automotive applications. Polyester spunbonds are widely used in the automotive industry and they are easily customized. They can be moulded and contoured to fit almost all interior, trim or other complex surfaces. The uniform appearance of the fabrics not only serves the technical needs but also the visual expectations.

**2.7. Needle Punching**

Needle punching is the oldest method of producing nonwoven products. The first needle looms produced in the United States was made by the James Hunter Machine Co in 1948. Then, in 1957, James Hunter produced the first high speed needle loom, the Hunter Model 8, which is still used today opine Naik and Pancholi (2008).

Simpson and Crawshaw (2002) reveal that around 1870, the commercial production of needle punching machines was established for driving barbed needles through fibrous webs to introduce the mechanical entanglement needed to form a fabric that is commonly referred to as a ‘needle felt’. In basic form, a needle punching machine consists of a perforated stripper plate set immediately above which assists in stripping the reciprocating needles on their return stroke (as the needle withdraw from the batt). The barbed needles are designed to collect and transfer fibres perpendicular to the surface of the fabric and then release them when they withdraw from the batt.

**2.7.1. Needle Punching Process**

Nonwoven fabric manufacture starts by the arrangement of fibres in a sheet or web (www.pgi-industrial-europe.com). The formation of web starts with the opening of the fibre supply. The opening process mechanically separates the fibres from each other to create a ‘cloud’ of fibre. This mass is typically deposited onto a conveyor belt creating a continuous roll of ‘fluffy’, low density material remark Bogdanovich and Pastore (1996). The carded web is passed through a stripper plate which helps to reduce the bulk view Demboski and Bogoeva-

Gaceva (2005). Then numerous barbed needles are inserted into the web which forces some of the fibres downward causing them to be entangled with fibres in lower layers of the web. Further entanglement occurs in the upward movement of the needles report Fung and Hardcastle (2001). Thus the fibres are mechanically interlocked into a stable configuration states Delleur (1999).

The density and strength of the fabrics can be regulated by the strokes per minute of the batt, the advance rate of the batt, the degree of penetration of the needles and the weight of the batt stresses Gooch (2010). Among many fabrication techniques the needle punching process attracts much interest because it provides a uniform fibrous structure and can be easily applied to large parts with cost effectiveness refers Curzio (2008).

### 2.7.2. Properties of Needle Punched Fabrics

The properties of needle punched fabrics depend on the nature of component fibres, the manner in which fibres are arranged in the structure, the machine type and web parameters says Midha (2011). Needle punched fabrics have the appearance of felt and may be relatively thick. Needle punched fabrics made from staple fibres have an even greater elongation than continuous filament needle punched fabrics opines Forrester (2001).

### 2.7.3. Uses of Needle Punched Fabrics

Needle punched fabrics are widely used in geotextiles, automotive trim, filtration media and land scape fabrics. Needle punched fabrics find application in geotextiles as separation, filtration, reinforcement, drainage and erosion control and can be used in roads, railways, air runways, coastal shore protection, etc. Nowadays more and more needle punched nonwovens are getting into the interior of the car Pal (2009). They are even used in passenger cars as a flooring material and in automobiles as headliners, filtration, insulation felts, coated/laminated fabric backings, bedding, home furnishing materials, interlinings, roofing etc regard Smith and Cothren (1999); (www.technicaltextile.net).

## 2.8. Surface Modification of Fibres

The development of natural fibre based composites requires the modification of the fibre surface characteristics. In surface treatment only the external layers of the fibre (skin) were modified whereas in bulk treatment the entire fibre is modified express Fakirov and Bhattacharyya (2007).

The surface modification was employed to cellulose fibres with a view to provide the fibres with specific functionalities, so that they can play determining roles in applications such as reinforcing elements for composite materials, self-contained composite structures, anti-pollution aids, hybrid materials, super hydrophobic surfaces, conductive and magnetic materials remark Belgacem and Gandini (2008).

According to Thomas and Pothan (2009) researchers all over the world were found to use these four types of surface modification namely chemical (acetylation, alkali treatment, mercerization, silane treatment, etc.), physico - chemical (solvent extraction), physical (use of different rays or plasma, steam explosion) and mechanical methods (rolling, swaging).

Kalia etal. (2011) discuss that alkali treatment improves the fibre matrix adhesion due to the removal of natural surface and artificial impurities from the fibre surface as well as the change in the crystal structure of the cellulose. Moreover, alkali treatment reduces fibre diameter thereby increases the aspect ratio and develops rough fibre surface topography. This offer better fibre matrix interface adhesion resulting in better mechanical interlocking due to the amount of cellulose exposed on the fibre surface.

**2.9. Composites**

Ageorges and Ye (2002) define that composite is a material that contains a physical mixture of two or more phases that are chemically different and separated by a distinct interface to obtain a unique material to exhibit better properties than either of the original constituents. The majority of composites is made up of a continuous phase called a matrix, in which a stronger phase consisting of fibres or particles is embedded says Fischer (2009).

Kannan (2008) discusses that mostly green composites are produced by natural fibres derived from bamboo, hemp, flax and are being added to the starch based resin example soy protein. Ellison and McNaught (2000) suggests the use of natural fibre composites for automotive interior components is an emerging market. Nearly about hundred kilotons of natural fibres are consumed annually in the World wide automotive production.

Natural fibre reinforced composites are characterized by low density which allows mass reduction and favorable mechanical, acoustic and processing properties, which make them particularly suitable for use in automobile parts discuss Mussig and Stevens (2010).

### 2.9.1. Types of composites

According to the nature of the matrix material composites are classified into three major classes namely polymer matrix composites ($PMC_s$) or organic matrix composites, ceramic matrix composites ($CMC_s$) or mineral matrix composites and metal matrix composites ($MMC_s$) express Altenbach etal. (2004); Chawla (2003).

**Polymer matrix composites**

Harper (2003) states that polymer composites are engineered materials in which the major component is a high-strength fibrous reinforcement and the minor component is an organic binder often referred to as matrix resin. $PMC_s$ are classified as thermoplastic composites and a thermosetting composite views Ratna (2007). Barbucci (2002) opines that the high viscosity of thermoplastic polymers in the molten state makes the fabrication of long fibre reinforced composites a quite difficult and complex task. For this reason thermoplastic materials are predominantly used to obtain short fibre composites.

In the World market about 50 per cent of the thermoplastic and 24 per cent of the thermoset composites are used by the automotive segment regard Baksi and Biswas (2011). Thermoplastic composites have unlimited shelf life, rapid cycle times, ease of fabrication, high toughness and recyclability opines Abrate (2011). Thus there is increasing emphasis on the use of thermoplastic matrix composites. Thermoplastic composites made of polyamide or polypropylene matrix materials are suitable for use in automotive applications say Tucker and Lindsey (2002).

**Ceramic matrix composites**

Ceramic matrix composites are characterized by carbon or ceramic fibres embedded in ceramic matrices (oxide or non-oxidized) with comparatively low bonding forces between the fibres and the matrix remarks Krenkel (2008).

**Metal matrix composites**

The matrix material for metal matrix composites can be aluminium, titanium, or intermetallics. Reinforcements include continuous fibres made of aluminium oxide, silicon carbide, boron, or carbon, discontinuous fibres in the form of particulates and particulate reinforcements, such as Sic, $B_4C$, $Al_2O_3$ reports Liu (2005).

**2.9.2. Types of processing techniques**

According to Chakraborty etal. (2010) there are various types of composite processing techniques available to process the various types of reinforcements and resin systems. They include resin transfer moulding, compression moulding process, injection moulding, autoclave and pultrusion. Mukhopadhyay (2005) points out the methods used to develop natural fibre composites as follows:

- Compression moulding of
  - Resinated plant fibre mats
  - Plant fibre / PP fibre mats
  - Natural fibre mat reinforced thermoplastics
- Structural reaction injection moulding
- Injection moulding with short fibre reinforcement.

**2.9.3. Properties of Composites**

Composites have low specific weight, high strength, irregular surface morphology, low specific heat, relatively higher thermal stability, renewable resource, friendly processing, thermal recycling possible, good thermal and acoustic insulating properties opines Roul (2009). Natural fibre composites have lower impact strength, higher moisture absorption which brings about dimensional changes thus leading to micro cracking, as well as poor thermal stability, which may also lead to thermal degradation during processing discuss Anandjiwala etal. (2007).

**2.9.4. Uses of Composites**

According to Kutz (2002) composites are important materials that are now used widely, not only in the aerospace industry, but also in a large and increasing number of commercial applications. Composites are used in motor caps, hood covers, hatchback doors, bumpers, roofs, shock absorbers, seat frames, side panels, central consoles and holders, headlight supports, oil tanks, cover for cylinder heads and gear box parts report Aparaj etal. (2010).

Wilson (2008) states several natural fibre composites are used in the manufacture of components in some of our vehicles. Mukhopadhyay and Fangueiro (2008) reveal that a variety of natural fibre composites made of kenaf, hemp, flax, jute, coir and sisal fibres have appeared in car door panels, seat backs and dashboards. Hardwood, softwood, rice hull, kenaf and coir fibres can be found in foamed composite decking, siding and window blinds. The use of natural fibre composites in automotive industry is expanding rapidly with Daimler, now using more than 50 bio based components in its Mercedes - Benz cars.

### 2.10. Fabric Evaluation

The tensile strength of a material is the maximum amount of tensile stress that it can be subjected to before failure (www.sciencedaily.com). The flexural strength or bend strength is an important mechanical property regard Siegesmund and Snethlage (2011). Impact strength is an important factor in choosing composite material suggest Chitale and Gupta (2007). Air permeability is the property which permits the passage of air and it indicates substance's porosity of the fabric. Stiffness is one of the most widely used parameters to judge bending rigidity and fabric handling opine Yuksakkaya etal. (2008). Thermal properties are among the most important features of textiles which includes thermal conductivity, resistance and diffusion say Frydrych etal. (2002).

### 2.11. Technical Textiles

Technical textiles are textile materials intended for end uses other than non protective clothing, household furnishing and floor covering, where the fabric or fibrous component is selected principally but not exclusively for its performance properties as opposed to its aesthetic or decorative characteristics describes Joseph (2005). Technical textiles include textile structures for automotive applications, medical textiles (e.g. implants), geo - textiles (e.g. reinforcement of embankments), agricultural textiles (e.g. textiles for crop protection), protective clothing (e.g. against heat and radiation for fire fighters, space suits for astronauts), construction textiles, etc views Joseph (2003). Technical textiles are also known as industrial textiles, high performance textiles, engineered textiles and functional textiles. They are a group of products attempting to provide solutions to many technical challenges present in our society Kothari (2008).

#### 2.11.1. Classification of Technical Textiles

Technical textiles are divided into the following areas reports Arun (2001).

- Agrotech – textiles used for agriculture, horticulture and forestry

- Buildtech – textiles used for building and construction
- Clothtech – textiles used for components of shoes and clothing
- Geotech – textiles used for geo-technical and civil engineering
- Hometech – textiles used for components of furniture, household textiles and floor coverings
- Indutech – textiles used for filtration, cleanings and industrial applications
- Medtech – textiles used for hygiene and medical applications
- Packtech – textiles used for packing
- Mobiltech – textiles used for automobiles, shipping, railways and aerospace
- Oekotech – textiles used for environmental protection
- Protech – textiles used for personal and property protection
- Sporttech – textiles used for sports and leisure.

**Advantages**

According to Goyal and Prabhu (2008) the phenomenal growth of technical textiles in the World is due to the attributes such as contribution of quality of life, cost effectiveness, durability, high strength, light weight, versatility, customization, user friendliness, eco friendliness and logistic convenience

**2.11.2. Application of Technical Textiles**

- ❖ The product for **industrial** application includes hoses, ropes, conveyor belts, tyres, composites, etc.
- ❖ The main areas of textiles in **agriculture** include applications in farming, animal husbandry and horticulture say Sankhe and Chitnis (2002).
- ❖ **Automobile** textiles include seat upholstery, carpets, seat belts, headliners, tyre cords, liners, noise vibration and harness (NVH) components, etc reports Rajesh (2011).
- ❖ **Medical** application includes surgical dressing, spare parts for the human body, sutures in surgery, medical devices, etc remark Pardeshi and Manjrekar (2002).
- ❖ **Home textile** generally includes household linen such as blankets, towel, sheets, pillow cases and table cloths, curtain, floor coverings, bedding and upholstery suggest Ghosh and Dalal (2008).

- Some examples of technical textile applications are fibre reinforced plastic composites, business machine fabrics, mechanical rubber goods, industrial and commercial fabrics, protective textiles reveals Joseph (2003).

### 2.11.3. Automotive Textiles

Automobile textiles are non apparel textiles which are widely used in vehicles like cars, trains, buses, aircrafts and marine vehicles. Hence the term automobile textile means all types of textile components e.g. fibres, filaments, yarns and the fabric used in automobiles. It is widely used in the automotive industry right from light weight vehicles to heavy duty vehicles (www.fibre2fashion.com).

In recent years, car manufacturers have been looking for lighter, safer, more economical, more comfortable and at the same time, ecologically compatible material to face the global competition reveal Stauber and Vollrath (2007). The light weight material increases fuel efficiency and reduces pollutant emissions. Both these needs are being met through lightweight materials like composites and textiles instead of moulded plastics refers Naidu (2009). Further the textile material made of low density fibres was increasingly utilized in automobile construction suggests Wiley-VCH (2008).

Chapman (2010) states that nonwoven fabrics are increasingly used in the automotive industry due to its higher productivity and lower production cost. It is reported that nonwoven fabrics currently cover more than 30 automotive applications and share about 11 per cent of the total vehicle fabrics.

#### 2.11.3.1. Application of Textiles in Automobiles

The applicability of textiles in automotive industry are seat cushioning, seat covers, seat belts, air bags, headliners, carpets, package trays, door trims, trunk liners, trunk cover, clutch facings, tyre, upholstery, tyre cords, window runners, shoulder harness, fan belts and gaskets. Textiles are also used as a reinforcement fibre in moulded plastic parts point out Kadolph (2009); Sakthivel etal. (2011).

Kothari (2006) discusses that parts of the bodywork and the suspension system are even made of glass fibre reinforced composites. Heat resistant and sound absorbing textiles may be used to insulate various parts of the vehicle. Oil and fuel filters made of textiles are used to keep the car operating smoothly.

Nonwoven media are used to filter the air that enters the passenger compartment.

### 2.12. Noise Pollution

According to Tai etal. (2010) pollutions most frequently seen in our daily life includes noise pollution, water pollution, waste pollution and air pollution. Agarwal (2009) defines noise pollution as an unwanted sound which gets dumped into an environment without regarding the adverse effects it may be having.

Sharma (2008) says a loud, unwanted or unpleasant sound that causes discomfort is called noise. The noise level can range from 0 to more than 120dB. Noise beyond 120dB causes physical discomfort. Prolonged exposure to noise of 80dB or more may lead to impairment of hearing. A noise above 140dB becomes painful.

Noise reduction coefficient (NRC) is the average of the sound absorption coefficients at the frequency bands of 250, 500, 1000 and 2000Hz expressed to the nearest integral multiple of 0.05. The sound absorption coefficient of a surface in a specified frequency band is the fraction of randomly incident sound energy absorbed or otherwise not reflected remarks Garrison (2002).

#### 2.12.1. Causes of Noise Pollution

According to Hiremath (2007) some of the chief causes of noise pollution are machines and modern equipment of various types, automobiles, train, aircraft, use of explosives, bursting of firecrackers, dog barking, use of loud speakers, loud rock and roll concerts, domestic stereo, noise from rail / roads, industrial noise, noisy amusement parks and noise in the building.

#### 2.12.2. Effects of Noise Pollution

Noise causes following health hazards

i) Fatigue and nervousness
ii) Irritability / ill – temper / violent behavior
iii) High blood pressure, ulcers, depression, cardiovascular problems
iv) Headache, stress, strain and tension, annoyance
v) Working efficiency is reduced
vi) Concentration and communication interference
vii) Sleep interference

viii)Noise increases secretion of hormones such as adrenaline and alters blood circulation views Basak (2009).

Soundarapandian (2007) opines that prolonged exposure to noise may cause a progressive symmetric bilateral impairment of hearing. Continued exposure to noise pollution can lead to a gradual decline in hearing ability and eventually lead to deafness refers Sagar (2008). In fact, the way noise pollution is increasing, it is predicted that in the next few years, all people above the age of 10 will not be able to hear normally suggests Gupta (2005).

### 2.12.3 Control Measures of Noise Pollution

i) Delimitation of acoustic zoning
ii) Use of cotton plugs or ear muffs in occupational exposure
iii) Development of quieter machines
iv) Restricted use of loud speakers
v) Acoustic furnishing and low voice radio / TV
vi) Regulation of noise on road
vii) Green muffler describes Sharma (2009).

Fibre based acoustical products has been traditionally used as a sound absorber due to its cost effectiveness. In the automotive sector importance is given to fibre products specifically in vehicle noise control package to improve sound absorption and transmission loss opines Wyerman (2010).

### 2.12.4. Evaluation for Sound Absorption

Evaluation of acoustical performance of sound absorption coefficient values has been studied using Standing wave method Srivastava etal. (2006). According to ASTM (2007) Standing wave apparatus covers the use of an impedance tube for the measurement of impedance ratios and the normal incidence sound absorption coefficients of acoustical materials.