LECTURES NOTE

ON

ADVANCED CONSTRUCTION TECHNIQUES AND EQUIPMENTS

FOR

6TH SEMESTER DIPLOMA CIVIL ENGG.

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QUALIFICATION: BTECH IN CIVIL ENGINEERING

ADVANCE CONSTRUCTION MATERIALS

Now a days the construction technology and the equipment becomes very advanced. The advanced construction techniques such as under water construction, trenchless technology and many new innovative materials used in advanced construction techniques and equipments to speed up any construction work.

FIBERS

Fiber is a class of material which are having continuous filaments or having discrete elongated pieces similar to the length of thread. 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 fiber, lead fiber and asbestos are mineral fibers of which glass fiber and lead fiber are synthetic fibers. Steel fiber, carbon fiber and glass fiber are the new and recent trends used in the construction work.

Fibers are considered as a construction material to enhance the flexural and tensile strength and as a binder that cloud combine Portland cement in bonding with cement matrices. Fiber is such a reinforcing material. Fibers are small pieces of reinforcing material processing certain characteristics and properties. Fibers are usually used in concrete to control cracking due to plastic shrinkage and drying shrinkage.

General Uses of Fibers

- Fibers are used for packing and making fabrics and felts.
- Glass fiber made of very fine fibers of glass is used for making acid-proof and fire-proof fabrics.
- Glass fiber is also used as a packing material for heat, sound and electric insulation. It is commonly used in a solar water system.
- Lead fiber 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.

Similar to traditional steel reinforcement, the key characteristic of steel fibres is their high tensile capacity. Steel fibres have been broadly studied in concrete applications, hence, they are commonly used to improve the mechanical properties of concrete.

Research has shown that when steel fibres are used to reinforce concrete structures, there are many improvements in the overall properties . Steel fibres help improve the concrete behaviour in terms of cracking, shrinkage , ductility, toughness, resistance to fatigue, and impact and blast loading . Furthermore, strength properties, such as tensile strength, compressive strength, and flexural strength, are increased for the parent material . This strength increase is due to the steel fibres' characteristics of

absorbing energy and controlling cracks. Steel fibres can be an ideal additive to specific applications as they possess good electric, magnetic, and heat conductivity .

Fig: Types of steel fiber

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.
- 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.

Fig: shotcrete construction

- https://www.youtube.com/watch?v=XYiRY5o99yQ&ab_channel=Bekaertchannel
- https://www.youtube.com/watch?v=lYa40TDiySw&ab_channel=BarChipInc.
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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.

Carbon fibres have been added in materials to form composites with improved properties. The addition of carbon fibres creates a composite that has outstanding mechanical properties, performs well in high temperature environments, and possesses the benefit of durability . Although carbon fibres are quite brittle, with careful consideration in the design stage, carbon fibre-reinforced composites have excellent properties . The disadvantages of carbon fibres are that due to their excellent properties the expense of manufacturing carbon fibres is high , and the bonding between the fibres and material matrix may be difficult to achieve .Carbon fibres are mostly used for repair purpose of old structural element against shear and flexural failure.

There are many positives and benefits to carbon fibres, the production of carbon fibres leads to concerns for the environment and questionable sustainability. The problem of the disposal of carbon fibre composites at the end of life phase is also well known . For most carbon fibre composites, recycling could be a possibility, however most products are simply burnt or buried , which is not good for the environment.

Fig: Carbon fiber

Fig: use of carbon fiber in construction

- https://www.youtube.com/watch?v=_FUw1AS6Zw0&ab_channel=ConstructUtopia
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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 motorsports along with other competition sports.

3. Glass fibers

Glass fiber is the material made from extremely fine fibers of glass. 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.

Different types of glass exist, with various colours, chemical compositions, and characteristics. Glass fibres have great mechanical properties and excel in terms of strength thermal properties durability and have good interfacial bonding to the matrix . Glass fibres are.most frequently used as reinforcement in resins and composites as they have amazing properties in strengthening composites.

Glass fibres are generally used to reinforce polypropylene systems . A composite is formed between the elements to form an excellent material. The resulting composite is cost effective, easy to procure, and possesses the strength and toughness characteristics of glass fiber.

Fig: Glass Fiber

Fig: mixing of glass fiber to concrete

Fig: - structure constructed from glass fiber reinforced concrete

- https://www.youtube.com/watch?v=QoDhr89hocg&ab_channel=TrinicLLC

Properties of Glass Fibers

- It has high ratio of surface area to weight.
- They have good thermal insulation(**Thermal insulation** is the reduction of **heat** transfer between objects) .
- 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.

PLASTIC AS CONSTRUCTION MATERIAL

Plastic is a general name given to a wide range of synthetic materials that are based on polymers. The construction industry uses plastic for a wide range of applications because of its versatility, strength-to-weight ratio, durability, corrosion resistance, and so on.

Plastic can be manufactured into forms such as; pipes, cables, coverings, panels, films, sheets and so on; and can be formed or expanded to create low-density materials; and be dissolved in solvents.

Some of these plastics main uses in the construction industry are:

- Cladding panels.
- Cables
- Pipes and gutters.
- Windows and doors.
- Shuttering
- Wall linings
- Floor covering
- Ceiling panels.
- Roof coverings.
- Sinks, basins, baths, and showers.

Fig: Cladding panels

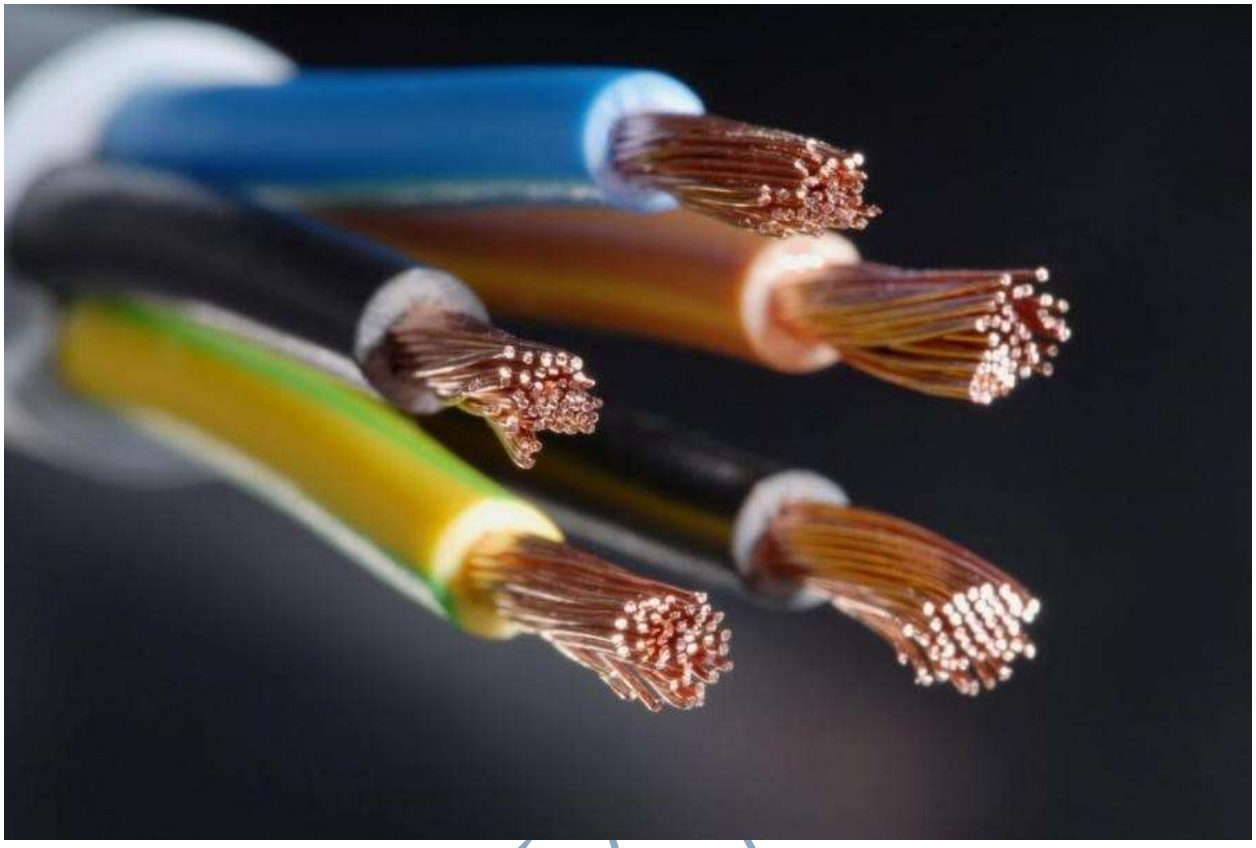


Fig: Cables

Fig: Plastic rain water gutter

Fig: plastic pipes

Fig: wall linings

Fig: Plastic Floor covering

Fig: Roof covering

The advantages of using plastic in construction are that it is lightweight yet strong which makes it easier to transport and shift around sites. It is also resistant to rot and corrosion and has strong weather ability due to it being capable of achieving tight seals.

: The disadvantages of plastic are that it has a high embodied energy content and a low modulus of elasticity, meaning that it is generally unsuitable for load-bearing applications.

PROPERTIES:-

: Typically, construction professionals select plastic materials based on the following criteria:

1.Durability

2. Cost effectiveness

3. Recycling

4. Energy saving

5. Safety

6. Easy to install

Use of Plastics in Different Aspects of the Construction Industry

1.Flooring

Plastic materials like polyvinyl chloride (PVC) and polyethylene are used to make flooring less prone to wear and tear. It also decreases the sound pollution level and can be cleaned easily.

2.Roofing

To protect the outer surface of the roof from damage, two layers of different plastic materials are required. The upper part is made of colored thermoplastic olefin or vinyl while the lower part consists of polyurethane foam which consumes less energy and keeps the interior of a house cooler.

3.Insulation

Polyurethane spray is frequently used for insulation when constructing green or low energy buildings. Rigid polyurethane foam is known for its high thermal resistance which promotes temperature consistency. Polyurethane foam is also popular because it is lightweight, chemical resistant, and flame retardant. Due to its closed cell nature, polyurethane insulation performs as an air barrier, resulting in significant energy savings.

4.Wall

A structural insulated panel (SIP) is a sandwich of expanded polystyrene amidst two slim layers of oriented strand board. This type of pre-fab, composite wall board can be transferred to the work place easily for a particular task and provide good support to columns and other associated essentials during renovation.

5.Pipes

Commonly made up of polyvinyl chloride (PVC), CPVC, acrylonitrile butadiene styrene (ABS) or polyethylene, plastic pipes are flexible and very light in weight, making them easy to install. All of these plastic materials are also highly chemical and water resistant, making them suitable for many extreme environments.

6.Windows

Polycarbonate is used to manufacture building windows. This plastic material is strong, clear and very light in weight. Polycarbonate windows are considered more burglar-proof than regular glass windows. Two plastics materials, vinyl and fiberglass, are used commonly in the production of window frames. Fiberglass is extremely strong while vinyl is quite durable and also inexpensive.

7.Doors

Some construction projects use doors made from a stiff polyurethane foam core with a fiber reinforced plastic (FRP) coating. The sandwich structure of these doors makes them incredibly strong.

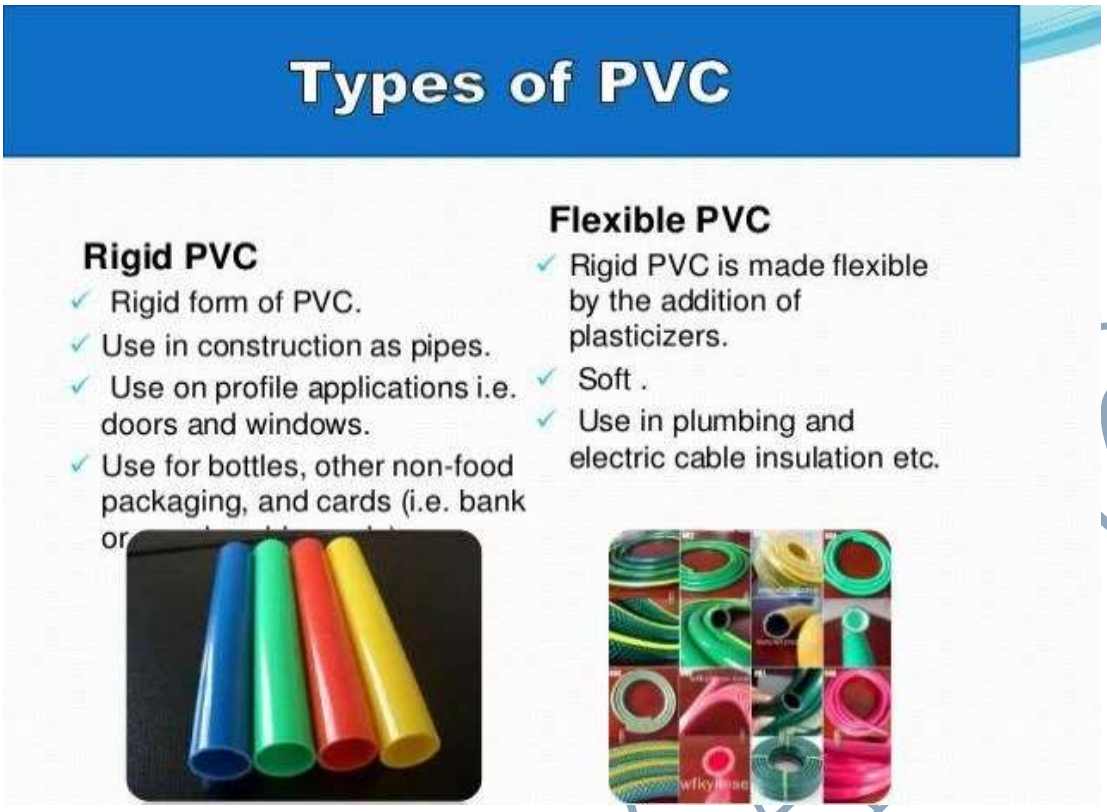
TYPES:-

PVC:-

Polyvinyl chloride (PVC), a synthetic resin made from the polymerization of vinyl chloride. Second only to polyethylene among the plastics in production and consumption, PVC is used in an enormous range of domestic and industrial products, from raincoats and shower curtains to window frames and indoor plumbing. A lightweight, rigid plastic in its pure form, it is also manufactured in a flexible “plasticized” form.

RPVC:-

RPVC means Rigid PolyVinyl Chloride which comes from PVC. Polyvinyl chloride (PVC), also known as vinyl, is a common plastic polymer (a polymer being a large molecule). It comes in two basic forms: flexible and rigid (RPVC). RPVC is used in construction (especially pipes), packaging etc. RPVC Pipes with high impact strength & load bearing capacity.

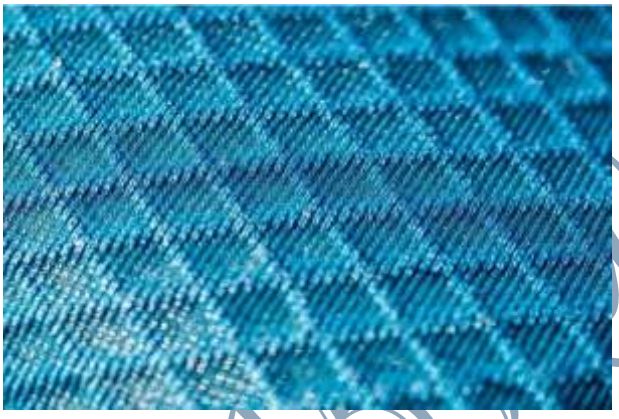


HDPE:-

High density polyethylene (HDPE) piping systems have been used for municipal and industrial water applications for over 50 years within Building & Construction Division. HDPE pipes are also used for ground source geothermal applications.

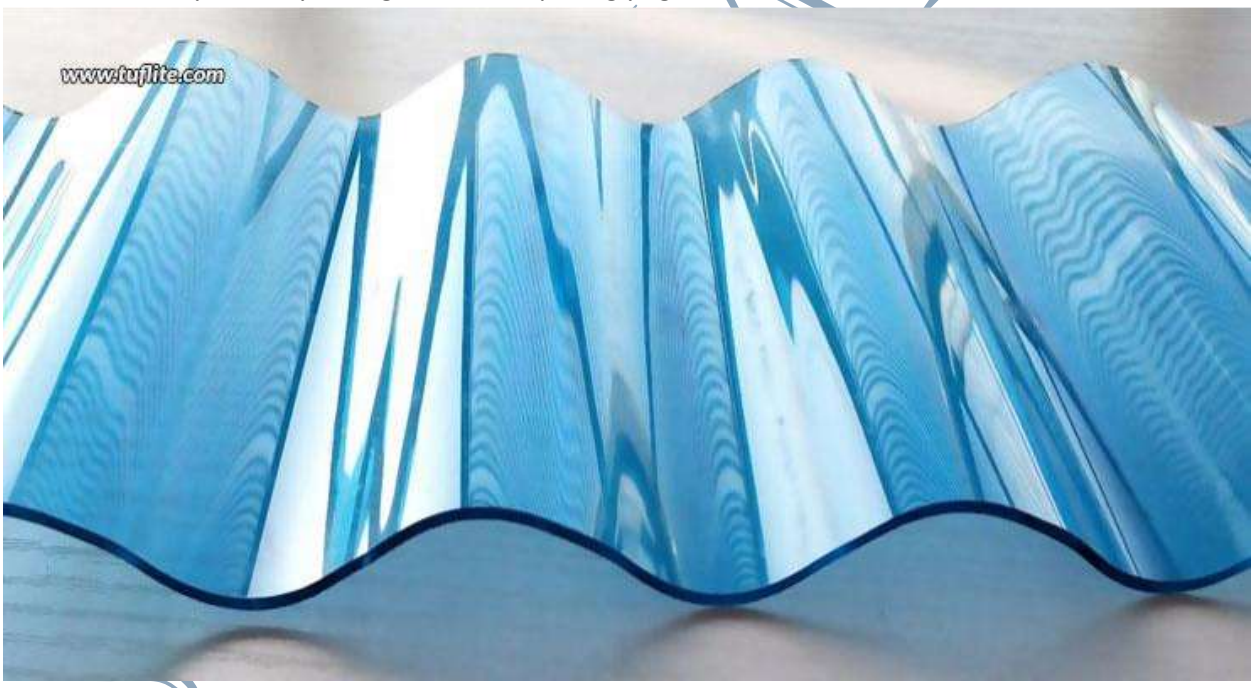
FRP:-

Fibre-reinforced plastic (FRP) (also called fiber-reinforced polymer).FRP bars are used as internal reinforcement for concrete structures. FRP bars, sheets, and strips are used for strengthening of various structures constructed from concrete, masonry, timber, and even steel. Fibre reinforced polymers are used in the construction of special structures requiring electrical neutrality.



GRP:-

GRP stands for 'Glass Reinforced Plastic' a material made from a polyester resin, which is reinforced by chopped strand mat glass fibres to form a GRP laminate. It is a very popular composite material to use because not only is it very strong but also surprisingly light.



Coloured Plastic Sheets:-

Plastic film is a thin continuous polymeric material. Thicker plastic material is often called a "sheet". Plastic sheets are generally low cost, easy to manufacture, durable, strong for their weight, electrically and thermally insulative, and resistant to shock, corrosion, chemicals, and water.

Artificial timber

The timber which is converted in a factory by some mechanical processes is termed as 'Artificial timber' or 'Industrial timber'. And such timber possesses desired shape, appearance, strength and durability. 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.

Properties of artificial timber

- Just as wood can be cut into various sizes and shapes. Artificial timber can be re-sized for various uses in furniture, flooring, or even construction. It can be made in the form of blocks, beams, and panel etc.
- Its density can be changed .That's why it can be made heavier/stronger or lighter depending on what it is going to be used for. 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.
- 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.
- It retards fire. 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.
- It 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.
- It does not rot.
- Artificial timber invention prevents pollution.

Different Types of Artificial Timber and their uses

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.

- https://www.youtube.com/watch?v=bdcrAs9YcH8&ab_channel=PeterMu

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°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.

Miscellaneous Materials.

A category of asbestos-containing building material comprised mostly of nonfriable asbestos products and materials, such as ceiling tiles, floor tiles, roofing felt, transit pipes and panels, exterior siding, fabrics, and sheetrock systems.

Acoustics Material

When the sound intensity is more, then it gives the great trouble or nuisance to the particular area like auditorium, cinema hall, studio, recreation centre, 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).

Properties of Acoustic Material

1.Sound energy is captured and adsorbed.

2.It has a low reflection and high absorption of sound.

3.Higher density improves the sound absorption efficiency at lower frequencies.

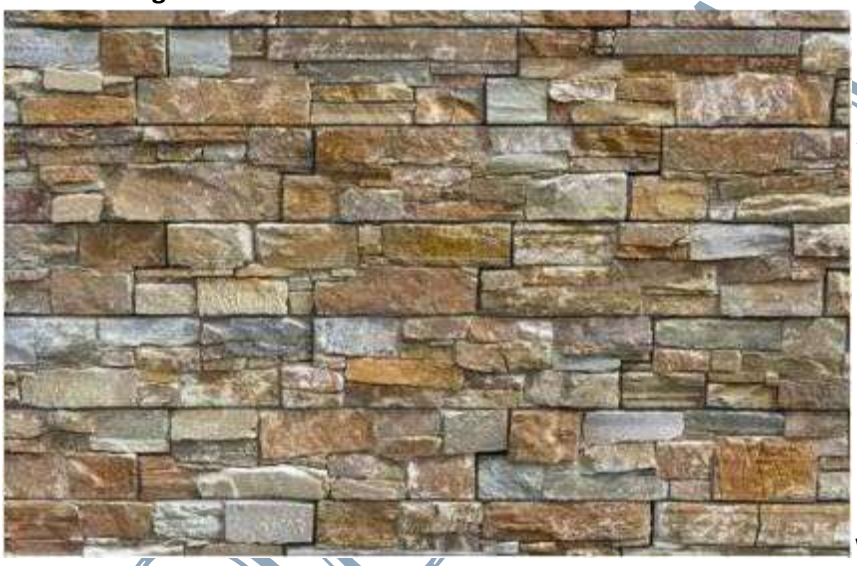
4.Higher density material help to maintain a low flammability performance. Hence acoustic material should have higher density.

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

Uses of Acoustic Material

1.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.
2.It suppresses echoes, reverboration, reflection and resonance.
3.Important specifications for noise reduction and noise absorption products include noise attenuation and noise reduction coefficient.
4.A vinyl acoustic barrier blocks controls airborne noise (street traffic, voices, music) from passing through a wall ceiling or floor.
5.Acoustic foam and acoustic ceiling tiles absorb sound so as to minimize echo and reverboration within a room.
6.Sound proof doors and windows are designed to reduce the transmission of sound.
7.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 cladding



Wall cladding is a type of decorative covering intended to make a wall look like it is made of a different sort of material than it actually is. Some of the most common examples are on the outside of buildings, but cladding can also be an artistic element in interior decorating.
The most common types of cladding are Stone Cladding, Brick Cladding, Timber Cladding, Metal Cladding, Concrete Cladding, Glass Cladding.

Plasterboard

Plasterboard is a panel made of calcium sulfate dihydrate (gypsum) usually pressed between a facer and a backer. It is used to make interior walls and ceilings. This 'Drywall' construction became popular as a quicker alternative to traditional lath application.

Microsilica

Microsilica or silica fume is an excellent admixture for concrete as it leads to better engineering properties. It reduces thermal cracking, improves durability, and increases strength. Silica fume concrete has a number of construction applications.

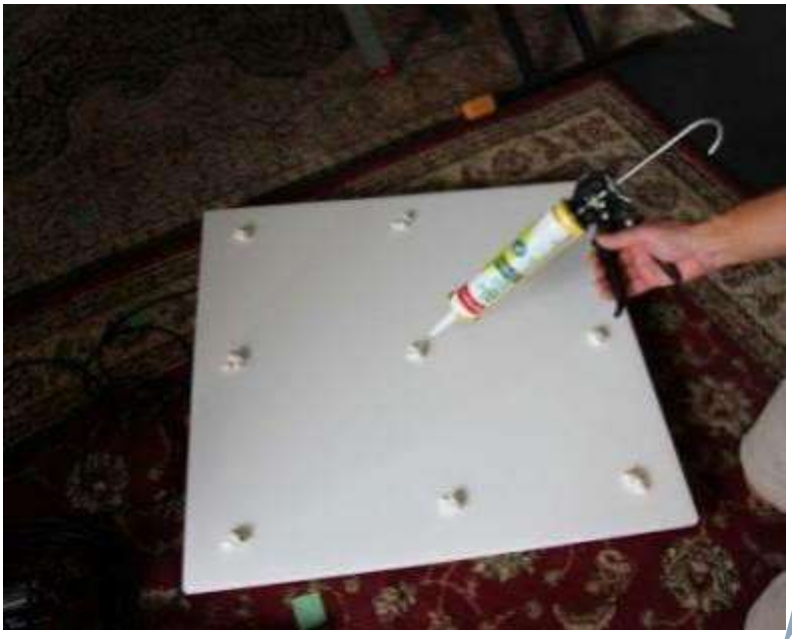
Artificial Sand

Artificial sand, also called crushed sand or mechanical sand, refers to rocks, mine tailings or industrial waste granules with a particle size of less than 4.75 mm, which are processed by mechanical crushing and sieving, but does not include soft and weathered granules.

Bonding Agents

Bonding agents are natural, compounded or synthetic materials used to enhance the joining of individual members of a structure without employing mechanical fasteners. The most commonly used types of bonding agents are generally made from natural rubber, synthetic rubber or from any other organic polymers. The polymers include polyvinyl chloride, polyvinyl acetate etc. With the addition of bonding agent in repair mortar or concrete, the reduced water-cement ratio can be adopted for the same workability, thereby reducing drying shrinkage.

Adhesive



Construction adhesive is a general-purpose adhesive used for attaching drywall, tile, molding, and fixtures to walls, ceilings, and floors. It is most commonly available in tubes intended for use.

PREFABRICATION

Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located. The term is used to distinguish this process from the more conventional construction practice of transporting the basic materials to the construction site where all assembly is carried out.

Prefabrication is the process of making buildings, or components of buildings, in a different location than the job site itself. Construction companies will transport the completed unit to the final site, where they will also complete the setup and handover buildings to their new owners. This process eliminates the need for traditionally sourced construction materials because off-site assembled parts result in less waste. As the raw materials are built off-site and shipped partially assembled, prefabrication reduces the cost of labor and the cost of materials.

The term *prefabrication* also applies to the manufacturing of things other than structures at a fixed site. It is frequently used when fabrication of a section of a machine or any movable structure is shifted from the main manufacturing site to another location, and the section is supplied assembled and ready to fit. It is not generally used to refer to electrical or electronic components of a machine, or mechanical parts such as pumps, gearboxes and compressors which are usually supplied as separate items, but to sections of the body of the machine which in the past were fabricated with the whole machine. Prefabricated parts of the body of the machine may be called 'sub-assemblies' to distinguish them from the other components.

HISTORY OF PREFABRICATION

- Prefabrication has been used since ancient times. For example, it is claimed that the world's oldest known engineered roadway, the Sweet Track constructed in England around 3800 BC, employed prefabricated timber sections brought to the site rather than assembled on-site.
- Sinhalese kings of ancient Sri Lanka have used prefabricated buildings technology to erect giant structures, which dates back as far as 2000 years, where some sections were prepared separately and then fitted together, specially in the Kingdom of Anuradhapura and Kingdom of Polonnaruwa.
- After the great Lisbon earthquake of 1755, the Portuguese capital, especially the Baixa district, was rebuilt by using prefabrication on an unprecedented scale. Under the guidance of Sebastião José de Carvalho e Melo, a new Pombaline style of architecture and urban planning arose, which introduced early anti-seismic design features and innovative prefabricated construction methods, according to which large multistory buildings were entirely manufactured outside the city, transported in pieces and then assembled on site. The process, which lasted into the nineteenth century, lodged the city's residents in safe new structures unheard-of before the quake.
- Also in Portugal, the town of Vila Real de Santo António in the Algarve, founded on 30 December 1773, was quickly erected through the use of prefabricated materials en masse. The first of the prefabricated stones was laid in March 1774. By 13 May 1776, the centre of the town had been finished and was officially opened.

CURRENT USES

The most widely used form of prefabrication in building and civil engineering is the use of prefabricated concrete and prefabricated steel sections in structures where a particular part or form is repeated many times. It can be difficult to construct the formwork required to mould concrete components on site, and delivering wet concrete to the site before it starts to set requires precise time management. Pouring concrete sections in a factory brings the advantages of being able to re-

use moulds and the concrete can be mixed on the spot without having to be transported to and pumped wet on a congested construction site. Prefabricating steel sections reduces on-site cutting and welding costs as well as the associated hazards.

Fig: A house being built with prefabricated concrete panels.

Prefabrication techniques are used in the construction of apartment blocks, and housing developments with repeated housing units. The quality of prefabricated housing units had increased to the point that they may not be distinguishable from traditionally built units to those that live in them. The technique is also used in office blocks, warehouses and factory buildings. Prefabricated steel and glass sections are widely used for the exterior of large buildings.

Detached houses, cottages, log cabin, saunas(a small room used as a hot-air or steam bath for cleaning and refreshing the body.), etc. are also sold with prefabricated elements. Prefabrication of modular wall elements allows building of complex thermal insulation, window frame components, etc. on an assembly line, which tends to improve quality over on-site construction of each individual wall or frame. Wood construction in particular benefits from the improved quality. However, tradition often favors building by hand in many countries, and the image of prefab as a "cheap" method only slows its adoption. However, current practice already allows the modifying the floor plan according to the customer's requirements and selecting the surfacing material, e.g. a personalized brick facade can be masoned even if the load-supporting elements are timber.

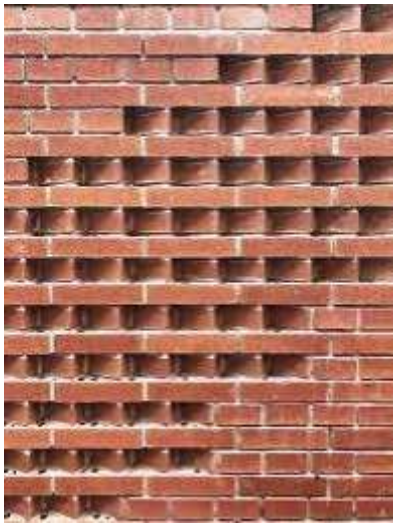


Fig: Brick Façade(construction with brick and mortar)

Transportation of prefabricated Airbus wing assembly

Prefabrication saves engineering time on the construction site in civil engineering projects. This can be vital to the success of projects such as bridges and avalanche galleries(An **avalanche gallery** is a permanent full or partial enclosure around a line of communication such as a road or railroad in order to protect it from avalanches.), where weather conditions may only allow brief periods of construction. Prefabricated bridge elements and systems offer bridge designers and contractors significant advantages in terms of construction time, safety, environmental impact, constructability, and cost. Prefabrication can also help minimize the impact on traffic from bridge building. Additionally, small, commonly used structures such as concrete pylons are in most cases prefabricated.

Fig: Avalanche protection Gallery

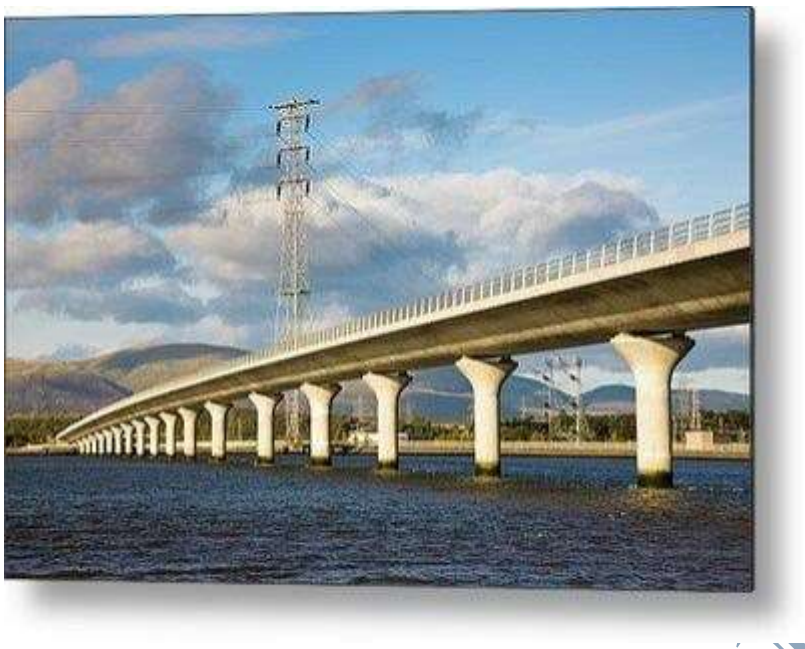


Fig: Concrete pylons

TYPES OF PREFABRICATED SYSTEM

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 certain order and discipline. The system of prefabricated construction depends on the extend of the use of prefabricated components. There are four types of prefabricated system.

- Large Panel system
- Frame system
- Slab-column system with walls

LARGE PANEL SYSTEM

The designation “Large panel system” refers to multi-storied structures composed of large wall and floor concrete panels in the vertical and horizontal direction so that the wall panels enclose appropriate spaces for the rooms within a building. These panels form a box-like structure . Both the horizontal and vertical resists gravity load. Wall panels are usually one storied high. Horizontal floor and roof panel span either as one way or two way slabs. When properly joined together , the horizontal elements act as diaphragms that transfer the lateral loads to the walls.

Fig: Large Panel prefabrication system

- https://www.youtube.com/watch?v=AIj2HP3XCWY&ab_channel=FPMcCann

https://www.youtube.com/watch?v=AIj2HP3XCWY&ab_channel=FPMcCann

FRAME PREFABRICATION SYSTEM

In this system of prefabrication components are usually linear elements. The beams are seated on corbels of the pillars usually with hinged joints (where rigid is also an option). Then joints are filled with concrete at site.

Fig: Steel frame prefabricated structure

- https://www.youtube.com/watch?v=g6sSbazsyLw&ab_channel=NikkiMoreauxNikkiMoreaux
- https://www.youtube.com/watch?v=WsL-xkAO67Q&ab_channel=NikkiMoreauxNikkiMoreaux

SLAB COLUMN SYSTEM WITH WALLS

These system rely on shear walls to sustain lateral load effects , whereas the slab-column structure resists mainly gravity loads. There are two main systems in this category.

→ Lift-slab system with walls

→ Prestressed slab column system

Lift-slab system with walls

- Lift-Slab Construction is a precast method of construction of slab on the ground and then lifting it to the structure**.**
- In this type of precasting used in building construction involves casting floor and roof slabs at or near ground level and lifting them to their final position.
- It normally requires fewer joints than other types of precast building systems.
- Typically, columns are erected first, but not necessarily for the full height of the building. Near the base of the columns, floor slabs are cast in succession, one atop another, with a parting compound between them to prevent bond. The roof slab is cast last, on top.
- Usually, the construction is flat plate, and the slabs have uniform thickness; waffle slabs or other types also can be used.
- Openings are left around the columns, and a steel collar is slid down each column for embedment in every slab. The collar is used for lifting the slab, connecting it to the column, and reinforcing the slab against shear.
- To raise the slabs, jacks are set atop the columns and turn threaded rods that pass through the collars and do the lifting. As each slab reaches its final position, it is wedged in place and the collars are welded to the columns.

Prefabricated lift slab structure

- https://www.youtube.com/watch?v=BcXQsnnaA00

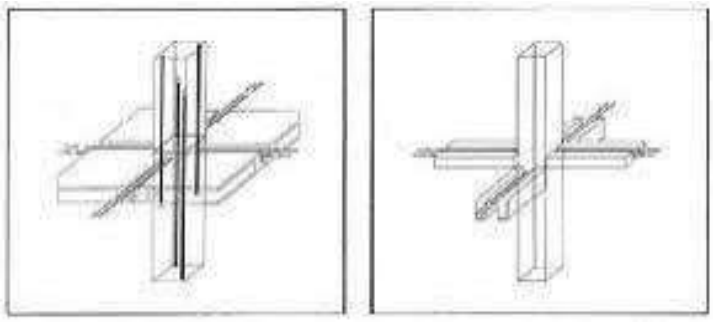
PRESTRESSED SLAB-COLUMN SYSTEM

- The prestressed slab-column system uses horizontal prestressing in two orthogonal direction to achieve continuity.

- The precast concrete column elements are 1 to 3 stories high. The reinforced concrete floor slabs fit the clear span between columns. After erecting the slabs and column of a storey , the column and floor slab are prestressed by means of prestressing tendons that pass through ducts in the column at the floor level and along the gaps left between adjacent slabs.

- After prestressing ,the gaps between the slabs are filled with in situ concrete and the tendons then become bonded with the spans.

- Seismic loads are resisted mainly by the shear walls (precast or cast-in-place) positioned between the columns at appropriate locations.



➢ https://www.youtube.com/watch?v=mfZo_HvMmM8

THE THEORY AND PROCESS OF PREFABRICATION

The theory behind the method is that time and cost is saved if similar construction tasks can be grouped, and assembly line techniques can be employed in prefabrication at a location where skilled labour is available, while congestion at the assembly site, which wastes time, can be reduced. The method finds application particularly where the structure is composed of repeating units or forms, or where multiple copies of the same basic structure are being constructed. Prefabrication avoids the need to transport so many skilled workers to the construction site, and other restricting conditions such as a lack of power, lack of water, exposure to harsh weather or a hazardous environment are avoided. Against these advantages must be weighed the cost of transporting prefabricated sections and lifting them into position as they will usually be larger, more fragile and more difficult to handle than the materials and components of which they are made.

❖ **Some of the important Indian Standards relating to modular co-ordination are IS 7921 : 1987, IS 7922 : 1987 and IS 6820 : 1978 published by the Bureau.**

Classification of Prefabrication

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

Classification of Prefabrication (Cont.,)

1. Small prefabrication :

- For eg:- brick is a small unit precasted and used in buildings. This is called as small prefabrication. That the degree of precast element is very low.

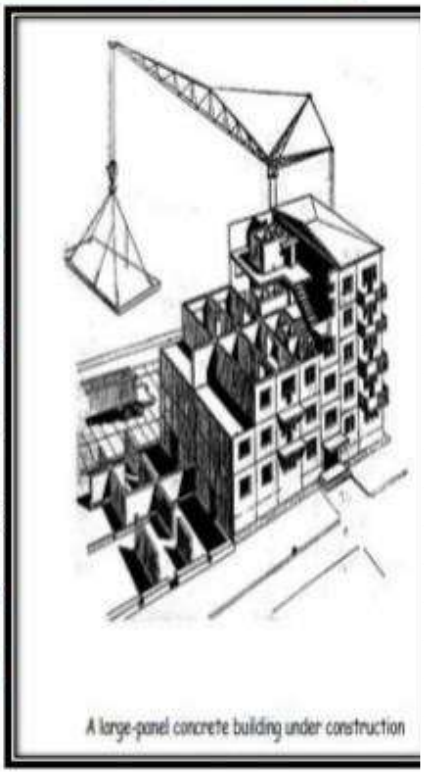
2. Medium Prefabrication :

- Suppose the roofing systems and horizontal member are provided with precast elements.
- These constructions are known as medium prefabricated construction. Here the degree of precast elements are moderate.

Classification of Prefabrication (Cont.,)

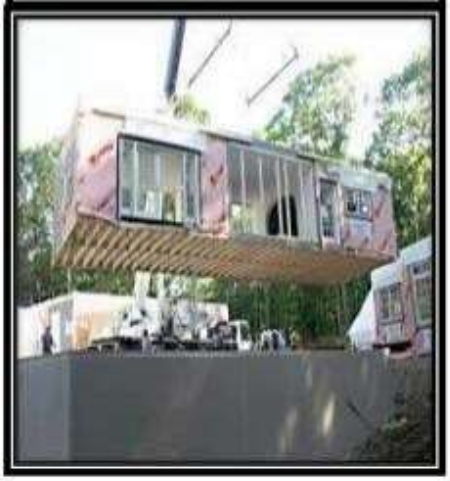
3. Large Prefabrication:

- In large prefabrication most of the members like wall panels, roofing/flooring systems, beams and columns are prefabricated.
- Here degree of precast elements are high.
- One of the main factors which affect the factory prefabrication is transport.
- The width of road and mode of transport vehicles are the factors which factor the prefabrications which is to be done off site (or) Factory.
- Small elements the conveyance is easier with normal type of lorry.
- On site prefabrication is preferred for following reasons:
  - factory situated at a long distance from the construction site.
  - vehicle have to cross a congested traffic.
  - heavy weighed elements to transport.



A large-panel concrete building under construction

Classification of Prefabrication (Cont.,)



4. Open system of prefabrication:

- In the total prefabrication systems, the space framers are casted as a single unit and erected at the site.
- The wall fitting and other fixing are done on site.

5. Closed system of prefabrication :

- In this system the whole things are casted with fixings and erected on their position.

Classification of Prefabrication (Cont.,)

6. Partial prefabrication :

- In this method of construction the building element (mostly horizontal) required are precast and then erected.
- Since the costing of horizontal elements (roof / floor) often take there time due to erection of from work the completion of the building is delayed and hence this method is restored.
- Use of double tees, cored slabs, slabs etc., are some of the horizontal elements.
- This method is efficient when the elements are readily available when the building reached the roof level.
- The delay caused due to erection of formwork, delay due to removal eliminated completely in this method of construction Suitable for any type of building provided lifting and erection equipments are available.

Classification of Prefabrication (Cont.,)

7. Total Prefabrication :

- Very high speed can be achieved by using this method of construction.
- The choice of these two methods depend on the situations when the factory produced elements are transported and erected site we call if off-site prefabrication.
- If this method is to be adopted then we have a very good transportation of the products to site.
- If the elements are cast near the building site and erected, the transportation of elements can be eliminated, but we have consider the space availability for establish such facilities though it is temporary.
- The choice of the method of construction also depends on the following;
    1. Type of equipment available for erection and transport.
    2. Type of structural scheme (linear elements or panel)
    3. Type of connections between elements.
    4. Special equipment devised for special method construction.

Advantages of prefabrication

- Self-supporting ready-made components are used, so the need for formwork, shuttering and scaffolding is greatly reduced.
- Construction time is reduced.
- Speed up construction because of curing is not necessary.
- Improve the quality as the components can be manufactured under control condition.
- Use locally available materials with required characteristics.
- Minimize of wastage.
- Onsite construction is minimized.
- Requirement of skilled labors such as mason, carpenters, bar benders etc., can be reduced.
- It save manpower.
- Shrinkage of the units which largely eliminated.
- Less expansion joints are needed.
- More accurate & better workmanship.
- Cross section of member can be reduced by use of high strength concrete.

Disadvantages of prefabrication

- Careful handling of prefabricated components such as concrete panels or steel and glass panels is required.
- Attention has to be paid to the strength and corrosion-resistance of the joining of prefabricated sections to avoid failure of the joint.
- Similarly, leaks can form at joints in prefabricated components.
- Transportation costs may be higher for voluminous prefabricated sections than for the materials of which they are made, which can often be packed more compactly.
- Height restrictions under bridges.
- Road transport maximum widths.
- Additional cost of temporary bracing for transportation and/or lifting or permanent framing to support prefabricated assemblies.
- Large prefabricated sections require heavy-duty cranes and precision measurement and handling to place in position.
- Greater Erection equipments are needed.

Uses of Prefabrication

The following are the uses of introducing the prefabrication system:

- Prefabricated components speed up construction time, resulting in lower labor costs;
- Prefabrication allows for year-round construction;
- Work is not affected by weather delays (related to excessive cold, heat, rain, snow, etc.);
- The mechanization used in prefabricated construction ensures precise conformity to building code standards and greater quality assurance;
- There are less wasted materials than in site-built construction;
- There is less theft of material/equipment (and less property damage due to vandalism);
- Materials are protected from exposure to the elements during construction;
- Worker safety and comfort level are higher than in site-built construction;
- Quality control and factory sealing and design can ensure high energy

Materials used for Prefabrication:

- Materials like concrete, steel, treated wood, aluminum, Cellular concrete, Light weight concrete etc...
- Special characteristics while choosing materials
  - Light weight for easy handling and transport and to economic an sections and sizes of foundations.
  - Easy available
  - Economy
  - Easy workability
  - Durability
  - Thermal insulation property
  - Sound insulation

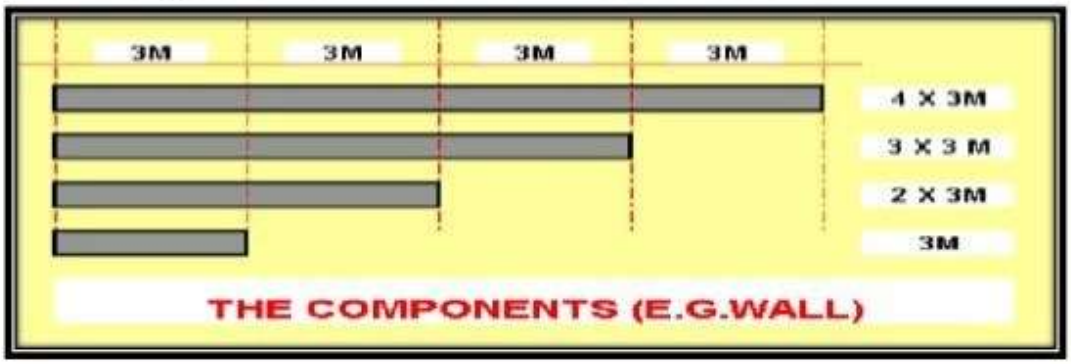
Modular Coordination

- Modular coordination is a concept of coordination of **dimension** and **space** in which building components are positioned in terms of **basic unit** or **MODULE(M)**
  - 1M= 100mm
- It is internationally accepted by the International Standard Organization and many other countries including Malaysia.
- **A module:** a basic dimension which could for example form the basis of a planning grid in terms of multiples and submultiples of standard module.

Modular Coordination (Cont.,)

AIMS:

- To achieve dimensional compatibility between building dimensions, span, or spaces and the sizes of components or equipment by using related modular dimensions.
- Making the planning simpler & clearer by distinct indication of location of the building component in the building, both in respect to each other & a modular grid.
- Simplification of site work.
- Limiting the member of sizes of building component so that the linkage is based on modular measurement.



Modular Coordination (Cont.,)

Basics of module :

- **The basic module is known as 1M which is equivalent to 100mm.**

1M = 100mm

There are three type of MODULE :-

(I) Basic Module :

It is the fundamental unit of size in modular coordination and for general application to building & components. The size of basic Module is taken as 100mm denoted by "M.

(II) Multi Module :

multiples of basic module usually expressed in as "M" with numeric prefix as 2M , 3M, 4M etc are referred to as multi module.

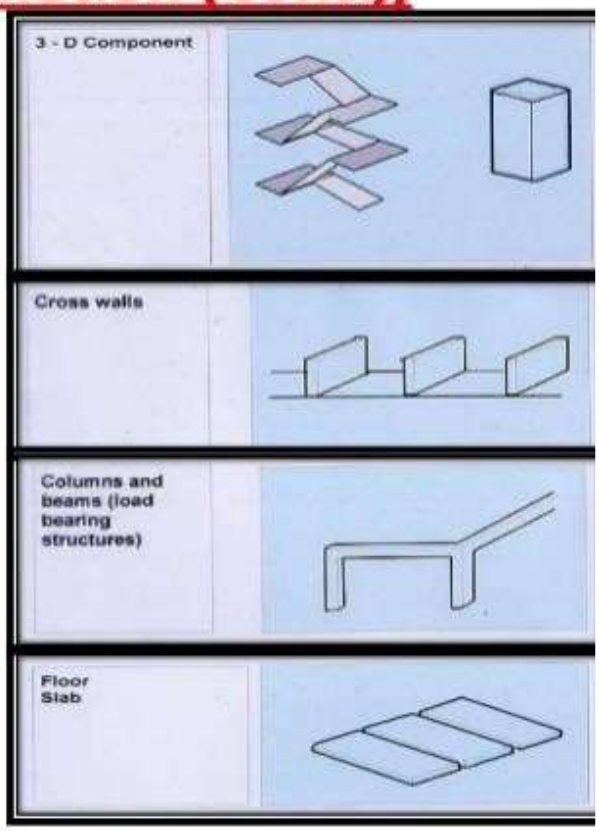
(III) Sub Module:

smaller than the basic module. For practical considerations, this sub modular increment shall be expressed as "M" with fractional prefix as 1/5M, 1/4M, 1/3M,etc.

Modular Coordination (Cont.,)

Positioning of Building Components:

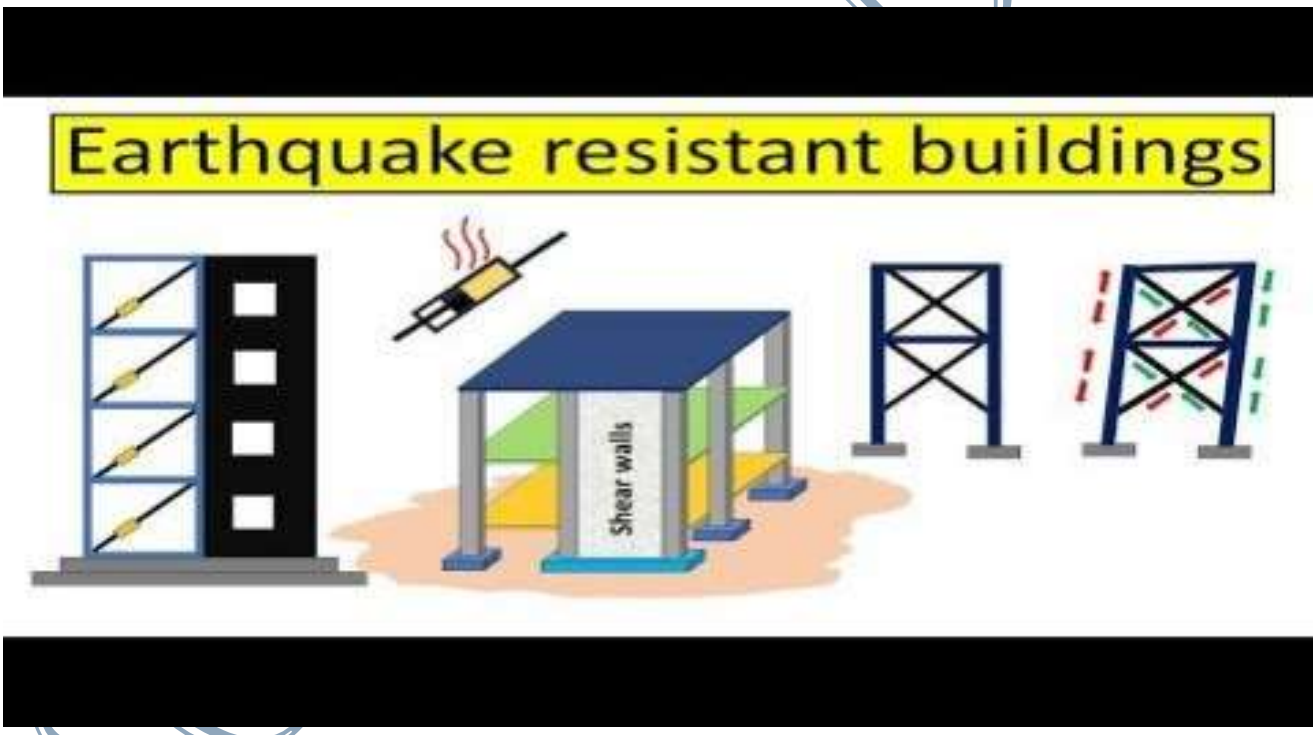
- **Structural components**
  - Columns
  - Beams
  - Floor slabs
  - Walls
  - Staircases and lift cores
- **Non structural components**
  - Doors
  - Windows
- **Finishes**
  - Ceiling finishes
  - Floor finishes
  - Wall finishes



EARTHQUAKE RESISTANT CONSTRUCTION

An earthquake is the shaking of the surface of the Earth resulting from a sudden release of energy in the Earth's lithosphere that creates seismic waves. An earthquake is measured on Richter's scale. A seismometer detects the vibrations caused by an earthquake. It plots these vibrations on a seismograph. The strength, or magnitude, of an earthquake, is measured using the Richter scale. Quakes measuring around 7 or 8 on the Richter scale can be devastating. The effects of an earthquake are terrible and devastating. Many building, hospitals, schools, etc. are destroyed due to it. A lot of people get killed and injured. Many people lose their money and property. It affects the mental health and emotional health of people.

The effect of earthquake can be prevented or minimized by taking certain preventive measures as per standard scientific guidelines. In Earthquake prone areas, these measures may prevent the loss of lives and material. This is the need of hour to educate the masses to adhere to the standard measures during the process of construction in earthquake prone areas. Organization of different workshops and revision of curriculum in engineering courses from the view point of frequent earthquakes in different parts of the country may be of great help to minimize the damage.



Building configuration

An earthquake is a natural phenomenon, occurring with uncertainties which is the result of sudden release of energy in the earth's crust that creates seismic waves. Certain preventive measures are needed to be incorporated during the construction resulting in the Earthquake resistant structures. Earthquake resistant structures are the structures, designed to resist the effect of earthquake on them. The type of construction in which there is either no effect of earthquake or it is negligible is said to be Earthquake Resistant Construction. Although no construction can be entirely immune to the damage caused by the

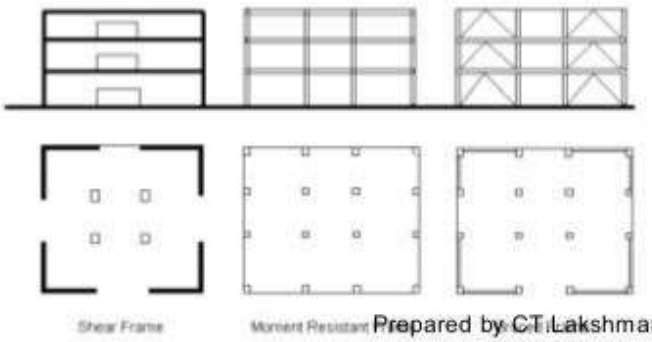
earthquakes. But the basic goal of earthquake resistant construction is to erect structures which can withstand seismic activities or conditions than their counterpart conventional structures so that loss of life is minimized by taking preventive measures during the construction stage. Hence in the areas which are prone to seismic effects, construction requires measures to ensure stability, serviceability, strength with considerable levels of safety.

Building Configuration: This term defines a building's size and shape, and structural and nonstructural elements. Building configuration determines the way seismic forces are distributed within the structure, their relative magnitude, and problematic design concerns.

- *Regular Configuration* buildings have Shear Walls or Moment-Resistant Frames or Braced Frames and generally have:
    - Low Height to Base Ratios
    - Equal Floor Heights
    - Symmetrical Plans
    - Uniform Sections and Elevations
    - Maximum Torsional Resistance
    - Short Spans and Redundancy
    - Direct Load Paths
- *Irregular Configuration* buildings are those that differ from the "Regular" definition and have problematic stress concentrations and torsion.

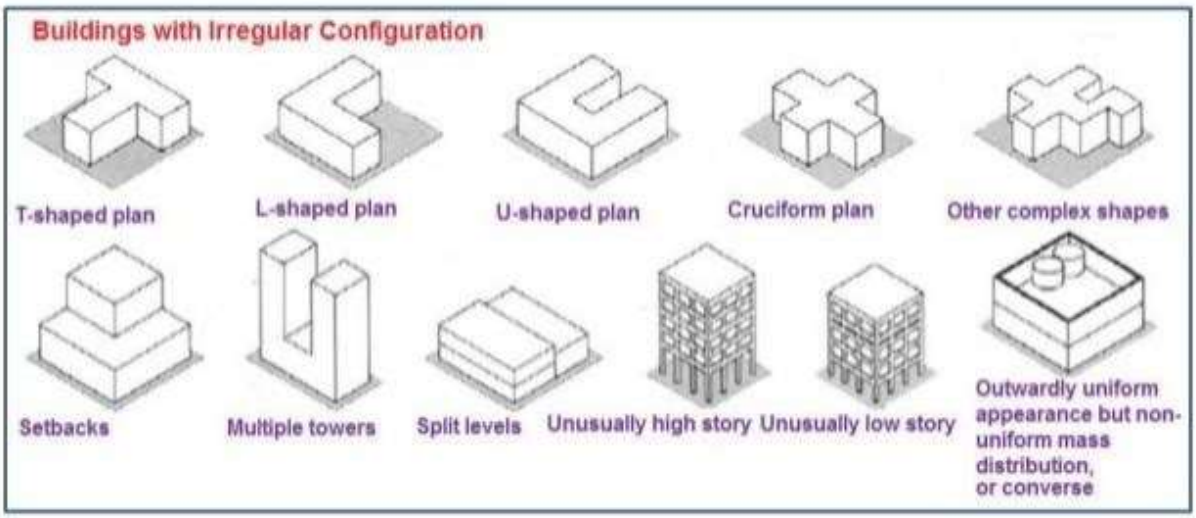
Regular Configuration

- Regular configuration is seismically ideal. These configurations have low heights to base ratio, symmetrical plane, uniform section and elevation and thus have balanced resistance.



These configurations would have maximum torsional resistance due to location of shear walls and bracings. Uniform floor heights, short spans and direct load path play a significant role in seismic resistance of the building.

Avoid Irregular Configurations



Lateral load resisting structure

Lateral loads are live loads that are applied parallel to the ground; that is, they are horizontal forces acting on a structure. They are different to gravity loads for example which are vertical, downward forces.

The most common types are:

- Wind load.
- Seismic load.
- Water and earth pressure.

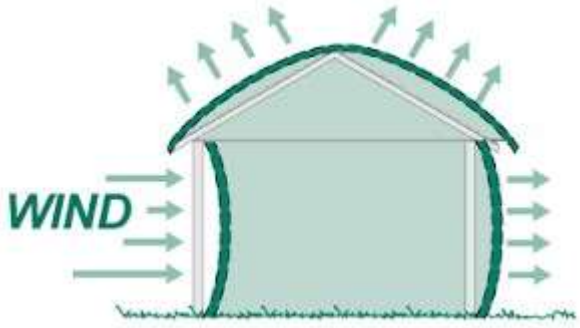
Wind load may n ot be a significant concern for small, massive, low-level buildings, but becomes more importance with height, the use of lighter materials and the use of shapes that may affect the flow of air, typically roof forms.

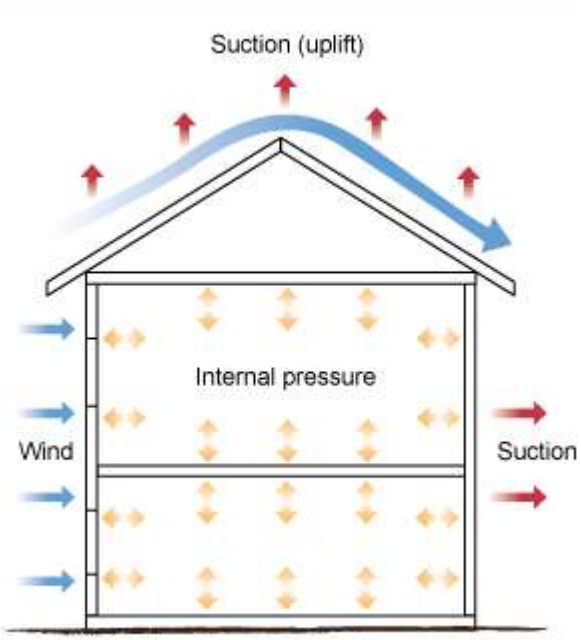
Significant seismic loads can be imposed on a structure during an earthquake. They are likely to be relatively instantaneous loads compared to wind loads. Buildings in areas of seismic activity need to be carefully designed to ensure they do not fail if an earthquake should occur.

Water pressure tends to exert a lateral load which increases linearly with depth and is proportional to the liquid density. Similarly, earth pressure (such as settlement) can be applied against below-ground structures such as basement walls, retaining walls, and so on.

Lateral loads such as wind load, water and earth pressure have the potential to become an uplift force (an upward pressure applied to a structure that has the potential to raise it relative to its surroundings). For more information, see Uplift force.

Structures should be designed carefully with likely lateral loads in mind. A structural element that is typically used to resist lateral loads is a shear wall. In simple terms, lateral forces could push over parallel structural panels of a building were it not for perpendicular shear walls keeping them upright.





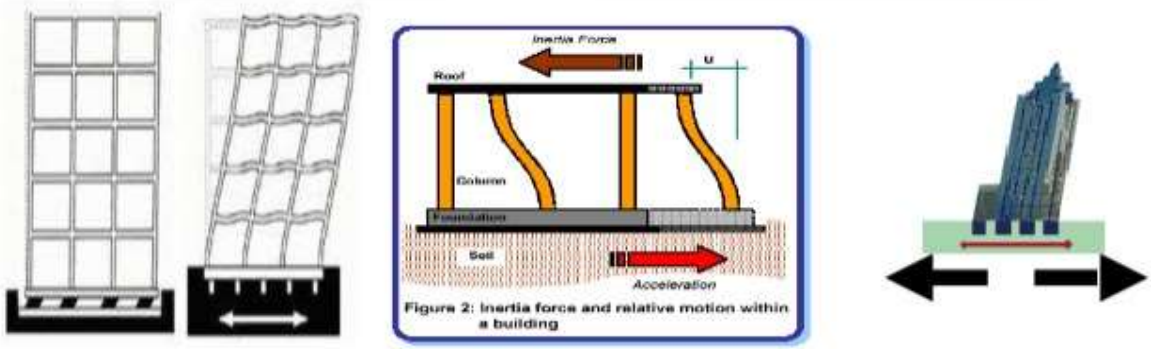
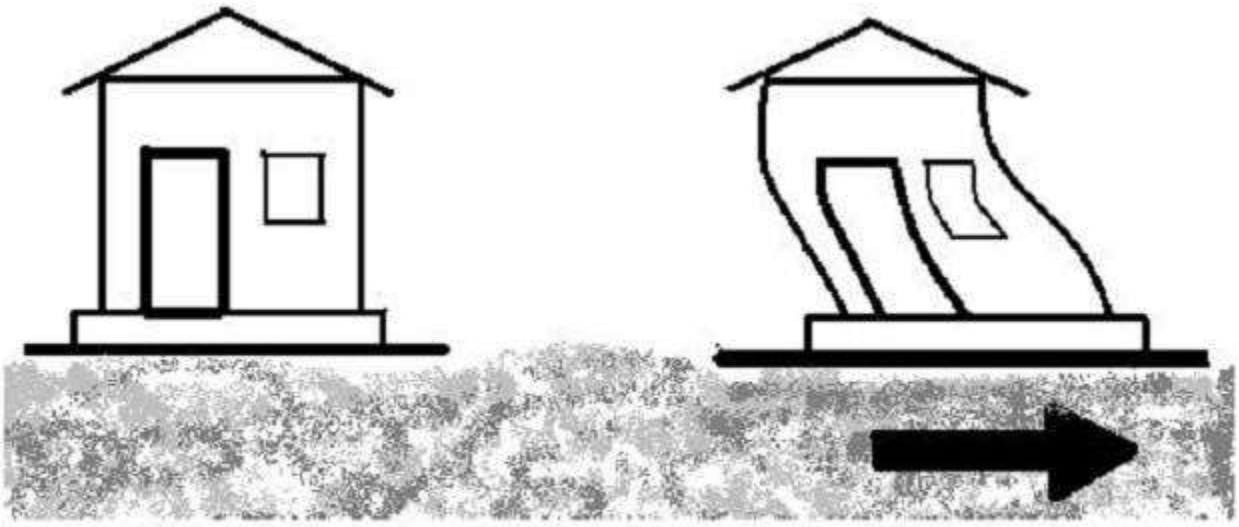
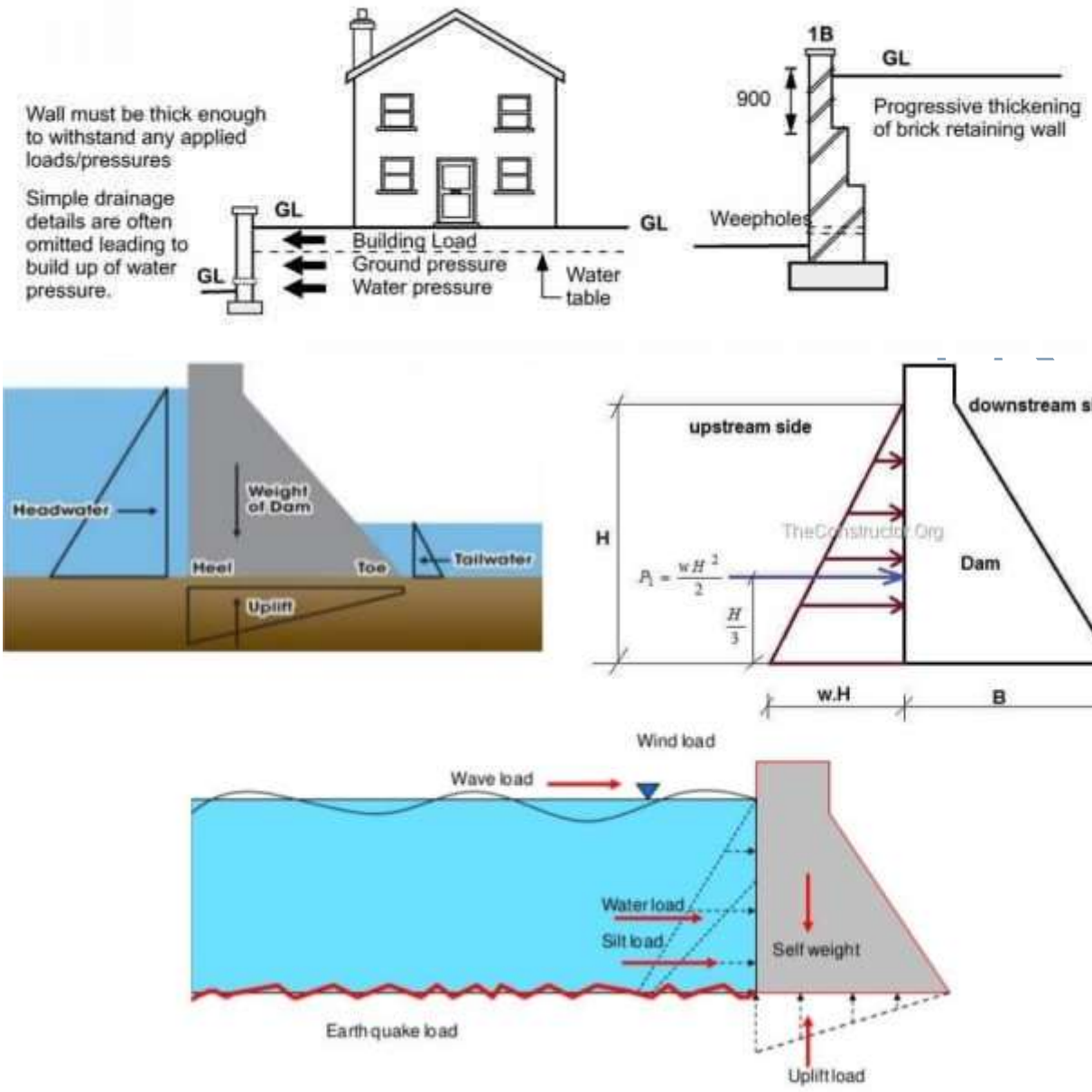


Figure 2: Inertia forces and relative motion within a building

Fig. 5: Ground acceleration during Earthquake causes iner



Effect of Inertia in a building when shaken at its base



BUILDING CHARACTERISTIC

Earthquake-resistant construction, the fabrication of a building or structure that is able to withstand the sudden ground shaking that is characteristic of earthquakes, thereby minimizing structural damage and human deaths and injuries. Suitable construction methods are required to ensure that proper design objectives for earthquake-resistance are met. Construction methods can vary dramatically throughout the world, so one must be aware of local construction methods and resource availability before concluding whether a particular earthquake-resistant design will be practical and realistic for the region.

There are four aspects of buildings that architects and design engineers work with to create the earthquake-resistant design of a building, namely torsion, seismic structural configuration, lateral

stiffness, lateral strength and ductility, in addition to other asepcts like form, aesthetics, functionality and comfort of building. Lateral stiffness, lateral strength and ductility of buildings can be ensured by strictly following most seismic design codes. But, good seismic structural configuration can be ensured by following coherent architectural features that result in good structural behaviour.

(a) Torsion

Objects and buildings have a center of mass, a point by which the object (building) can be balanced without rotation occurring. If the mass is uniformly distributed then the geometric center of the floor and the center of mass may coincide. Uneven mass distribution will position the center of mass outside of the geometric center causing "torsion" generating stress concentrations. A certain amount of torsion is unavoidable in every building design. Symmetrical arrangement of masses, however, will result in balanced stiffness against either direction and keep torsion within a manageable range.

(b) Seismic Structural Configuration

Seismic structural configuration entails three main aspects, namely (a) geometry, shape and size of the building, (b) location and size of structural elements, and (c) location and size of significant non-structural elements (Figure 1.8).

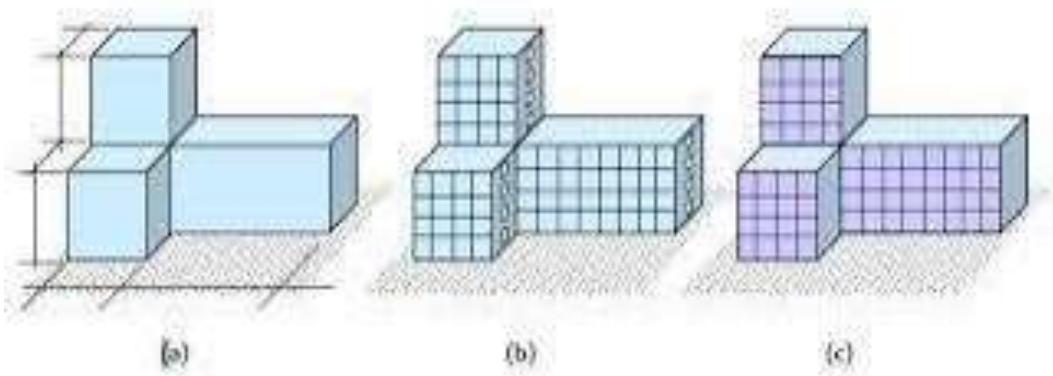


Figure 1.8: Components of seismic structural configuration: (a) overall geometry, (b) structural elements (e.g., moment resisting frames and structural walls), and (c) significant non-structural elements (e.g., façade glass)

(c) Structural Stiffness, Strength and Ductility

The next three overall properties of a building, namely lateral stiffness, lateral strength and ductility, are illustrated in Figure 1.11, through the lateral load – lateral deformation curve of the building. Lateral stiffness refers to the initial stiffness of the building, even though stiffness of the building reduces with increasing damage. Strength is a property of a material to resist and bear applied forces within a safe limit. Stiffness of a material is a degree of resistance to deflection or drift (drift being a horizontal story-to-story relative displacement). Lateral strength refers to the maximum resistance that the building offers during its entire history of resistance to relative deformation. Ductility is the characteristic of a material (such as steel) to bend, flex, or move, but fails only after considerable

deformation has occurred. Non-ductile materials (such as poorly reinforced concrete) fail abruptly by crumbling. Good ductility can be achieved with carefully detailed joints. Ductility towards lateral deformation refers the ratio of the maximum deformation and the idealised yield deformation.

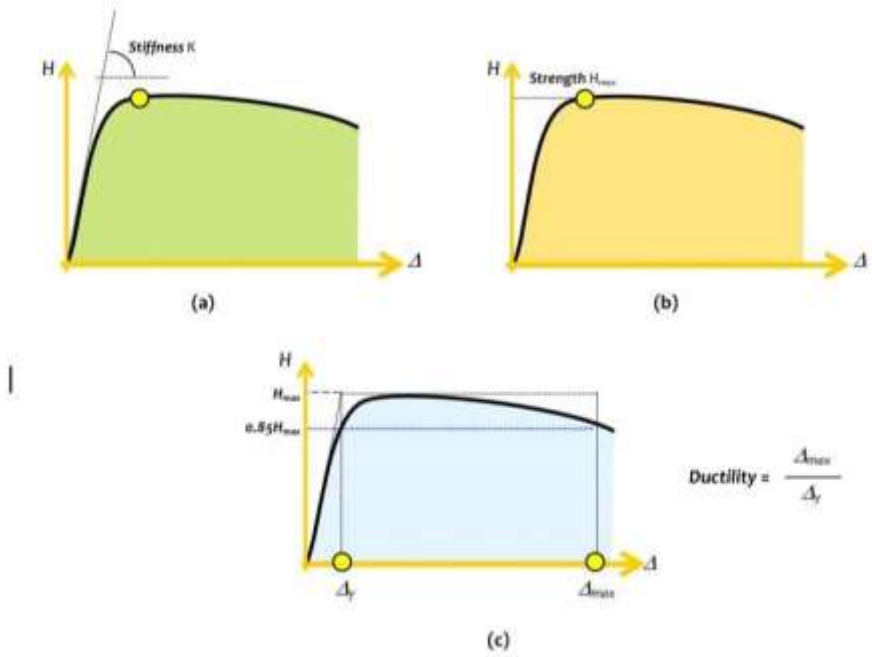


Figure 1.11: *Structural Characteristics*: Overall load deformation curves of a building, indicating (a) lateral stiffness, (b) lateral strength, and (c) ductility towards lateral deformation

Retrofitting means to apply new technologies to an older structure .Retrofit is the process of adding some new features that were not there before. Retrofitting in the construction industry refers to the re-strengthening of the existing structure to make them seismic resistant. Retrofitting is an economical approach to increase the life span of an existing structure rather than redeveloping it.

The process of retrofitting involves the careful balancing of different elements and their effects on the overall performance of a building. A change in one part of a building can affect another, and sometimes this is only apparent after irreversible defects have occurred. For example:

- Sealing buildings to improve their air-tightness can cause condensation problems.
- Insulating a roof without also ventilating it can cause decay of timber structure.
- Internal wall insulation will remove the benefits of thermal mass which may have a detrimental effect on fuel usage.
- External wall insulation will prevent the thermal store of heat from solar gain to be utilised within the building.
- Poorly installed cavity wall insulation can create cold spots that then have damp problems that are extremely difficult to rectify.
- Pre-existing problems can be covered up, and so more difficult to diagnose and rectify.

Sources of weakness in RC building

In the area where the earthquakes occurred, almost all the reinforced concrete buildings were affected. Damages appearing in the buildings may occur due to several reasons such as site effect, poor construction quality, poor concrete strength, poor detailing in beam-column joints, detailing of stronger beam than column, soft stories, weak stories, inadequate reinforcement, short lap splices, incorrect end hook angle, and short columns. Aftershocks also caused progressive damages on the buildings within 17 days after the earthquakes.

Retrofitting techniques

- **Concrete Jacketing**

One way of retrofitting the beams is by concrete jacketing. This involves placing an additional layer of concrete around the existing beam, together with additional longitudinal bars and stirrups, to enhance the flexural and/or shear capacities. The present paper reports an investigation into the strengthening of beams with bottom bars discontinuous at the joints. Concrete jacketing is needed to increase bearing load capacity following a modification of the structural design or to restore structural design integrity due to a failure in the structural member. This technique is used on vertical surfaces such as walls, columns and other combinations such as beam sides and bottoms.

- **Glass and carbon wrapping system**

Carbon fiber has very high tensile strength and is also very lightweight. When bonded to the exterior of a concrete column, beam, or slab, it can add significant strength without adding weight that would increase the load on foundations and other structural members. The composite material is called fiber-reinforced plastic (FRP). FRP wraps are easy to apply and can be used on any size or shape of structural member. Traditional techniques for strengthening, such as adding concrete and reinforcing steel around the outside of a structural member (often with shotcrete), external post-tensioning, or adding structural steel supports (shoring) often are more expensive due to the extra work to get everything into place. The primary reason to use this technique is to add strength to an existing structure. In some cases, it might be used on new construction, although at this time that is usually only in response to some sort of design or construction error.

- ***Jacketing columns***

Jacketing is a technique used to increase the strength of existing structural members (e.g. Columns, Beams etc.) by providing a “Jacket” of additional material around the existing member. Columns are designed to transfer loads from top to bottom. Now due to long age or non calculated excessive loadings or change of functions, there might be different loading than designed for on the columns in order to support this extra loadings, the sizes of columns will have to be increased. This extra

layer of reinforcement and concrete over and above the completed column is known as jacketing of column. It is generally used in case of buildings after earthquakes or very old buildings to increase its life.

- ***Jacketing of beam – column joints***

According to Indian Standard codal provisions for earthquake considerations it has been found that many structures located in seismically active zones are not capable of withstanding seismic waves. Moreover the seismic behaviour of the existing buildings is affected due to design deficiency, construction deficiency, additional loads, additional performance demand, etc. During recent Earthquakes it is observed that the principal cause of collapse of many moment-resisting frame buildings is because of the Shear failure of beam – column joints. So it aims to strengthen a structure to satisfy the necessities of the current codal provisions for seismic design. In recent years it has been found that among various retrofitting methods, seismic retrofit with FRP materials has gained notable acceptance. Retrofitting with FRP materials is now extensively being used as a seismic retrofitting method and it is a technically sound and cost effective repairing technology.

- ***Strengthening of individual footings***

Generally, strengthening of the foundations might be needed due to the alterations in serviceability of the buildings. One method of strengthening can be carried out by constructing a concrete jacket to the existing footings. Strengthening foundations by installing jackets can be achieved either without increase in bearing area at the base or increasing it, whenever the soil has inadequate bearing capacity. Below mentioned procedure is for soil with adequate bearing capacity.

Steps to be followed are-

- **Step1 –** Excavate the surcharge soil around the footing.
- **Step2 –** Roughen the top surface of the base slab for proper bond between the poured concrete and existing one
- **Step3 –** Drilling holes in the existing concrete of footing to install dowels.
- **Step4 –** Fastening the new steel bars with the dowels using steel wires. The diameter and number of steel bars should be according to the design.
- **Step5 –** Coating the external footing surface for proper bond between new concrete and old concrete.
- **Step6 –** Completing the Jacketing of the footing by pouring new concrete in the steel cage.

- ***Base Isolation***

Base isolation is one of the most popular means of protecting a structure against earthquake forces. It is a collection of structural elements which should substantially decouple a superstructure from its substructure that is in turn resting on the shaking ground, thus protecting a building or non-building structure's integrity. Base isolation is one of the most powerful tools of earthquake engineering pertaining to the passive structural vibration control technologies. The isolation can be obtained by the use of various techniques like rubber bearings, friction bearings, ball bearings, spring systems and other means. It is meant to enable a building or non-building structure to survive a potentially devastating seismic impact through a proper initial design or subsequent modifications. In some cases, application of base isolation can raise both a structure's seismic performance and its seismic sustainability considerably.

- ***Tuned mass damper***

A tuned mass damper (TMD), also known as a harmonic absorber or seismic damper, is a device mounted in structures to reduce the amplitude of mechanical vibrations. Their application can prevent discomfort, damage, or outright structural failure. They are frequently used in power transmission, automobiles, and buildings. A tuned mass damper (TMD) is a device consisting of a mass, a spring, and a damper that is attached to a structure in order to reduce the dynamic response of the structure. The frequency of the damper is tuned to a particular structural frequency so that when that frequency is excited, the damper will resonate out of phase with the structural motion. Energy is dissipated by the damper inertia force acting on the structure.

- ***Wall Thickening***

The existing walls of a building are added certain thickness by adding bricks, concrete and steel aligned at certain places as reinforcement, such that the weight of the wall increases and it can bear more vertical and horizontal loads, and also its designed under special conditions that the transverse loads does not cause sudden failure of the wall.

- ***Seismic retrofitting***

Seismic Retrofitting Techniques are required for concrete constructions which are vulnerable to damage and failures by seismic forces. In the past thirty years, moderate to severe earthquakes occur around the world every year. Such events lead to damage to the concrete structures as well as failures. Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes with better understanding of seismic demand on structures.

Composite Wraps

Composite wraps or carbon fiber jackets are used to strengthen and add ductility to reinforced concrete and masonry components without requiring any penetration. Composite wraps are most effective on reinforced concrete columns by providing additional confinement.

- ***Addition of shear walls***

Shear wall is a structural member used to resist lateral forces i.e. parallel to the plane of the wall. For slender walls where the bending deformation is more, Shear wall resists the loads due to Cantilever Action. In other words, Shear walls are vertical elements of the horizontal force resisting system.

A shear wall is stiffer in its principal axis than it is in the other axis. It is considered as a primary structure which provides relatively stiff resistance to vertical and horizontal forces acting in its plane. Under this combined loading condition, a shear wall develops compatible axial, shear, torsional and flexural strains, resulting in a complicated internal stress distribution. In this way, loads are transferred vertically to the building's foundation. Therefore, there are four critical failure mechanisms. The factors determining the failure mechanism include geometry, loading, material properties, restraint, and construction.

WATER DISTRIBUTION IN HIGH RISE BUILDINGS

COVER STORY

B. SRINIVASA RAJKUMAR & ANDERS NIELSEN

Introduction:

The desire to build high into the sky has been a part of human existence for thousands of years. Just think of the pyramids in Egypt, the lighthouse of Alexandria in ancient Greece, or the Angkor Wat temple in Cambodia. High rise buildings have been used to represent political power and affluence; to honor statesmen or religious icons.

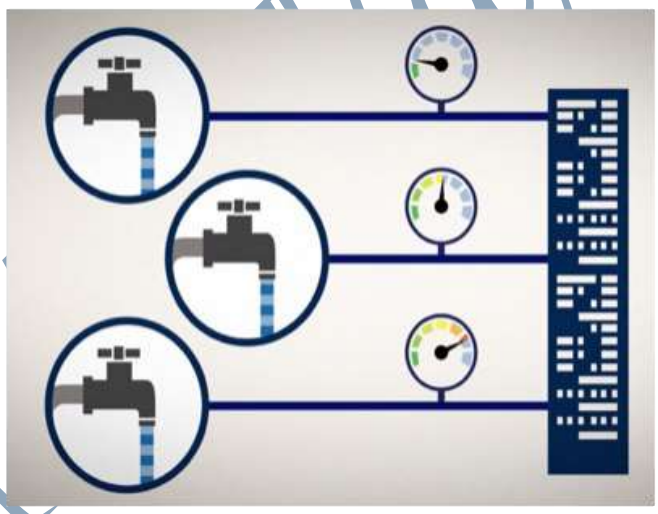
Over the last couple of hundred years, however, a more practical aspect has been built into these high-profile projects. High rise buildings reflected the need to make the best possible usage of a relatively small area of land in densely populated urban spaces across the world.

Further with the increase in density of population in Indian cities, there is an exponential vertical development calling for high rise structures sprawling the city skylines. This poses a huge challenge when it comes to design of efficient waterdistribution systems in these high-rise structures. And when we talk about design of these distribution system, it does not stop only with capacity calculation and piping design, but also on the intricacies of booster controls, which also avoids certain operating issues while running a booster system in high rise structures.

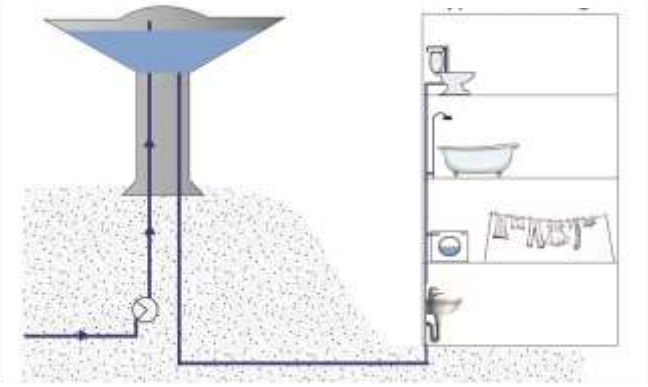
Water Distribution in general:

Pressure boosting can be necessary for one or more reasons as follows:

- Buildings placed on a hilltop where pressure supplied from mains is inadequate



Water pressure supplied from the mains is not sufficient to cover top floors



The principle of an elevated water tower

- Tall buildings where the height of the building prevents the community water from reaching the top floors. For example, a mains pressure of 3.0 bar should, theoretically, be sufficient for a 30-m tall building, but this is not the case. There must be sufficient surplus pressure

to cover resistance in riser pipes, single components such as shower heads, toilets and cooling towers

- The peak load flow might be greater than what is possible to supply from the mains. In these cases, a break tank is supplied to the building, from where one or more booster sets take the water and boost it to the required pressure level. The normal specifications are that the pressure on each floor does not fall below 1.5 bar and does not exceed 5 bar

Use of overhead tanks in high rise buildings:

The use of overhead tanks to ensure adequate water pressure in buildings, and especially tall buildings, is very common. The alternative to overhead tanks is the use of pressurized systems, where several booster pumps provide the necessary pressure. Overhead tank solutions were originally created more than a century ago, as buildings grew taller and taller. The required water pressure for both fire-fighting and domestic use increased and mains water was insufficient to supply a whole building.

Moreover, reliable and efficient pumps for pressurized systems were not available. The immediate solution was to use standard pumps to lift the water to the tank. From the tank, gravity ensured a natural downwards flow and sufficient pressure. Despite improved and energy-efficient pressure booster technology, many buildings still have overhead tanks.

Overhead tanks allow the users to have both water pressure and water supply in situations where there is no electrical power. Overhead tanks vary greatly in size, but common to them all is that they feature “water at the ready”, storing water for domestic purposes and fire-fighting.

The simple construction basically entails a tank, inlet and discharge piping, a float switch, and a pump. When the water level in the tank drops below a certain level, the float switch engages the pump, refilling the tank.

Though from a functional point of view, overhead tanks of today work adequately in many aspects, on the flip side, overhead tanks involve elements that are not always desired. Examples include higher capital costs due to the tank set-up and greater structural requirements, high operating costs, a lack of pressure control, and difficulty in maintaining the overhead tank itself.

Water pressure supplied from the mains is not sufficient to cover top floors

In addition to serving as a storage device and creating pressure, roof-top tanks unfortunately can also serve as breeding grounds for bacteria constituting a major health risk. The exceptionally resistant bacteria legionella often appears as an unwelcome guest in water systems. To survive, the habitat for legionella and other microorganisms arises in the biofilm created in the water system. Biofilm is created inside pipes and water tanks, serving as a protective barrier and breeding ground for the bacteria.

System Elements & Layout

System Elements

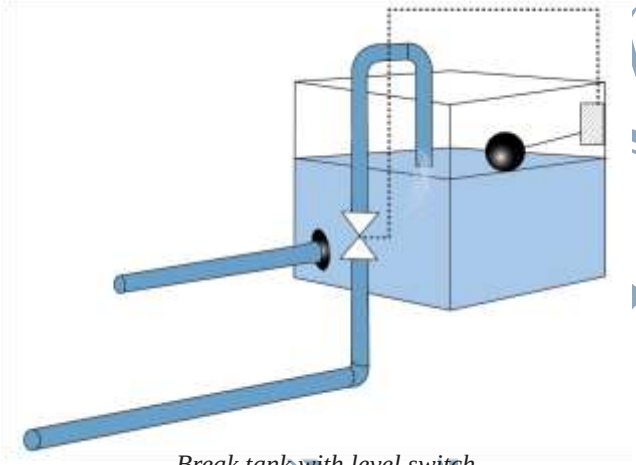
The booster system is based on several basic hydraulic elements that can be combined in different ways. Below, the most important elements are described briefly about the functionality and role in the booster application in general.

1) Break tanks or Underground tanks

Break tanks are implemented in boosting systems in order to supply the system if the mains supply becomes insufficient during peak demand, or if it is unstable. It is also used to ensure that a surge from starting and stopping pumps does not affect the mains distribution. Tanks are also implemented in series-connected boosting layouts to create

manageable pressure zones. Here, the break tanks supply the taps in the tank's own boosting zone as well as all the zones above it.

A major disadvantage with the break tank is that it is a pressure-neutral tank that absorbs the pressure coming from the public supply, removing any potential inlet pressure. This means that the booster system should supply all the pressure itself, instead of using some of the pressure coming from the inlet. Hygiene is also an issue for break tanks. Because of retention time, the tank should be cleaned regularly and break tanks often feature more than one compartment making it possible to clean the tanks. In some countries, it is not permitted to install booster sets directly on the incoming mains supply. This is primarily to ensure that water cannot be pressed back into the mains supply, thus avoiding the risk of contamination. In those countries, break tanks are a necessity in all booster installations. Normally, the break tank is sized by the consulting engineer and it is generally not regarded as part of the booster set.



Break tank with level switch

Boosting with break tank

Advantages
Water always in stock
Break tanks used on different floors in high rise buildings, makes sizing easier compared to single boosting from basement
Disadvantages
Pressure in mains is not utilized
Space is a scarce resource in modern high rise buildings, making it difficult to have the needed space allocated for break tanks
Break tanks must be kept clean and appropriately cleaning should be a scheduled activity

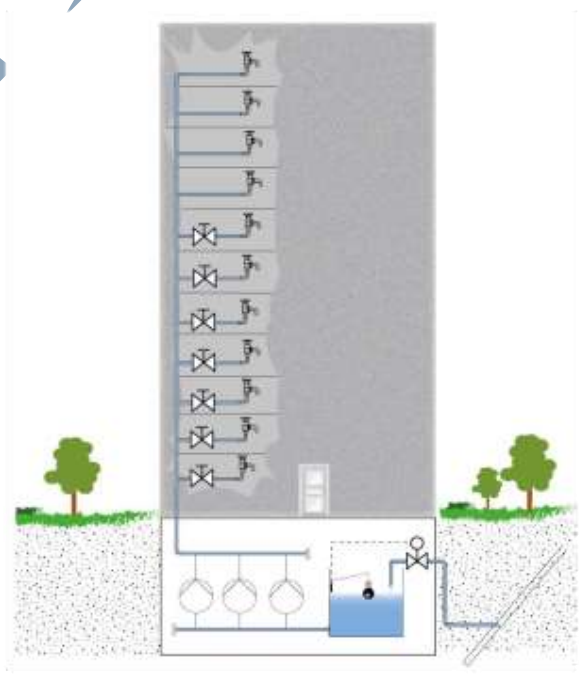
A water tank is placed before the pump system and filled with water from the mains. This allows the capacity of the mains to be lower than the building's peak demand, ensuring constant pressure even in peak flow situations. The break tank is filled with water during low-consumption periods, always ensuring even water supply to the booster pumps.

2) Booster Pumps:

Water distribution to buildings is vital for several reasons. People who live in multi-story buildings always need sufficient water and so does industrial processes. Therefore, high-quality pumps are crucial in booster systems.

What counts for all though, is the way the core of the pump is designed. Multi-stage pumps for boosters are all in-line multi-stage pumps. That means water pressure is gradually built up when the water passes through the different stages. When the final pressure level is met, the water exits the pump at the same level it entered. This is the in-line principle.

3) Risers and branches:



Building with one branch per floor

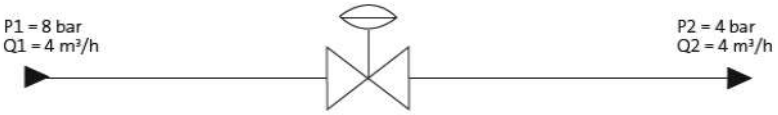
building supply system is normally divided into risers and branches. In the risers, the geodetic height has been overcome, and the water is distributed to the different floors. The branches distribute water to each tap point. When using pressure reduction valves (PRV), the branches are often joined into main branches, creating a zone

for each PRV to reduce the required number of PRVs. If the buildings are identical and with only one riser, PRVs will be needed at each floor. In the example shown to the right, we need to add PRVs on each branch on the building.

4) Pressure reduction valves (PRV)

Example: Energy wasted in the pressure relief valve

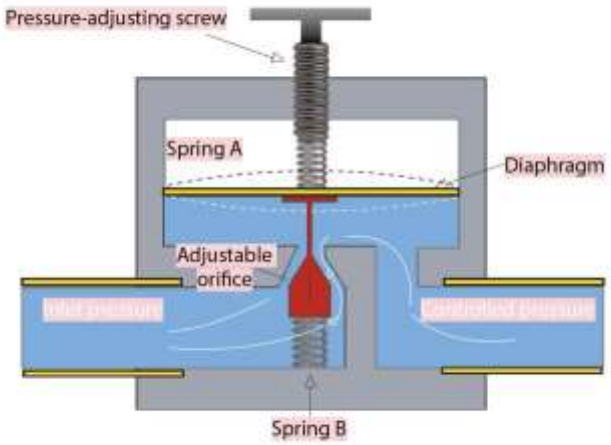
The presence of PRVs will cause a waste of built-up pressure and thus energy. This is illustrated by a simple example.
A high-rise building needs pressure boosting from the basement floor. In the example, a maximum water tap pressure of 4 bar is allowed. However, due to the system layout, excessive pressure is present in the lower part of the system. This is dealt with by installing PRVs in main branches before the taps. Below it is illustrated how an excess pressure of 8 bar is reduced to the allowed 4 bar. The pipe will supply a water flow of 4 m³/h.



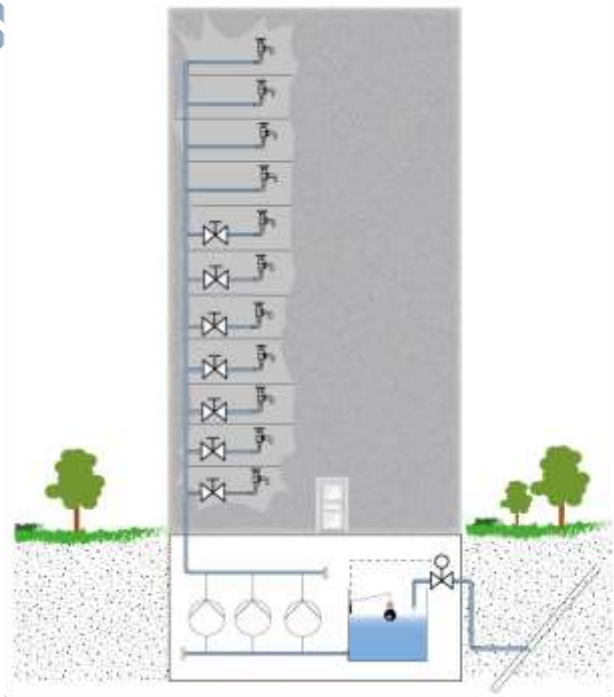
Available hydraulic power before the PRV:
$P1 = q1/3{,}600 \times p1 \times 10^2$
P1 = 4 m³/h / 3,600 s/h x 8 bar x 102 kPa/bar = 0.91 kW

After the PRV, the pressure is halved from 8 bar to 4 bar, resulting in only half the hydraulic power, P2 = 0.45 kW. As such, the PRV represents a power loss of 0,45 kW. Depending on the number of operating hours, this necessary excess pressure will potentially consume a lot of energy. For, e.g., 4,000 hours of operation per year, this PRV alone will 'consume' 1,800 kWh/year.

To equalize pressure on all floors, PRVs are often used in multi-story buildings. The pressure is mechanically reduced directly by the spring, making it possible to adjust the pressure precisely for each floor. The PRV can either be used individually with one on each floor or in a branch of a riser supplying 2-3 floors. The PRV is a rather simple way of controlling the pressure throughout a tall building. However, there are some disadvantages when using PRVs:



- For each PRV needed in the building layout, the initial cost increases
- The PRVs also need maintenance and therefore they need to be placed at an accessible place
- Each PRV represents a loss, because of the energy consumed by creating higher pressure is wasted
- Risk of pipe damage and flooding if a pressure reduction valve fails and lets high pressure into a lower graded pipe net This article delves more on the various system layouts that are practically used in water distribution in high rise buildings, indicating its merits and demerits.
- Booster systems may be designed in several different ways with the elements described above. Which layout to choose depends on many factors and the specific task in question, e.g. local legislation and traditions, flexibility requirements or the possibility for future expansions etc. Any one system layout is not ideal for all scenarios.



Single Booster system with one branch per floor

Below, the advantages and disadvantages of some the most used system layouts are described.

Single booster system

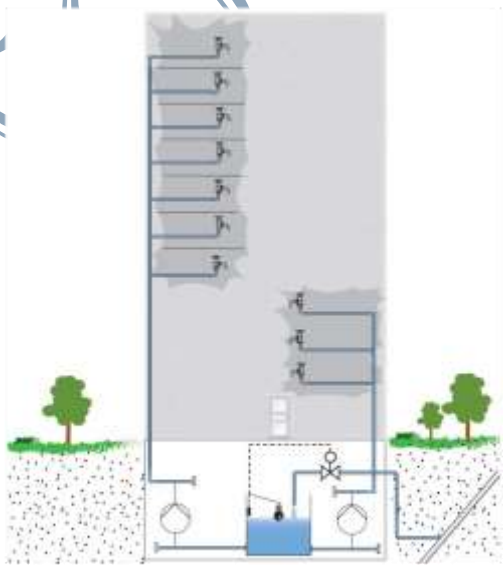
Single Booster System
Advantages
Only one riser needed (simple design)
No Space required on upper floors
Disadvantages
Excess pressure on lower floors in buildings exceed ten floors (PRVs and high pressure graded pipes needed)

A single booster system is perhaps the simplest booster system available. It relies on a single set of pumps supplying pressure boosting from the basement to the point farthest away from the booster system. Basically, such systems may be configured with or without initial break tanks.

Zone-divided booster systems

The building is divided into pressure zones of ten floors or less with a booster supplying each zone from the basement through dedicated risers.

Advantages
Manageable pressure zones
Increased flexibility and security due to zoning
No space required on upper floors Low-cost operation due to no residual pressure
Disadvantages
Higher initial cost than single-zone systems
Higher static pressure in upper zones (highpressure graded pipes)

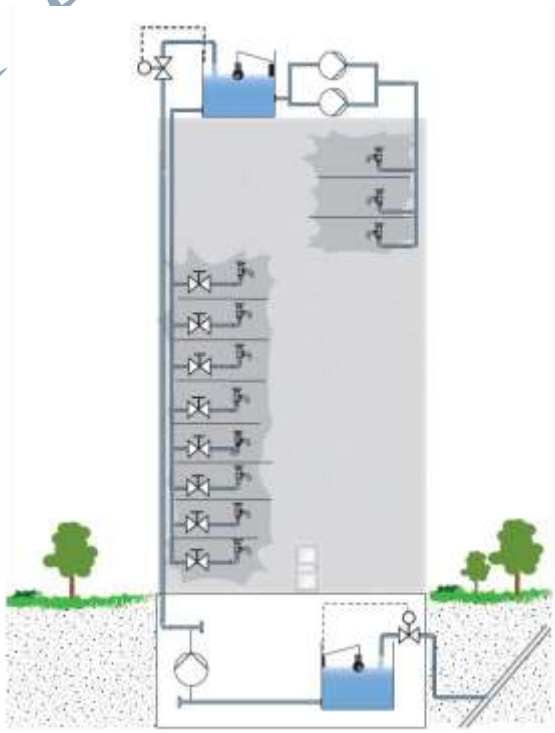


Zone-Divided System

Overhead tanks with terrace booster system

Overhead tank systems use a transfer pump in the basement to fill the overhead tank by a level switch-operated control. The solution requires pressure reduction valves on each floor if the building exceeds approximately 15 stories, to avoid unwanted high static pressure at the taps in the lower floors. It also requires a terrace booster to provide the top floors with the required pressure, as static pressure there will be too low due to insufficient geodetic height at the overhead tank.

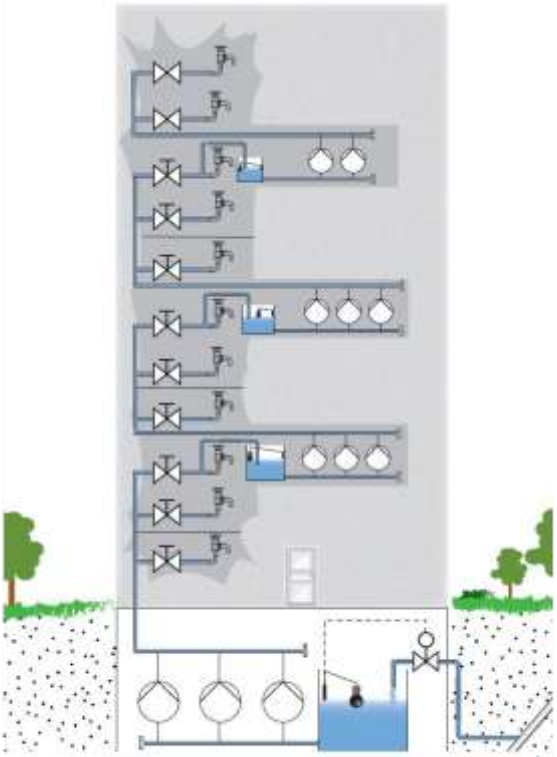
Advantages
Mature Technology
Small booster power due to roof tank working as buffer
Reserve capacity in roof tank
Disadvantages
Higher initial cost than single-zone systems
High static pressure in upper zones (high-pressure graded pipes)



Series-connected systems with intermediate break tanks

eries-connected systems with intermediate break tanks draw on several other systems, utilizing centrally-placed break tanks to supply

both the taps, the tank's own boosting zone and all the zones above it. With this system, a building is divided into smaller and more manageable pressure zones. Every zone is then served by its own booster set.

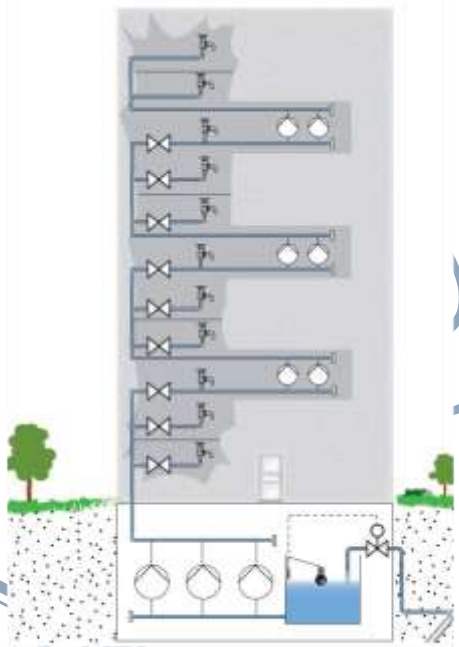


Series-connected systems with intermediate break tanks. In this example, we have three boost zones.

Advantages
Low pressure in each zone (no PRVs and less pressure-graded pipes needed)
Manageable pressure zones
Easy to size because each zone has its own supply tank
Disadvantages
Higher initial cost than single-zone systems
Space required for booster sets and tank on service floors
Risk of Microbiological growth in tanks

Series-connected systems without intermediate break tanks

A series-connected system operates on the same principles as the previously mentioned system, but without the intermediate break tanks. This enables an effective usage of power as the water is only pumped to the part of the zone where it is used and not past it. However, complete control is very important. When a consumer draws water on the upper floors, the booster systems must be able to deliver the water from the bottom of the building.

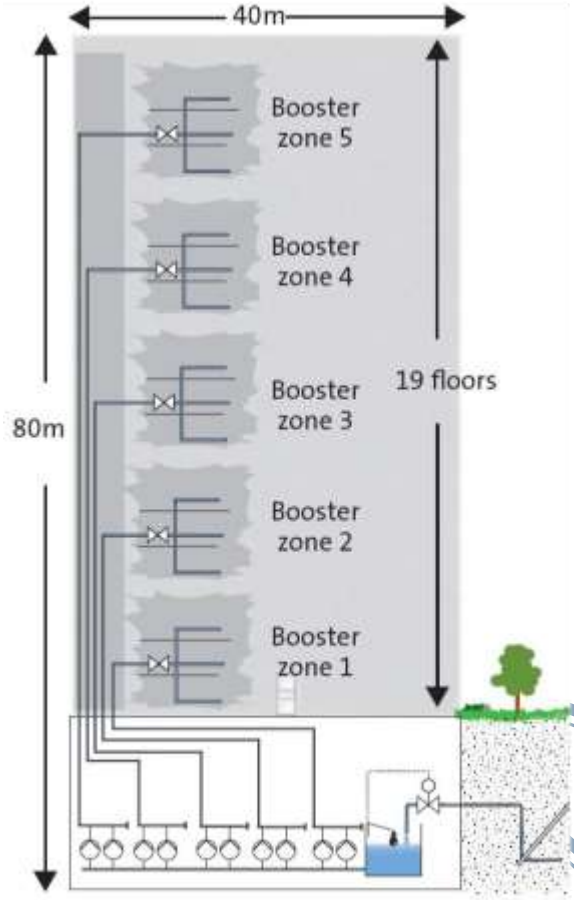


Series-connected systems without intermediate break tanks

Advantages
Low pressure in each zone (no PRVs and less pressure-graded pipes needed)
Manageable pressure zones
No space required for tanks
Less excess boosting (low operation costs)
Disadvantages
Higher initial cost than single-zone systems
Space required for booster sets and tank on service floors
Complex control

Illustration

An example is given to illustrate the differences between the previously mentioned system layouts in terms of necessary hydraulic power (P4) and energy consumption (E4) for water transport in a high-rise building.



The Building foot print is 1,600 m2 (40m x 40m)

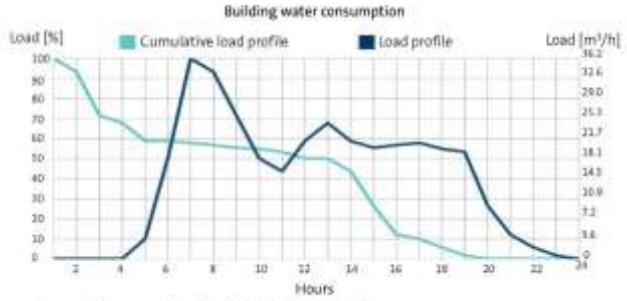
Building case

The imaginary building case is 80 meters tall, comprising 19 floors and 5 different hydraulic zones as illustrated on the building to the left. The building footprint is 1,600 m2 (40 m x 40 m).

Each of the five hydraulic zones has different users and thereby different consumption profiles, operating hours, peak flow requirements, etc. These conditions are listed below.

The zone weight-averaged load profile is shown in the graph below. The graph represents the combined water consumption pattern during a typical day (dark blue curve) for the whole building. Arranged as a cumulative load profile (light blue), the number of hours at different duty points are easily interpreted.

The total building peak flow demand is 46.8 m3/h. However, taking the load profile into consideration the peak flow is simultaneity corrected to 36.2 m3/h.



Zone weight-averaged load profile for the whole building.

Evaluated booster layouts

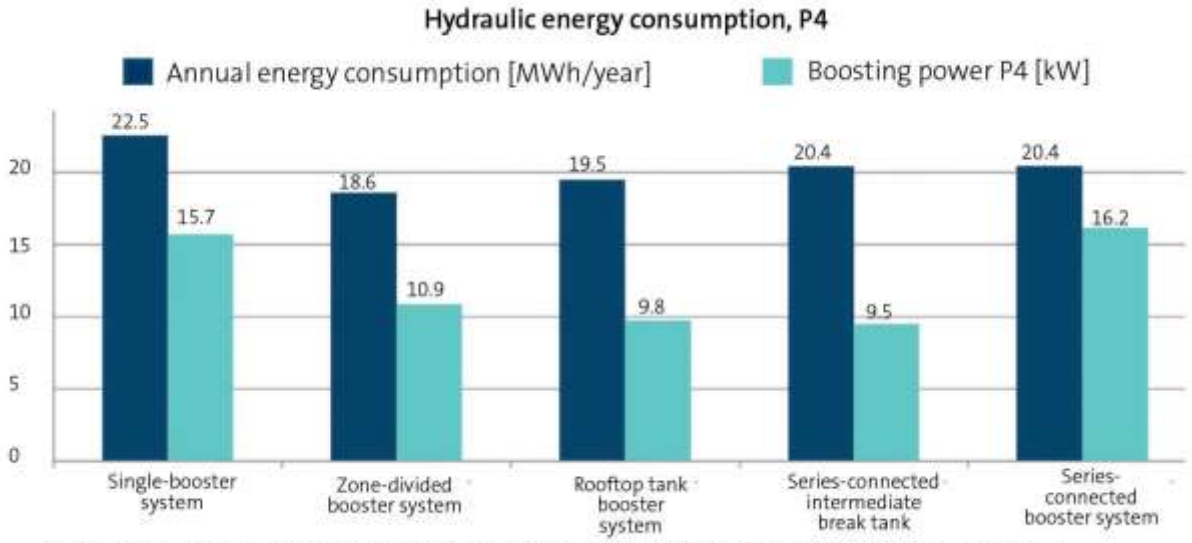
- A: Single-booster system
- B: Zone-divided single booster system
- C: Single-booster system with roof top tank
- D: Series-connected booster system with intermediate break tanks in zones
- E: Series-connected booster system without break tanks

In this example, layouts with tanks (C and D) are designed so that the tank capacity equals 4 hours of peak load. This corresponds to approximately 60% of the daily water consumption.

Booster zone	No. of floors	Zone height	Usage	Persons	Min. tap pressure	Peak flow
Zone 5	1 floor	4 m	Penthouse apartments	16 residents	200 kPa	0.3 m³/h
Zone 4	1 floor	4 m	Restaurant	160 seats	200 kPa	6.0 m³/h
Zone 3	7 floors	30m	Apartments	450 residents	150 kPa	8.3 m³/h
Zone 2	6 floors	25 m	Landscaped offices	640 employees	150 kPa	27.6 m³/h
Zone 1	4 floors	17 m	Shopping centres	100 employees	150 kPa	4.6 m³/h

Hydraulic booster size and energy consumption

The necessary hydraulic booster power (P4) and energy consumption linked to the building case varies per booster system configuration in question.



Energy consumption and required hydraulic booster power using different system layouts.

The result of a rough sizing is shown in diagram above.

In this example, series-connected pressure boosting systems with break tanks require the smallest boosting power closely followed by the roof tank solution.

However, choosing a zone-divided system, where each zone is supplied by its own booster system will reduce the annual energy consumption by approximately 10% and only require approximately 15% larger booster capacity. Additional benefits like eliminating the need of intermediate break tank, separation of system in hydraulic zones etc. could easily make such systems favorable.

Also, equally important are the booster system controller's capabilities to address to certain practical issues in high rise buildings, such as:

1. Avoiding surge in vertical pipe lines/shafts through Soft fill functionality
2. Proportional Pressure functionality to reduce higher pressures on pipes and fitting during low flow system conditions
3. Low flow stop functionality to avoid churning of pumps during low consumption periods

Generally, major operating issues occur in high rise structures since these factors are not taken into consideration while designing the booster systems controls.

To conclude, a properly sized, zone divided booster system would be more efficient for the operating life of a high rise building when compared to other systems discussed in this article.

Mr.B.Srinivasa Rajkumar is a Technical Marketing Manager at Grundfos Pumps India Pvt Ltd., He holds around 25 years of Industry experience, wherein 15 years are in the field of pumps & control systems in applications like pressure boosting, HVAC and district cooling. His specialisation is in the field of automation and controls to optimize the system energy performance.

Mr. Anders Nielsen is an Application Manager within the commercial building segment in Grundfos Denmark. He holds a 25 + years of experience within Grundfos in the field of pressure boosting, HVAC and latest District Energy. Hisspecialization in above fields is to increase system efficiency by utilizing different modern pump/system features and also to optimize the system.

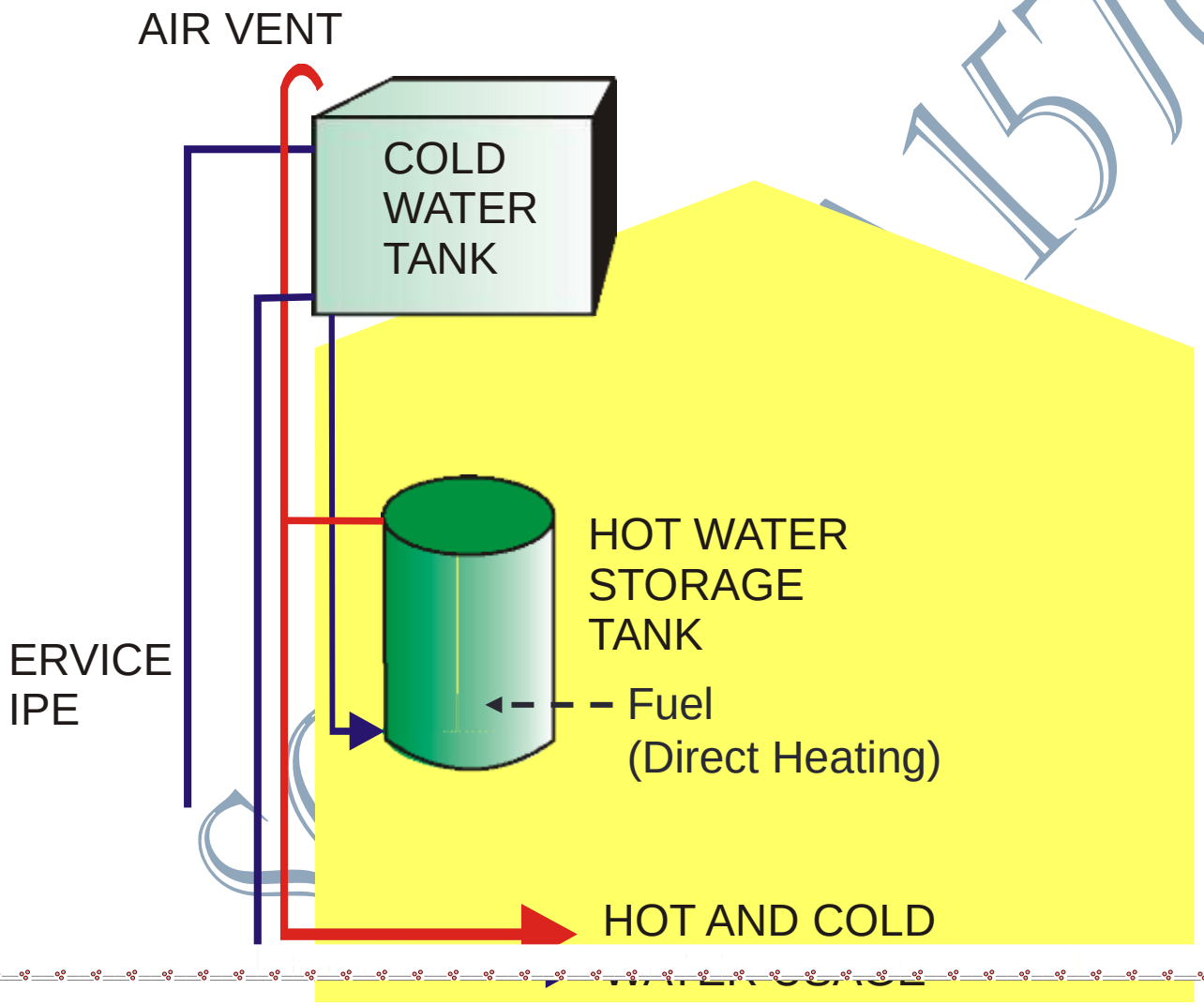
CHAPTER 3
HOT WATER SUPPLY

Prof. Dr. Uğur Atikol

Introduction

- Hot water is required for the comfort of people in buildings.
- Hot water supply must be adequate in order to meet the occupants' demand.
- There are different ways of heating water. Depending on the resources available the technologies used can be:
  - Solar water heaters
  - Gas water heaters
  - Electric water heaters
  - Heat pumps
- On the other hand hot water preparation can be integrated with central heating systems.

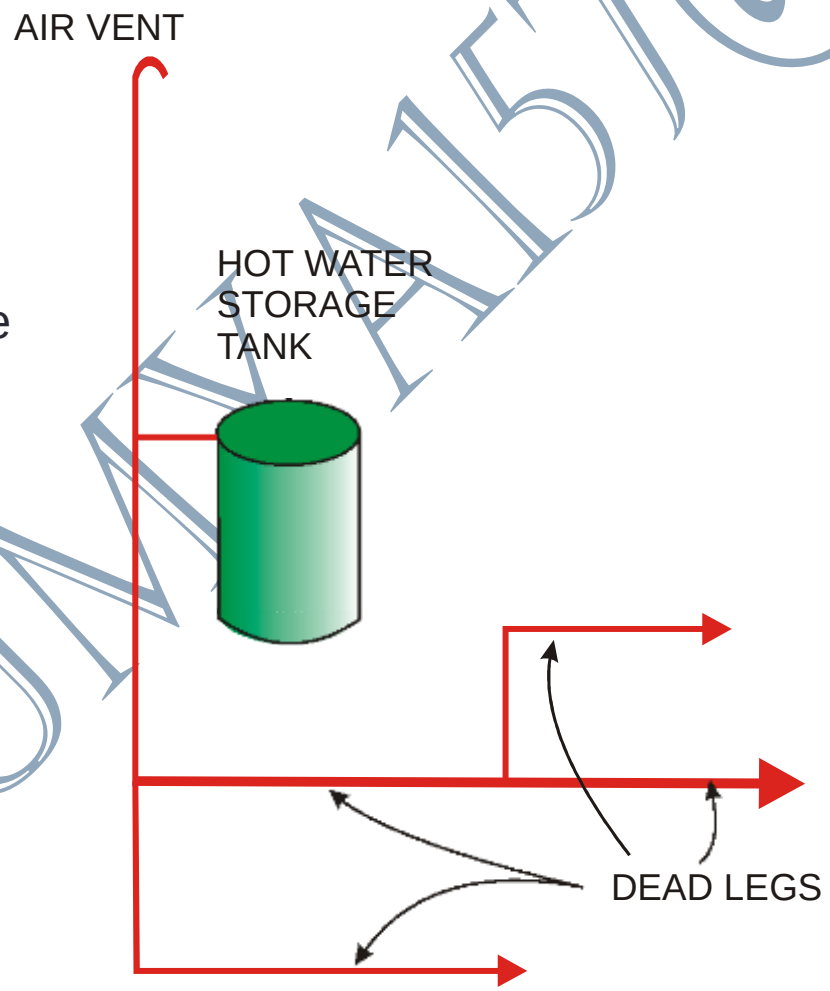
Water Heating System in Houses



Heat Losses from Pipes

DEAD LEGS:

Connections from the hot water source (or secondary flow) to the taps are known as dead-legs.



Dead Legs

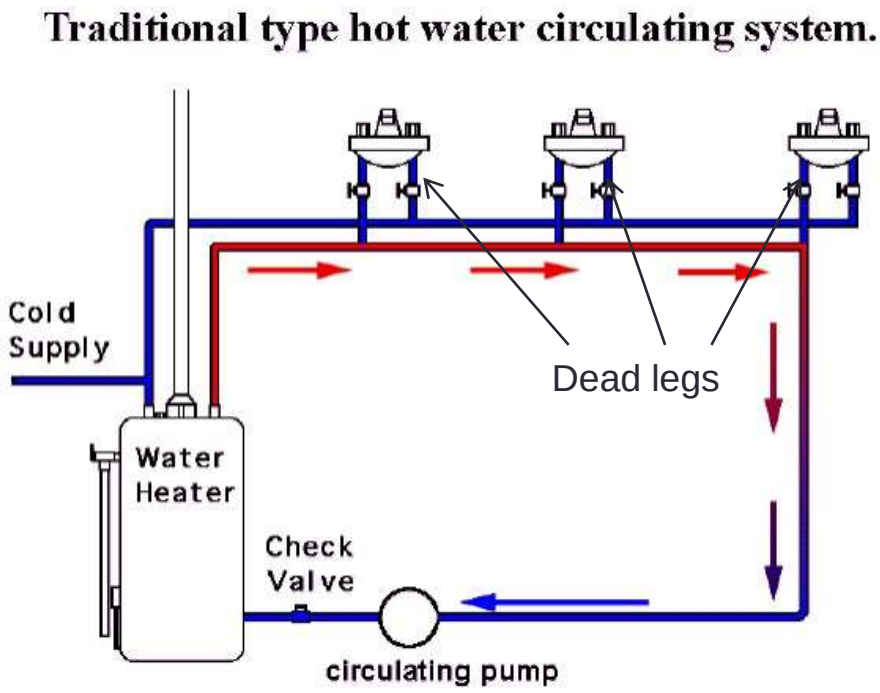
- Dead legs occur in hot water systems where water does not move for a period of time.
- In central systems there are pipework linking the central supply with the draw-off points.
- Between draw-offs the water in the pipe will cool and the next draw off will involve running the cold water to waste before it reaches the tap, creating dissatisfaction, waste of water and heat.
- In these systems in order to keep consumption within reasonable limits dead legs of pipework serving hot-water taps are governed to following maximum lengths:

Pipe diameter	Maximum Length (m)
20 mm	12 m
25 mm	7.6 m
More than 25 mm	3 m
Spray taps	1 m

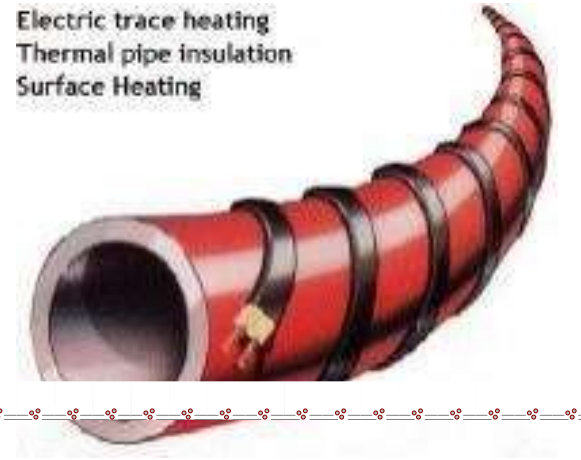
How to Avoid Dead Legs

To avoid dead legs in plumbing systems there are two common approaches;

1. Install a secondary return pipe.
2. Maintain the water temperature at all times with trace heating.



Trace heating takes the form of an electrical heating element run in physical contact along the length of a pipe.



Hot Water Storage

- Estimation of hot-water storage

Code of Practice 342 (Centralized Hot-Water Supply, UK)

Type of Building	Storage per person (litres)	Type of Building	Storage per person (litres)
Colleges & Schools:		Hospitals:	
Boarding	23	General	27
Day	4.5	Infectious	45.5
		Maternity	32
		Nurses' homes	45.5
Dwelling houses	45.5		
Factories	4.5		
Flats	32	Hostels	32
Hotels (Average)	35	Offices	4.5
		Sports pavilions	36

By use of the table, a dwelling with 3 occupants will require 45.5 x 3 = 136.5 litres of hot water-storage.

Hot Water Storage

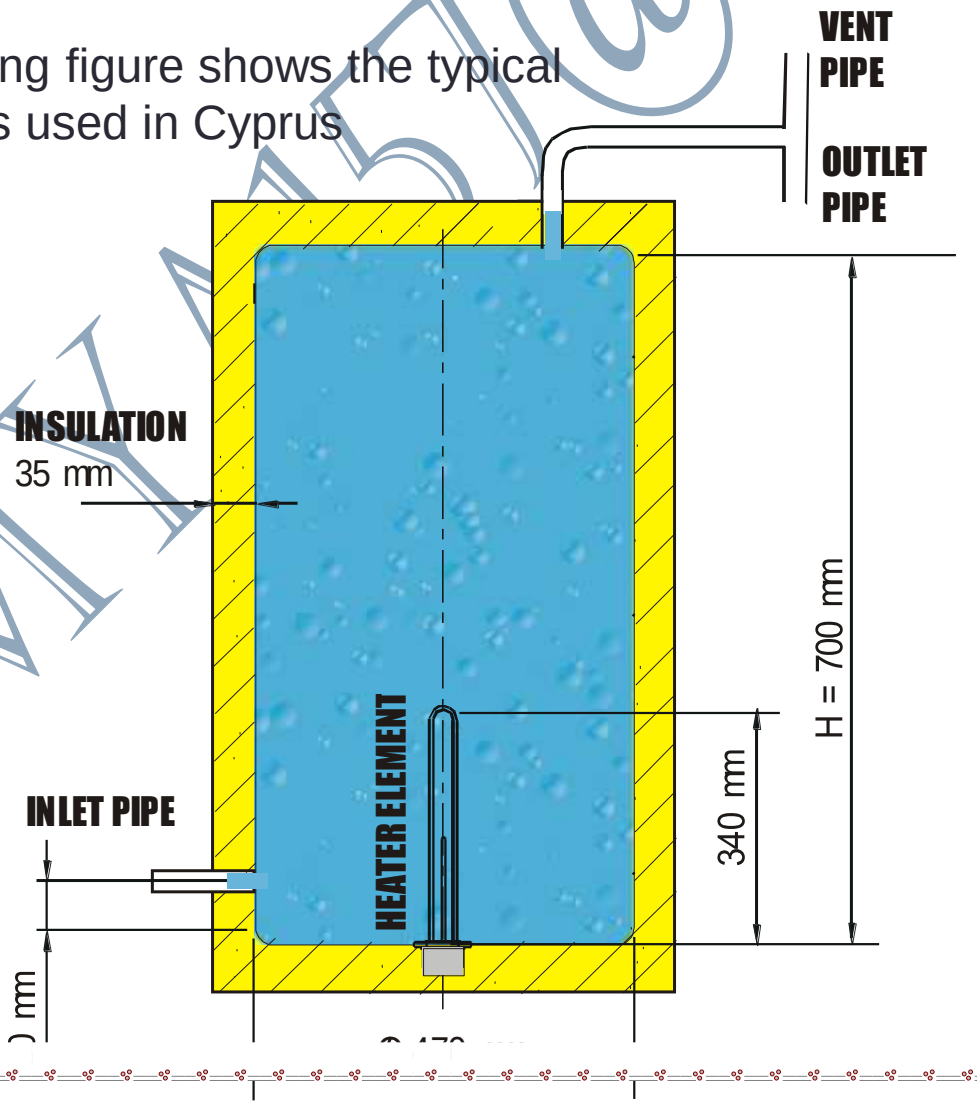
- Estimation of hot -water storage

If the number of occupants is not known the following table may be used

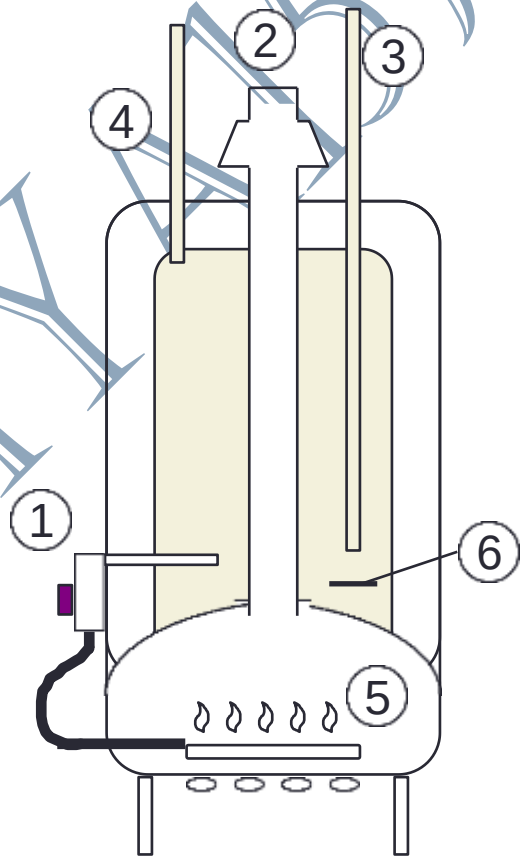
APPLIANCE	VOLUMES OF HOT WATER (Litres)
WASH BASIN Hand wash Wash Hair wash	 1.5 3 6
SHOWER	13
BATH	70
WASHING MACHINE	70
SINK Wash up Cleaning	 15 5

Storage-Type Electric Water Heater

The following figure shows the typical dimensions used in Cyprus

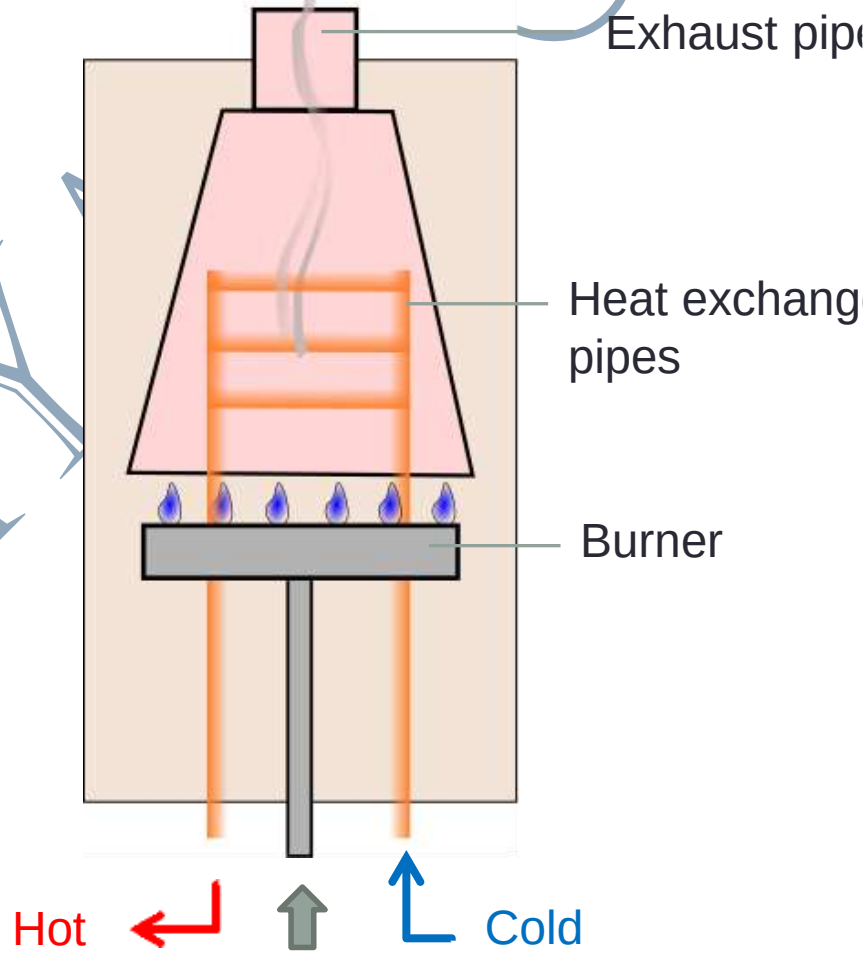


Storage-Type Gas-Fired Water Heater



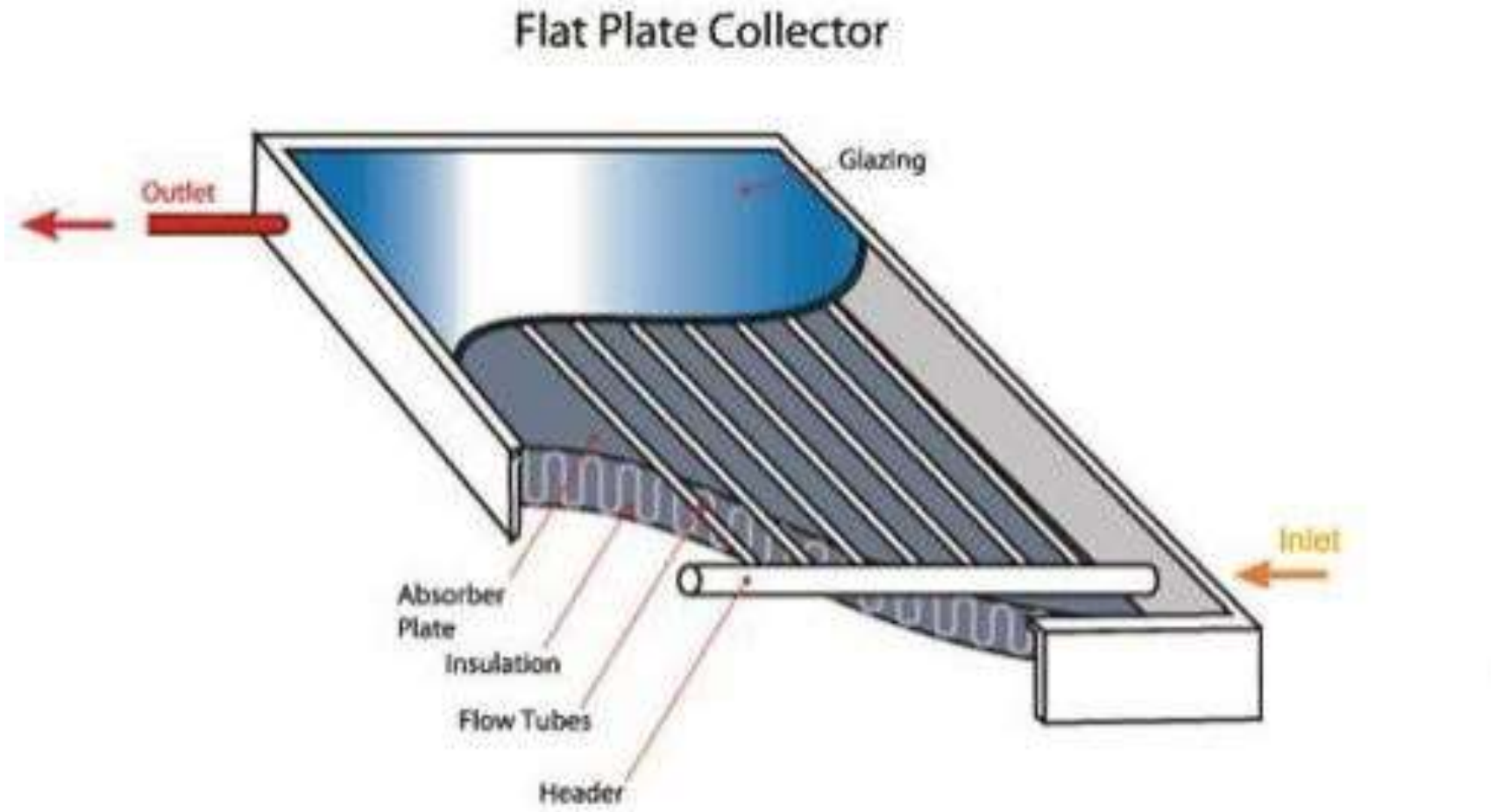
1. Thermostat
2. Flue pipe
3. Cold water fee
4. Hot water outle
5. Burner
6. Buffer

Instantaneous Gas Water Heater

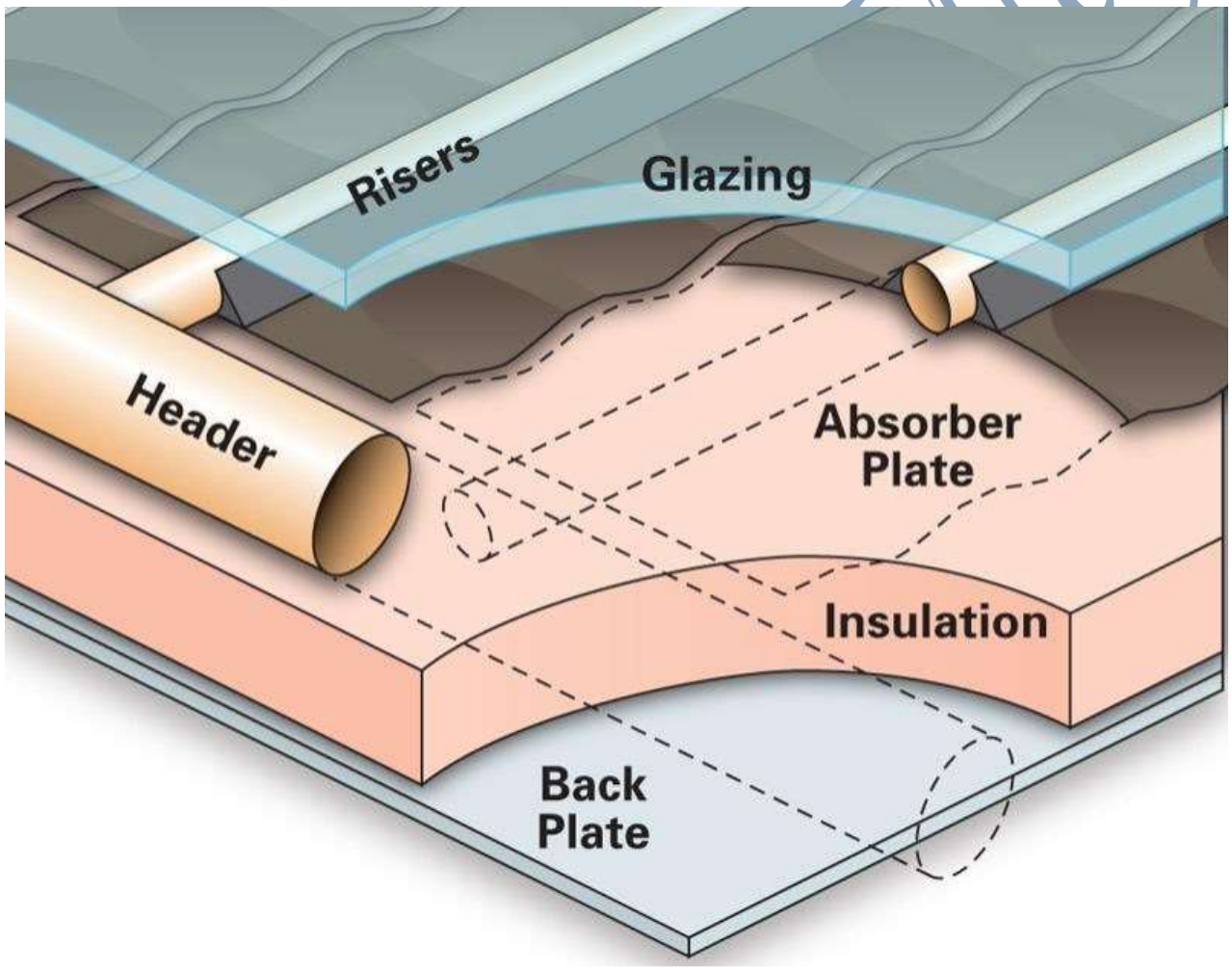


Instantenous Electrical Water Heater

Solar Water Heating System

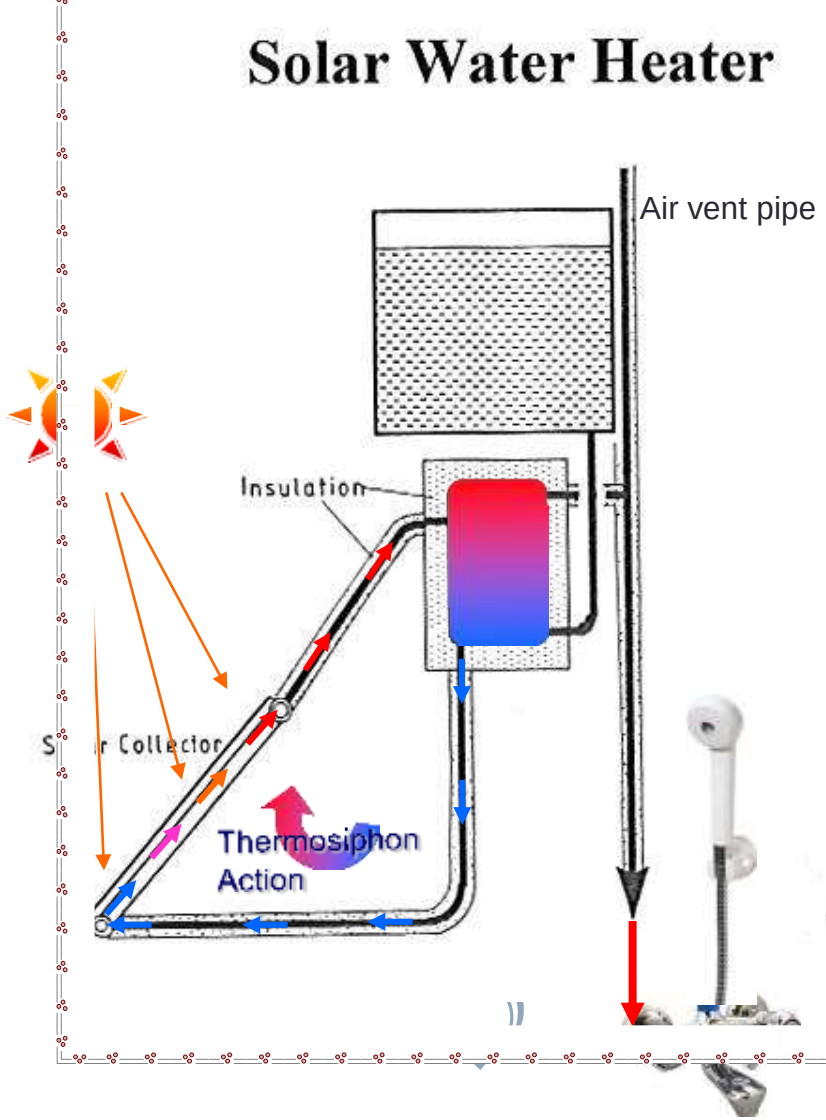


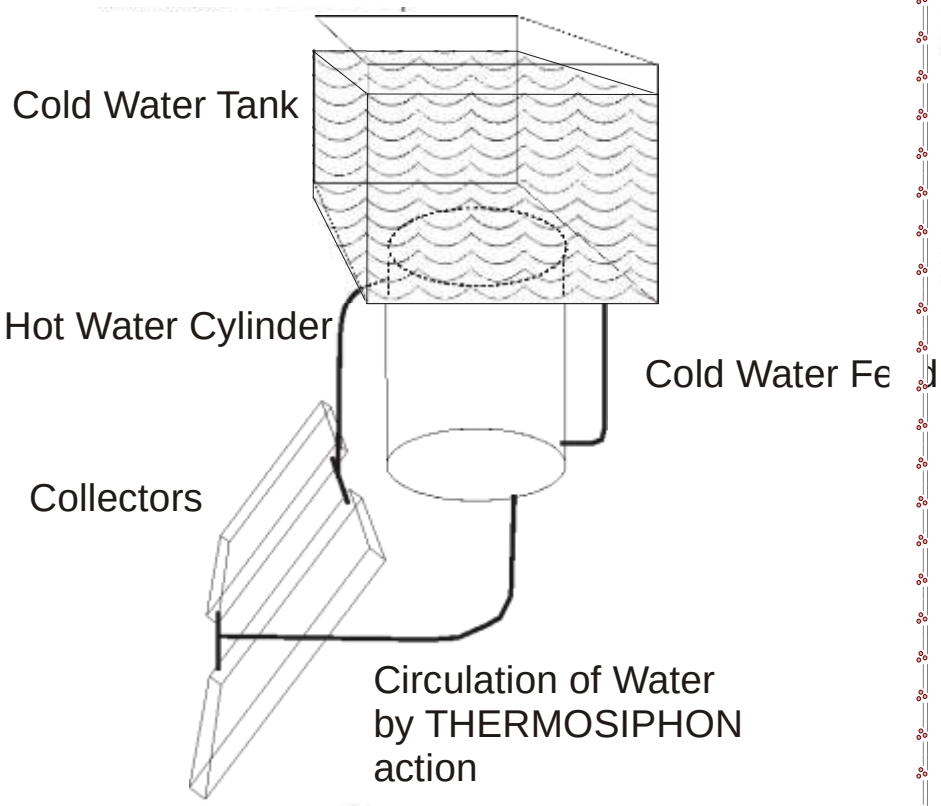
Solar Collector Assembly

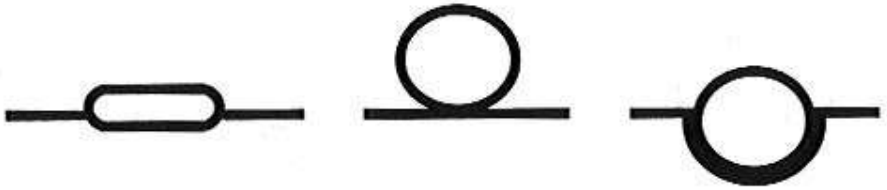


Source: homepower.com

Thermosyphon-Type Solar Water Heater

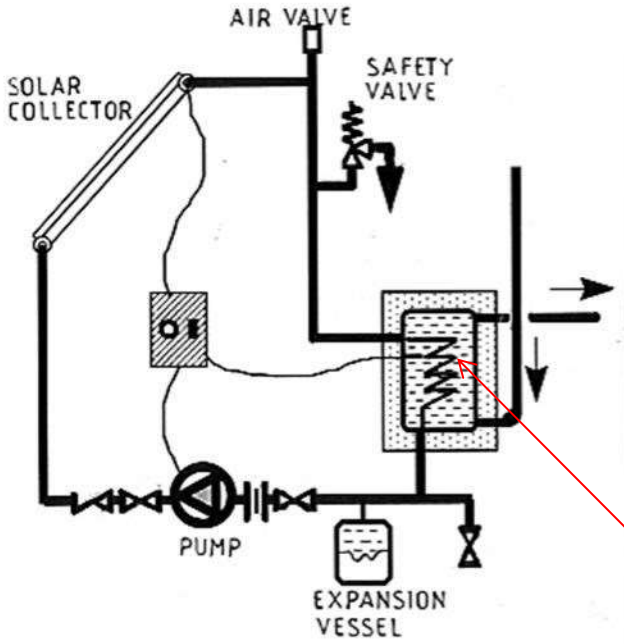


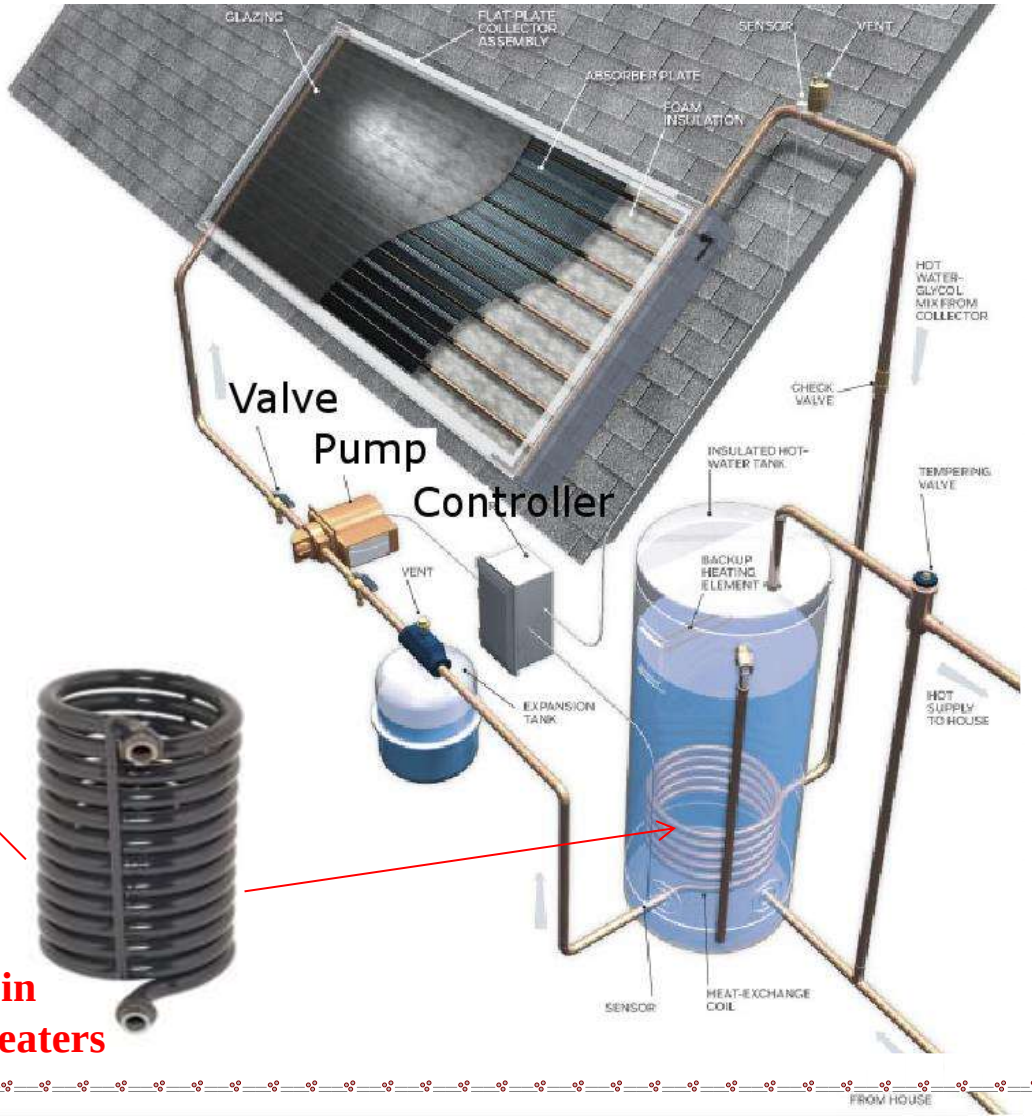




Forced Circulation Solar Water Heating

Solar Heating System
(Water Circulation with a Pump)





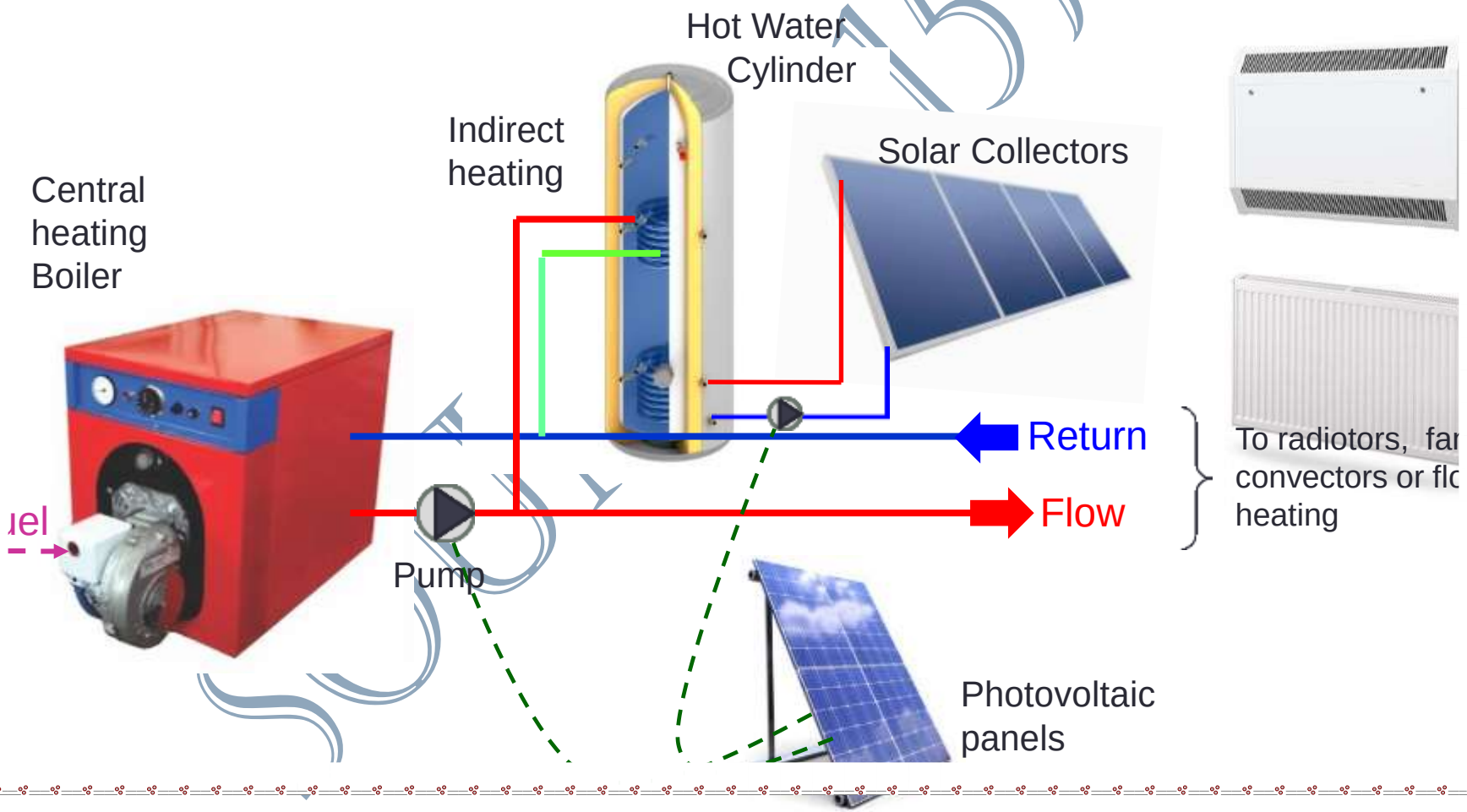
Coil used in indirect heaters

Source; http://www.pacificenergysales.com/for-homeowners/solar

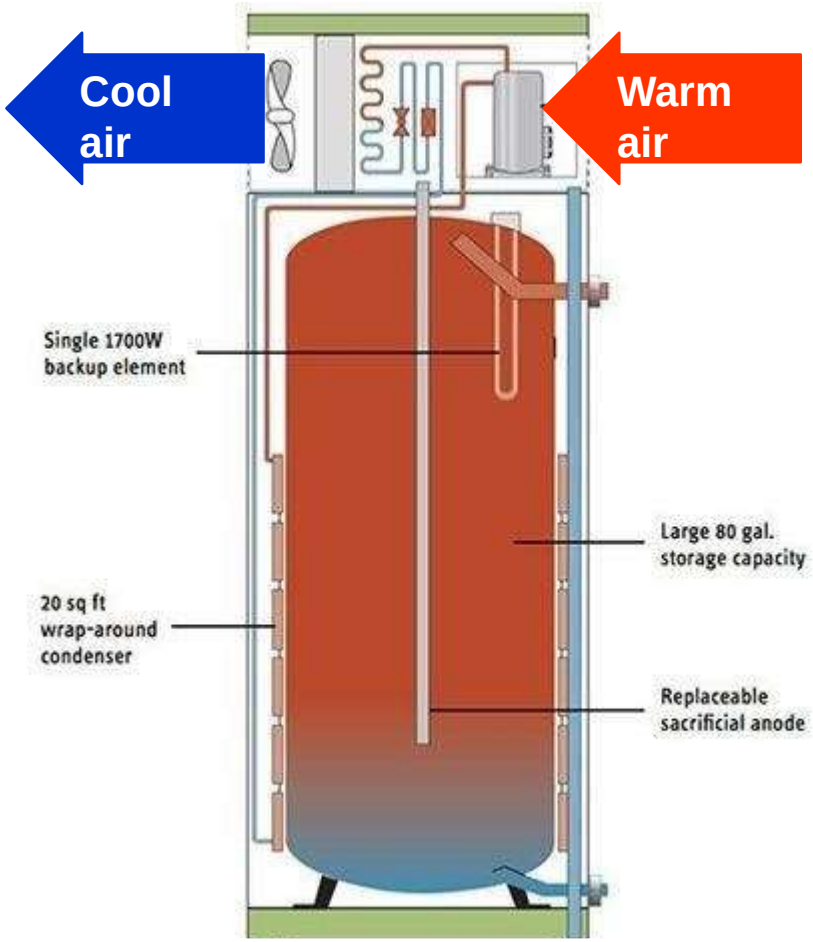
Solar Collectors Integrated into the Inclined Roof Structure

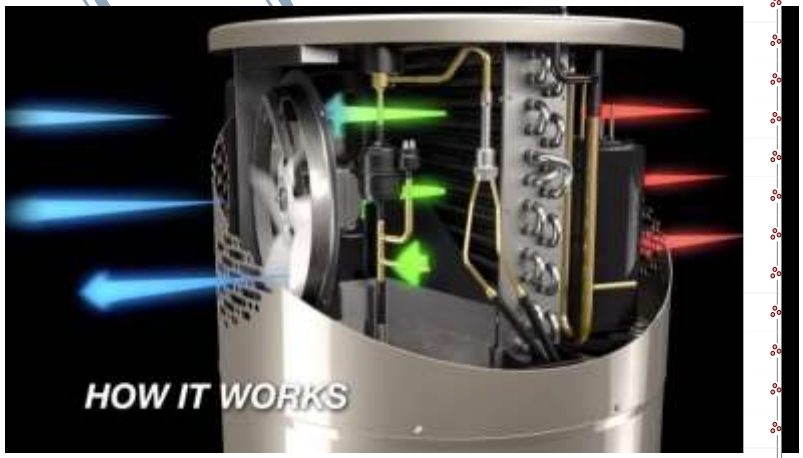
Hot Water Generation with Central Boiler

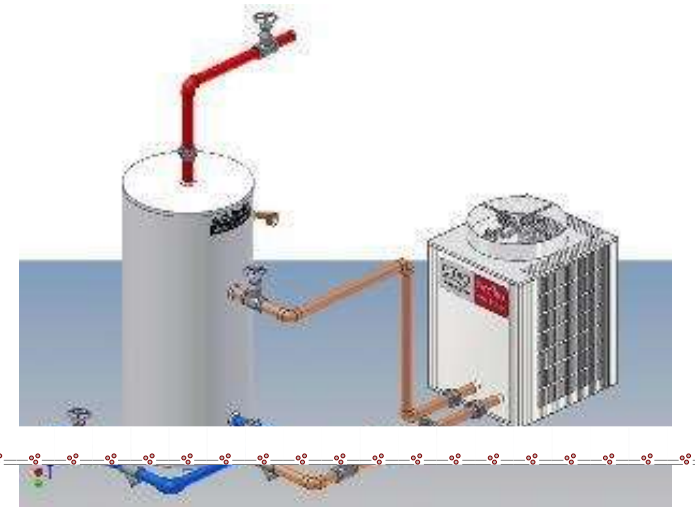
- Hot water can be generated by the central boiler plant and stored



Hot Water Generation with Heat Pumps







Unit 5

Pipe Fittings, Joints and Valves

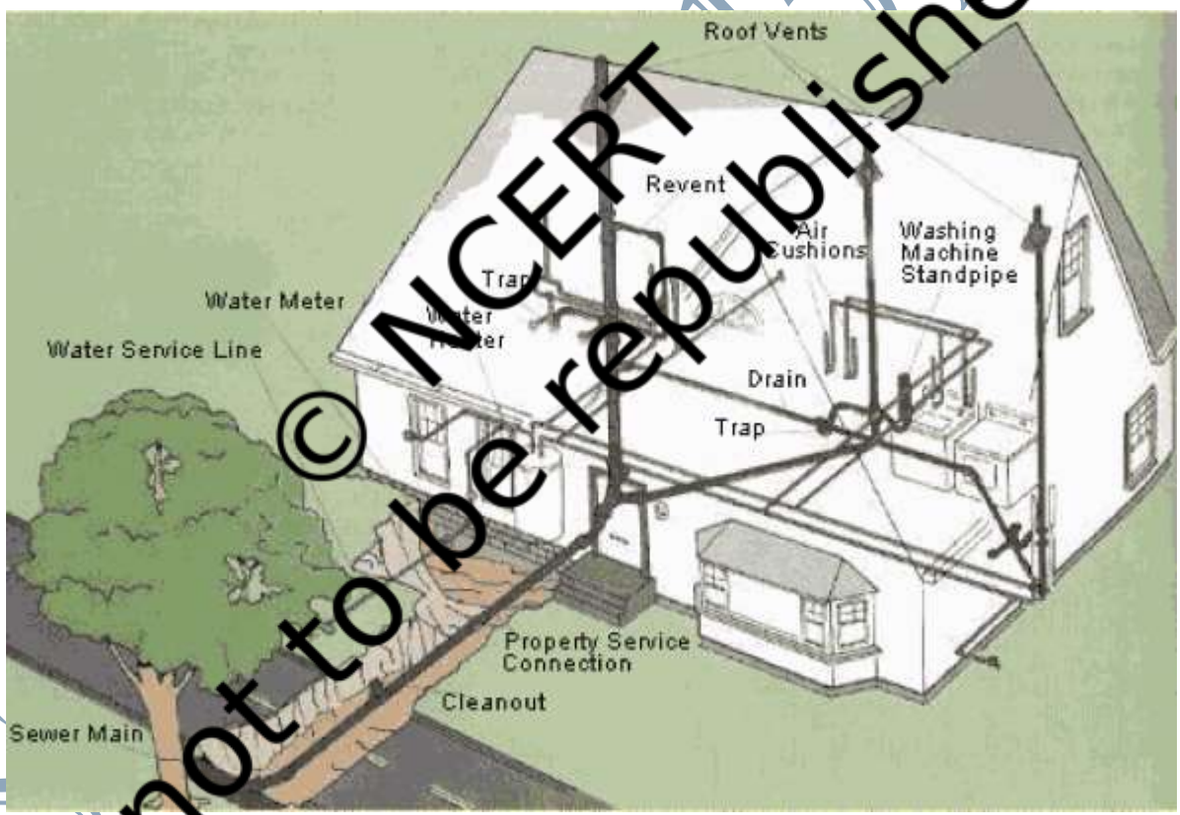


Fig. 5.1: Layout of pipeline (internal) in a building

I I

In Unit 4, we studied the importance of measurements in carrying out various plumbing tasks. At the same time,

a plumber must also have knowledge of the various pipe fittings like elbow, union, gasket, etc., joints and valves, and where these should be used while carrying out the tasks. Not only does this help in smooth functioning, but also ensures cost-effectiveness. For proper installation of the plumbing system in a building, various types of joints are used, which are shown in Fig. 5.1. As already mentioned, various types of fittings like elbow, gasket, union, etc., are used for making joints. It helps in changing the direction of water supply from main pipes to subsidiary pipes. Proper fitting also helps in checking leakage in the plumbing lines.

Pipe Fitting

Pipe fittings are an important component of the plumbing system. In plumbing, many types of fixtures are joined with the help of various types of material as per the requirement. Fittings are fixed in the plumbing system to join straight pipes or any section of tubes. We can say that the water-supply fittings like elbow, tee, socket, reducer, etc., are fitted to change the direction of flow, distribute the water supply from the main pipe to other pipes of equal size or lower size, etc.

Any part used in connection with water supply, distribution, measurement, controlling, use and disposal of water is known as a pipe fitting (Fig. 5.2).

Fig. 5.2: Pipe fittings

Type of Fittings

1. Collar
2. Elbow
3. Gasket
4. Union
5. Reducer
6. Tee
7. Nipple
8. Trap

Collar

While joining two pipes in the same length, collar is used. Collar is fitted in the end of pipe (Fig. 5.3).

Fig. 5.3: Collars

Elbow

It is installed at the time of joining two pipes. With the help of an elbow, the direction of liquid is changed. Normally a 45° or 90° elbow is used. When the two sides of pipes differ in size, an elbow of reducing size is used. This is called reducing type elbow or reducer type elbow. Elbows are categorised as follows—

Long Radius (LR) Elbows

Here, the radius is 1.5 times the diameter of pipe.

Short Radius (LR) Elbows

In this, the radius is 1.0 times the diameter of pipe.

90° Elbow

This is used when the change in direction required is 90° (Fig. 5.5).

45° Elbow

This is used when the change in direction required is 45° (Fig. 5.4).

Fig. 5.4: Bend 45°

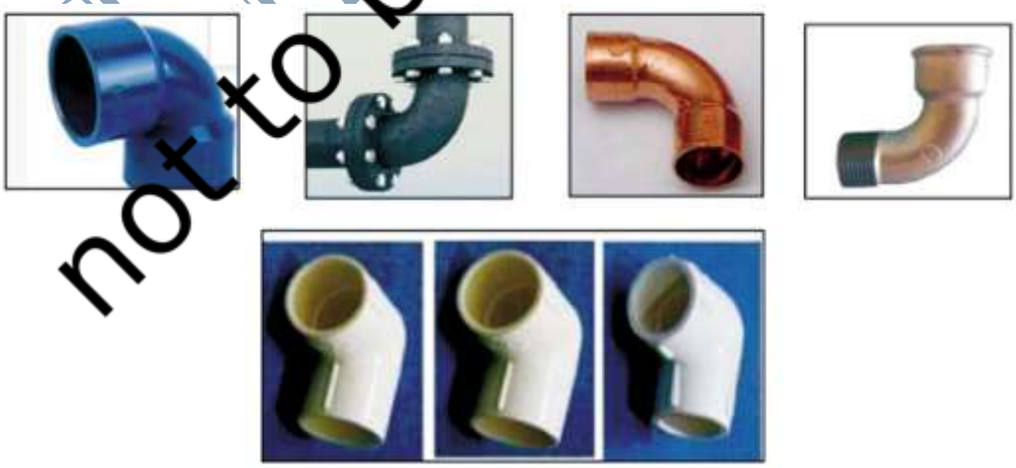


Fig. 5.5: Bend 90°

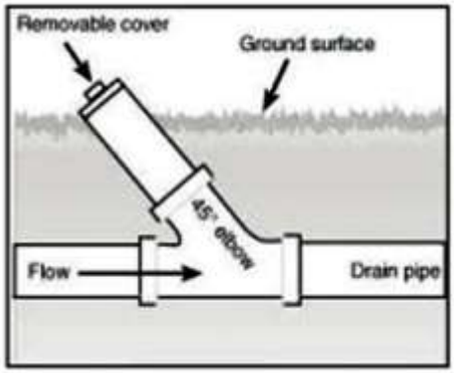


Fig. 5.6: Y-T Joint

Fig. 5.7: Double Y-T Joint-1

Fig. 5.8: Double Y-T Joint-2

Fig. 5.9: T Trap

Gasket

Fig. 5.10: Gasket

They are mechanical seals, generally ring-shaped type and fitted for sealing flange joints. A flange joint is a plate or ring to form a rim at the end of a pipe when fastened to the pipe. Gaskets are made as per by construction, materials and features. Important gaskets used are non-metallic, spiral-wound and ring-joint type (Fig. 5.10).

Union

Fig. 5.11: Union

When two ends of pipes are joined, the pipe fitting used is called union. A union is made of three parts namely a nut, a male end and a female end. The male and female ends are assembled with the support of the nuts, and necessary pressure is made to connect the joint. Since the pairing ends of the union are interchangeable, the union can be changed easily in a short time (Fig. 5.11).

Reducer

It is used to connect pipes of different diameters. A reducer may be of various types like reducer tee, reducer elbow and reducer socket (Fig. 5.12).

Fig. 5.12: Reducers

Tee

It is an important fitting with a side outlet at 90^0 to the run of the pipe. Tees connect pipes of various diameters and help in changing the direction of water or material in a pipe. Tees are made in various sizes like equal or

unequal. The equal tee is most commonly used (Figs. 5.13–5.15).

Fig. 5.13: Single tee socket

Fig. 5.14: Single tee socket

Fig. 5.15: Double tee socket

Nipple

It is a piece of pipe having thread at both sides, and could be used for short extension of plumbing lines. It

Fig. 5.16: Nipple

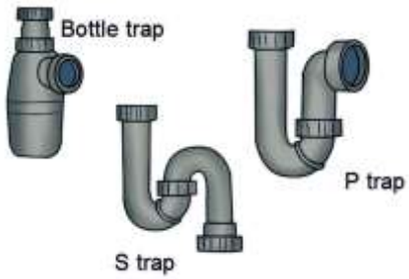


Fig. 5.17: Trap

Fig. 5.18: Cross

Fig. 5.19: Offset

can also be used for connecting two fittings within small distance (Fig. 5.16).

Trap

It is a fitting in a P, U, S or J-shaped type (Fig. 5.17). Traps are fitted near a plumbing fixture. The trap bend is fitted to prevent sewer gases from entering the building. If the gases are inserted back into home, then it could lead to people inhaling foul smell, which could cause illnesses. It could even explode.

Cross

When four pipes are joined,a cross is formed. It is also called a cross branch line or a four-way fitting (Fig. 5.18). This fitting has three outlets and one inlet. Cross fittings may deteriorate when temperatures change, because cross fitting is made at the centre of the four connection points.

Offset

When an assembly of fittings on a pipeline makes one section of pipe out of line and parallel to a second section, then it is known as an offset (Fig. 5.19).

L I F I PI P I B IL I (I L W)

GI (galvanised iron) pipes in the internal work of a building are laid either on the surface or concealed in the wall. For fixing on the surface, the pipes should be kept 1.5 cm apart from the wall and should be laid perfectly vertical or horizontal. The pipes should be held in pipe clamps which are embedded in the wall, roof, etc., with cement mortar 1:3 (1 cement: 3 coarse sand) (Table 5.1).

Table 5.1: Pipe clamp spacing

Diameter of pipe(mm)	Horizontal length (metres)	Vertical length (metres)
15	2.00	2.5
20	2.5	3.0
25	2.5	3.0

32	2.5	3.0
40	3.0	3.5
50	3.0	3.5
65	3.5	5.0
80	3.5	5.0

The following points should be kept into consideration during laying of pipes.

1. GI pipes should not come in contact with lime or lime-mortar. They should be treated with anti-corrosive paints.
2. Whenever a pipe passes through a wall, provision of expansion should be made.
3. Under the floors, the pipes must be placed in the layer of sand to allow expansion.

Pip J i

Pipes are connected with the help of joints. A variety of joints are used in an assembly of pipes. Connecting two or more pipes together is called a fitting. Various types of joints could be used in a pipe as per the requirement. Joints are also used for multiple pipe connections and are an important component of the plumbing system. Generally, the pipe joint fitted can easily sustain the pressure created in the pipe.

Types of pipe joints

Various types of pipe joints are as follows.

1. Threaded joint
2. Welded joint (butt welded, socket welded)
3. Brazed joint
4. Soldered joint
5. Grooved joint
6. Flanged joint
7. Compression joint

Threaded joint

When pipes are joined by screwing in threads which are provided in the pipe, it is called a threaded joint. In this

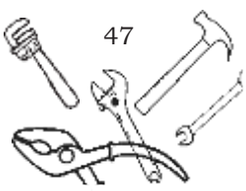


Fig. 5.20: Threaded joint

joint, one of the pipes has internal threads whereas the other pipe has threads externally. Thethreads are also made in various pipes like PVC, CI pipes, copper pipes and GI pipes, etc. (Fig. 5.20).

Threaded joints are used from 6 mm diameter to 300 mm diameter pipes.

Welded joints (Butt-welded joints)

It is one of the most common methods of joining pipes used in large infrastructure like commercial, institutional and industrial systems. Cost of material are low, but the labour costs are more due to the non-availability of trained welders and fitters. (Fig. 5.21).

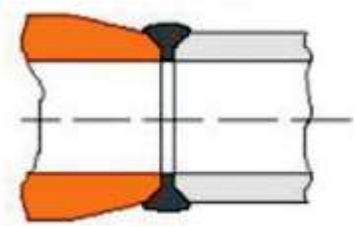


Fig. 5.21: Welded joint

Socket-welded joints

These are used when there is a high chance of leakage in the joints. Pipes are joined as putting one into other and welded around the joint, as shown in Fig. 5.22. Pipes having different diameters are suitable for this type of a joint. Socket-welded joint gives good results as compared to other joints.

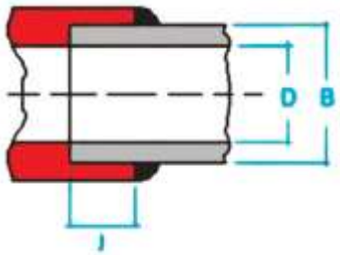


Fig. 5.22: Socket-welded joint

Brazed joints

When pipes are joined with the help of molten filler material at above 840°C, it is called brazing. Brazing is done for connecting copper pipes or copper alloy pipes. It is important to note that the melting point of the parent material (pipe material) should be higher than the filler material. Brazed joints have less mechanical strength, and are preferred in case of moderate temperatures (Fig. 5.23).

Fig. 5.23: Brazing

Soldered joints

Soldering and brazing are similar activities. In soldering, the filler material melts below 840°C. With the help of soldering, copper and copper alloy pipes are joined. During soldering, flux or metal joining material is used to prevent oxidation due to the flame. Soldered joints are suitable for low temperature areas and have low mechanical strength (Fig. 5.24 and Fig. 5.25).

Fig. 5.24: Brazed and soldered joint

Grooved joints

Fig. 5.25: Solder joint

When two pipes are joined together by making grooves (narrow cuts or depression) at the end of pipes with the help of sockets or couplings, such joints are called grooved joints. Due to the ease of assembly of the grooved joints, the labour cost is less. The piping system can be easily uninstalled and reinstalled frequently for maintenance (Fig. 5.26). These are mostly used for fire protection.

Fig. 5.26: Grooved joint

Flanged joints

This joint is commonly used for joining pipes in pumping stations, filter plants, hydraulic laboratories and boiler houses, etc. (Fig. 5.27). These joints are preferred due to easy process of assembly and disassembly, however these connections are costly. These joints can be disassembled and re-assembled when required. A pipe has flanged ends on both sides of the pipe length. Both the ends of pipes are joined at a proper level near one another. A hard rubber washer is placed between flanges and bolted. Flanges are generally fixed to the pipe by welding or threading. In certain cases, a flange-type joint is also called a lap joint. It may also be made by forging the process and machining the pipe end. There is no leakage in flanged joints even after rapid temperature fluctuations.

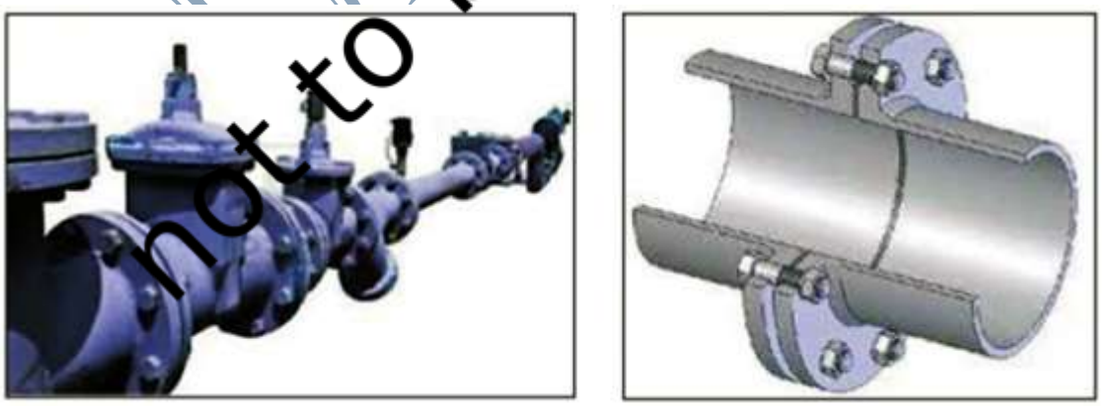
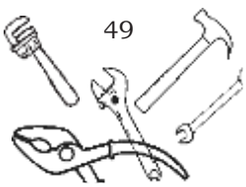


Fig. 5.27: Flanged joints



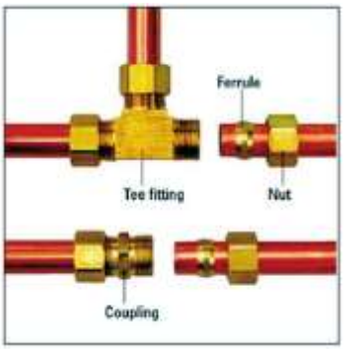


Fig. 5.28: Compression joints

Compression joints

These are applied to join the pipe without any preparations. The cost of installation of these joints is very economical. The pipes having plain ends are joined by fixing fittings at their ends, and such a joint is called a compression joint. The pipe ends are joined with threaded fittings or couplings. Joints are placed properly to check the flow pressure, otherwise, leakage may occur. These fittings are manufactured from different types of material. Selection of fittings is done as per requirement (Fig. 5.28).

V LV

For proper functioning of the pipeline, valves made of iron or brass are used in the water-supply mains. Valves stop or control the flow of fluid like liquid, gas, condensate, etc. These are classified according to their usage like isolation, throttling and non-return corrector. Various types of valves are manufactured depending upon their use and type of construction.

Fig. 5.29: Sluice valve

Sluice valve

It is fitted at an important place like at the entrance of a pipe. It may be the start of a new pipe from a tank, or a number of branches from the tank. This valve isolates the water-supply, as and when required. The sluice valve is specified by the pipe bore (diameter) of the water-way. The standard sizes are 50 mm, 65 mm, 80 mm, 100 mm, 150 mm, 200 mm, 250 mm and 300 mm. The sluice valves are classified as Class 1 and Class 2 (Fig. 5.29 and Table 5.2).

Table 5.2: Test pressure in sluice valve

Class	Test Pressure kg/cm²		Max. working Pressure kg/cm²
	Body	Seat	
Class 1	20	10	10
Class 2	30	15	15

Scour valve

This valve is provided at the lower level in a pipeline, so that such sections can be supplied and drained for maintenance purpose. The water is distributed into natural drains. It is basically a sluice valve and the very nature of its use has created the difference in the name (Fig. 5.30).

Fig. 5.30: Scour valve

Air valve

It is fitted to release the air automatically when the pipe is filled with water. This valve also permits entry of air when the pipe is drained. This valve is fixed at the end of a communication pipe and controls or stops the supply of water. This valve is specified by the standard bore (diameter) of the socket or pipe outlet, to which it is fitted. The standard sizes are 8 mm, 10 mm, 15 mm, 20 mm, 25 mm, 32 mm, 40 mm and 50 mm (Fig. 5.31).

Fig. 5.31: Air valve

The body components and washer plate are made of cast brass or leaded tin bronze. The washers are made from fibre, leather, rubber or nylon. This valve is available in two types: internally threaded and externally threaded.

Gate valve

It is used for starting or stopping flow. For a straight-line flow of fluid, minimum flow restriction can also be done with gate valve. In service, these valves are generally either fully open or fully closed. These valves are used for various types of liquids and make a tight seal when closed.

Fig. 5.32: Split taper non-rising gate valve

Types of gate valve

Gate valves have gates of wedge type, solid or split type, or gate of double disc or parallel type. The movement of the gate shall be by the internal or external screw on the spindle. The spindle, which controls the flow of a liquid, can be of the rising or non-rising type. See Fig. 5.32 and Fig. 5.33.

Fig. 5.33: Rising spindle split wedge gate valve

Parallel slide valve

It has two discs without spreading mechanism which slides between the two parallel body seats. The activation

of the valve discs is by the internal and the external screw on the spindle and the spindle may be of the rising or non-rising type (Fig. 5.34).

Fig. 5.34: Parallel slide valve

Globe valve

It is a type of valve used for controlling flow in a pipeline. A component of valve includes a movable disc element and a stationary ring seat fitted in a generally spherical body. The globe valve is used for controlling flow control (Fig. 5.35).

Fig. 5.35: Globe valve

Angle valve

It is used to control the movement of a fluid like liquids, gases, fluidised solids, or slurries by opening, closing or partially obstructing various pathways. This type of a valve generally has a round body, in which the body ends are fitted at right angles with each other and the disc moves up and down. The valve is moved to action by the internal or external screw on the spindle. The spindle may be of the rising or non-rising type. See Fig. 5.36 and Fig. 5.37.

Fig. 5.36: Angle valve-1

Fig. 5.37: Angle valve-2

Check valve or non-return valve

It is a valve which permits (fluid) water to move in one direction but checks all the returning flow. It is operated by the pressure above, having no external means of control (Fig. 5.38).

Fig. 5.38: Check valve or non-return valve

Ferrule

It is used for connecting a service pipe to the water main. It is usually made of non-ferrous metal and screwed to the main pipe (Figs. 5.39–5.42).

Fig. 5.39: Ferrule

Foot valve

It is a valve used in the pump. It is also called check valve, as it makes sure that the pump is ready to use. If

Fig. 5.40: Swing check

Fig. 5.41: Horizontal check

Fig. 5.42: Vertical check

the pump is off, then the foot valve keeps enough fluid in the pump to ensure that it can start again. In a well, the foot valve will be between the water surface and the pump. In a water intake system, the foot valve will be at the end of the water intake line. The foot valve has a strainer on the outside which prevents obstructions also (Fig. 5.43).

Fig.5.43: Foot valve

Float valve

It is used for stopping water when the water tank or flush toilet is filled, so that it stops overflowing. When the water level rises, the float also rises; once it rises to a pre-set level, the water level forces the lever to close the valve and stops the water flow. A float valve is a fitting used for filling water tanks as well as flush toilets (Fig. 5.44).

Fig. 5.44: Float valve

Practical Exercises

Activity 1

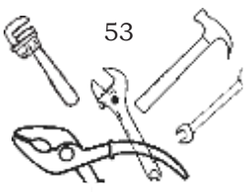
Prepare a list of fittings available in the market.

Material Required

1. Different types of fitting
2. Notebook
3. Pen

Procedure

1. Survey the local market.
2. Visit the plumbing hardware shop.
3. Identify the fittings available in the shop.
4. Prepare a list of the identified fitting items seen in the market.
5. Note down the cost of the fitting items and their manufacturing company's name.



Activity 2

Draw figures of the various types of bends.

Material Required

1. 45° and 90° bend
2. Notebook
3. Pen

Procedure

1. Inspect the plumbing items fitted in the school.
2. Identify the bends fitted.
3. Draw the figures of bends in your notebook.

Activity 3

Practice joining a pipe.

Material Required

1. Joints
2. Pipe
3. Tools

Procedure

1. Collect the pipe joints, pipes and tools.
2. Identify the components.
3. Collect the joints.
4. Join the pipe with the help of proper pipe joining tools.

Activity 4

Draw the figure of joints.

Material Required

1. Threaded joints, grooved joints and compression joints
2. Pen
3. Pencil

Procedure

1. Collect the figures or joints of threaded joints, grooved and compression joints.
2. Draw the figure of the joints.

Check Your Progress

A. Answer the following questions

1. Why are fittings used in plumbing? Write a short note on any four types of fittings.

2. Why are joints necessary? Discuss in detail, with suitable figures.
3. State the difference between threaded joint and a welded joint.
4. Explain the importance of valves. Write about two types of valves and their uses.
5. What is the role of a float valve? List down its uses and advantages.

B. Mark the correct option

1. Which of the following fittings is used to connect two pipes with each other?
   (a) Tee (b) Connector
   (c) Elbow (d) All of the above

2. Which of the following fittings is used to connect four pipes?
   (a) Offset (b) Union
   (c) Cross (d) Reducer

3. The valve which avoids both overflow and back flow of water is_____.
   (a) float valve (b) angle valve
   (c) foot valve (d) check valve

C. Match the following

Column A	Column B
1. Nipple	(a) 
2. Ferrule	(b) 
3. Soldered joint	(c) 
4. Foot valve	(d) 

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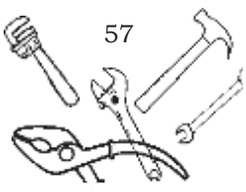
Unit	Fill in the blanks	Match the following	Mark the correct option	Full forms
1.	1. Water 2. Plumbing fixtures 3. Pipes 4. Installation, repair, maintenance, servicing		1. (c) 2. (d) 3. (d) 4. (a)	
2.	1. Holding 2. Mason's square 3. Pickaxe 4. Drill machine` 5. Cutting	1. (b) 2. (c) 3. (d) 4. (a)		
3.			1. (c) 2. (a) 3. (b)	1. Galvanized Iron 2. Asbestos Cement 3. Unplasticised Polyvinyl 4. Cast Iron
4.	1. 12 2. 1.09 3. 2.2046 4. 4.546 5. 27.68 6. 1		1. (b) 2. (b) 3. (d)	
5.		1. (d) 2. (c) 3. (b) 4. (a)	1. (d) 2. (c) 3. (a)	



L

Assembly: *Process by which part samples (belonging to the same assembly standard [RFC]) are connected to one another. Assembling two basic parts always results in a new, larger composite part that can be used in future assemblies.*

Bending: *A technique used in various metal forming processes with the aim of increasing the fabrication capabilities of plumbing fixtures. The pipe can be bent at varying angles and in different directions. The simplest curve turns the tube at an angle of 90 degrees forming an elbow. Besides, pipe bending can be done in several other geometries that include 2D and 3D dimensions.*

Chipping: *Removal of wood, spatter, rust or old paints from iron work or plumbing work using hammer and cold chisel.*

Die: *It is used to cut or form the male portion of the mating pair (for example, a bolt).*

Disassembly: *When referring to hardware, disassembly is the process of breaking down a device into separate parts. A device may be disassembled to help determine a problem, to replace a part, or to take the parts and use them in another device or to sell them individually.*

Drilling: *Process of creating a smooth hole in a material with a drill and motor.*

Filing: *Process of removing excess material and deburring the surface. Sandpaper may be used as a filing tool for material, such as wood.*

Sawing: *Process wherein a narrow slit is cut into the workpiece by a tool consisting of a series of narrowly spaced teeth, called a saw blade. Sawing is used to separate work parts into two or more pieces, or to cut off an unwanted section of a part.*

Tap: *It is used to cut or form the female portion of the mating pair (e.g., a nut).*

Taps and **dies:** *Tools used to create screw threads, which is called threading. Many are cutting tools; others are forming tools.*

Tapping: *Process of cutting or forming threads using a tap. It is the action that creates a thread into the side of the hole.*

Threading: *Process of cutting or forming threads using a die.*

CONSTRUCTION AND EARTHMOVING EQUIPMENTS

Construction equipment planning and selection plays crucial role for the success of construction firms. Inadequate manual processes of equipment, planning and selection and the subjective decisions of equipment managers usually result in major losses in construction firms. An indispensable item of resources, it produces output at accelerated speed, enables completion of task in limited time. Equipment saves manpower, which is becoming costly and more demanding day by day. Equipment improves quality, productivity and safety. Construction equipment planning aims at identifying construction equipment for executing project tasks, assessing equipment performance capability, forecasting date wise requirement of number and type of equipment and finally participating in the selection of equipment to be acquired. To derive full benefits from the equipment, there should be proper selection and good planning of its operations.

Appropriate selection and planning is essential for successful completion of project and to secure maximum profit out of it. The type of equipment selected usually depends upon the characteristics of material to be handled. Whether to use wheeled equipment or track equipment; whether to use dragline excavator or power shovel, are some of the typical questions that are to be answered by the planner of construction equipment.

PLANNING AND SELECTION OF CONSTRUCTION EQUIPMENTS

➢ PROPPER PLANNING

- ✓ Modern highway construction projects are complex in nature and success of a project depends greatly on proper and scientific planning.
- ✓ Before starting any project its planning is done with great care, as the efficiency of the whole project largely depends upon its planning.
- ✓ While planning each and every detail should be worked out in anticipation and should be considered carefully. Planning of a construction project involves deciding about the extent of mechanization, equipment planning, and execution planning etc. while planning a highway project equipment manager should be carefully decided the extent of mechanization so as to minimize the cost of project.

➢ SELECTION

- ✓ Proper selection of equipment for a construction project is of vital importance for its speedy and economical completion.
- ✓ Problem of equipment selection has become more complicated, because large variety of equipments are being manufactured now-a-days.
- ✓ For selection of equipment, a considerable experience in the operation and maintenance in the field is essential.
- ✓ Records kept for operation, maintenance and actual output obtained under comparable conditions of previous projects will greatly help in taking decision for equipment selection.
- ✓ With the undertaking of new projects and the retirement of old machinery and equipment, it becomes necessary to acquire new construction equipment.
- ✓ In this stage, sufficient knowledge base of current brands and products is necessary. It is also important to determine what sort of equipment and capacity is needed.

- ✓ Selection of equipment for the project is one of the key decisions in planning and executing a construction project, which affects how the work will be done, the time required to complete the work, and the cost that will be accrued.
- ✓ Final decision on the equipment required for the projects is generally given by equipment managers, project managers, and construction planning group together.
- ✓ Often, the decision making process can create tensions in the firm. Once the selection of equipment is made, a choice has to be made whether to buy, rent, or lease it. These decisions are given based on the economic standing and strategy of the firm, and the nature and frequency of equipment use.

➢ SOURCING INFORMATION

The contractor may decide on the choice of the manufacture based on its own past experience of from experience of other.

The information collected about equipment should include-

- Name of manufacturer
- Model number
- Engine type, horse power and speed
- Machine dimensions
- Type of controls
- Operating pressure
- Fuel consumption
- Type of transmission
- Weight
- Warranty periods
- Maintenance details etc.

➢ COMMON FACTORS AFFECTING SELECTION OF EQUIPMENT

- ✓ Scope of work to be carried out
- ✓ Use of available
- ✓ Suitability for job conditions
- ✓ Uniformity in type
- ✓ Size of equipment
- ✓ Use of standard Equipments
- ✓ Unit cost production
- ✓ Country of origin
- ✓ Availability of spare parts
- ✓ Versatility
- ✓ Selection of manufacturer
- ✓ Suitability of local labor
- ✓ Technical consideration

STUDY ON EARTHMOVING EQUIPMENTS LIKE DRAGLINE, TRACTOR, BULLDOZER, POWER SHOVEL

❖ Dragline excavator

- A dragline bucket system consists of a large bucket which is suspended from a boom (a large truss-like structure) with wire ropes.
- The bucket is maneuvered by means of a number of ropes and chains.
- The hoist rope, powered by large diesel or electric motors, supports the bucket and hoist-coupler assembly from the boom.
- The dragrope is used to draw the bucket assembly horizontally.
- By skillful maneuver of the hoist and the dragropes the bucket is controlled for various operations.
- Draglines used in civil engineering are almost always of this smaller, crane type. These are used for road, port construction, pond and canal dredging, and as pile driving rigs. These types are built by crane manufacturers such as Link-Belt and Hyster.

https://www.youtube.com/watch?v=JaUUbVRF34M&ab_channel=JMLoca%C3%A7%C3%B5esdeVe%C3%ADculos%2CM%C3%A1quinaseEquipamentosLTDA
https://www.youtube.com/watch?v=tyb2iLCKALc&ab_channel=LynnHawkins

Operation

- ✓ In a typical cycle of excavation, the bucket is positioned above the material to be excavated.
- ✓ The bucket is then lowered and the dragrope is then drawn so that the bucket is dragged along the surface of the material. The bucket is then lifted by using the hoist rope.
- ✓ A swing operation is then performed to move the bucket to the place where the material is to be dumped. The dragrope is then released causing the bucket to tilt and empty. This is called a dump operation.
- ✓ On crane-type draglines, the bucket can also be 'thrown' by winding up to the jib and then releasing a clutch on the drag cable.
- ✓ This would then swing the bucket like a pendulum. Once the bucket had passed the vertical, the hoist cable would be released thus throwing the bucket.
- ✓ On smaller draglines, a skilled operator could make the bucket land about one-half the length of the jib further away than if it had just been dropped. On larger draglines, this is not a common practice.

Limitation

- The primary limitations of draglines are their boom height and boom length, which limits where the dragline can dump the waste material.
- Their dig depth is limited by the length of rope the draglines can utilize.
- Inefficient and is not suitable to load piled up material.
- If the blasted rocks are of large lump causes insufficient filling and bucket and drag rope wear rapidly.
- Production cost more compared to shovel
- Lesser output than powered shovel
- Bucket fill factor is less as compared to powered shovel
- Lesser efficiency than shovel

❖ BULLDOZER

A bulldozer is heavy machinery equipped with a substantial metal plate (known as a blade) in the front and typically equipped at the rear with a claw-like device (known as a ripper). A dozer is a tractor unit which has a blade attached to its front. The blade is used to push, shear, cut and roll materials ahead of the tractor. The dozer is an effective and versatile earthmover. They are used as both support and production machines on many construction projects, where they may be used from start to finish.

The bulldozer is one of the most commonly used pieces of earthmoving equipment. It has a number of applications, from clearing and grubbing to site maintenance. In addition, there are several attachments that increase the versatility of the bulldozer. A bulldozer is a tractor that has

a blade attached to its front. The tractor is mounted on either crawlers or wheels. Bulldozers are commonly classified based on these mountings. The blade attached to the front of the bulldozer is used to push soil, debris, or other material. The blade can be lowered and raised, allowing it to excavate and distribute soil. On many bulldozers, the blade can also be angled to the left or the right, so that material is pushed forward and to one side.

Fig-wheeler type bulldozer

Fig- Crawler type bulldozer

Applications

The bulldozer is commonly used in excavation and embankment construction. The bulldozer can also be used in clearing and grubbing, topsoil removal, and maintenance of haul roads and borrow pits.

- Moving earth for haul distances up to 100m.
- Helping load tractor pulled scrapers.
- Spreading and leveling earth fills.
- Back filling trenches.
- Clearing, the construction sites of debris and rubbish.
- Maintaining haul roads.
- Clearing the floors of borrows and quarry pits.
- Stripping of the top soil that is not usable.

Limitations

- It cannot dig as clean a trench bottom as dedicated trenching equipment.
- Needs skilled operators.
- Equipment is costly (including various attachments.)
- High repair and maintenance cost.
- Used only for small projects.
- Dig depth is limited.
- Noise nuisance
- Transportation of equipment from one place to another takes time.

❖ POWER SHOVEL

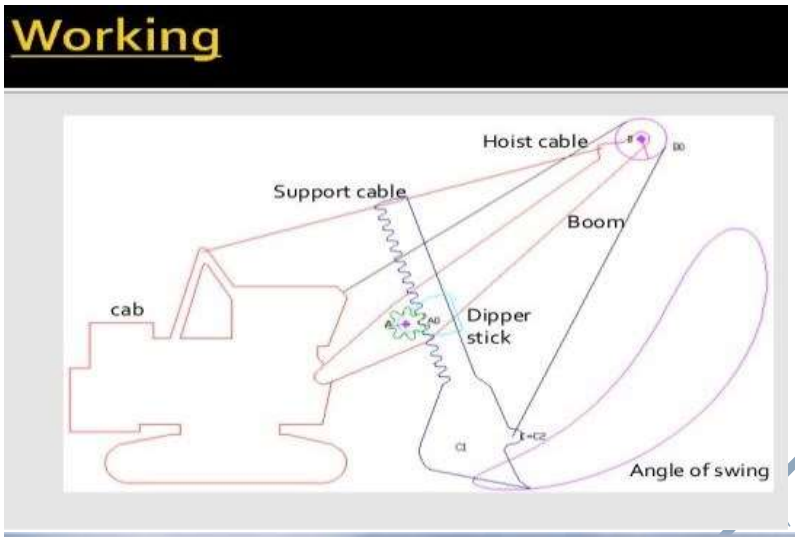
✓ A **power shovel** is a bucket-equipped machine, usually electrically powered, used for digging and loading earth or fragmented rock and for mineral extraction. Power shovels are a type of rope/cable excavator, where the digging arm is controlled and powered by winches and steel ropes, rather than hydraulics like in the more common hydraulic excavators. Basic parts of a power shovel include the track system, cabin, cables, rack, stick, boom foot-pin, saddle block, boom, boom point sheaves and bucket. The size of bucket varies from 0.73 to 53 cubic meters.

✓ Power shovels are used principally for excavation and removal of overburden in open-cut mining operations; they may also be used for the loading of minerals, such as coal.

https://en.wikipedia.org/wiki/File:Rope_shovel.gif

https://www.youtube.com/watch?v=eUwY9aQ9feE&ab_channel=MFACivilEngineering

https://www.youtube.com/watch?v=yi-OrH5H2jE&ab_channel=Minesutra



Power shovels normally consist of a revolving deck with a power plant, drive and control mechanisms, usually a counterweight, and a front attachment, such as a crane ("boom") which supports a handle ("dipper" or "dipper stick") with a digger ("bucket") at the end The machinery is mounted on a base platform with tracks or wheels. Modern bucket capacities range from 8 m^3 to nearly 80 m^3.

Other uses of the power shovel include:

1. Close range work.
2. Can excavate all classes of earth except solid rock, without prior loosening.
3. Removing large boulders.
4. Excavating material and loading trucks.

5. Various other types of jobs such as digging in gravel banks, in clay pits, cuts in support of road work, road-side berms, etc.

OPERATION

The shovel operates using several main motions including:

- Hoisting - Pulling the bucket up through the bank of material being dug.
- Crowding - Moving the dipper handle in or out in order to control the depth of cut or to position for dumping.
- Swinging - Rotating the shovel between the dig site and dumping location.
- Propelling - Moving the shovel unit to different locations or dig positions.

A shovel's work cycle, or digging cycle, consists of four phases:

- Digging
- Swinging
- Dumping
- Returning

The **digging** phase consists of crowding the dipper into the bank, hoisting the dipper to fill it, then retracting the full dipper from the bank. The **swinging** phase occurs once the dipper is clear of the bank both vertically and horizontally. The operator controls the dipper through a planned swing path and dump height until it is suitably positioned over the haul unit (e.g. truck). **Dumping** involves opening the dipper door to dump the load, while maintaining the correct dump height. **Returning** is when the dipper swings back to the bank, and involves lowering the dipper into the track position to close the dipper door.

Limitations

•The weight limitations imposed by most states for hauling on highways may restrict the size of shovel

•Power shovel can dig far more easily and faster, but it does use lots of fuel.

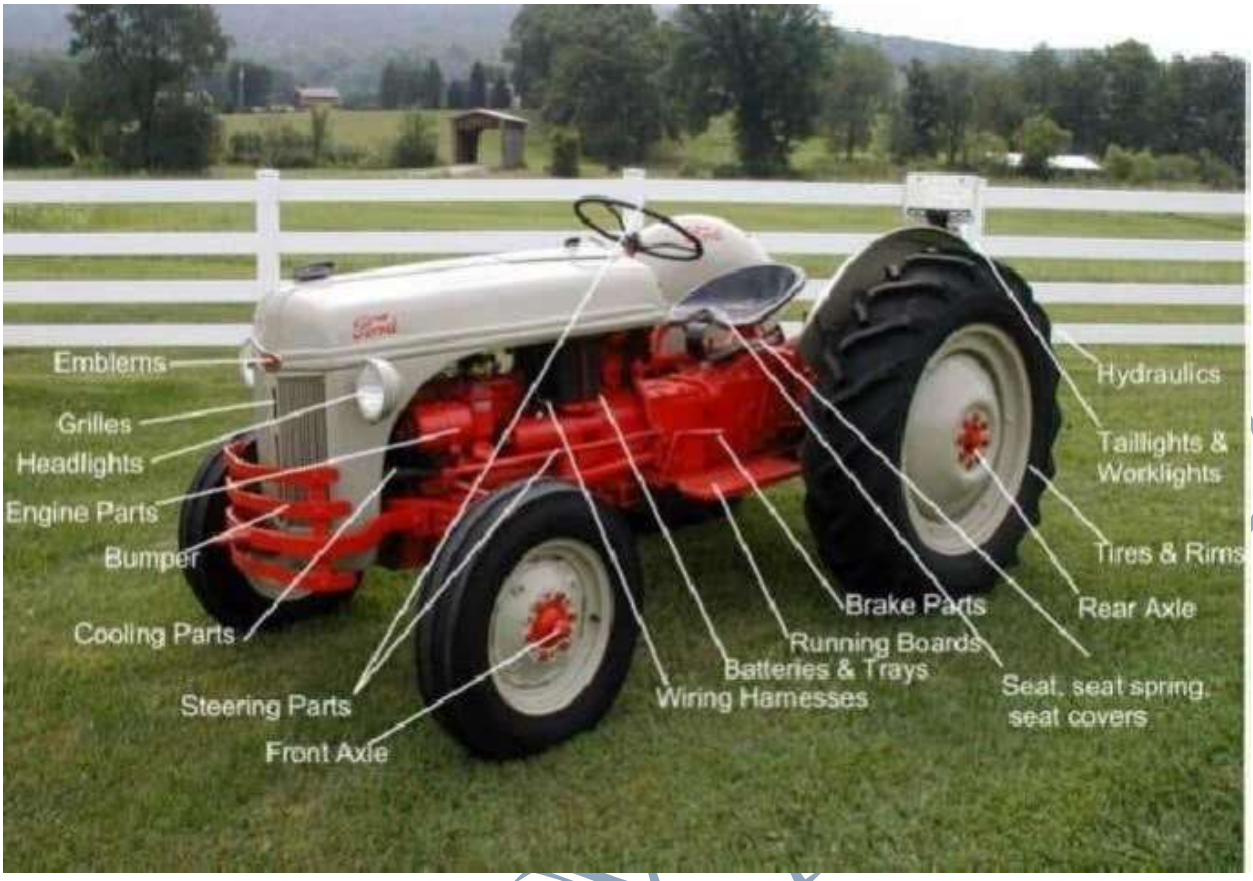
•Transportation cost for crawler mounted power shovel is more and is directly proportional to its size.

•Efficiency of shovel depends upon the skill of the operator and physical condition of the shovel.

❖ TRACTOR

The primary purpose of tractor is to pull or push loads, and it may be unused also as mount for many types of equipment such as bulldozer, shovel, dragline, hoe, trenchers etc. Therefore, it is regarded as one of the most important equipment and is indispensable on most of the construction projects whether small or big.

There are sizes and types to fit almost any job for which they are meant for. The tractor is a high-powered utility vehicle designed to tow implements or attachments for use in the agricultural and construction industries. Initially designed to aid in farm work, the tractor has grown into a multi-functional piece of heavy equipment.



There are two types of tractor .

1. Crawler tractor
2. Wheeler tractor

Crawler tractor

If a tractor is mounted on crawler, it is called crawler tractor. A crawler track is an endless chain consisting of steel links made of steel plats connected together by pins and bushings. Among the construction equipment, the crawler tractor is the most basic and versatile machine. Generally, it is used for moving heavy units on rough surface having poor traction.

Wheeler tractor

One of the basic advantages of a wheel tractor when compared with a crawler tractor lies in its higher speed. For any earth moving project, job conditions will influence the layout of the project and the performance of the machine working on it. But under all conditions, speed is what must be stressed when applying the rubber tired tractors. Its useful life lies between 8 to 10 years depending upon on its horsepower which is generally more than 75 HP.


C45E

Study and uses of compacting equipments like tamping rollers, Smooth wheel rollers, Pneumatic tired rollers and vibrating compactors

❖ TAMPING ROLLERS

The tamping roller is a type of road roller that's mainly used in compacting dirt effectively. It works similarly with a normal smooth drum roller but the main difference is the actual texture and shape of the tamping roller. Instead of a smooth drum, the drum has a lot of bumps and knobs. It is also named as sheep footed roller. Front steel drum of sheep foot roller consists of many rectangular shaped boots of equal sizes fixed in a hexagonal pattern.

Tamping roller done compaction by static weight and kneading of respective layer. This makes tamping roller better suited for clay soils. Contact pressure of tamping roller varies from 1200- 7000Kpa.

Functions of a Tamping Roller

- ✓ The tamping roller can be used for compacting soil effectively. Soil tends to be a bit harder to compact, especially if the soil has other components like solid rocks and formations.
- ✓ Heavy clay is no match for a good tamping roller. There are two types of tamping rollers, one uses static force and another uses vibratory force. The second type functions similarly to a smooth drum roller.
- ✓ The effectiveness of the tamping roller can be increased depending on what kind of drum and lugs are being used on the drum itself.
- ✓ The pressure added and used while rolling can make each pass more effective depending on the operation of the tamping roller.

- ✓ The grooves penetrate the soil and insert pressure. The most effective pressure can be achieved with the tamping roller is by using it when it's in a vertical position.

Uses of a Tamping Roller

Tamping rollers can be used for compacting soil in dams, embankments, subgrade layers, and railroad projects. Most soils in these sites tend to be much heavier and it might not be effectively compacted with a smooth drum roller. The tamping roller can add extra force with its knobs and bumps to create a greater force that can compact the heavy soil.

❖ SMOOTH WHEEL ROLLER (STATIC ROLLER)

Smooth-wheel rollers, as the name implies, uses one large, smooth steel drum in the front and either one or two wheels on the rear end for compaction. These are either tandem (two-wheel) or three-wheel rollers. Smooth wheel rollers are ideal for gravel, sand, ballast, and surface dressings.

Smooth wheel roller and vibratory rollers are the same. Both have the same characteristics. Only the difference in both is vibratory equipment. Smooth wheel roller has no vibrator attached with the drum. This makes smooth wheel roller best suited for rolling of weaker aggregates, proof rolling of subgrades and in compacting asphalt pavements. Compaction of clay or sand is not a good choice to done with smooth wheel roller. This is so, because there are many empty voids in clay soil and sand, which cannot be minimized without vibrators.

Double Drum or Tandem Roller

The tandem, or double drum roller, has one steel drum in the front and one in the back. As the two drums move, this moves the roller. The efficiency of the tandem roller comes from the two drums — entire sections of a highway can be flattened and paved quickly and efficiently.

These rollers are great for flat or gradual surfaces like asphalt, but because they have very little traction, they're not recommended for anything specialized.

Single Drum or Three-wheeled Roller

These rollers have a steel drum in the front and two special wheels in the back that can prevent most flat tires from happening.

Single drum rollers can work in tighter spaces and more specialized projects due to their smaller size. They're great for creating foundations for buildings and paving highways or sidewalks, but because of the extra weight in the front, they won't roll over some surfaces.

PNEUMATIC TYRED ROLLER

Also known as rubber tyred rollers, these consist of a heavily-loaded wagon with several rows of closely-spaced tyres. The rubber tires provide an 80% coverage area and uniform pressure throughout the width of the tires. They provide uniform pressure throughout the width covered, and are often used in pavement subgrade works, as they are suitable for compacting uniform coarse soils and rocks.

They are also used to finish embankments compacted by sheep foot rollers. The factors which affect the amount of compaction that can be achieved are the weight, tyre inflation pressure and the area of contact.

❖ VIBRATING COMPACTORS

Vibratory rollers are almost identical to smooth wheel rollers (including the single and double drum) except for one major difference: they come with a specialized vibrating component. As the roller compacts and flattens the surface, it will vibrate.

Vibratory type rollers have two smooth wheels/ drums plus the vibrators. One is fixed at the front and the other one is on the rear side of vibratory roller. Both wheels/drums are of the same diameter, length and also of same weight. Vibratory roller covers the full area under wheel. To make vibratory roller more efficient, vibrators are also fixed with smooth wheel rollers. Vibration of vibrators arrange the particles by first disturbing even the arranged ones. On the other hand weight of wheels exerts direct pressure on the layer. Vibrators are turned off during the reversed motion of roller. In that time only static weight directly acts on the soil layer.

Vibration is to reduce the air voids and to cause densification of granular soils. During vibration of soil layer, rearrangement of particles occurs due to deformation of the granular soil because of oscillation of the roller in a cycle.

OWNING AND OPERATING COST

There are several methods of determining the probable cost of owning and operating construction equipment. No method will give the exact costs under all operating conditions. At best the estimate is only a close approximation of the expenses. Records of previously used equipment should provide information that may be used for the particular equipment. However, there is no assurance that similar equipment will involve similar costs, particularly if the equipment is used under varying conditions. Factors that affect the cost of owning and operating construction equipment include the cost of the equipment delivered to the owner, the severity of job conditions, and the number of working hours in a year, the number of years the equipment is used, the care with which the owner maintains and repairs it, and the demand for used equipment when it is disposed off, which will affect the salvage value.

When the cost of owning and operating of construction equipment is to be estimated before it is purchased, the cost records based on past experience, will generally not be available. The costs which should be considered include capital investment and depreciation (i.e. the ownership costs) maintenance, repairs, petrol, oil, and lubrication charges (i.e. the operating costs).

RESEARCH ARTICLE OPEN ACCESS

Soil Reinforcement Techniques

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ABSTRACT
In many activities concerned with the use of soil, the physical properties like Stiffness, Compressibility and Strength are some of the few important parameters to be considered. Of the many methods involved in improvement of soil properties, soil reinforcement is method concerned with increase of *strength* properties of soil. In soil *reinforcement*, the reinforcements or resisting element are of different materials and of various forms depending upon the intended use. The reinforcement can be provided permanently or temporarily to increase strength of adjacent structures. The present topic of discussion involves different materials, forms and applications of soil reinforcement

Keywords: strength, reinforcement, materials, applications.

I. HISTORY OF THE SOIL REINFORCEMENT

Basic principles of soil reinforcement already existing in nature and are demonstrated by animals, plants and birds. The modern form of the soil reinforcement was first applied by Vidal (1969). Based on the Vidal's concept the interaction between soil and the reinforcing horizontal member is solely by friction generated by gravity.

Applying this concept retaining walls were built in France in 1986. Nowadays this technique is widely used in Europe and U.S.A. This technique is yet to become popular in India, and the constraining factor being identified as the non-availability of fiber and cost of reinforcing material.

Reinforced soil is somewhat analogous to the reinforced concrete. But direct comparison between the functions of reinforcement in the two cases is not valid. The mode of action of reinforcement in soil is not one of carrying the developed tensile stresses as in reinforced concrete but of anisotropic reduction of normal strain rate.

II. MECHANISM

To understand the mechanism by which reinforcement improves the performance of soil, let us look at two laboratory scale experiments. In the first case, a tank ABCD as shown in figure is filled with dry sand. When we remove side AB of the container, the vertical face of the sand does not remain stable and the soil mass rearranges itself as a sloping surface. We now repeat the same experiment by using geotextile material as reinforcement in soil mass. The geotextile is the flexible material that resembles a strong or thick sheet of cloth. This material is placed in horizontal layers when the sand is filled in the tank and it is folded at the ends as shown in figure. After removing the side AB, the vertical side does not collapse. We may observe some bulging but the face remains vertical and stable. This is so because, when the soil particles in the failure zone begin to collapse, the geotextile reinforcement prevents their movement

1. During the shearing stage, prior to failure, the reinforced soil sample shows lower radial and axial strain under the same deviator stress as compared to unreinforced sample.
2. At failure, the deviator stress of the reinforced sample is significantly larger than that of sample without reinforcement indicating higher shear strength of the former

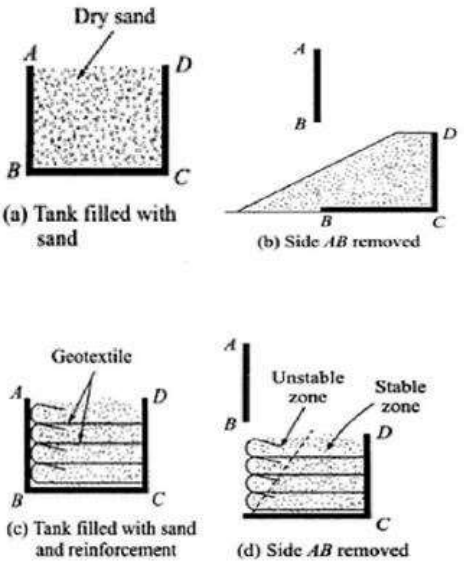
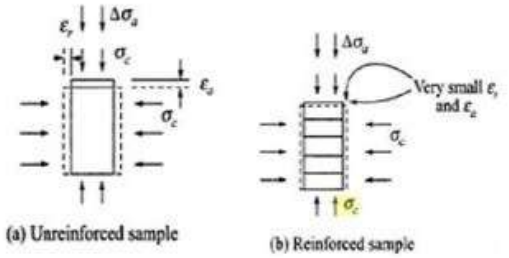


Figure 2.1

If we take two samples of medium-dense sand, one reinforced and the other not reinforced and test them in the triaxial apparatus under consolidated drained conditions. The reinforcement is introduced in one of the soil sample in the form of four discs of thin aluminium foil placed horizontally in the sample. Two important observations can be made from these tests:



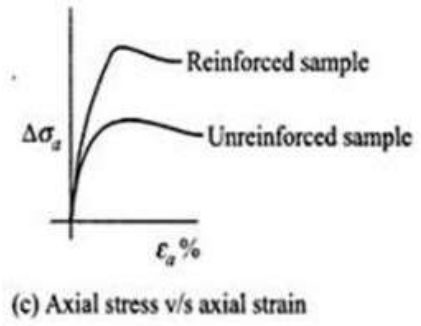


Figure 2.2

III. MATERIALS

There are two basic materials used in the construction of reinforced soil.

- Soil or fill matrix
- Reinforcement or anchor system

There used to be adequate inter-relationship between the materials used. Based on the design strength and availability, the materials are selected. We will discuss one by one, the materials that are being used.

Soil or fill matrix

The shear properties of soil can be improved as theoretically any soil could be used to form earth reinforced structure. In long term conventional structures the soil used is the well graded cohesionless soil or a good cohesive frictional fill although pure cohesive soils have been used with success. The advantages of cohesionless soil are that they are stable, free draining, not susceptible to frost and relatively non-corrosive to reinforcing elements.

The only disadvantage is its cost. As a convenient compromise between the technical benefits from cohesionless soil and economic benefits from cohesive soil, cohesive frictional may be preferred.

Sometimes the use of waste material as fill for reinforced soil structures is attractive from an environmental as well as economic view point. Mine wastes and pulverized fuel ash are the wastes usually employed

Reinforcement

A variety of material including steel, concrete, glass, fiber, wood, rubber, aluminium and thermoplastics can be used as reinforcing material. Reinforcement can have the form of strips, grids, anchors and sheet material chain, planks, rope, vegetation and combinations of these or other material forms.

- Strips are flexible linear elements having their breadth greater than their thickness. Strips are formed from aluminium, copper, polymers and glass fiber reinforced plastic and bamboos. The forms of stainless galvanized or coated steel strips are either plain or with projections such as to increase the friction between reinforcement and fill.

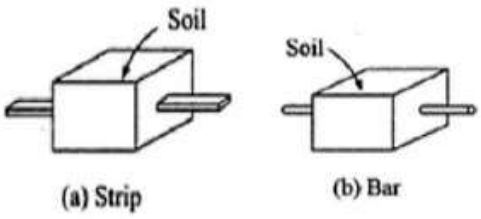


Figure 3.1

- Grids or are also used as reinforcement. Grids are formed from steel in the form of plain or galvanized weld mesh or from expanded metal.

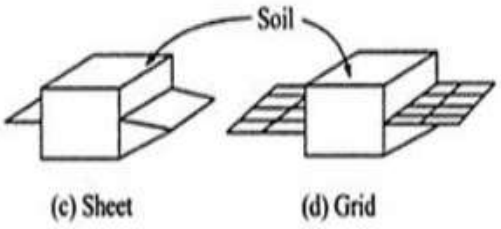


Figure 3.2

- Sheet reinforcement may be formed from metal such as galvanized steel sheet, fabric or expanded metal not meeting the criteria for a grid

Flexible linear elements having one or more pronounced distortions which act as abutments or anchors in the fill or soil. They may be made from materials like steel, rope, plastic or combination of materials such as webbing and tyres, steel and tyres etc.

Composite reinforcements can be formed by combining different materials and materials forms such as sheets and strips, grids and strips and anchors, depending on the field problem requirement.

The principal requirements of reinforcing materials are strength, the stability (low tendency to creep), and durability, case of handling, a high coefficient of friction, and/or adherence with the soil, together with low cost and ready availability.

Geosynthetics

Geosynthetics are manmade products. They are flexible and planar (sheet-like). They are manufactured from synthetic polymeric materials and sometimes from natural materials. They find use in Geotechnical engineering as a separator, filters, drains, reinforcement, hydraulic barriers, protectors and erosion control system.

I. Geotextiles are porous geosynthetics that resemble a thick strong cloth or blanket with its strands and fiber visible. They are planar permeable, polymeric material that are usually made from polypropylene and sometimes from polyester, polyethylene or from natural fibers such as jute .they can be woven, non-woven or knitted. Woven geotextiles are produced by weaving or interlacing, usually at right angles of two or more set of fibers. Non-woven geotextiles are produced by mechanical bonding or needle punching of randomly oriented fiber. Geotextiles can be 0.25 to 7.5 mm thick and have a mass/unit area of 150 to 2000 gm/mm^2

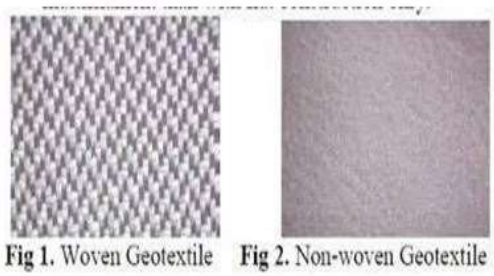


Fig 1. Woven Geotextile Fig 2. Non-woven Geotextile

Figure 3.3

II. Geogrids are mesh like or grid like geosynthetics with square or rectangular openings that are larger than the thickness of the ribs. the rib thickness ranges from 5 to 15mm and the mass /unit area lies between 200 to 1500 gms

Figure 3.4

III. Geonets are similar to geogrids but have thinner member sand angular apertures ,not square or rectangular but resembling parallelograms

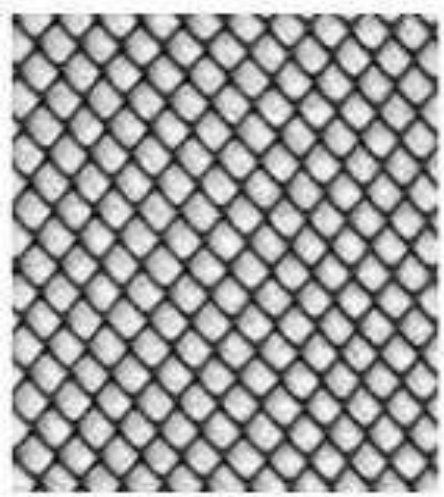


Figure 3.5

IV. SOIL REINFORCEMENT TECHNIQUES

Soil reinforcement techniques can be divided into two major categories

1. Insitu soil reinforcement
2. Constructed soil reinforcement

In the insitu reinforcement technique the reinforcement is placed in an undisturbed soil to form a reinforced soil structure. This includes the technique of soil nailing and soil dowelling. The reinforcement used for insitu structures is usually linear owing to the method of installation.

1. Open excavation using soil nails:

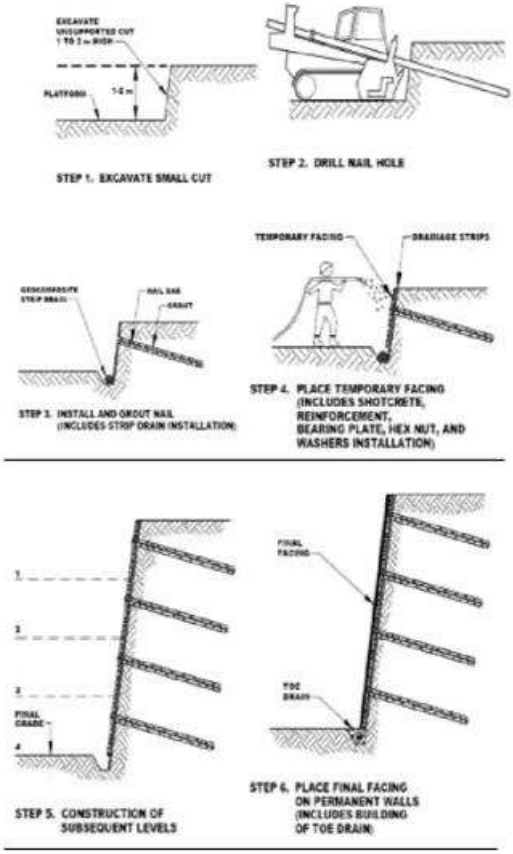


Figure 4.1

Vertical or steeply inclined cuts can be made for open excavation using rigid soil nails as reinforcements. Such cuts are also referred to as nailed soil walls. Unlike reinforced soil walls are constructed from bottom to top, nailed soil walls are constructed from top to bottom. The facing of such walls is usually in the form of a wire-mesh reinforced shot Crete panels, although metal plates and other types of panels have also been used. Soil nails are installed at an inclination of 20 to 25 degrees to the horizontal near the ground surface so as to avoid intercepting underground utilities and the inclination is reduced to 10 to 15 degrees as we go deeper into the cut.

2. Constructed soil reinforcement technique:-

1. Reinforced soil structures with vertical face:-

The facing usually comprises of prefabricated concrete or steel panels joined together by an interlocking arrangement. The soil used as backfill in such cases is granular soil with less than 15% fines to enable development of large friction between the reinforcement and soil. The most often used reinforcement is steel strips since they have large tensile strength as well as low extensibility. Construction takes place from bottom upwards and the reinforcement is placed sequentially as layers of soil are compacted, one after the other.

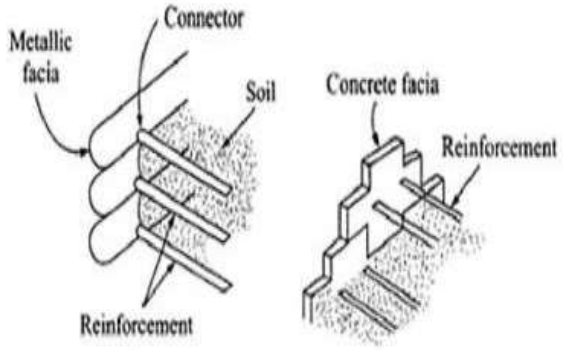


Figure 4.2

The constructed soil reinforcement technique describes the technique where the reinforcement is placed at the same time as an imported and remolded soil. Such technique are often called as bottom up process as they involve the placement of a fill and reinforcement simultaneously, these include structures such as reinforced soil embankments and bridge abutments. The reinforcement used for the constructed category is in the form of strips, mats or grids.

V. APPLICATIONS OF SOIL REINFORCEMENT

1. Slope failure repairs

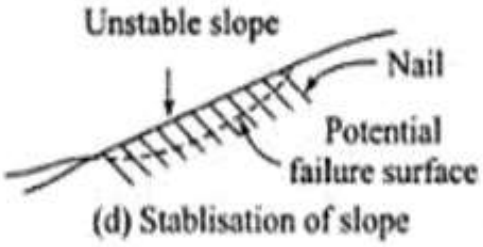


Figure 5.1

Large and small landslides and failures of natural slopes often occur in areas where the value of the environment (for technical or economical or touristic or artistic reasons) call for the repair of the slope to the original (or as close as possible to the original) geometry. Geogrids allow using the same soil of the landslide to reinstate the slopes thus achieving fundamental savings over the solution of importing a soil with better mechanical characteristics. The geogrid reinforced slope can be easily vegetated with the local essences, in order to obtain the best integration with the surrounding

environment.

2. Slope cutting repairs

The installation of pipelines and other underground structures often requires cutting a slope in protected or valuable areas where the Authority imposes to repair the cutting to the original situation. This may produce geotechnical problems due to the fact that the excavated soil results in lower mechanical characteristics than the original soil in the slope. Geogrids allow improving the stability of the soil: the slope can be rebuilt without using expensive consolidation techniques.

3. Steep slopes embankments and bunds

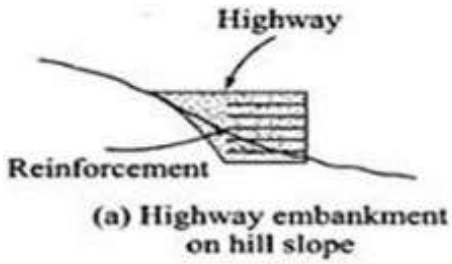


Figure 5.2

There are many situations where the shortage of space or fill material calls for the construction of embankments and bunds with very steep slopes, greatly in excess of the naturally stable angle.

Geogrid reinforced soil structure provide a safe, sound and economical solution which can be used for some of these applications:

- Noise protection bunds along highways, railways and airport taxiways
- Blast protection embankments
- Increase of the available volume in exhausted landfills
- Construction of embankment dams for solid or liquid impoundments.

In all these applications, the inherent flexibility, the ease of construction, and the use of any locally available fill soil are the technical and economic advantages of geogrid reinforced soil structures.

4. Widening of slope crest.

There are different cases where a rather flat slope has to be converted to a sub-vertical wall enlargement of parking areas, smoothing of sharp road bends, land reclamation projects and housing developments are just examples of them. In most of these cases the toe of the slope cannot be moved forward, due to the right-of-way limits or natural boundaries (rivers, roads, etc.). Therefore the crest of the slope shall be widened, making the slope steeper or even vertical. Geogrids allow building steep slopes and walls with almost any locally available fill soil. The face can be built with a vegetated or concrete finishing different solutions can be easily implemented at design and construction stages to meet technical, architectural, environmental requirements. The original slope has usually to be cut at the bottom to yield enough space for placing the reinforcing geogrids. All the operations can be performed with standard earth-moving machinery and easily available tools, even by unskilled labourers. And, very important, the traffic and the activities in front of the slope are not disturbed by the construction operation.

5. Bridge abutments and wing walls

Bridge abutments and wing walls are often the earth retaining structures that support the highest loads. Besides the high vertical and horizontal loads directly applied by the bridge deck, dynamic loads from heavy traffic, and sometimes seismic loads, challenge the design engineer. Soft foundation soils, high water table, environmental impact regulations often provide further problem. Geogrid reinforced soil structures provide strong, yet flexible, retaining structures. Bridge abutments and wing walls can be designed and built to resist all the anticipated loads with the required Factors of Safety, even with low quality fill soil. Soft soil stabilization and drainage problems can be solved with geogrids and geocomposites. The face can be designed to fulfill any requirement regarding visual and environmental impact.

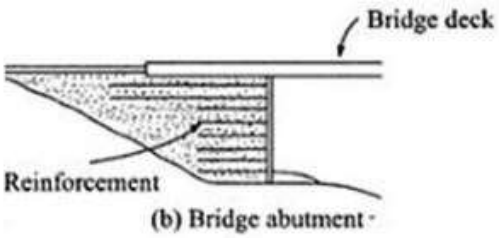


Figure 5.3

6. Soil retaining structures

Soil retaining structures can be divided into:

- FACE WALLS which are usually designed to cover a steep rock slope or a cliff, for environmental and safety reasons. This kind of wall usually has only small or no horizontal pressures from the backfill, but has to resist the internal outward pressure of the fill soil.
- COUNTERSCARP WALLS which must support the constant load of a sloping terrain

on the top. The soil pressures to be resisted are usually much higher than for a face wall.

- RETAINING WALLS which are usually designed to support both static and dynamic loads. The design and construction of face walls, retaining walls and counterscarp walls may have to deal with technical, practical and economical problems due to availability of the fill soil, access to the job site with operating machines, speed of construction, aesthetics, and overall cost and so on. The Technical Authorities and the client often require specific solutions, sometimes with a vegetated face, while sometimes a concrete face or another type of "rigid" face is preferred.

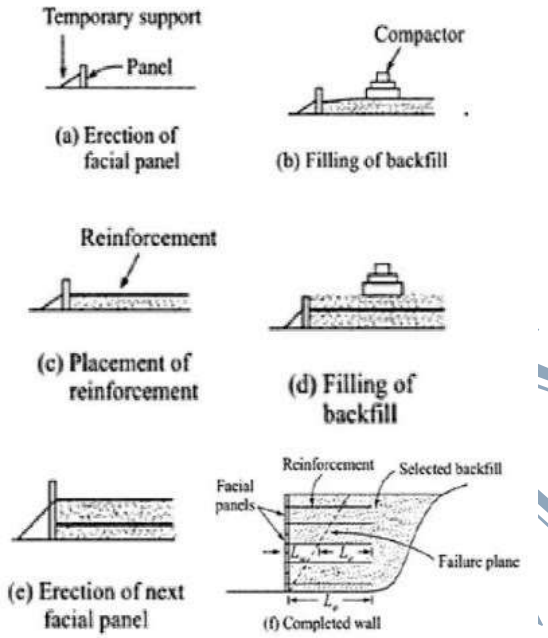


Figure 5.4

Geogrid reinforced walls can be designed and built to fulfill the most varied requirements in terms of load support and face finishing geogrids reinforced soil structures provide a cheap and diversified solution to wall construction problems the experience of engineers can help to find the proper solution, either with a vegetated or concrete face or new solutions can be developed for the face finishing as well as for the construction method and all the ancillary design details.

7. Road and Railway embankments

Road and railway embankments are usually large and high earth structures, which require considerable quantities of fill soil and land.

The cost of the fill soil and its transport from the quarries, as well as the value of the land, may be so high that some alternatives may be considered, such as designing steeper slopes or using lower quality fill soil. Geogrids allow the slope to be built at any inclination with the required Factors of Safety. The specific surcharge loads, as well as the dynamic or seismic loads, can be incorporated into the design to provide safe construction to the Client, the Engineer and the Contractor. Almost any locally available soil can be used for the geogrid reinforced embankment: this facility can produce very large savings in both costs and construction time.

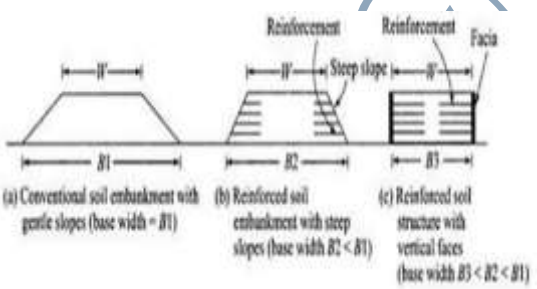


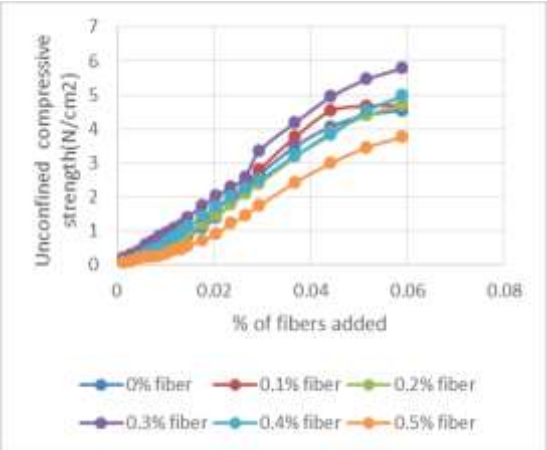
Figure 4.5

VI. TEST RESULTS

The locally available black cotton soil was used for the experiment. The properties of soil used are as follows

1. % of soil passing 75 micron – 54.95%
2. Liquid limit of soil –61.25%
3. Plastic limit of soil –31.15%
4. Shrinkage limit of soil –15.02%
5. Soil classification –Highly cohesive clayey soil
6. Specific gravity – 3.09
7. Maximum dry density –1.35gram/cubic cm
8. Optimum moisture content –27%

Unconfined compressive strength test has been carried out for locally available soil with different percentages of the glass fibers. The strength variation for different percentages of fibers can be given graphically as follows



The results are as follows

Sr. No	% of fibers added	Unconfined compressive strength(N/cm^2)
1	0%	4.676614383
2	0.1%	4.690550575
3	0.2%	4.704426486
4	0.3%	6.090866115
5	0.4%	5.787868872
6	0.5%	4.594023642

VII. CONCLUSION

The use of reinforcement and its effect in increasing soil strength has been discussed. The different material techniques used and its application area have been discussed. In addition to this economical aspect of reinforced soil with unreinforced soil and traditional structure has been discussed and soil reinforced structure is found to be economical.

According to the results, the strength of soil increases on addition of fibers but up to certain limits. Further increase in percentage of fiber results in decrease in the strength. This may be caused because of balling action of fibers, which may result in poor compaction of soil. In this study we observed 0.3% was optimum percentage of fibers causing increase in strength.

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