LECTURER NOTES ON ADVANCED CONSTRUCTION TECHNIQUES & EQUIPMENT

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Ch-01 ADVANCE CONSTRUCTION MATERIAL D-06-01-2020

Fibre :-

→ The fibre is a filament or thread like piece of any material. This term sometimes also refers to a raw material that can be drawn into thread.

→ Fibre is a small piece of reinforcing material possessing certain characteristics properties. It is a long and thin material can be circular or flat.

→ Fibre is desired by a parameter called aspect ratio.

Aspect ratio :-

It is the ratio of length of fibre to its diameter or least lateral diameter or dimension in case of flat fibre. It ranges from 30 - 150.

Types of fibre :-

a) steel fibre
b) carbon fibre
c) Glass fibre
d) plastic fibre
e) Asbestos fibre
f) Jute fibre
g) cellulose fibre

a) Steel fibre :-

→ Steel fibres is one of the most commonly used fibres. Generally round fibres are used. The diameter may vary from 0.25 - 0.75mm.

→ The steel fibre is likely to get rusted and lose some of its strength.

→ Use of steel fibre makes significant improvements in flexural, impact and fatigue strength of

→ The steel fibres have fairly high tensile strength i.e., 280 N/mm² - 440 N/mm² as well as high young's Modulus. These are useful for imparting more flexural strength as compared to polypropylene fibres.

Properties of steel fibres :-

Following are the properties of steel fibre.

a) steel fibres are more strong, tough and hard.

b) They are more ~~strong~~ elastic in nature and avoid corrosion and rust stains.

c) They increase the tensile strength of concrete.

Uses :-

a) This fibre has been extensively used in various types of structures and for overlays of roads, airfield pavements and bridge deck.

b) steel fibres are used in shotcrete.

c) They are used in precast concrete construction.

d) They are used in tunnel lining work.

b) carbon fibre :-

→ Carbon fibres have very high tensile strength 2110 N/mm² - 2815 N/mm² and Young's modulus chopped carbon fibres with random carray may used. These are very costly.

→ It has been reported that cement composite made with carbon fibre as reinforcement will have very high modulus of elasticity and flexural strength. The limited studies have been shown good durability.

Properties of carbon fibres :-

→ carbon fibre are chemically inert and are resistant to Ao corrosion.

→ They have high tensile strength.

→ carbon fibre have low thermal expansion and the fibres content about 85 % carbon has good flexural strength.

→ They are available in low weight.

Uses :-

→ The use of carbon fibres for structures like cladding, panels and shells will have promising future.

→ carbon fibres are most commonly used to reinforcement composite materials.

→ These are used in reinforcement carbon in which they increase tensile strength of concrete.

2) Glass fibre :-

→ Glass may be softened and drawn mechanically into thread or glass wool that is finer than silk. A glass stand composed of 60 filaments: each filament having a diameter of 0.0036mm, possesses the tensile strength approaching 70,000 kg/m².

→ A stand glass fibre may be 1/15 of the diameter of human hair but have a tensile strength of steel. These may be woven into fabric or used in loosely packed from for both sound and thermal insulation in building

→ Thermal conductivity of the material ranges from 0.035 - 0.045 Kcal/m/hr. Ag depending upon the bulk density. Tests have shown that 25mm of glass cool is equivalent in terms of thermal insulation of 42mm of brick or 62cm of concrete.

Properties of glass fibre :-

→ Glass fibres has good thermal insulation.

→ It has excellent corrosion resistance and moisture resistance.

→ It has good tensile strength.

Uses of Glass fibre :-

→ The glass reinforced plastic is used in the manufacturing corrugated sheeting, mainly used for roof lights and also used for interior panelling and decoration.

→ It is used for sound deadening and thermal insulation in walls, floors and ceilings.

→ Natural Jute fibres are used in plumbing works.
→ The glass fibres are used for packing and making fabrics and felts.
→ Used for making acid-proof and fire proof fabrics.
→ Used for material of packing for heat, sound, electric insulation.

Q Write down the uses of fibres as construction material?

Ans⇒ Fibre is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fibre is often described by a convenient parameter called "aspect ratio". The aspect ratio of the fibre is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 - 150.

→ Fibre reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres.

→ Fibre-reinforcement is mainly used in shotcrete, but can also be used in normal concrete. Fibre reinforced normal concrete are mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts either alone or with hand-tied rebar.

→ Concrete reinforced with fibres is less expensive than hand-ties rebar, while still increasing the tensile strength many times. Shape, dimension and length of fibre is important. A thin and short fibre for example short hair-shaped glass fibre, will only be effective the first hours after pouring the concrete but will not increase the concrete tensile strength.

D - 08 - 01 - 2020

4) Plastic fibre :-

→ High polymers are the magic construction materials of the current era. They include engineering materials like plastics, rubber, fibre glass etc.

→ Plastic specially have occupied an indispensable position in our daily life. They have replaced a number of traditionally used materials.

→ The present themselves in every work of life. All modern industries like radio, telephone, automobiles, electric motores etc. are basically dependend upon plastics.

→ Plastic is any substance which shows the property of plasticity. Plasticity is the property, by virtue of which, a material undergoes a permanent deformation, when subjected to heavy and continuous stress or pressure.

→ Therefore, in its broadest meaning, many materials like rubber, glass, shellac can be termed as plastic. But now the term plastic has a precise and limited meaning.

Properties of plastics :-

→ Plastics are very light in weight.

→ Plastics have low electrical conductivity.

→ Plastics have low thermal conductivity.

→ Plastic can be transperent, transulent or opaque.

→ Plastics can be formed and moulded into any shape.

→ Plastics have good sound absorption properties, good tensile strength, good resistance to peeling and good dimensional stability.

Advantages of plastics :-

→ Plastics are available in a wide range of colours and shades.

→ Plastics offered good resistance to attack by organic acids, bases, salts and living organisms.

1) Thermosoftening plastics :-

These are also called thermoplastics and are formed by addition polymerization. These plastics can be softened by heating, reshaped and reused as many times as desired. These are soluble in suitable organic solvents.

The common e.g of this plastic are polythene, polyvinyl, cellulose nitrate etc.

2) Thermo setting plastics :-

This type of plastics are formed by condensation polymerization. These plastics are cannot be remoulded and reused. The thermosetting plastics are insoluble in organic solvents.

E.g → Bakelite, polyester etc.

THERMOSOFTENING PLASTICS	THERMO SETTING PLASTICS
→ These are formed by polymerization by addition.	→ These are formed by polymerization by condensation.
→ They consists of linear structure of long chains with negligible number of cross-links.	→ They have three dimensional networks of chains, joined by prominent cross-links.
→ The secondary bonds between the chains are very weak can be easily broken by heat or pressure.	→ The bond retain strength upon heating. which donot get broken on applying heat or pressure.
→ Heat converts these plastics into a fluid material. Hence, they can be reshaped and reused.	→ They retain their original shape and structure even on heating. So they can not be reshaped & reused.
→ They are usually weak, soft and less brittle.	→ They are strong, hard and more brittle.
→ Because of weak bonds, they are soluble in organic solvents.	→ Because of strong bonds, they are insoluble in organic solvents.

PVC (polyvinyl chloride) :-

→ It is one of the most commonly used polymers produced by the polymerization of vinyl chloride. It is widely employed in the fabrication of plastics.

→ PVC is usually available commercially in the form of a white amorphous powder having a density of about 1.49 cm^{-3}

→ PVC can be manufactured in expended or cellular form. It is available in two forms in flexible and in rigid form. It can be easily moulded and extruded into desired shape. The joints are obtained by solvent welding.

→ This is the cheapest and most widely used plastic.

Properties of PVC :-

→ It is flexible, strong, tear resistance and good ageing properties

→ PVC has tendency to decompose when it is heated or exposed to sunlight with time.

→ It is resistance to impact invariably deteriorates with time

→ It becomes soft beyond 80°C. when heated to more than 160°C, it disintegrates and give off hydrogen chloride.

→ Its electrical properties are not as good as those of rubber, but it offers more resistance to oxygen, ozone and sunlight.

→ It has light weight and resistance to wear.

Uses of PVC :-

→ It is used for flooring, wall facing, various extrusions like hand rails, skirting boards, pipes, fillers etc.

→ It is used for cable jackets, lead-wire insulation, fabric coating etc.

→ It is used for corrugated roofing sheets, rain water goods.

→ It is used to manufacture water pipes and it is accessories rain coats and shower curtain.

→ It is used in plastic pressure pipe system for pipelines of water and sewer.

→ It is used in magnetic strip cards, vinyl siding, window profiles, plumbing and conduit fixtures, gramphone records etc.

RPVC (Rigid polyvinyl chloride) :-

The Rigid polyvinyl chloride (RPVC) is also known as Ultra-Plasticized polyvinyl chloride (UPVC). This material is available in a range of colours and finished including a photo-effect wood finish and is used as a substitude for painted wood.

Properties of RPVC :-

→ RPVC is more durable and hard.
→ It has high tensile strength.
→ It is more rigid and has high resistance to chemical action.
→ It is corrosion resistance.

GRP (Glass Reinforced Plastic) :-

This is a composite material made of a plastic reinforced by fine glass fibres. This plastic is formed by combining the glass fibres and plastic resins. The glass fibres are very strong in tension but weak in compression, where as the plastic resins are strong in compression and weak in tension.

CPVC (chlorcinated polyvinyl chloride) :-

→ CPVC stands for chlorcinated polyvinyl chloride. It is a thermoplastic pipe fitting material made of compounds.
→ CPVC products are specifically used for potable water distribution and corrosive fluid handling industry etc. It is very cost-effective system.

HDP (High Density polyethylene) :-

→ It is a thermoplastic polymer produced from monomer ethylene.

→ It is some times called alkathene or polythene.

Properties of HDP :-

Density = 940 kg/m³

melting point = 130.8°c.

uses :-

It is used in house and plastic mailing envelope.

Fibre reinforced polymer :-

→ It is also called fibre reinforced plastic.

→ It is a composite material made up of a polymer matrix reinforced with fibre.

→ The fibres are usually glass, carbon and basalt.

→ FRPs are commonly used in the aerospace, automatic marine and construction industries.

→ It is also used for strengthening the beam, column and slab of a building and bridge.

Artificial timber :-

Properties of artificial timber :-

1) weather Resistance :-

It should possess adequate resistance against weathering effects such as alternate drying and wetting, alternate heating and cooling because of temperature variations, wide effects etc.

2) Durability :-

It should be capable of resisting the various action due to fungal insects, chemical, physical and mechanical agencies.

3) Fire Resistance :-

The artificial timber should offer sufficient resistance against fire so that it does not easily ignite. It helps in fire protection in buildings.

4) Workability :-

The artificial timber should be easily workable and should not clog the teeth of saw. It should also be capable of being easily planned or made smooth.

5) Elasticity :-

This timber should be capable of regaining its original shape when load causing deformation is removed. This property is important when it is should be used for bows, carriage shafts, sport goods, wooden beams and wooden floors.

6) Toughness and abrasion :-

It should be capable of offering resistance to shocks due to vibration and should not deteriorate due to mechanical wear.

7) soundness :-

It is should have sufficient weight an artificial timber with sufficient weight is considered to be sound and strong.

8) Hardness :-

It should have sufficient hardness, i.e., resistance penetration. when the artificial timber is hard. It resists the abrasive action as for it is used for flooring, mallets, tool handles, rollers and bearing shaft.

9) Resistance to shear :-

The artificial timber having closely interlocked is very strong in shear across and even along the grains.

10) Strength :-

The artificial timber should be strong enough to load wheather being applied slowly or suddenly. It should possess enough strength in direct compression and transverse direction.

Uses of artificial timber :-

→ The artificial timber is corrosion resistant, and hence it can be used where the corrosion is likely to occur in the structures.

→ It is convinient in maintainance and superficial similarity to wood.

→ It is used to make various structural members.

→ It is used in maintainance work.

→ It is also used as a ceiling proofing material in building construction.

→ It is used to make doors and window frames.

→ It is used for making the planks, square and round shape for furniture.

→ Density can be varied in between 0.8 – 1.2 KN/m³ depending on the requirement.

Types of artificial timber :-

a) veneers
b) Ply woods
c) Particle board
d) Fibre boards
e) Batten boards.

a) Veneers :-

→ There are thin sheet of wood, which are obtained by slicing timber or by rotary cutting or by peeling of logs of wood. Now a days, rotary cutting is more common as this produces veneer of large size and reduces amount of joining.

→ However, most attractive decorate figures occur on radial face and are obtained by slicing woods like Teak Mahagony, walnut and oak. veneers are normally cut from wood at higher moisture contents and are dried before application of adhesive and assembly. Then veneers are pressed together using hot Processing method.

→ Veneers are used in the manufacture of plywood, each veneer being at right angles to the adjacent veneer. so that cross sectional movement can be restrained, with the aid of modern high strength adhesives. veneers are also used in manufacture of batten board, particle board.

b) Plywood :-

→ Plywoods are formed together by gluing thin sheets of odd numbers of veneers. The sheets are placed in such a way that, grains of one layer are at right angles to the others.

→ As a result, on application of load on the sheet, movement in both the direction is reduced. The outer piles are decorative in nature and are called as face piles and the inner ones are called as core or cross band.

c) Particle Board :-

→ In particle boards, particles or chips are randomly mixed with strong adhesive and are compressed together under high pressure to form a board.

→ In particle board, the movement is randomly oriented in all directions and restraint is dependent on strength and concentration of adhesive.

→ particle ~~is~~ board is much weaker than plywood because, the adhesive joints between the individual chips involve end grains surface. Properties of plywood largely ~~involve~~ depend upon wood species used where as, in particle ~~wo~~ board, it largely depends upon the adhesives and particle shape.

→ If particle of boards are all cubes, the formation of the board will result in large portion of joints involving end grains; thus producing weak boards.

→ In contact, long thin chips will overlap, rather than butt and will result strong boards. With long and flat chips coarse. To avoid this sometimes boards are manufactured in three layers.

d) Fibre Board :-

→ Fibre boards also called as pressed woods are rigid boards manufactured using wood waste like saw dust, small piece of wood, etc.

→ Wood is chipped into small pieces of about 20mm size, and boiled in water. These wet particles are then passed to an autoclave, where it is subjected to steam pressure of 2300 KN/m² for about 1/2 minute and there after to a pressure of 7000 KN/m² for new seconds.

e) Batten Boards :-

→ In all these boards, thin veneers are used on faces and are glued to core. veneers may be ~~decorated~~ decorative or non-decorative. Grains of veneers are at right angle to those of core.

→ In batten boards, core consists of about 8 cm wide woodens strips called as battens. If the width of strips ~~Caused as battens~~ is less than 2.5 cm. It is called as block board. In laminated boards, width of core strip is less than 7 mm.

→ Batten boards and block boards are used for making partitions, packing cases, furniture panelling, ceiling, interior decoration; bus bodies, etc. However are liable to crack or split, Laminated boards are stronger than block boards and are not liable to crack or split.

D - 13-01-2020

Strength of artificial timber :-

→ Artificial timber should be strong enough to withstand the loads whether being applied slowly or suddenly. It should possesses enough strength in direction of direct compression and transverse direction.

ACOUSTIC MATERIAL :-

Acoustic is the science of sound including its production, transmission and effects. Acoustic is a broad field which embraces music, radio, sound reproduction and other fields.

Properties of acoustic material :-

→ Acoustic material has low reflection and high absorption of sound.
→ It controls the sound and noise levels from machineary and other sources.
→ It suppresses revibration echoes and reflection.
→ It has capacity to capture and absorb the sound energ
→ It reduces the sound energy waves.

Types of acoustic material :-

The acoustic material can be broadly classified into following 3 groups.

a) Soft material :-

These have sufficient porousity and are good sound absorbers. Rock wools, glass silk fall in this category.

b) Semi-hard material :-

These are steep enough to stand rough handling can also serve as building panels. Mineral wool board, cane fibre are included under this category.

c) Hard material :-

These are hard material which have been made porous during manufacture. They also serve as protective surfaces. The porous tiles of masonry are commonly employed for this purpose.

Acoustic tiles :-

→ Advantages of such tiles is that the absorption of sound is uniform from tile to tile and can be easily fixed to any other surface and they are costly but most suitable for smaller area where acoustical treatment to be given.

→ The materials are available in market under different trade names. It is made in factory.

D - 20-01-2020

1) Acoustic plaster :-

→ This is mainly composed of asbestos and cellulose fibre mixed with certain binders and preserving chemicals.

→ This dry fibrous material, on addition of water becomes plastic and can be applied to wall and ceiling surfaces to a thickness of upto 2cm.

→ The material is applied in layers of 6 mm thickness, in the same manner as plaster. Being plastic it is easily shaped and finished.

2) Fibrous plaster :-

→ This type of material is also known as acoustic plaster. It is made by mixing of cement and granular insulating material.

→ The preparation of cement should be properly be maintained so as to become plaster more effective for acoustics.

→ The acoustic plaster boards are also used and can be fixed on the wall. The acoustic plaster should have an absorbent coefficient of 0.30 at

3) Straw board :-

→ This material can also be used as absorption of 0.30 at 500 cycles per second. These boards are available in 13 mm size.

→ It is comparatively cheap, therefore economical.

5) Vermiculite acoustical plaster :-

→ This is an inert, feather weight, granular substance manufactured from vermiculite. Gypsum and lime or portland cement is the other constituent.

→ water is added to the material to make it plastic for application.

→ The material is adapted to every type of architectural treatment and is used mainly for interior finishes.

6) Acoustical boards or tiles :-

→ They are usually made of either compressed cane or wood fibre or mineral wool.

→ These boards and tiles have uniform physical and sound absorption characteristics.

→ They are prefinished at the factory and can be painted or coloured to give desirable decorative appearance and light reflection characteristics.

→ These tiles are very costly as compared to other acoustical materials.

7) Limpet asbestos :-

→ This is asbestos fibre which is applied to a surface by means of a special spray gun.

→ The asbestos fibres are fed to the hopper of a machine from which they are carried to a boiler. The dry fibre is then conveyed in an air system and then passed through a spray gun where it gets damp before the final application.

CLADDING

Cladding is a type of skin or extra layer on the outside of a Building. It can be attached to a buildings framework or an intermediate layer of battens or spacers. cladding does not have to be waterproof, but it often controls how elements hit or fall on a surface,

It was usually a hard substance like cedar wood or stone, or a material resistant to corrosion like copper, brass band bronze. such metals will react with the elements, but they still protect what's beneath them.

Types of cladding used in construction :-

1) Stone cladding :-

Stone cladding helps create a natural stone look. while bringing in a touch of style and elegance to your walls. perfect for both interior and exteriors, Stone cladding uses thin layers of natural or faux stone to lend your home a brilliant earthy and rustic look. Stone cladding panels are extremely easy to install. virtually maintainance free and gracefully ages with time.

2) Wood cladding :-

It helps create a stunning facade and is a great way to protect your home from the elements. suitable for both interiors and exteriors, it helps create a highly distinctive character as nothing beats the look or real wood while blending well with any decor. Exterior cladding is individually

proced and protects the structural integrity of your house while also enhancing the exterior appearance by several notches. Extremely durable and highly energy efficient owing to its insulation properties, wood cladding helps to make your home a tranquil haven.

3) uPVC cladding :-

It helps add a different dimensions to your home and requires absolutely zero maintainance. This basically translates to no time consuming painting or cumbersome repairs. Ideal for both internal and external walls, uPVC cladding not only suits every kind of home but also not prone to severe damage by weather elements. Besides being economical, it's quite easy to add insulation as well, can be fully customized and comes in a range of colours.

4) Tile cladding :-

A ~~fir~~ fairly new entrant to the cladding world, tile cladding is an extremely versatile cladding option and comes in the form of a panel or tile suited for both exteriors and interiors of your house. Long lasting and easy to maintain, these can transform your house to a contemporary abode. You can play with either sleek modern designs or opt for a natural textured look. Incredibly durable and long lasting, you can even combine tiles that are of different shapes and sizes to give your house a truly unique and suave look. Moreover, these tiles also act as great insulators thus providing to be energy efficient as well.

5) Glass cladding :-

It help transform your building exteriors and offer a gamut of customization and design options. Glass always impress and this cladding is available in wide range of tempered, laminated, curved and enameled options while being cost effective and economical. Furthermore, glass creates a remarkably modern and contemporary look while offering enormous freedom in shape, design, composition and size, making it optimally suited for modern cladding applications.

6) Aluminium composite panel (ACP) :-

This cladding system is made from lightweight aluminium and is frequently used for ~~extremely~~ external cladding as it's very rigid and strong despite its light weight. Moreover, being aluminium being weather and UV resistant facilities for a bevy of customization options including colours, prints, patterns and shading. Available in varying thickness levels; it enables quick installation while also being versatile enough to be used for fascias, canopies, partitions and even false ceiling.

7) Ceramic cladding :-

This solutions have been around for ages and been a popular choice for architects around the world for decorative purposes. Being lightweight, it requires very little maintainance while possessing a superior resistance to chemical and atmospheric attacks from population, acid rain and smog. It's innovative design and durability also facilitate greater versatility in terms of tile size and arrangement.

8) Porcelain cladding :-

It is widely used as a mean for external cladding because of its exceptional properties. Scratch and abrasion resistant with a surface together than granite or steel, its durable, tough and extremely strong and does not accumulate surface dirt. Additionally its, non-porous and impervious to chemical while also being freeze and thermal shock resistant which makes it the ideal material for creating cost-effective, low-maintainance, hard-wearing surfaces.

D - 25-01-2020

Micro silica :-

→ Micro silica is a light grey cementitious material composed of at least 85% ultra fine, amorphous non-crystaline (glassy) spherical silicon dioxide (SiO_2).

→ It is also called as silica fume. It is produced as a by-product during the manufacturing of silicon metal or ferrosilicon alloys by reduction of high purity quartz in a sub-merged-arc electric furnance heated to 2000°c with coal, coke and wood chips as fuel.

→ The micro silica, which condenses from the gases escaping from the furnance, has very fine spherical particles having diameter of 0.1 micrometer.

→ Ferro silicon alloys are produced with nominal silicon ~~cess~~ contents 60% - 98%. As the silicon content increases in the alloys, the SiO_2 content increases in the micro silica.

Properties of micro-silica :-

→ Specific gravity of micro silica is 2.20.
→ Its bulk density varies from 200 kg/m³ - 250 kg/m³
→ It has minimum surface area of 15,000 to m²/kg
→ The content of SiO_2 is at least 85%..
→ It gives long term corrosion protections.

Uses of micro silica :-

→ This material has very recently found its application in our country in the nuclear power plants and bridge construction.
→ Micro silica have been used extensively in off-shore concrete platforms, high rise multistoried buildings and various other structures demanding high performance in very aggressive environmental conditions.

D - 27 - 01 - 2020

Artificial sand :-

→ Natural sands are obtained by the weathering action, abrasion of particles of rocks along with flow of stream. Depending on parent rock, action on particles size and grading of natural river sand varies from place to place.
→ Dams are constructed on upstream of river, so nowadays sands are not available on downstream of dams. At locations, grading of sand available may not contain certain fractions which are required for ideal grading.

→ strength, durability of concrete mix depends on size, shape, grading of fine aggregate. Since good quality sand may not be available, crushed sand is produced. It also helps in protecting ecological balance, by restricting use of natural resources to minimum.

→ Artificial sand is a specific purpose produced materials which will satisfy the strength, durability, size, shape, grading requirements of fine aggregate in concrete mix. The stone metal or crushed stone waste, below 25mm from good parent rock is fed to disintegrator.

Properties of artificial sand :-

→ The density of artificial sand lies in between 18 kN/m³ – 25 kN/m³.

→ It does not contain any organic impurities.

→ Water absorption in case of artificial sand is almost negligible.

→ Specific gravity of artificial sand lies in between 2.65 – 2.8.

Advantages of Artificial sand :-

→ Artificial sand is well graded.

→ This sand is having superior surface texture.

→ It can be compacted properly to reduce voids.

→ Less quantity of cement materials required.

→ It can be produced in required quantity and desired quality.

→ If economy at large is considered, artificial sand, many times proves to be economical.

Adhesives :-

→ Adhesion is attraction between unlike surfaces - cohesion is attraction between like surfaces. usually due to primary or secondary forces of attraction, adhesives are used to joint two or more parts into a unit.

→ There are advantages of adhesive bonding over methods of assembly like bolting, riveting, welding etc.

→ Adhesives join the surfaces in three ~~layer~~ ways :. Specific adhesion of surfaces are joined together by intermolecular forces of attraction; mechanic adhesion, of the adhesive fill the voids of porous or rough surfaces ~~and~~ and hold the surfaces by interlocking action, and fusion of surfaces which are partially dissolved in the adhesive or its solvent.

Advantages :-

→ Corrosion may be prevented between different metals joined by adhesives.

→ The joints become impermeable for water and gas.

→ Adequate strength is produced by using adhesive.

→ The adhesive application process is economical, easy and speedy.

→ Leakage problem of water can be stopped by the application of adhesives.

Disadvantages :-

→ Adhesive requires time to attain desired strength
→ Specific adhesive is required to be used for specific substances.
→ Adhesives are unstable at high temperature.

1) Animal Protein Glues :-

These glues are obtained from hide trimmings, bones and trashing by boiling these by hot water. Animal glues provide strong, tough, easily made joints; but they are affected by damp and moist conditions. It is supplied in the form of flakes, pearls, sheets, cakes, granules, cubes or jelly. Animal glues having three grades depending upon the water absorption. i.e.; 18, 15, 10 times the dry weight of glue.

Use of animal protein glue :-

This is used in the manufacture of plywood, laminated timber.

2) Blood Albumin Glues :-

It is made by drying the raw blood and affected by damp and moist conditions. This glue has good water resistance properties and also durable.

Use of blood and albumin glues :-

They have good adhesive properties for paper, textile and metals, hence largely used in food packaging leather dressing and for wood working.

Starch adhesives :-

It is made from vegetables starch having good dry strength but not resistant to moisture. Alkali or acid modifiers are used to make starch paste thick and tacky. This glue has poor resistant but bond quickly to paper and textile. They are cheaper than animal glues.

use of starch adhesives :-

→ This glue is spread and dried easily.
→ They are used in automatic package machines.
→ These glues are also used in manufacture of low strength and low water resistance plywood.

Gum arobic :-

→ These forms the most useful natural resin adhesive.
→ It contains mixed mineral salt of arobic acid, which is obtained from acacie trees.
→ It is used for joining paper and wood and in high speed packing and labelling machine.

Bonding agent :-

→ Bonding agents are natural compound or synthetic material used to enhance the joining of individu member of a structure without using mechanical fasteners.
→ These products are often use in repaired applicatio

such as:- bonding of fresh concrete, spread concrete, fresh mortar and old concrete.

→ when bonding agent applied on the old concrete that time surface of old concrete work should be clean for proper bonding.

D:-28-01-2020

Pre-fabrication :-

Definition :-

The Pre-fabrication is practice of assembly components of a structure in a factory or other manufacturing side and transporting complete assembly to the construction site where the structure is to be located.

use of Pre-fabrication :-

→ The most widely used form of Pre-fabrication in building and civil Engineering is the use of Pre-fabricated concrete and Pre-fabricated ~~concrete~~ steel sections in structures.

→ Pre-fabricated steel section reduces on side cutting and welding cost as well as the associate hazards

→ Pouring concrete sections in a factory brings the advantages of being able to reuse and the concrete can be mixed on the spot without having to be transported and Pumped weight on a confusted constructions site.

Disadvantages :-

→ careful handling of Pre-fabricated components such as concrete pannel and steel or glass pannel is required.

→ Attention has to be made to this strength and corrosion resistant of the joining of fabricated section to avoid failure of the joining.

→ similarly leaks can be formed at the joint in fabricated components.

→ Transportation cost may be higher for a given volume.

Pre-fabricated section are required more volume than raw material used in in-site construction

Principle :-

The main reason to choose pre-cast construction method over conventional method :-

→ Economy in large scale project with high degree of repetition in work experience.
→ The special requirement in finishing.
→ consistency in ~~for~~ structural quality control.
→ fast speed of construction.
→ constrainter in availability of site resources. (Labour & material).
→ Large group of building from the same type of Pre-fabricated elements.

Pre-fabrication elements :-

→ flooring and roofing system.
→ Pre-cast column.
→ Pre-cast slab
→ Pre-cast beam

Classification :-

1) Small pre-fabrication
2) Medium pre-fabrication
3) Large pre-fabrication
4) Cast in site pre-fabrication
5) factory pre-fabrication.
6) closed system pre-fabrication.
7) open system pre-fabrication
8) Partial pre-fabrication
9) Total pre-fabrication

D - 03-02-2020

1) small Pre-fabrication :-

→ The first 3 types are mainly classified according to their degree of pre-cast.

→ ~~Elem~~ Elements using in their construction for e.g → brick is a small unit precast and used in building, this is called a small pre-fabrication (The degree of precast element is very low).

2) Medium Pre-fabrication :-

Suppose the roofing system and horizontal members are provided with pre-stressed element these construction are known as medium pre-fabricated construction. (Here the degree of pre-cast element are moderate)

3) Large Pre-fabrication :-

In large pre-fabrication most of the member like wall panel roofing or flooring system beam and column are pre-fabricated. (here the degree of pre-cast element are high).

4) Cast in site pre-fabrication / site (factory) pre-fabrication

→ one of the main factor which affect the factory pre-fabrication is transport.

→ The width of pre-fabricated walls are difficult to transport and vehicles or mode of transportation are the factors which pre-fabrication is to be done on side or factory are the factors which affects cast in site pre fabrication.

5) Open system pre-fabrication :-

→ In the total prefabrication system is are ~~case~~ carted as single unit and erected at site.

→ The wall fitting and other fixing are done on side. These type of construction is known as

open system fabrication.

6) Closed system prefabrication :-

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

7) Partial Pre-fabrication :-

→ In the method of construction building element (mostly horizontal) are required for Pre-fabrication.

→ since the casting of horizontal elements (roof, or floor) often take their time due to erection of formwork and to get complete strength. So that building is delayed and hence this method is restored.

→ In most of the building site this method is popular.

8) Total Pre-fabrication :-

→ Very high speed can be achieved by the using this method of construction.

→ This method can be employed for frame type of construction or for pannel type of construction.

→ The total pree-fabrication can be done on site or off site.

→ The choice of this 2 methods depend on the situation when the factory produced element are transported and erected at site is ca off site pree-fabrication.

→ If this method is to be adopted then we have a very good transport of product to site.

→ If the elements are cast nearly building site and erected the transportation of the elements can be eliminated but we have to consider the space availibility for establish such facilities though it is temporary.

→ The choice of method of construction also depends on the following :-

a) Type of equipment available for erection & transport
b) Type of structural scheme (Linear element or panel)
c) Type of connection between elements.

D - 04 - 02 - 2020

Q Write down the materials used in pre-fabrication system.

Ans- 1) Concrete
2) Steel
3) Treated wood
4) Aluminium
5) Cellular concrete
6) Light weight concrete Element
7) Ceramic products.

Prefabricated material buildings are galvanized steel and Galvalume as the chief materials for building. Galvalume is a form of steel coated with aluminium zinc. This is to protect the building against corruption rust and fire.

It also provides a study and protective covering to the prefabricated building. Almost all the components of a metal building such as beams, frames columns wall and roofs are made of steel. Most fabricated military buildings are steel or aluminium frames. Synthetic materials are used for the walls and roofs.

To provide enhanced security a combination of both ~~material~~ metal and cloth materials are used plastic flooring materials can be quickly assembled and are very durable. Prefabricated building materials used for small prefabricated buildings are steel, wood, fibre glass plastic or aluminium materials.

These materials are cheaper than regular brick and concrete buildings. Materials like steel, fibre glass, wood and aluminium are used as prefabricated building materials for sports buildings. These materials provide flexibility and are preferred for making structures and accessories like stands and seats for stadium and gyms.

For making low cost houses prefabricated materials like straw, ferro cement consists of a cement matrix reinforced with a mesh of closely spaced iron rods or wires. In this type of construction the techniques used are simple and quick. Using prefabricated material one can make durable, water and fire resistant and cheap prefabricated buildings. Most of the pre-fabricated building materials are eco-friendly and affordable.

Advantages of prefabrication :-

→ Moving partial assemblies from a factory often costs less than moving pre-production resources to each site.

→ Deploying resources on-site can add costs; Prefabricating assemblies can save costs by reducing on-site work.

→ Factory tools – jigs, cranes, conveyors, etc., – can make production faster and more precise.

→ factory tools – shake tables, hydraulic testers, etc. can offer added quality assurance.

→ Consistent indoor environments of factories eliminate most impacts of weather on production.

→ cranes and reusable factory supports can allow shapes and sequences without expensive on-site false work.

→ Higher-precision factory tools can aid more controlled movement of building heat and air, for lower energy consumption and healthier buildings.

→ Factory production can facilitate more optimal materials usage, recycling, noise capture, dust capture etc.

→ Machine-mediated parts movement, and freedom from wind and rain can improve construction safety.

Ch → 03

D - 12 - 02 - 2020

Earthquake Resistance construction :-

Building configuration :-

→ Building configuration may be defined as the overall size and shape of a building together with nature and location of those elements of the building that are significant to its seismic performance.

→ IS : 1893 - 2016 has recommended building configuration system in section for the better performance of building during earthquake.

→ To perform well in earthquake a building should possesses four main attributes.

a) simple and regular configuration.

b) Adequate lateral strength

c) stiffness

d) Ductility

→ Building having simple and regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation, suffer much less damage than building with irregular configuration.

→ A building shall be consider as irregular for the purposes of this standard if atleast one of the following condition is applicable.

Definition of irregular building :-

Plan irregularities :-

→ Torsional irregularities
→ Reentrant corners
→ Floor slabs having excessive cut-outs or opening.
→ Out-of plane offset in vertical elements.
→ Non-Parallel lateral force system.

Vertical irregularities :-

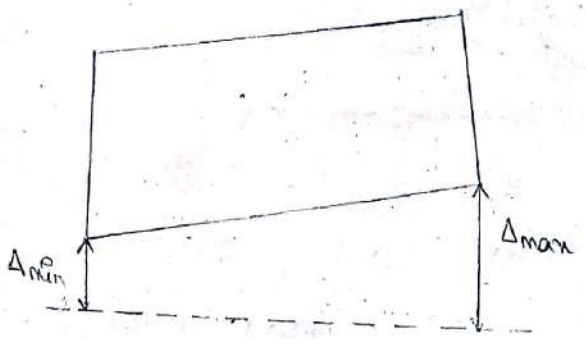
→ Stiffness irregularity (soft storey).
→ Mass irregularity.
→ Vertical geometry irregularity.
→ In plane discontinuity in vertical element resisting lateral force.
→ Strength irregularity
→ Floating or stub column.
→ Irregular modes of oscillation in two principal plan direction.

Torsional Irregularity :-

A building is said to be torsionally irregular, when
→ the maximum horizontal displacement of any floor in the direction of the lateral force at one end of the floor is more than 1.5 times its minimum horizontal displacement at the far end of the same floor in that direction; and
→ the natural period corresponding to the fundamental torsional mode of oscillation is more than those of the first two translational modes of oscillation along each principal plan direction.

In torsionally irregular buildings, when the ratio of maximum horizontal displacement at one end and the minimum horizontal displacement at the other end is.

$\Delta_{max} > 1.5\,\Delta_{min}$



(Plan)

(TORSIONAL IRREGULARITY)

Re-entrant corners :-

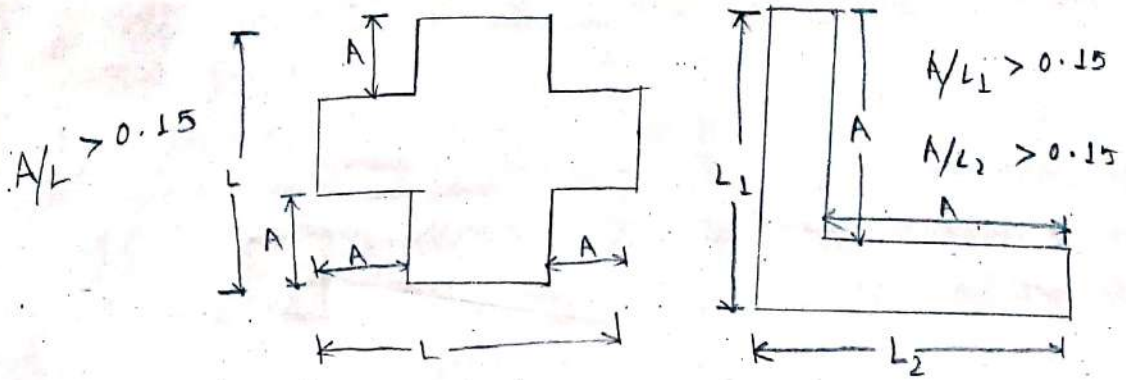
A building is said to have a re-entrant corner in any plan direction, when its structural configuration in plan has a projection of size greater than 15 percent of its overall plan dimension in that direction.

In building with re-entrant corners, three-dimensional dynamic analysis method shall be adopted.

Floor slabs having Excessive cut-outs or openings :-

Openings in slabs result in flexible diaphragm behaviour, and hence the lateral shear force is not shared by the frames and/or vertical members in proportion to their lateral translational stiffness. The problem is particularly accentuated when the opening is close to the edge of the slab. A building is said to have discontinuity in their in-plane stiffness, when floor slabs have cut-outs or openings of area more than 50 % of the full area of the floor slab.

In buildings with discontinuity in their in-plane stiffness, if the area of the geometric cut-out



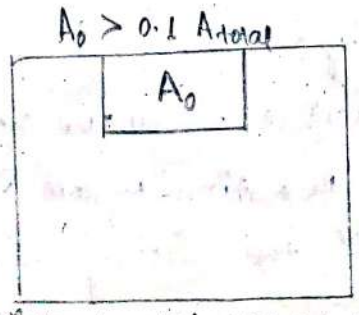
(Re-entrant corners)

Out-of-plane offsets in vertical elements :-

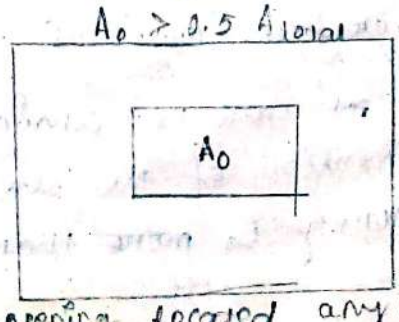
Out-of-plane offsets in vertical elements resisting lateral loads cause discontinuities and detours in the load path, which is known to be detrimental to the earthquake safety of the building. A building is said to have out-of-plane offset in vertical elements, when structural walls or frames are moved out of plane in any storey along the height of the building.

Non-Parallel Lateral Force System :-

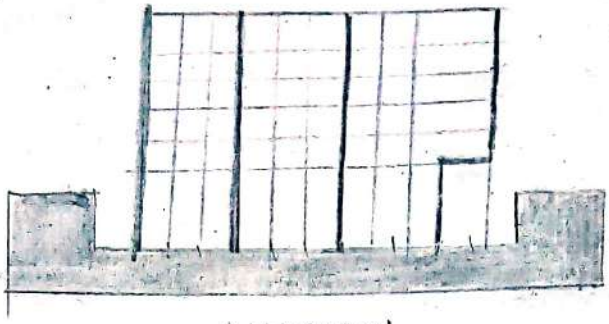
Buildings undergo complex earthquake behaviour and hence damage, when they do not have lateral force resisting systems oriented along two plan directions that are orthogonal to each other. A building is said to have non-parallel system when the ~~vertically oriented structural system when the~~ vertically oriented structural systems resisting lateral forces are not oriented along the two principal orthogonal axes in plan.



Opening Located Along any edge of the slab

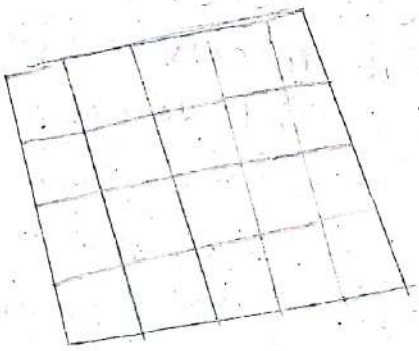


Opening located anywhere in the slab



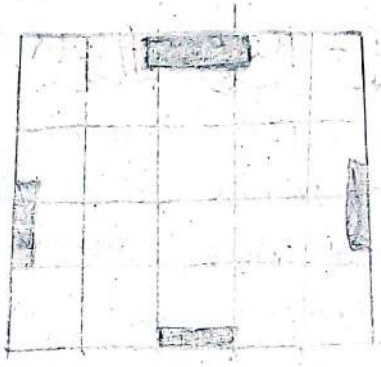
ELEVATION

(3D OUT-OF PLANE offsets in vertical elements)



Plan

(1)



Plan

(2)

3E NON-parallel lateral force system.

Types of vertical Irregularities :-

1) Stiffness Irregularity (Soft storey)

A soft storey is a storey whose lateral stiffness is less than that the storey above.

2) Mass Irregularity :-

Mass irregularity shall be considered to exist, when the seismic weight of any floor is more than 150 % of that of the floors below.

3) Vertical Geometric Irregularity :-

It shall be considered to exist, when the horizontal dimension of the lateral force resisting system in any storey is more than 125 % of the storey below.

4) In-plane Discontinuity in vertical Elements resisting Lateral force :-

In-plane discontinuity in vertical elements which are resisting lateral force shall be considered to exist, when in-plane offset of the lateral force resisting elements is greater than 20% of the plan length of these elements.

5) strength irregularity (weak storey) :-

A weak storey is a storey whose lateral strength is less than that of the storey above.

6) Floating or stub columns :-

Such columns are likely to cause concentrated damage in the structure.

7) Irregular modes of oscillation in Two principal plan directions :-

stiffness of beams, columns, braces and structural walls determine the lateral stiffness of a building in each principal plan direction.

Q Describe different building characteristics from seismic performance point of view.

Ans → The seismic weight of the whole building is the sum of the seismic weights of all the floors.

→ Any weight supported in between storeys shall be distributed to the floors above and below in inverse proportion to its distance from the floors.

→ For calculating the design seismic forces of the structure the imposed load on roof need not be considered;

→ The seismic weight of each floor is its full dead load plus appropriate amount of imposed load,

→ while computing the seismic weight of each floor the weight of columns and walls in any storey shall be

equally distributed to the floores above and below the storey.

→ The total design seismic base shear along any principal direction shall be determined by the following expression.

$$V_B = a_h \times W$$

where, a_h = design horizontal acceleration spectrum value.

W = seismic weight of the building.

Q What is lateral load resisting system?

Ans The first step in architectural planning of a building is to select the lateral load resisting system. The load resisting system must be of closed loops, so that it is able to transfer all the forces acting either vertically or horizontal to the ground.

Q Enumerate safety considerations during additional construction and alteration of existing building.

Ans If sufficient precautions w.r.t. safety of work are not taken, there are chances of serious accidents involving heavy loss of men and materials. some of the safety rules to be observed during the erection process of structures are as follow:-

→ All guys and anchorages should be closely viewed regularly so as to ascertain their being capacity of load.

→ suitable packing pieces must be provided at the required points so as to avoid the slipping of load.

→ The chains should not be dropped from a height, but should be lowered gradually.

→ The equipment and devices employed in the erection procedure should never be over-loaded.

→ The legs of brother chains should not be opened out to such as angle so as to endanger the stability of the work.

→ The levels of panel points on the falsework should be maintained as per the desired camber for truss to avoid strain or distraction during assembly.

→ The lifting devices and mechanisms should be maintained in perfect running order so to avoid their sudden failure without notice.

→ The lifting should be carried out smoothly without sudden shocks.

D-03-03-2020

Earthquake resistance in masonary building :-

→ Masonry walls are slender because of their small thickness compare to their height and length.

→ A simple way of making these wall behaves as well in earthquake shaking is by making them act together as a box along with the roof and the top and with the foundation at the bottom.

→ This can be achieved by

a) Ensuring good interlocking of masonry courses at the junction.

b) Employing horizontal band at various levels, particularly at the lintel level. The size of door and window opening need to be kept small.

1) Lintel Band :-

During earthquake shaking, the lintel band undergoes bending and pulling action. To resist these actions, the construction of lintel band requires special attention. Bands can be made of wood or of reinforced concrete (RC). The straight lengths of the band must be properly connected at the wall corners. This will allow the band to support walls loaded in their weak direction by walls loaded in their strong direction. Small lengths of wood spacers or steel links are used to make the straight lengths of wood runners or steel bars act together. In wooden bands, proper nailing of straight lengths with spacers is important. Likewise, in RC bands, adequate anchoring of steel links with steel bars is necessary. Lintel band is provided at the lintel level on all internal and external longitudinal as well as cross walls except partition walls.

2) Sill Band :-

Sill band is provided at sill level for all internal and external longitudinal walls as well as cross walls. For full integrity of walls at corners and junctions of walls and effective horizontal bending resistance of bands, continuity of reinforcement is essential.

The band should be made of reinforced concrete of grade not leaner than M15 or reinforced brick work in cement mortar not leaner than 1:3.

3) Plinth Bands :-

Plinth band is a band provided at plinth level of walls on top of the foundation wall. This is to be provided where strip footings of masonry are used and the soil is either soft or uneven in its properties, as it frequently happens in hill tracts. This band will serve as damp proof course as well.

4) Roof band :-

Roof band is a band ~~on floors~~ provided immediately below the roof or floores. In buildings with ~~floors~~ flat reinforced concrete or reinforced brick roofs, roof band is not required because the roof slab also plays the role of a band. However, in buildings with flat timber or CGI sheet roof, roof band needs to be provided. In buildings with pitched or sloped roof, roof band is very important.

5) Gable Band :-

A gable band is a horizontal member which is placed at the top of the ridge of the sloping slab to support the ends of the ~~ref~~ rafters and transferring loads to posts or gable end walls.

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Ch-04 RETROFITTING OF STRUCTURES

1) What are the sources of weakness in RCC framed building ?

Ans- **Source of weakness in RCC frame building :-**

Earthquake engineering is not a pure science rather it has been developed through the observation of failure of structure during earthquake. Damage survey reports of past earthquakes reveal the following main sources of weakness in reinforced concrete moment resisting frame buildings.

- → discontinuous load path.
- → Lack of deformation compatibility of structural members.
- → Quality of workmanship and poor quality of materials.

i) **Structural Damage due to Discontinuous Load path :-**

Every structure must have two load resisting system :-

a) vertical load resisting system for transferring the vertical load to the ground and

b) Horizontal load resisting system for transferring the horizontal load of the vertical load system.

It is imperative that the seismic forces should be properly collected by the horizontal framing system and properly transferred into vertical lateral resisting system. Any discontinuity in this load path or load transfer may cause one of the major contributions to structural damage during strong earthquake.

(ii) Structural Damage due to lack of Deformation :-

→ The main problems in the structural members of moment resisting frame building are the limited amount of ductility and the inability to redistribute load in order to safety with stand the deformations imposed upon in response to seismic load.

→ The regions of failure may be in columns beams walls and beam column joints.

→ It is important to consider the consequences for member failure of structural performance.

→ Inadequate strength and ductility of the structural member can and will result in local or complete failure of the system.

(iii) Quality of workability and materials :-

→ There are numerous instances where faculty construction ~~faulty~~ practices and lack of quality control have contributed to the damage.

→ The faculty construction practices may be like, lack of amount and detailing of reinforcement as per requirement of code particularly when the end of lateral reinforcement is not bent by 135 degrees as the code specified.

→ Many buildings have been damaged due to poor quality control of design material strength as specified, spalling of concrete by the corrosion of embedded reinforcing bars, porous concrete, age of concrete, proper maintenance etc.

D-04-03-2020

2) Classify retrofitting techniques and describe their uses.

Ans:- **Retrofitting :-**

→ It is the seismic strengthening of existing damaged or undamaged structures.

→ It is an improvement over the original strength when the evaluation of the building indicates that the strength is available before the damage was insufficient and restoration alone will not be adequate in future quake/earth quakes.

Objectives of retrofitting :-

→ Increasing the strength (Lateral) in wall or both direction by reinforcement or by increasing wall areas or the no. of walls and columns.

→ Giving unity to the structures by providing a proper connection between its resisting elemen

Retrofitting Techniques

- Global
  - Additional shear wall
  - Adding in fill wall
  - Adding bracing
  - Adding wing wall/ buttresses
  - Wall thickness
  - Mass reduction
  - Supplemental damping and base isolation
- Local
  - Jacketing of beam
  - Jacketing of columns
  - Jacketing of beam columns joints
  - Strengthening individual footing

There are 2 ways to enhance the seismic capacity of existing structures.

1) The first is a structural - level approach of retrofitting which involves global modifications to the structural system.

2) The 2nd is a member level approach of retrofitting or local retrofitting which deals with an increase of the ductility of components with adequate capacities to satisfy their specific limit state.

Structural Level Global Retrofitting :-

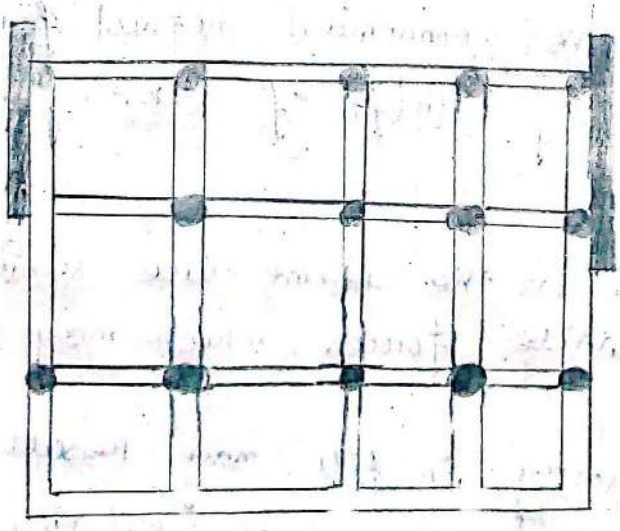
Adding New Shear walls :-

One of the most common methods to increase the lateral strength of the R.C. buildings. It is the last simple method.

Limitation :-

Increase in lateral resistance but it concentrated at a few places.

→ Increase dead load of the structure.



Adding steel bracing :-

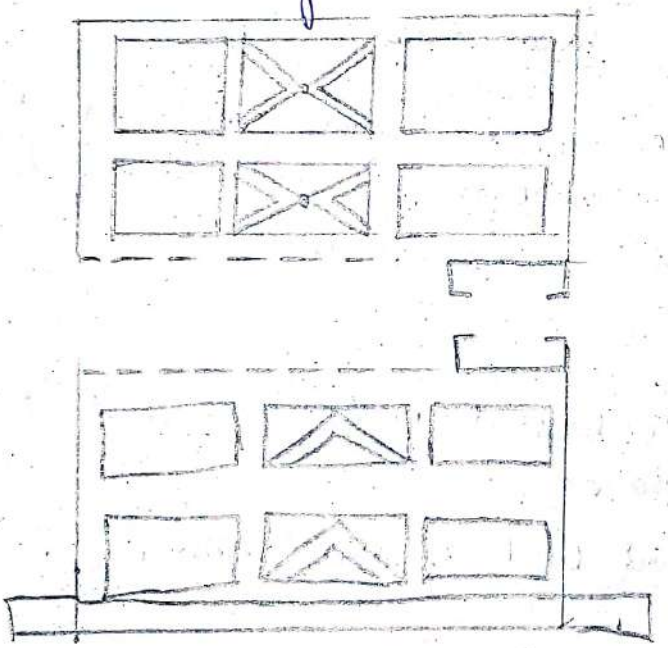
Higher strengths stiffness can be proved. opening for natural light can be made easily. It have much less cost.

Limitation :-

A moderate to high level of skilled labour is necessary.

→ Lack of information about the seismic behaviour of the added bracing.

→ undesirable changes takes place.



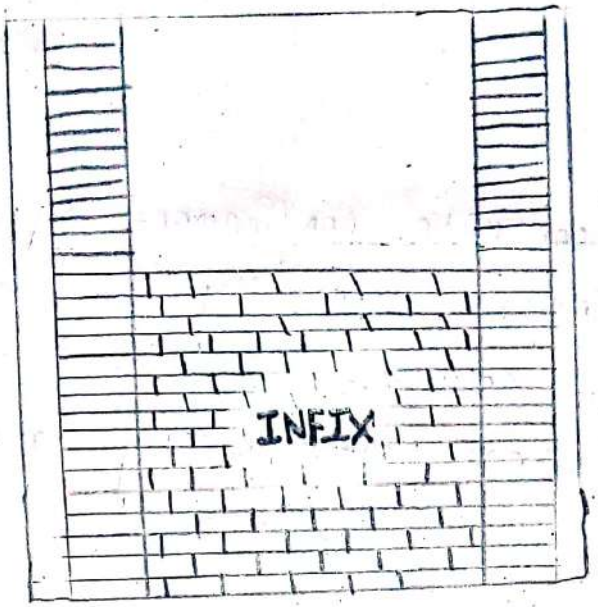
Adding Infill wall :-

It is an effectives economical method for improving strengths reducing drift of existing frames.

Limitation :-

→ some columns in the frame are subjected to large axial tensile forces, which may exceed the capacity.

→ A strong masonry in fill may result in a failure of the columns of existing frame.



Local or member Retrofitting :-

→ Local retrofitting are typically used either when ~~the retrofit~~ the retrofit objectives are limited or direct treatment of the vulnerable components is needed.

→ The most popular frequently used method in local retrofitting is Jacketing or confinement by the Jackets of R.C. steel, fibre reinforced Polymer (FRP) carbon fibre etc.

→ Jacketing around the existing members increases its lateral load capacity of the structure in a uniformly distributed way with a minimal increase in loading in any single foundation with no alternative in the basic geometry of the building.

Jacketing :-

→ Jacketing is the most popularly used materials for strengthening of building.

→ The most common types are steel Jacket, R.C., Jacket, fibre reinforced polymer composite Jacket, Jacket with high tension materials like carbon fibre,

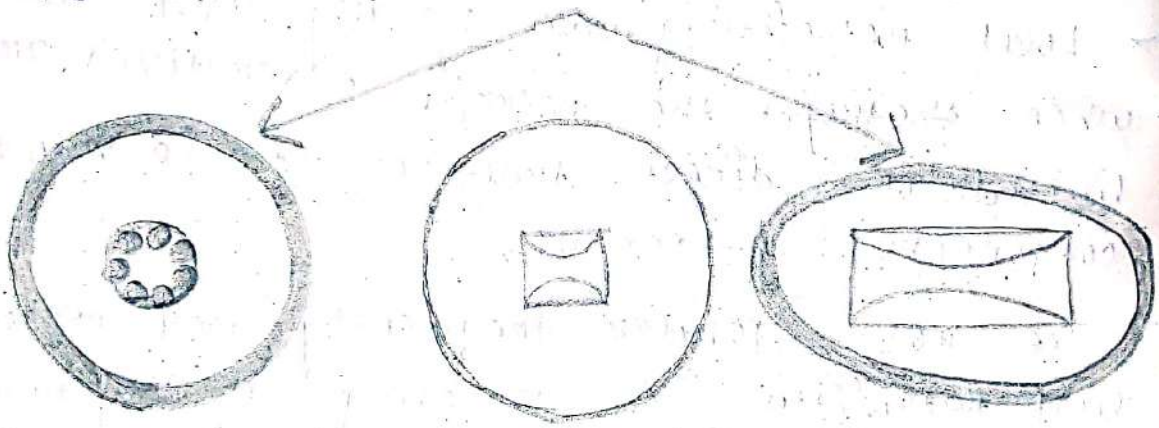
glass fibre etc.

Purpose :-

→ To increase concrete confinement by transverse fibre / reinforcement, especially for circular cross-sectional column..

→ To increase shear strength by transverse reinforcement.

→ To increase flexural strength by longitudinal fibre.



F.R.P jacketing :-

→ carbon fibre is flexible and can be made to contact the surface tightly for a high degree of confinement.

→ confinement is of high degree coz carbon fibre is of high strength and high modulus of elasticity.

→ It has light weight & rusting does not occur.

PART-C

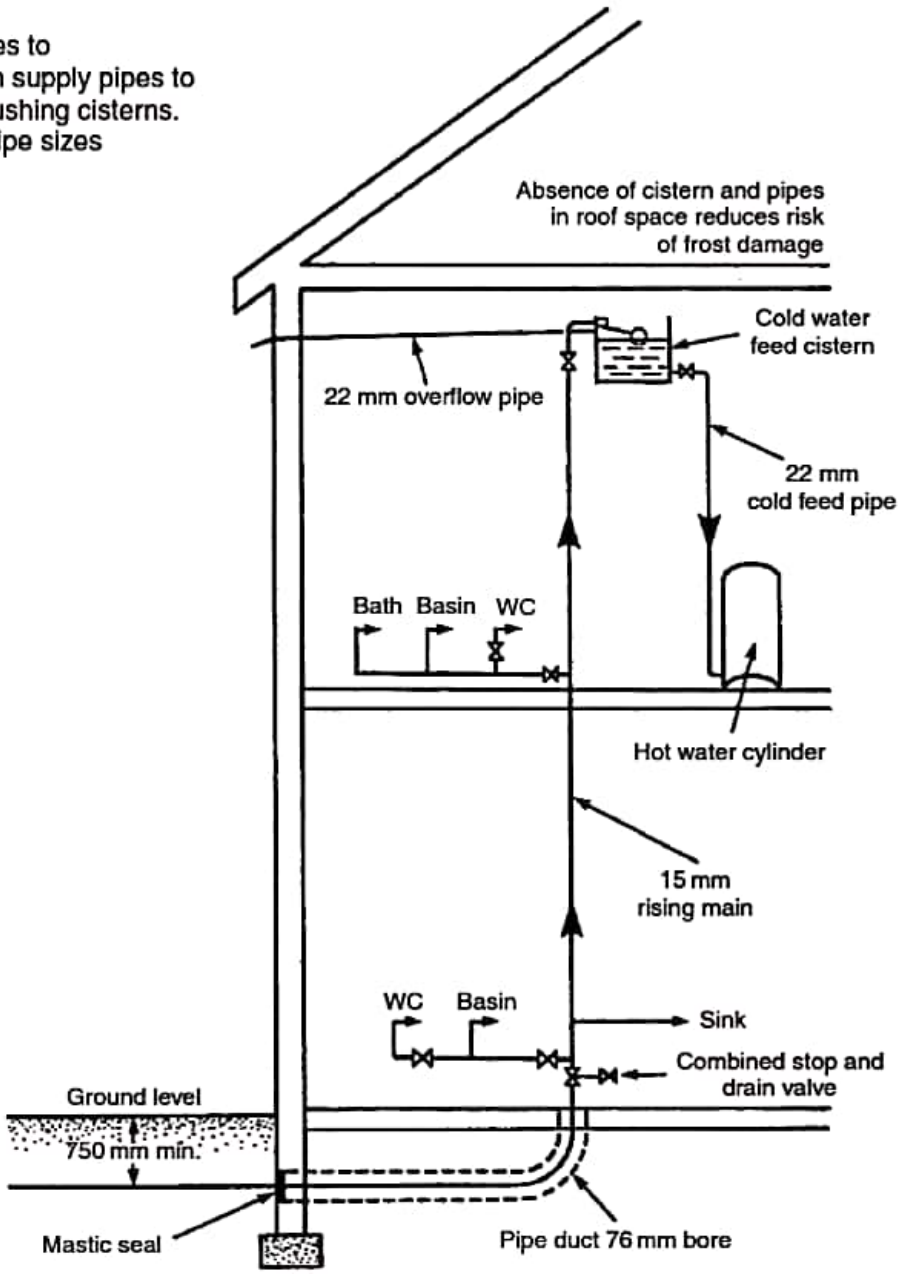
5.BUILDING SERVICES

Direct System of Cold Water Supply

For efficient operation, a high pressure water supply is essential particularly at periods of peak demand. Pipework is minimal and the storage cistern supplying the hot water cylinder need only have 115 litres capacity. The cistern may be located within the airing cupboard or be combined with the hot water cylinder. Drinking water is available at every draw-off point and maintenance valves should be fitted to isolate each section of pipework. With every outlet supplied from the main, the possibility of back siphonage must be considered.

Back siphonage can occur when there is a high demand on the main. Negative pressure can then draw water back into the main from a submerged inlet, e.g. a rubber tube attached to a tap or a shower fitting without a check valve facility left lying in dirty bath water.

Notes:
(1) Servicing valves to be provided on supply pipes to storage and flushing cisterns.
(2) Copper tube pipe sizes shown.

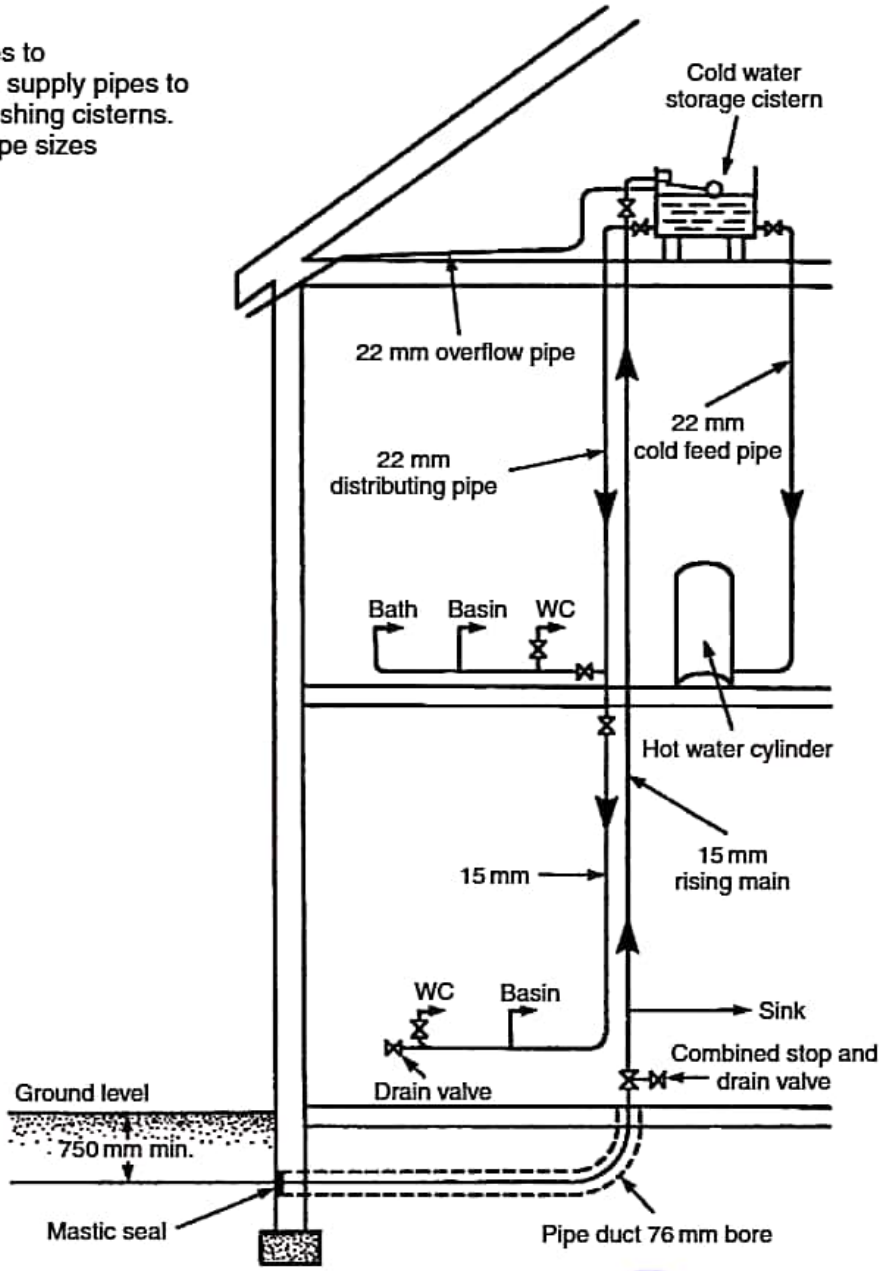


Ref.: The Water Supply (Water Fittings) Regulations 1999.

Indirect System of Cold Water Supply

The indirect system of cold water supply has only one drinking water outlet, at the sink. The cold water storage cistern has a minimum capacity of 230 litres, for location in the roof space. In addition to its normal supply function, it provides an adequate emergency storage in the event of water main failure. The system requires more pipework than the direct system and is therefore more expensive to install, but uniform pressure occurs at all cistern-supplied outlets. The water authorities prefer this system as it imposes less demand on the main. Also, with fewer fittings attached to the main, there is less chance of back siphonage. Other advantages of lower pressure include less noise and wear on fittings, and the opportunity to install a balanced pressure shower from the cistern.

Notes:
(1) Servicing valves to be provided on supply pipes to storage and flushing cisterns.
(2) Copper tube pipe sizes shown.



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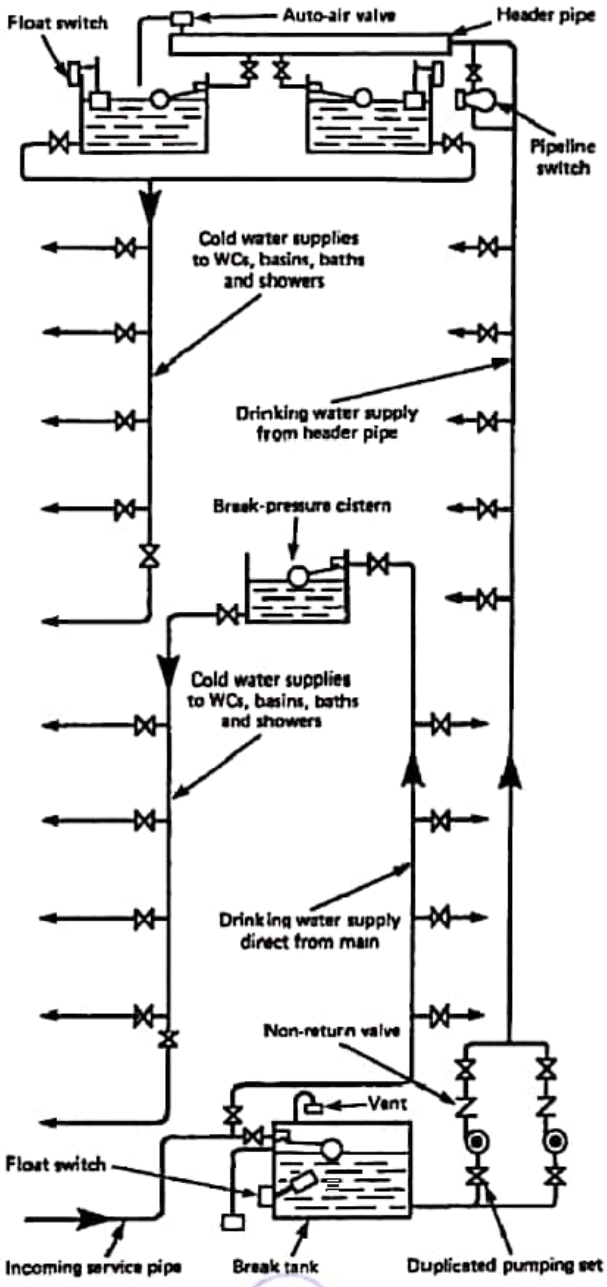
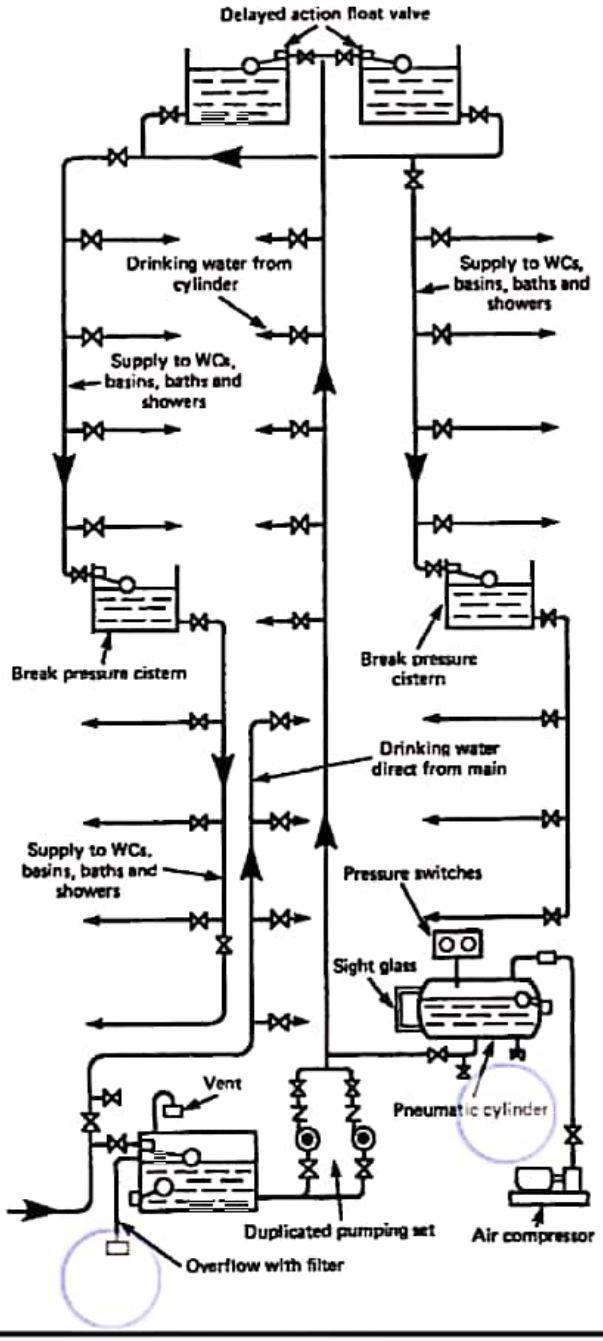
Boosted Cold Water System – 1

For medium and high rise buildings, there is often insufficient mains pressure to supply water directly to the upper floors. Boosting by pump from a break tank is therefore usually necessary and several more of these tanks may be required as the building rises, depending on the pump capacity. A break pressure cistern is also required on the down service to limit the head or pressure on the lower fittings to a maximum of 30 m (approx. 300 kPa). The drinking water header pipe or storage vessel supplies drinking water to the upper floors. As this empties and the water reaches a predetermined low level, the pipeline switch engages the duty pump. A float switch in the break tank protects the pumps from dry running if there is an interruption to mains supply. The various pipe sections are fitted with isolating valves to facilitate maintenance and repairs.

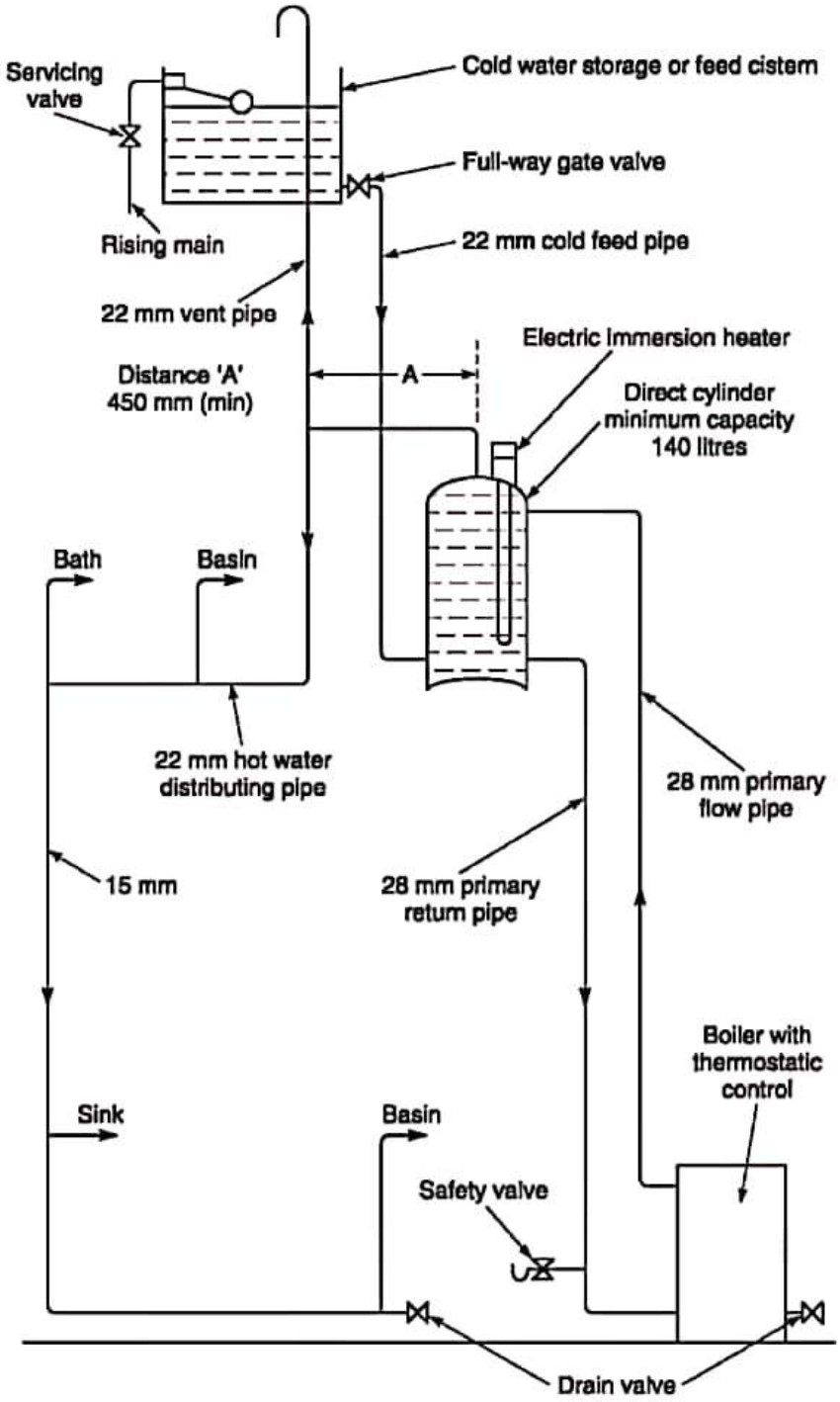


As an alternative to the drinking water header pipe, an auto-pneumatic cylinder may be used. Compressed air in the cylinder forces water up to the float valves and drinking water outlets on the upper floors. As the cylinder empties a low pressure switch engages the duty pump. When the pump has replenished the cylinder, a high pressure switch disengages the pump. In time, some air is absorbed by the water. As this occurs, a float switch detects the high water level in the cylinder and activates an air compressor to regulate the correct volume of air. Break pressure cisterns may be supplied either from the storage cisterns at roof level or from the rising main. A pressure reducing valve is sometimes used instead of a break pressure cistern.



Direct System of Hot Water Supply

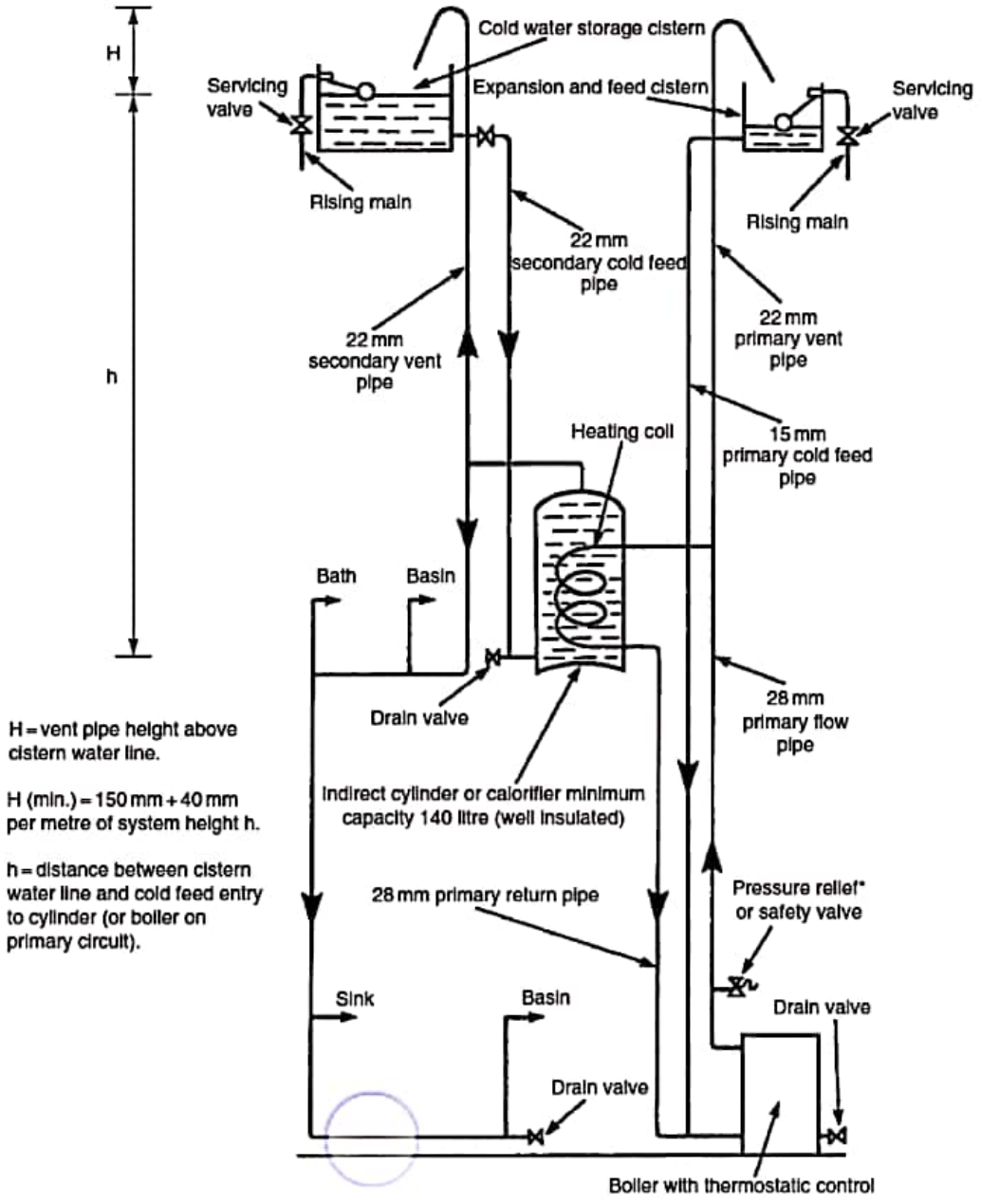
The hot water from the boiler mixes directly with the water in the cylinder. If used in a 'soft' water area the boiler must be rust-proofed. This system is not suited to 'hard' waters, typical of those extracted from boreholes into chalk or limestone strata. When heated the calcium precipitates to line the boiler and primary pipework, eventually 'furring up' the system to render it ineffective and dangerous. The storage cylinder and associated pipework should be well insulated to reduce energy losses. If a towel rail is fitted, this may be supplied from the primary flow and return pipes.



Note: All pipe sizes shown are for copper outside diameter.

Indirect System of Hot Water Supply

This system is used in 'hard' water areas to prevent scaling or 'furring' of the boiler and primary pipework. Unlike the direct system, water in the boiler and primary circuit is not drawn off through the taps. The same water circulates continuously throughout the boiler, primary circuit and heat exchange coil inside the storage cylinder. Fresh water cannot gain access to the higher temperature areas where precipitation of calcium would occur. The system is also used in combination with central heating, with flow and return pipes to radiators connected to the boiler. Boiler water temperature may be set by thermostat at about 80°C.



H = vent pipe height above cistern water line.

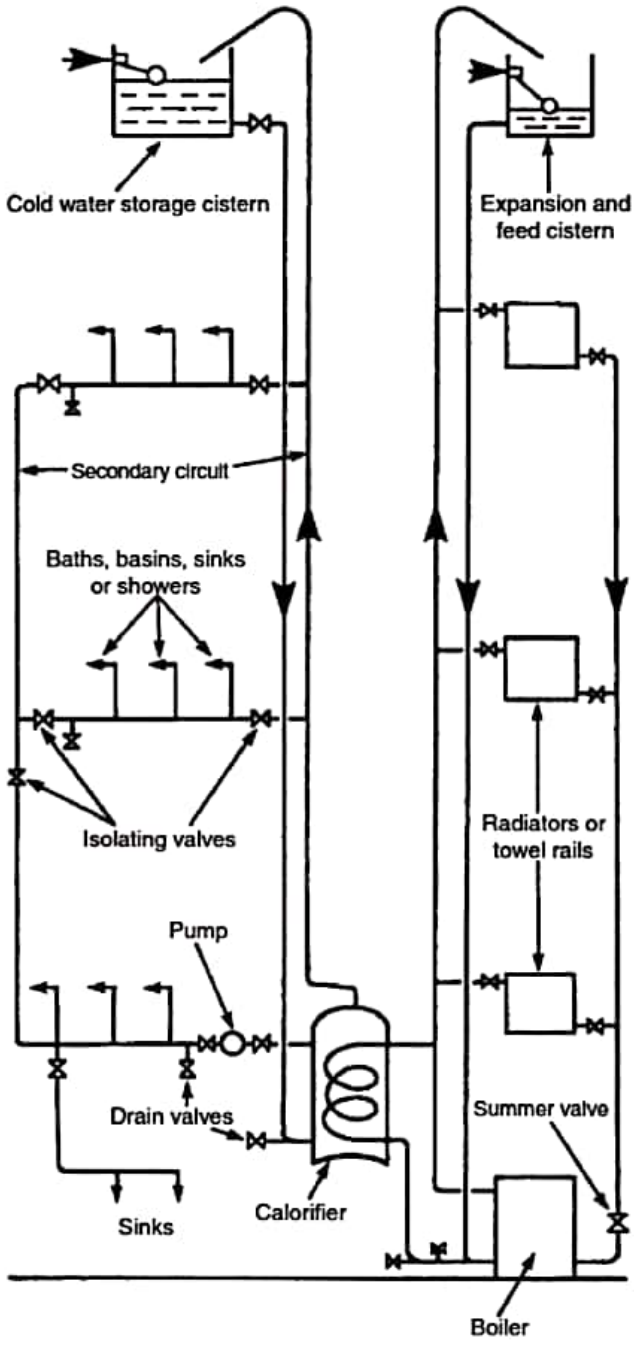
H (min.) = 150 mm + 40 mm per metre of system height h.

h = distance between cistern water line and cold feed entry to cylinder (or boiler on primary circuit).

*A safety valve is not normally required on indirect open vent systems, as in the unlikely occurrence of the primary flow and vent becoming obstructed, water expansion would be accommodated up the cold feed pipe.

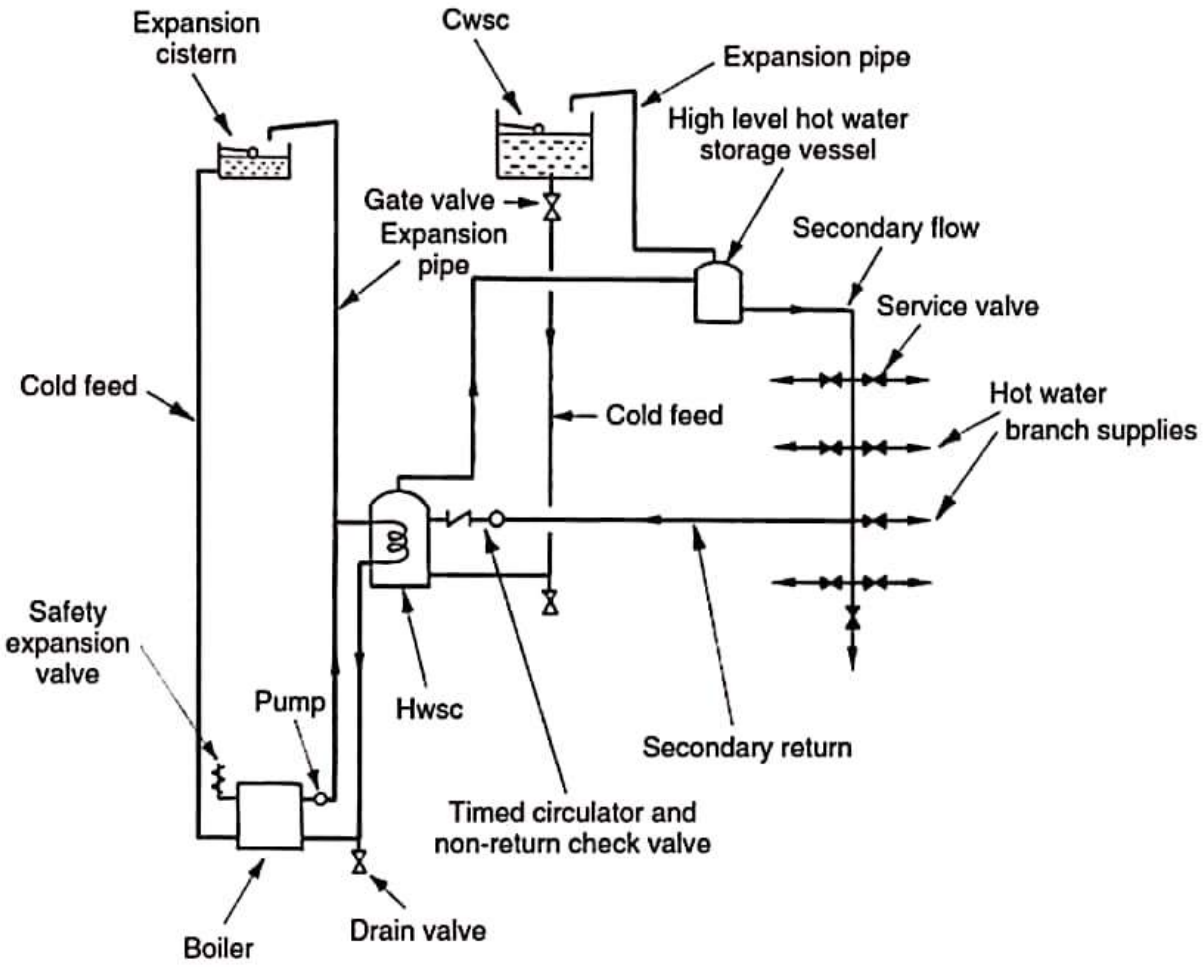
Indirect Hot Water System for a Three-storey Building

For larger buildings a secondary circuit will be required to reduce 'dead-legs' and to maintain an effective supply of hot water at all outlets. Convection or thermo-siphonage may provide circulation, but for a more efficient service a circulatory pump will be necessary. In buildings which are occupied for only part of the day, e.g. schools, offices, etc., a time control or programmer can be used to regulate use of the pump. Also, one of the valves near the pump should be motorised and automatically shut off with the pump and boiler when hot water is not required. All secondary circuits should be well insulated to reduce heat losses through the pipework. A heating installation can operate in conjunction with this system, but may require duplication of boilers or separate boilers for each function.



Indirect Supplementary Hot Water System

Hot water provision in moderately large buildings such as spacious houses, small hotels, hostels and other situations where demand is periodically high, can be from a large storage cylinder or cylinders installed in duplicate. Alternatively or additionally, depending on requirements, a supplementary storage vessel may be strategically located at high level. This vessel is relatively small, containing no more than 20% of the total design capacity.



Advantages over a single storage facility:

- Smaller secondary flow and return distribution pipes.
- Less concentrated dead load on the structure.

SANITATION

Single Stack System

The single stack system was developed by the Building Research Establishment during the 1960s, as a means of simplifying the extensive pipework previously associated with above ground drainage. The concept is to group appliances around the stack with a separate branch pipe serving each. Branch pipe lengths and falls are constrained. Initially the system was limited to five storeys, but applications have proved successful in high rise buildings of over 20 storeys. Branch vent pipes are not required unless the system is modified. Lengths and falls of waste pipes are carefully selected to prevent loss of trap water seals. Water seals on the waste traps must be 75 mm (50 mm bath and shower).

Branch pipe slope or fall:

Sink and bath – 18 to 90 mm/m

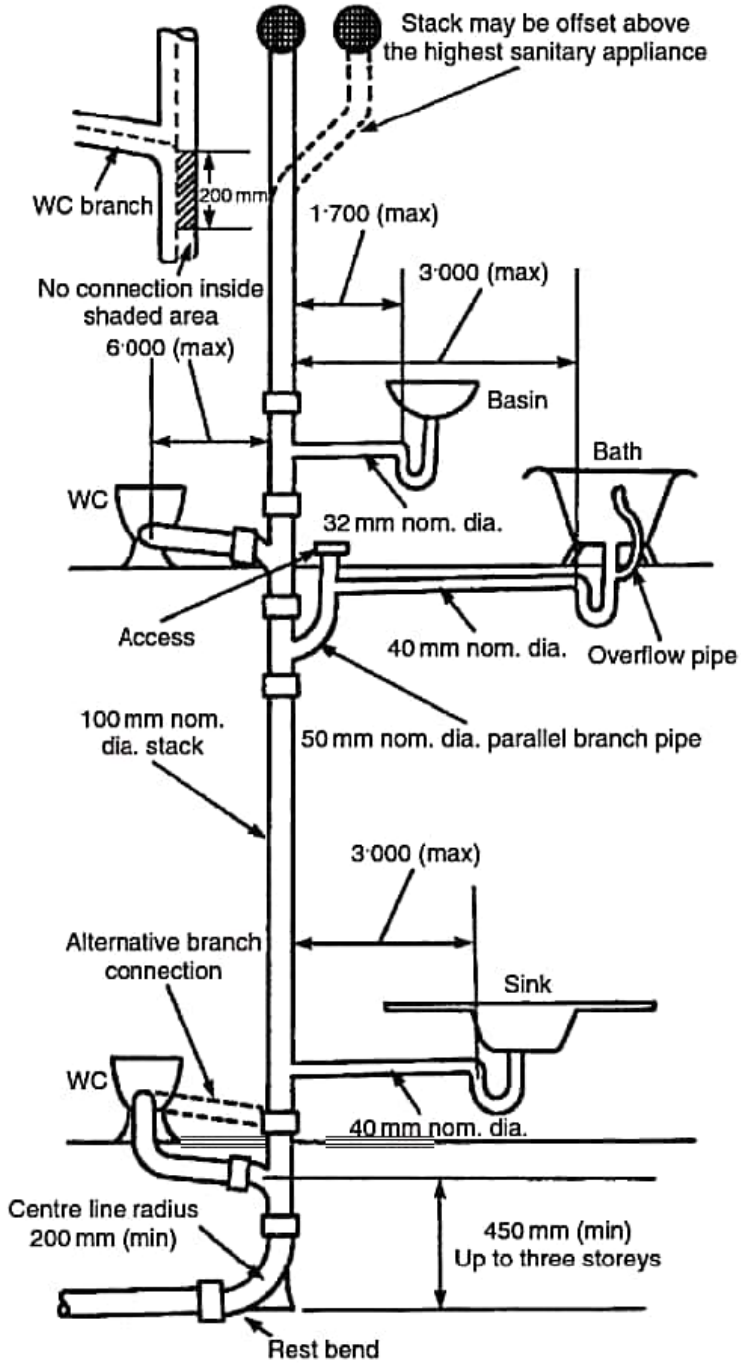
Basin and bidet – 20 to 120 mm/m

WC – 9 mm/m.

The stack should be vertical below the highest sanitary appliance branch. If an offset is unavoidable, there should be no connection within 750 mm of the offset.

The branch bath waste connection must be at least 200 mm below the centre of the WC branch to avoid crossflow. This may require a 50 mm nom. dia. parallel pipe to offset the bath waste pipe, or an 'S' trap WC to offset its connection.

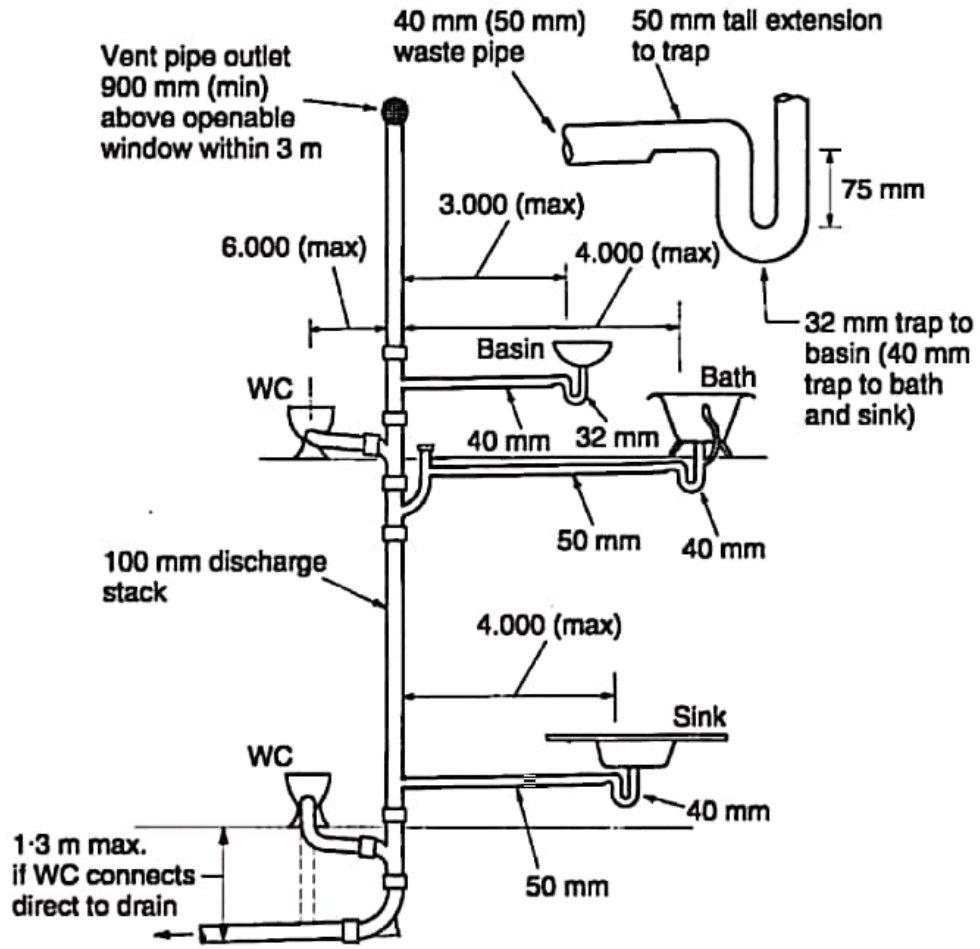
The vent part of the stack may reduce to 75 mm nom. dia. when it is above the highest branch.



Single Stack System – Modified

If it is impractical to satisfy all the requirements for waste pipe branches in a standard single stack system, some modification is permitted in order to maintain an acceptable system performance:

- Appliances may be fitted with resealing or anti-siphon traps (see page 309).
- Branch waste pipes can be ventilated (see pages 314 and 315).
- Larger than standard diameter waste pipes may be fitted.



All pipe sizes nominal diameter

Note: Where larger than standard branch pipes are used, the trap size remains as standard. Each trap is fitted with a 50 mm tail extension before connecting to a larger waste pipe.

Refs: Building Regulations, Approved Document H1, Section 1: Sanitary pipework.
BS EN 12056: Gravity drainage systems inside buildings (in 6 parts).

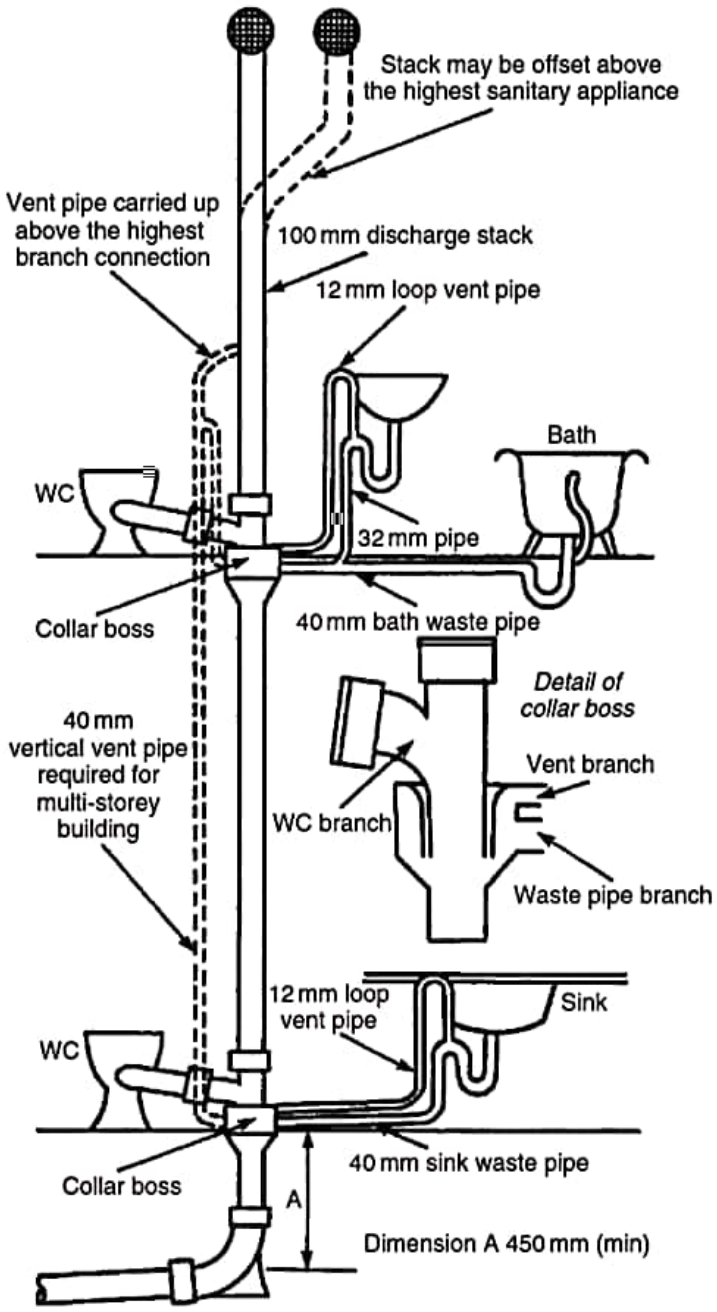
Collar Boss Single Stack System

The collar boss system is another modification to the standard single stack system. It was developed by the Marley company for use with their uPVC pipe products. The collar is in effect a gallery with purpose-made bosses for connection of waste pipes to the discharge stack without the problem of crossflow interference. This simplifies the bath waste connection and is less structurally disruptive.

Small diameter loop vent pipes on (or close to) the basin and sink traps also connect to the collar. These allow the use of 'S' traps and vertical waste pipes without the possibility of siphonage, even when the bath waste discharges and flows into the combined bath and basin waste pipe. Vertical outlets are also likely to be less obtrusive and less exposed than higher level 'P' trap waste pipes.

If the branch waste pipes are kept to minimal lengths, the loop vents may not be required. However, the system must be shown to perform adequately under test without the loss of trap water seals.

All pipe sizes shown are nominal inside diameter. There may be some slight variation between different product manufacturers, particularly those using outside diameter specifications. Note that there is not always compatibility between different manufacturers' components.



Modified Single Stack System

The ventilated stack system is used in buildings where close grouping of sanitary appliances occurs - typical of lavatories in commercial premises. The appliances need to be sufficiently close together and limited in number not to be individually vented.

Requirements:

WCs:

8 maximum

100 mm branch pipe

15 m maximum length

Gradient between 9 and 90 mm/m ($\theta = 90\frac{1}{2}°-95°$).

Basins:

4 maximum

50 mm pipe

4 m maximum length

Gradient between 18 and 45 mm/m ($\theta = 91°-92\frac{1}{2}°$).

Urinals (bowls):

5 maximum

50 mm pipe

Branch pipe as short as possible

Gradient between 18 and 90 mm/m.

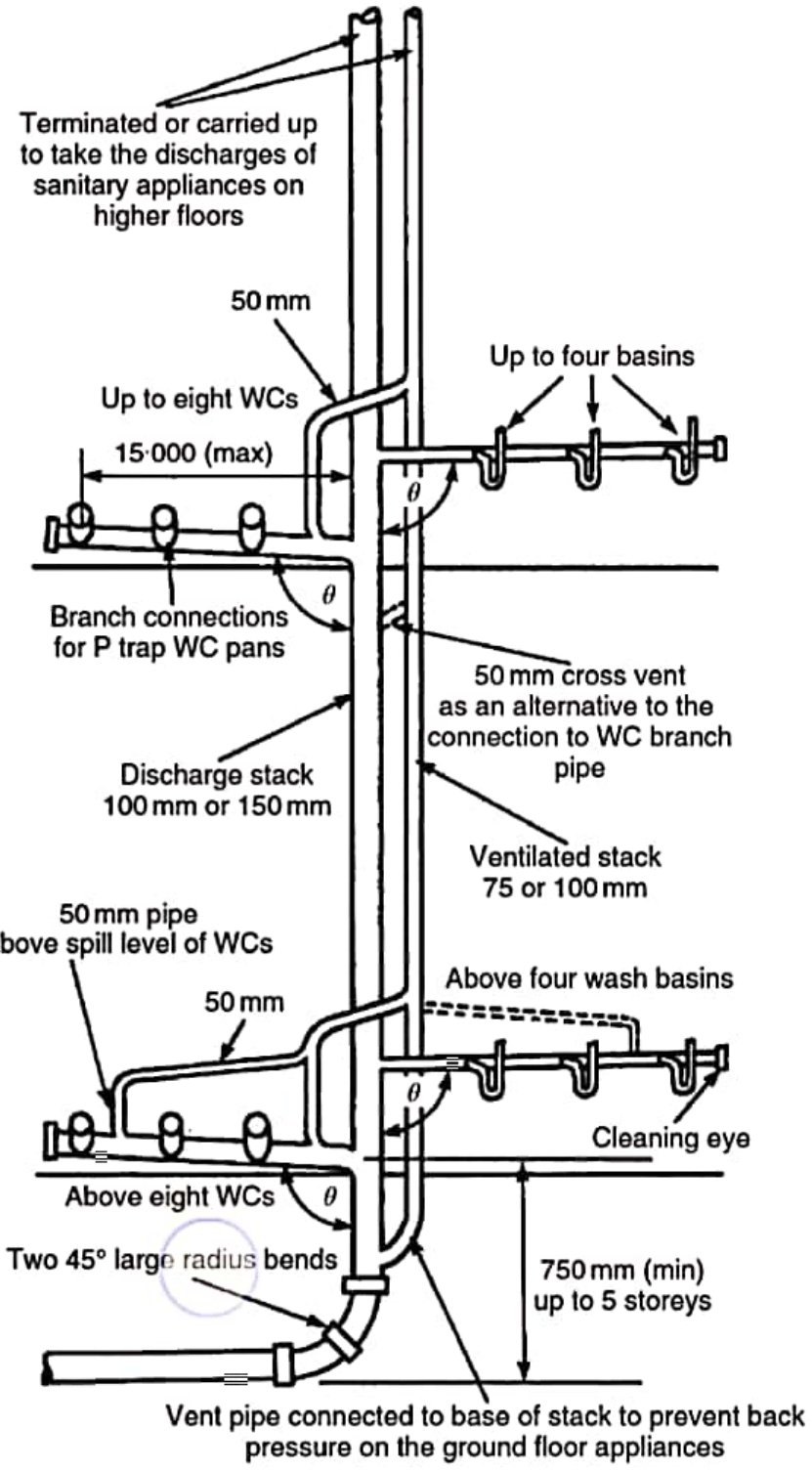
Urinals (stalls):

7 maximum

65 mm pipe

Branch pipe as for bowls.

All pipe sizes are nominal inside diameter.



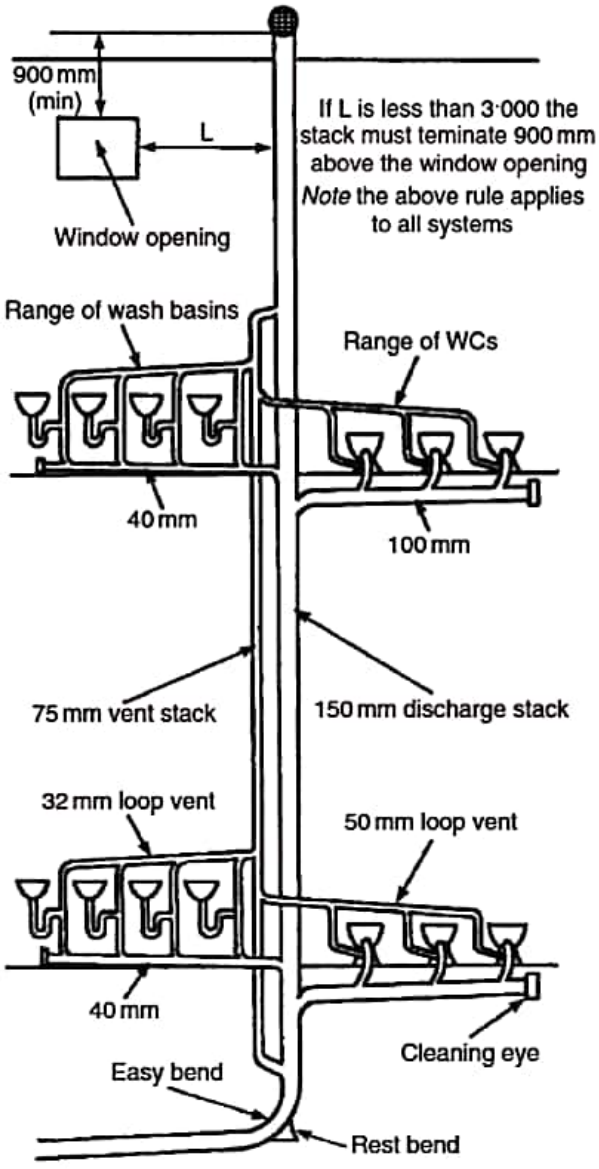
Fully Vented One-pipe System

The fully vented one-pipe system is used in buildings where there are a large number of sanitary appliances in ranges, e.g. factories, schools, offices and hospitals.

The trap on each appliance is fitted with an anti-siphon or vent pipe. This must be connected within 300 mm of the crown of the trap.

Individual vent pipes combine in a common vent for the range, which is inclined until it meets the vertical vent stack. This vent stack may be carried to outside air or it may connect to the discharge stack at a point above the spillover level of the highest appliance.

The base of the vent stack should be connected to the discharge stack close to the bottom rest bend to relieve any compression at this point.



Size of branch and stack vents:

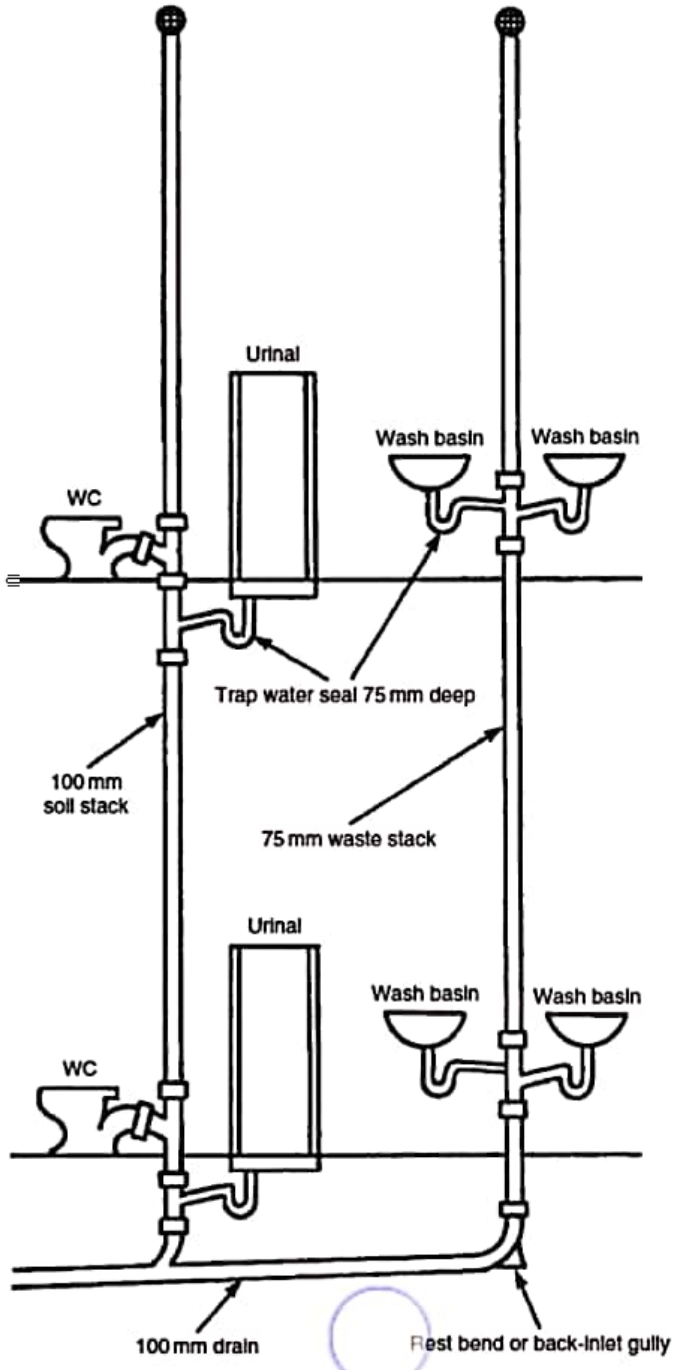
Discharge pipe or stack (D) (mm)	Vent pipe (mm)
<75	0·67D
75–100	50
>100	0·50D

All pipe sizes are nominal inside diameter.

The Two-pipe System

This system was devised to comply with the old London County Council requirements for connection of soil (WC and urinal) and waste (basin, bath, bidet, sink) appliances to separate stacks. For modern systems the terms soil and waste pipes are generally replaced by the preferred terminology, discharge pipes and discharge stacks.

There are many examples of the two-pipe system in use. Although relatively expensive to install, it is still permissible and may be retained in existing buildings that are the subject of refurbishment.



It may also be used where the sanitary appliances are widely spaced or remote and a separate waste stack is the only viable method for connecting these to the drain.

A variation typical of 1930s dwellings has first floor bath and basin wastes discharging through the wall into a hopper. The waste stack from this and the ground floor sink waste discharge over a gully.

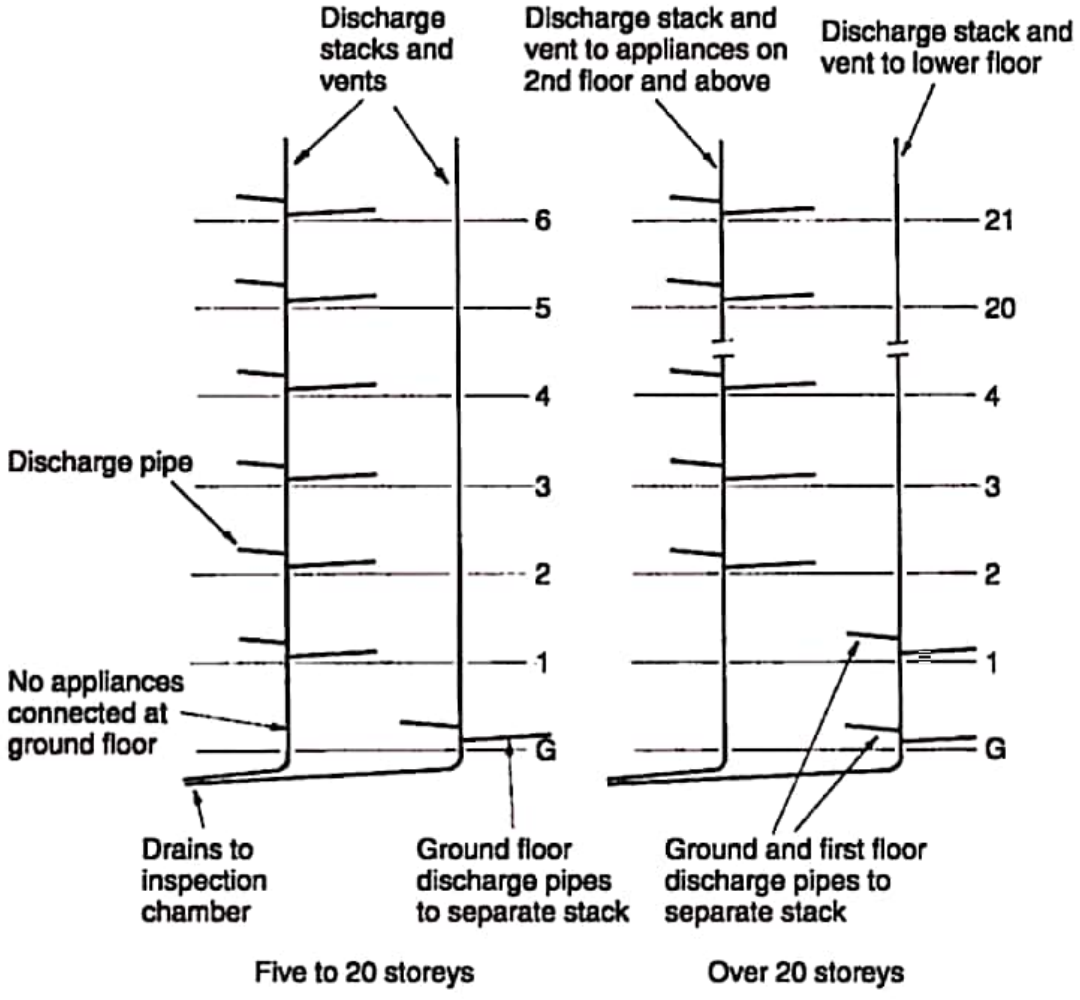
A gully may be used as an alternative to a rest bend before the drain.

Ground Floor Appliances – High Rise Buildings

Lowest discharge pipe connection to stack:

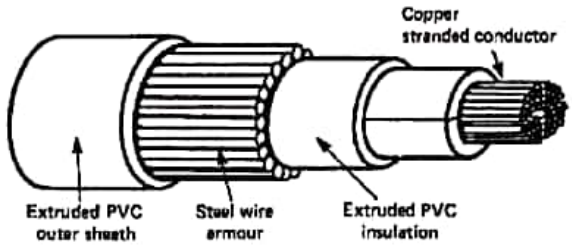
Up to three storeys - 450 mm min. from stack base (page 311).
Up to five storeys - 750 mm min. from stack base (page 314).

Above five storeys, the ground floor appliances should not connect into the common stack, as pressure fluctuations at the stack base could disturb the lower appliance trap water seals. Above 20 storeys, both ground and first floor appliances should not connect into the common stack. Ground and first floor appliances so affected can connect directly to a drain or gully, or be provided with a stack specifically for lower level use.



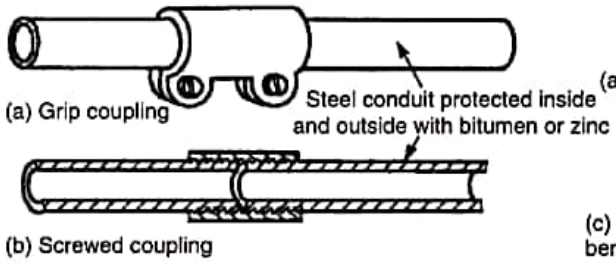
Access - required for clearing blockages. Rodding points should be fitted at the end of discharge pipes, unless trap removal provides access to the full pipe length. Discharge stacks are accessed from the top and through access plates located midway between floors at a maximum spacing of three storeys apart.

Armoured cable is used for mains and sub-mains. The cable is laid below ground level, breaking the surface where it enters sub-stations or transformers and other buildings. High voltage cable is protected below ground by precast concrete 'tiles'.

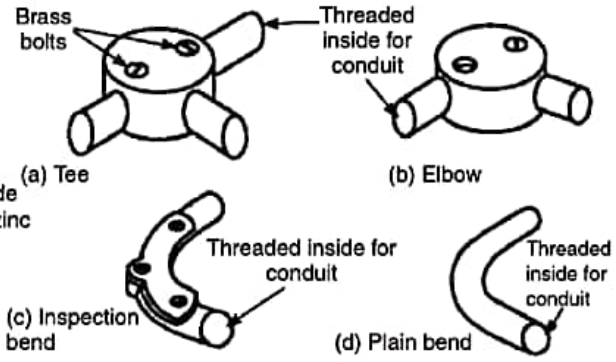


Armoured three-phase four wire cable for laying below ground level

Conduit for electrical services is produced in steel (galvanised or painted black) or plastic tube into which insulated cables are drawn. The conduit protects the cable from physical damage and heat. It also provides continuous support and if it is metal, it may be used as an earth conductor. Standard outside diameters are 20, 25, 32 and 40 mm. Steel is produced in either light or heavy gauge. Light gauge is connected by grip fittings, whilst the thicker walled heavy gauge can be screw threaded to fittings and couplings. Plastic conduit has push-fit connections.



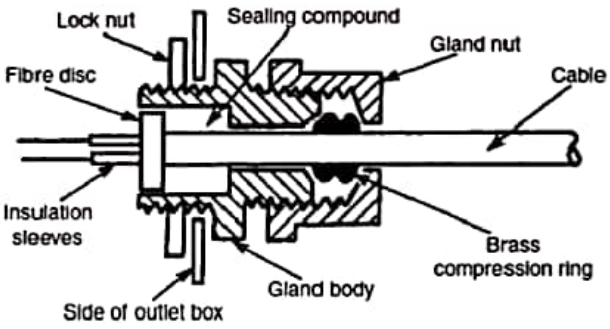
Couplings for steel conduit



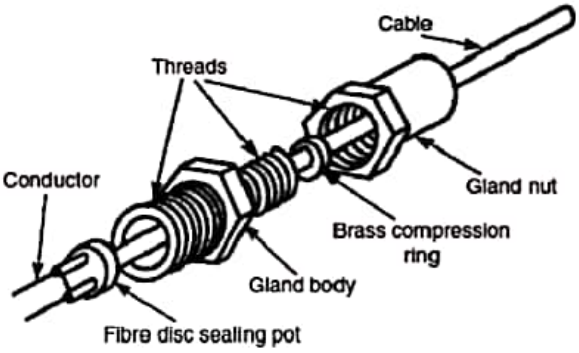
Fittings for steel conduit

Refs: BS 6346: Electric cables. PVC insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V.
BS EN 61386: Conduit systems for cable management.
BS 7846: Electric cables. 600/1000 V armoured fire resistant cables having thermosetting insulation and low emission of smoke and gases when affected by fire.

Mineral insulated copper covered cable (MICC) has copper conductors insulated with highly compressed magnesium oxide powder inside a copper tube. When installing the cable, it is essential that the hygroscopic insulant does not come into contact with a damp atmosphere. Cutting the cable involves special procedures which are used to seal the insulant from penetration of atmospheric dampness. The cable provides an excellent earth conductor; it is also resistant to most corrosive atmospheres and is unaffected by extremes of heat.

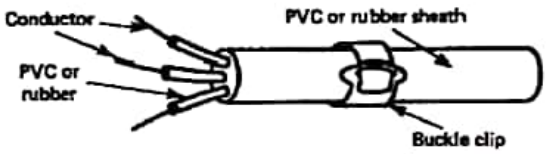


Section of termination joint for mineral insulated copper covered cable (MICC)

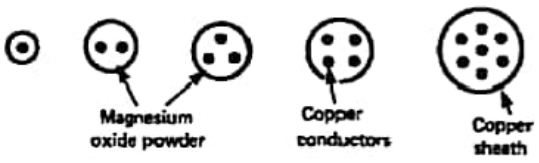


Exploded view of termination joint for mineral insulated copper covered cable

PVC and rubber insulated cables are relatively inexpensive and simple to install, requiring clipped support at regular intervals. PVC cables are in general use, but they have a temperature limitation between 0°C and 70°C. Below zero they become brittle and are easily damaged and at the higher temperature they become soft, which could encourage the conductor to migrate through the PVC. Outside of these temperatures, the cable must be protected or an appropriate rubber insulant specified. Cables usually contain one, two or three conductors. In three-core cable the live and neutral are insulated with brown and blue colour coding respectively. The earth is bare and must be protected with green and yellow sleeving where exposed at junction boxes, sockets, etc. Grey and black insulated conductors are occasionally used where an additional facility is required, e.g. two-way lighting.



PVC or rubber insulated cable



Core arrangements of mineral insulated copper covered cables

Refs: BS 6004 Electric cables. PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring.
BS 6007: Electric cables. Single core unsheathed heat resisting cables for voltages up to and including 450/750 V, for internal wiring.

Testing Completed Installation – 1

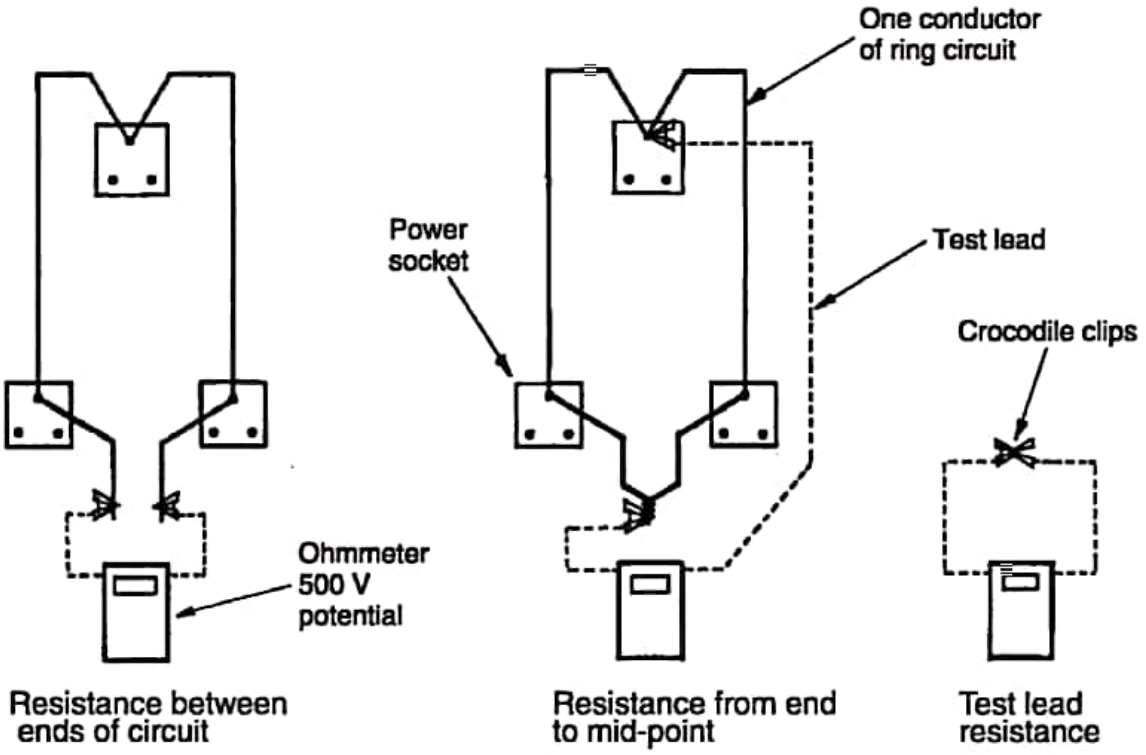
Electrical installations must be tested on completion to verify that the system will operate efficiently and safely. The tests are extensive, as defined in the Institution of Electrical Engineers Regulations. They can only be carried out by a competent person, i.e. a qualified electrician or electrical engineer. The following tests are an essential part of the proceedings:

- Continuity.
- Insulation.
- Polarity.

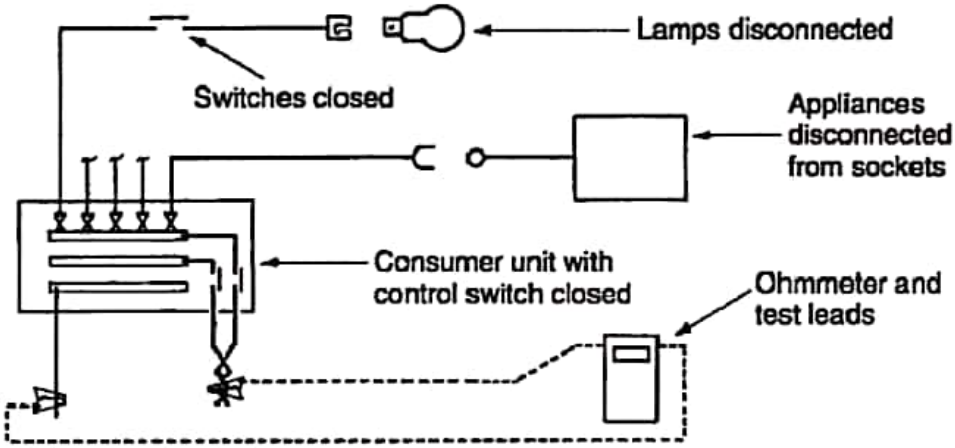
Testing is undertaken by visual inspection and the use of a multi-purpose meter (multimeter) or an instrument specifically for recording resistance, i.e. an ohmmeter.

Continuity – there are several types of continuity test for ring mains. Each is to ensure integrity of the live, neutral and earth conductors without bridging (shorting out) of connections. The following is one established test to be applied to each conductor:

- Record the resistance between the ends of the ring circuit (A).
- Record the resistance between closed ends of the circuit and a point mid-way in the circuit (B).
- Check the resistance of the test lead (C).
- Circuit integrity is indicated by: A ÷ 4 approx. = B – C.

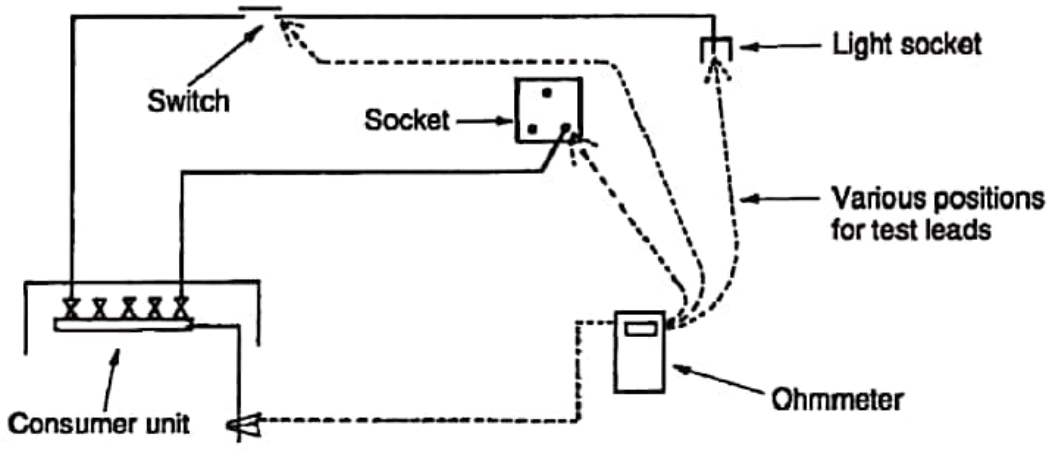


Insulation - this test is to ensure that there is a high resistance between live and neutral conductors and these conductors and earth. A low resistance will result in current leakage and energy waste which could deteriorate the insulation and be a potential fire hazard. The test to earth requires all lamps and other equipment to be disconnected, all switches and circuit breakers closed and fuses left in. Ohmmeter readings should be at least 1 MΩ



Insulation test

Polarity - this is to ensure that all switches and circuit breakers are connected in the phase or live conductor. An inadvertant connection of switchgear to a neutral conductor would lead to a very dangerous situation where apparent isolation of equipment would still leave it live! The test leads connect the live bar in the disconnected consumer unit to live terminals at switches. A very low resistance reading indicates the polarity is correct and operation of the switches will give a fluctuation on the ohmmeter.



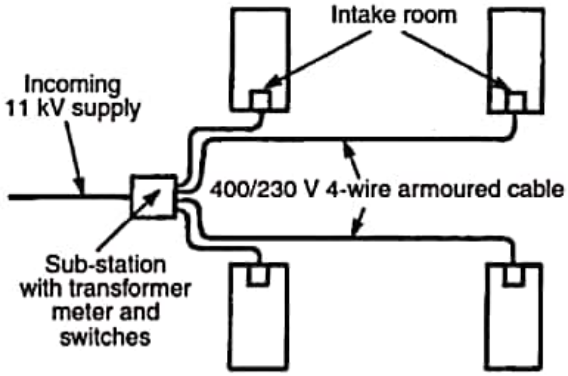
Polarity test

Ref: BS EN 61010-1: Safety requirements for electrical equipment for measurement, control and laboratory use.

Electricity Supply to Groups of Large Buildings

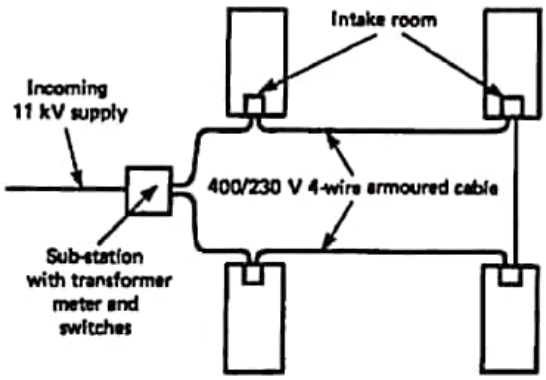
For large developments containing several buildings, either radial or ring distribution systems may be used.

Radial system – separate underground cables are laid from the sub-station to each building. The system uses more cable than the ring system, but only one fused switch is required below the distribution boards in each building.

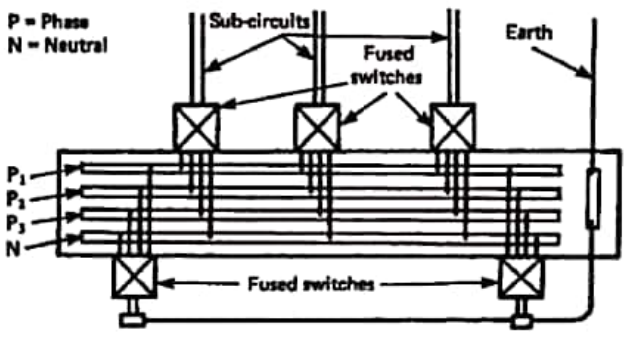


Radial distribution (block plan)

Ring circuit system – an underground cable is laid from the sub-station to loop in to each building. To isolate the supply, two fused switches are required below the distribution boards in each building. Current flows in both directions from the intake, to provide a better balance than the radial system. If the cable on the ring is damaged at any point, it can be isolated for repair without loss of supply to any of the buildings.



Ring distribution (block plan)



Detail of equipment in the intake room for the ring distribution

Earthing Systems – 1

Supply systems require a safety electrical earthing facility. The manner in which this is effected will depend on whether the supply is overhead or underground and the conductive property of the ground surrounding the installation. Systems are classified in accordance with a letter coding:

First letter – type of earthing:

T – at least one point of the supply is directly earthed.

I – the supply is not directly earthed, but connected to earth through a current limiting impedance. Not acceptable for public supplies in the UK.

Second letter – installation earthing arrangement:

T – all exposed conductive metalwork is directly earthed.

N – all exposed conductive metalwork is connected to an earth provided by the supply company.

Third and fourth letters – earth conductor arrangement:

S – earth and neutral conductors separate.

C – earth and neutral conductors combined.

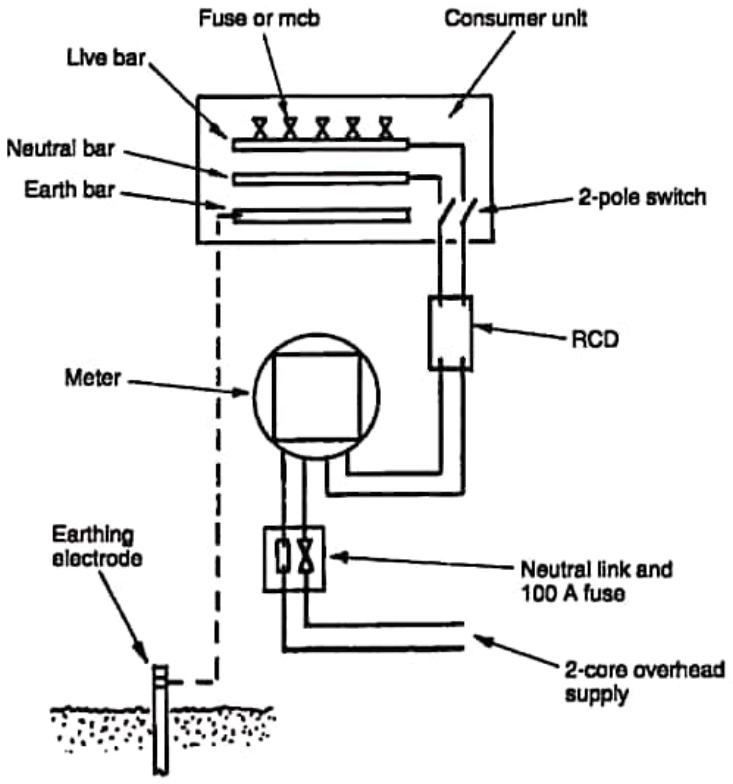
Common supply and earthing arrangements are:

TT (shown below).

TN-S and TN-C-S (shown next page).

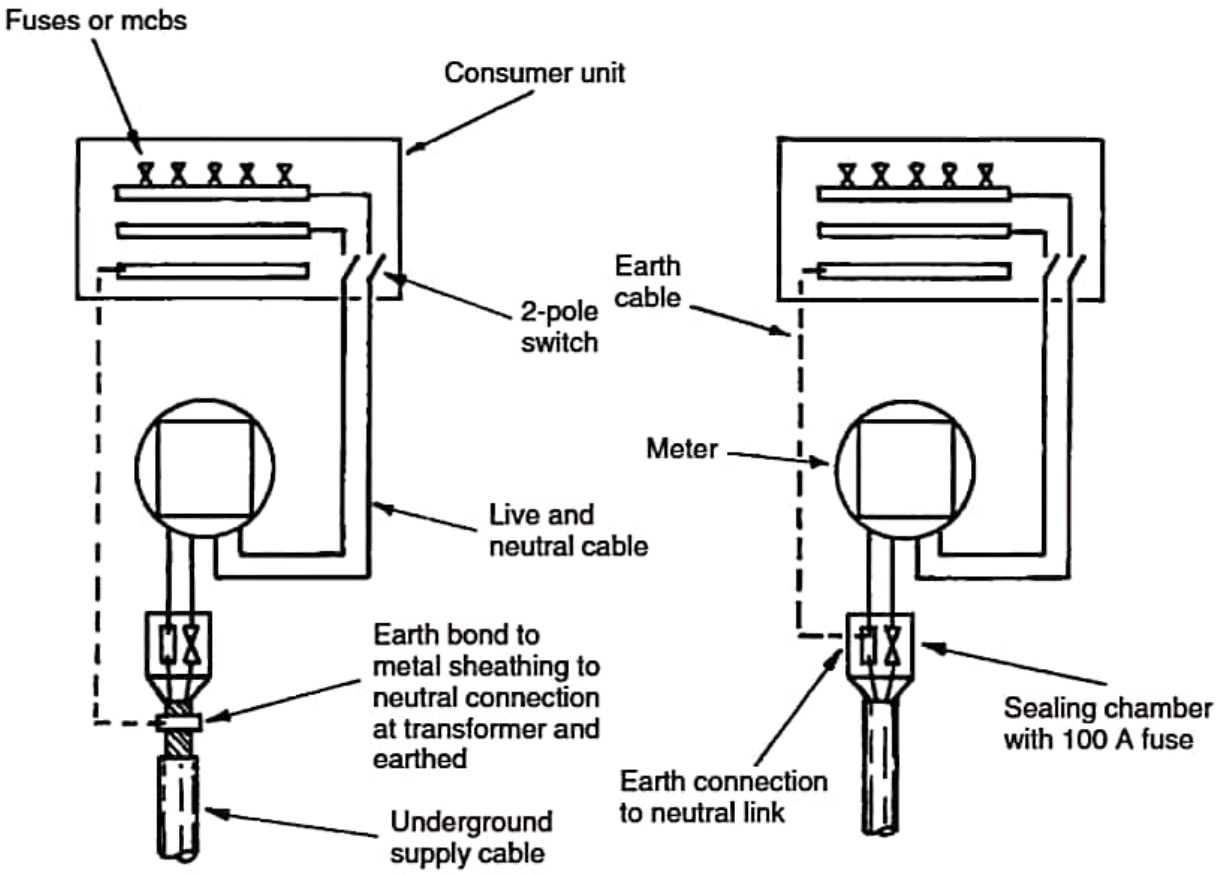
TT system:

Most used in rural areas where the supply is overhead. An earth terminal and electrode is provided on site by the consumer. As an extra safety feature, a residual current device (RCD), generally known as a trip switch, is located between the meter and consumer unit. The RCD in this situation should be of the time delayed type – see page 398.



TN-S system – this is widely used in the UK, with the electricity supply company providing an earth terminal with the intake cable. This is usually the metal sheathing around the cable, otherwise known as the supply protective conductor. It connects back to the star point at the area transformer, where it is effectively earthed.

TN-C-S system – this is as the TN-S system, but a common conductor is used for neutral and earth supply. The supply is therefore TN-C, but with a separated neutral and earth in the consumer's installation it becomes TN-C-S. This system is also known as protective multiple earth (PME). The advantage is that a fault to earth is also a fault to neutral, which creates a high fault current. This will operate the overload protection (fuse or circuit breaker) rapidly.



TN-S system

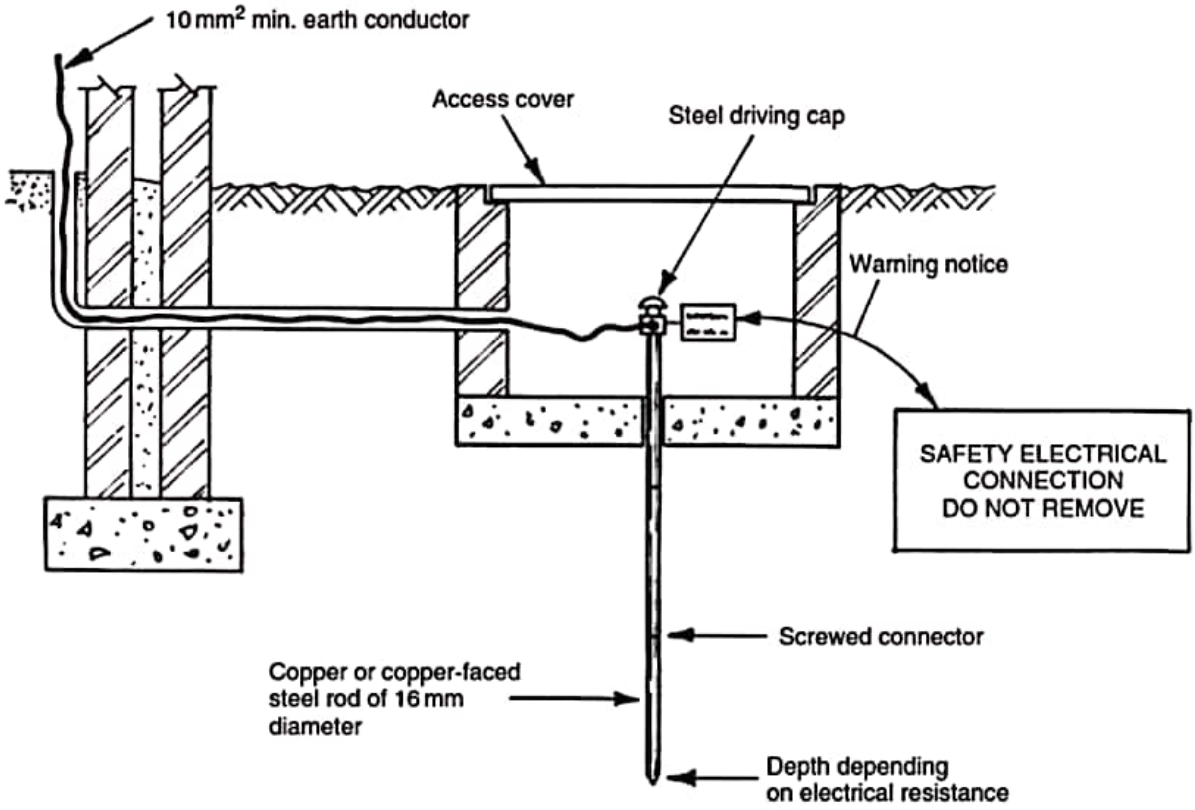
TN-C-S system

Note: Specification of installation cable between supply company's sealing chamber and consumer's unit – phase/live and neutral 25 mm², earth 10 mm² cross-sectional area.

Connection to Earth

Pages 380, 381 and 385 show that the consumer's earth conductor is connected to the neutral and earthed at the local transformer. For below ground supplies this arrangement provides a path of low resistance for an electrical fault. With an overhead supply typical of rural areas, individual consumers must provide a suitable earth terminal or electrode as shown on page 384.

Unless wet, the ground surface is not usually a very good conductor, therefore ground contact is made at about 1·5 to 2 m below the surface. In the past this was achieved by earth bonding to metal water and gas mains. Since the introduction of plastic pipe materials, this is of course no longer acceptable. Current practices include burying a metal plate or a metal tape mesh arranged over several square metres, or driving a metal rod electrode into the ground. The latter is normally adequate for domestic and other small-scale installations. In some instances, the electrode is housed as shown below. Whatever earth method used, a low resistance to an electrical fault is essential. The IEE Wiring Regulations recommend that the earth electrode resistance should not exceed 200 ohms.

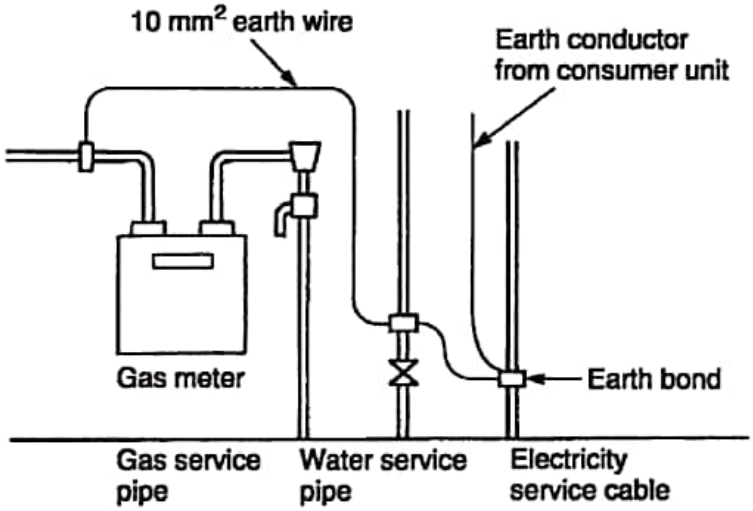


Installation of a housed earth electrode

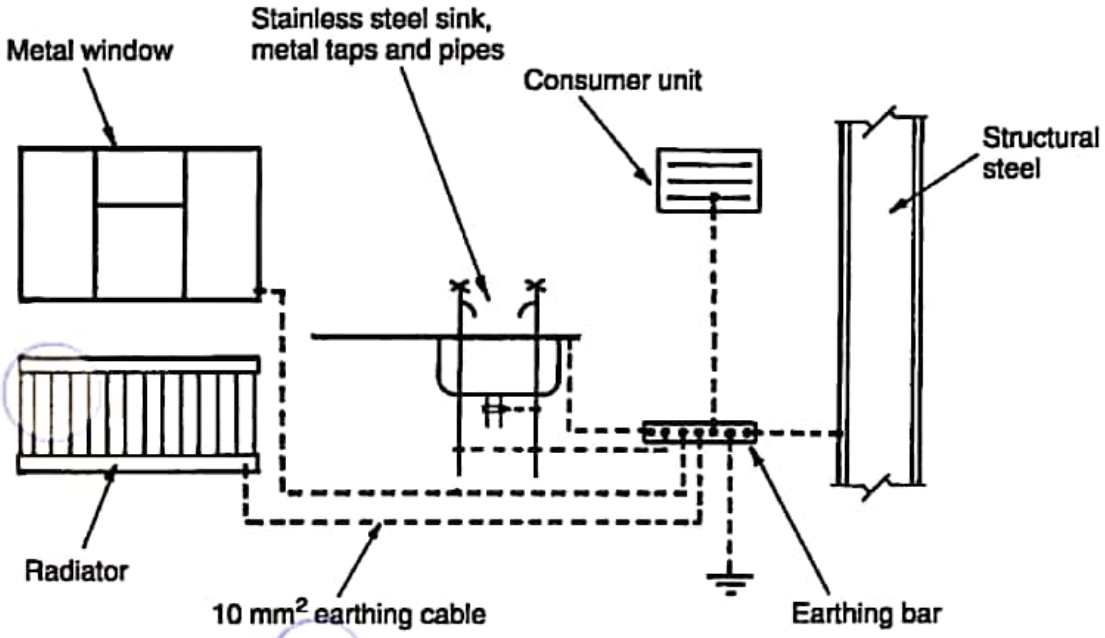
Earth Bonding of Services and Extraneous Metalwork

The Institution of Electrical Engineers (IEE) Wiring Regulations require the metal sheaths and armour of all cables operating at low and medium voltage to be cross-bonded to ensure the same potential as the electrical installation. This includes all metal trunking and ducts for the conveyance and support of electrical services and any other bare earth continuity conductors and metalwork used in conjunction with electrical appliances. The bonding of the services shall be as close as possible to the point of entry of the services into a building. Other fixed metalwork shall be supplementary earth bonded.

Earthing clamp for pipes



Bonding of services at intake

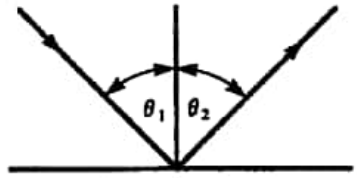


Supplementary bonding of extraneous metalwork

Light and Light Sources – 1

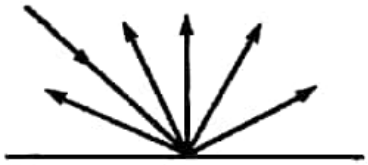
Light is a form of electromagnetic radiation. It is similar in nature and behaviour to radio waves at one end of the frequency spectrum and X-rays at the other. Light is reflected from a polished (specular) surface at the same angle that strikes it. A matt surface reflects in a number of directions and a semi-matt surface responds somewhere between a polished and a matt surface.

Angle of incidence θ_1
Angle of reflection θ_2



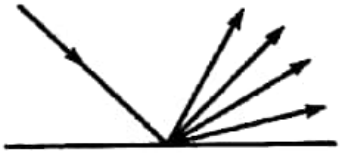
Light reflected from a polished surface

Light is reflected in all directions



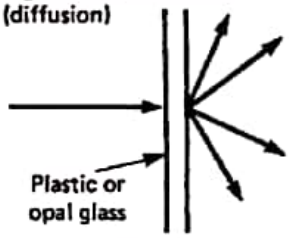
Light reflected from a matt surface

Some light is scattered and some light is reflected directionally



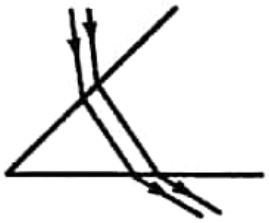
Light scattered and reflected from a semi-matt surface

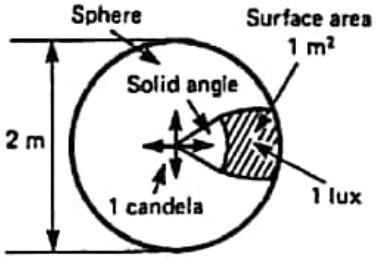
Light is scattered in all directions (diffusion)



Light passing through a diffusing screen

Light is bent or refracted when passing through a surface between two media





Intensity of light and lux

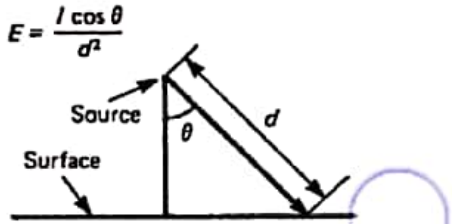
Illumination produced from a light source perpendicular to the surface:

$$E = I \div d^2$$

E = illumination on surface (lux)

I = Illumination intensity from source (cd)

d = distance from light source to surface (m).



Illumination produced from a light source not perpendicular to the surface

Definitions and units of measurement:

- Luminous intensity – candela (cd), a measurement of the magnitude of luminance or light reflected from a surface, i.e. cd/m^2.
- Luminous flux – lumen (lm), a measurement of the visible light energy emitted.
- Illuminance – Lumens per square metre (lm/m^2) or lux (lx), a measure of the light falling on a surface.
- Efficacy – efficiency of lamps in lumens per watt (lm/W). Luminous efficacy = Luminous flux output ÷ Electrical power input.
- Glare index – a numerical comparison ranging from about 10 for shaded light to about 30 for an exposed lamp. Calculated by considering the light source size, location, luminances and effect of its surroundings.

Examples of illumination levels and limiting glare indices for different activities:

Activity/location	Illuminance (lux)	Limiting glare index
Assembly work: (general)	250	25
(fine)	1000	22
Computer room	300	16
House	50 to 300*	n/a
Laboratory	500	16
Lecture/classroom	300	16
Offices: (general)	500	19
(drawing)	750	16
Public house bar	150	22
Shops/supermarkets	500	22
Restaurant	100	22

* Varies from 50 in bedrooms to 300 in kitchen and study.

The Building Regulations, Approved Document L2 requires that non-domestic buildings have reasonably efficient lighting systems and make use of daylight where appropriate.

Ventilation Requirements

Ventilation – a means of changing the air in an enclosed space to:

- Provide fresh air for respiration – approx. 0·1 to 0·2 l/s per person.
- Preserve the correct level of oxygen in the air – approx. 21%.
- Control carbon dioxide content to no more than 0·1%. Concentrations above 2% are unacceptable as carbon dioxide is poisonous to humans and can be fatal.
- Control moisture – relative humidity of 30% to 70% is acceptable.
- Remove excess heat from machinery, people, lighting, etc.
- Dispose of odours, smoke, dust and other atmospheric contaminants.
- Relieve stagnation and provide a sense of freshness – air movement of 0·15 to 0·5 m/s is adequate.

Measures for control:

Health and Safety at Work, etc. Act.
The Factories Act.
Offices, Shops and Railway Premises Act.
Building Regulations, Approved Document F – Ventilation.
BS 5925: Code of practice for ventilation principles and designing for natural ventilation.

The statutes provide the Health and Safety Executive with authority to ensure buildings have suitably controlled internal environments. The Building Regulations and the British Standard provide measures for application.

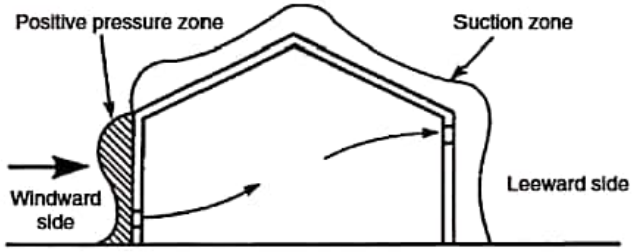
Requirements for an acceptable amount of fresh air supply in buildings will vary depending on the nature of occupation and activity. As a guide, between 10 l/s of outdoor air supply per person can be applied between the extremes of a non-smoking environment, to an extract air rate of 36 l/s per person in a room dedicated specifically for smokers. Converting this to m^3/h (divide by 1000, multiply by 3600), equates to 36 to 130 m^3/h per person.

Air changes per hour or ventilation rate is the preferred criteria for system design. This is calculated by dividing the quantity of air by the room volume and multiplying by the occupancy.

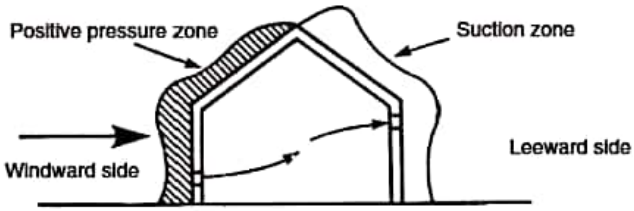
E.g. 50 m^3/h, 100 m^3 office for five persons: 50/100 × 5 = 2·5 a/c per h.

Natural ventilation is an economic means of providing air changes in a building. It uses components integral with construction such as air bricks and louvres, or openable windows. The sources for natural ventilation are wind effect/pressure and stack effect/pressure.

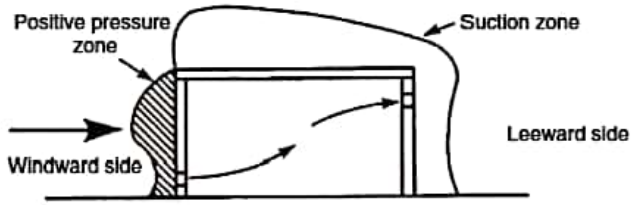
Stack effect is an application of convected air currents. Cool air is encouraged to enter a building at low level. Here it is warmed by the occupancy, lighting, machinery and/or purposely located heat emitters. A column of warm air rises within the building to discharge through vents at high level, as shown on the following page. This can be very effective in tall office-type buildings and shopping malls, but has limited effect during the summer months due to warm external temperatures. A temperature differential of at least 10 K is needed to effect movement of air, therefore a supplementary system of mechanical air movement should be considered for use during the warmer seasons.



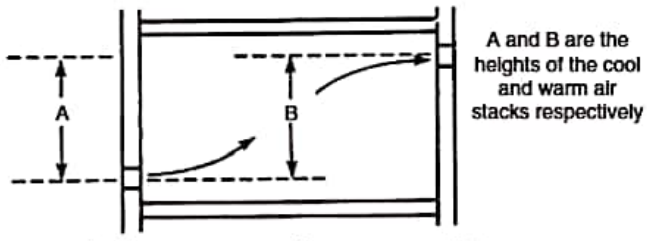
Wind pressure diagram for roofs with pitches up to 30°



Wind pressure diagram for roofs with pitches above 30°



Wind pressure diagram for flat roofs



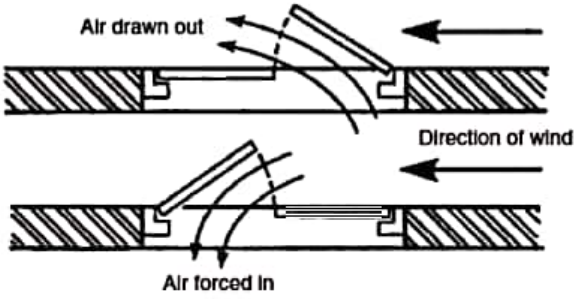
Stack pressure causing cross ventilation

Natural Ventilation – 2

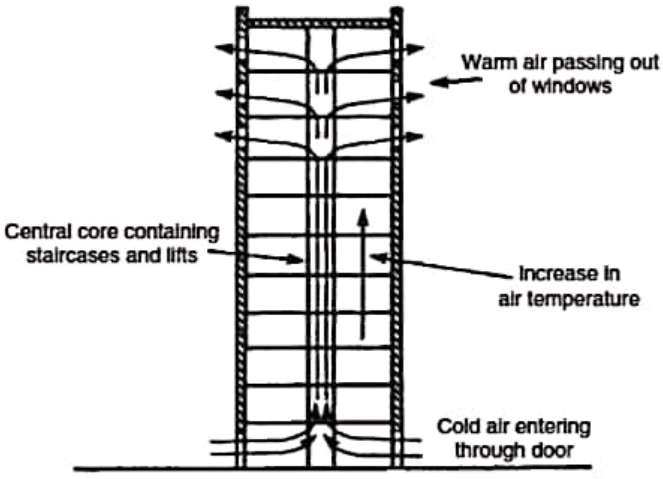
The rates of air change are determined by the building purpose and occupancy, and local interpretation of public health legislation. Public buildings usually require a ventilation rate of 30 m^3 per person per hour.

Wind passing the walls of a building creates a slight vacuum. With provision of controlled openings this can be used to draw air from a room to effect air changes. In tall buildings, during the winter months, the cool more dense outside air will tend to displace the warmer lighter inside air through windows or louvres on the upper floors. This is known as stack effect. It must be regulated otherwise it can produce draughts at low levels and excessive warmth on the upper floors.

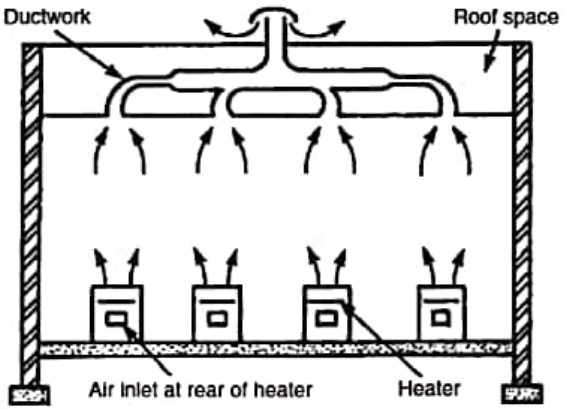
Ventilation and heating for an assembly hall or similar building may be achieved by admitting cool external air through low level convectors. The warmed air rises to high level extract ducts. The cool air intake is regulated through dampers integral with the convectors.



Wind causing ventilation through windows



Stack pressure in a tall building

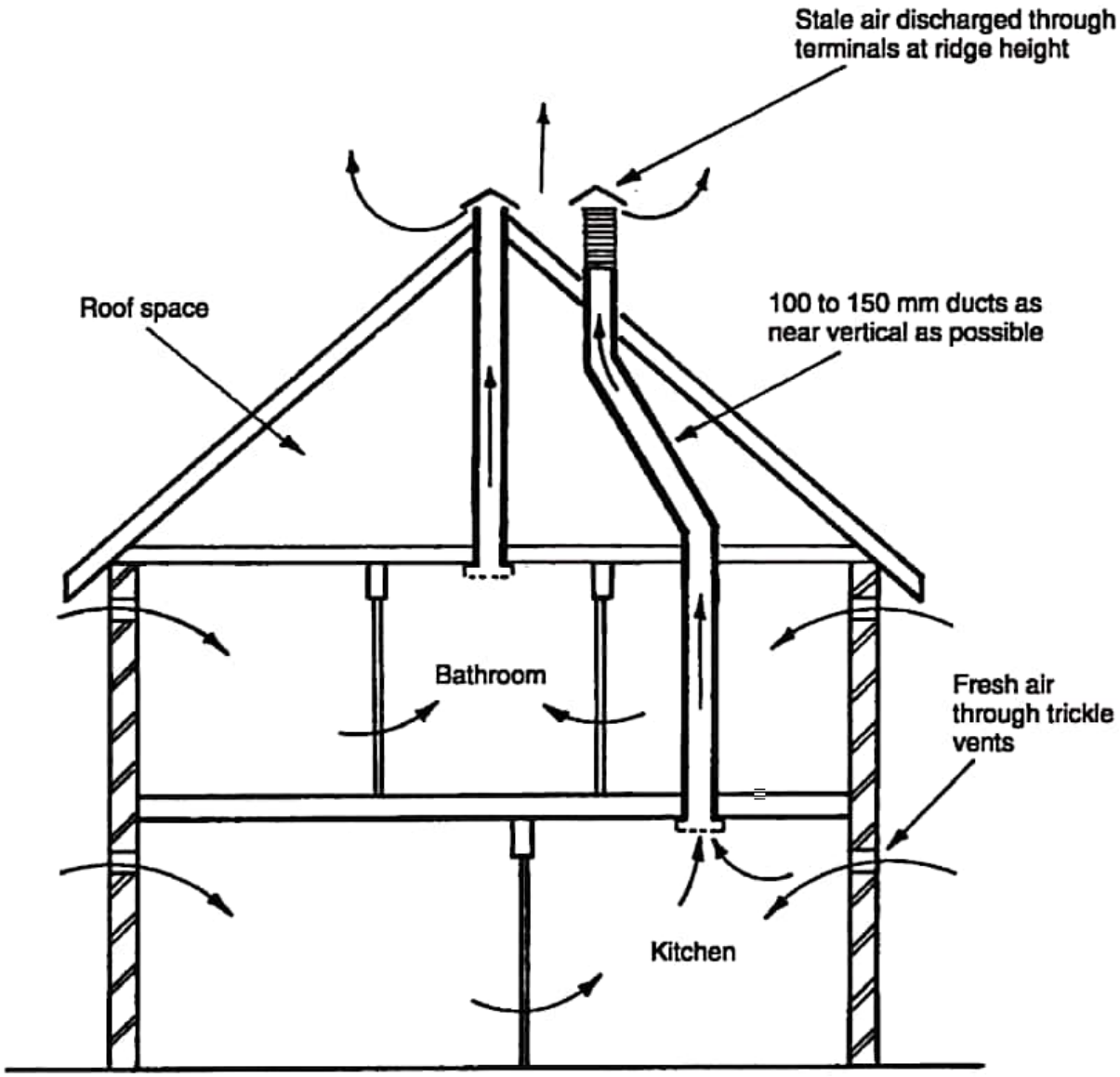


Ventilation for an assembly hall by passing fresh air through heat emitters

Natural Ventilation – Passive Stack Ventilation (PSV)

PSV consists of vertical or near vertical ducts of 100 to 150 mm diameter, extending from grilles set at ceiling level to terminals above the ridge of a roof. Systems can be applied to kitchens, bathrooms, utility rooms and sometimes sanitary accommodation, in buildings up to four storeys requiring up to three stacks/ducts. More complex situations are better ventilated by a Mechanical Assisted Ventilation System (MAVS), see next page.

PSV is energy efficient and environmentally friendly with no running costs. It works by combining stack effect with air movement and wind passing over the roof. It is self-regulating, responding to a temperature differential when internal and external temperatures vary.



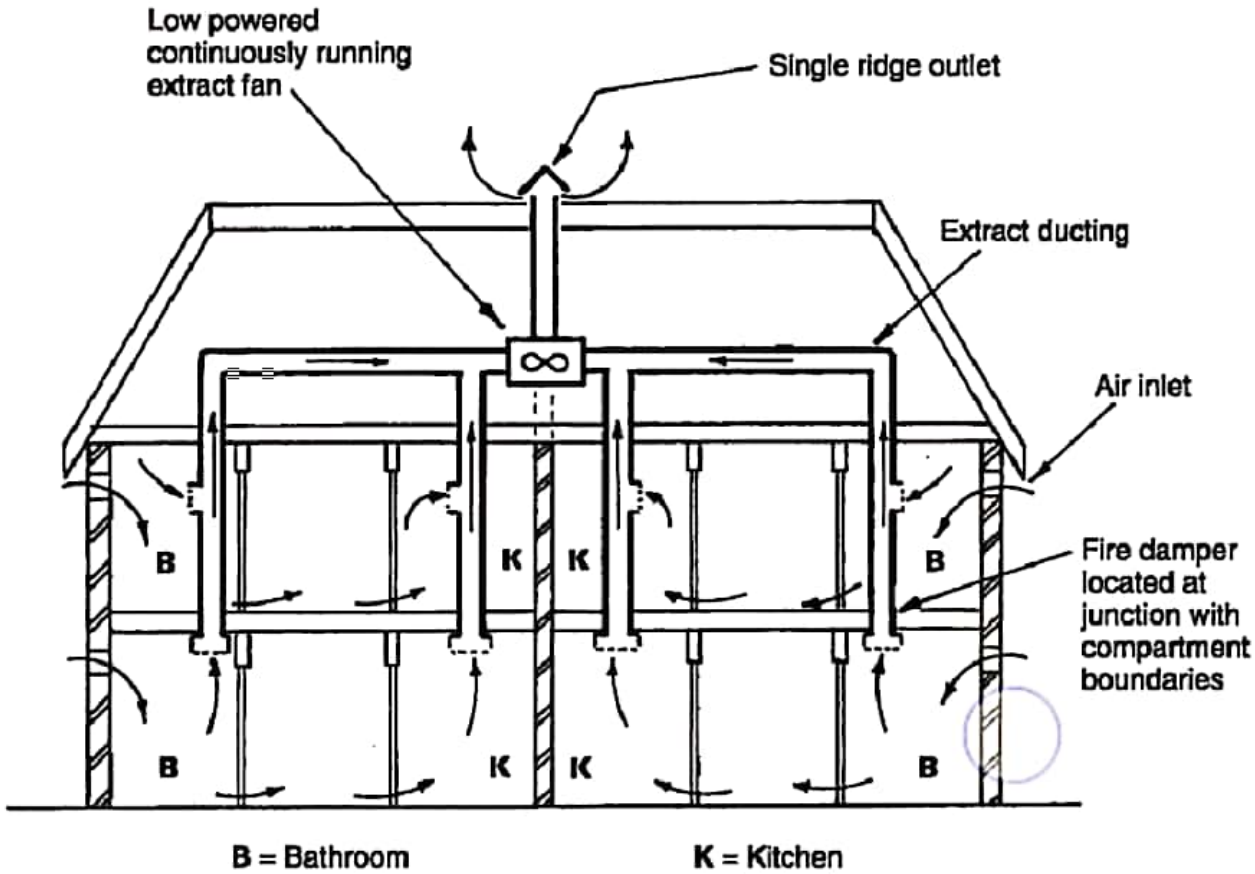
PSV to a dwelling house

Ref.: Building Regulations, Approved Document F1.

Mechanically Assisted Ventilation Systems (MAVS)

MAVS may be applied to dwellings and commercial premises where PSV is considered inadequate or impractical. This may be because the number of individual ducts would be excessive, i.e. too space consuming and obtrusive with several roof terminals. A low powered (40 W) silent running fan is normally located within the roof structure. It runs continuously and may be boosted by manual control when the level of cooking or bathing activity increases. Humidity sensors can also be used to automatically increase air flow.

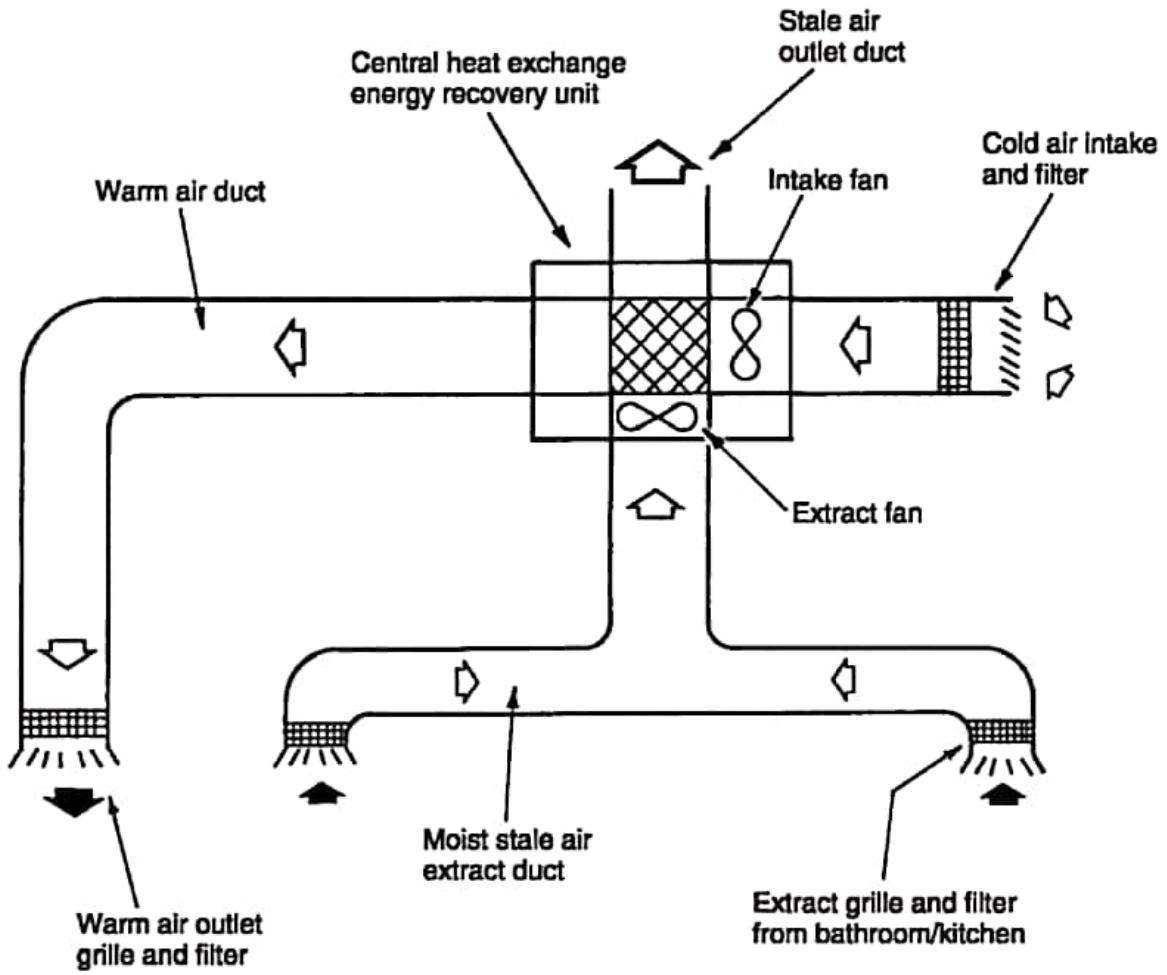
MAVS are acceptable to Approved Document F1 of the Building Regulations as an alternative to the use of mechanical fans in each room. However, both PSV and MAVS are subject to the spread of fire regulations (Approved Document B). Ducting passing through a fire resistant wall, floor or ceiling must be fire protected with fire resistant materials and be fitted with a fusible link automatic damper.



MAVS in a group of flats

Mechanical Ventilation with Heat Recovery (MVHR)

MVHR is a development of MAVS to include energy recovery from the warmth in fan extracted moist air from bathrooms and kitchens. The heat recovery unit contains an extract fan for the stale air, a fresh air supply fan and a heat exchanger. This provides a balanced continuous ventilation system, obviating the need for ventilation openings such as trickle ventilators. Apart from natural leakage through the building and air movement from people opening and closing external doors, the building is sealed to maximise energy efficiency. Up to 70% of the heat energy in stale air can be recovered, but this system is not an alternative to central heating. A space heating system is required and MVHR can be expected to contribute significantly to its economic use. MVHR complies with the 'alternative approaches' to ventilation of dwellings, as defined in Approved Document F1 to the Building Regulations.



Schematic of an MVHR system of ventilation

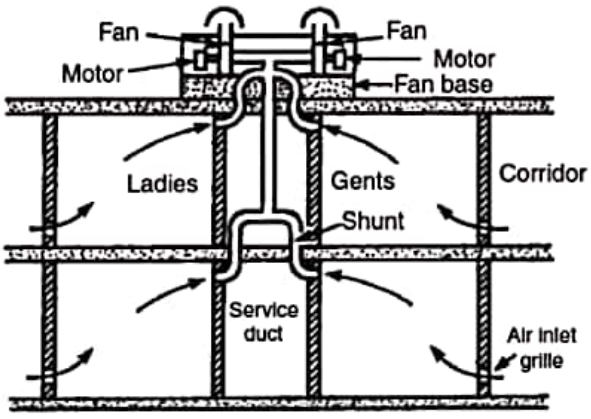
Mechanical Ventilation – 1

Mechanical ventilation systems are frequently applied to commercial buildings, workshops, factories, etc., where the air change requirements are defined for health and welfare provision. There are three categories of system:

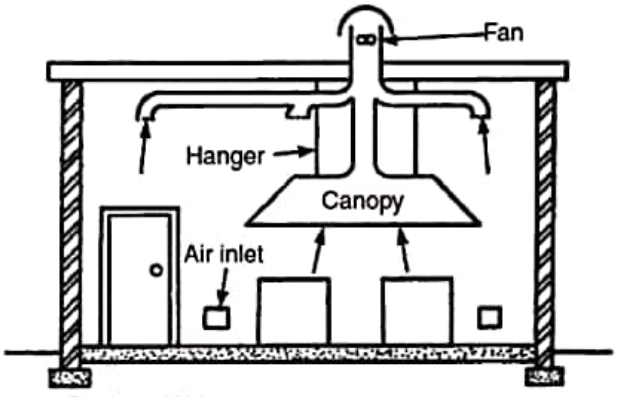
1. Natural inlet and mechanical extract
2. Mechanical inlet and natural extract
3. Mechanical inlet and mechanical extract

The capital cost of installing mechanical systems is greater than natural systems of air movement, but whether using one or more fans, system design provides for more reliable air change and air movement. Some noise will be apparent from the fan and air turbulence in ducting. This can be reduced by fitting sound attenuators and splitters as shown on page 174. Page 180 provides guidance on acceptable noise levels.

Internal sanitary accommodation must be provided with a shunt duct to prevent smoke or smells passing between rooms. In public buildings, duplicated fans with automatic changeover are also required in event of failure of the duty fan.

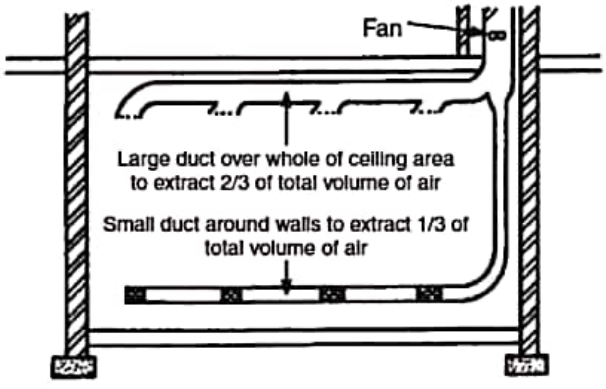


Internal sanitary accommodation



Canteen kitchen

Basement car parks require at least 6 air changes per hour and at exits and ramps where queuing occurs, local ventilation of at least 10 air changes per hour. Duplicate fans should be provided with a fan failure automatic change over.



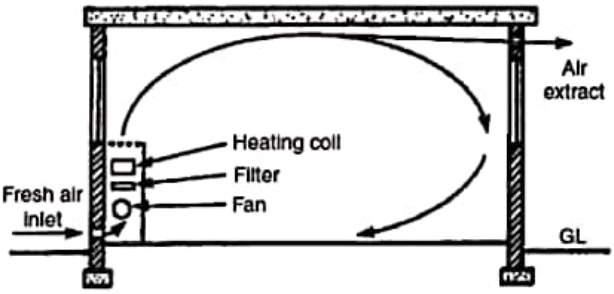
Basement car park

Fan assisted ventilation systems supplying external air to habitable rooms must have a facility to pre-heat the air. They must also have control over the amount of air extracted, otherwise there will be excessive heat loss. A mechanical inlet and mechanical extract system can be used to regulate and balance supply and emission of air by designing the duct size and fan rating specifically for the situation.

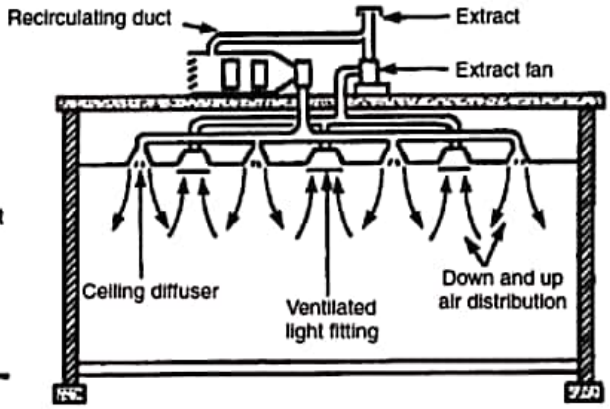
Air may be extracted through specially made light fittings. These permit the heat enhanced air to be recirculated back to the heating unit. This not only provides a simple form of energy recovery, but also improves the light output by about 10%. With any form of recirculated air ventilation system, the ratio of fresh to recirculated air should be at least 1:3. i.e. min. 25% fresh, max. 75% recirculated.

In large buildings where smoking is not permitted, such as a theatre, a downward air distribution system may be used. This provides a uniform supply of warm filtered air.

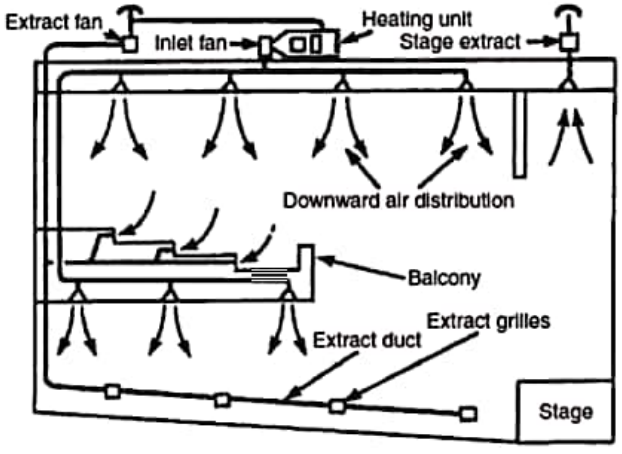
Ductwork in all systems should be insulated to prevent heat losses from processed air and to prevent surface condensation.



Mechanical inlet and natural extract



Mechanical inlet and mechanical extract for an open plan office or supermarket



Mechanical inlet and mechanical extract for a theatre

Ventilation System Heating Load

When designing ventilation systems, provision must be made for the displacement of heat energy resulting from the movement of air. This is necessary for maintenance of the building or room ambient temperature. Also, to prevent cold draughts and condensation.

Cold supply air is pre-heated to discharge at the same temperature as the design air temperature for the room served. This will have no real effect on any separate heating system and can be regulated independently by a control thermostat. The following formula can be used to establish the ducted air heater rating in kW, relative to design temperature parameters:

Heater rating = m × Shc × Temp. diff. (int. – ext.)

Where:

m = mass air flow rate (kg/s)

Shc = Specific heat capacity of air (1·0 kJ/kg K)

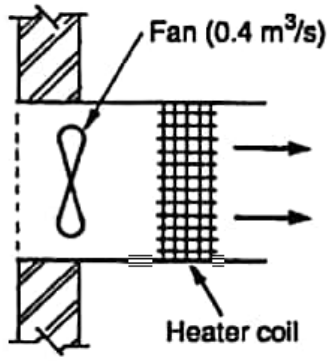
Temp. diff. = Temperature differential between internal room air and external supply air (K)

Air flow rate by volume (Q) is calculated in m^3/s. To convert this to mass air flow rate in kg/s, the volume rate is multiplied by air density (ρ) of 1·2 kg/m^3.

Therefore:

Heater rating = Q × ρ × Shc × Temp. diff. (int. – ext.)

For example, a room with total fabric and infiltration heat losses of 3 kW (see method of calculation on page 125), with air supply and temperature design factors as given below:



Air duct heater calculation

Heater rating = 0·4 × 1·2 × 1·0 × (22 – –4)
= 12·48 kW

Therefore if the ducted air is required to supply all heating needs, then 12·48 kW is added to the room losses of 3 kW, bringing the total heat input to 15·48 kW. If the ducted air system is to provide for the design room heat loss of 3 kW, the discharge air temperature (T) can be found by rewriting the formula:

Room heat losses = Q × ρ × Shc × (T – int. air temp.)

Or: T = [Room heat losses ÷ (Q × ρ × Shc)] + 22

T = [3 ÷ (0·4 × 1·2 × 1·0)] + 22 = 28·25°C

Roping Systems for Electric Lifts – 1

High tensile steel ropes are used to suspend lift cars. They have a design factor of safety of 10 and are usually at least four in number. Ropes travel over grooved driving or traction sheaves and pulleys. A counterweight balances the load on the electric motor and traction gear.

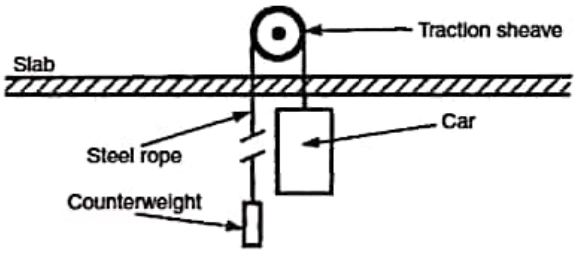
Methods for roping vary:

Single wrap 1:1 – the most economical and efficient of roping systems but is limited in use to small capacity cars.

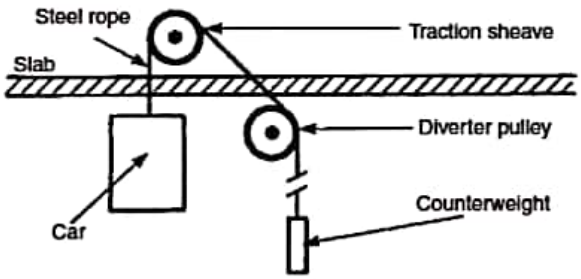
Single wrap 1:1 with diverter pulley – required for larger capacity cars. It diverts the counterweight away from the car. To prevent rope slip, the sheave and pulley may be double wrapped.

Single wrap 2:1 – an alternative for use with larger cars. This system doubles the load carrying capacity of the machinery but requires more rope and also reduces the car speed by 50%.

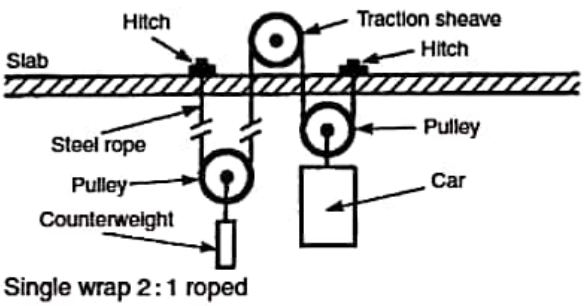
Double wrap – used to improve traction between the counterweight, driving sheave and steel ropes.



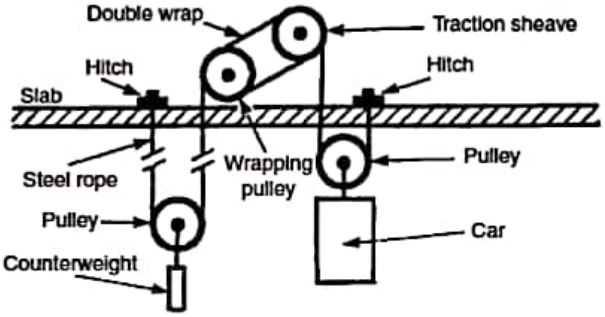
Single wrap 1 : 1 roped



Single wrap 1 : 1 roped with diverter pulley



Single wrap 2 : 1 roped

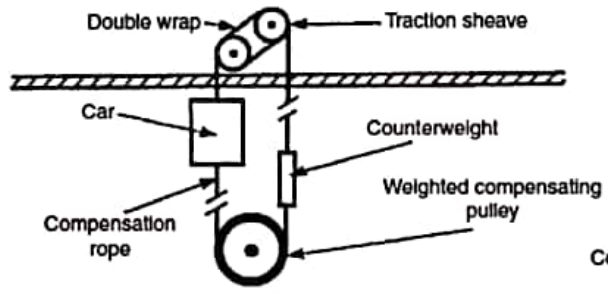


Double wrap 2 : 1 roped (for high speed and medium to heavy duty loads)

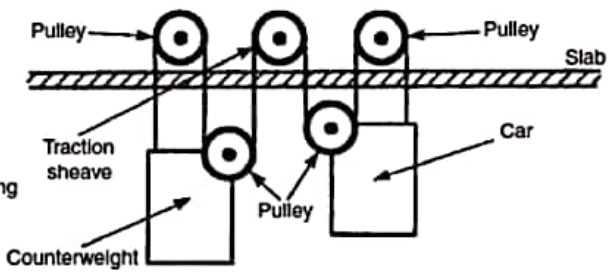
Single wrap 3:1 – used for heavy goods lifts where it is necessary to reduce the force acting upon the machinery bearings and counterweight. The load carrying capacity is increased by up to three times that of uniform ratio, but the capital costs are higher with increased pulleys and greater length of rope. By comparison, the car speed is also reduced to one-third.

Drum drive – a system with one set of ropes wound clockwise around the drum and another set anti-clockwise. It is equally balanced, as one set unwinds the other winds. The disadvantage of the drum drive is that as height increases, the drum becomes less controllable, limiting its application to rises of about 30 m.

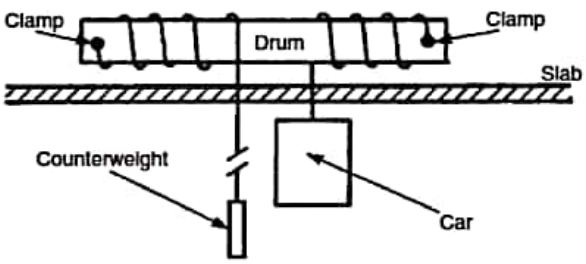
Compensating rope and pulley – used in tall buildings where the weight of the ropes in suspension will cause an imbalance on the driving gear and also a possible bouncing effect on the car. The compensating ropes attach to the underside of car and counterweight to pass around a large compensating pulley at low level.



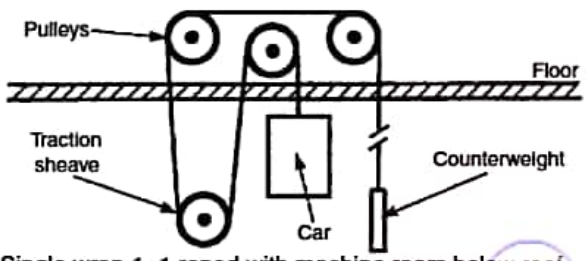
Double wrap 1 : 1 roped with compensating rope



Single wrap 3 : 1 roping



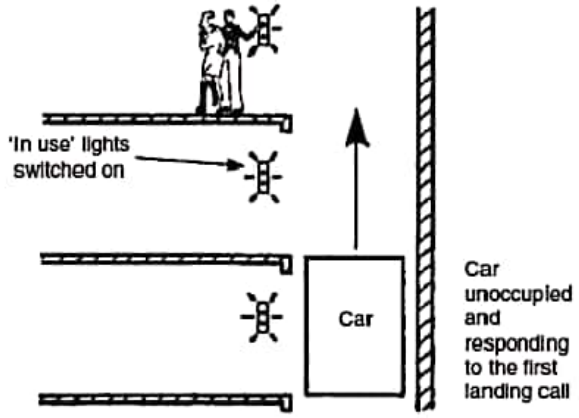
Drum drive



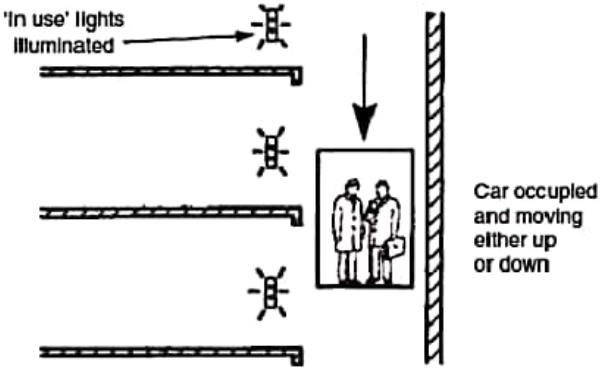
Single wrap 1 : 1 roped with machine room below roof level. The length of rope is increased which limits the travel and speed of car

Single Automatic Lift Control

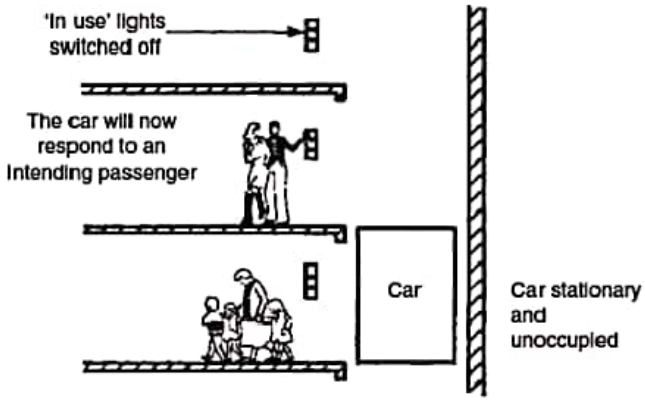
The single automatic push button system is the simplest and least sophisticated of controls. The lift car can be called and used by only one person or group of people at a time. When the lift car is called to a floor, the signal lights engraved 'in use' are illuminated on every floor. The car will not respond to any subsequent landing calls, nor will these calls be recorded and stored. The car is under complete control of the occupants until they reach the required floor and have departed the lift. The 'in use' indicator is now switched off and the car is available to respond to the next landing call. Although the control system is simple and inexpensive by comparison with other systems, it has its limitations for user convenience. It is most suited to light traffic conditions in low rise buildings such as nursing homes, small hospitals and flats.



Lift car called to a floor. 'In use' lights switched on



Lift car in control of occupant and cannot be called by other passengers

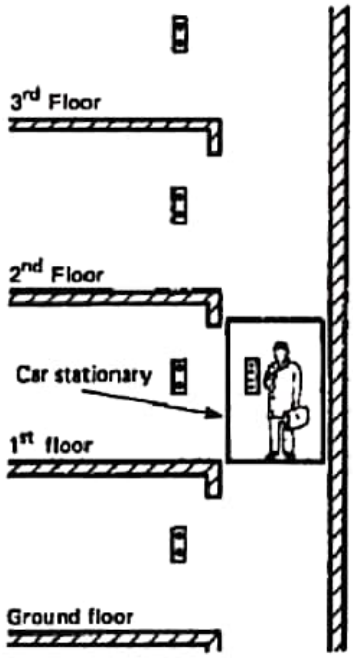


Lift car vacated. 'In use' lights switched off. Lift can now be called by other passengers

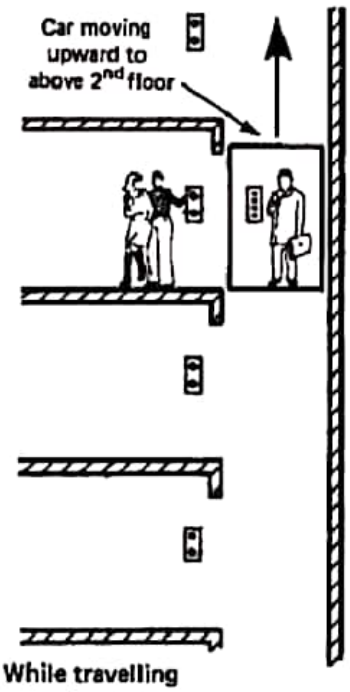
Ref. BS 5655-7: Lifts and service lifts. Specification for manual control devices, indicators and additional fittings.

Down Collective Lift Control

Down collective - stores calls made by passengers in the car and those made from the landings. As the car descends, landing calls are answered in floor sequence to optimise car movement. If the car is moving upwards, the lift responds to calls made inside the car in floor sequence. After satisfying the highest registered call, the car automatically descends to answer all the landing calls in floor sequence. Ony one call button is provided at landings. This system is most suited to flats and small hotels, where the traffic is mainly between the entrance lobby and specific floors.

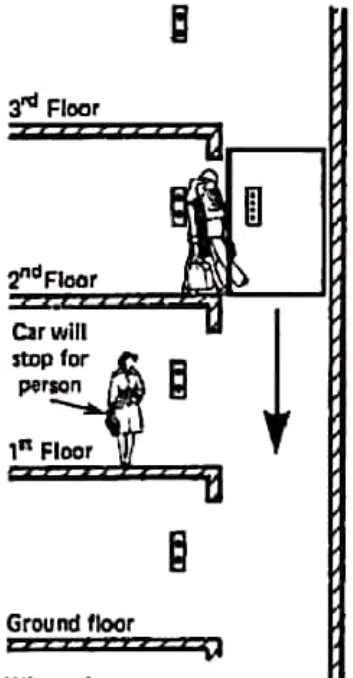


Passenger enters the car and press buttons to travel upwards

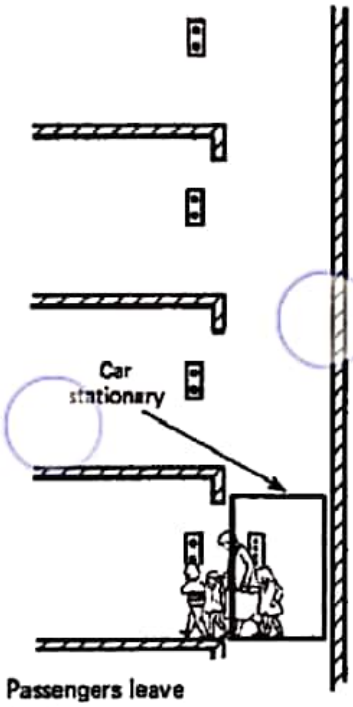


While travelling upwards all the landing calls are by-passed

Full or directional collective - a variation in which car and landing calls are immediately stored in any number. Upward and downward intermediate landing calls are registered from one of two directional buttons. The uppermost and lowest floors only require one button. The lift responds to calls in floor order independent of call sequence, first in one direction and then the other. It has greater flexibility than the down collective system and is appropriate for offices and departmental stores where there is more movement between intermediate floors.



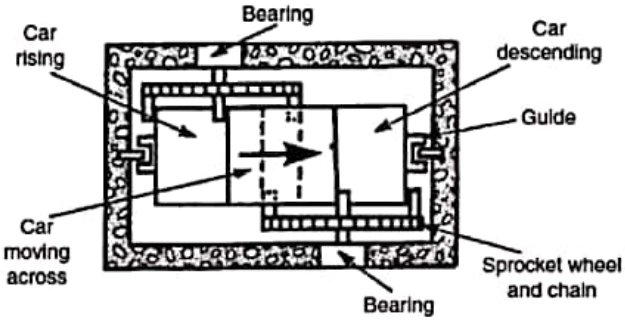
When the car moves down all landing calls are collected floor by floor



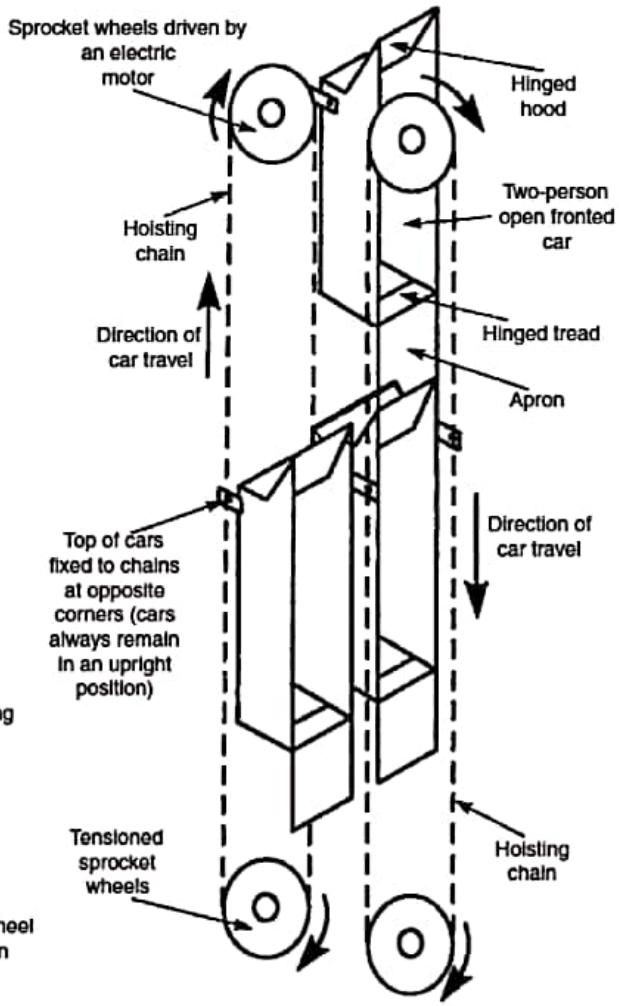
Passengers leave the car

Paternoster Lifts

A paternoster consists of a series of open fronted two-person cars suspended from hoisting chains. Chains run over sprocket wheels at the top and bottom of the lift shaft. The lift is continuously moving and provides for both upward and downward transportation of people in one shaft. Passengers enter or leave the car while it is moving, therefore waiting time is minimal. Passengers will have to be fairly agile, which limits this type of installation to factories, offices, universities, etc. It is not suitable in buildings that accommodate the infirm or elderly! When a car reaches its limit of travel in one direction, it moves across to the adjacent set of hoisting chains to engage with car guides and travel in the other direction. In the interests of safety, car speed must not exceed 0·4 m/s.



Plan of lift at top changeover



View of installation

Paternosters convey about 600 persons per hour. This type of lift has the advantage of allowing passengers to begin their journeys undelayed, regardless of travel direction. Simplicity of control gear adds to the advantages, resulting in fewer breakdowns by eliminating normal processes of stopping, starting, accelerating and decelerating. They are most suited to medium-rise buildings.

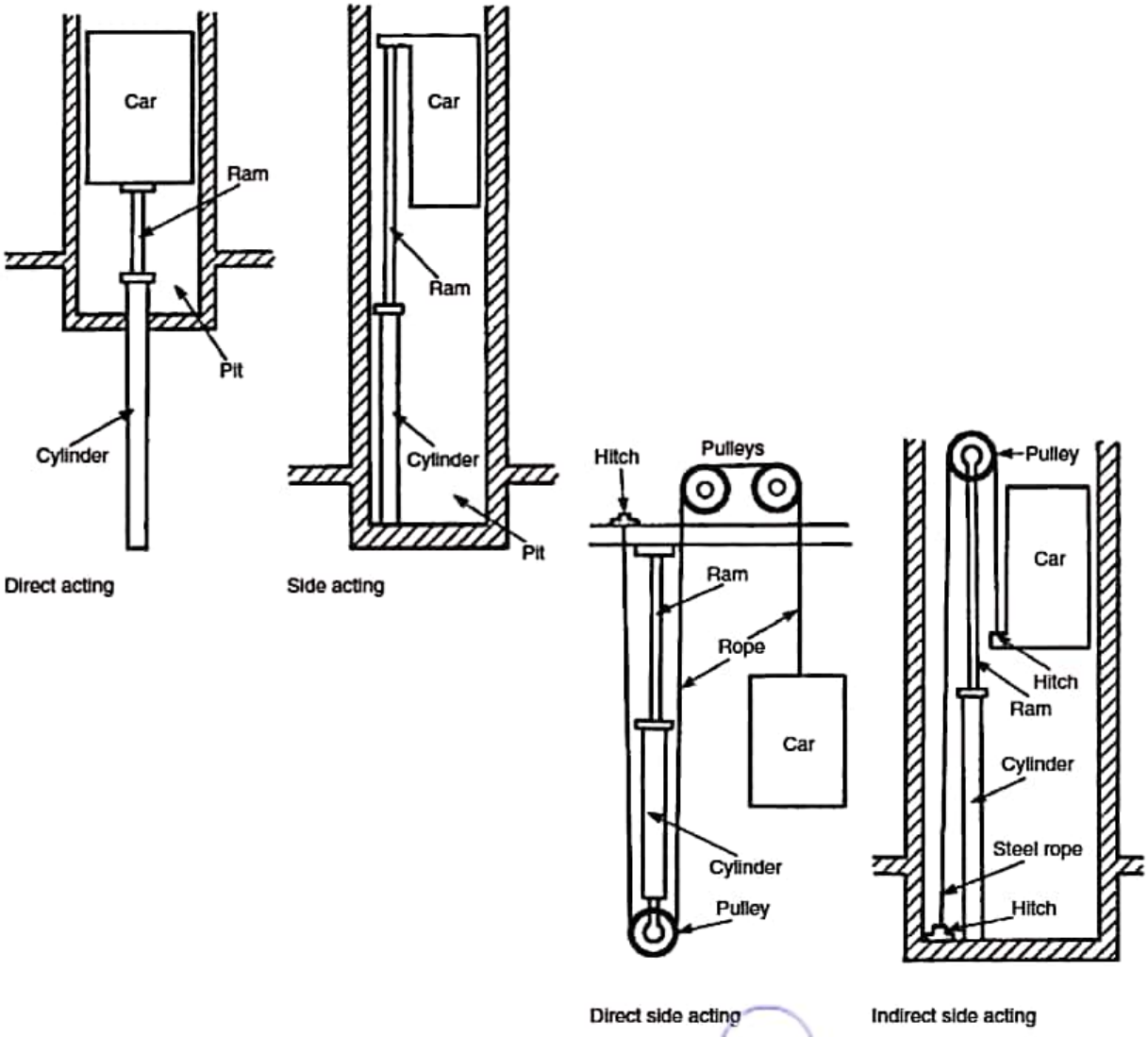
Oil-hydraulic Lifting Arrangements

Direct acting – the simplest and most effective method, but it requires a borehole below the pit to accommodate the hydraulic ram. The ram may be one piece or telescopic. In the absence of a counterweight, the shaft width is minimised. This will save considerably on construction costs and leave more space for general use.

Side acting – the ram is connected to the side of the car. For large capacity cars and heavy goods lifts, two rams may be required, one each side of the car. A borehole is not necessary, but due to the cantilever design and eccentric loading of a single ram arrangement, there are limitations on car size and load capacity.

Direct side acting – the car is cantilevered and suspended by a steel rope. As with side acting, limitations of cantilever designs restrict car size and payload. Car speed may be increased.

Indirect side acting – the car is centrally suspended by a steep rope and the hydraulic system is inverted.



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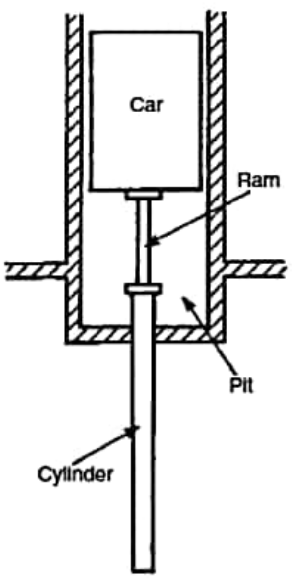
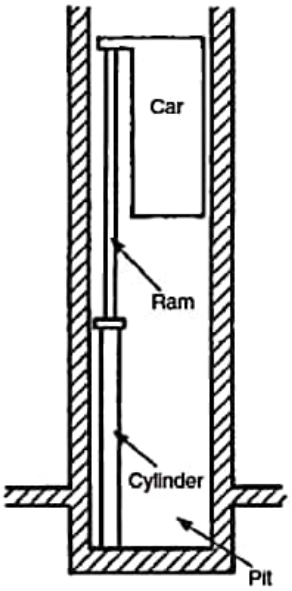
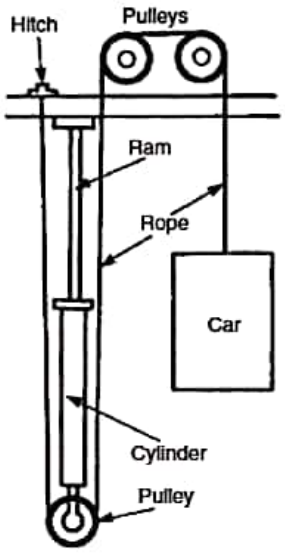


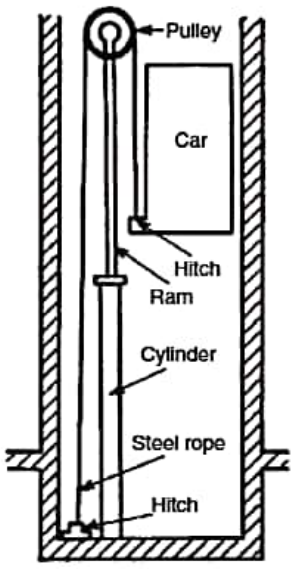
Direct acting



Side acting



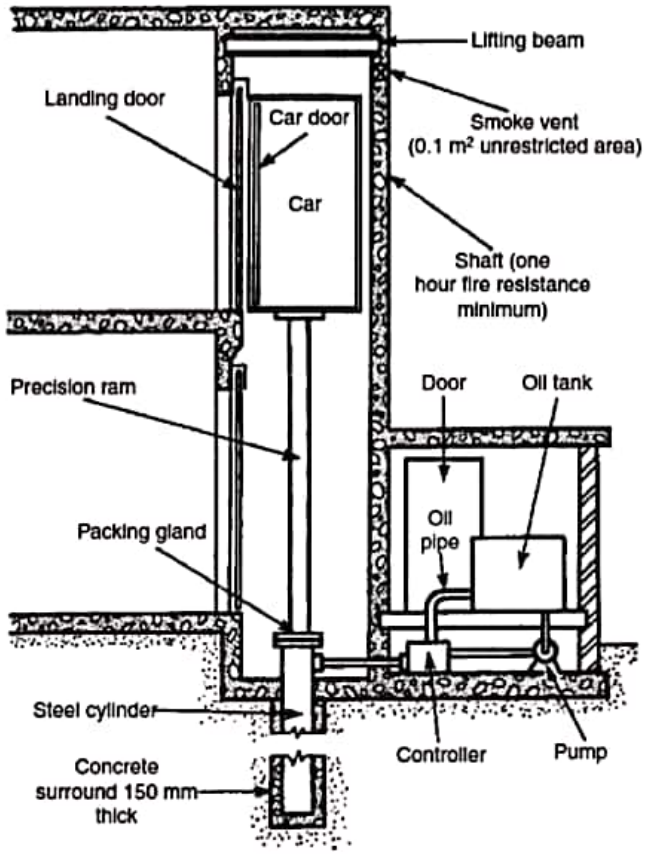
Direct side acting



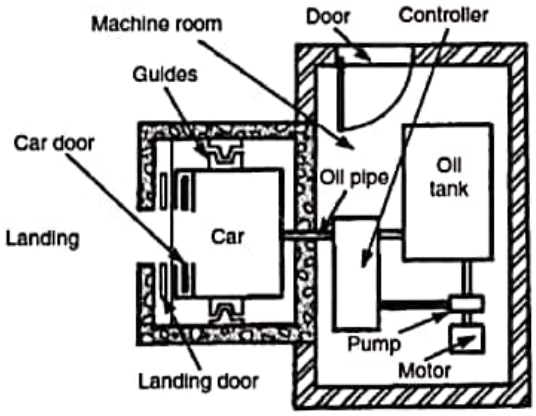
Indirect side acting

Details of Oil-hydraulic Lift Installation

Originally, hydraulic lifts used mains water supply as the operating medium. The main was pressurised from a central pumping station to service lift installations in several buildings. The oil-hydraulic system has oil pressure fed by a pump into a cylinder to raise the ram and lift car. Each lift has its own pumping unit and controller. These units are usually sited at or near to the lowest level served, no more than 10 m from the shaft. The lift is ideal in lower rise buildings where moderate speed and smooth acceleration is preferred. Car speed ranges from 0·1 to 1 m/s and the maximum travel is limited to about 21 m. The lift is particularly suitable for goods lifts and for hospitals and old people's homes. Most hydraulic lifts carry the load directly to the ground, therefore as the shaft does not bear the loads, construction is less expensive than for a comparable electric lift installation.



Vertical section



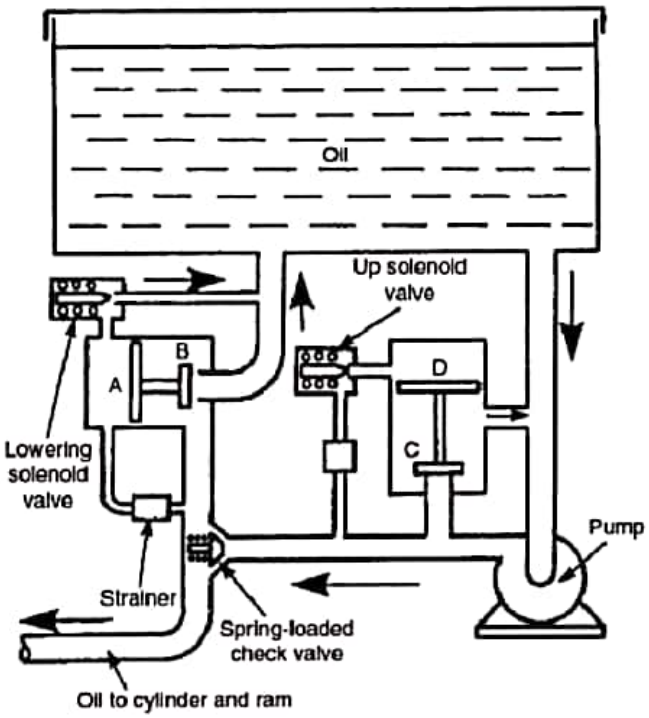
Plan

BS 5655-10·2 provides specific guidance for the testing and examination of hydraulic lifts.
See also BS EN 81-2 for safety rules applied to constructing and installing hydraulic lifts.

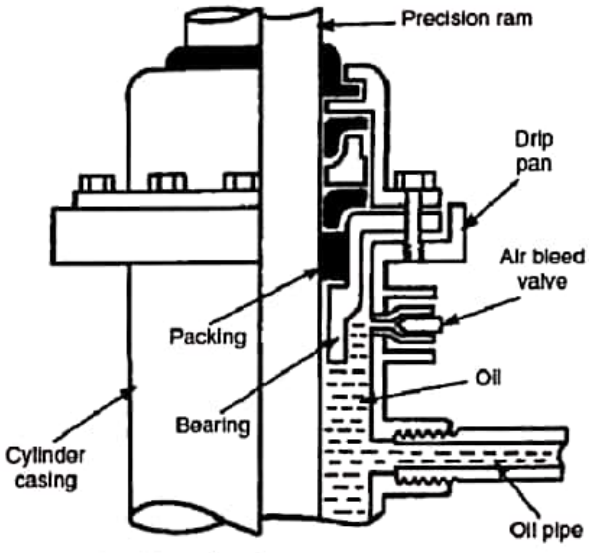
Upward movement – the oil pressure must be gradually increased. The up solenoid valve is energised by an electric current and opens to allow oil to enter above piston D. As the area of piston D is greater than valve C, the oil pressure closes the valve and allows high pressure oil to flow to the cylinder and lift the ram and the car.

Downward movement – the oil pressure must be gradually decreased. The lowering solenoid valve is energised by an electric current and opens allowing oil to flow back to the tank through the by-pass. As the area of piston A is greater than valve B, the reduced oil pressure behind the piston allows valve B to open. Oil flows into the tank and the car moves downwards.

A special packing gland with several seals is required between the cylinder and ram.



Oil tank, pump and controls

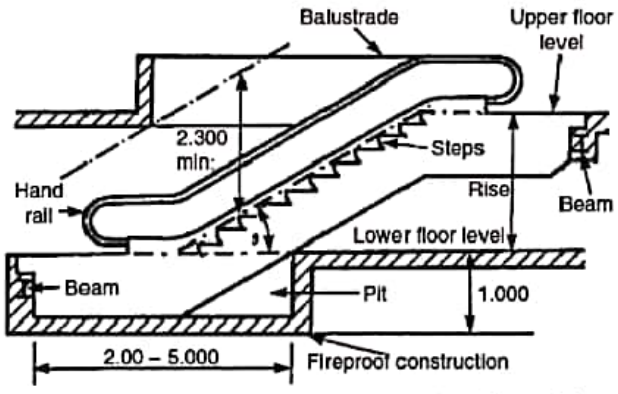


Detail of packing gland

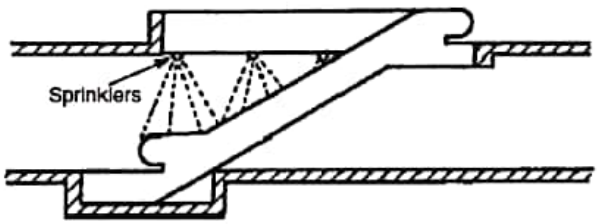
Escalators are moving stairs used to convey people between floor levels. They are usually arranged in pairs for opposing directional travel to transport up to 12 000 persons per hour between them.

The maximum carrying capacity depends on the step width and conveyor speed. Standard steps widths are 600, 800 and 1000 mm, with speeds of 0·5 and 0·65 m/s. Control gear is less complex than that required for lifts as the motor runs continuously with less load variations. In high rise buildings space for an escalator is unjustified for the full height and the high speed of modern lifts provides for a better service.

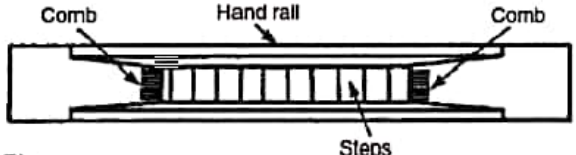
To prevent the exposed openings facilitating fire spread, a water sprinkler installation (see Part 12) can be used to automatically produce a curtain of water over the well. An alternative is a fireproof shutter actuated from a smoke detector or fusible links.



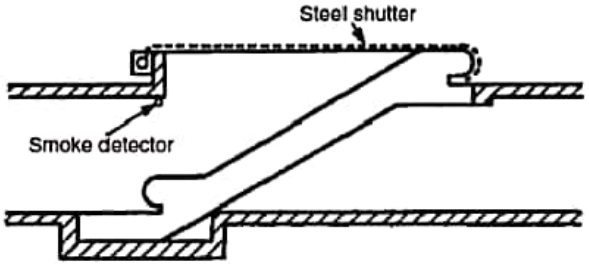
Elevation



Water curtain



Plan

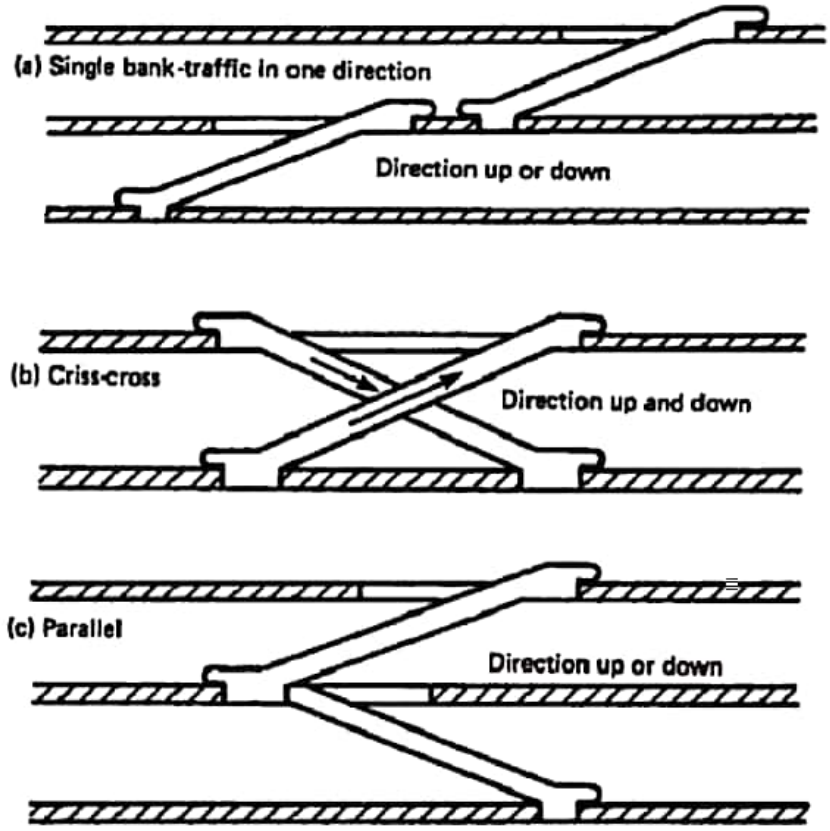


Fireproof sliding shutter

Escalator Arrangements and Capacity

Escalator configurations vary depending on the required level of service. The one-directional single bank avoids interruption of traffic, but occupies more floor space than other arrangements.

A criss-cross or cross-over arrangement is used for moving traffic in both directions.



Escalator arrangements

Escalator capacity formula to estimate the number of persons (N) moved per hour:

$$N = \frac{3600 \times P \times V \times \text{cosine}\,\theta}{L}$$

where: P = number of persons per step
V = speed of travel (m/s)
θ = angle of incline
L = length of each step (m).

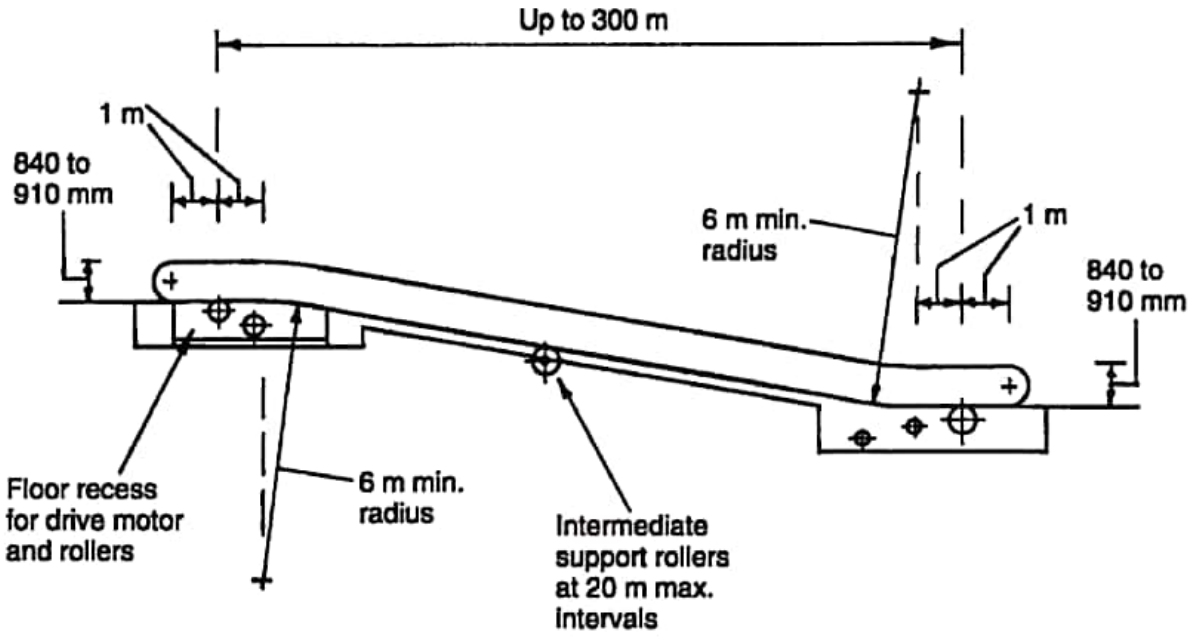
E.g. an escalator inclined at 35°, operating with one person per 400 mm step at 0·65 m/s.

$$N = \frac{3600 \times 1 \times 0{\cdot}65 \times 0{\cdot}8192}{0{\cdot}4} = 4792 \text{ persons per hour}$$

Travelators – also known as autowalks, passenger conveyors and moving pavements. They provide horizontal conveyance for people, prams, luggage trolleys, wheelchairs and small vehicles for distances up to about 300 metres. Slight inclines of up to 12° are also possible, with some as great as 18°, but these steeper pitches are not recommended for use with wheeled transport.

Applications range from retail, commercial and store environments to exhibition centres, railway and airport terminals. Speeds range between 0·6 and 1·3 m/s, any faster would prove difficult for entry and exit. When added to walking pace, the overall speed is about 2·5 m/s.

There have been a number of experiments with different materials for the conveyor surface. These have ranged from elastics, rubbers, composites, interlaced steel plates and trellised steel. The latter two have been the most successful in deviating from a straight line, but research continues, particularly into possibilities for variable speed lanes of up to 5 m/s. However, there could be a danger if bunching were to occur at the exit point.



Capacity 6500 to 10 800 persons per hour

Typical inclined travelator

PART-D

6.Construction and earth moving equipments

PART-D

6.Construction and Earth moving equipments

INTRODUCTION

- Construction equipments are one of the very important resource of modern-day construction, especially in infrastructure projects.
- In such projects equipments are used for most of the works including earth moving operation, aggregate production, concrete production and its placement etc. In fact, we cannot think of any major construction activity without the involvement of construction equipment.
- There are types of construction equipments suitable for different activities in a construction project.
- The selection of construction equipment defines the construction method, which in a way leads to the determination of time and cost for the project.
- For selecting the right equipment to perform a specific task at the least cost, it is essential to know the features of a construction equipment including its rate of production and the associated cost to operate the equipment.
- While dealing with the construction stage, selection of the most suitable equipment is a very typical problem which is generally faced by the construction engineers or contractors.
- A contractor may not afford to have all types or sizes of equipment which are required for execution of the projects.
- Choice is made after considering many factors like nature of the project, cost of equipment, depreciation, possibility of its future uses on other projects, its resale value after certain period, the saving expected from the use of such equipments etc.

CLASSIFICATION OF CONSTRUCTION EQUIPMENTS

Construction equipments can be classified into many ways.

1. Basis of function of equipment – for example, material loading function, material – transporting function etc.

   On the basis of functions equipments can be grouped into

   (a) Power Units

   (b) Prime movers

   (c) Tractors

   (d) Material-Handelling equipment

   (e) Material-processing equipment

2. Basis of Operation of equipment:
   (a) Equipments used for moving and loosening the materials found in their natural state eg– pumps, excavators, earth moving, trenchers, compressors etc.
   (b) Equipments used for processing the materials, for example aggregate, concrete and asphalt production.
   (c) Equipments used for transporting the processed materials
   (d) Equipments used for placing finish materials.
3. Basis of purpose of equipment
   (a) **General Purpose** : Earthwork equipment, Hoisting, Concreting.
   (b) **Special equipments** : Piling rig, coffer dams, tunnel boring machine, caissons equipments etc.

SELECTION OF CONSTRUCTION EQUIPMENT

- For speedy and economic construction of a project, proper choice of equipment is of primary importance.
- The problem of proper selection is further complicated because of the wide range of equipment commercially available.
- Following factors must be considered before having a final choice

1. Use of Existing Equipment

- When the full utilization of new equipment for the future projects is uncertain, it may be desirable to use existing old equipment even if its operation is somewhat more expensive.
- Depreciation cost of the new machine is likely to be high, and this would raise the owning cost of the equipment and hence the unit cost of work.

2. Availability of the Equipment

- The equipment which is easily available in the market should be selected for the purpose because any delay in delivery may increase the construction cost, repairing of such equipments will also be done easily.

3. Use of Standard Equipment

- Standard equipment is commonly manufactured in large numbers and hence these are readily available and moderately priced.
- Spare parts of standard equipment are easily available and are less costly.
- After the work is over, Selling off standard equipment and its spare parts is generally easier than in comparison to non-standard or specialized equipment.

4. Country of Origin

- It is always suggestable to buy equipment from own country because this will decrease the repair cost and downtime cost and at the same time it will boost up nation's economy.
- For imported equipment, it is preferable to import from a soft currency rather from a hard currency country, to save foreign currency reserves.

5. Suitability for Future Use

- If a machine is required only for some part of its use full life, then ways to disposed off or its deployment on some other site should be considered.
- Obsolescence of the machine should not be overlooked.

6. Suitability for Site Conditions

- The equipment chosen should suit the conditions of the job, soil, valley, working conditions and climate of the region.

7. Size of Equipment

- Larger equipment give higher outputs on full load, but its cost of production is usually greater than that of smaller units working on partial load.
- For larger equipment transportation to site is generally difficult and costly in comparison to smaller equipment.
- Servicing, maintenance and repair facilities have to be greater for larger units. However, larger machines are usually more suitable for tough working conditions.
- Standby cost of larger size equipment is more than, that of smaller equipment.

8. Versatility

- If possible the machine selected should be able to do more than one function and should be inter convertible where ever possible.

9. Suitability of Local Labour

- The locally available operators and technicians should be able to handle the selected equipment.
- Special equipment may have excellent performance but may be difficult to get repaired during break down.

COST OF OWNING AND OPERATION

- Cost of possession of an equipment is called cost of owning to which can be added the cost of fuel for running the equipment.
- It is the amount by which an equipment should be hired. It is generally estimated on hourly basis.
- It should be noted that this does not include the operators cost.

Following factors should affect the cost of owning and operating.

(a) Initial cost of equipment, which includes equipment cost, transportation cost, loading and unloading charges and installation cost.

(b) Severity of service condition under which it is used.

(c) Number of hours used in a year.

(d) Quality of Maintenance and repair.

(e) Demand of equipment at the end of service life.

(f) Service life of equipment.

- **Following cost constitutes the cost of owning and operating.**
  - (i) Depreciation cost
  - (ii) Maintenance & Repair cost
  - (iii) Investment cost
  - (iv) Fuel or energy consumption cost
  - (v) Lubricating oil cost

Note: Annual maintenance and repair cost = 50 to 100% of annual depreciation but 100% is a fair value.

$$\text{Annual depreciation} = \frac{\text{Intial value} - \text{Salvage value}}{\text{Useful life of equipment}}$$

ECONOMIC LIFE OF CONSTRUCTION EQUIPMENT

- A construction equipment has two types of life.
  - (a) **Physical life :** The potential service life or time period, of an equipment before which it physically becomes unable to produce a good or service.
  - (b) **Economic life :** It is defined as the time period over which an equipment is expected to be use able, with normal repairs and maintenance, for the purpose it is hired.
- A machine can be used for long period (till the end of physical life) through expensive repair and maintenance cost, may have small economic life i.e. during which it gives maximum profit and lowest operating cost.

Note: Economic life may also be defined as the period of replacement of an equipment that maximises the profit from the equipment or minimizes the cumulatively hourly owning and operating cost.
Generally the economic life of an equipment is given in terms of years and working hours.

- **When should the equipment be replaced?**
- If the equipment is replaced too early, he will experience capital loss, and if too late, the equipment might have passed its period of economic operation.
- The owner must consider all costs related to the ownership and operation of the equipment, and the effect which the continued use will have on these costs.

The costs to be considered are:

1. Investment Costs

- It is the fixed cost which is incurred at the time of purchasing equipment but it also includes some other parameters inclusive which definition get modified as :

  Investment cost comprises fixed cost which is incurred at the time of purchasing equipment, interest on the money invested in buying the equipment , taxes pertaining to the ownership of the equipment, insurance and storage.
- Money spent in the purchase of equipment, if invested in a bank would bring a return in terms of interest
- Opportunity of earning this interest is lost due to purchase of the equipment, and so the recovery of this amount should be made on the machine's amount.
- Generally a combined investment cost including interest, taxes, insurance and storage is taken as about 10 to 12% per year of the value of the equipment at the beginning of year.

- **Average annual cost of the equipment is found out in following ways.**

Case -I. When there is no salvage value of the equipment

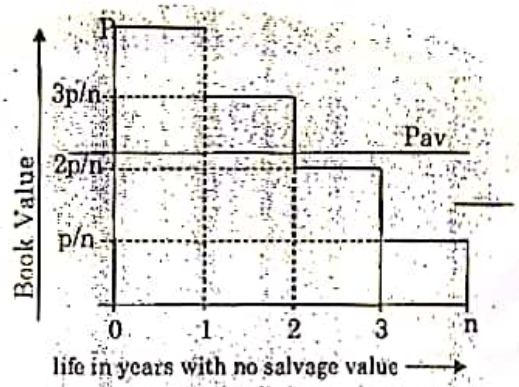
$$P_{av} = \frac{P + \frac{P}{n}}{2} = \frac{P(n+1)}{2n}$$

where,

P = Total initial cost

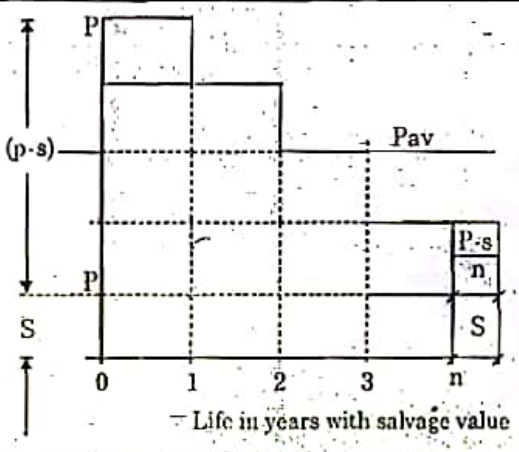
P_{av} = Average value

n = life in years



Value of equipment by year

Case -II. When there is salvage value of the equipment; The average value of the equipment is the sum of the values at the beginning of the first year and the end of the last year divided by 2.



Value of equipment by year

$$P_{av} = \frac{P + \frac{P-S}{n} + S}{2} = \frac{P(n+1)+S(n-1)}{2n}$$

where,

P = Total original cost

P_{av} = Average value

n = Life in years

S = Salvage value

Note: In both cases above, the book value is based on straight line depreciation.

2. Depreciation and Replacement Costs

- When one considers the replacement of equipment, it is necessary to know the salvage value of the machine and the replacement cost of a similar equipment.
- Replacement cost of an equipment must be increased 5% every year to balance the increase in cost of equipment every year.

3. Maintenance and Repair Costs

- It is necessary to keep accurate records of maintenance and repair costs as large variations are observed in these costs every year.

4. Downtime Cost

- Downtime is the time that a machine is not working because it is undergoing repairs, adjustments.
- Downtime tends to increase with usage.

Note: Availability is a term that indicates the portion of the time that a machine is in actual production, expressed as a percent. Thus, if a machine is down 12% of the time, its availability is 88%.

5. Obsolescence Cost

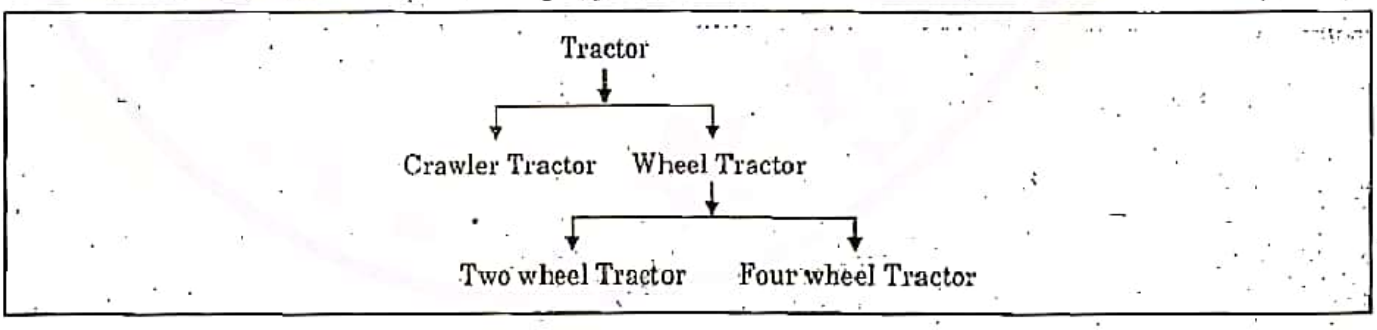
- Continuing improvements in the productive capacities of construction equipment have resulted in lower production costs.
- It observed that ; if by installing a new machine the production cost is reduced by 5%, when compared with the production costs of an existing machine, the existing machine will suffer a loss in value equal to 5%. This is defined as obsolescence loss.
- These improvements, whose advantages can be gained only by the replacement of older equipment with newer equipment, decrease the desirability of continuing to use the older equipment.

TRACTOR

- Primary purpose of a tractor is to pull or push loads, and it may be used also as mount for many types of equipment such as bulldozer, shovel, dragline, hoe, tenchers etc. Therefore.
- It is considered as one of the most important equipments and is indispensable on most of the construction projects whether small or big.

Types of Tractors

Tractors are divided into following types :



Factors affecting in selection of a tractor

- In selecting a tractor, several factors should be considered and some of them are enumerated as follows;
  (a) size required as per magnitude of the job.
  (b) kind of job for which it is to be used like bulldozing, pulling a scraper, clearing land etc.
  (c) type of footing over which it is to operate i.e. high tractive or low tractive efficiency.
  (d) firmness of haul road.

(e) smoothness of haul road

(f) slope of haul road.

(g) slope of haul road.

(h) type of work it is no do after this job is completed.

Crawler tractor

- If a tractor is mounted on crawler, it is called crawler tractor.
- Crawler track is an endless chain consisting of steel links made of steel plates connected together by pins and bushings.
- It is used for moving heavy units on rough surface having poor traction. The optimum pull that a crawler tractor can provide depends upon its weight and is equal to the coefficient of traction (depending upon road surfaces) multiplied by the weight of unit, regardless of the power supplied by the engine. Its
- Maximum speed is limited to 10 kmph while average speed lies between 4.5 to 5.6 kmph. It is suited for short haul say 60 to 150 m.
- Special advantage lies in its ability to travel over very rough surfaces and to climb very steep grades up to 25 to 29% at a speed of 2.75 kmph.
- It has a life of 8 to 12 years (9000 to 16000 hrs) depending upon its horse power which varies form 100 to 300 HP.

Advantages of crawler tractors

(i) Having more tractive effort it can operate on soft footing such as loose or muddy soil.

(ii) It can operate in rocky formations where rubber tyres may be seriously damaged.

(iii) It can travel over rough surfaces which may reduce the cost of maintaining haul roads.

(iv) It has greater floatation because of lower pressure under the tracks.

(v) Being compact and powerful, it can handle very difficult jobs.

Wheel tractor

- The basic advantages of a wheel tractor when compared with a crawler tractor lies in its higher speed. In order to attain a higher speed, a wheel tractor must sacrifice its pulling effort. As the speed is increased with the help of higher gears. Rimpull will be decreased in approximately the same proportion.

Note: For a given unit whose engine is operated at a rated power, speed × rimpull will always be constant.

- It possesses a lower coefficient of traction between rubber tyres and some soil surfaces, the wheel tractor starts slipping before developing its rated rimpull.
- Its useful life lies between 8 to 10 years (12,000 to 15,000 hrs) depending upon on its horsepower which is generally more than 75-HP.

Advantages of wheel tractors

(i) It can travel at higher speed (maximum speed up to 50 kmph) on the job or more from one job to another.

(ii) It can give greater output where considerable travelling is necessary.

(iii) It can travel over paved highways without damaging the surfaces.

(iv) It can operate easily which makes the operator less fatigue.

(v) A wheel tractor is very useful in the following conditions:

(a) Long push distance

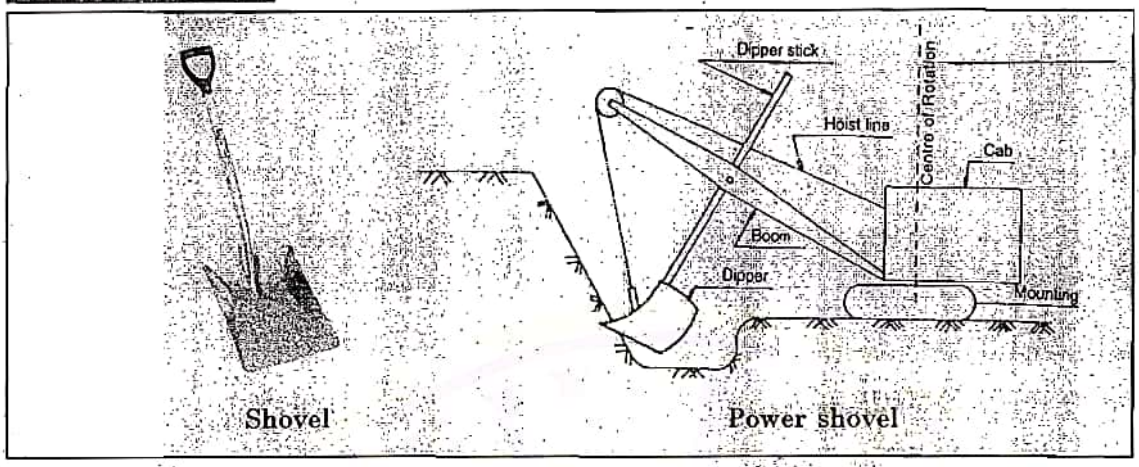
(b) Fast return

(c) Loose soil little or no rock

(d) Level or downhill work

(e) Good underfoot conditions

POWER SHOVELS



- Basicly a shovel is a tool for digging, lifting, and moving bulk materials, such as soil, coal, gravel, snow, sand, or ore.
- Shovels are extremely common tools that are used extensively in agriculture, construction, and gardening.
- When a shovel is mounted on a Power vehicle it is called as Power Shovel.
- Power shovels are used mainly to excavate earth and load into trucks or tractor-drawn wagons.
- Power shovels can excavate all types of earth except solid rock without prior loosening.
- The basic parts of a power shovel include Mounting, Cab, Boom, Dipper stick, Dipper.
- Size of power shovel is indicated by capacity of its dipper, generally expressed in cubic meters.
- Power shovels are commonly available in dipper sizes of 0.29, 0.38, 0.57, 0.76, 0.95, 1.14, 1.33, 1.53 and 1.91 m3.

Types of Power Shovels

1. Crawler mounted power shovel,
2. Rubber tyred mounted power shovel,

Crawler mounted Shovels

- It is mounted on crawler tracks.
- It is has very low travel speed.
- It exerts low pressure on the soil and hence suited for muddy and soft ground surface.

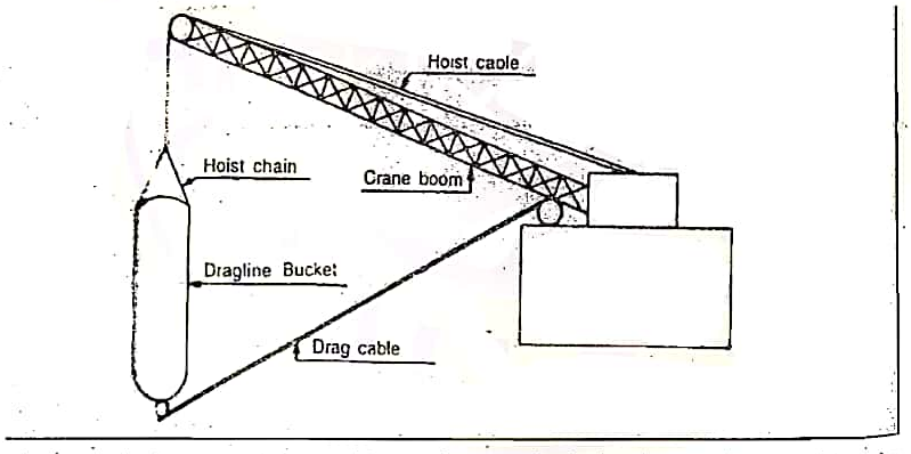
Rubber Tyre mounted Shovels

- It is mounted on Rubber-tyres.
- It has higher travel speeds are useful for small jobs where considerable travelling is involved.
- It exerts considerable pressure on the soil surface hence suitable for road and the firm ground surfaces.

Operations of Shovels

- Position the shovel near the face of the earth to be excavated.
- The dipper is lowered to the floor of the pit, with the teeth pointing into the face.
- A penetrating force is applied through the dipper shaft and at the same time tension is applied to the hoisting line to pull the dipper up along the face of the pit.
- If the depth of the face (called the depth of cut) is just right, the dipper will be filled as it reaches the top of the face.
- If the depth is shallow it will not be possible to fill the dipper completely without excessive penetrating force and hoisting tension.
- If the depth of cut is more than is required to fill the dipper, the depth of penetration of the dipper into the face must be reduced, if the full face is to be excavated or to start the excavation above the floor of the pit.

DRAGLINES



As the basic character of the machine is, dragging the bucket against the material to be excavated, it is known as Dragline.

- Draglines are used to excavate earth and load it into haul units, such as trucks or to deposit it on spoil banks and embankments near the place from where it is excavated.
- Size of dragline is expressed by the size of its bucket

Advantages of Dragline:

1. It does not have to go into the pit to excavate.It may operate on natural firm ground.
2. If it has a long boom then it can dispose of the earth in one operation without the need for haul
3. It can excavate below its level and under water.
4. It can excavate trenches without shoring.

Disadvantage of Dragline

- One of the disadvantages of a dragline is that its output is only 75-80% that of a power shovels.

Types of Draglines

1. Crawler-mounted Draglines-These can operate on soft and muddy ground surfaces and has speed of 1.6 kmph.
2. Rubber-tyre-mounted Draglines- These can operate on hard surfaces and has speed of 50 kmph.

Operation of Dragline

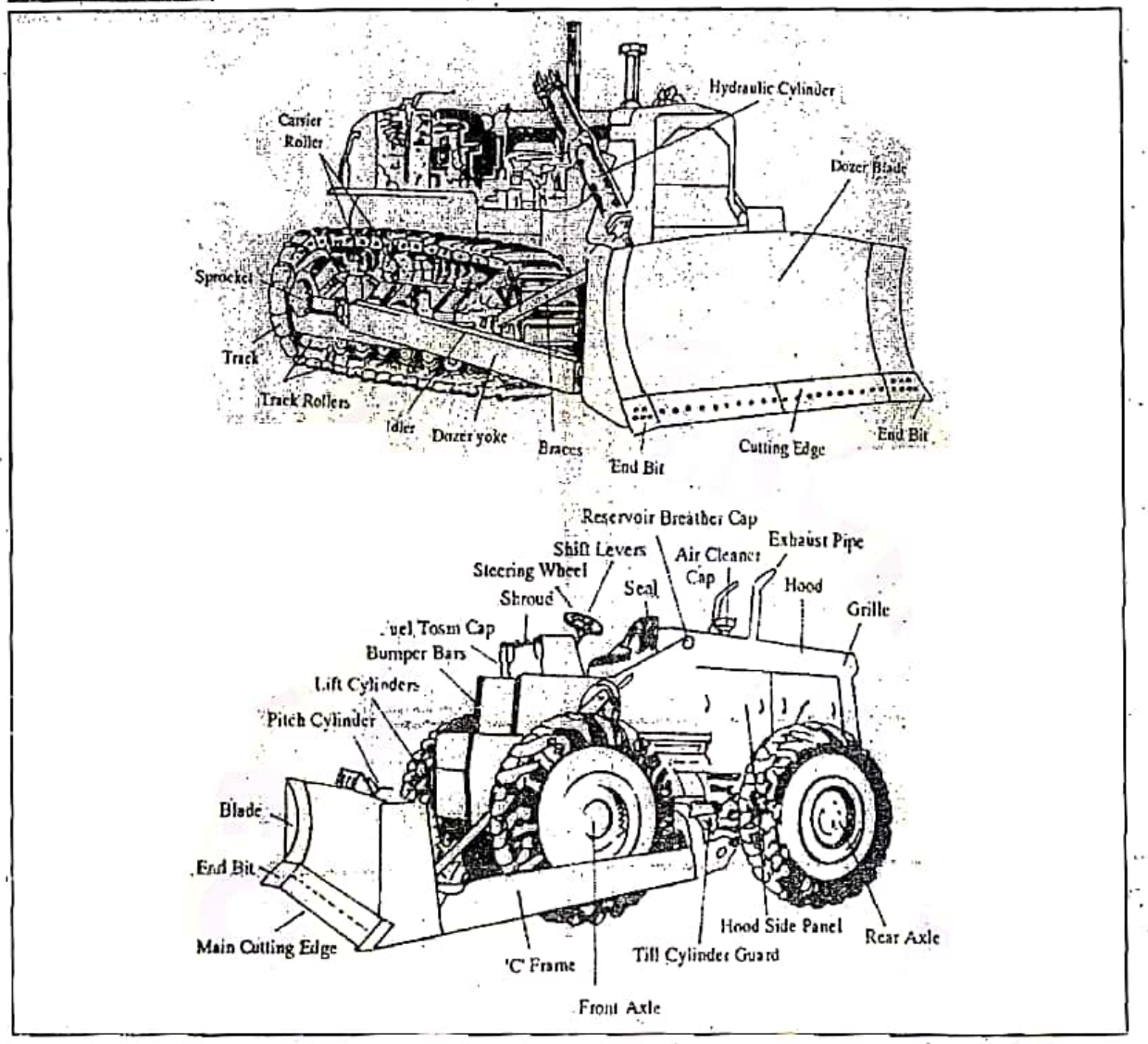
- Excavation is started by swinging the empty bucket to the digging position at the same time loosen the drag and the hoist cables.
- Excavation is done by pulling the bucket toward the machine while maintaining tension in the hoist cable.
- When the bucket is filled. the operator takes in the hoist cable while playing out the drag cable.
- Dumping is done by releasing the drag cable.
- Filling the bucket, hoisting. swinging and dumping of the loaded bucket, followed in that order, constitute one cycle.

Note: Since it is difficult to control the accuracy in dumping from a dragline, a larger capacity of haul units is desirable to reduce the spillage.

Output of Draglines

- While the effect of job and management conditions on the output of the dragline will be about the same as for a power shovel, and the job and management factors may be used for obtaining the probable output of draglines, the size of bucket and length of boom have a direct effect on the output of a dragline.
- Buckets are available in classes, such as light-duty, medium-duty and heavy-duty.
- Light-duty buckets are for materials that are easily dug, such as sandy loam, sandy clay, or sand.
- Medium-duty buckets are for general excavating service such as digging clay, soft shale or loose gravel.
- Heavy-duty buckets are for handling blasted rock and other abrasive materials.
- Buckets are often perforated to permit draining of water from the loads.
- In selecting the size and bucket type, the dragline and bucket should be matched for best efficiency.
- In selecting the bucket size care should be taken that the combined weight of the load and the bucket does not exceed the safe load recommended for the dragline.

BULLDOZERS



- Bulldozers are very efficient excavating tools for short haul applications up to 100 m.
- It is essentially a heavy steel blade which is mounted on the front of a tractor. The heavy blade attached to the tractor pushes the material from one place to another.
- The size of a bulldozer is indicated by the length and height of the blade.
- Bulldozers are classified on the basis of :

(1) Position of angles

(a) Bulldozers- In these blade is set perpendicular to the direction of movement. It pushes the earth forward and dump to some place.

(b) Angle Dozers- In these blade is set at an angle with the direction of movement. It pushes the earth forward and to one side.

(2) Based on mounting

(a) Wheel mounted

(b) Crawler mounted

Advantages of the crawler-mounted bulldozer:

(a) ability to deliver greater tractive effort on soft, loose or muddy soil

(b) ability to travel on muddy surfaces

(c) ability to operate in rock formations, where rubber tyres may get damaged, which may reduce the cost of maintaining haul roads

(d) greater flotation because of lower pressures under the tracks

(e) greater use-versatility on jobs.

Advantages of the wheel-mounted bulldozers:

(a) higher travel speeds on the job or from one job to another

(b) elimination of hauling equipment for transporting the bulldozer to the site

(c) greater output, especially when significant travelling is required

(d) less operator fatigue

(e) ability to travel on bitumen roads without damaging the surface.

(3) Based on control- for raising and lowering the blade

(a) Cable controlled

(b) Hydraulically controlled

Advantages of the Cable controlled bulldozers

(a) Simple to install, operate and control

(b) Easy in reparing

(c) Reduction in the danger of damaging a machine

Advantages of the Hydraulically controlled bulldozers

(a) Able produces a high down pressure on blades to force blades into ground

(b) Able to maintain a precise setting of the position of the blade.

- **In addition to excavating and hauling many other functions are also performed by Bulldozers from start to completion of an project like:**

(i) Clearing land of timber and vegetation

(ii) Opening up temporary roads through mountains and rocky areas

(iii) Moving earth for haul distances up to about 100 m

(iv) Pulling loaded tractors and scrapers

(v) Levelling and spreading earth fills

(vi) Backfilling trenches

(vii) Clearing construction sites of debris

(viii) Maintaining haul roads

(ix) Clearing the floors of borrows and quarry pits

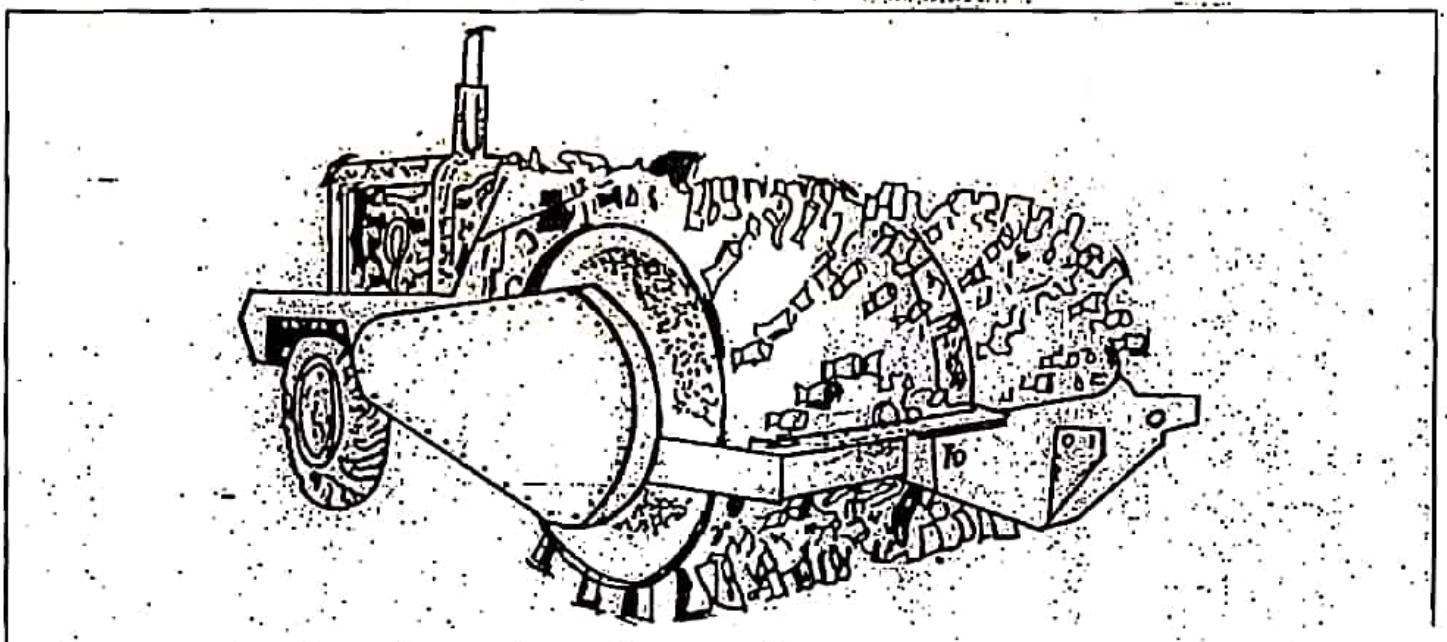
Compacting Equipment

INTRODUCTION

- Compaction is the method of artificially densifying the soil by pressing soil particles together into close contact, resulting in the expulsion of air and/or water from the soil mass.
- Compaction is done to increase the strength of an earth fill or an embankment.
- Compaction refers to the method employed by a compactor to impart energy into the soil to achieve compaction.
- Compactors are designed to use one or a combination of the following types of compactive efforts:
  (1) Kneading action –Manipulation or rearranging
  (2) Static weight – Pressure application
  (3) Impact – Sharp blow
  (4) Vibration– Shaking

TYPES OF ROLLERS

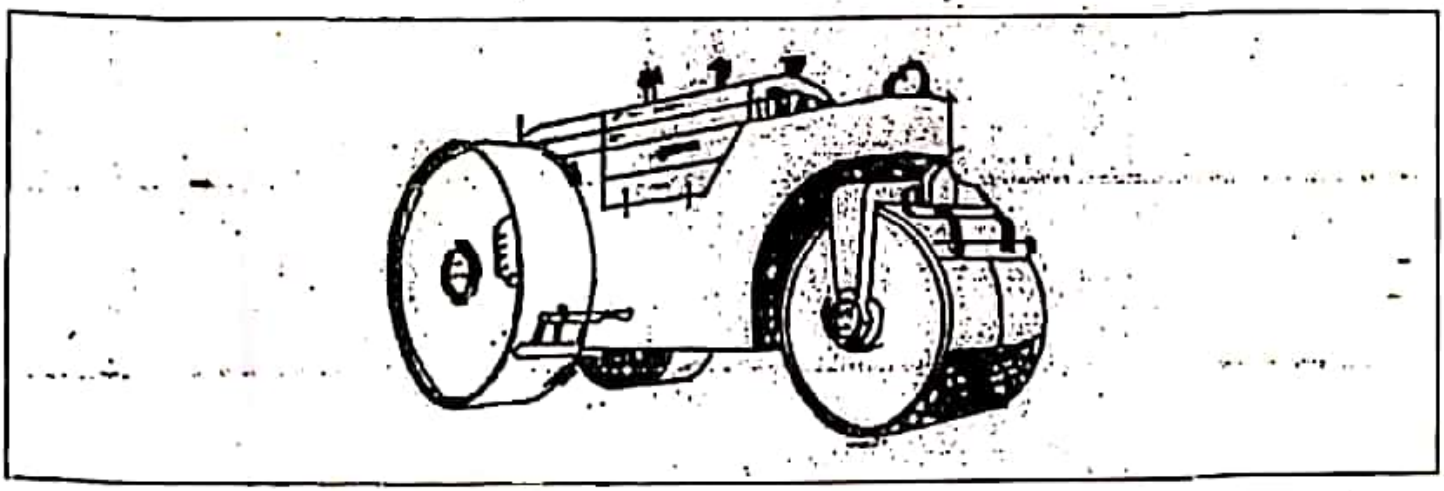
Sheep's Foot Rollers



Sheep's Foot Roller

- Sheep's foot rollers are suitable for compacting fine grained materials such as clays and mixtures of sand and clay.
- These cannot compact granular soils such as sand and gravel.
- Depth of a layer of soil to be compacted is limited to approximately the length of the feet.
- They are used for manipulation and compaction of plastic clays where stratification must be eliminated, such as clay cores in dams.
- Sheep's foot rollers can be towed or self-propelled, and its drums consist of a cylindrical shell with protruding 'feet' which provide areas of high contact pressure under the machine.
- Feet can have numerous shapes and terms such as **taper foot** and **club foot** have been used to describe their particular features.
- Because of the small contact area of the sheep's foot roller it requires a large number of passes to provide even one complete coverage of an area of soil.
- Sheep foot rollers are slow, have a very high rolling resistance and therefore cost per unit volume compacted is high.

Smooth-wheel Rollers

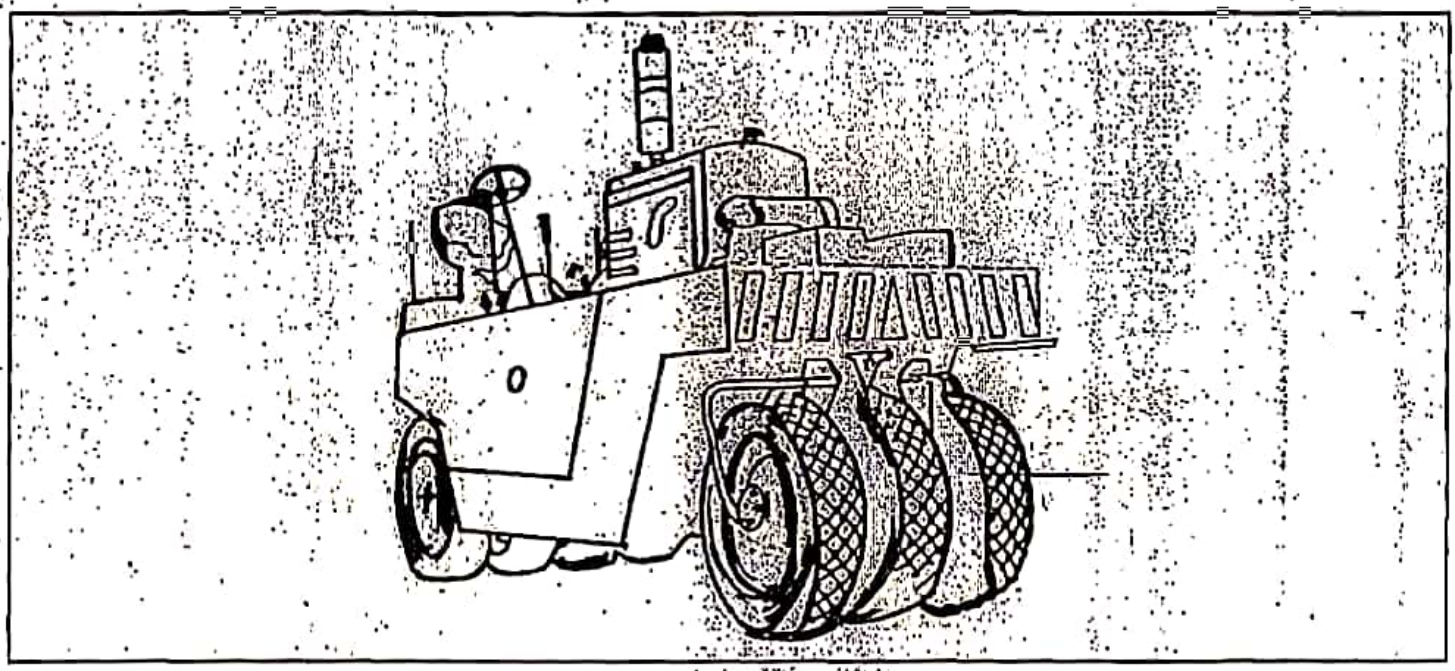


Smooth-wheel Roller

- Smooth-wheel Rollers can be self-propelled or of the towed type with smooth steel roll surfaces.
- These rollers may be classified by type or by weight.
- These rollers are effective in compacting granular soils, such as sand, gravel, and crushed stone and they are also effective in smoothening surfaces of soils that have been compacted by tamping rollers.
- When compacting cohesive soils, these rollers tend to form a crust over the surface, which may prevent adequate compaction in the lower portion of a lift.
- Self- propelled category the machine can be a three roll (tricycle configuration) with the front wheel used for steering while the rear wheels are powered for driving.
- They can be tandem two rolls type also.
- Contact area between the drum of the roller and the surface of the soil is a narrow strip and, as a result, the stresses in the soil fall off rapidly as depth in the layer increases.
- This type of roller is, therefore, limited in performance such as, to compaction of fairly thin layers, that is, 10 to 30 cm, depending on the size of the equipment.
- The steel drums of the rolls may be ballasted with water or sand to increase the weights.

- If a roller is designated as 7.3-12.8 t, it means that the minimum weight of the machine only is 7.3 t and that it can be ballasted to give a maximum weight of 12.8 t.

Pneumatic-tyred Rollers



Pneumatic-tyred Roller

- Pneumatic-tyred Rollers are surface rollers, which apply the principle of kneading action to effect compaction below the surface.
- These rollers are used for rolling subgrades, airfeild and bases of earthfill dams.
- They can be self-propelled or towed. , small or large-tyred units.
- These rollers rely on dead weight acting or upon pneumatic tyred wheels to produce the compacting effort.
- The weight of a unit may be increased by ballasting.
- The large-tyred rollers are available varying from 13.6-180 tonnes gross weight.

Tamping Rollers

Tamping foot compactors (Fig. 5.3) are high-speed, self-propelled, nonvibratory rollers. These rollers usually have four steel-padded wheels and can be equipped with a small blade to help level the lift. The pads are tapered with an oval or rectangular face. The pad face is smaller than the base of the pad at the drum. As a tamping roller moves over the surface, the feet penetrate the soil to produce a kneading action and a pressure to mix and compact the soil from the bottom to the top of the layer. With repeated passages of the roller over the surface, the penetration of the feet decreases until the roller is said to walk out

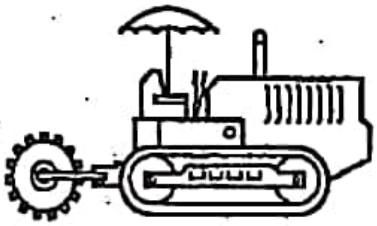
Vibrating drum rollers are actuated by an eccentric shaft that produces the vibratory action. The eccentric shaft need be only a body that rotates about an axis other than the one through the center of mass. The vibrating mass (drum) is always isolated from the main frame of the roller. Vibrations normally vary from 1,000 to 5,000 per min.

Vibration has two measurements—**amplitude**, which is the measurement of the movement, or throw, and frequency, which is the rate of the movement, or number of vibrations (oscillations) per second or minute (vpm). The amplitude controls the effective area, or depth to which the vibration is transmitted into the soil, while the frequency determines the number of blows or oscillations that are transmitted in a period of time.

amplitude
The vertical distance the vibrating drum or plate is displaced from the rest position by an eccentric moment.

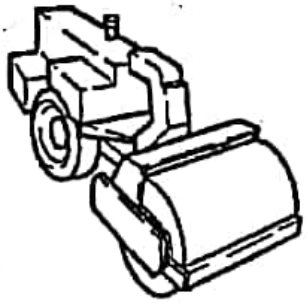
The impacts imparted by the vibrations produce pressure waves that set the soil particles in motion, producing compaction. In compacting granular material, frequency (the number of blows in a given period) is usually the critical parameter as opposed to amplitude.

Compaction results are a function of the frequency of the blows, the force of the blows, and the time period over which the blows are applied. The frequency/time relationship accounts for the slower working speed requirement when using vibratory compactors. Working speed is important as it dictates how long a particular part of the fill is compacted. A working speed of 2 to 3 mph provides the best results when using vibratory compactors.



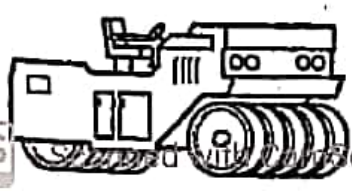
1. Sheepsfoot rollers

2. Tamping rollers



3. Smooth-drum vibratory soil compactors

4. Pad-drum vibratory soil compactors



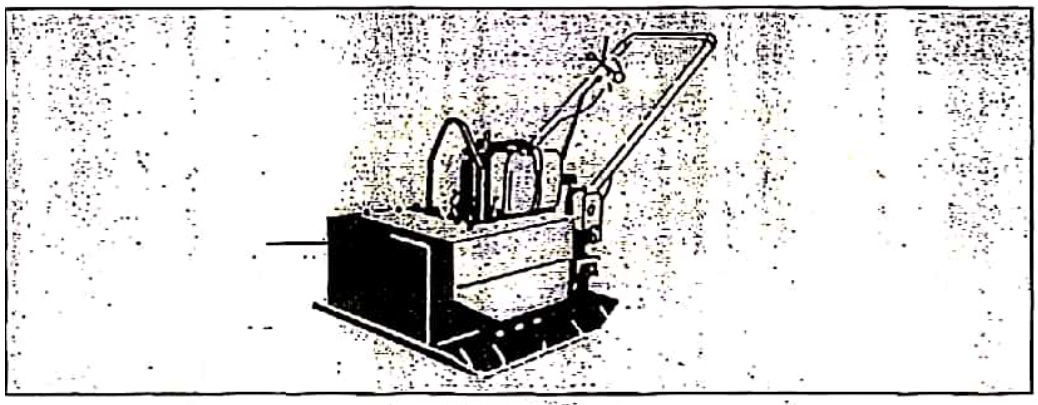
5. Pneumatic-tired rollers

Vibrating Compactors

- Vibratory compactors enhance the performance of static weight rollers by adding dynamic forces, usually achieved by a rotating eccentrically weighed shaft mounted inside the roller.
- Vibrating compactors have shown their abilities to produce excellent densification of soils such as sand, gravel and relatively large stones.
- As these materials are vibrated, the particles shift their position and nestle more closely with adjacent particles to increase the density of the mass.

- Types of Vibrating compactors are :
  (a) Vibrating sheep's foot rollers,
  (b) Vibrating steel-drum rollers,
  (c) Vibrating pneumatic-tyred rollers,
  (d) Vibrating plates or shoes.

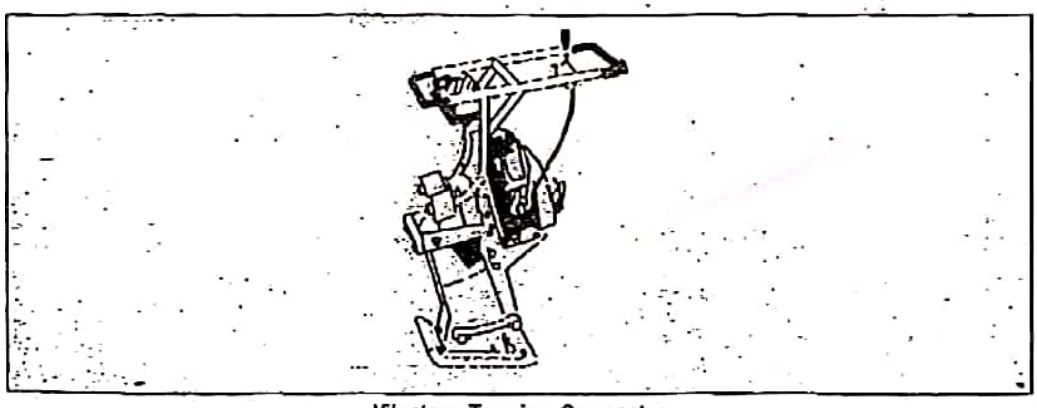
Manually Operated Vibratory Plate Compactors



Vibrating Plate Compactor

- These machines have a flat plate in contact with the soil.
- Because of their much smaller size, vibrating plate compactors have lower outputs of compacted soil than the larger vibrating rollers
- These are usedfor compaction of cohesion-less soil in confined areas or spaces.
- Power unit and control handles, for the pedestrian operator are attached to a chassis suspended above the base-plate on springs or other form of flexible mounting.

Manually Operated Vibratory Tamping Compactors

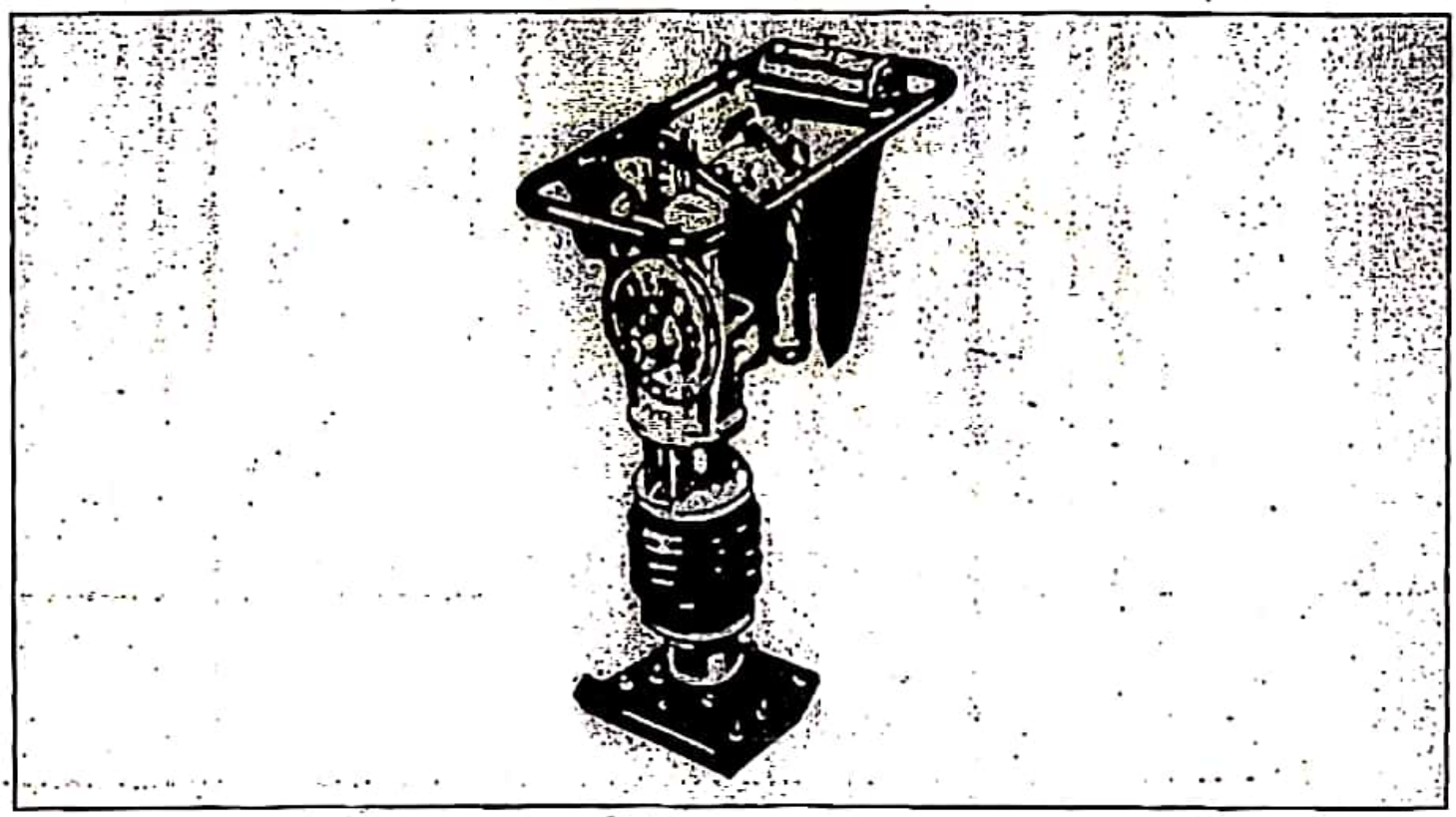


Vibratory Tamping Compactor

- Vibro tampers have an engine-driven reciprocating mechanism which acts on a spring system through which vertical oscillations, with amplitude of about 10-80 mm, are set up in the base plate.

- The most commonly used machines have a mass in the range of 50–150 kg, and usually operate at a frequency of about 10 Hz.
- Their main mode of compaction is by impact and they are suited for the compaction of most types of soil.
- Because of their low output they are used in confined areas or spaces, where their portability and maneuverability are a particular advantage.

Manually Operated Rammer Compactors



Rammer Compactor

- Rammer compactors are self-propelled in which each blow moves them ahead slightly to contact new soil.
- These units range in impact from 40 to 120 per sec at an impact rate up to 850 per min.
- Performance criteria include kg/blow, area covered per hour, and depth of compaction (lift) in cm.

PART-D

7.Soil reinforcing techniques

Reinforced Soil

Reinforcement in different forms is added to soil, in order to improve its mechanical properties. Soils are strong in compression but weak in tension. This weak property of soil is improved by introducing reinforcing elements in the direction of tensile stress. Reinforcement material generally consists of galvanized or stainless steel strips, bars, grids or fabrics of specified material, or wood, polymer and plastic, etc. The reinforcement is placed more or less the same way as steel in concrete. The end product is called reinforced soil, and is very effectively used for retaining structures, embankments, footings and subgrade, etc.

Soil Nailing

It is a method of reinforcing the soil with steel bars or other materials. The purpose is to increase the tensile and shear strength of the soil and restrain its displacements. The nails are either placed in drill boreholes and grouted along their total length to form "grouted nails", or simply driven into the ground as "driven nails". The technique permits stabilization of both natural slopes, and vertical or inclined excavations.

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.

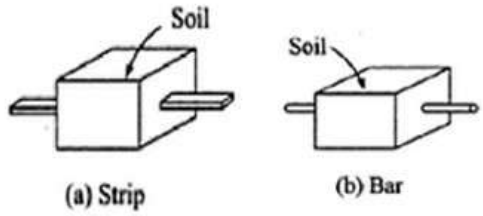


Figure 3.1

- 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.

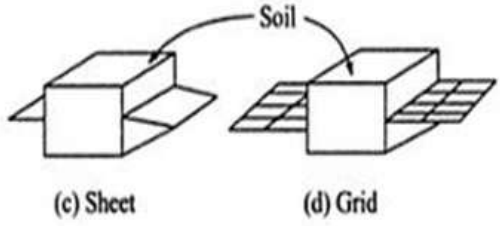


Figure 3.2

- 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

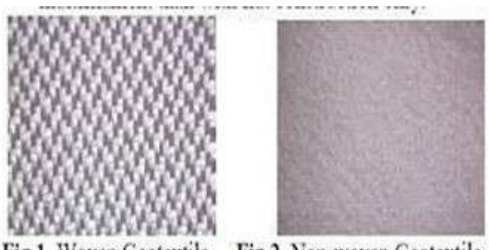


Fig 1. Woven Geotextile Fig 2. Non-woven Geotextile

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

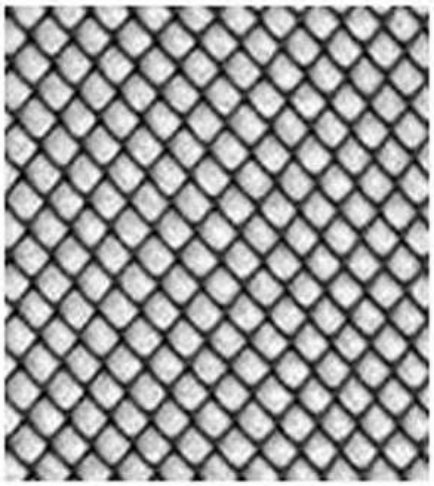


Figure 3.5

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:

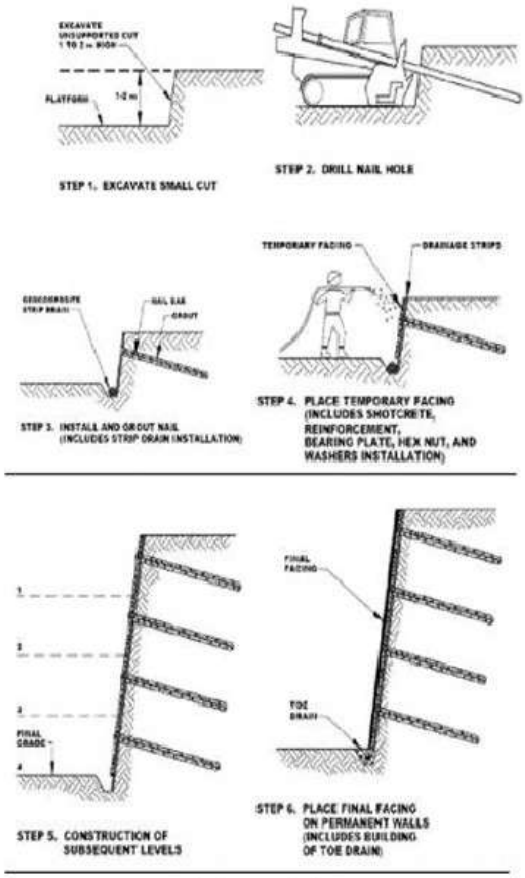


Figure 4.1

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.

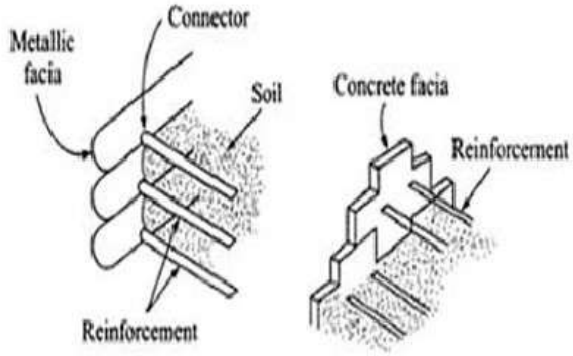


Figure 4.2

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

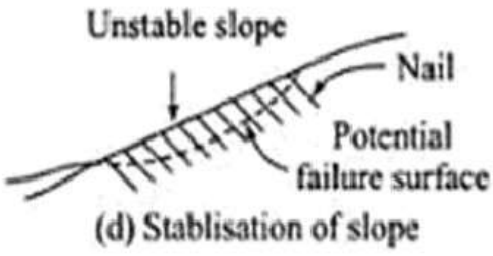


Figure 5.1

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

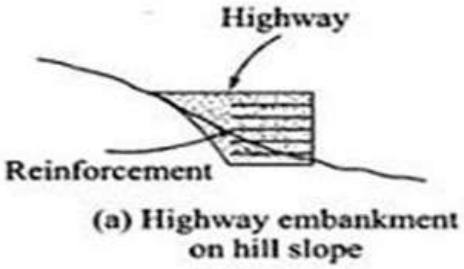


Figure 5.2

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.

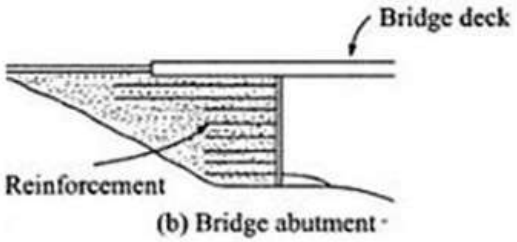


Figure 5.3

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.

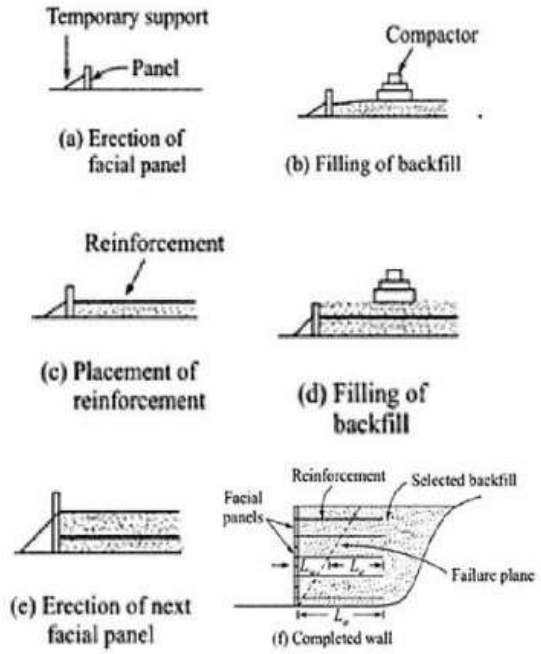


Figure 5.4

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.

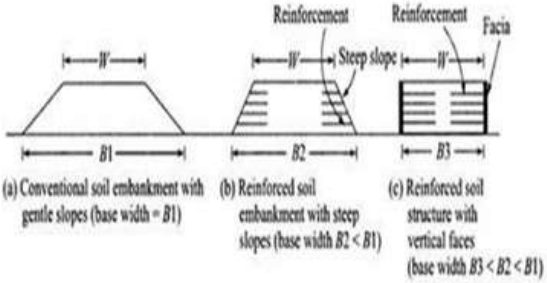


Figure 4.5