# Properties, and Applications of Different Types of Fibres in the Construction industry

**SIVA PRASAD GANDHAM** *Research Scholar, Department of CIVIL, Maharishi University of Information Technology (MUIT), Noida, Uttar Pradesh, India.*

**Dr ANOOP NARAIN SINGH** *Professor, Department of CIVIL, Maharishi University of Information Technology (MUIT), Noida, Uttar Pradesh, India.*

*1Sivaprasad.civil@gmail.com ; [2]anoopnarain1407@gmail.com*

***Abstract***

*Fibres have been utilized in building materials for a long time. The inclusion of natural and synthetic fibres in composite materials has shown considerable advantages in terms of the composite's overall physical and mechanical qualities in prior research and examinations. When comparing fibre reinforcement to conventional reinforcement, the ratio of fibre needed is greatly reduced, making fibre reinforcement both energy and cost-efficient. Recently, the use of waste fibres as reinforcement in building materials has been examined. Due to landfill area limitations, as well as the high energy and pollutants produced during the incineration process, garbage accumulation is a well-known problem across the globe. Construction materials made from waste fibres may help ease these problems and encourage ecologically beneficial and long-term solutions. There are a vast variety of fibres used in a variety of building materials, and this research examines their characteristics and uses.*

***Keywords:*** *natural fibres, synthetic fibres, basalt fibres, Properties, Application.*

## 1. Introduction

In the building industry, fibres have been utilized for a very long time all over the world. Composite materials have been around for a long time, and fibres have been employed as reinforcement [1]. Natural fibres like straw and horsehair were used in the construction of mud bricks as far back as the Egyptian era. The United States began using straw as the primary material for supporting walls in the late 1800s. Construction of homes is essential for society, and bricks may be utilized to make these structures. Earthen materials have been utilized in building for thousands of years and are still in use today [2]. Of course, the materials used in the building range from country to country due to differences in economic conditions and the availability of certain resources.

Many natural materials, such as coconut (coir), sisal (from palms), flax (from flax stalks), straw (from bamboo), and cane (from cane stalks), have a long history of use because they are easily accessible. The physical and mechanical qualities of natural fibres are influenced by the surrounding environment at the time of harvest [3]. This covers everything from the soil's state to the extraction procedure, treatment, humidity, and temperature in the air, among other things.

In the construction business, concrete is a popular building material. Construction and civil engineering applications have been using fibres for concrete for around 50 years. FRP has been employed in the building sector for more than two decades, displaying beneficial advantages such as enhanced strength [4], light weightiness and corrosion resistance.

It's important to remember that any building material has both good and bad qualities. For example, concrete's great compressive strength is a well-known quality. However, it has a weak tensile capacity.

 

Soil tensile and shear strength is often deficient. The addition of fibres to building materials improves their performance and reduces their environmental impact. It is possible to enhance the qualities of these materials by introducing certain fibres, making the final product more well-rounded. Differing manufacturing processes and raw material compositions for synthetic fibres may result in variable mechanical characteristics [5]. Fibres exist in a variety of forms and sizes, and each one has a unique set of features.

## 2. Types and Properties of Fibres

Natural fibres and synthetic fibres are the two main types of fibres. The outside of plants, trees, and straw are the most common sources of natural fibres. When compared to synthetic fibres, natural fibres have a far longer history. It's important to note that synthetic fibres are created fibres that have a specific function [6].

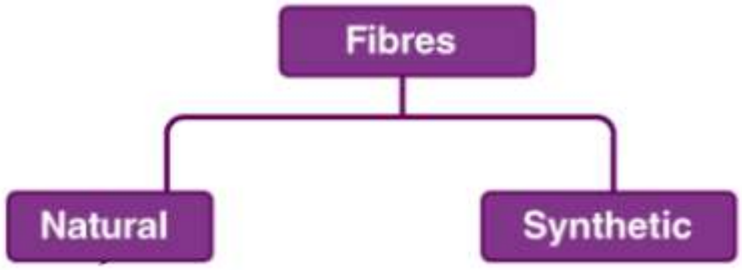


**Figure 1: Types of Fibres**

### 2.1. Natural Fibres

Natural fibres include coconut (coir), sisal, palm, jute, flax, straw, bamboo, cane, and many more. Cereal straw, wood, basalt, palm tree fibres, and leaf fibres are just a few examples of the many subcategories of naturally occurring fibres. The physical and mechanical qualities of natural fibres are influenced by the surrounding environment at the time of harvest [7]. There are several variables to take into consideration when it comes to determining the quality of a soil sample.

Natural fibres have a long and distinguished history of usage. All across the globe, different natural fibres may be discovered that grow naturally in the environment. Using them in the construction sector reduces the environmental effect since they are widely accessible, plentiful, need little to no energy to create, can be recovered from waste material, and are affordable and low in cost. Naturally occurring fibres may aid in the utilization of environmentally friendly materials. Although these fibres have the benefit of being biodegradable, their primary drawback is that they often have limited endurance and may deteriorate naturally over time.

In recent years, researchers have been investigating ways to make natural fibres in composites last longer [8]. There are many ways to alter the hydroxyl group in organic natural fibres, including chemical treatment, coating, and other methods. The gain in durability may just be transient, thus further study is needed to find out. Leaching and exposure to biological, chemical, thermal, and UV-related degradation have not been well studied, and these procedures are expensive and potentially harmful.

 


**Figure 2: Type of Natural Fibers**

Civil engineers have been looking at the possibility of using easily renewable materials that have the best qualities while also being environmentally friendly. Natural fibres and industrial waste may be used to achieve sustainability. In thermal applications, such as passive dwellings and low-energy greenhouses, natural materials show tremendous promise because of their thermal insulating capabilities and ability to regulate temperature and humidity. Additionally, natural fibres have a wide range of features that make them ideal for a variety of applications, including excellent adhesion, cheap cost, environmental friendliness, biodegradability, ease of extraction, and high toughness. When used in the structural envelope, plant materials and fibres may assist to retain dust and lower noise levels, while also acting as a barrier from the sun and weathering impacts. As lightweight fibres, plant fibres in composites may assist reduce a material's usual dead load and increase its useful life. Three types of plant fibres may be isolated from natural plants: cellulose, lignin, and lignocellulose.

Natural fibres and their qualities are covered in the following.

**2.1.1. Bast Fibres**

There are a variety of fibres that may be classified as bast fibres, including flax, jute, hemp, sisal, and kenaf. [2] These fibres are taken from the outside of a variety of different plants. Bast fibres have high tensile strength and are effective thermal insulators, making them a useful material for a variety of applications.

One of the most well researched natural fibres is jute, which is made from jute plants. The bark of the jute plant contains the fibres that are used to make jute cloth. Jute fibres come in a variety of forms, each with its own set of characteristics. Filtration, drainage, and soil stability are all made easier by their use in building materials. Composite construction materials have benefited from the usage of flax fibres by increasing their ductility and by reinforcing them.

### 2.1.2. Palm Tree Fibres

Coconut (coir) fibres, oil palm fibre, and date palm fibre are all palm tree fibres [2]. There are a lot of palm fibres to choose from since they are cheap, plentiful and long-lasting. They are also light and absorb a lot of water. It is common for palm fibres to have low tensile strength and high flexibility.

From the coconut's monocarp, coir fibres are removed. Short coir fibres are those that are less than 130 mm in length, while long coir fibres are those that are more than 130 mm in length. Fibres made from agricultural waste are a ubiquitous and ever-present source of pollution in our planet's ecosystem. Normally, coconut trash is burned or thrown, however, it may be put to good use. Strong, resilient, durable, plentiful and inexpensive; resistant to rot and fungal; difficult to burn; high elongation; coir fibres are all of these things and more. The coir fibres retain most of their tensile strength even when wet, making them ideal for insulation and bedding.

Date palm fibres are hydrophilic lightweight fibres with mechanical qualities such as durability and tensile strength and are inexpensive, simple to obtain and well-withstanding degradation [11]. Because these fibres are capable of securing individual particles and groups of particles together, they may increase the overall strength of composite materials. The mechanical and physical qualities of natural fibres are highly influenced, as previously stated, by the state of the environment and the time of harvest. A decayed parent tree's date palm fibres may be brittle, have reduced tensile capacity, have decreased modulus of elasticity, and have an increased water absorption when harvested from the decomposing tree.

### 2.1.3. Cereal Straw

The grass is a typical building material, as is straw. Wheat straw, barley straw, oat straw, and straw are all part of the "cereal straw" category. Straw is a widely used agricultural byproduct all over the globe. In the past, straw was used to strengthen mud bricks in a different country, and it has been utilized ever since [12]. Reduced shrinkage, faster curing, better ductility, and increased tensile and compressive strength have all been shown using cereal straw. In terms of water absorption, hay excels.

Straw's energy efficiency and fire-retardant properties have been cited as prospective advantages. SEM technique was used in this study to examine the straw's ground samples. Straw has a low bulk density, which means it may be used to build lightweight materials and enhance a structure's hydrothermal quality.

### 2.1.4. Leaf Fibres

To put it another way: The term "leaf fibres" refers to the three types of plant fibres that come from tropical plants: sisal, banana, and pineapple fibres. It is one of the most well researched natural fibre types, and sisal fibres are no exception. The fibres of the sisal plant are harvested from the leaves of over 57 different kinds. Sizes vary from 6 to 10 centimeters wide by 50 to 250 centimeters long. The climatic conditions, soil conditions, harvesting period, and kind of sisal will all affect the size of the sisal leaf. [5]

The length of sisal fibres may be divided into three categories: A short fibre is less than 600 millimeters in length. A medium-sized fibre has a length of more than 600 mm but less than 700 mm. A fibre that is more than 700 millimeters long is classified as a long fibre. The fibre has a diameter of between 0.06 mm and 0.4 mm. Historically, gypsum plaster sheets were reinforced with sisal fibres because of their strong water absorption qualities (60 to 70 per cent).

### 2.2. Synthetic Fibres

There is a reason for the creation and production of synthetic fibres. In addition to carbon fibres, they include steel and glass fibres, plastic fibres, macro and micro plastic fibres, as well as synthetic fibres. The mechanical characteristics of the fibres will vary depending on the technique of manufacturing and the composition of the base material. The sorts of synthetic fibres and their qualities have evolved throughout time with the advancement of technology and the study of synthetic fibres [13]. Several synthetic fibres and their qualities are described in the following sections.

#### 2.2.1. Polymeric Fibres

Polymeric fibres come in a variety of forms, with polypropylene, nylon, and polyethene being the most often utilized. Micro plastic fibres or macro-plastic fibres are two types of polymeric fibres. Fibres made of polypropylene, polyethylene terephthalate, and polyethylene terephthalate are all macro synthetic fibres (PET). Mechanical and physical attributes are determined by the process used to create it as well as its raw material geometry and aspect ratio [10]. Even the recycled material's properties are taken into consideration if it was utilized to make the fibre. They may be utilized in the same ways as steel fibres, but they are lighter and more corrosion resistant.

Interest in macro plastic fibres has skyrocketed owing to their promise to be more environmentally friendly than steel reinforcement. As a result, polypropylene fibres are widely utilized and praised for their many benefits, including their ability to withstand corrosive and abrasive environments, as well as their resistance to alkalis, chemicals, and chlorides. Because they just need a little amount of material, they are reasonably priced. The strong tensile strength and high modulus of elasticity of polypropylene fibres make them ideal for a variety of mechanical applications. Polypropylene fibres have a low density, which may lead to floating difficulties in certain composite matrices. This might be a problem for some matrices since they have poor hydrophilic properties because they are hydrophobic.

#### 2.2.2. Steel Fibres

Steel fibres may lower building costs since they can be used in place of heavier and more time-consuming conventional reinforcement, such as steel mesh and steel rebars. Moreover, maintenance and labor costs are reduced, while the building site's security is enhanced [12]. As with steel reinforcement, one of the drawbacks of steel fibres is their susceptibility to corrosion, which may lead to degradation and deterioration of the original material over time.

**Properties of Steel Fibers**

- It increases the tensile strength of concrete.
- It is harder.
- It avoids corrosion and rust stains.
- They are more elastic.
- Steel fibres are available with standards as ASTM 820/96, ASTMC 1116/95 and DIN 1045.

- It has a tensile strength of 1.100 N/mm².
- They are available in the shapes like flat, hooked and undulated

### 2.2.3. Glass Fibres

The spinneret process used to make continuous basalt fibres is also used to make glass fibres. It is common to practice to employ overhead gas burners to heat glass fibres during manufacture. At 1400–1600 °C, the melting point of the glass is. Glass fibres have a lower alkali resistance than basalt fibres, but they outperform basalt in acid environments [14].

**Properties of Glass Fibers**

- It has a high ratio of surface area to weight.
- They have good thermal insulation.
- It has good tensile strength but has no strength against compression.
- Compressive strength is weak but can be increased by reinforcing it with plastic.
- When the glass fibre is reinforced with plastic, then reinforced material can resist both compressive and tensile forces as well.
- It is resistant to chemical attacks. However, if their surface area is increased, then it makes them more susceptible to chemical attack.
- They are corrosion resistant.

### 2.2.4. Carbon Fibres

Composites with better characteristics have been created by incorporating carbon fibres into materials. The incorporation of carbon fibres results in a composite with exceptional mechanical qualities, which can withstand high temperatures and have the added advantage of long-term durability. Despite the brittleness of carbon fibres, composites reinforced with carbon fibres offer exceptional characteristics [3]. It is difficult to make a strong link between carbon fibres and the material matrix because of their great qualities, and the production costs are expensive [15].

**Properties of Carbon Fibers**

- It has high tensile strength, low weight and low thermal expansion.
- They are rigid materials that are resistant to stretching and compression.
- It is chemically inert or unreactive materials.
- They are resistant to corrosion.
- Fibres containing about 85% carbon has an excellent flexural strength

Comparison of natural fibres and synthetic fibres show in below table 1

**Table 1. Comparison between natural fibres and synthetic fibres.**

| Aspects | Property | Natural fibres | Synthetic fibres |
|---|---|---|---|
| Technical | Mechanical properties | Moderate | High |

| | | | |
|---|---|---|---|
| | Moisture sensitivity | High | Low |
| | Thermal sensitivity | High | Low |
| Environmental | Resource | Infinite | Limited |
| | Production | Low | High |
| | Recyclability | Good | Moderate |

## 3. Applications of Fibres in Construction Material

In a variety of fields, including construction, the use of fibre-reinforced materials in composites has increased steadily across the world [16]. There are several advantages of using fibre-reinforced materials over non-reinforced ones. Examples of such advantages include the following:

1. Strength, toughness, durability, rigidity, and ductility have all been enhanced.
2. Improved resistance and performance in various conditions, as well as against physical and chemical corrosion and other assaults.
3. Stability has been increased.
4. In addition, the thermal characteristics and operating temperature have been improved significantly.
5. There will be a decrease in the thermal conductivity of the material.
6. Weight and density may be reduced to provide lighter and more energy and cost-effective product.
7. Fibres may take the place of more conventional techniques of reinforcing structures to reduce their complexity and installation costs.
8. Reduction in landfill volume and energy savings if a waste product is put to good use.
9. Prevents shrinkage, fissures, spalls, and swelling in the concrete
10. Natural, energy-efficient, or waste fibres have the added benefit of being environmentally friendly, economical, and long-lasting.

Fibres may be utilized for a wide range of applications and purposes. It is also possible to create high-performance composites with different matrices, which may be utilized for a variety of purposes. For example, fibres may be used in concrete, asphalt concrete pavements and binders and soil as well as in blocks and bricks and other building materials in the following area.

### 3.1. Fibres in Normal Concrete

Throughout the globe, concrete is one of the most common building materials used in both residential and commercial construction projects. Concrete can be molded into a wide variety of forms, is fire resistant, has a long lifespan, and is simple to work with. For concrete to function better, it must be reinforced to compensate for its weaknesses in compression and tension [17]. Dry materials are aggregates and cement, which are combined with water in a basic combination. Concrete often contains Portland cement.

 

Concrete may be used to create nonstructural and structural features that can withstand a variety of loads. Many types of infrastructure are built using concrete: pipelines; road networks; transportation systems; and buildings. Shotcrete, slabs-on-the-ground, and industrial slabs are just a few of the many applications for this versatile material. Fibres may be employed in their natural condition or formed into forms, such as reinforcing bars, to replace the heavier and more energy-intensive steel bars and meshes.

### 3.2. Fibres in Asphalt Concrete Pavements and Binders

Construction of road infrastructure and pavements worldwide relies heavily on asphalt concrete. Road performance, durability, and cost-effectiveness may all be improved by thoughtfully designing asphalt pavements [18]. An asphalt concrete pavement is made of the aforementioned material.

To enhance the HMA's toughness, fracture crack resistance, and stabilization of asphalt binders, adding fibres to asphalt mixes is essential. Fibres may enhance the mixture's down drained properties and even prevent the down drain from occurring. During the mixing process, bitumen may get separated from the binder and cause a variety of problems. Permanent deformation, rutting, fatigue fractures, thermal difficulties, raveling due to oxidation, and hardening of the binder are some of the issues with asphalt pavements. Due to the increased demands of today's traffic, durability is also a concern.

### 3.3. Fibres in Soil

In general, the soil is weak in both tension and shear strength, making it vulnerable to damage. Deformation is especially dangerous for soils that are too soft. Soil reinforcement is used to improve the soil's qualities. Clay, sand, silt, and gravel are the most prevalent types of soil. Soil qualities are influenced by local environmental factors, such as the climate.

Fibres may be used to increase the soil's tensile capacity, shear strength, ability to compress, density, and hydraulic conductivity, among other attributes that are lacking in the soil. It is also possible to limit or even eliminate shrinkage, which is a factor in the emergence of soil fractures. It is possible to increase the capacity of the soil to carry the load and to reduce settlement and deformation along a lateral plane by enhancing these qualities. Soils have been reinforced with a wide variety of natural and synthetic fibres for a variety of purposes. Pavement layers, retaining walls and rail embankments, slopes and foundations, and seismic engineering are just a few examples of where this material might be used.

### 3.4. Fibres in Earth Materials, Blocks, and Bricks

Since ancient times, the earth has been utilized as a building material all across the globe, particularly in areas with a poor economic status. Earth materials provide several ecological and economic advantages, including a lower environmental impact since they are easily accessible, emit less carbon dioxide, and need minimum processing. Even though the soil is classified as an earth material, the goal of this section is to examine the many kinds of fibres used to reinforce earth material in buildings, notably those intended for residential usage.

Fibres may be added to adobe bricks, compressed earth blocks, and procedures like earth plaster to improve their performance. Wet and soil components are the primary ingredients in the sundried blocks known as "adobe" blocks. In addition to the more typical compaction process, which involves pouring the material into a mould and compacting it with a vibrator before setting it in place, there are a variety of other ways for producing the various kinds of blocks, such as drying, baking, and firing them.

There are several advantages to using different fibres in different types of soil. As a result of the decreased weight of the block and the improved mechanical characteristics of the material (such as greater compressive strength and tensile strength as well as layer coherence and geometric integrity), these qualities may be improved. As the amount of garbage at landfills and the burning techniques used to dispose of it are decreased or eliminated, the use of natural fibres in earth material or blocks is sustainable, ecologically benign, and also saves energy and money.

### 3.4. Fibres in Other Applications

Fibres have been used in a variety of businesses outside of the building industry. Automobile, power, chemical, petrochemical, windmill blade, sports, ballistic, defense, and aeronautic sectors are only a few examples of this kind of business. The following is a list of some of the most popular ones.

Because of their superior mechanical qualities, carbon fibre composites have found widespread use in the automobile sector. Lightweight materials may be created by reinforcing them with carbon fibres, although this is often costly. For instance, a vehicle's dead weight may be reduced by 40% to 60%. Carbon fibres have also been employed in the aerospace, space technology, defense, and sports sectors when particular and advanced uses or technology are needed.

Since they have such good mechanical qualities, are lightweight, and can be made cheaply, glass fibre-reinforced polypropylene composites are becoming more popular in the automobile sector [20]. These composites have been used to make products like bus bumpers and vehicle seats.

For example, brake disc pads and automobile headliners are made from basalt fibres. Recyclability, high strength, ductility, corrosion resistance, impact, and wear make them desirable. Because of their high thermal conductivity and corrosion resistance, basalt fibres have been employed in the power business, and they've also been used to coat and preserve things in the chemical industry. Fibres of basalt have been employed in the petrochemical sector because of their poor heat conductivity.

Many sectors, including aircraft and automobiles, are becoming more interested in employing natural fibres [21]. This is mostly owing to their low price, their status as a renewable resource, and their promise for long-term growth. They may be used as a replacement for synthetic fibres in certain cases.

## 4. Conclusions

This research looked at the types, qualities, and uses of various fibres in a broad variety of building materials, such as ordinary concrete, asphalt concrete, soil, earth materials, blocks and bricks, composites, and other applications. They were compared and contrasted in terms of their benefits, drawbacks, and limits. Because they are lighter and take less energy, materials, and time to manufacture, synthetic fibres may cut building costs by replacing conventional reinforcements like steel mesh and steel rears. Synthetic fibres, on the other hand, are man-made, demand resources and energy, are difficult to recycle, and have a negative environmental effect.

There are several advantages to using natural fibres over synthetic fibres. They are easily accessible, inexpensive, energy-efficient, environmentally friendly, and may save resources and energy. They are biodegradable, renewable, and quite light in weight, too. Synthetic fibres might be replaced with natural fibres in certain cases. Natural fibres are more beneficial in construction for impact loading balancing since they are lighter and easier to make than synthetic fibres.

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