LECTURE NOTE

on

ADVANCE CONSTRUCTION TECHNIQUES & EQUIPMENTS

(6TH SEM. CIVIL)

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FIBERS :

Fiber or fibers is a class of material which are having continuous filaments or having discrete elongated pieces similar to the length of thread. Fibers are very important in the biology of plants and animals for holding tissue together. They are often used in the manufacture of other materials. Fibers can be spun into filaments or string or rope which can be used as a component of composite material or matted into sheets so as to make the products like paper or felt. Fibers are inorganic or organic, natural or synthetic. Synthetic fibers can be produced very cheaply and in large amounts as compared to natural fibers. Rayon and nylon are organic synthetic fibers. Burlap is a coarse jute or hemp which is a natural fiber. Hessian is a jute fabric. Silk and cotton are produced from natural fibers. Glass wool, lead wool and asbestos are mineral fibers of which glass wool and lead wool are synthetic fibers. Steel fiber, carbon fiber and glass fiber are the new and recent trends used in the construction work.

General Uses of Fibers

- Fibers are used for packing and making fabrics and felts.
- Glass wool made of very fine fibers of glass is used for making acid-proof and fire-proof fabrics.
- Glass wool is also used as a packing material for heat, sound and electric insulation. It is commonly used in a solar water system.
- Lead wool prepared from fine fibers of lead is used in water pipe joints to stop leakage of water. Natural jute fibers are extensively used in plumbing work to stop leakage of water.

Types of Fibers :

There are mainly three types of fibers which are commonly used as a construction materials.

1. Steel fiber

Steel fiber are made from the cold drawn steel wire with low content of carbon or stainless steel wire. They are manufactured in various types such as hooked steel fibers, undulated or flat steel fibers according to the need required in the construction project. These fibers are used in the construction for concrete reinforcement. Steel fiber reinforced concrete is less expensive than hand tied re-bar shape, dimensions and length of the fiber are more important because it increases the tensile strength of the concrete.

Steel fibers can only be used on surfaces so as to avoid corrosion and rust stains. Fiber-reinforced normal concrete is mostly used for on-ground floors and pavements and also used for the construction parts such as beams, pillars, foundation etc.

Properties of Steel Fibers

- It increases the tensile strength of concrete.
- It is more tough and hard.
- It avoids corrosion and rust stains.
- They are more elastic in nature.
- Steel fibers 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.

Applications of Steel Fibers on Field

- Steel fibers are highly used in tunnel lining work.
- It is mostly used in the construction of airport runways and highway pavements.
- Most commonly used in precast concrete so as to increase the tensile strength.
- They are used in shotcrete.
- Used in the construction of parking.
- It is used in anti-seismic buildings.

2. Carbon fibers

Carbon fiber is a material consisting of extremely thin fibers about 0.005 mm to 0.010 mm in diameter and mostly composed of carbon atoms. Carbon fiber is alternately called graphite fiber. The carbon atoms are bonded together in microscopic crystals which are more or less aligned parallel to the long axis of the fiber. The crystal alignment makes size of fiber more strong. Number of carbon fibers are twisted together so as to form a Yarn which can be used as it exist or woven into a fabric.

It can be combined with a plastic resin and wound or moulded to form composite materials like carbon fiber reinforced plastic to provide a high strength to weight ratio of the materials. The atomic structure of carbon fiber is similar to that of graphite consisting of sheets of carbon atoms arranged in a regular hexagonal pattern. Carbon fibers shows the number of properties very close to the properties of asbestos. Each carbon filament thread is a bundle of many thousand carbon filaments. A single such filament is a thin tube with a diameter of 5-8 μm (i.e. 5-8 micrometers) and consists of almost exclusively of carbon.

Properties of Carbon Fibers

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

Application of Carbon Fibers

- Carbon fiber is mostly used to reinforce composite material.
- Reinforced Carbon-Carbon (RCC) consists of carbon fiber-reinforced graphite and is used structurally in high temperature applications.
- It increases the tensile as well as compressive strength of concrete.
- Due to high tensile strength, low weight and low thermal expansion it makes the carbon fiber very popular in aerospace, military and motersports along with other competition sports.

3. Glass fibers

It is also called as fiber glass. Glass fiber is the material made from extremely fine fibers of glass. It was invented in 1938 by Russell Games Slayter. In 1893, Edward Drummond Libbey exhibited a dress at the World's Calumbian Exposition incorporating glass fibers with the diameter and texture of silk fibers. This was first worn by the well known and popular stage actress of the time Georgia Cayvan. There are two main types of glass fiber manufacture and two main types of glass fiber product. First fiber is made either from a direct melt process or a marble remelt process. Both start with the raw materials in solid form.It is almost and always mode of platinum alloyed with rhodium for better durability. Platinum is used because the glass melt has a natural affinity for wetting it. The fresh and thin fibers are more strong because the thinner fibers are more ductile.

Properties of Glass Fibers

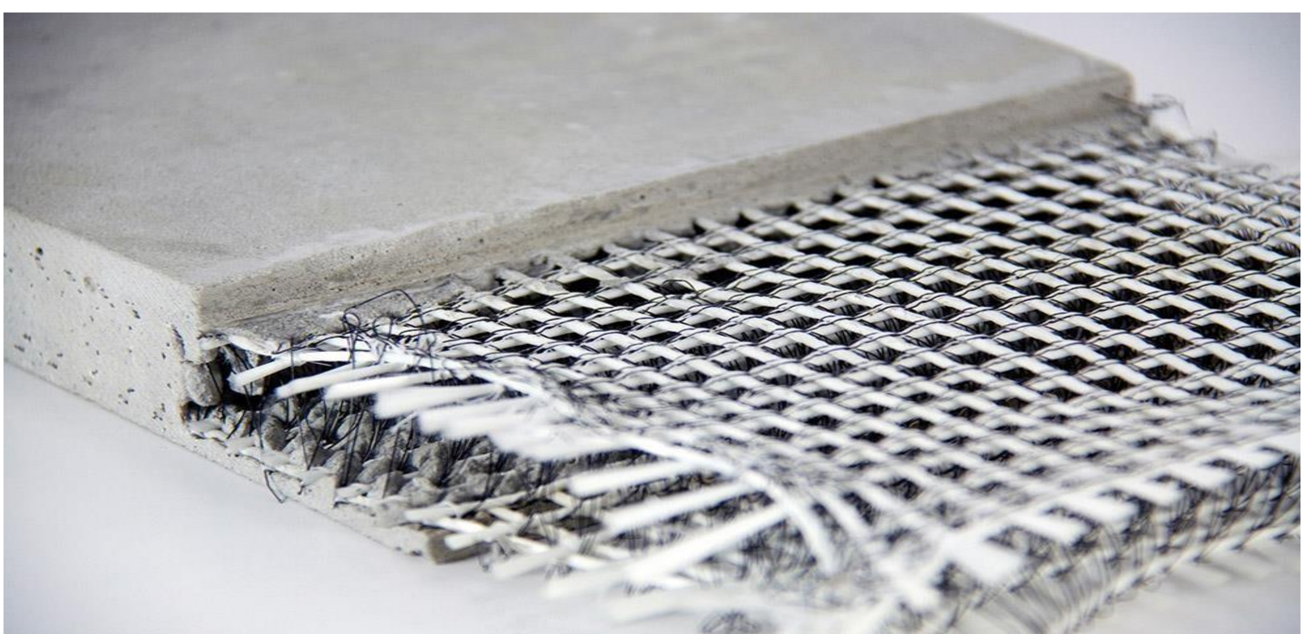
- It has high ratio of surface area to weight.
- They have good thermal insulation.
- It has a good tensile strength but has no strength against compression.
- Compressive strength is weak but can be increased by reinforcing it with plastic.
- When the glass fiber is reinforced with plastic, then reinforced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

- They are corrosion resistant.

Application of Glass Fibers

- Corrugated fiber glass panels are widely used for outdoor canopy or greenhouse construction.
- It is used as a reinforcing agent for many polymer products like FRP and GRP which uses tubs, pipes for drinking water and ‘sewers, office plant containers and flat roof systems etc.
- It is reinforced with plastic material so as to increase tensile strength.
- Uses of regular fiber glass are mats, insulation, reinforcement sound absorption, heat resistance fabrics, corrosion resistant fabrics and high strength fabrics.
- Glass fiber reinforced plastics are used in the house building market for the production of roofing laminate, door surrounds, over-door canopies, window canopies and dormers, chimneys, coping system, heads with keystone and sill etc.
- The reinforced glass fiber with polymer and plastic is commonly used in fire water systems, cooling water systems, drinking water systems, sewage systems, waste water systems, gas system etc.

Steel Fibers



Glass Fibers

Carbon Fibers

What is Industrial Timber?

Industrial timber is nothing but timber product manufactured scientifically in factories. Because of its scientific nature, it is stronger and durable than ordinary timber materials. It also contains desired shape and size.

Properties of Artificial Timber:

- It can be made in the form of blocks, beams, and panel. Just as wood can be cut into various sizes and shapes, our artificial timber can be re-sized for various uses in furniture, flooring, or even construction.
- Its density can be changed, that is, it can be made heavier/stronger or lighter. Depending on what it is going to be used for, RRT's artificial timber panels can be made to strong enough to take on huge loads or light enough for a baby's cot.
- It resembles and feels like natural timber in grain and color. Any natural wood finish can be arrived at to present an authentic appearance.
- It can be sawed and painted on. It can also be carved on and made into door or wall panels with elaborate designs, for instance (please see picture of carved wood panel.
- It has nail and screw holding capacity.
- It is a good thermal insulator, it helps retain heat in wood houses. Wood flooring is very common in colder countries, because it helps trap heat apart from the aesthetic value. Artificial wood serves both purposes. Finally, just like natural wood, artificial wood is bio-degradable and can be powdered and disposed off safely.
    - Termite-proof/borer-resistant.
    - Retards fire. RRT's innovation, artificial wood, is not inflammable. This quality is one of its greatest strengths when compared to natural wood. So, the artificial wood can be safely used indoors as well as in industrial uses.
    - Is buoyant, helps make boats and other floating devices. Also, as its density can be changed, too, it is ideal material for building boats.

- Resistant against the action of hot water and chemicals including salts, acids, and bases. This makes it ideal in use even in industrial settings as flooring or paneling.

Different Types of Industrial Timber

Following are the different form of industrial timber:

- Veneers
- Plywood
- Fiber boards
- Impreg timbers
- Compreg timbers
- Hard boards
- Glulam
- Chip board
- Block board
- Flush door shutters

Veneers

Veneers are nothing but thin layers of wood which are obtained by cutting the wood with sharp knife in rotary cutter. In rotary cutter, the wood log is rotated against the sharp knife or saw and cuts it into thin sheets. These thin sheets are dried in kilns and finally veneers are obtained. Veneers are used to manufacture different wood products like plywood, block boards etc.

Plywood

Ply means thin. Plywood is a board obtained by adding thin layers of wood or veneers on one above each other. The joining of successive layers is done by suitable adhesives. The layers are glued and pressed with some pressure either in hot or cold condition. In hot conditions 150 to 200^{o}C temperature is marinated and hydraulic press is used to press the layers. In cold conditions, room temperature is maintained and 0.7 to 1.4 N/mm^2 pressure is applied. Plywood has so many uses. It is used for doors, partition walls, ceilings, paneling walls, formwork for concrete etc. Due to its decorative appearance, it is used for buildings like theaters, auditoriums, temples, churches, restaurants etc. in architectural purpose.

Fiber Boards

Fiber boards are made of wood fibers, vegetable fibers etc. They are rigid boards and called as reconstructed wood. The collected fibers are boiled in hot water and then transferred into closed vessel. Steam with low pressure is pumped into the vessel and pressure increased suddenly. Due to sudden increment of pressure, the wood fibers explode and natural adhesive gets separated from the fibers. Then they are cleaned and spread on wire screen in the form of loose sheets. This matter is pressed in between steel plates and finally fiber boards are obtained. Fiber boards are used for several purposes in construction industry such as for wall paneling, ceilings, partitions, flush doors, flooring material etc. They are also used

as sound insulating material.

Impreg Timbers

Impreg timber is a timber covered fully or partly with resin. Thin layers of wood or veneers are taken and dipped in resin solution. Generally used resin is phenol formaldehyde. The resin solution fills up the voids in the wood and consolidated mass occurs. Then it is heated at 150 to 160^{o}C and finally impreg timber develops. This is available in market with different names such as sungloss, sunmica, Formica etc. Impreg timber has good resistance against moisture, weathering, acids and electricity. It is strong, durable and provides beautiful appearance. It is used form making wood molds, furniture, decorative products etc.

Compreg Timbers

It is similar to impreg timber but in this case, the timber is cured under pressure conditions. So, it is more strengthened than impreg timber. Its specific gravity lies from 1.30 to 1.35.

Hard Boards

Hard board is usually 3 mm thick and made from wood pulp. Wood pulp is compressed with some pressure and made into solid boards. The top surface of board is smooth and hard while the bottom surface is rough. Hard boards are generally classified as three types as follows:

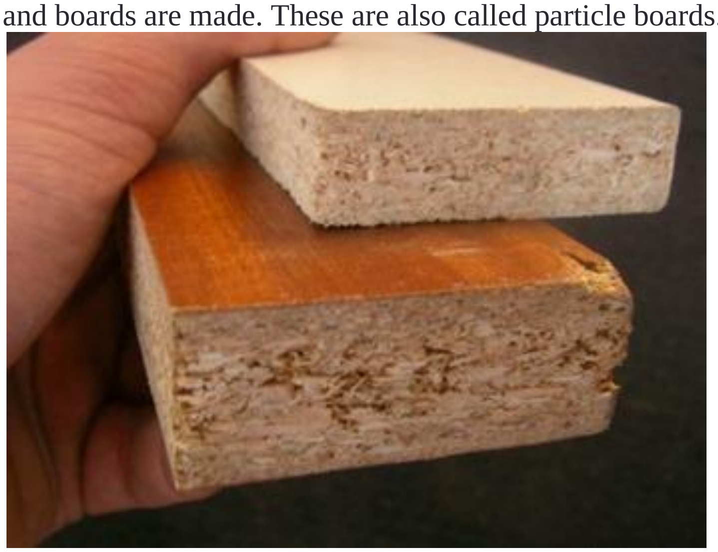
Types	**Density (kg/m^3)**	**Available thickness (mm)**
Medium	480 – 800	6,8,10,12
Normal	800-1200	3.4.5.6.9.12
Tempered	>1200	3,4,5,6,9,12

Glulam

Glulam means glued and laminated wood. Solid wood veneers are glued to form sheets and then laminated with suitable resins. This type of sheet is very much suitable in the construction of chemical factories, long span roofs in sports stadium, indoor swimming pools etc. Curved wood structures can also be constructed using glulam sheets.

Chip Board

Chip boards are another type of industrial timber which are made of wood particles or rice husk ash or bagasse. These are dissolved in resins for some time and heated. After then it is pressed with some pressure and boards are made. These are also called particle boards.



Block Board

Block board is a board containing core made of wood strips. The wood strips are generally obtained from the leftovers from solid timber conversion etc. These strips are glued and made into solid form. Veneers are used as faces to cover this solid core. The width of core should not exceed 25mm. If the width of core is less than 7mm then it is called as lamin board. Block boards are generally used for partitions, paneling, marine and river crafts, railway carriages etc.

Flush Door Shutters

Flush door shutters made in factories are widely using nowadays. They are generally available with 25mm, 30mm or 35mm thicknesses. Factory made flush board shutters are of different types such as cellular core, hollow core, block board core etc.

Acoustic Materials

When the sound intensity is more, then it gives the great trouble or nuisance to the particular area like auditorium, cinema hall, studio, recreation center, entertainment hall, college reading hall. Hence it is very important to make that area or room to be sound proof by using a suitable material called as ‘Acoustic material’. It is measured in decibles (db).

Acoustic material play a vital role in the various area of building construction. In studio, class room, reading hall, cinema theatre, more concentration is required to listen, hence the acoustics treatment is provided so as to control the outside as well as inside sound of the various building until such that sound will be audiable without any nuisance or disturbance.

Types of Acoustic Material

- Acoustic plaster.
- Acoustic tiles.
- Perforated plywood.
- Fibrous plaster.
- Staw board.
- Pulp board.
- Compressed fibre board.
- Hair felt.
- Cork board slabs.
- Foam glass.
- Asbestos cement boards.
- Thermocoal.
- Foam plastic.
- Chip boards.
- Gasket cork sheet.
- Acoustic foam.

Properties of Acoustic Material

- Sound energy is captured and adsorbed.
- It has a low reflection and high absorption of sound.
- Higher density improves the sound absorption efficiency at lower frequencies.
- Higher density material help to maintain a low flammability performance. Hence acoustic material should have higher density.

- It controls the sound and noise levels from machinery and other sources for environmental amelioration and regulatory compliance.
- Acoustic material reduces the energy of sound waves as they pass through.
- It suppresses echoes, reverberation, resonance and reflection.

Uses of Acoustic Material

- Acoustic materials can be used for noise reduction and noise absorption.
- It makes the sound more audiable which is clear to listen without any disturbances.
- It suppresses echoes, reverboration, reflection and resonance.
- Important specifications for noise reduction and noise absorption products include noise attenuation and noise reduction coefficient.
- A vinyl acoustic barrier blocks controls airborne noise (street traffic, voices, music) from passing through a wall ceiling or floor.
- Acoustic foam and acoustic ceiling tiles absorb sound so as to minimize echo and reverboration within a room.
- Sound proof doors and windows are designed to reduce the transmission of sound.
- Building techniques such as double wall construction or cavity wall construction and staggering wall studs can improve the sound proofing of a room.
- A sound proof wall (treated by a accurate material) can incorporate sound proofing and acoustic materials to meet desired sound transmission class (STC) values.

Wall Claddings:

Wall claddings are available in several types and forms - from normal wooden panels to 3D wall panels. Their types differ in material, texture and dimensions. Some of the common indoor wall cladding types are wood cladding, steel cladding, stone cladding, etc.

Important types of indoor wall cladding available in the market are discussed in this article.

1. Stone Cladding

Among all the cladding types, the stone cladding is regarded as the most natural and fresh-looking cladding. It can be installed over a surface either made of concrete or steel. These are referred to as lightweight simulated stone products which have a concrete type-base that facilitates its instalment.


Fig.1. Stone Cladding

Stone cladding is mainly used in the living rooms, indoor gardens and in bathroom walls. The cladding unit is highly durable but is really expensive to install.

2. Vinyl Cladding

Vinyl cladding is a plastic cladding option provided for the exterior walls of the building. It is applied mainly for small apartments, decoration and for weatherproofing. It is used by the majority of homes as it provides adequate protection and also because it is a low-cost option. When compared with wood and aluminium cladding material, this is not considered a good quality option.


Fig.2. Vinyl Cladding; Image Courtesy: prosideselect

3. Aluminium Cladding

Aluminium cladding is costly when compared with vinyl cladding units. But aluminium cladding guarantees more durability and longer life than the vinyl cladding. These units are subjected to less maintenance or replacement over the years. Aluminium cladding is used mainly for basement and storage walls of the building. High quality and treated aluminium cladding are used for large commercial buildings and structures.

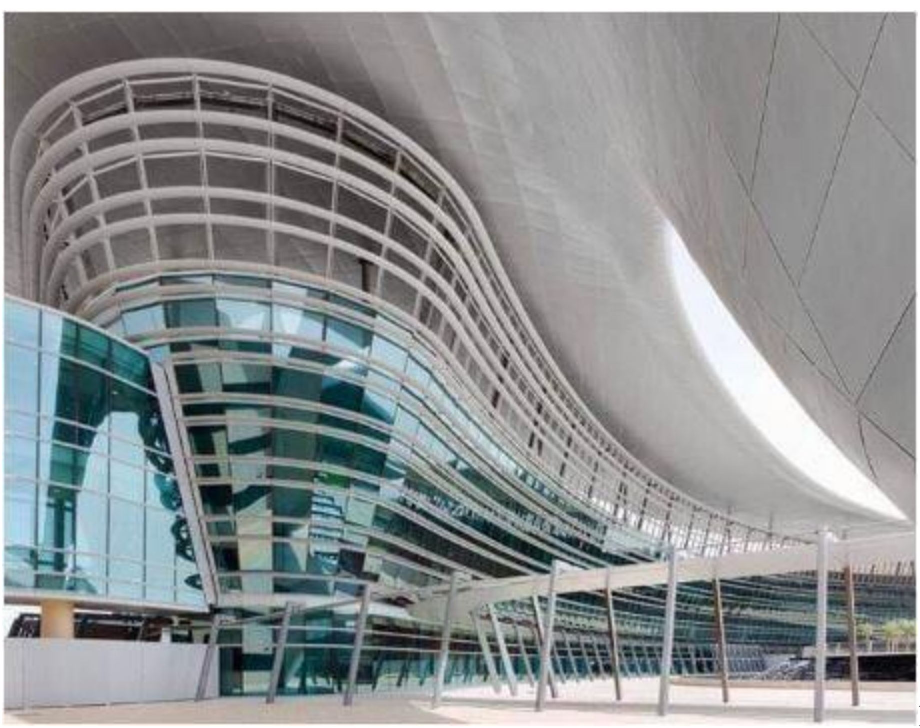


Fig.3. Aluminium Cladding; Image Courtesy: AFS International

4. Wooden Cladding

This is one of the highly-rated claddings next to stone cladding. Wooden cladding is stronger than aluminium and vinyl cladding. Wooden cladding brings an attractive finish to the wall when installed. So this is mostly used to improve the aesthetic appearance. Cedar or redwood are mainly used to create wooden cladding units.

Wooden cladding instalment is a very expensive process. Its maintenance is also costly which makes this a costly cladding option.

Fig.4. 3D Wooden Cladding; Image Courtesy: Higgins Cladding

5. Brick Cladding

Brick cladding provides a lovely decorative look to the walls. The installation of the brick cladding unit is difficult and expensive. But in terms of maintenance brick cladding is less expensive compared with wooden cladding units. If you can't afford wooden cladding, it is recommended to go for brick cladding units.


Fig.5. Brick Cladding Units; Image Courtesy: Deco Stones

6. Fibre Cement Cladding

Fibre cement cladding unit is an alternative for people who are looking for strong and beautiful cladding units for the building walls. These units gain high strength and are almost similar to wooden cladding units. These unit are very easy to install and are less expensive. Fibre cement cladding units have zero maintenance.


Fig.6. Fibre Cement Cladding

7. Stainless Steel Cladding

The stainless steel cladding is a very durable cladding solution. It has high resistance to environmental effects. It is manufactured with a minimum of 10% of chromium so that when exposed to oxygen in the atmosphere an oxide of chromium is formed. This oxide forms a passive layer on the surface of the cladding that is a protecting coating towards further corrosion.

Fig.7. Stainless Steel Cladding Units; Image Courtesy: ArchiExpo

Plaster Boards:

1. Plasterboard is basically an inner layer of gypsum sandwiched between two outer layers of lining paper including various additives in the gypsum layer and varying the weight and strength of the lining paper, will give the finished board different properties
2. Gypsum is made up of crystals containing a small amount of water (known as water of crystallisation). In a fire, this water is driven-off, helping to keep the temperature of the fire down, and preventing rapid fire spread. Plasterboards, such as Gyproc FireLine, are therefore used extensively for fire protection proving up to 4 hours protection in some special multi-layer system applications.
3. Plasterboard is good for cutting down noise transmission particularly airborne sounds such as speech and music. High performance plasterboards, such as Gyproc SoundBloc, have a specially designed core that provides even better insulation against sound.
4. Whilst standard plasterboard is ideal for most environments, it shouldn't be used in constantly wet conditions. For kitchens, bathrooms and similar wet areas, Gyproc Moisture Resistant, specially designed with silicone additives in the core, or Glasroc H Tilebacker, a highly water resistant Class A1, non-combustible glass reinforced gypsum board, should be used.
5. Glasroc F MultiBoard, a glass-fibre reinforced gypsum board, is not made in the traditional way with lining paper. Instead, the boards are strengthened with layers of glass fibre immediately below each surface. This gives them good all-round performance, a high quality durable plaster finish, and enables them to be easily bent for use on curved structures. They are excellent for semi-exposed areas, such as soffits and the like.
6. Most common plasterboards come with the option of either tapered edge or square edge. Tapered edge boards are ideal for either jointing or skimming, while square edge is generally used for textured finishes.
7. Plasterboard generally comes in 1200mm wide sheets, designed to suit the standard 600mm stud spacing used in housing today. Other widths are available for specific systems.
8. Most standard plasterboard has one ivory face and one brown. The liner on the ivory face is specially designed for plastering plaster should not be applied to the brown reverse face. Paper liners are generally made from recycled paper a big plus for the environment.
9. Joint cracking on plasterboard ceilings is almost invariably caused by warping of the joists as the wood dries out. Screw fixing the boards will generally prevent the problem occurring. If you want to go further use the British Gypsum Gypframe RB1 Resilient Bar or Gypframe RB2 SureFix Bar, designed to upgrade ceilings to Building Regulations Approved Document E acoustic standards, which will virtually eliminate the chance of movement problems.
10. Although you can apply wallpaper directly to the paper surface of plasterboard, ideally the surface should first be sealed with one coat of Gyproc Drywall Sealer to allow easy stripping at a later date.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Micro Silica:

Concrete is the most important engineering material in construction industry because of its inherent strength properties. However, the addition of some other materials may change the properties of concrete. With increase in trend towards the wider use of concrete for pre-stressed concrete and high rise buildings there is a growing demand of concrete with higher compressive strength. Micro-silica, also called as silica fumes is produced in electric arc furnace as a byproduct of the production of elemental silicons or alloys containing silicon. It consists primarily of very fine smooth spherical silicon oxide particles with an extremely high surface area. Micro-silica particles are 100 times smaller than the average cement particle. Its handling and disposal is a point of concern because of the environment concerns. Silica fume is usually categorized as a supplementary cementitious material. These materials exhibit pozzolanic properties, cementitious properties and a combination of both properties.

Due to these properties, it can affect the concrete behavior in many ways. The paper highlights the important physical and chemical properties of microsilica and its contribution in improving the qualities of concrete. Keywords: silica fumes, pozzolanic, cementitions, improving, concrete.

1. Introduction Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by- product of the silicon and at al ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. Silica fume is an ultrafine airborne material with spherical particles. Micro-silica in concrete contributes to strength and durability two ways: As a pozzolanic material, micro-silica provides a more uniform distribution and a greater volume of hydration products. As a filler, micro-silica decreases the average size of pores in the cement paste. Micro- silica effectiveness as a pozzolanic material and as a filler depends largely on its composition and particle size which in turn depend on the design of the furnace and the composition of the raw materials with which the furnace is charged. 2. Physical and Chemical Composition Table 1: Micro-silica's chemical and physical typical composition. Unit Micro-silica SiO_2 % 90 – 98, CaO % 0.2 - 0.7 , Al_2O_3 % 0.4 - 0.9, Fe_2O_3 % 1 – 2 Other % 2 – 3 S.G Kg/m3 2200 Bulk density Kg/m3 550 – 650 Surface area m2/kg 20,000 .

4. Silica Fume Applications in Concrete Because of the pozzolanic and micro-filler effect of micro-silica, its use in concrete can improve many of its properties opening up a wide range of applications including:-

Corrosion Resistance: The reduced permeability of micro-silica provides protection against intrusion of chloride ions thereby increasing the time taken for the chloride ions to reach the steel bar and initiate corrosion. In addition, micro-silica concrete has much higher electrical resistivity compared to OPC concrete thus slowing down the corrosion rate. The combined effect generally increased structures life by 5 –10 times.
Sulphate Resistance :Micro-silica concrete has a low penetrability and high chemical resistance that provides a higher degree of protection against sulphates than low C3A sulphate resisting cements or other cementitious binder systems.

Heat Reduction: By replacing cement with Micro-silica and observing the efficiency factor of Microsilica, a lower maximum temperature rise and temperature differential will take place for concrete with the same strength. It performs better than slag and fly-ash blends in thick sections. It is also the most effective way of achieving low heat without sacrificing early age strength.

Waterproofing : Silica Fume Waterproof Concrete Because of its low permeability, micro-silica can be use as an integral water-proofer for below ground structures where some dampness is acceptable, eg Car parks.

High Strength Concrete: Micro-silica in conjunction with super-plasticizers is used to produce very high strength concrete (70 – 120 MPa). It is also much easier to pump micro-silica concrete up the high rise buildings during construction.

Abrasion Resistance: Micro-silica concrete has very high abrasion resistance. In floor and pavement construction it's use saves money and time and improves operational efficiencies for the facility operator. It also improves the hydraulic abrasion-erosion resistance of concrete thus making it suitable for use in dam spillways.

Chemical Resistance: Micro-silica concrete is widely used in industrial structures exposed to an array of chemicals aggressive. In the alimentary industry the exposure comes from fat acids and other acids, detergents, etc. In the chemical industry there is exposure from mineral acids, phosphates, nitrates, petrochemicals, etc. Micro-silica concrete is therefore invaluable in the industrial and agricultural sectors.

Artificial Sand:

Artificial sand, also called crushed sand or mechanical sand (m sand), refers to rocks, mine tailings or industrial waste granules with a particle size of less than 4.75 mm. It is processed by mechanical crushing and sieving.

In China, the artificial sand was mainly used in the construction of hydropower systems. For example, the Three Gorges Project and the Yellow River Xiaolangdi Project used artificial sand to prepare concrete. Due to the remote environment of the hydropower project and the high quality of sand and gravel, the projects have taken the materials locally.

Many Indian states have decreed the use of crushed sand in infrastructure construction because of its high compressive strength and cohesion and the adverse environmental effects of river sand mining, which will greatly boost the demand for artificial sand.

Artificial sand

The factors that promote the development of artificial sand

There are both natural and human factors in the increasing demand for artificial sand. The former is that the natural sand is about to run out, while human factors include people's requirements for environmental protection and the need for high-quality concrete.

1. Natural sand depletion

With the development of infrastructure, the natural sand resources formed by hundreds of thousands of years in many countries and regions have been almost exhausted, which has affected the further development of construction projects.

2. The need for energy saving and environmental protection

Reason 1: River sand mining causes river pollution.

Driven by huge interests, natural sand has been indiscriminately mining, which changes the river course, affects the safety of river embankments, destroys the living environment of fish and contaminates the groundwater. The crushed stone sand is an important alternative resource to change this phenomenon.

Reason 2: River sand mining causes tailings.

In the process of mining river sand, it often produces a large amount of tailings which is not used reasonably. Especially in small mines, the tailings are piled up at random, occupying land and polluting the environment.

Reason 3: A lot of construction waste is wasted.

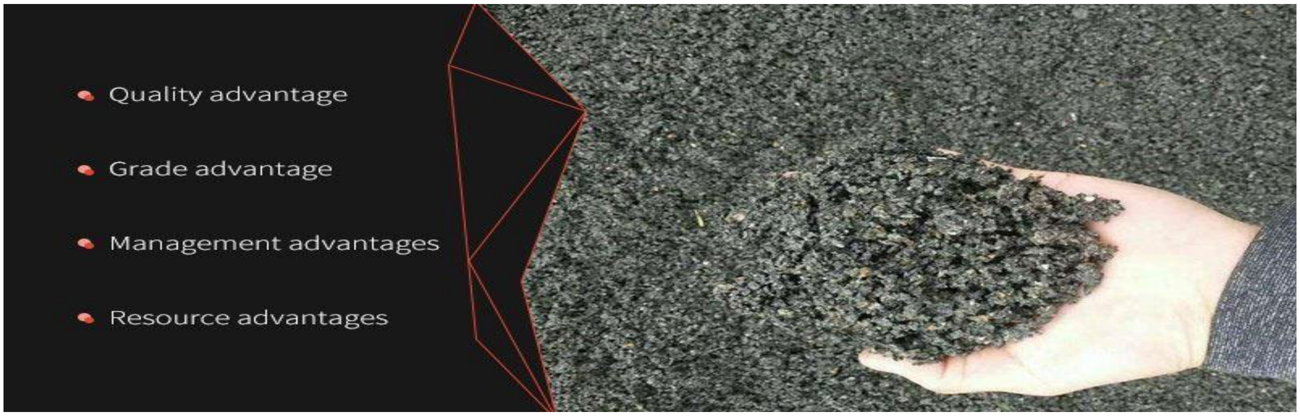
Besides, in urban planning and construction, a large amount of construction waste is generated, which actually can be crushed by the crushers to produce the artificial sand and aggregates for promoting resource utilization.

3. The need for the development of high-performance concrete technology

With the rapid development of concrete technology, the comprehensive performance of high-performance concrete and high-strength structural concrete has higher requirements on the quality of aggregates, requiring it with stable quality, good gradation and shape, while less and less natural sand meets the requirements. Therefore, people are turning their focus on artificial sand.

Artificial sand and mixed sand are mainly used in building construction, municipal construction, transportation, and other projects whose concrete strength grade is below M60. When meeting the corresponding technical requirements, they can also be used for concrete projects such as ports and water conservancy.

Comparison of artificial sand and natural sand



Comparison between artificial sand and natural sand

1. **Quality advantage:** The source of sand resources is stable; mechanized production mode ensures an adjustable and controllable quality.
2. **Grade advantage:** artificial sand has high surface energy and hydrophilicity; it has complete gradation; the particles gradation is stable and adjustable; the grain shape can be improved.
3. **Management advantages:** There are stable legal entities, mining licenses, fixed business locations, which is easy to trace.
4. **Resource advantages:** In addition to mines, various waste resources such as tailings and construction waste can be utilized.

5. Properties of artificial sand vs river sand

Shape	Cubical	Spherical
Ability to hold surface moisture	10%	7%
Compressive strength	Higher	Lower
Flexural strength	Higher	Lower
Impurity	Less	More (seaweed, bones, shells, mica and silt, etc.)
Grade	Can be controlled	Cannot be controlled

Bonding Agents & Adhesives:

Concrete bonding agents are natural or synthetic materials used to join the old and new concrete surfaces. This agent can also be used to join the successive concrete layers. This chemical helps to allow different concrete surfaces to behave like a single unit.

The properties, functions, and types of concrete bonding agents are explained briefly in this article.

Functions of Concrete Bonding Agent

The cement present in a concrete mix does not have any bonding agent within it. When a layer of fresh concrete is added over an existing or old concrete layer, they exist as two separate layers without any bond. So a bonding agent must be introduced between the layers.

The use of a bonding agent helps the different concrete layers to behave like a single unit, thus increasing the strength and performance of the structure.

The bonding agent is applied over the existing surface of the concrete so that the new layer of fresh concrete successfully adheres to the old layer. The two main factors that affect the bonding between old and new concrete are:

1. Surface preparation and cleanliness of the existing surface
2. Strength and integrity of the old surface

Characteristics of Bonding Agents

The main characteristics of bonding agents are:

1. Bonding agents are easy to use and apply.
2. They reduce cracks formed in shrinkage
3. The permeability of concrete is reduced
4. The use of bonding agents improves adhesion between the layer of concrete.
5. The tensile, flexural and bond strength of the concrete or mortar are increased
6. Bonding agents have high resistance against frost and chemical actions

How to Use Concrete Bonding Agent?

The application of bonding agent is performed by the following procedure:

1. Initially, the existing concrete surface is cleaned. Any dirt, dust, oil, efflorescence on the surface must be removed completely to facilitate the proper working of the bonding agent. Excessive dirt on concrete surfaces can be cleaned by pressure washing or vacuum shot blasting.

2. After the concrete surface is cleaned, the admixture is prepared. The chemical is shaken before use. It is diluted with water and mixed properly. It is always recommended to look through the manufacturer's guidelines to clearly follow the application procedures.
3. The next step is to properly mix the mixture. The manufacturer's guidelines would give an idea about the time within which the mix must be applied once the chemical is diluted with water.
4. A primary layer of bonding agent is applied on the existing surface over which the fresh concrete mix is placed. The concreting must be done before the primary coating starts to dry.
5. After placing the concrete layer, it is smoothened using a trowel and later cured.

Different Types of Concrete Bonding Agents Used in Construction

Different concrete bonding agents are

1. Epoxy Bonding Agents

This is an ideal resin for high performance and lightweight concrete parts. This resin wets-out fast. They impart high compressive strength, strong adhesion, and high chemical resistance. They are not only used to bond concrete layers but also to join concrete and steel.

2. Acrylic Latex Bonding Agents

This agent is primarily used to bond fresh concrete with a surface of old concrete. These are a combination of polymers and copolymers which is milky white in color. Acrylic latex bonding agents are applied on the surface either by brush, or trowels or rollers.


Fig.1. Application of Latex Bonding Agent

3. Polyvinyl Acetate(PVA)

This agent is mainly used for the repair works in concrete. PVA offers great water resistance, ultraviolet stability, and aging characteristics. It has gained popularity due to its compatibility with cement.

Prefabrication Building Construction: An Indian Perspective

Prefabrication has brought a substantial change in the development of construction industry worldwide over the last few decades. It ensures the strength, economy and environmental performance of the structures and hence is preferred over the onsite construction. Pre-assembly, prefabrication, modularisation, system buildings and industrialised buildings are the various terms used to describe the processes of manufacturing of modular units on-site or off-site. There are various types of modular precast building construction techniques prevalent worldwide. This article discusses the various types of prefabrication technologies along with available standards & codal provisions, its advantages, disadvantages.

Prefabrication usage large panel technology was initially developed in the mid 1960s. This is quick construction of huge numbers of building units at a minimal cost[1]. It is referred as off-site construction and fabricating of some or all elements of structure in industrial units, and transporting and assembling them to the construction site where the building is to be made[2]. It is learnt that this construction technique exists from prehistoric times and has not been evolved recently. “The Stonehenge” is a prominent example as it was also completed in different stages as shown in Fig. 1. Concentric rings are made by the arrangement of columns standing in height. To ensure the stability of structure Tenon and Mortise joints were used [3].

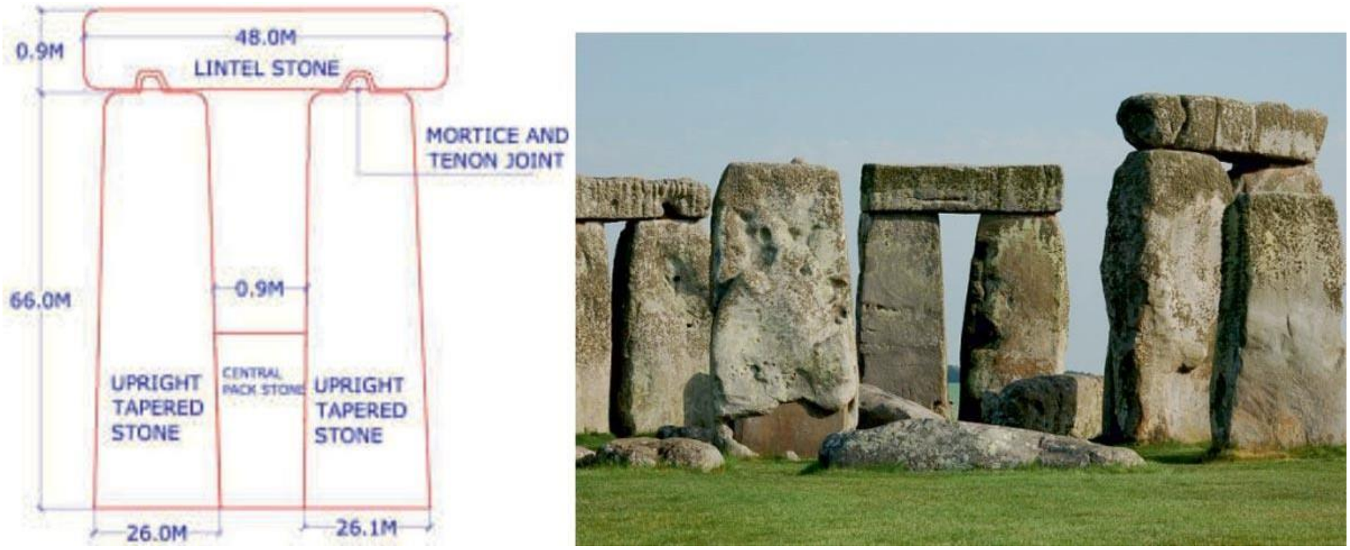


Figure 1: Stone Henge

Presently, construction materials and techniques have a severe competition: concrete against steel, precast concrete against in situ concrete or steel [4]. It can be produced with excellent quality construction as manufacturing is done under controlled conditions. Thus it’s a large potential of the future in the construction site [5]. Precast concrete buildings systems are attracting people for wide applicability as they are accessible in numerous shape, sizes, as well as structural elements and unreinforced pieces. In construction industry of every country it is the backbone for the expansion of fresh ideas [6].Designing with prefab mechanism is not a barrier to creativity; on the contrary these are standardized components and provide group customization at lower costs through economies of high volume work [7].

Global Scenario

The prefabricated construction system has been identified as one of the replacement to altering the speed of conventional construction methods at a rapid rate. These modules are then transported and installed on-site as load-bearing structural blocks of the structure. This type of prefabricated structure also provides environmental benefits, such as the decline of construction waste and CO_2 emissions, and less interruption to the building site’s neighbours by minimizing on-site noise and dust. These advantages are the driving force within the European building industry for the expansion of prefabricated building systems. Moreover, due to increase in population, other countries (i.e. US, Canada, Japan, etc.) also use modular construction technology to construct houses, apartments, offices, etc [8]. Sustainable growth has become globally essential as human race moves through the 21st century. The mainstream construction “work” is, consequently, transferred from the site to the manufacturing units. Assembly lines will carry out most of the work, which means numerous parallel activities can be carried out with no stoppage. The procedure is highly planned, which requires a smaller labour force at higher productivity. Prefabricated construction improves quality, safety, productivity, labour efficiency, construction timeframe, construction waste, noise, dust, and energy use. These advantages can improve the entire industry and benefit all stakeholders in the industry chain, making prefabricated construction more green, environmentally-friendly, and sustainable [9].

Prefabrication Adoption in India

The prefab production was pioneered by Hindustan Housing Factory. The corporation transformed its name due to the diversity of its operations and is now recognized as Hindustan Prefab Limited or HPL. The government-run corporation prefabricates mainly precast concrete for architectural and civil projects and is located in Delhi. When components are manufactured in a stable environment, quality of construction increases. Materials are used more resourcefully, are safer from climatic damage, and can be reused [2]. In the last few decades, Indian Infrastructure and Construction sector has grown exponentially. It is main driving factor for the economic growth. The manufacturing is focusing to take up more versatile and technically intense projects. Consequently, the focal point has moved from cost efficiency to time and capability [10]. On 25th June 2015 The Pradhan Mantri Awas Yojna (PMAY) was launched which involve manufacture of about 20 million houses by 2022 for urban poor while rural housing which envisages 10 million houses in next three years was launched on 1st April, 2016. In order to attain this enormous task, Ministry of Housing and Urban Development, GoI has adopted numerous innovative pre-fab construction systems, developed within the country[11]. So, there is a need to change our gears in the direction of the prefabrication and pre-cast techniques which stress upon the reduced time and the enlarged productivity. It will not end-the product but would only have an effect on the procedure of construction. As it will offer opportunity for dealing with the lack of skilful labour and the deteriorating workmanship standards. The quality of construction is much superior when components are manufactured in a steady environment [12].

They also have the potential to deal with the problem of mass housing crisis in India that we face these days. There is a huge housing crisis in cities which has rendered millions to live in dilapidated conditions. The simple way to clear this build-up is mass housing. The idea of mass housing with a superior density and floor area ratio seems to resolve the setback considerably. This reduces cost on individual owners. Mass housing further economises by standardising resources and structural components, thus ensuing in well-organized management of materials and resources. Even though precast technology is extensively used all over the country but the utilization of this technology is restricted in some parts. At present it is used in business-related towers and a small number of government housing projects. Following are the reasons why precast construction is unpopular in India:

1. Contractors' prefer for employing low cost labour as against high capital investment
2. Lack of appropriate transportation systems is main obstacle for precast technology as huge precast elements are transported from factory to construction site for erection.
3. Less level of standardization of technology [13-14].

Prefabrication Technologies

There is a recent advancement in design and technology along with increasing importance in the construction area to address the technical, social, and economic and sustainability issues of prefabricated construction techniques. This is a feasible solution compared to the existing conventional techniques. Majority of the advanced nations have by now accepted prefabricated construction technique and is gaining its advantages.

Few techniques adopted by India are given in Table 1 [2].

Table 1: Prefabrication Technology	
Prefabrication Technology	**Types**
Formwork Systems	1. Monolithic concrete construction system 2. Modular tunnel form 3. Kayson's formwork system: 4. Sismo building technology
Precast Sandwich Panel Systems	1. Panel prefab system: 2. Advanced building system 3. Ferrocement sandwich panel 4. Structural insulated panels (SIPs) 5. Glass fibre reinforced gypsum (GFRG) panel system 6. Prefabricated modular units using organo-clay/ glass fibre reinforced polymer composite
Light Gauge Steel Structural Systems	1. Pods- Small rooms of light steel frame with all fittings and finishing
Precast Concrete Construction Systems	1. Industrialized 3-S System using cellular light weight concrete slabs & precast columns: 2. Pre-stressed precast system using hollow core slab, beams, columns etc: 3. Waffle crete building system:
Steel Structural Systems	1. Speed floor system: 2. Timber-concrete prefabricated composite wall system: 3. Factory made fast track modular building system

Formwork Systems

Monolithic concrete construction system: In this system, using suitable grade of concrete RCC framed construction of columns and beams; all walls, floors, slabs, columns, beams, stairs, together with door and window openings are cast-in-place monolithically in one operation. This is made up of Aluminium/Plastic/Aluminium-Plastic Composite especially custom designed modular formwork is simple to handle with minimum labour & without use of any apparatus as shown in Fig. 2. Being modular formwork system, it facilitates in speedy construction of multiple/mass unit scale. Lightweight Aluminium formwork systems are used. In the concrete form a soft alloy weld wire is utilized in the weld process. Fixing of the formwork is finished using tie, pin & wedges system. Skilled labour is not required to do the work [15].

Figure 2: Monolithic construction by aluminium plastics

Modular tunnel form: Tunnel formwork is used to reduce cycle time and also the slab & the wall are cast monolithically, this system is one type of construction techniques used for multi storied building construction as shown in Fig. 3. Steel components are used. Its effectiveness also stems from the fact that no starter concrete is necessary for walls; it allows easy arrangement and de-shuttering, hot air curing to allow early stripping. It also favours a consistent working sequence to improve labour efficiency. The major element of the system is the half tunnel, it provides the firmness and smooth face needed to produce a consistently high quality finish to the concrete and Manufacturing is entirely done from steel. When two half tunnels are placed together this creates a tunnel. These tunnel sections are in two lengths, 1.25 and 2.5m and are set together to construct a tunnel length that suits the building dimensions. The tunnel is customized to the room width and height by the inclusion of infill sections which are sacrificed at the end of the job. These are not loose fittings but are an integral part of the tunnel [16].

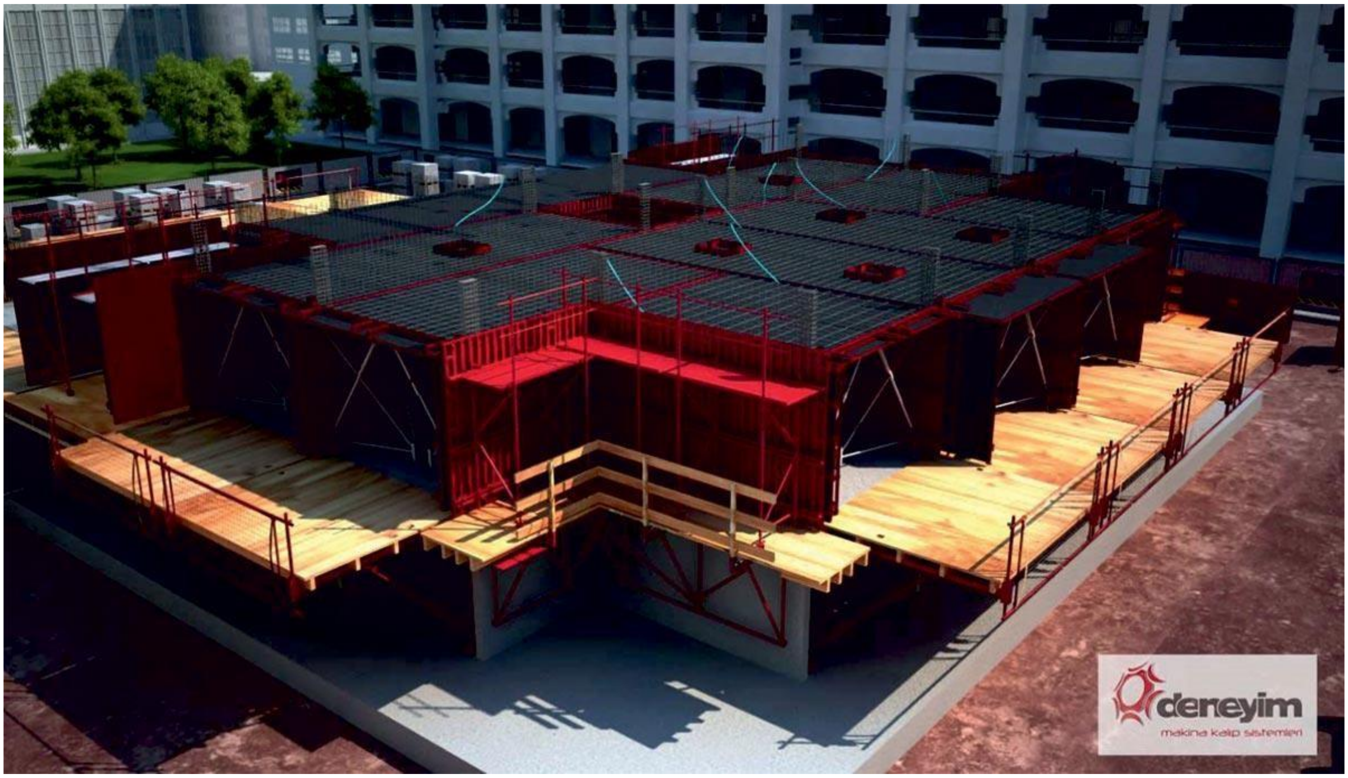


Figure 3: Cellular construction using modular tunnel

Figure 4: Kayson’s formwork system construction

Kayson’s formwork system: The Cast-in-situ monolithic reinforced concrete construction system is Kayson’s integrated solution to the problem of large-scale residential housing development as shown in Fig. 4. It is widely recognized as one of the most practical, economically and technically feasible solutions to the problem of building cost-effective, descent, durable and earthquake-proof housing on a mass scale. Indeed, Kayson's constant efforts over the past thirty years to adapt the system to varied topographical and climatic conditions has resulted in the development of a unique method for building large scale housing faster, better and at a lower cost, in virtually any corner of the globe.

- This utilizes a large steel formwork system.
- These forms are simple to install, durable, more accurate and produce higher quality structures. It gives the opportunity to repeat the entire construction phase within a period of only 48 hours.
- It uses a formwork system that allows the builder to cast foundations, walls, and ceilings in accordance to a pre-defined cycle. It is a combination of speed; quality and precision of factory/off site production with the flexibility and economy of in-situ construction.
- Other formwork systems are heavier than these forms.
- The wall forms can be removed within just five to eight hours [17].

Sismo Building Technology: It is an insulating shuttering kit for complete building based on a three-dimensional lattice made of galvanized steel wire. The lattice is filled with different materials to serve as formwork as shown in Fig. 5. Steel wire lattice is the basic structure of the module. At the external sides of the lattice, infill panels are inserted, which convert the lattice into a closed structure that can be filled with concrete. Depending on the function of the wall these infill panels are used: load bearing or not, insulated or otherwise. As during the concrete filling steel wire acts as armature and anchoring for the finished material and it holds reinforcement bars in position. There are a variety of components made from this technology: 3D lattice (2.2 mm Ø galvanized steel wire), Infill panels (EPS, rock wool, and mineral board), Structural filler (concrete) and Finishing (plastering, natural stone, panelling etc.)[18].

Figure 5: Construction of a wall with Sismo Technology

Precast Sandwich Panel Systems

Advanced building system: These are industry made panels, consisting of self extinguishing expanded polystyrene sheet (generally corrugated) with minimum thickness not less than 60 mm and density of 15 kg/m3, sandwiched between two engineered sheet of welded wire fabric mesh. High strength galvanized wire of 2.5 mm to 3 mm dia is used in it. It is pierced entirely through the polystyrene .30 mm thick shotcrete of cement & coarse sand in the ratio of 1:4 applied to make these panels with minimum under pressure. Successfully used in many countries with involvement of different agencies and brand names Morocco, Algeria, South Africa, Kenya, Austria, Malaysia, Ireland, Romania & Australia [19]. The system is shown in Fig. 6.

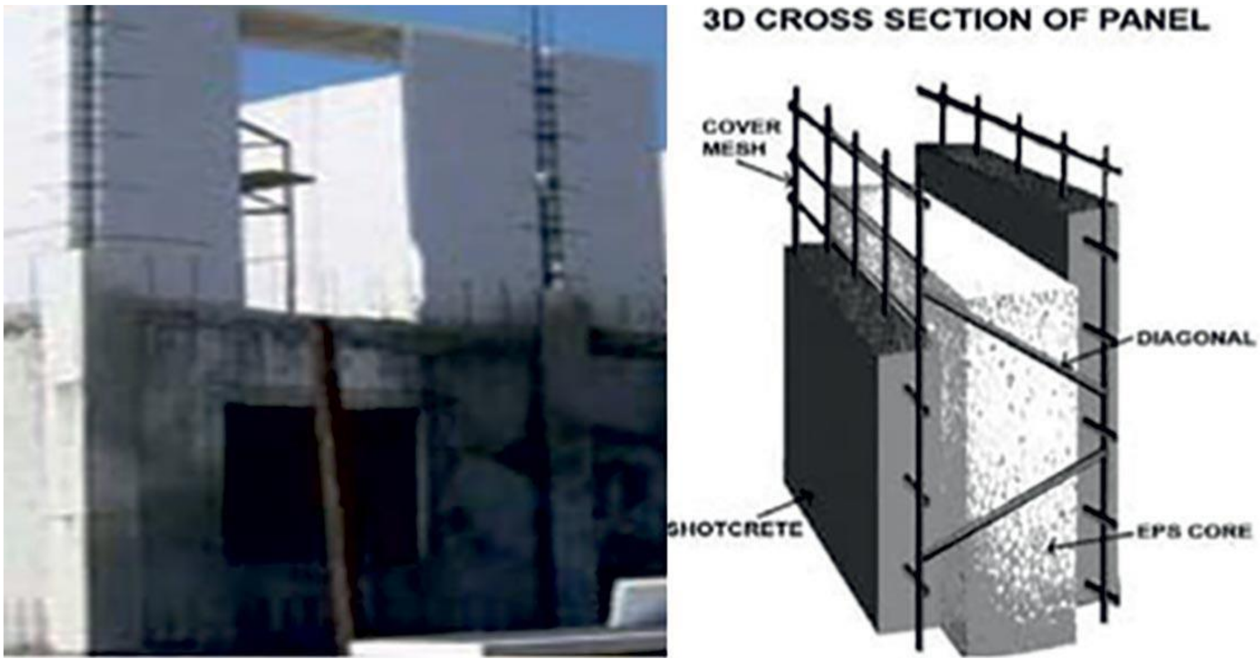


Figure 6: Expanded Polystyrene (EPS) core panel system

Panel prefab system: Precast construction system is in general a large panel system, modular system or a grouping of both. Precast large construction panel system consists of a range of precast elements such as walls, beams, slabs, columns, staircase, landing and a few personalized elements that are standardized and planned for stability, durability and structural integrity of the structure as shown in Fig. 7. Designing, strategic yard planning, lifting, handling and transportation of precast elements is involved in precast residential buildings. This technology is appropriate for construction of high-rise buildings resisting seismic and wind induced lateral loads along with gravity loads. Maximum number of repetitions of moulds is obtained in planning of building frame. These elements are cast in a factory which is developed at or near the site which provides a cost-effective solution in terms of storage space and transportation [20].

Figure 7: Panel prefab system

Ferrocement sandwich panel: In developed countries, ferrocement is a significant laminated unit of building constructions as shown in Fig. 8. It might be used as an independent part of structures like water tanks, walls, infill frames, chemises, silos and marine structures. Cement, sand, wire mesh and water are constituents of Ferrocement and have some attractive properties such as fire-resistance, antirust, seismic resistance, and rot or blow down in hurricanes. It is used in repairing of damaged buildings or retrofitting also. Ferrocement acquire large tensile strength and supreme cracking behaviour if compared to regular reinforced concrete [21].

Structural insulated panels (SIPs): SIP is a sandwich panel utilised as construction member such as wall, roof, and floor for concrete structures as shown in Fig. 9. It vary in altered thicknesses of two layers of rigid material as skin and a thicker layer as core. Based on its appliance, it can be made of a variety of materials. It is usually made of plastic foam such as Polyurethanes (PUR). PUR foam has superior performance against fire, flaming, and smoke rating. Injected PUR foam can be easily adhered to all SIP components such as skin material, top plates, and electrical boxes. Thus, it allows tough bond between mating surface and the foam [22].

Figure 9: Structural insulated panels (SIPs)


Figure 10: Glass fibre reinforced gypsum panel system

Glass fibre reinforced gypsum (GFRG) panel system: Glass Fibre Reinforced Gypsum (GFRG) Panel also identified as Rapid wall is made-up of calcined gypsum plaster, reinforced with glass fibres as shown in Fig. 10. The panel was initially developed in 1990 in Australia for mass scale building construction. In recent times, these panels are being created in India and are being used. The thickness of panel is 124mm to a length of 12m and height of 3m, contains cavities that may be fully filled, partially filled or unfilled with reinforced concrete as per structural requirement. Filling these with plain reinforced concrete possesses substantial strength capable of resisting lateral loads due to earthquake and wind. GFRG panel can also be used favourably as in-fills (non-load bearing) in grouping with RCC framed columns and beams. GFRG Panel is manufactured in semi-automatic plant using water repellent emulsion and glass fibre rovings, cut, spread and imbedded uniformly into the slurry with the help of screen roller. Before shifting to storage area or the cutting table the panels are dried at a temperature of 275oC. These panels can be cut as per dimensions & requirements of the building planned. It is suitable for low rise to medium rise building.[19].

Light Gauge Steel Structural Systems

Pods: Small rooms of light steel frame with all fittings and finishing. It is based on factory made galvanized light gauge steel components, designed as per code requirements as shown in Fig. 11. Cold forming method is used to produce the panels and assembled forming structural steel framework of a building of varying sizes of wall and floor. Special types of screws and bolts are used in joining. In residential floors, industrial buildings, commercial buildings, hotels Cold formed sections are broadly used. LGSF is gaining ground in India due to its flexibility, fast construction and durability after being used in North America, Australia and Japan. It is usually ideal for one to three storey high buildings (residential and commercial). Advisable maximum span for these buildings should be 7.5 m. These could be used for short-term or permanent structures such as schools and classroom, military and civil housing needs, post – disaster relief structures and industrial units [19].

Figure 11: Light Gauge Steel Structural Systems Pod

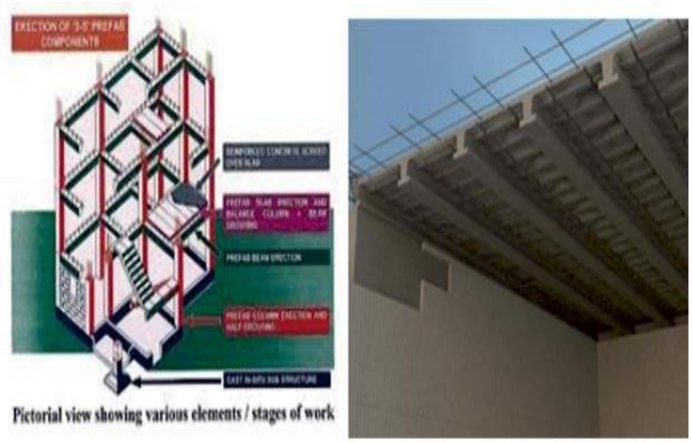


Figure 12: 3-S System

Precast Concrete Construction Systems

Industrialized 3-S System using cellular light weight concrete slabs & precast columns: This technology is being used since 1972, and is based on industrial unit mass manufactured structural prefab components meeting the requirements of Indian Standards. The major precast elements are:

- RCC hollow columns with notches
- RCC solid beams (T/L/Square Shape)
- Staircase
- RCC precast slab
- AAC precast slab
- AAC precast block

Appropriate sizes of precast dense concrete hollow column shell are used in mixture with precast dense concrete rectangular / ‘T’ shape / ‘L’ Shape beams with light weight reinforced autoclaved cellular concrete/Precast RCC slabs for floors and roofs. On-site concerting along with secured embedded reinforcement of components and jointing is accomplished for various structures with appropriate size, length and configuration to ensure monolithic continuous resilient, ductile and durable behaviour. The hollow columns are grouted with appropriate grade of in situ concrete. Autoclaved Aerated Concrete slabs could also be used as floor / roof slabs. Joints are filled with reinforced screed concrete (minimum 40 mm thick) of M20 grade minimum. RCC screed is laid over whole area of slab before flooring / water proofing [15]. The system is shown in Fig. 12.

Wafflecrete building system: It consists of huge, structural, ribbed panels of reinforced precast concrete, bolted together and the joints between the panels are caulked to form the walls, floor and pitched or flat roofs of buildings as shown in Fig. 13. The surface of each panel consists of 51 mm thick slab with overall panel thickness of 152 mm or 203 mm. In single storey buildings, floors are constructed using precast reinforced concrete floor panels supported on precast concrete grade beams on well- compacted earth is used in single storey buildings. While for buildings of more than one storey, the walls are supported on foundations designed as per the soil condition. Where there is a danger of water or wind erosion of the ground adjacent to the building a concrete apron is laid around the perimeter of building. Internal walls consist of either reinforced precast concrete ribbed panels, conventional masonry walls or concrete walls. Before the walls are lined services like water supply and electricity shall be normally accommodated in preformed slots in the ribs of panels. Trapping the moisture generated from the concrete curing time is reduced. The structure after construction can be shifted from one place to another as the structure is joined using bolt connections [19].

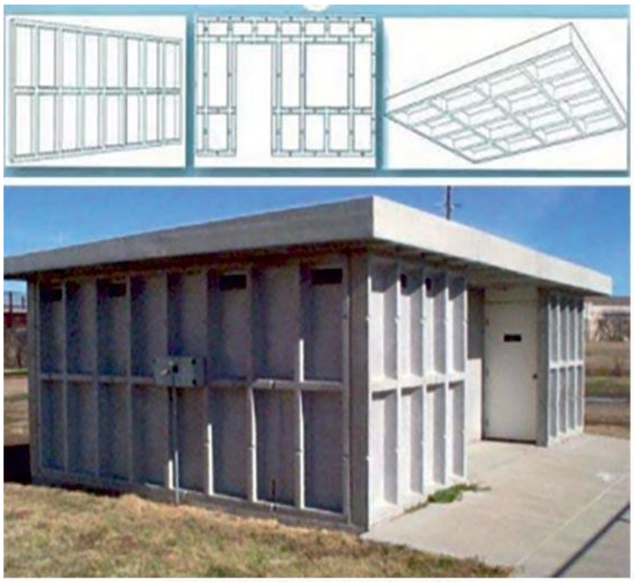


Figure 13: Wafflecrete building system

Figure 14: Pre-stressed precast system using hollow core slab

Pre-stressed precast system using hollow core slab, beams, columns etc: The current and future market demand for the building industry can be fulfilled by the precast pre stressed hollow core slab. A precast hollow core slab is a pre-stressed concrete member with constant voids which extend all through the length of the slab, provided to decrease the weight and, hence the cost and as a side advantage, to use for covered electrical or mechanical runs. Mainly used as floor or roof deck systems, hollow core slabs also have appliance as wall panels, spandrel, members and bridge deck units. Hollow core slab Span length reach up to (18m) with no columns or any supporting. This arrangement can be preferably used in residential, commercial, car parks or repetitive construction projects. Precast prestressed hollow core slabs provide maximum structural efficiency with the use of high strength concrete, yet at the same time requiring less material utilization [23]. The system is shown in Fig. 14.

Steel Structural Systems

Speed floor system: These are suspended concrete flooring system using a roll formed steel joist as an essential part of the final concrete and steel composite floor. An integrated continuous one-way slab and a hybrid concrete/steel tee-beam in other direction as shown in Fig. 15. The joists of altered depths are manufactured from pre-galvanized high tensile steel in a one pass roll former, where it is roll formed, punched, pushed and slotted in a fully mechanized instrument. Depending on the span. The joist depth and the concrete thickness may vary, forced loads and other efficient considerations. It’s suitable for use in all types of construction[19].

Figure 15: Speed floor system

Figure 16: Factory made fast track modular building system

Factory made fast track modular building system: This comprises of prefabricated steel construction with different walling components. With minimal usage of concrete, about 70 percent of the work is done in the factory, which enables system to deliver the building within a few days of work at site as shown in Fig. 16. The flooring, ceiling tiles, electrical and plumbing fittings are pre-fitted with steel unit. These modules are transported to the site for putting in place which is completed using crane and other required machineries., factory made 3–D Expanded Polystyrene (EPS) wall panels are fixed and shotcreting is done from both sides after all the components are assembled and erected at site. The distinctiveness of system is the well-organized and synchronized activities of site preparation and building construction in factory, rather than two phased traditional process [19].

Timber-concrete prefabricated compo- site wall system: Wood has been used as building material mainly attached with brickwork or stone in Europe. In order to develop the seismic resistance of masonry buildings wooden structural elements has been in a practice. It was composed basically of two parts, a slab of reinforced concrete (RC) with a thickness of 50 mm connected with particular connectors. A structure made of CGF panels for load-bearing walls and floors is a modular system in which the panels are prefabricated. The panels are then assembled providing insulation inside the frames and then are easily transported to the site as shown in Fig. 17. After having a foundation curb in the ground, the panels are hooked to it and to each other with nails and screws [24].

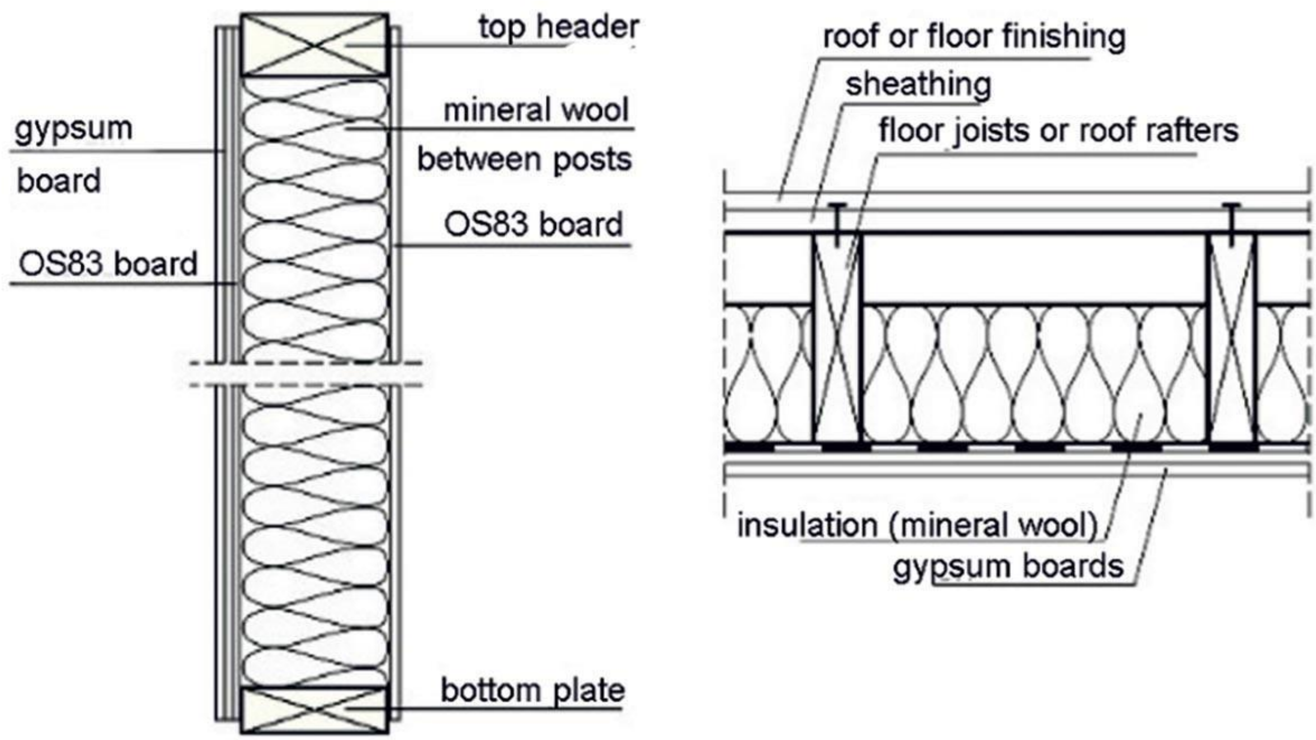


Figure 17: Section through a panel Timber-concrete prefabricated composite wall system

Sim[PLY] framing system: In these framing system plywood subcomponents, fastened together with tab and slot joints with hand-fastened steel cable ties are composed together to form structural members in the system as shown in Fig. 18. Due to its renewability, low-carbon footprint, ease-of-use, minimum weight, and affordability Wood is the perfect choice for this sustainable light-frame system. Furthermore, the CNC procedure allows for systems within a given house, including electrical wiring and plumbing. This promotes quick and exact assembly. Mainly are used to maximize material efficiency and lessen plywood waste. The prefabrication allows for disassembly of the house to be rapid and simple, taking only three days. Small, efficient, and mass-produced structures use this Sim [PLY] system [25].

Figure 18: Sim[PLY] framing system

Ultra-thin phase change material technology: To improve the thermal performance of building envelops and to achieve the goal of energy saving, thermal energy storage (TES) is one of the best ways to get better thermal performance. Ultra-thin phase change materials (PCMs) are a series of functional materials that give high-energy storage density in a thin temperature interval. PCM the appliance areas are mostly some cities of Europe [26].

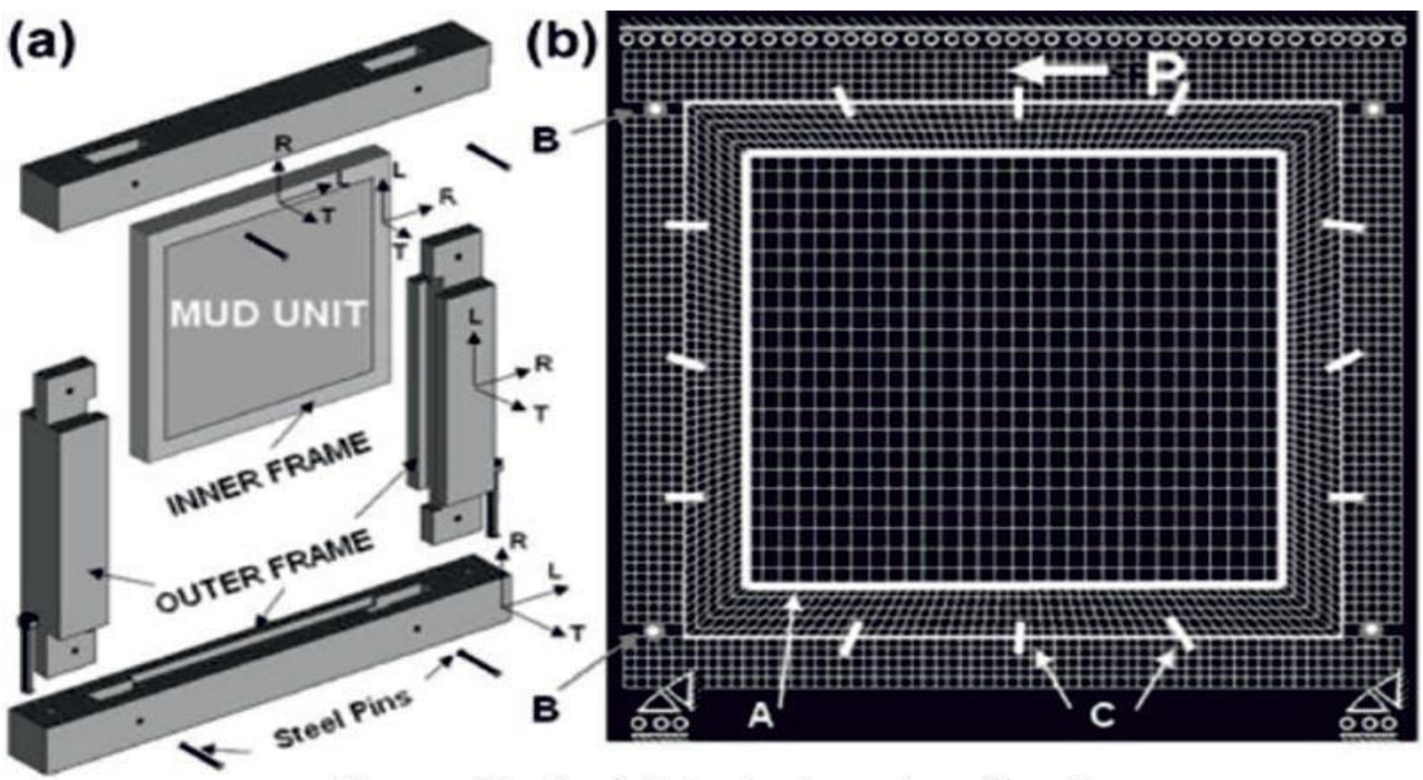


Figure 19: Prefabricated mud wall unit

Prefabricated mud wall unit: For faster building construction Low-cost materials are in use. Encouraged to improve and "modernize" natural construction systems, which are environmentally friendly as shown in Fig. 19. Tsuchikabe (in Japanese),also recognized as mud wall, is a combined designed for walls built with clay and mud using customary Japanese craft techniques. It is also identified as wattle-and-daubin Western countries, and has been used globally since the Bronze Age [27].

Futuristic Pathways

Prefabrication is a promising strategy to realize lean construction. Among the diverse degrees of prefabrication, modular buildings make the most of the gain in time savings, because they are prefabricated to a better degree of finish. These are based on local building codes and standards, in the similar way as on-site built construction; thus, of equal quality to an on-site built construction. Although, maintenance during occupancy, deconstruction, and recycle or reuse of modular buildings as they are just not limited to design, manufacturing, and construction stages [28]. Abundant projects incorporating prefab (on various levels) have already been completed successfully, and numerous more are planned. The potential for enlargement in the building economy; embracing higher output, total sustainability, improving place of work and workforce security, was hypothetical some ages ago, but is a practical recognition today and in future, through prefab[7]. The effective factors are shown in Table 2.

Table 2: Effective factors in increased used of prefabrication systems in future

Effective factor	**Effect of using prefabrication**
Program	The ability to progress work as a parallel operation in a factory and on a construction site
Factory tolerances and workmanship	They will show a higher quality and consistency to that achieved on site
Energy consumption	Reduction in energy consumption due to the automation
Labour markets	Access to cheaper labor markets according to factory base systems
Program certainty	Greater program certainty as a result of computerization
Safety	The factory environment can allow better safety than the construction site

Issues in Prefab Construction

The joints to be provided linking the core structure and the components should be well-built enough to transmit all types of stresses. The strength and stoutness of the entire building depends totally on the strength of the joint. Therefore, it is necessary to have comprehensive studies on entire system rather than component based study. Requirement of skilled labor at site and shortage of onsite automation is one of the major issues in acceptance of prefabrication technologies in construction which requires accuracy and preciseness. Thus, skill development and native automation is mandatory for installation of the prefabricated systems. During erection or transportation of heavy machinery units are likely to get damaged thus the arrangement of the units has to be done precisely and this procedure becomes clumsy in a congested area. Labor maintenance is one more issue as skilled labor is required in the prefabricated construction as it is different from in-situ construction, which requires machine oriented skills both on-site and in the manufacturing process [29].

Advantages of Prefab Construction

Prefabrication Technology has various advantages like overhauling the view with energy efficiency, minimal wastage and inspection struggle, dependable construction, pace of work, security, sustainability and quality [7].

- The requirement for formwork, shuttering and scaffolding is significantly reduced as Self-supporting ready-made components are used.
- Construction time is reduced thus resulting in lower labour costs.
- Reduced amount of waste materials than in site built construction.
- Reduction in Construction time allowing an earlier return of the principal invested.
- Building ensures accurate conformity to building standards and superior quality assurance.
- High-energy efficiency along with quality control and factory sealing.
- Prefabrication site can be positioned where skilled labour is more readily accessible and the expenses of labour, power, materials, space and overheads are minimized.
- Prefabrication allows construction all over the year irrespective of the weather (related to excessive cold, heat, rain, snow, etc.).
- Construction material wastage is less.
- Independent of climatic condition.
- In off-site construction safety and comfort level of worker are higher [30].

Disadvantages of Prefab Construction

It is known to have the subsequent limitations limited options in design, decreased resell value, high initial investment, non-suitability for foundation and transportation of precast units [7].There are more disadvantages too. They are as follows:-

- At joints in prefabricated components leakage occurs.
- Transportation costs may be high for huge prefabricated sections.
- Increased production volume is necessary to make sure affordability through prefabrication.
- Initial construction cost is higher.
- The initial design development is time consuming.
- Huge prefabricated sections need heavy-duty cranes and accuracy measurement from handling to place in site.
- Local jobs may be lost, as it requires skilled labour.
- Design and construction of modular buildings, require high levels of collaboration among project parties, especially architect, structural engineer and manufacturer.
- Due to its shorter economic life these buildings typically depreciate more quickly than traditional site-built housing [30].

Prefabrication :

Prefabrication is the Practice of assembling components of a structure in a factory or other Manufacturing site and transporting complete assemblies to the construction site where the structure is to / be located.

Principles:

▯ The Main reasons to choose Precast Construction method over conventional in method.

1. Economy in large scale project with high degree of repetition in work construction.
2. Special requirement in finishing.
3. Consistency in structural quality control.
4. Fast speed of construction.
5. Constraints in availability of site resources(e.g. materials & Laborites)
6. Other space & environmental constraints.
7. Overall assessment of some or all of the above factors which points to the superiority of adopting precast construction over convention method.

The following details gives. The cost implications of precast construction & conventional in situ method.

8. Large groups of buildings from the same type of prefabricated elements tend to look drab and monotonous.

Prefabrication Elements :

1. Flooring / Roofing system.
2. Priciest Beams
3. Precast Columns
4. Precast walk panels.
5. recast Stabs.

▯ Classification :

The Prefabrication is classified as follow from the view of degree of Precast construction.

1. Small prefabrication
2. Medium Prefabrication
3. Large Prefabrication
4. Cast in Site Prefabrication
5. Off-Site (or) factory Prefabrication
6. Open system of prefabrication
7. Closed system of prefabrication
8. Partial prefabrication
9. Total prefabrication

Prefabricated Materials :
Prefabricated building materials are used for buildings that are manufactured off-site and shipped later to assemble at the final location same of the commonly used prefabricated building materials are aluminum steel, wood, fiberglass and concrete. Prefabricated metal buildings use galvanized Steel and galvalume as s the chief materials for building.
Galvalume is a form of Steel coated with aluminum Zinc. This is to protect the building against corrosion rust and fire. It also provides a sturdy and protective covering to the prefabricated building. Almost all the components of a metal building such as beams, frames, columns, walls & roofs are made of steel. Most prefabricated military buildings use steel or aluminum frames. (Synthetic materials are used for the walls & roofs. To provide enhanced security a combination of both metal and cloth materials are used.
Plastic flooring materials can be quickly assembled and are very durable)
Prefabricated, building materials used for small prefabricated buildings are steel, wood, fiberglass.
Plastic or aluminum materials. These materials are cheaper than regular brick and concrete buildings. Materials like steel, fiberglass, wood and aluminum are used as prefabricated building materials for sports buildings. These materials provide flexibility and are preferred rfor making structures and accessories like stands and seats for stadium and gyms. For making low cost housed, prefabricated materials like straw bale, Ferro cement calcium silicate. Products, campsites and other cheap wood based materials are currently being used calcium silicate bricks are strong and durable. Ferro cementconsists of a cement matrix reinforced with a mesh of closely-spaced iron rods or wires. In this type of construction, the techniques used are simple & quick.
Using Prefabricated materials one can make durable water and fire resistant and cheap prefabricated buildings. Most of the prefabricated building materials are eco-friendly & affordable.

Precast structure Installation (Erection)
The following steps to be followed to erect the precast structure :
1. Planning for precast installation
2. Installation process.
3. Installation using Big canopy
4. Installation construction Management.
5. Mishandling of precast panels.
6. Common defects in precast panels.
7. Precast failures.

 Planning for precast installation.:
Planning co-ordination. It is important to have the precaster erector / installer and builder working together to achieve best performances.
Site Access and storage :
 Check for site accessibility and precast panels delivery to site especially low bed trailers.

 Check whether adequate space for temporary storage before installation and ground conditions firm ground & leveled)
 Uneven ground will cause overstress & crack panels.
Planning crane Arrangement :
1. Plan the crane capacity and lifting gears based on
1. Heavies weight of precast panels.
2. Lifting heights.
3. Working radius.
4. Position of crane in relation to final location.

 Plan other equipments
1. Boom lift and scissor lift for unhooking installed panels.
2. Lifting gears.

 Skilled personnel's :
1. Competent crane operators.
2. Rigger
3. Signaled etc.

 General consideration for crane selection.
1.Total lifting
weight. 2.Crane
Model
3. .Crane safe working load (SWL)
i.e. Based on 75% capacity build in F.O.S,1.33 – Lifting capacity must be 1.5 times the total weight i.e) F.O.S. 1.5
4. Lifting and swing radius.
5. Crane counter weight.
6. Crane boom length is relation to the vertical and horizontal clearance from the building.
7. Installation process.
8. Installation of vertical components.
9. Verification of delivered panels.
10. Check the panels delivered for correct marking liftinglook and position etc.
11. Surface finishing conditions.
12. Pc Dimension compliance.
13. Reinforcement provision
14. Architectural detail
 compliance. Setting out.
1. Check the panels delivered for marking lifting hook and condition.
2. Set the reference lines & grids.
3. Check starter bars for vertical components before hoisting for installation.

 Setting out quality control points.:
1. Ensure correct offset line.
2. Check 'Shim Pad'/plate level and firm.

3. Rubber gasket property secured.
4. For external wall / column place backer rod.

 Hoisting, Rigging and installation :

1. While tilting provide rubber pad to avoid chip off.
2. Lift and rig the panel to designated location.
3. Adjust the panel in position and secure.
4. Lifting of space adding items with balanced center of gravity.
5. Ensure horizontal alignment correct.
6. Ensure panel vertically to correct plumb.
7. Check panel to panel gap consistency.
8. Check stability of prop before releasing hoisting cable.

 Grouting works :

1. Prepare and apply non shrink mortars to seal gap
2. For corrugated pipe sleeve or splice sleeve pour NSGT or proprietary grouts into pipe sleep.
3. Keep installed panels undisturbed for 24 yrs.
4. Check joint widths are consistent before grouting.
5. Grout used should be same grade of components and self compacting to prevent cracking.
6. Collect test cube sample for testing for critical elements or load bearing elements.

 Connecting joints :

1. Cast in situ joints, install rebar’s as required
2. Set up forms for casting joints.
3. Do connecting.
4. Remove forms after sufficient strength.
5. For external connections welding as required.

2.2 Installation of Horizontal Elements :

 Setting out :

1.Set reference line / offset line to required alignment and level of slab / beam during installation.
2.Put temporary prop to support the precast slab / bear elements. 3.Before hoisting check dimensions.
4.Check level and stability of shim.
5.Check protruding / starter bars are within the specified tolerance any obstruction
Specified colerance to prevent any obstruction during the erection process Hoisting installation
1.Put temporary props to support slab or beam. 2.Lift and rig the elements to designated location 3.Align and check the level before placement 4.The beams shall prop atleast two locations
5. check level of precast elements

Connection and jointing
1.precast with cast-in0situ joints place the lap rebars as required. 2.Set formwork for casting joints
3.Remove formwork after concrete strength is achvieved
4.Supporting beams shall be designed to form part of formwork joints 5.The connecting or lapping rebars tied and secured
6.same grade of concrete to be used that of panel

1.4 Modular Coordination

Modular coordination means the interdependent arrangement of a dimension based on a primary value accepted as a module. The strict observance of rules of modular coordination facilitated,

1. Assembly of single components into large components.
2. Fewest possible different types of component.
3. Minimum wastage of cutting needed.

Modular coordination is the basis for a standardization of a mass production of component. A set of rules would be adequate for meeting the requirements of conventional and prefabricated construction. These rules are adaptable for,

a. The planning grid in both directions of the horizontal plan shall be
1. 3M for residential and institutional buildings,
2. For industrial buildings, 15M for spans up to 12m
30M for spans between 12m and 18m 60M for spans over 18m

The centre lines of load bearing walls shall coincide with the grid lines

b. In case of external walls the grid lines shall coincide with the centre line of the wall or a line on the wall 5 cm from the internal face of the wall

C. The planning module in the vertical direction shall be 1M up to and including a ht of2.8M.

d. Preferred increments foa the still heights,doors,windows and other fenestration shall be1M.

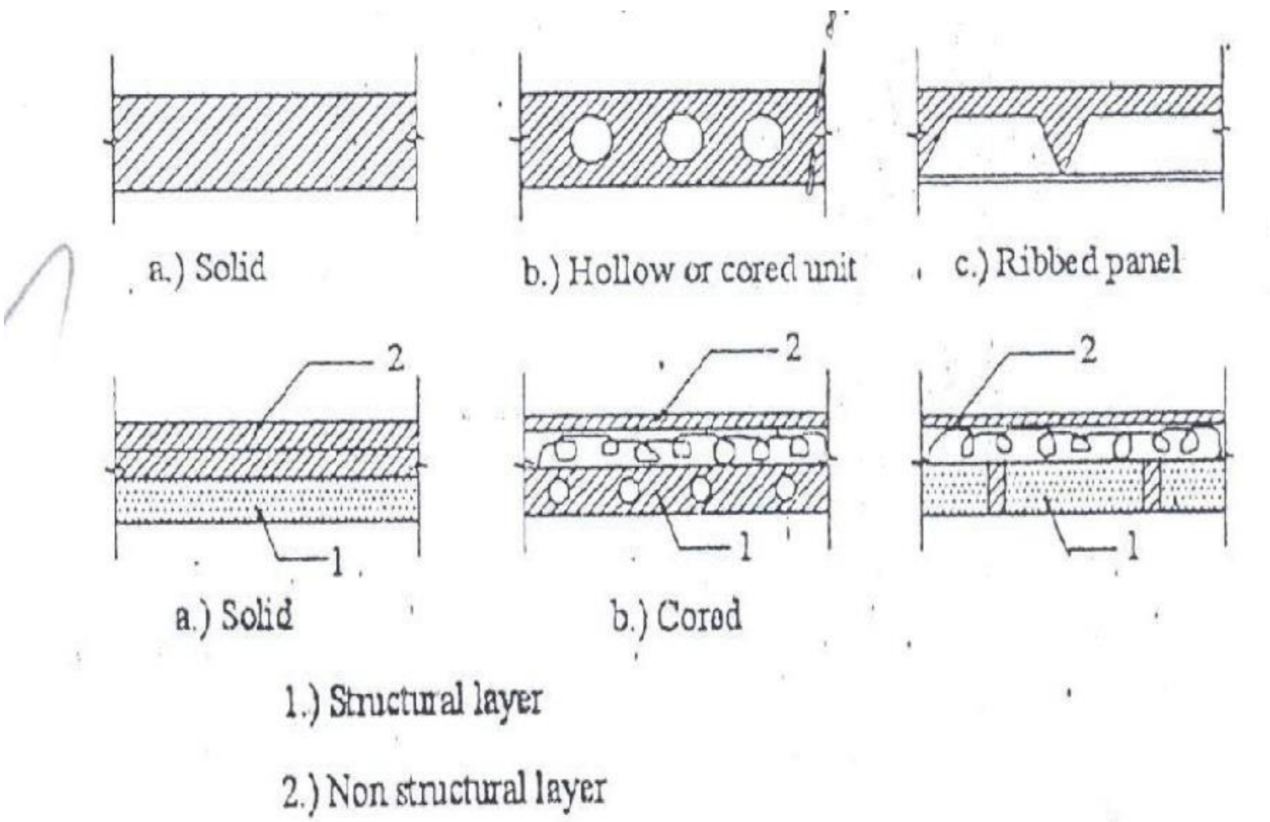
e. In case of internal coluums the grid lines shall coincide with the centre lines of columns.In case of external columns,the grid lines shall coincide with the centre lines of the columns in the storey or a line in the column from the internal face of the column in the topmost storey. A basic module can be represented as module andfor larger project modules are represented as Mp.

For eg: For a project module in horizontal coordination,the component can be of 30cm and forvertical component size be of 10cm.

The storey height is fixed between finished floor levels as 2.8m and if the thickness of slab is<15cm storey height is fixed as 2.7m. The centre distance between the load bearing walls can be chose from a set of modules. The use of other dimensions is not allowed.

In the design of a building,modular grid can be used consisting of parallel line spaced at a value of module M or Mp and a grid line chosen as a base for setting out a part of a building becomes a modular axis. In the fig (a),, a typical grid is chosen for load bearing walls without duct. The interior walls are placed so that their centerlines coincide with the modular axis. In the fig (b), a grid is shown for load bearing walls with hollw ducts in between. The centre line of the grid is found by deducting the size of duct.

Systems of prefabrication:



System is referred to a particular method of construction of buildings using the prefabricated components which are inter related in functions and are produced to a set of instructions.

With certain constraints, several plans are possible, using the same set of components, the degree of flexibility varies from system to system. However in all the systems there is a certin order and discipline. The system of prefabricated construction depends oon the extend of the use of prefab components, their characteristics to be considered in devising a system:

i. Intensified usage of spaces
ii. Straight and simple walling scheme
iii. Limited sizes and numbers of components
iv. Limited opening in bearing walls

v. Regulated locations of partitions
vi. Standardized service and stair units
vii. Limited sizes of doors and windows with regulated positions
viii. Stuctural clarity and efficiency
ix. Suitability for adoption in low rise and high rise blocks
x. Ease of manufacturing storing and transporting
xi. Speed and ease of errection
xii. Simple jointing system

REINFORCED EARTH

The concept of combining two materials of different strengths characteristics to form a composite material of greater strength is quite familiar in civil engineering practices and is in use for ages.

The reinforced concrete constructions are examples for such composite materials.

It combines the high tensile strength of steel with the high compressive, but relatively low tensile strength of concrete.

Likewise, soils which have little if any tensile strength can also be strengthened by the inclusion of materials with high tensile strength.

This mobilization of tensile strength is obtained by surface interaction between the soil and the reinforcement through friction and adhesion.

The reinforced soil is obtained by placing extensible or inextensible materials such as metallic strips or polymeric reinforcement within the soil to obtain the requisite properties.

Soil reinforcement through metallic strips, grids or meshes and polymeric strips sheets is now a well-developed and widely accepted technique of earth improvement.

Anchoring and soil nailing is also adopted to improve the soil properties. The use of reinforced earth technique is primarily due to its versatility, cost effectiveness and ease of construction.

The reinforced earth technique is particularly useful in urban locations where availability of land is minimum and construction is required to take place with minimum disturbance traffic.

Types of reinforcing materials:

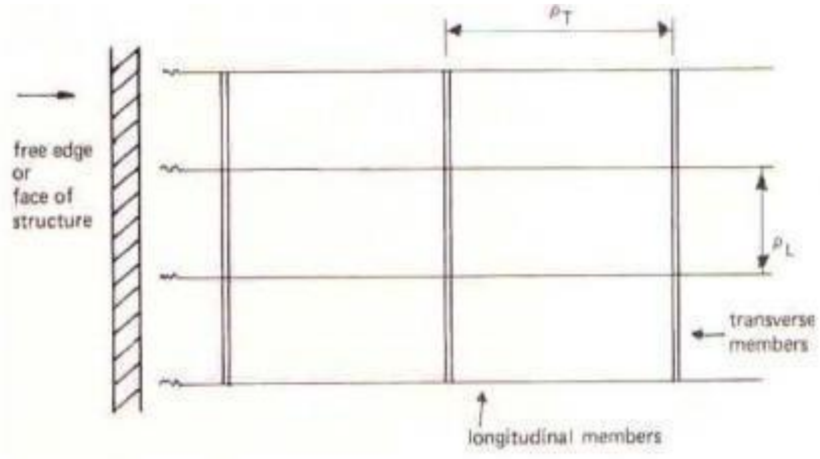
- **Strips:** These are flexible linear element normally having their breadth „b‟ greater than their thickness, „t‟. Dimensions vary with application and structure, but are usually within the range t = 3-5 mm, b = 5-100 mm. The most common strips are metals. The form of stainless, galvanized or coated steel strips being either plain or having several protrusions such as ribs or gloves to increase the friction between the reinforcement and the fill. Strips can also be formed from aluminum, copper, polymers and glass fibre reinforced plastic (GRP). Reed and bamboo reinforcements are normally categorized as strips, as are chains.

- **Planks:** Similar to strips except that their form of construction makes them stiff. Planks can be formed from timber, reinforced concrete or pre-stressed concrete. The dimensions of concrete planks vary; however, reinforcements with a thickness, „t‟=

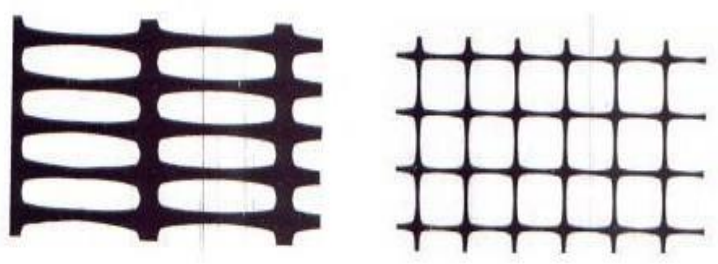
100 mm and breadth, b= 200–300 mm have been used. They have to be

handled with care as they can be susceptible to cracking.

) **Grids and Geogrids:** Reinforcing elements formed from transverse and longitudinal members, in which the transverse members run parallel to the face or free edge of the structure and behave as abutments or anchors as shown



The main purpose is to retain the transverse members in position. Since the transverse members act as an abutment or anchor they need to be stiff relative to their length. The longitudinal members may be flexible having a high modulus of elasticity not susceptible to creep. The pitch of the longitudinal members, pL is determined by their load carrying capacity and the stiffness of the transverse element. A surplus of longitudinal and transverse elements is of no consequence provided the soil or fill can interlock with the grid. Mono and Bi Oriented grid as shown



(a) Mono Oriented geogrid (b) Bi- Oriented geogrid

Grids can be formed from steel in the form of plain or galvanized weld mesh, or from expandedmetal.Gridsformedfrompolymersareknownas“Geogrids”andare normally in the form of an expanded proprietary plastic product.

ii) **Sheet reinforcement:** May be formed from metal such as galvanized steel sheet, fabric (textile) or expanded metal not meeting the criteria for a grid.

v) **Nailing:** Earth may be protected by geo-synthetics with earth nailing.

v) **Anchors:** Flexible linear elements having one or more pronounced protrusions or distortions which act as abutments or anchors in the fill or soil. They may be formed from steel, rope, plastic (textile) or combinations of materials such as webbing and tyres, steel and tyres, or steel and concrete

v) **Composite reinforcement:** Reinforcement can be in the form of combinations of materials and material forms such as sheets and strips, grid and strips and anchors, depending on the requirements.

The Components Of Reinforced Earth

SOIL

It should be granular, cohesion less material, not too much silt or clay having particle size not more than 125 mm.

Not more than 10 percent of the particles shall pass 75 micron sieve & the earth reinforcement coefficient of friction to be either higher than or equal to 0.4 & Plasticity Index < 6.

The soil must have moisture content suitable for compaction.

The materials shall be substantially free of shale or other soft, poor durability particles.

SKIN

Skin is the facing element of the reinforced soil wall.

These elements keep the reinforcement at a desired elevation in the reinforced soil wall and also protect the granular at the edge falling off.

Made of either metal units or precast concrete panels.

REINFORCING MATERIAL

A variety of materials can be used as reinforcing

- materials Steel
- Concrete
- Glass fibre
- Wood Rubber
- Aluminum
- Reinforcement may take the form of strips, grids, anchors & sheet material, chains, planks, rope, vegetation and combinations of these or other material forms.

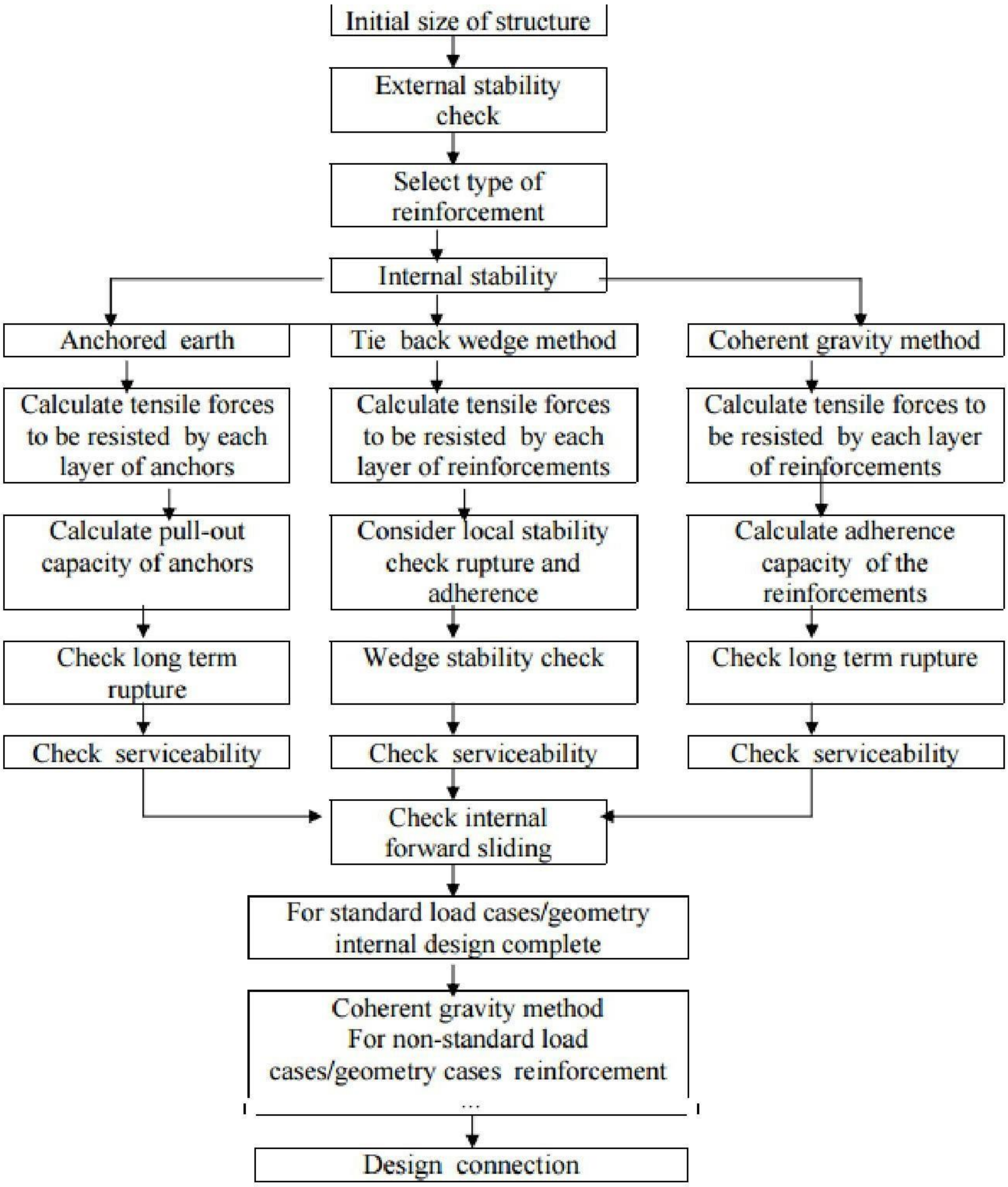
THE DESIGN PRINCIPLES OF REINFORCED EARTH WALL

- Rankine or Columb earth pressure theory should be used
- Active earth pressure or passive earth pressure or at rest earth pressure are adopted.
- The various forces acting horizontal, vertical and shear stress should be distributed on reinforced earth.
- Suitable geometry surface failure is assumed on reinforced earth Reinforcing strip length can resist the failure occurred by the slippage.
- Safety factors are required and calculated from Rankine, Active earth pressure theory.
- The earth pressures on a reinforced earth walls can be calculated by both horizontal and vertical earth pressures

Factors affecting the behavior and Performance of Reinforced Soil

REINFORCEMENT	REINFORCEMENT DISTRIBUTION	SOIL	SOIL STATE	CONSTRUCTION
Forms(fibers,grid,anchor, bar,strip)	Location	Particle size	Density	Geometry of structure
Surface properties				compaction
Dimensions	Orientation	Grading	Over burden	Construction system
Strength		Mineral Content	States of stress	Aesthetics
Stiffness	Spacing	Index properties	Degree of Saturation	Durability

The Design Procedure For Reinforced Earth Wall In Form Of A Flowchart



Stability Checks:

External Stability (as for any earth-retaining structure)

The external stability of a reinforced soil wall is easily investigated since it behaves essentially as a rigid body and conforms to the simple laws of statics external stability assessment should consider the effects of dead loads, other loads (live load, dynamic load etc.) and forces acting on the structure. The failure for sliding, overturning, tilting/bearing and slip should be checked by external stability

- Sliding Overturning
- Bearing Capacity

Short and long term stability of soil needs to be considered to allow for the construction and in-service condition as well as in changes in pore water pressure. Passive earth pressure acting on the foot of the wall/structure below ground level may be ignored while considering various forces for stabilization.

Internal Stability (MSE retaining structures)

Stability within a reinforced structure is achieved by the reinforcing elements carrying tensile forces and then transferring to the soil by friction, friction and adhesion, or friction and bearing. In addition forces can be transferred the soil through fill trapped by the elements of the grid. The fill is than able to support the associated shear and compressive forces. In the case of anchored earth such as soil nailing, stability within a structure is achieved by the anchor elements carrying tensile forces and transferring these by friction along the anchor shaft or anchor loop and bearing of the anchor to the surrounding fill.

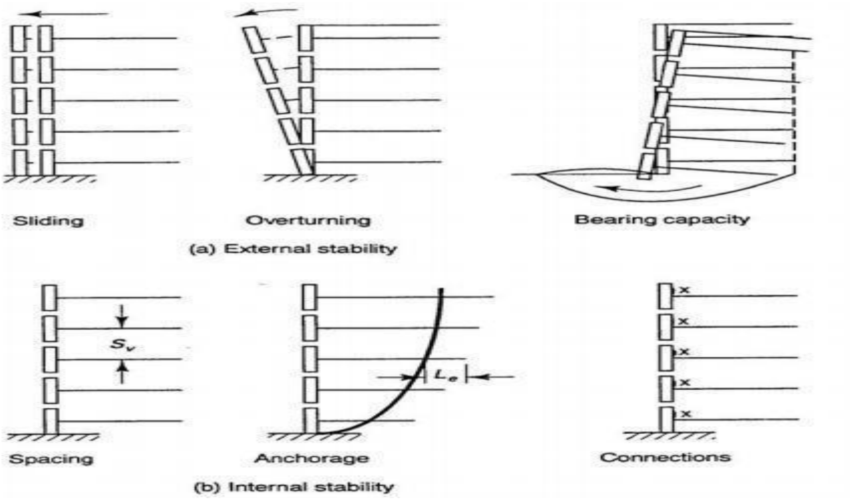
Reinforcement Failure
Pullout
Failure of Reinforcement/Facing Connection

Local stability check

The resistance of the reinforcing element should be checked against rupture and adherence failure whilst carrying the factored loads.

Wedge stability

The reinforcement structure will assume to fail internally in the form of wedge. It is not known at which level the wedge is originated. Therefore the wedge originate from different level to be checked. Checked for stability considering all the forces acting on it. Wedges are assumed to behave as rigid bodies and may be any size and shape. Stability of any wedge is maintained when friction forces acting on the potential failure plane in connection with the tensile resistance/ bond of the group of reinforcing elements or embedded in the fill beyond the plane are able to resist the applied loads tending to cause movement,



Geosynthetics

Geo-synthetics are synthetic products used to stabilize terrain.

These are human-made materials made from various types of polymers used to enhance, augment and make possible cost effective environmental, transportation and geotechnical engineering construction projects.

They are used to provide one or more of the following functions; separation, reinforcement, filtration, drainage or liquid barrier.

They are generally polymeric products used to solve civil engineering problems.

These include eight main categories geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners,geofoam, geocells and geocomposites.

The polymeric nature of the products makes them suitable for use in the ground where high levels of durability are required.

They can also be used in exposed applications.

Geo-synthetics are available in a wide range of forms and materials.

These products have a wide range of applications and are currently used in many civil, geotechnical, transportation, hydraulic and private development applications including roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, dams, landfill liners, land fill covers structures.

The Important Properties Of Geo-Synthetics Required For Reinforcement Function Basic Physical Properties

a. Constituent material and method of manufacture b.

Mass per unit area

c. Thickness

d. Roll width, roll length

- Mechanicalproperties
  - a. Tensile strength
  - b. Tensile modulus
  - c. Seam strength
  - d. Interface friction
  - e. Fatigue resistance
  - f. Creep resistance

Hydraulic Properties

- a. Compressibility
- b. Opening size
- c. Permittivity
- d. Transmissivity

Constructability/survivability Properties

- a. Strength and stiffness
- b. Tear resistance
- c. Puncture resistance
- d. Penetration resistance
- e. Burst resistance
- f. Cutting resistance
- g. Inflammability
- h. Absorption

Durability (Longevity)

- a. Abrasion resistance
- b. Ultra-violet stability
- c. Temperature stability
- d. Chemical stability
- e. Biological stability
- f. Wetting & drying stability

The Functions Of Geo-Synthetics

- Reinforceme
- nt Filtration
-
-
-
-

Separation
Drainage
Erosion
Control

Reinforcement:

Reduction of Stress Intensity (Concentration) through Wider Distribution The stresses over the subgrade are higher in unreinforced flexible pavements than in geo-synthetic-reinforced pavement due to stress distribution factor

Reinforcement Mechanisms Induced by Geo-synthetics:

(a) Lateral Restraint

(b) Increased Bearing Capacity; and

(c) Membrane Tension Support

Filtration

Retaining soil particles subjected to hydraulic forces which allow the passage of liquids/gases. This function is often partnered with separation.

Separation

a. Preventing intermixing of soil types or soil/aggregate to maintain the integrity of each material yet still allow the free passage of liquids/gases. Commonly used in between sub-base/subgrade and around drainage materials.

b. Contamination of the base course layers leads to a reduction of strength, stiffness and drainage characteristics, promoting distress and early failure of roadway.

Drainage

Allowing fluids and gases to flow both through the plan of the material. Commonly used as components in geo-composites used for surface water runoff or for gas collection under membranes.

Separation and Drainage Functions

a. Piping Resistance: Apparent Opening Size - AOS (as related to soil retention),
b. Permeability: Flow capacity, and clogging potential.
c. Strength and Durability: Grab, Puncture strengths

Erosion Control

Protecting and reinforcing slopes and drainage channels from erosive agents whilst allowing the establishment of vegetation cover.

Barrier/Protection

Preventing or limiting localized damage to an adjacent material, usually a geomembrane used to line a lagoon or a landfill. Thick geotextiles prevent puncture or excessive strain in the membrane.

Geo synthetics classified

Geo synthetics are classified as follows

- Geotextiles
- Geogrids
- Geonets
- Geo-membranes
- Geo-synthetic clay liners
- Geocells/geo web members
- Geofoam
- Geo-composites

Geotextiles aredefinedas“anypermeabletextileusedwithfoundationsoil,rock,earth, or any other geotechnical engineering-related material as an integral part of a human-made project,structure,orsystem”.

Geogrids

They have open grid like configuration i.e. they have large aperture between individual ribs.They have Low strain and stretch about 2% under load.

Strength is more that other common geotextiles. Function: Used exclusively for reinforcement

Geonets are open grid-like materials formed by two sets of course, parallel, extruded polymeric strands intersecting at a constant acute angle. The network forms a sheet with in- plane porosity that is used to carry relatively large fluid or gas flows.

Geomembranes are continuous flexible sheets manufactured from one or more synthetic materials. They are relatively impermeable and are used as liners for fluid or gas containment and as vapour barriers.

Geosynthetic clay liners (GCLs) are geocomposites that are prefabricated with a bentonite clay layer typically incorporated between a top and bottom geotextile layer or geotextile bentonite bonded to a geomembrane or single layer of geotextile. Geotextile-encased GCLs

are often stitched or needle punched through the bentonite core to increase internal shear resistance. When hydrated they are effective as a barrier for liquid or gas and are commonly used in landfill liner applications often in conjunction with a geomembrane.

Geocells are relatively thick, three-dimensional networks constructed from strips of polymeric sheet. The strips are joined together to form interconnected cells that are infilled with soil and sometimes concrete. In some cases 0.5 m to 1 m wide strips of polyolefin geogrids have been linked together with vertical polymeric rods used to form deep geocell layers called geomattresses. soil confinement

Geofoam blocks or slabs are created by expansion of polystyrene foam to form a low- density network of closed, gas-filled cells. Geofoam is used for thermal insulation, as a lightweight fill or as a compressible vertical layer to reduce earth pressures against rigid walls.

Geocomposites are geosynthetics made from a combination of two or more geosynthetic types. Examples include: geotextile-geonet; geotextile-geogrid; geonet geomembrane; or a geosynthetic clay liner (GCL). Prefabricated geocomposite drains or prefabricated vertical drains (PVDs) are formed by a plastic drainage core surrounded by a geotextile filter.

The Properties Of Geotextiles

- Physical properties
  Mechanical
  properties Hydraulic
  properties
  Endurance

properties
Degradation
properties

Physical properties of Geotextiles

a. Specific gravity
b. Mass per unit area
c. Thickness
d. Stiffness

Mechanical properties of Geotextiles

a. Compressibility
b. Tensile strength
c. Seam strength
d. Fatigue strength
e. Burst strength
f. Tear strength
g. Impact strength
h. Puncture strength
i. Friction strength
j. Pull out strength

THE CLASSIFICATION OF GEO TEXTILES

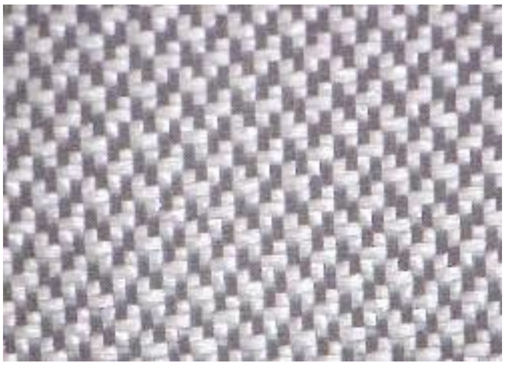
Geotextile:

Geotextiles are polymer fabrics used in the construction of roads, drains, harbour works, and breakwaters,and for land reclamation and many other **civil engineering purposes**. Geotextiles, a newly emerging field in the civil engineering and other fields, offer great potential in varied areas of applications globally.

Types of geotextiles:

Geotextiles are a permeable synthetic material made of textile materials. They are usually made from polymers such as polyester or polypropylene. The **geotextiles** are further prepared in three different categories – woven fabrics, non-woven fabrics and knitted fabrics.

Woven Fabrics: Large numbers of geosynthetics are of woven type, which can be sub- divided into several categories based upon their method of manufacture. These were the first to be developed from the synthetic fibers. As their name implies, they are manufactured by adopting techniques which are similar to weaving usual clothing textiles. This type has the characteristic appearance of two sets of parallel threads or yarns .the yarn running along the length is called warp and the one perpendicular is called weft.



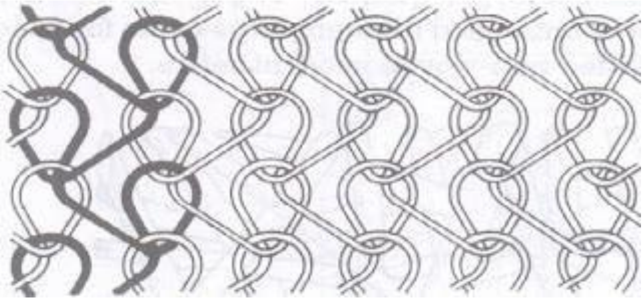
Woven fabric

The majority of low to medium strength woven geosynthetics are manufactured from polypropylene which can be in the form of extruded tape, silt film, monofilament or multifilament. Often a combination of yarn types is used in the warp and weft directions to optimize the performance/cost. Higher permeability is obtained with monofilament and multifilament than with flat construction only.

Non-woven: Non-woven geo-synthetics can be manufactured from either short staple fibre or continuous filament yarn. The fibers can be bonded together by adopting thermal, chemical or mechanical techniques or a combination of techniques. The type of fibre (staple or continuous) used has very little effect on the properties of the non – woven geo synthetics. Non-woven geotextiles are manufactured through a process of mechanical interlocking or chemical or thermal bonding of fibres/filaments. Thermally bonded non- wovens contain wide range of opening sizes and a typical thickness of about 0.5-1 mm while chemically bonded non-wovens are comparatively thick usually in the order of 3 mm. On the other hand mechanically bonded non-wovens have a typical thickness in the range of 2-5 mm and also tend to be comparatively heavy because a large quantity of polymer filament is required to provide sufficient number of entangled filament cross wires for adequate bonding.

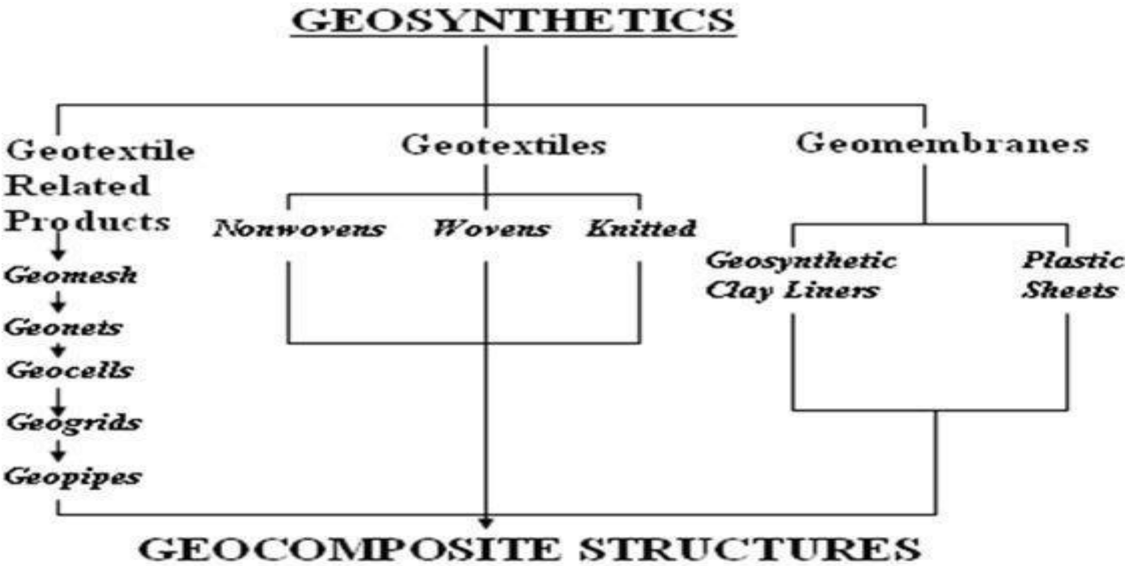
Nonwoven

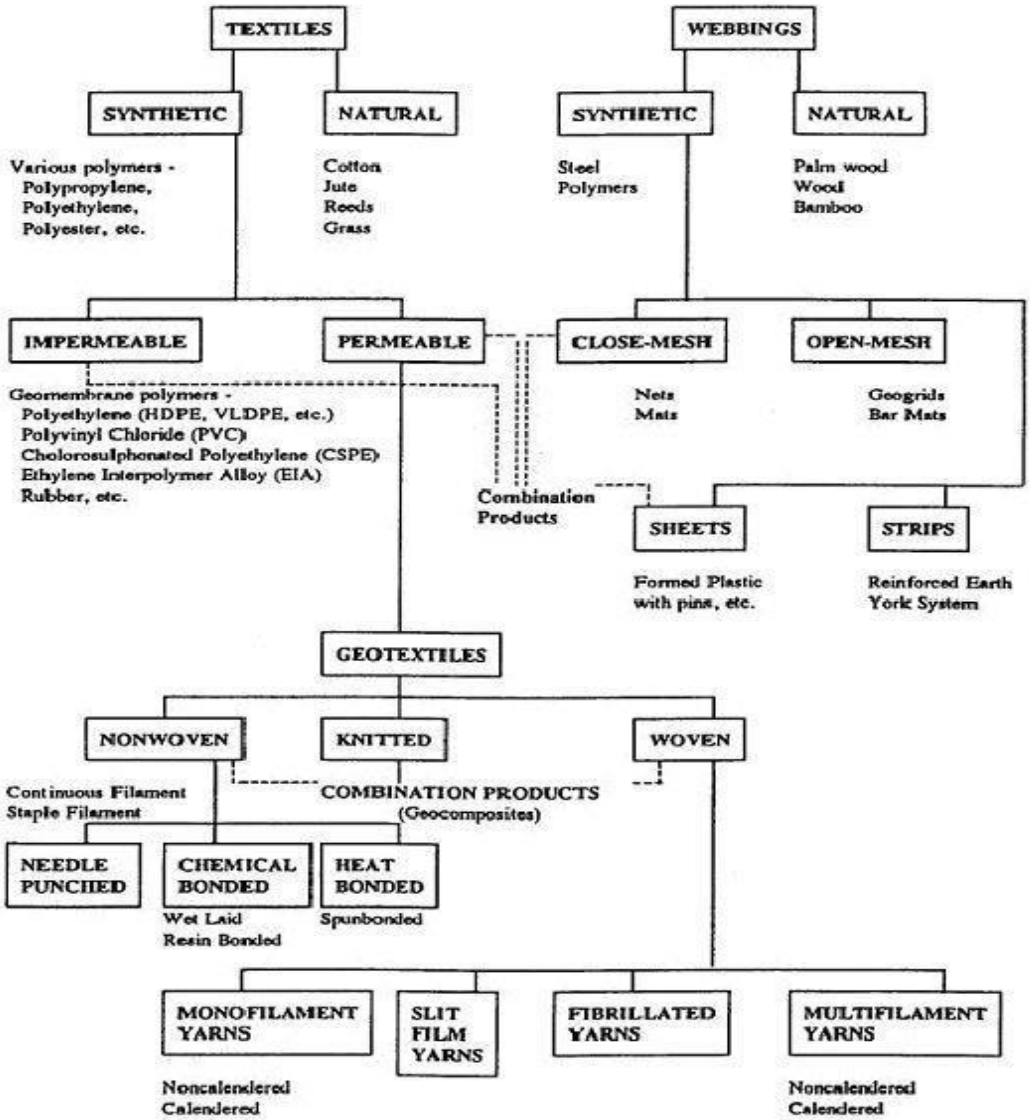
Knitted Fabrics: Knitted geosynthetics are manufactured using another process which is adopted from the clothing textiles industry, namely that of knitting. In this process interlocking a series of loops of yarn together is made. An example of a knitted fabric is illustrated in figure. Only a very few knitted types are produced. All of the knitted geosynthetics are formed by using the knitting technique in conjunction with some other method of geosynthetics manufacture, such as weaving.



Knitted fabric

Apart from these three main types of geotextiles, other geosynthetics used are geonets, geogrids, geo-cells, geo membranes, geo composites, etc. each having its own distinct features and used for special applications.





TEXTILES
WEBBINGS
SYNTHETIC
NATURAL
SYNTHETIC
NATURAL
Various polymers - Polypropylene, Polyethylene, Polyester, etc.
Cotton Jute Reeds Grass
Steel Polymers
Palm wood Wood Bamboo
IMPERMEABLE
PERMEABLE
CLOSE-MESH
OPEN-MESH
Geomembrane polymers - Polyethylene (HDPE, VLDPE, etc.) Polyvinyl Chloride (PVC) Cholorosulphonated Polyethylene (CSPE) Ethylene Interpolymer Alloy (EIA) Rubber, etc.
Nets Mats
Geogrids Bar Mats
Combination Products
SHEETS
STRIPS
Formed Plastic with pins, etc.
Reinforced Earth York System
GEOTEXTILES
NONWOVEN
KNITTED
WOVEN
Continuous Filament Staple Filament
COMBINATION PRODUCTS (Geocomposites)
NEEDLE PUNCHED
CHEMICAL BONDED
HEAT BONDED
Wet Laid Resin Bonded
Spunbonded
MONOFILAMENT YARNS
SLIT FILM YARNS
FIBRILLATED YARNS
MULTIFILAMENT YARNS
Noncalendered Calendered
Noncalendered Calendered

Applications And The Purpose Of Geotextiles And Geomembranes

- **Pavements on soft soil** Increase in bearing capacity

Pavement overlays Inhibit

crack propagation. Rail roads

Prevent ballast contamination, distribute load on subgrade. Embankments
Improve stability, provide drainage.

Retaining structures Reinforce and protect backfill

Natural slopes

Protect slope against erosion, reinforce soil, and provide drainage. Rivers, canals and reservoirs

Replace or improve traditional filter layers, erosion control.

- Water pollution control

Extract and collect granular pollutants, reinforce and protect geomembranes, relieve pore water or gas pressure below membranes.

- Shore protection

Prevent erosion and sand migration, act as filter and drainage layer

Building elements

Form soil- cement filled bags and tubes to create columns

IMPORTANT QUESTIONS

1. (a) Write the advantages and applications of reinforced earth structures with neat sketches.

(b) Discuss the external stability aspects in the design of reinforced earth wall.

2. (a) What is the main difference between geo-grid and geo-textile? Explain the field applications of geo-grid and geo-textiles.

(b) Explain separation and filtration functions of geo-textile. Mention applications based on these functions.

3. (a) What is the objective of soil reinforcement?

(b) What are the factors governing the design of reinforced earth walls?

4. (a) What are geomembranes? How geomembranes differ from geo textiles?

(b) What are the applications of geotexitiles?

5. Explain the basic mechanism of reinforced earth. Discuss the various design formulae in reinforced earth wall.
6. (a) What are geotextiles? Write a note on common nomenclature of geosynthetics.

(b) Explain with suitable examples the principles involved in geo-textile material as reinforcement for improving the bearing capacity of soil.

7. (a) Explain any four engineering applications of reinforced earth with sketches.

(b) Describe the procedure of designing a reinforced earth wall.

8. (a) Distinguish between geo textiles and geo grids.

(b) Explain the applications of geo-textiles based on their separation and drainage functions.

9. Explain the design principle of reinforced earth wall.
10. Explain clearly the functions of Geotextiles.

11. (a) What is reinforced earth? How does it differ from reinforced cement concrete and mechanically stabilized soil?

(b)Distinguishbetween“frictionalfill”and“cohesivefrictionalfill”usedinreinforced earth constructions.

12. (a) Distinguish between woven and non woven geotextiles. How they are manufacture and what functions they can perform?

(b) What is a geo-grid? Explain different types of geo grids. How do they differ from geotextiles functionally?

13. (a) What are the factors governing design of reinforced wall?

(b) With a neat sketch explain the various components of reinforced earth structure.

14. (a) What polymers are used as geosynthetics? What are their properties?

(b) Compare geotextiles and geomembrane.