Civinnovate

Discover, Learn, and Innovate in Civil Engineering

CHAPTER 1 Functional Requirements of Buildings

1.1 Buildings and their types

Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, verandah, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures is known as building.

Buildings are classified according to the occupancy into the following types:

Group(A) Residential buildings-are those buildings in which the sleeping accommodation is provided for normal residential purposes, with or without cooking or dining or both facilities, except any building classified under category C.

Group(B) Educational – are those building used for school, college, or day care purposes for more than 8 hours per week.

Group(C) Institutional-these include any building which is used for purposes such a medical or other treatment or care of persons suffering from any physical or mental illness. Institutional buildings generally provide accommodation for the occupants.

Group(D) Assembly-these include any building where group of people gather for recreation, social, religious, travel and similar purposes.

Group(E) Business-these include any building used for business transaction, for keeping of accounts and records, lunch counters for less than 100 people, beauty parlor etc.

Group(F) Mercantile-these include any building which is used for shops, stores, markets, for display and sale of merchandise.

Group(G) Industrial buildings are those where products of materials of all kinds and properties are fabricated, assembled or processed.

Group(H) Storage are those building used for storage of any goods, wares or merchandise except highly combustible materials.

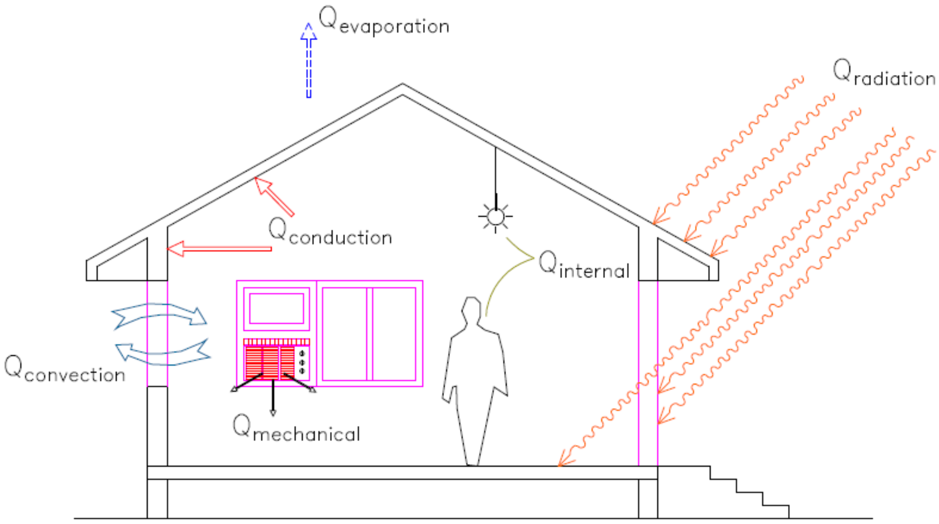
Group(I) Hazardous-buildings used for the storage, handling, manufacture or processing of highly combustible or explosive materials or products.

1.2 Heat phenomena in Building (thermal performance of building components, thermal comfort, thermal design)

Thermal performance of building components:

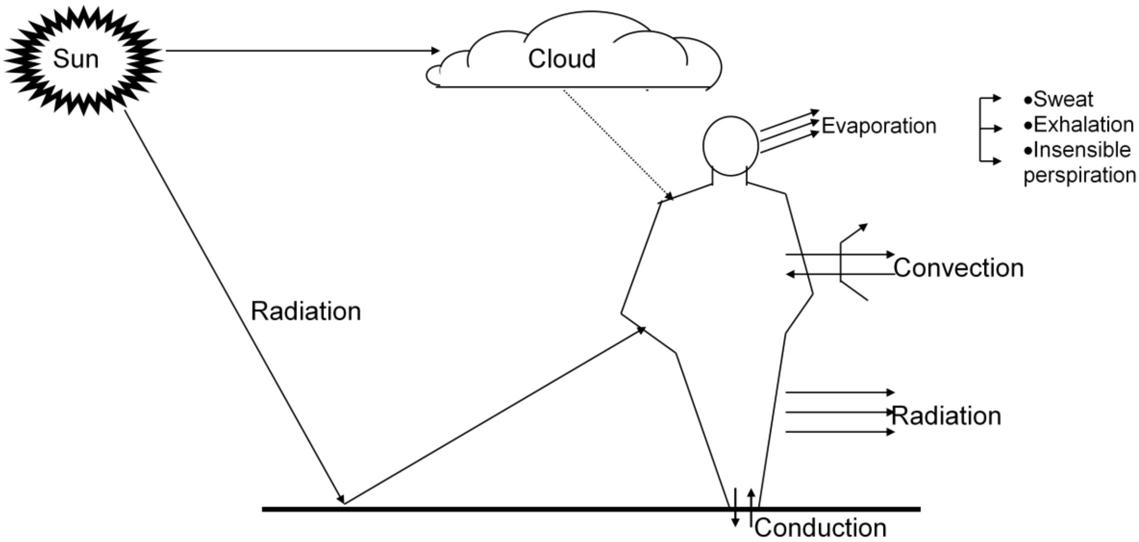
For a non-conditioned building, it calculates temperature variation inside the building over a specified time and helps one to estimate the duration of uncomfortable periods.

Various heat exchange processes are possible between a building and the external environment. Heat flows by conduction through various building elements such as walls, roof, ceiling, floor, etc. Heat transfer also takes place from different surfaces by convection and radiation. Besides, solar radiation is transmitted through transparent windows and is absorbed by the internal surfaces of the building. There may be evaporation of water resulting in a cooling effect.



Heat exchange process between a building and the external environment

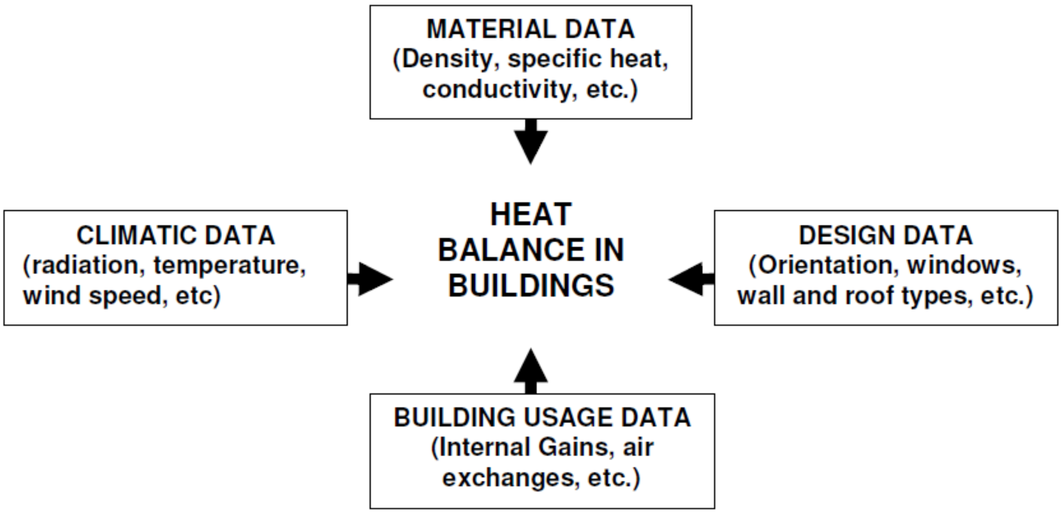
Heat is also added to the space due to the presence of human occupants and the use of lights and equipments. The interaction between a human body and the indoor environment is shown in Fig above. Due to metabolic activities, the body continuously produces heat, part of which is used as work, while the rest is dissipated into the environment for maintaining body temperature. The body exchanges heat with its surroundings by convection, radiation, evaporation and conduction. If heat is lost, one feels cool. In case of heat gain from surroundings, one feels hot and begins to perspire. Movement of air affects the rate of perspiration, which in turn affects body comfort.



Sun and thermal balance of human body

The thermal performance of a building depends on a large number of factors. They can be summarised as :
(i) Design variables (geometrical dimensions of building elements such as walls, roof and windows, orientation, shading devices, etc.);
(ii) Material properties (density, specific heat, thermal conductivity, transmissivity, etc.);

(iii) Weather data (solar radiation, ambient temperature, wind speed, humidity, etc.); and
(iv) A building's usage data (internal gains due to occupants, lighting and equipment, air exchanges, etc.).



Thermal simulation flow paths of a building

- **Thermal comfort**

State of heat balance of the human body is thermal comfort. The fluctuations of this heat balance causes discomfort. The metabolism that generates heat in the body depends on the daily life cycle of human being-state of activities, fatigue and recovery. Unfavorable climatic conditions affects daily life cycle resulting stress on body and mind causes discomfort, loss of efficiency and may eventually lead to a breakdown of health. Human response to the thermal environment depends to a great extent on the ease with which the body is able to regulate the heat balance in such a way that the internal body temperature is maintained constant at 37.4°C.

1.3 Ventilation (requirements, standards, design) & air conditioning

Ventilation may be defined as supply of fresh outside air into an enclosed space or the removal of all the vitiated air from the enclosed space. Ventilation is necessary for the following reasons:-

- Creation of air movement
- Prevention of undue accumulation of carbon dioxide
- Prevention of flammable concentration of gas vapor
- Prevention of accumulation of dust and bacteria-carrying particles.
- Prevention of odour caused by decomposition of building material.
- Removal of smoke, odour and foul smell generated /liberated by the occupants.
- Removal of body heat generated/liberated by the occupants.
- Prevention of condensation or deposition of moisture on wall surfaces.
- Prevention of suffocation conditions in conference rooms, committee halls, cinema halls big rooms etc.

Requirements of ventilation

1. Air changes or air movement
2. Humidity
3. Quality of air
4. Temperature

Systems of ventilation

1. **Natural ventilation**: It is the type in which ventilation is done by careful design of doors, windows, ventilators and sky lights. It is considered suitable for residential buildings and small houses. In this the rate of ventilation depends upon wind effect and stack effect.

2. **Mechanical or artificial ventilation** is the one in which some mechanical arrangements are mad to increase the rate of air flow. The system is more useful for large buildings.

General rules of natural ventilation:

1. Inlet openings in the buildings should be well distributed and should be located on the windward side at a low level and outlet openings should be located on the leeward side near the top so that incoming air stream is passed over the occupants.
2. Inlet openings should not be obstructed by nearby buildings.
3. Inlet and outlet should be of the same size.
4. If wind direction is variable, place the inlet openings equal in all directions.
5. Windows of living rooms should open on the open side.

Air conditioning

Air conditioning may be defined as the process of treating air so as to control simultaneously its temperature, humidity, purity and distribution to meet the requirements of the conditioned space. The various requirements of a conditioned space may be comfort and health of human beings, needs of certain industrial processes, efficient working of commercial premises etc.

Purpose:-

- It helps in preserving of maintaining health, comfort and convenience of occupants of residential building.
- It helps in improving the quality of products in certain industrial processes such as artificial silk, cotton cloth etc. In other cases of industries, it provides comfortable working conditions for the workers, resulting in the increase of the production.
- It helps in making the commercial premises such as shops, banks, offices etc, more active and efficient.
- It provides more comfortable entertainment in theatres etc.

From Functional requirements points of view:

1. Comfort air conditioning
2. Industrial air conditioning

Essentials of comfort air conditioning

1. Temperature control
2. Humidity control
3. Air velocity control
4. Air quality control

Essentials of air conditioning system

1. Filtration
2. Heating(in winter season)
3. Cooling(in summer season)
4. Humidification
5. Dehumidification
6. Air circulation or distribution

1.4 Lighting (illumination requirements, daylight, artificial lighting)

Light is required in various quantities to perform work. Each task has a specific recommendation for illumination levels.

Definitions

Luminous Flux (Φ) : Luminous energy emitted per second Unit: **lumen** (lm)
Luminous intensity (I) : Luminous flux per unit solid angle Unit: **lm / Sr**

Solid angle (w): cone of radiation Unit: **steradian** (Sr)

Relation : $\mathbf{I = \Phi / w}$

Candela (cd) Practical unit for luminous intensity of 1/60 sq. m. of the surface of a black body at temp. of freezing platinum under 101323 Newton / sq.m. pressure Relation : 1 lm = 1 cd x sr

Functions	**Illumination level (lux)**	**Limiting glare index**
Offices		
Drawing studio	500	19
General	500	16
Boards	750	16
Auditorium & Foyer	100	
Shops	500	19
Living spaces		
General	50	
Reading	150	
Sewing	300	

Iluminance (E) Luminous flux per unit area reflected from a surface Unit: Lux (Lx) or lm / sq.m.

Luminance (L) Luminous flux per unit area coming from a source Unit : cd / sq.m.

Glare: A condition of vision of discomfort to see object due to an unsuitable distribution or range of luminance

Natural Light

Sun is the sole source of natural lighting and heating. Depending on the different seasons, time of day and weather conditions, sun light may be harsh, hazy or subdued. How it enters the rooms depends on type, size & placement of windows and orientation of the building.

Lighting Requirements

- The source of light should be steady
- Glare should be avoided
- Inconvenient shadow should be avoided by proper shading at the source
- Light color on wall and ceiling

Day-lighting

The sun is the source of day light, however how and in what intensity it reaches a room depends on various components;

a. Diffused light/ skylight
b. Light reflected on external surfaces
c. Light reflected in the internal surfaces
d. Direct sunlight

Climatic conditions greatly influence the quantity and the quality of the above components.

Overcast Sky

Direct rays from the sun is achieved under clear sky condition, however in practice cloud covered sky (overcast) is taken into account in design. The illumination received from the sky varies greatly with different sky conditions and the time of the day. A complete overcast sky is assumed as the standard for day lighting analysis. The total illumination at the ground level is approximately taken as 5000 lux.

Day-light factor

The ratio of indoor illumination to the simultaneous outdoor illumination is taken as constant. The percentage ratio is

Room	Daylight factor	Penetration	Daylight area
Kitchen	2 %		n. 5 M^2)
Living room	1 %		
Bedroom	0.5 %	¾ depth	6 M^2
Office	1 %	4 Meters	
Drawing studio	5 %	Over whole of the area	

Ei is the indoor illumination, taken at a point
Eo is the outdoor illumination from an unobstructed sky

DF = SC + ERC + IRC

termed as the day light factor (DF);

$$DF = \frac{Ei}{Eo} \times 100 \ (\%)$$

The day light factor concept is valid only under overcast conditions. Three major factors contribute to the daylight factor;

1 Sky component (SC)
2 Externally reflected component (ERC)
3 Internally reflected component (IRC)

Controlling day lighting

Design stage: layout of structures, proper orientation of the Building and controlled light penetration

Construction stage: Use of windows/ fenestrations of proper size and at suitable locations
Use of roof lighting
Use of courtyard / atriums

Minimum day lighting standards

1.3.4 Artificial light

In conditions where natural lights cannot reach; inner rooms & lobbies, after sunset or where special lightings are required artificial lighting system is used. It is generally static and steady. However with dimmer or track light mechanism the brightness can be controlled.

Various electric lighting sources

1. Incandescent bulb (filament lamp)
2. Fluorescent lamp (discharge tube)
3. Halogen lamp, Low voltage lamp
4. Sodium vapor lamp , High pressure lamp
5. Induction lighting
6. Illuminating optical fiber

Method of increasing the electrical lighting system efficiency

1. Selection of luminaries with high luminous efficiency
2. Selection of internal surface finishing of high reflectance value
3. Adjusting luminaries height as per the work plane level
4. Regular maintenance of the system
5. Functional positioning / proper layout of the luminaries

1.5 Sound and Acoustics (sound & noise, acoustic defects, sound insulation)

Acoustic is the science of sound, which deals with the origin, propagation and auditory sensation of sound and also with design and construction of different building units to set optimum conditions for producing and listening speech, music etc.

Sound

Anything that can be heard is sound. It is the sensation caused by a vibrating medium acting on the air. Source of sound is most often vibrating solid body. The medium conveying sound to ear can be gas, liquid or solid.

It is transmitted as the longitudinal wave motion. Wave length determines pitch of sound. Higher the frequency higher would be the pitch (frequency is the waves per unit time).

Generally sound can be divided into air borne sound and impact sound. Airborne sound is transmitted through air and travels direct to the ear of the person. Impact sound is transmitted first through the structures such as noise of footsteps, furniture movement, dropping of utensils etc.

Noise

The sound which causes annoyance, interference with speech, damage to hearing and results in reduction in efficiency of work performance is called noise.

Magnitude of noise level		
Types of sounds	**Noise level (dB)**	**Effects**
Light road traffic	**60 – 70**	**Physiological effect (annoyance)**
Medium road traffics	**70 – 80**	**Physiological effect (annoyance)**
Heavy road traffics	**80 – 90**	**Prolonged exposure causes permanent hearing loss**
Rail traffics	**90 – 100**	**Prolonged exposure causes damage to auditory organ**
Air traffics	**100 – 130**	**Causes pain**
	>130	**Instantaneous loss of hearing**

Effects of Noise:

- Annoyance -irritation
- Disturbance to sleep
- Interface or disturbing conversation
- Damage of ear

Echoes:

When a reflecting surface is so far away from the surface that the sound is reflected back as a distinct repetition of the direct sound, the reflected sound is called an echo. Echoes are produced, when the time interval between the direct and the reflected sound waves is about $1/15^{th}$ of a second. This defect is particularly common when the reflecting surface is curved in shape. To minimize this defect in curved walls, the walls are covered with highly absorbent materials on the face work.

Reverberation

When the sound waves get reflected, a part of the sound energy is converted into heat energy by friction and is absorbed by the walls. Subsequently the reflected waves get inter-reflected from one surface to another until they gradually fade and become inaudible. This phenomenon of undue prolongation of sound by successive reflections from surrounding surfaces after the source sound has ceased is termed as reverberation. A certain amount of reverberation is necessary to enhance the sound. However, excessive reverberation is damaging to clarity.

Sound insulation of buildings:

Control of noise transmission is essential to minimize the disturbing effect of sound passing from one room to another, through walls, partitions and floors or ceilings.

General consideration

1. Isolate sound source
2. Proper orientation of building , i.e. no opening towards noise
3. Properly planned rooms in building
4. Furnishing materials in room helps sound absorption
5. Partitions – Ridge and Movable
6. Control of impact sound i.e. sue of resilient materials as carpets in floor
7. Discontinuing the path of vibration by using sound absorbing materials
8. Use of headphones and air plugs in case of high sound.

S. No.	Types of wall	Approx. wt. of wall kg/m²	Average sound reduction dB
1.	One brick wall plastered in both side	490	50
2.	One and half brick wall plastered in both side	710	53
3.	Cavity (50mm) with half brick in both leaves	490	50-53
4.	Half brick or concrete with plaster both side	170	45
5.	200 mm concrete wall	185	45
6.	Gypsum board partition on timber frame	70	45
7.	75mm hollow clay block with plaster both side		36

The constructional measures to be adopted for noise control and sound insulation are briefly discussed below:

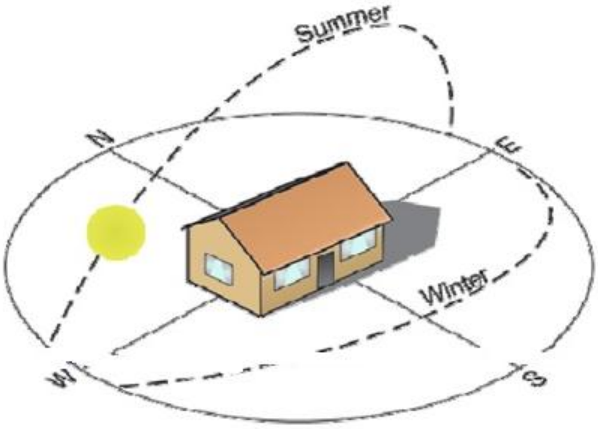
Wall construction:
The sound insulation rating of a wall is generally governed by the net sound transmission loss it provides and also the efficiency with which it serves as a barrio for speed sound. Weight of walls is the governing factor in wall is the governing factor is wall insulation. It is seen that a solid one brick wall plastered on both sides, proves quite effective as a sound insulation partition wall. It has an average reduction of 50dB. A cavity wall type of construction can be made to have increased insulation value by filling the cavity with some resilient material.

Floors:

Transmission of sound takes place more easily through floors. This is on account of the fact that the sound producing source has actual contact with floor. Hence the floor serves as the most common path for the transmission of impact noise. The ordinary R.C.C. floor weighing less than 220kg/sq.m has a sound reduction of only 45dB. Thus bare concrete and timber floors do not function effectively as barrier against impact sound. A floating floor resting on a resilient material like glass wool, mineral wool, quilt, hairfelt etc., has an increased rating for impact sound insulation.

1.6 Orientation & planning of buildings (principles, site-selection, economy, setting-out)

Orientation of building is a very important factor which is directly connected to the standards of thermal comfort and ventilation within building. It is guided by natural elements like sunlight and its intensity, direction of the wind, seasons of the year and temperature variations. Orientation is determined by climatic factors of wind and solar radiation.



The building orientation can have an impact on heating, lighting and cooling costs. By maximizing southern exposure, for example, one can take optimal advantage of the sun for daylight and passive solar heating. Minimizing western exposures will result in lower cooling costs, where it's most difficult to provide shade from the sun.

1. **Hot climatic zones:**

The buildings should be oriented from solar point of view so that as a whole it should receive the maximum solar radiation in winter and the minimum in summer. Longer walls of building should face north & south. Non-habitat rooms can be located on outer faces to act as thermal barrier. Preferably, the kitchen should be located on leeward side of the building to avoid circulation of hot air and smell from the kitchen.

- Large openings with heavy shutters should be provided on northern and western faces as light coming from north is always diffused and indirect.
- Thick walls are preferred to act as insulating barrier.
- Should be built up with good insulating material having slope in windward direction. False ceiling can be used to improve thermal performance of building.
- Large shady trees whose roots do not strain foundation and basement should be planted near external walls to provide shade

2. **Warm and humid climatic zone:**

Orientation of buildings in this zone should be preferably in North-South direction for habitable rooms i.e. longer walls should face north & south so that shorter sides are exposed to direct sunlight.

- Proper cross ventilation of building is of extreme importance; therefore large openings should be positioned on windward and leeward direction. However, openings should be provided with suitable protection like sunshades, chhajjas etc. from Sun and rain.
- Walls of Low thermal capacity material should be used in construction and walls can be thinner as temperatures are not very high.
- Roofs: should have large overhangs to avoid rainwater hitting the wall. Roof should be finished with materials of low thermal conductivity.
- Shrubs of medium height which do not act as wind barriers are recommended.
- Good rain-water drainage is essential.

3. **Cold climatic zone:**

Cold climate occurs in mountainous regions and plateaus 800 to 1200 meters above sea level.

- Orientation should preferably be in north – south direction i.e. longer walls should face north & south to receive more solar heat during winter months.
- Glazing windows upto 25% floor area may be provided. Double glazing is preferable to avoid heat losses during winter nights.
- Thin walls with insulation from inner side (2.5cm thick insulation) are preferable.
- Roofs should be preferably made of asbestos cement or G.I. sheets backed by false ceiling of wood, 2.5cm wood-wool board or equivalent material.
- The roof should have sufficient slope for quick drainage of rainwater and snow.
- Provision for heating of building should be kept like fire places etc.

Factors affecting orientation:

Sensory

- Thermal—solar exposure, wind direction, temperature
- Visual—varying daylight qualities in different locations and at different times of day
- Acoustical—direction of objectionable noises
- Environmental—smoke, dust, odors

Psychological

- Views
- Privacy
- Street activity

Local development patterns

- Street direction
- Spatial organization, land use, urban design
- Zoning

Accessibility requirements—main/secondary entrances, parking

Other considerations

- Aesthetic

- Direction of storms
- Site conditions—topography, geotechnical, wetlands
- Site vegetation—mature trees
- View corridors, scenic easements

Orientation principles:

1. **Slope and soil Considerations**
   Consider both long term storm water and short term erosion impacts during construction. Avoid very steep slopes.
2. **Site Plan**
   Bioclimatic design, Slopes to the south allow for plenty of solar access, while north facing slopes will provide good shading opportunities.
3. **for Rectangular Buildings**
   They should be oriented with the long axis running east west .In this configuration; east and west walls receive less direct sun in summer. So, unwanted heat gain is reduced. Same configuration works well for buildings in cold climates where passive solar heat gain on the south side during the winter is desired.
   A long narrow building plan also facilitates daylighting and natural ventilation.
4. **Solar Energy**: Both a friend and a foe
5. **Proximity of trees to building**
   Growth rate, life span of nearby trees should be considered
6. **Account prevailing winds**
7. **Driving and parking** lots should be located on the east or north side of the building in summer season (hot climate) and in cold climates, they should be kept on south and west to melt snow.

Planning of buildings:

The basic objective of planning of buildings is to arrange all the units of building on all floors and at level according to their functional requirements making best use of the space available for a building.
The shape of a plan is governed by several factors such as climatic conditions, site location, accommodation requirements, local bye-laws, surrounding environment etc.

Factors considered in planning:

1. **Aspect**: aspect means peculiarly of the arrangement of doors and windows in the external walls of a building which allows the occupants to enjoy the natural gifts such as sunshine, breeze, scenery etc. this consideration includes good view of nature or scenes according to the uses of space such a kitchen in east direction for early U-V ray, a reading rooms, class rooms in north direction for diffused light of the evening etc.

2. **Prospect:** is the impressions that house is likely to make on person who looks it from the outside. Hence, it includes the attainment of pleasing appearance by the use of natural beauties, disposition of doors and windows.
3. **Privacy:** it is one of the important principles in the planning of buildings of residential type.
4. **Grouping:** grouping means the disposition of various rooms in the layout in a typical fashion so that the rooms are placed in proper correlation of their functions and in proximity with each other. Services must be nearer to and independently accessible from every bed-room. Bathroom and toilets must be far away from the kitchen and dining rooms.
5. **Sanitation:** sanitation includes cleaning facilities, sanitation services, providing sufficient ventilation etc.
6. **Circulation:** it may vertical or horizontal circulation.
7. **Economy:** economy of the construction and operation of the building should be planned in advance.
8. **Practical considerations**: although different structural, financial and other considerations are discussed, practical possibility is the most considerable factor in planning of a building.

Setting out a building:

This is the process of obtaining the positions of the structural parts of a building in the geometrical construction. The positions of the structural parts of a building can be obtained by detailed structural drawings. These data has to be transferred to the field to start the geometrical construction with sufficient accuracy; enabling independent checks for readily detecting of any errors.

The first step in building setting out is to identify a base line according to the site layout plan. We can establish the base line considering the permanent structures and the relevant distances to structural parts from them as given in the drawings.

Setting out is done based on the principle of "Whole to part". According to this principle the largest possible rectangle of the building is found and set up first. Then it is further divided into small parts completing the major setting out for the building.

It is very important that setting out process is done in a horizontal plane. When the ground profile is not horizontal proper care must be paid to establish the setting out profiles in a one level. For simple applications a tube filled with water can be used to obtain the levels.

Main instruments involved in this process are Theodolite, Steel and Linen Tapes, Arrows, Wooden pegs, Wire nails and Nylon threads.

After establishing the base line, the main rectangle is set up using the pegs and theodolite. Arrows are used as temporary pegs and wooden pegs are driven for permanent pegs .90° angle is taken by the theodolite and **Pythagoras** rule is also commonly used for the process. When using the **Pythagoras** rule proper care must be paid to obtain the largest possible combination of triangles for higher accuracy. Steel tape must be used to measure long distances and it must be tightly stretched when taking the readings.

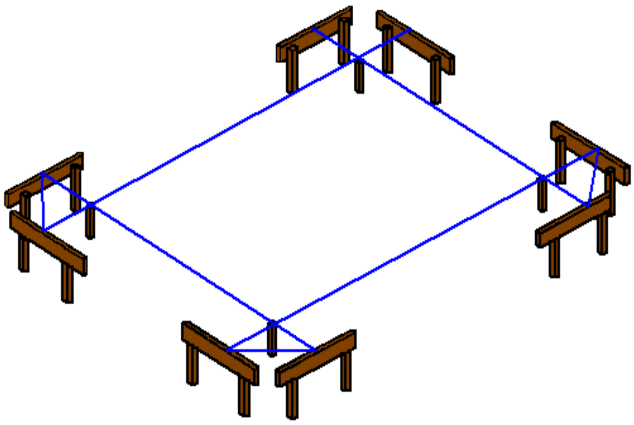
Wooden pegs atop by a wire nail are driven to establish the grid lines of the building. These pegs are driven at places such that they won't be disturbed by field work etc. Usually they are driven with a distance of 1.5 meter from the grid line.

The diagonals of the main rectangle are checked to determine its accuracy. Accurately set up main rectangle is then subdivided to obtain the consisting gridlines. These are obtained by the using structural drawings, Theodolite and steel tape. Nylon threads are stretched between the pegs to obtain the gridlines when necessary.

Usually apart from the pegs depicting the main grid lines, pegs which show the 500mm off sets are also established during the setting out process to facilitate the construction that follows.

1.7 <u>Moisture & its movement through building components and damp proofing</u>

Moisture or damp is water particles that appear on the surface of the materials. If we talk this in the building, it is one of the most important elements affecting the living condition inside and deteriorating the strength and durability of the building components. Damp appears in any surface of the building on the ceiling on the wall, on the floor and on the other surfaces inside or outside.



<u>Sources of Moisture</u>

Fundamentally, the sources of moisture may be noted as follows:

- Rainwater
- Ground water
- Water from condensation

Phenomenon of Condensation

The air that exists everywhere in the atmosphere is a mixture of dry gases and water vapour. Therefore, moisture is present normally in the atmosphere in the form of water vapour. This water vapour exists in the form of finely divided particles of superheated steam at the given air temperature (dry-bulb temperature). The amount of water vapour that a given quantity of air can hold increases with the temperature. If the air temperature is increased, it would take more water particles and if the air temperature is lowered the water particles diffuse each other and at a definite temperature, the air can go longer hold water molecules in vapour state. When air at any particular temperature contains as much as water vapour as it can hold, the air is said to be saturated and the condition of air is said to be moisture saturation state. The particular temperature at which the air is at the state of moisture saturation is known as its dew point. If the temperature of air is decreased from dew point, the excess vapour can no longer be held by the air and will be deposited on the surface as condensation.

Surface condensation and interstitial condensation:

When the temperature of any surface within a building is at temperature below the dew point of the adjacent air, some of the water particles in the air will condense on that surface, this is called surface condensation. Depending on the nature of the surface, the condensed moisture may either be absorbed by the material perhaps remaining unnoticeable or it may appear as liquid water on the surface.

Surface condensation will not occur if,

- The temperature of the surface is kept above the dew point of the adjacent air by adequate heating or by sufficient insulation behind the surface.
- The humidity of the air is limited so that its dew point is below the temperature of the surface.

With the occasional or intermittent surface condensation, an absorbent surface is advantageous, as it can retain a limited quantity of moisture until conditions change and re-evaporation can take place.

Condensation in building is not necessarily confined to exposed surfaces, but may under certain conditions occur within a material or on a surface within the thickness of a wall, roof or floor construction. This is called interstitial condensation.

Vapour diffusion: The flow of water vapour through a porous building material or composite slab is analogous to the flow of heat through the structure. Convection current transfers heat and moisture at the fluid solid boundary. Conduction heat transfers is similar to vapour diffusion through a porous material and is resistance to moisture flow varies with density as thermal resistance does but in the opposite sense.

The sources of water vapour in an occupied building are as follows:

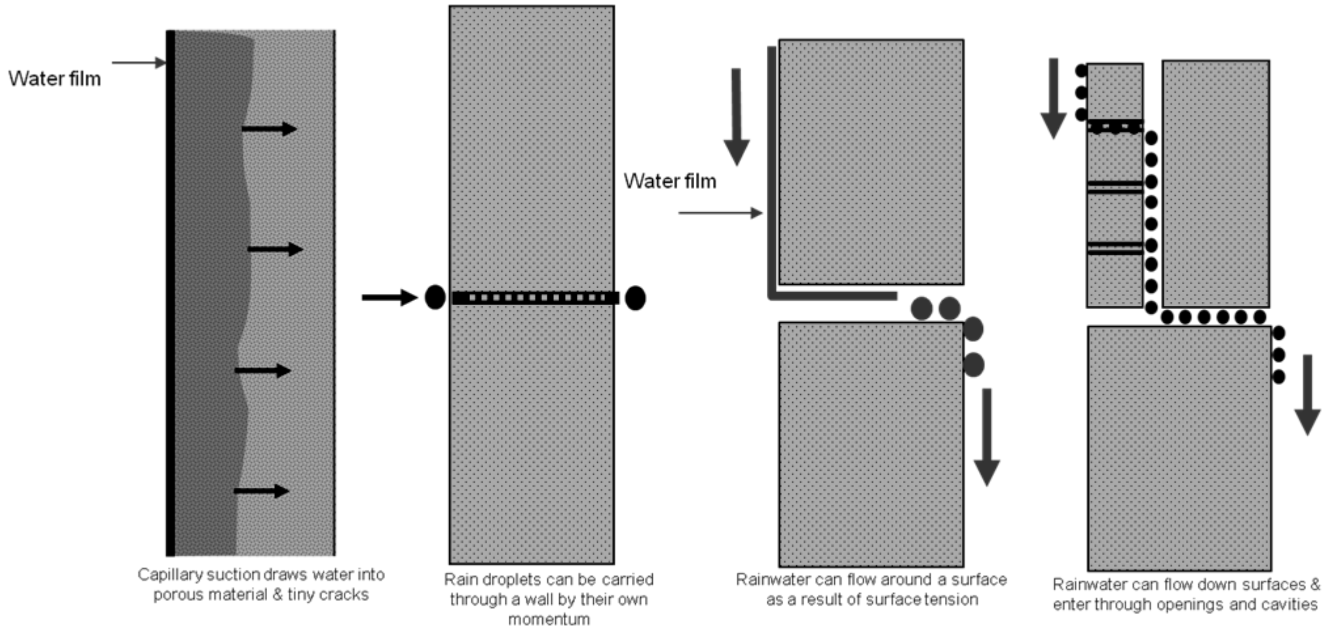
1. Transpiration
2. Cooking
3. Washing, bathing, and drying clothes.
4. Humidifiers and open water surfaces
5. Combustion of paraffin oil. (complete combustion of 1kg of C_2H_{20} produces 1.41 kg of water vapor)

The effects of Moisture

1. Efflorescence (disintegration of bricks, stones, tiles etc to powder like material)
2. Softening and crumbling of plaster.
3. Bleaching and flaking of paints with formation of patches.
4. Warping, buckling and rotting of timber.
5. Corrosion of metals (particularly ferrous metals)
6. Damage of electrical fittings.
7. Growth of fungus and termites.
8. Unhygienic condition to occupant in the building.
9. Damaging sound and thermal insulation.

Movement of Moisture: Almost all construction materials used in the building absorb water to some extent. There are definite phenomena for the absorption and movement of this water in the building components. Followings are different forces governing the movement of moisture through the building components.

1. Capillary action
2. wind loads (Momentum of water particles)
3. Surface tension of the building component
4. Gravity forces
5. Air pressure
6. Diffusion (occurs due to difference in vapor pressure)



Capillary action **Wind Load** **Surface tension** **Gravity force**

Moisture control

- **Ground water control-**The ground water and rain water percolating in to the ground causes great problem to the buildings. This is very sensitive work and due to the attention has to be paid to control the entry of moisture. Besides, condensation is also quite frequent in ground floor and basements.

Followings are the methods of moisture control in the substructure of the building.

1. Damp proofing
2. Water proofing
3. Subsurface drainage

Under damp proofing, it is meant by the application of simple damp proofing paints or membrane to control the capillary infiltration.

The requirements of an ideal material for damp proofing are:

1. It should be impervious.
2. It should be flexible.
3. It should be easy to carry out leak proofing joints.
4. It should be stable.
5. It should be durable.
6. It should resist the load safely.
7. It should not contain sulphates, chloride and nitrates.
8. It should be cheap.

Various methods of damp proofing are as given below:

1. Providing D.P.C. course
2. Providing cavity walls
3. Surface treatment
4. Integral treatment
5. Guniting and
6. Pressure grouting.

Under water proofing, it is meant by deliberate application of impervious layer under all adverse weather condition.

Subsurface drainage is the method of diverting underground water away from the foundation and basement. Depending upon the condition of the ground, the perforated underground drain may be directed towards the low land or a drywell of adequate capacity. Subsurface drainage can also be directed to sump pump and water collected may be pumped out. After this, there must be proper water proofing treatment in the foundation and walls of the basement.

- **Rain control**

  Rain is the most important factor to control in order to construct a durable building. Rain may enter in the building in many ways. Rain is more dependent on the climate and varies from place to place. It is difficult to forecast the intensity of rain in time and place. A general idea could be drawn from the amount of annual rainfall. Besides, the wind has substantial effect on the intensity, strength and direction of rain.

  Rain protection into and through building surfaces is governed by capillary action, momentum, surface tension, gravity forces and air pressure. Capillary forces draw water into rain water into pores and tiny cracks, while the remaining forces direct rain water into larger openings.

  Followings are the means of rain penetration control in practice:

1. Capillary breaks
2. Obstruction of horizontal openings
3. Drip edge or kerfs on horizontal openings
4. Use of flashings
5. Creation of pressure equalization

- **Vapor control**

  Water vapor moves in two ways, by vapor diffusion and by air transport. The mechanism differs for both the cases. If may happen that the means of effective control of the vapor diffusion may not be effective for air transport.
  Vapor diffusion is the movement of moisture in the vapor state through a material as a result of vapor pressure difference (concentration gradient) or a temperature difference (thermal gradient). It is not the movement of moisture as a result of air movement. Vapor diffusion moves moisture form an area of higher vapor pressure to an area of lower vapor pressure as well as form the warm side of the building component to the cold side. Therefore, the moisture will migrate by diffusion from where there is more to where there is less. The movement of the moisture from warm side to the cold side of the building component is called ‘thermally driven diffusion’. The moisture condenses on cold surfaces acting as dehumidifiers pulling more moisture towards them.The air transport is the process of movement of moisture present in the air from the area of higher air pressure to a area of lower air pressure.

2.1 Soil exploration (methods, improving bearing capacity, plate load test)

Refer foundation engineering

2.2Foundation and its types (deep, shallow)

Refer foundation engineering

2.3 Earthwork excavation of foundations (soft soil, hard rock, wet excavation)

Earthwork in excavation upto required depth is required for construction of foundation. It is very important part of construction process, and care must be taken while excavation in safety perspective. Different soil layers may be encountered while excavation, dewatering may be needed sometimes. These points must be kept in mind to take necessary action during excavation and backfilling. Correct measurement of excavation and backfilling is required because excavation cost is major part of the foundation construction.

Following are the sequence of works for excavation and backfilling of soil:
The following are the equipments used for the earthwork for foundation.
Hydraulic excavator, tractor / trucks, Spade, Pick Axe, Crow Bar, Rammer, Wedge, Boning Rod, Sledge Hammer, Basket, Iron Pan, Line and Pins, hydraulic compactor.

Drawings required for excavation:
1. Centreline Drawing
2. Layout Plan

Scope of the work:

- Setting out of corner benchmarks
- Survey for ground levels.
- Survey for top levels
- Excavation to approved depth.
- Dressing of loose soil.
- Making up to cut off level
- Constructing dewatering wells and interconnecting trenches.
- Marking boundaries of the building.
- Constructing protection bunds and drains

Working Procedure for soil excavation:

The extent of soil and rock strata is found by making trial pits in the construction site. The excavation depth is decided according to the following guidelines in the site.

- For Isolated footing the depth to be one and half times the width of the foundation.
- For adjacent footings with clear spacing less than twice the width (i.e. one and half times the length) 1.5m in general and 3.5 m in black cotton soils.

Setting out or ground tracing is the process of laying down the excavation lines and center lines etc. on the ground before the excavation is started. The center line of the longest outer wall of the building is marked on the ground by stretching a string between wooden or mild steel pegs. Each peg may be projected about 25 to 50 mm form the ground level and 2m from the edge of the excavation. The boundary is marked with the lime powder. The center lines of other walls are marked perpendicular to the longer walls. A right angle can be formed by forming 3, 4 and 5 triangles. Similarly, outer lines of the foundation trench of each cross walls are set out.

Backfilling and Removal of Excess Soil
Estimate the excavated stuff to be re-utilized in filling, gardening, preparing roads, etc. As far as possible try to carry excavation and filling simultaneously to avoid double handling. Select and stack the required material in such a place

that it should not obstruct other construction activities. The excess or unwanted material should immediately be carried away and disposed of by employing any of the following methods.

- Labour
- Tractor
- Trucks

Quality Checks for Excavation

- Recording initial ground level and check size of bottom.
- Disposal of unsuitable material for filling.
- Stacking suitable material for backfilling to avoid double handling.
- Strata classification approval by competent authority.
- Dressing bottom and sides of pits as per drawing with respect to centerline.
- Necessary safety measures observed.

Quality Checks for Backfilling

- Recording initial ground level
- Sample is approved for back filling.
- Necessary marking/ reference points are established for final level of backfilling.
- Back filling is being carried out in layers (15cm to 20cm).
- Required watering, compaction is done.
- Required density is achieved.

EXCAVATION IN ALL KINDS OF SOILS (soft soils)

All excavation manually or by mechanical means shall include excavation and 'getting out' the excavated materials. In case of excavation for trenches, basements, water tanks etc. 'getting out' shall include throwing the excavated materials at a distance of at least one meter or half the depth of excavation, whichever is more, clear off the edge of excavation. In all other cases 'getting out' shall include depositing/disposing the excavated materials as specified. Excavation shall be done from top to bottom. Undermining or undercutting shall not be done.

In firm soils, the sides of the trenches shall be kept vertical up to a depth of 2 meters from the bottom. For more depths, the excavation profiles shall be widened by allowing steps of 50 cm on either side after every 2 meters from the bottom. The excavation can also be done so as to give slope of 1:4 (1 horizontal: 4 vertical). Where the soil is soft, loose or slushy, the width of steps shall be suitably increased or side slopes or the soil shored up as per direction of Engineer-in-Charge. The contractor shall be responsible for obtaining clear instructions in writing from engineer in charge regarding the stepping, sloping or shoring to be down for excavation deeper than 2 meter.

The excavation shall be done true to levels, slope, shape and pattern indicated by the Engineering- in-charge. Only the excavation shown on the drawings with additional allowances for centering and shuttering or as required by the Engineer-in-Charge shall be measured and recorded for payment. In case of excavation for foundation in trenches or over areas, the bed of excavation shall be to the correct level or slope and consolidated by watering and ramming. The excavation shall be done manually or by mechanical means as directed by Engineer-incharge considering feasibility, urgency of work, availability of labour /mechanical equipments and other factors involved. Contractor shall ensure every safety measures for the workers. Neither any deduction will be made nor will any extra payment be made on this account.

EXCAVATION IN ORDINARY/HARD ROCK

All excavation operations shall include excavation and 'getting out' the excavated matter. In case of excavation for trenches, basements, water tanks etc. 'getting out' shall include throwing the excavated materials at a distance of at least one meter or half the depth of excavation, whichever is more, clear off the edge or excavation. In all other cases 'getting out' shall include depositing the excavated materials as specified. The subsequent disposal of the excavated material shall be either stated as a separate item or included with the item of excavation stating lead. During the excavation, the natural drainage of the area shall be maintained. Excavation shall be done from top to bottom. Undermining or under cutting shall not be done.

Where in hard rock blasting operations are considered necessary, the contractor shall obtain the approval of the Engineer-in-Charge in writing for resorting to the blasting operations. Chiseling shall be done to obtain correct levels, slopes, shape and pattern of excavation as per the drawings or as required by the Engineer-in-Charge and nothing extra shall be payable for chiseling. Where blasting operations are prohibited or are not practicable, excavation in hard rock shall be done by chiseling.

In ordinary rock excavation shall be carried out by crowbars, pick axes or pneumatic drills and blasting operation shall not be generally adopted. Where blasting operations are not prohibited & it is practicable to resort to blasting for excavation in ordinary rock, contractor may do so with the permission of the Eng-in-Charge in writing but nothing extra shall be paid for this blasting.

EXCAVATION IN WATER, MUD OR FOUL POSITION

All water that may accumulate in excavations during the progress of the work from springs, tidal or river seepage, broken water mains or drains (not due to the negligence of the contractor), and seepage from subsoil aquifer shall be bailed, pumped out or otherwise removed. The contractor shall take adequate measures for bailing and/or pumping out water from excavations and/or pumping out water from excavations and construct diversion channels, bunds, sumps, coffer dams etc. as may be required. Pumping shall be done directly from the foundation trenches or from a sump outside the excavation in such a manner as to preclude the possibility of movement of water through any fresh concrete or masonry and washing away parts of concrete or mortar. During laying of concrete or masonry and for a period of at least 24 hours thereafter, pumping shall be done from a suitable sump separated from concrete or masonry by effective means.

Capacity and number of pumps, location at which the pumps are to be installed, pumping hours etc. shall be decided from time to time in consultation with the Engineer-in-Charge.

Pumping shall be done in such a way as not to cause damage to the work or adjoining property by subsidence etc. Disposal of water shall not cause inconvenience or nuisance in the area or cause damage to the property and structure nearby. To prevent slipping of sides, planking and strutting may also be done with the approval of the Engineer-in-Charge.

Excavation of trenches for pipes, cables etc. and refilling works: This shall comprise excavation not exceeding 1.5 meter in width or 10 sq.m. in plan and to any depth trenches for pipes. Cables etc. and returning the excavated material to fill the trenches after pipes, cables etc. are laid and their joints tested and passed and disposal of surplus excavated material upto 50 m lead.

Width of Trench

Upto one meter depth the authorized width of trench for excavation shall be arrived at by adding 25 cm to the external diameter of pipe (not socket/ collar) cable, conduit etc. Where a pipe is laid on concrete bed/ cushioning layer, the authorized width shall be the external diameter of pipe (not socket/collar) plus 25 cm or the width of concrete bed/ cushioning layer whichever is more.

For depths exceeding one meter, an allowance of 5 cm per meter of depth for each side of the trench shall be added to the authorized width (that is external diameter of pipe plus 25 cm) for excavation. This allowance shall apply to the entire depth of the trench. In firm soils the sides of the trenches shall be kept vertical upto depth of 2 meters from the bottom. For depths greater than 2 meters, the excavation profiles shall be widened by allowing steps of 50 cm on either side after every two meters from bottom.

Where more than one pipe, cable, conduit etc, are laid, the diameter shall be reckoned as the horizontal distance from outside to outside of the outermost pipes, cable, conduit etc.

Where the soil is soft, loose or slushy, width of trench shall be suitably increased or side sloped or the soil shored up as directed by the Engineer-in-Charge. It shall be the responsibility of the contractor to take complete instructions in writing from the Engineer-in-Charge regarding increase in the width of trench. Sloping or shoring to be done for excavation in soft, loose or slushy soils.

Excavation: same as the above

Refilling works

Filling in trenches for pipes and drains shall be commenced as soon as the joints of pipe and drains have been tested and passed. The backfilling materials shall be properly consolidated by watering and ramming, taking due care that no damage is caused to the pipes.

Where the trenches are excavated in soil, the filling from the bottom of the trench to the level of the centreline of the pipe shall be done by hand compaction with selected approved earth in layers, backfilling above the level of the centre line of the pipe shall be done with selected earth by hand compaction or other approved means in layers.
In case of excavation of trenches in rock, the filling up to a level 30 cm. above the top of the pipe shall be done with fine materials, such as earth, muram etc. The filling up of the level of the centreline of the pipe shall be done by hand compaction in layers. Whereas the filling above the centreline of the pipe shall be done by hand compaction or approved means in layer not exceeding 45 cm. The filling from a level 30-cm above the top of the pipe to the trench shall be done by hand or other approved mechanical methods with broken rock filling mixed with fine material as available to fill up the voids.
Filling of the trenches shall be carried simultaneously on both sides of the pipe to avoid unequal pressure on the pipe.

EARTH WORK BY MECHANICAL MEANS
Earth work by mechanical means involves careful planning keeping in view site conditions i.e. type of soil, nature of excavation, distances through which excavated soil is to be transported and working space available for employing these machines. The earth moving equipment should be accordingly selected. The earth moving equipment consists of excavating and transporting equipment.

Excavators
The excavators generally used at site are as follows:
(i)Dipper-shovel (ii) Backhoe (in) Skimmer (iv) Dragline (v) Clamshell

Tractor-based Equipment
It is a self-propelled crawler or wheeled machine used to exert a push or pull force through mounted equipment. It is designed either as attachments to normal tracked or wheeled tractors or as machines in which the earth moving attachments and the tractor are designed as a single integrated unit. A tractor, which is hydraulically operated, can be rigged as:
Loaders: (i) Tractor Shovel: (ii) Trench Digger (iii) Scraper (iv) Bulldozer (v) Angle-dozer

Some common problems with existing foundations:

- Unequal settlement of sub-soil
- Unequal settlement of masonry
- Sub-soil moisture movement
- Lateral pressure on the walls
- Lateral movement of sub soil
- Weathering of sub soil due to trees and shrubs
- Atmospheric action

Foundation in black cotton soil

Black cotton soils have the property of high shrinkage on removal of water and high swelling on the removal of water from the soil. So this soil is dangerous for the structures due to its characteristics of high shrinkage and swelling which causes additional stresses on the foundation (sub-structures). In addition to this, these soils have very poor bearing capacity.

Precautions to be followed while designing foundation on black cotton soil:

- Safe bearing capacity should be properly determined.
- The foundation should be taken at least 50cm lower than the depth of moisture movement. This depth should be more than the depth of tension crack.
- Where this layer of this soil does not exceed 1-1.5m, the entire layer of soil should be removed.
- Where the depth of this soil is large, the foundation should be laid on sand by replacing this soil on the periphery of the foundation.
- Strip, pier and pile foundation are the best option for this type of soil.

Chapter 3 Mortars and Masonry works

3.1 Mortars (Types, properties, preparation process, Estimating mortar requirement)

Mortar is an intimate mixture of binding material, fine aggregate and water. When water is added to the dry mixture of binding material and the inert material, binding material develops the property that binds not only the inert material but also the surrounding stones and bricks. If the cement is the binding material, then the mortar is known as cement mortar. Other mortars commonly used are lime mortar and mud mortar. The inert material used is sand.

- **CEMENT MORTAR**

For preparing mortar, first a mixture of cement and sand is made thoroughly mixing them in dry condition. Water is gradually added and mixed with shovels. The cement to sand proportion recommended form various works is as shown is Table below.

Table: Cement to sand proportions for various works

S.N.	Works	Cement:Sand
1	Masonry works	1:6 to 1:8
2	Plastering masonry	1:3 to 1:4
3	Plastering concrete	1:3
4	Pointing	1:2 to 1:3

Curing: Cement gains the strength gradually with hydration. Hence it is necessary to see that mortar is wet till hydration has taken place. The process to ensure sufficient moisture for hydration after laying mortar/concrete is called curing. Curing is ensured by spraying water. Curing normally starts 6–24 hours after mortar is used. It may be noted that in the initial period water requirement is more for hydration and gradually it reduces. Curing is recommended for 28 days.

Properties of Cement Mortar: The following are the important properties of cement mortar:
1. When water is added to the dry mixture of cement and sand, hydration of cement starts and it binds sand particles and also the surrounding surfaces of masonry and concrete.
2. A mix richer than 1:3 is prone to shrinkage.
3. Well proportioned mortar provides impervious surface.
4. Leaner mix is not capable of closing the voids in sand and hence the plastered surface is porous.
5. The strength of mortar depends upon the proportion of cement and sand.

Uses of Cement Mortar
1. To bind masonry units like stone, bricks, etc.
2. To plaster slab and walls make them impervious.
3. To give neat finishing to walls and concrete works.
4. for pointing masonry joints.
5. for preparing building blocks.
6. As a filler material in Ferro cement works.
7. To fill joints and cracks in walls.
8. as a filler material in stone masonry.

- **LIME MORTAR**

Limes, wherein the hardening is due to the conversion of hydroxides to carbonates, were formerly widely used as the sole cementitious material, but their slow setting and hardening are not compatible with modern requirements. Use of limes is beneficial in that their slow setting promotes healing, the recementing of hairline cracks.

The limes are classified as fat lime, hydraulic lime and poor lime.

(i)Fat lime: It is composed of 95 percentage of calcium oxide. When water is added, it slakes vigorously and its volume increases to 2 to 2.5 times. It is white in colour. Its properties are:

(a) Hardens slowly
(b) Has high degree of plasticity
(c) Sets slowly in the presence of air
(d) White in colour
(e) Slakes vigorously.

(ii) Hydraulic lime: It contains clay and ferrous oxide. Depending upon the percentage of clay present, the hydraulic lime is divided into the following three types:
(a) Feebly hydraulic lime (5 to 10% clay content)
(b) Moderately hydraulic lime (11 to 20% clay content)
(c) Eminently hydraulic lime (21 to 30% clay content)
The properties of hydraulic lime are:

- Sets under water
- Colour is not perfectly white
- Forms a thin paste with water and do not dissolve in water.
- Its binding property improves if its fine powder is mixed with sand and kept in the form of heap for a week, before using.

✓ Fat lime and hydraulic lime are used for making lime mortar. If fat lime is used sand mixed is normally 2 to 3 times its volume. If hydraulic lime is used sand mixed is only 2 times the volume of lime. Lime is prepared by pounding, if quantity required is small or by grinding, if the required quantity is more.

Pounding: For pounding, pits are formed in hard grinds. The size of pit is usually 1.80 m long, 0.4 m wide and 0.5 m deep. It is provided with lining of bricks or stones. Lime and sand dry mixed with required proportion is placed in the pit. Small quantity of water is added at intervals. In each interval the mix is pounded with wooden pounders and mortar is turned up and down. The process is continued till uniform colour and desired consistency is achieved.

Grinding: This is the better way of getting good mix. The grinding may be carried out in bullock driven grinding mill or in power driven grinding mill.

Lime mortar is also having good grinding property. Fat lime mortar is used for plastering while hydraulic lime mortar is used for masonry construction. This mortar was considered cheap in olden days and was commonly used in small towns. However the cumbersome process of preparation and ease in availability of cement in market has almost replaced the use of lime mortar.

✓ **MUD MORTAR**

Clay lumps are collected and are wetted with water and allowed to mature for 1 or 2 days. It is kneaded well until it attains required consistency. Sometimes, fibrous material like gobber is added in the mix.
It prevents cracks in the plaster. If plaster is to be used for outer walls, it is sprayed or painted with bitumen.
It is cheap mortar. Its durability is less. It is normally used for the construction of temporary sheds and cheap houses in rural areas.

✓ **SPECIAL MORTAR**

1. **Cement Clay Mortar:** Quality of clay mortar can be improved by adding cement to the mix. Normal proportion of clay to cement is 1:1. It maintains the economy to some extent and there is sufficient improvement in the durability of mud-mortar.

2. **Gauged Mortar:** It is the mortar obtained by adding cement to lime mortar. The usual proportion of cement, lime and sand are 1:1:6, 1:2:9 and 1:3:12. This mortar is to be used within half an hour after mixing cement. Obviously, it is cheaper than cement mortar and its quality is between that of cement mortar and lime mortar.

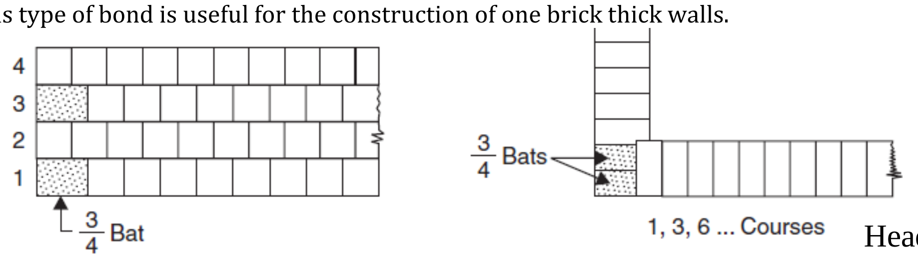
3. **Decorative Mortar:** These mortars are obtained by using coloured cement. They are used to give pleasant appearance to outer walls.

3.2 Brick masonry (types, specifications)

Brick masonry is built with bricks bonded together with mortar. For temporary sheds mud mortar may be used but for all permanent buildings lime or cement mortars are used. The various types of bonds generally used in brick masonry are:

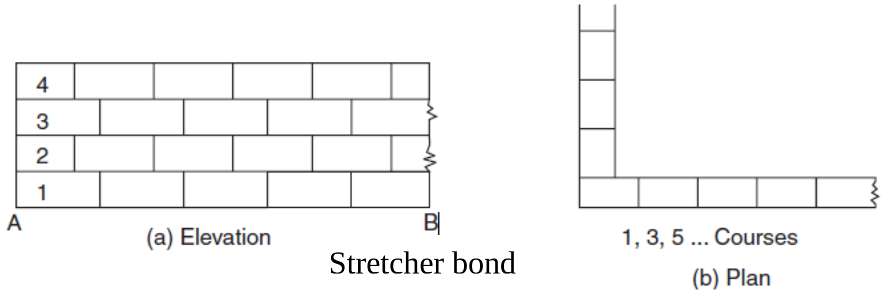
1. Stretcher bond **2. Header bond** **3. English bond** **4. Flemish bond.**

1. **Stretcher Bond:** A stretcher is the longer face of the brick as seen in the elevation. In the brick of size 190 mm × 90 mm × 90 mm, 190 mm × 90 mm face is the stretcher. In stretcher bond masonry all the bricks are arranged in stretcher courses as shown in Fig. 8.4. However care should be taken to break vertical joints. This type of construction is useful for the construction half brick thick partition wall.
2. **Header Bond:** A header is the shorter face of the brick as seen in the elevation. In a standard brick it is 90 mm × 90 mm face. In header bond brick masonry all the bricks are arranged in the header courses as shown in Fig. below This type of bond is useful for the construction of one brick thick walls.



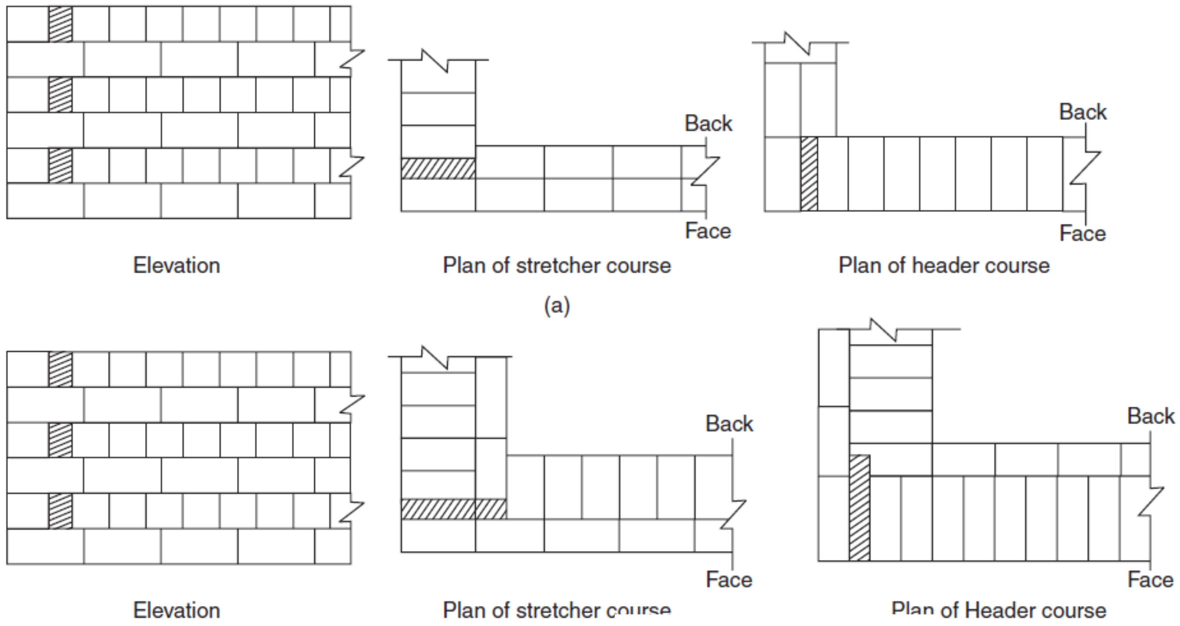
(a) Elevation (b) Plan

Header bond



Stretcher bond

3. English Bond: In this alternate courses consist of headers and stretchers. This is considered to be the strongest bond. Hence it is commonly used bond for the walls of all thicknesses. To break continuity of vertical joints a brick is cut lengthwise into two halves and used in the beginning and end of a wall after first header. This is called queen closer. Figure below shows typical one brick and one and half brick thick wall with English bond.



(b) English bond

4. Flemish Bond: In this type of bond each course comprises of alternate header and stretcher. Alternate courses start with stretcher and header. To break the vertical joints queen closers are required, if a course starts with header. Every header is centrally supported on the stretcher below it.

Flemish bonds may be further classified as
(*a*) Double Flemish Bond
(*b*) Single Flemish Bond.

In case of *double flemish bond*, both faces of the wall have flemish look, *i.e.* each course consist of alternate header and stretcher, whereas *single flemish bond* outer faces of walls have flemish look whereas inner faces have look of English bond.
Construction of Flemish bond needs greater skill. It gives more pleasing appearance. But it is not as strong as English bond. If only pointing is to be used for finished wall, Flemish bond may be used to get good aesthetic view. If plastering is going to be used, it is better to use English bond.

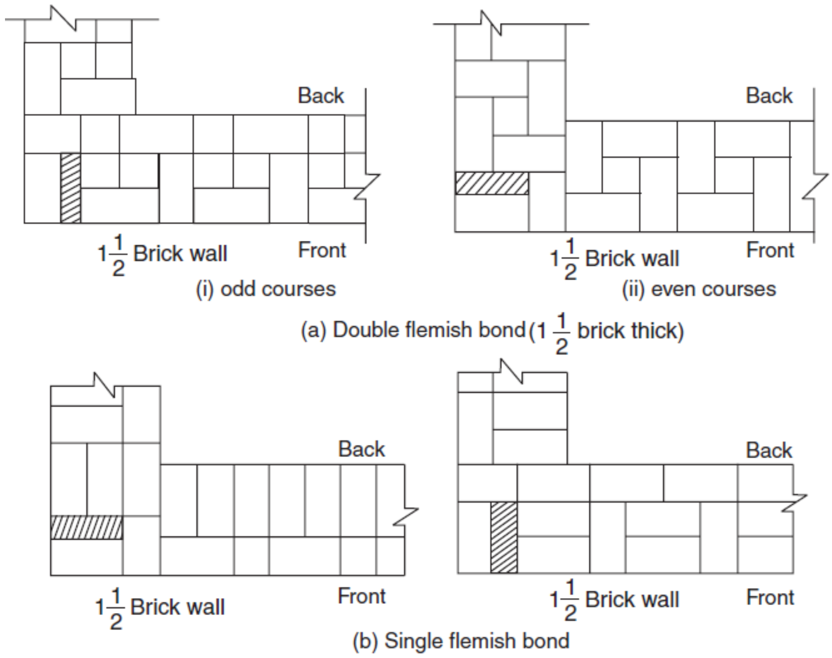


Fig. 8.7. Flemish bond

Advantages and Disadvantages of Brick Masonry over Stone Masonry

Advantages:

1. Since shape and size of bricks are uniform, it does not need skilled labour for the construction.
2. Bricks are light in weight and hence handling them is easy.
3. Bricks are easily available around cities and their transportation cost is less because their weight is less. Stones are to be brought from quarries which are located only at few places.
4. It is possible to use all types of mortar in brick masonry. For unimportant buildings even mud mortar can be used.
5. Thinner walls can be constructed with bricks but it is not so with stones.
6. It is easy to form openings for doors and windows.
7. Dead load of brick masonry is less.
8. In brick masonry mortar joints are thin and hence construction cost is reduced considerably.
9. Brick masonry has better fire and weather resistance compared to stone masonry.

Disadvantages:

1. Strength of brick masonry is less than that of stone masonry.
2. Durability of brick masonry is less.
3. Brick masonry needs plastering and plastered surface needs colour washing. Stone masonry doesn't need them and hence maintenance cost is more in brick masonry.
4. Brick masonry absorbs water and there is possibility of dampness. There is no such problem in stone masonry.
5. More architectural effects can be given in stone masonry compared to that in brick masonry.
6. Stone masonry gives massive appearance and hence monumental buildings are built in stone masonry.

Specifications of brick masonry:

Bricks: The bricks shall be of a standard rectangular shape, burnt red, hand-formed or machine-made, and with a crushing strength not less than 3.5 N/mm^2. The higher the density and the strength, the better they will be. The standard brick size of 240 x 115 x 57 mm with 10 mm thick horizontal and vertical mortar joints is preferable. Tolerances of -10 mm on length, -5 mm on width and ±3mm on thickness shall be acceptable for the purpose of walls of the thickness specified below.

Wall Thickness: A minimum thickness of one half-brick (115 mm) and a maximum thickness of one brick (240 mm) conforming to NS 1:2035 shall be used for the walls constructed as non-load bearing walls in the buildings.

Mortar: Cement-sand mixes of 1:6 and 1:4 shall be adopted for one-brick and half-brick thick walls, respectively. The addition of small quantities of freshly hydrated lime to the mortar in a lime-cement ratio of ¼ :1 to ½ :1 will increase its plasticity greatly without reducing its strength.

Bricks shall be laid in English Bond unless otherwise specified. In half brick wall, bricks shall be laid in stretcher bond. Half or cut bricks shall not be used except as closer where necessary to complete the bond. Closers in such cases, shall be cut to the required size and used near the ends of the wall. Header bond shall be used in foundation footings unless thickness of walls (width of footing) makes the use of headers impracticable. Where thickness of footing is uniform for a number of courses, the top course of footing shall be headers.

The surface for bricks work shall be cleaned with a wire brush and surface wetted. Bricks shall be laid on a full bed of mortar, when lying, each brick shall, be properly bedded and set in position by gently pressing with the handle of a trowel. It's inside face shall be buttered with mortar before the next brick is laid and pressed against it. Joints shall be fully filled and packed with mortar.

The walls shall be taken up truly in plumb or true to the required batter where specified. All courses shall be laid truly horizontal and all vertical joints shall be truly vertical. Vertical joints in the alternate course shall come directly one over the other. Quoin, Jambs and other angles shall be properly plumbed as the work proceeds. Care shall be taken to keep the perpends properly aligned within following maximum permissible tolerances:

(i) Deviation in verticality in total height of any wall of building more than one storey in height shall not exceed 12.5 mm.

(ii) Relative displacement between loads bearing wall in adjacent storey intended to be vertical alignments shall not exceed 6 mm.

(iii) Deviation from position shown on plan of any brick work shall not exceed 12.5 mm.

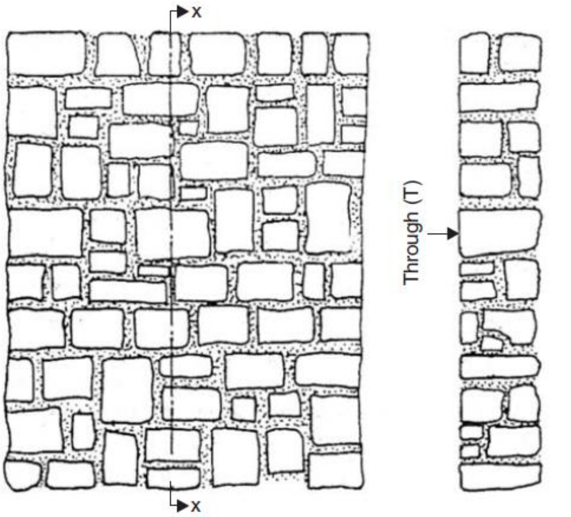
(iv) Deviation from vertical within a storey shall not exceed 6 mm per 3 m height.

3.3 Stone masonry (random rubble, course rubble, ashlar)

Masonry means construction of buildings using building blocks like stone, bricks, concrete blocks etc. Masonry is used for the construction of foundation, plinth, walls and columns. Mortar is the binding material for the building blocks. In this article different types of stone masonry used are explained and points to be observed while supervising stone masonry works are listed.

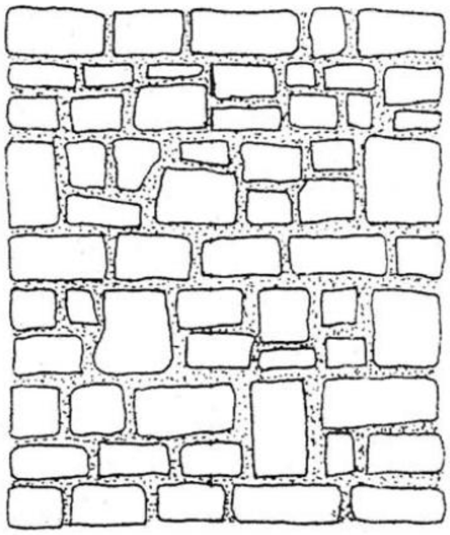
Types of Stone Masonry

1. Rubble Masonry: In this type of constructions stones of irregular sizes and shapes are used. To remove sharp shapes they may be hammered. The rubble masonry may be ***coursed*** or ***uncoursed*** . In *uncoursed rubble masonry* the wall is brought to level at every 300 mm to 500 mm. The mortar consumed in these constructions is more. Course rubble masonry is used for the construction of public and residential buildings. Uncoursed rubble masonry is used for the construction of foundations, compound walls, garages, labour quarters etc. A skilled mason may arrange the facing stones in *polygonal shapes* to improve the aesthetic of the wall.



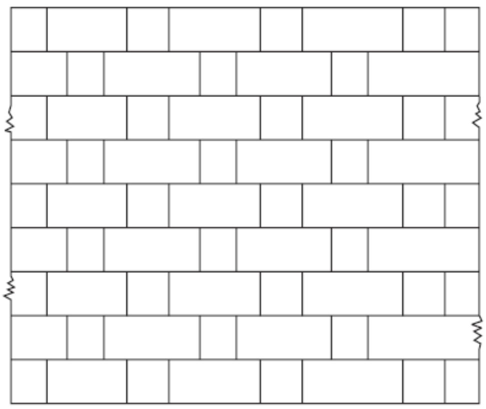
(a) Elevation (b) Section x – x

Uncoursed rubble masonry

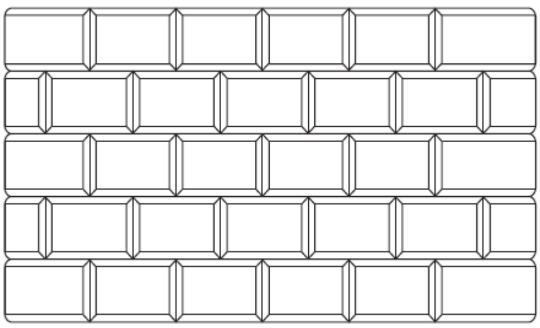


!. Coursed rubble masonry

2. Ashlar Masonry: In this type of masonry stones are dressed to get suitable shapes and sizes. The height of the stones varies from 250 mm to 300 mm. The length should not exceed three times the height. The dressing of the stone need not be very accurate on all sides. Usually good dressing is made on facing side. In such construction mortar consumption is less compared to rubble masonry. There are different types of ashlar masonry depending upon the type of dressing such as Ashlar fine dressed, Ashlar rough dressed, Ashlar rock or quarry faced, Ashlar facing, Ashlar chamfered etc. Figure 8.3 show some of such masonry.



(a) Fine finished ashlar



(b) Ashlar chamfered

<u>3.4 Walls: retaining walls, cavity walls, parapet walls</u>

<u>**Retaining walls:**</u> A **retaining wall** is defined as a structure whose primary purpose is to provide lateral support for soil or rock. In some cases, such as basement walls and certain types of bridge abutments, it may also support vertical loads. The more common types of retaining walls include **gravity walls, cantilevered walls, counterfort walls,** and **crib walls.** <u>**Ref: foundation engineering for more detail on retaining walls.**</u>

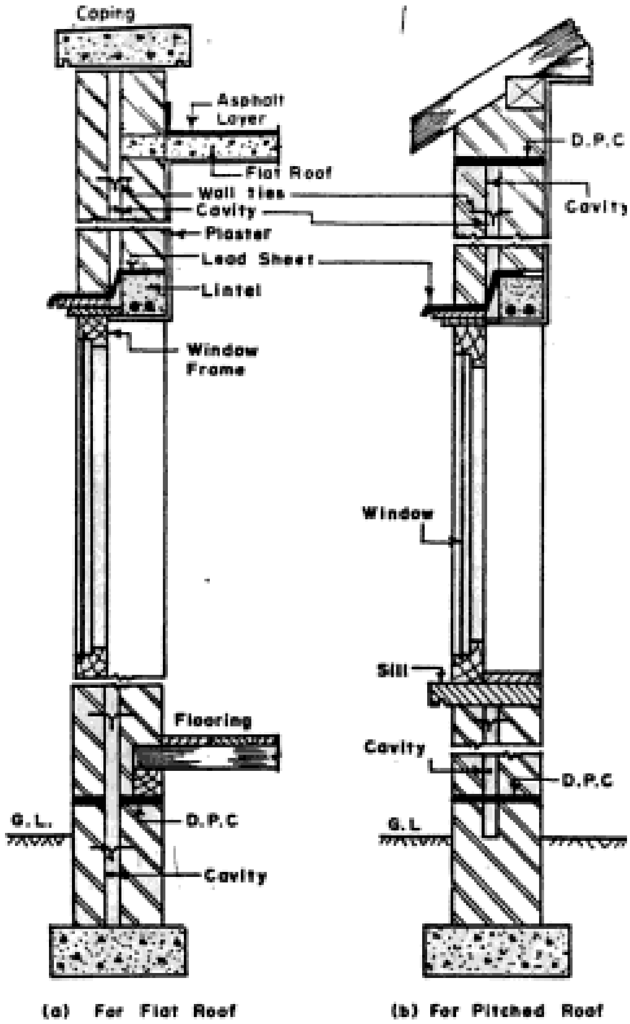


FIG. 9.1. BRICK CAVITY WALLS.

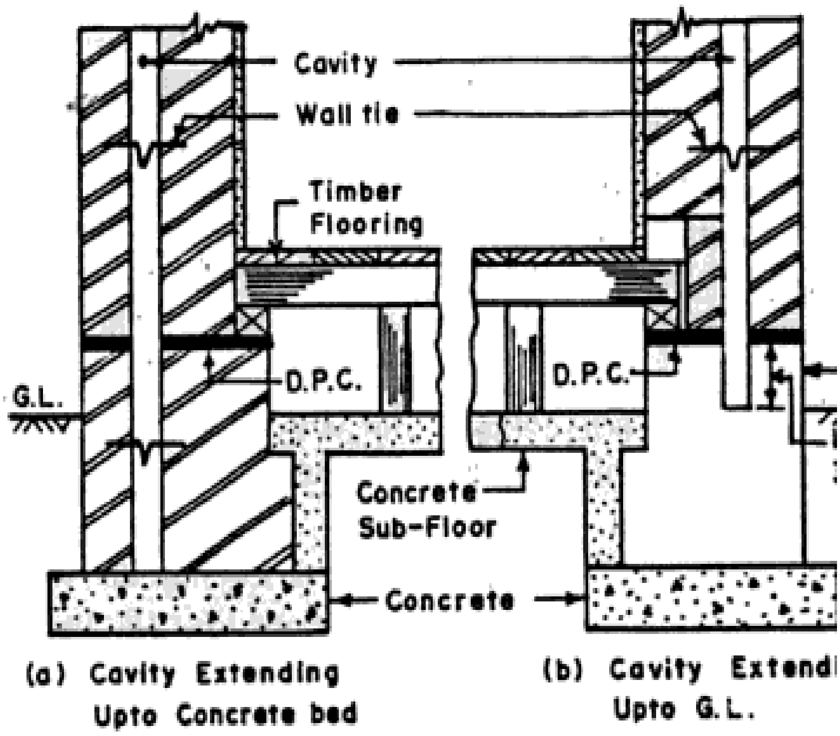
Cavity wall:

These consist of an outer brick or block leaf or skin separated from an inner brick or block leaf or skin by an air space called a cavity. These walls have better thermal insulation and weather resistance properties than a comparable solid brick or block wall and therefore are in general use for the enclosing walls of domestic buildings. The size of cavity varies from 4 to 10 cm. the inner and outer skins should not be less than 10cm each (half brick)

Advantages of cavity walls:

Cavity walls have following advantages over other walls:

- There is no direct contact between the inner and outer leaves of the wall. Hence the external moisture cannot travel inside the building.
- The cavity between the two leaves is full of air which is bad conductor of heat. Hence transmission of heat from external face to inside the room is very much reduced.
- Cavity walls also offer good insulation against sound.
- Efflorescence is reduced.
- They are cheaper and economical.
- Loads on foundations are reduced because of lesser solid thickness.



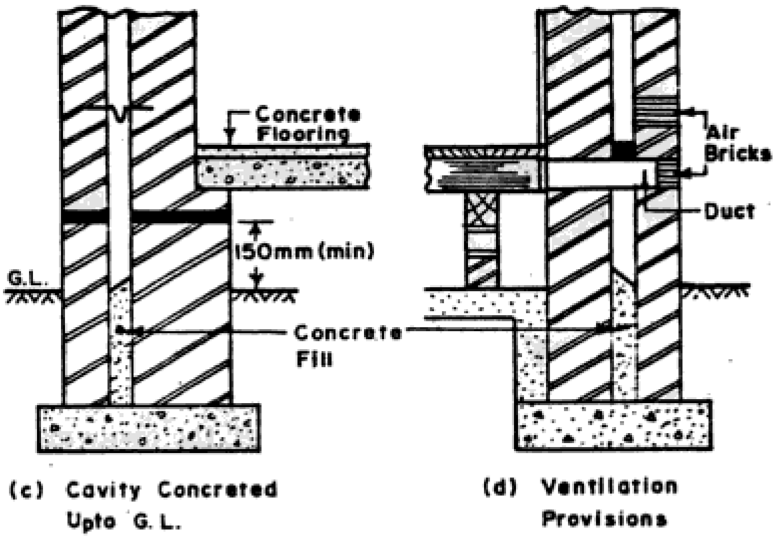


FIG. 9.2. POSITION OF CAVITY AT FOUNDATION LEVEL.

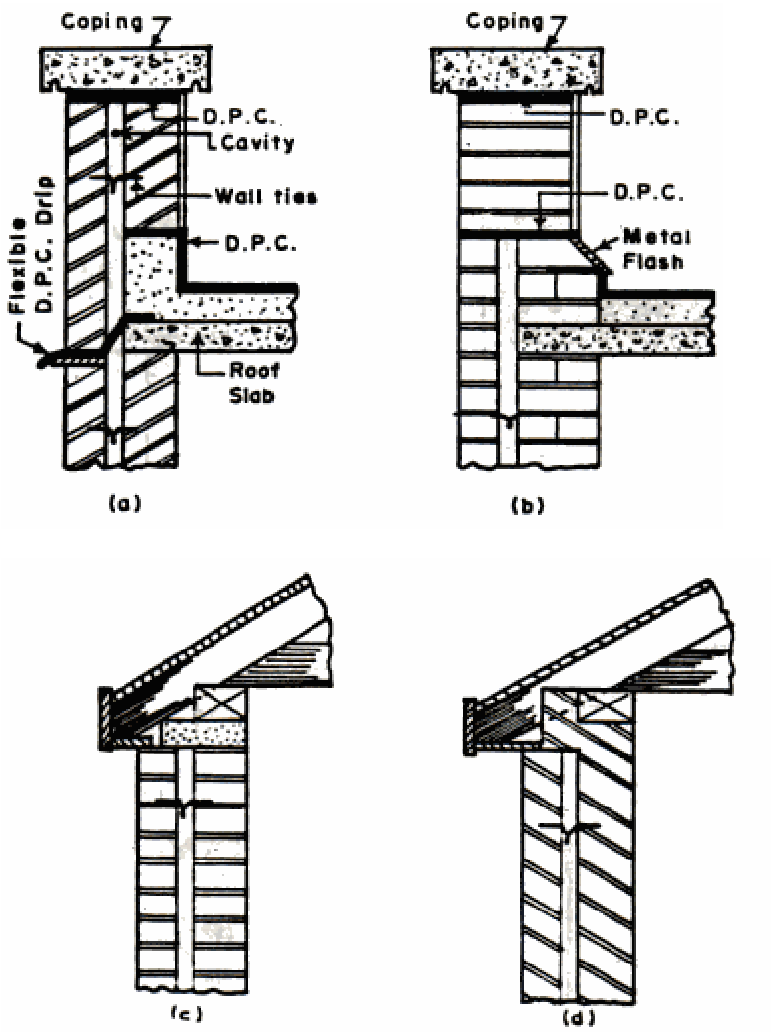
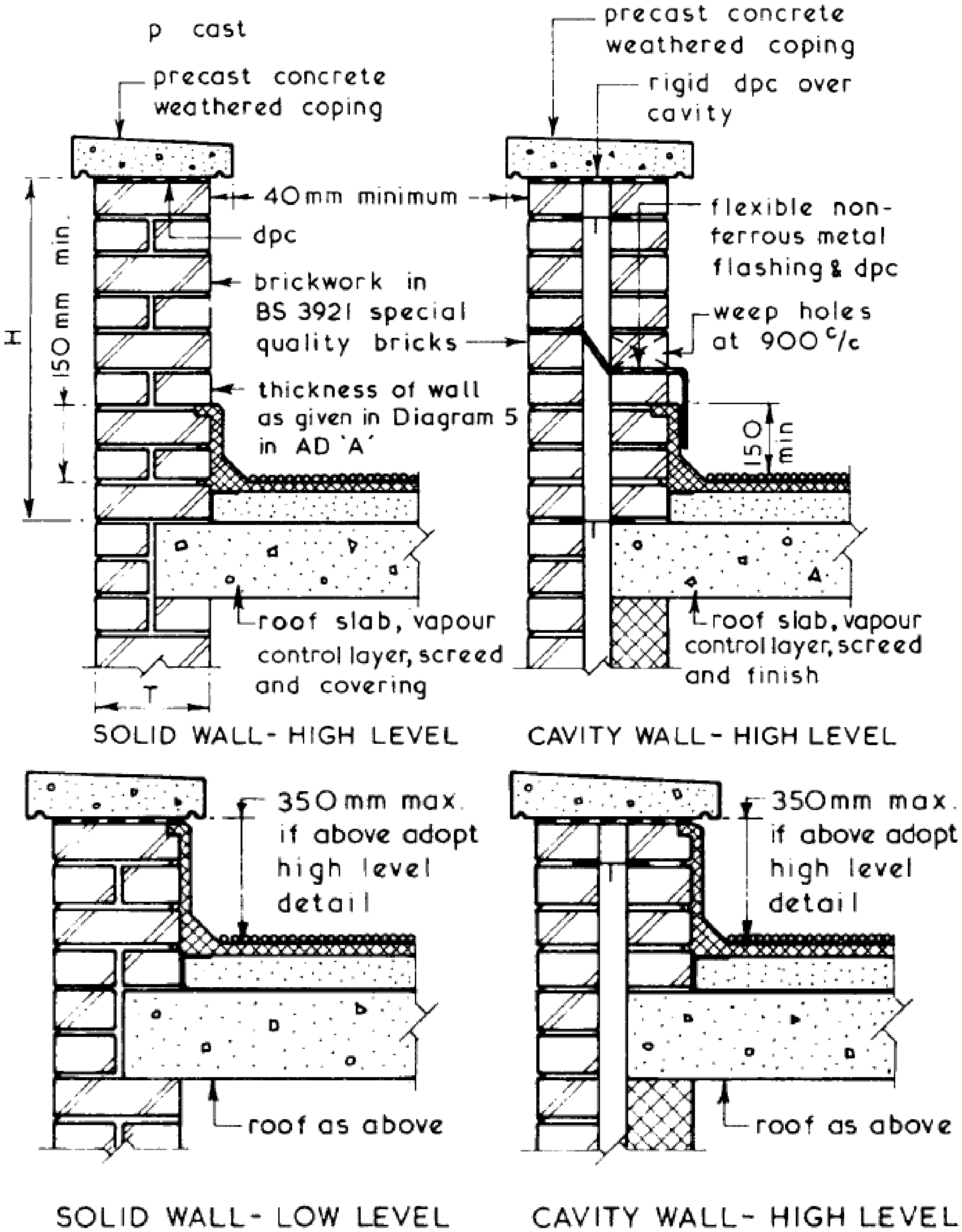


FIG. 9.3. POSITION OF CAVITY AT ROOF LEVEL.

Parapet wall is a low wall projecting above the level of a roof, bridge or balcony forming a guard or barrier at the edge. Parapets are exposed to the elements on three faces namely front, rear and top and will therefore need careful design and construction if they are to be durable and reliable.



Parapet walls require careful detailing. At the top of the wall it is good practice to provide a weathered coping. The coping can be once or twice weathered - in other words it can slope in one direction or in both directions. A once weathered coping normally directs the water onto the roof to avoid water running down the external face. In some designs brick copings are used although careful detailing may be required if the copings don't have drips (sometimes called throatings).

A good coping stone will overhang the wall either side and will incorporate small drips to prevent water running back under the coping. A full-width DPC should be bedded in mortar to prevent water penetrating the coping through the coping joints. The DPC should be laid on a rigid support to prevent it sagging into the cavity and allowing water to pond where it may freeze and expand in cold weather. Any sagging may also form a trough and allow water to penetrate the cavity where the DPC is lapped.

Because parapet walls are exposed on both sides a cavity tray is required to prevent water running down the cavity face of the inner leaf and penetrating the building.

CHAPTER 4 ROOFS

4.1 Roofs & their types

Roof may be defined as a covering provided over the top of a building with a view to keep out of rain, snow, sun and wind and to protect the building from the adverse effects of these elements. A roof basically consists of roof covering materials supported on structural elements installed on the building top. The structural elements may be trusses, flat slab, shell, dome or space frame whereas the roof covering materials may be thatch, wooden single, tiles, slates, A.C. sheets, G.I. sheets etc.

Functions of any roof:

- Prevent excessive heat loss in winter.
- Keep the interior of the building cool in summer.
- To keep out rain, wind, snow and dust.
- For strength and stability of building.
- For durability and free from maintenance.
- For fire safety.
- Provide resistance to the passage of sound.
- Safety to occupants.
- Aesthetic beauty.

Various types of roofs used may be divided broadly into three types:
1. Flat roofs **2. Pitched roofs** **3. Shells and folded plates**

Flat roofs are used in plains where rainfall is less and climate is moderate. Pitched roofs are preferred wherever rainfall is more. Shells and folded plate roofs are used to cover large column free areas required for auditoriums, factories etc.

1. Flat Roofs: These roofs are nearly flat. However slight slope (not more than 10°) is given to drain out the rain water. All types of upper storey floors can serve as flat roofs. Many times top of these roofs are treated with water proofing materials-like mixing water proofing chemicals in concrete, providing coba concrete. With advent of reliable water proofing techniques such roofs are constructed even in areas with heavy rain fall.

The ***advantages*** of flat roofs are:
(*a*) The roof can be used as a terrace for playing and celebrating functions.
(*b*) At any latter stage the roof can be converted as a floor by adding another storey.
(*c*) They can suit to any shape of the building.
(*d*) Over-head water tanks and other services can be located easily.
(*e*) They can be made fire proof easily compared to pitched roof.

The ***disadvantages*** of flat roofs are:
(*a*) They cannot cover large column free areas.
(*b*) Leakage problem may occur at latter date also due to development of cracks. Once leakage problem starts, it needs costly treatments.
(*c*) The dead weight of flat roofs is more.
(*d*) In places of snow fall flat roofs are to be avoided to reduce snow load.
(*e*) The initial cost of construction is more.
(*f*) Speed of construction of flat roofs is less.

Types of Flat Roofs: All the types listed for upper floors can be used as flat roofs.

2. Pitched Roofs: In the areas of heavy rain falls and snow fall sloping roof are used. The slope of roof shall be more than 10°. They may have slopes as much as 45° to 60° also. The sloped roofs are known as pitched roofs. The sloping roofs are preferred in large spanned structures like workshops, factory buildings and ware houses. In all these roofs covering sheets like A.C. sheet, G.I. sheets, tiles, slates etc. are supported on suitable structures.

3. Shells and Folded Plate Roofs: *Shell roof* may be defined as a curved surface, the thickness of which is small compared to the other dimensions. In these roofs lot of load is transferred by membrane compression instead of by bending as in the case of conventional slab and beam constructions. Caves are having natural shell roofs. An examination of places of worships built in India, Europe and Islamic nations show that shell structures were in usage for the last 800 to 1000 years. However the shells of middle ages were massive masonry structures but nowadays thin R.C.C. shell roofs are built to cover large column free areas.

4.1 Timber roofs (Single/double/ multiple timber roofs)

(*a*) **Single Roof:** If the span of roof is less than 5 m the following types of single roofs are used.

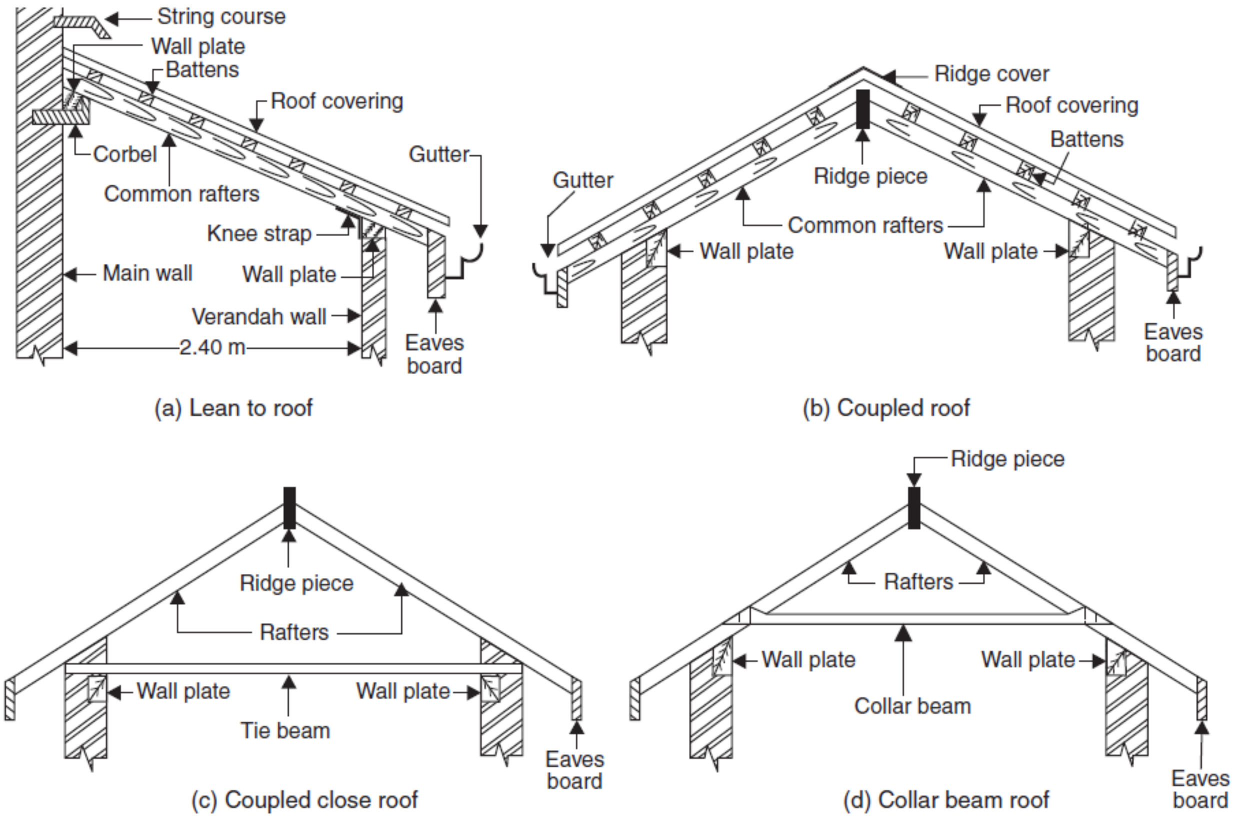
(*i*) Lean to roofs

(*ii*) Coupled roofs

(*iii*) Coupled-close roof

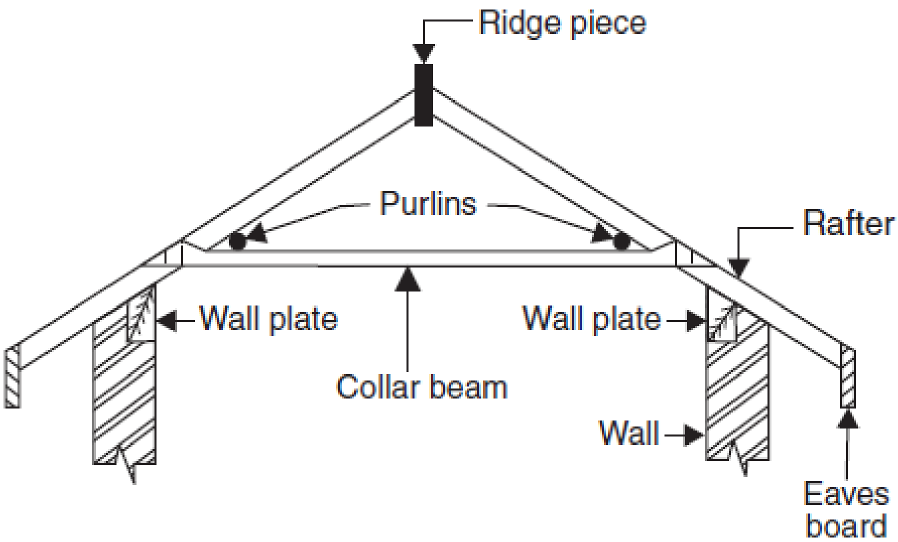
(*iv*)Collar beam roof

In all these roofs rafters placed at 600 mm to 800 mm spacing are main members taking load of the roof. Battens run over the rafters to support tiles. Figure below shows various types of single roofs.



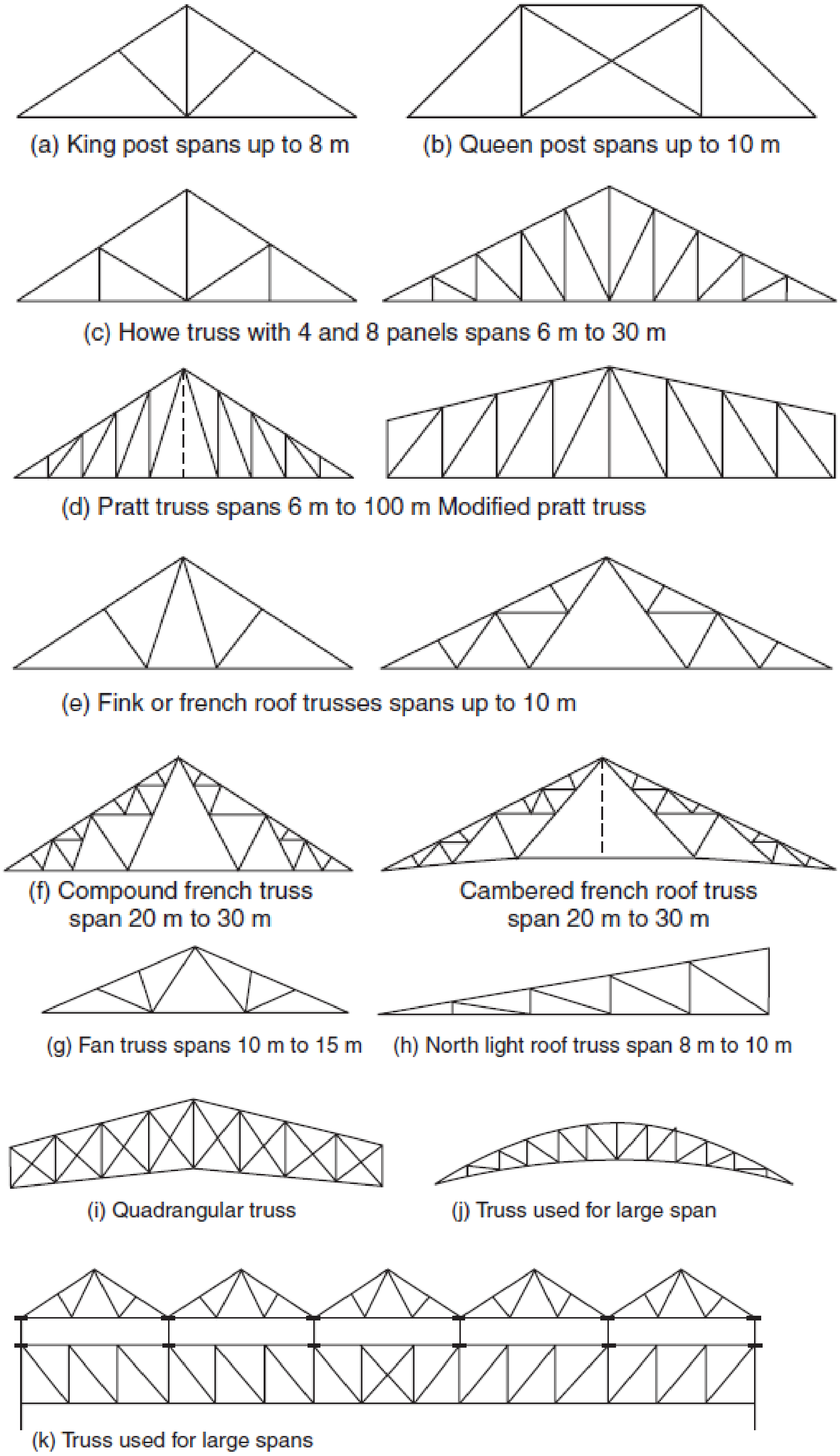
Single roofs

(*b*) **Double or Purlin Roofs:** If span exceeds, the cost of rafters increase and single roof becomes uneconomical. For spans more than 5 m double purlin roofs are preferred. The intermediate support is given to rafters by purlins supported over collar beams. Figure below shows a typical double or purlin roof.

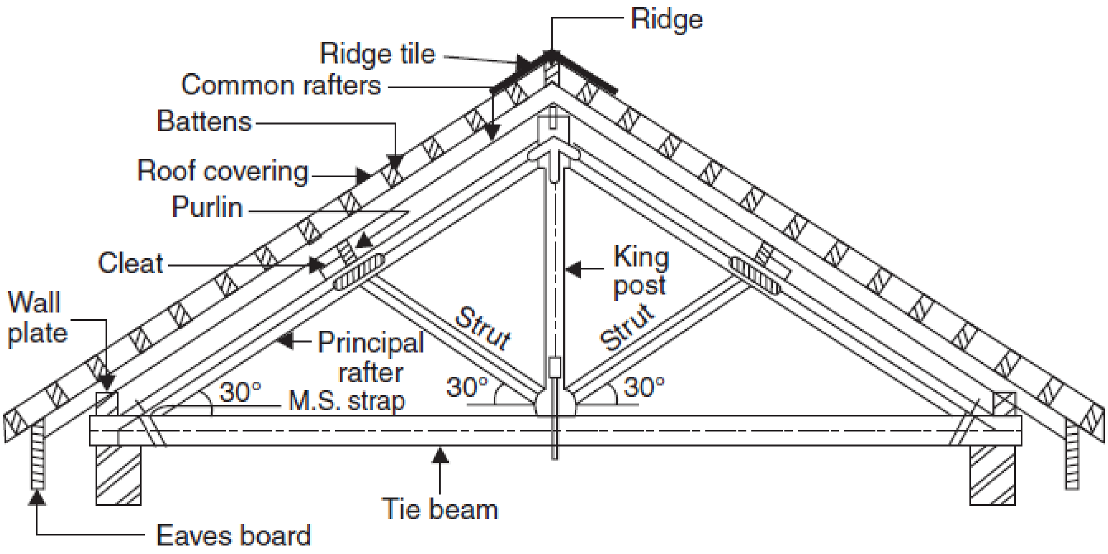


Double or purlins roofs

(*c*) **Trussed Roof:** If span is more, frame works of slender members are used to support sloping roofs. These frames are known as trusses. A number of trusses may be placed lengthwise to get wall free longer halls. Purlins are provided over the trusses which in turn support roof sheets. For spans up to 9 m wooden trusses may be used but for larger spans steel trusses are a must. In case of wooden trusses suitable carpentry joints are made to connect various members at a joint. Bolts and straps are also used. In case of steel trusses joints are made using gusset plates and by providing bolts or rivets or welding.
Depending upon the span, trusses of different shapes are used. End of trusses are supported on walls or on column.



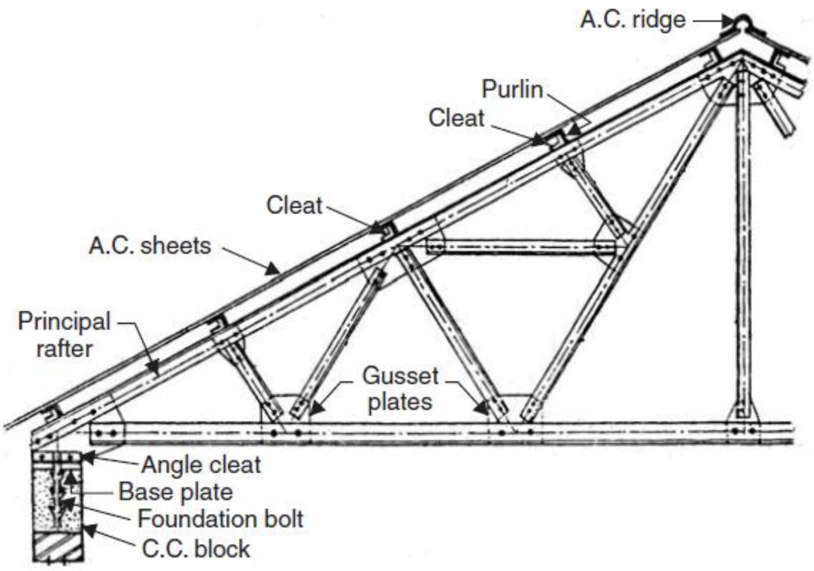
Types of trusses



A typical wooden truss (king past)

Steel trusses and their components (Angle & tubular truss)

They are used for span more than 10m.They are commonly used these days since they are more economical, easy to construct or fabricate , fire proof , more rigid and permanent. It consists of rolled steel sections welded and bolted in gusset plates. The sections may be tube (pipe) or angles.



Steel roof truss

In angular steel roof trusses, angle sections and plates are commonly used for fabrication though channel sections and T-sections can be also used. The roof truss is so designed that the members carry only direct stresses, (i.e., either compression or tension) and no bending stress are induced. The principal rafters as well as the main tie are generally made of two angle sections placed side by side, while the struts and ties are generally made of single angle sections. The members are jointed together, using a gusset plate, either through rivets or by welding.

Tubular Steel roof trusses are used for large span constructions such as factories, industry work sheds, shopping malls, huge exhibition centers, multiplexes etc. They are generally used for spans as large as 25-30m. Tubular trusses are quite popular since they are light weight and economical. Since external loads are transferred to a truss at the joints, various members of a truss are subject only to direct stresses, either tensile or compressive.
However, purlins are designed as flexural members.

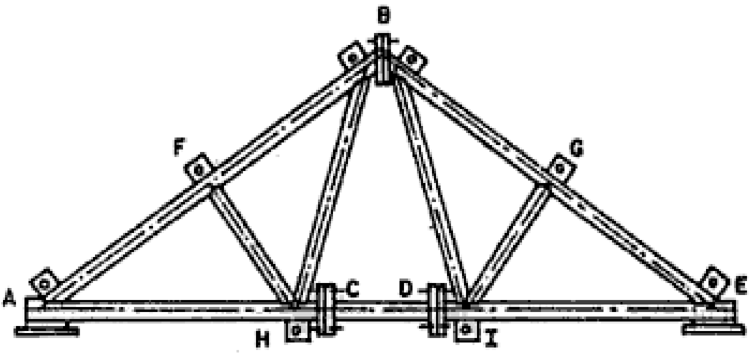


FIG. 17.1. TUBULAR ROOF TRUSS.

Roof coverings

Various types of covering materials are available for pitched roofs and their selection depends upon the climatic conditions, fabrication facility, availability of materials and affordability of the owner. Commonly used pitched roof covering materials are:

(*a*) Thatch
(*b*) Shingle
(*c*) Tiles
(*d*) Slates
(*e*) Asbestos cement (A.C.) sheets
(*f*) Galvanised iron (G.I.) sheets

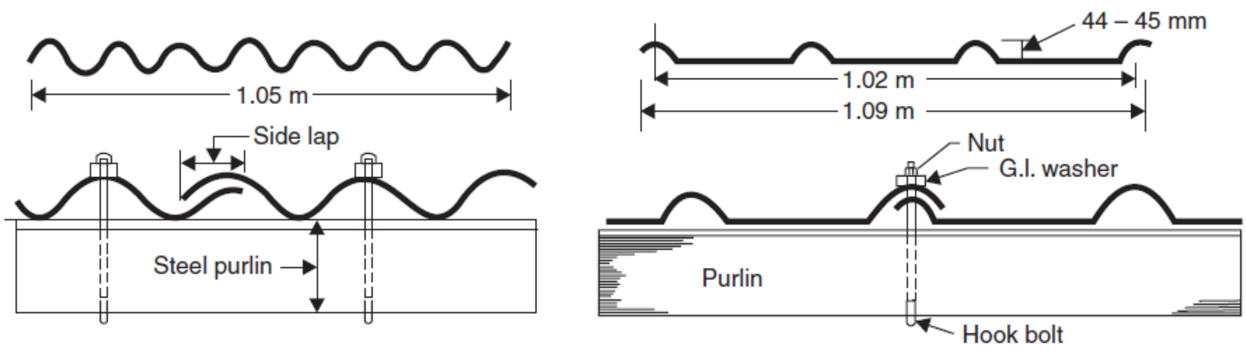
a) Thatch Covering: These coverings are provided for small spans, mainly for residential buildings in villages. Thatch is a roof covering of straw, reeds or similar materials. The thatch is well-soaked in water or fire resisting solution and packed bundles are laid with their butt ends pointing towards eves. Thickness varies from 150 mm to 300 mm. They are tied with ropes or twines to supporting structures. The supporting structure consists of round bamboo rafters spaced at 200 mm to 300 mm over which split bamboos laid at right angles at close spacing. It is claimed that reed thatch can last 50 to 60 years while straw thatch may last for 20–25 years.
The advantage of thatch roof is they are cheap and do not need skilled workers to build them.
The disadvantages are they are very poor fire resistant and harbour rats and other insects.

(*b*) **Shingles:** Wood shingles are nothing but the split or sawn thin pieces of wood. Their size varies from 300 mm to 400 mm and length from 60 mm to 250 mm. Their thickness varies from 10 mm at one end to 3 mm at the other end. They are nailed to supporting structures. They are commonly used in hilly areas for low cost housing. They have very poor fire and termite resistance.

(*c*) **Tiles:** Various clay tiles are manufactured in different localities. They serve as good covering materials. Tiles are supported over battens which are in turn supported by rafters/trusses etc. Allahabad tiles, Mangalore tiles are excellent inter-locking tiles. They give good appearance also.

(*d*) **Slates:** A slate is a sedimentary rock. Its colour is gray. It can be easily split into thin sheets. Slates of size 450 mm to 600 mm wide, 300 mm long and 4 to 8 mm thick are used as covering materials of pitched roofs in the areas where slate quarries are nearby. A good slate is hard, tough, and durable. They are having rough texture and they give ringing bell like sound when struck. They do not absorb water.

(*e*) **A.C. Sheets:** Asbestos cement is a material which consists of 15 per cent of asbestos fibres evenly distributed and pressed with cement. They are manufactured in sufficiently large size. The width of a A.C. sheet varies from 1.0 to 1.2 m and length from 1.75 to 3.0 m. To get sufficient strength with thin sections they are manufactured with corrugation or with traffords . They are fixed to the steel purlins using J-bolts. The roofing is quite economical, waterproof. However, not very good thermal resistant. They are commonly used as covering materials in ware houses, go downs or for larger halls. In auditorium etc., if these sheets are used, false ceilings are provided to get good thermal resistance.



(a) Corrugated sheet covers

(b) Trafford sheet covers

A.C. sheet roofing

(*f*) **G.I. Sheets:** Galvanised iron corrugated sheets are manufactured in the sizes 1.0 to 1.2 m wide and 1.65 m length. Galvanisation of iron makes them rust proof. They are fixed to steel purlins using J-bolts and washers. They are durable, fire proof, light in weight and need no maintenance. They are commonly used as covering materials for ware houses, go down, sheds etc. Table 8.6 gives comparison between GI and AC sheets for roof covering.

Comparison between GI and AC sheets

S. No.	*GI Sheets*	*A.C. Sheets*
1.	Sheets are thin.	Not as thin as GI sheets.
2.	Light in weight.	Slightly heavier.
3.	Do not break while handling.	Chances of breaking are there during handling.
4.	Chances of corrosion can not be ruled out	No problem of corrosion.
5.	More noisy, if something falls over them.	Less noisy, if something falls over them.
6.	Less fire resistant.	More fire resistant.
7.	Less resistance to acids and fumes.	More resistant to acids and fumes.
8.	Cost is more.	Less costly.

CHAPTER-5 STAIR, LIFTS AND ESCALATORS

5.1 Stair and its Elements

Stairs give access from floor to floor. The space/room housing stairs is called staircase. Stairs consists of a number of steps arranged in a single flight or more number of flights. The room or enclosure of the building where the stair is located is known as stair-case. It is also known as vertical circulation.

Elements of stair

Tread: The horizontal member of a stair, on which the foot is placed while ascending or descending. It is the horizontal distance between two successive risers. It is also known as the "Going".

Riser: The vertical member of a stair that supports tread. The vertical distance between two consecutive treads is known as the "rise".

Step: Riser and tread together

Staircase: The volume (enclosure) where stair is accommodated

Stairway/ Stairwell: The space where the stair is housed

Landings: Platform left between two flights for circulation and rest

Flight: Series of steps between landings

Winder: The trapezoidal tread

Nosing: The exposed edge of tread, projected outwards

Strings/ Stringers: The members receiving ends of step

Soffit: Underside of the a stair

Head room: Minimum clear distance between the tread and the overhead structure

Handrail: Protecting member usually parallel to the string, for support while ascending or descending

Baluster: The vertical infill member between the string and the handrail. A row of balusters surmounted with handrail is known as the "Balustrade".

Pitch line: An imaginary line connecting the nosing of all tread in one flight. Pitch or slope is the angle made by the line with the horizontal.

Newel: Post forming the junction of flights with landing or carrying the lower end of strings

5.2 Essential requirements & Types of stair

The requirements of good stairs are:
(*a*) **Width:** 0.9 m in residential buildings and 1.5 m to 2.5 m in public buildings.
(*b*) **Number of Steps in a Flight:** Maximum number of steps in a flight should be limited to 12 to 14, while minimum is 3.
(*c*) **Rise:** Rise provided should be uniform. It is normally 150 mm to 175 mm in residential buildings while it is kept between 120 mm to 150 mm in public buildings. However in commercial buildings more rise is provided from the consideration of economic floor area.
(*d*) **Tread:** Horizontal projection of a step in a stair case is called tread. It is also known as going.
In residential buildings tread provided is 250 mm while in public buildings it is 270 mm to 300 mm.
The following empirical formula is used to decide rise and tread:
$2R + T > 550$ mm but < 700 to 600 mm where R is rise in mm and T is tread in mm.
(*e*) **Head Room:** Head room available in the stair case should not be less than 2.1 m.
(*f*) **Hand Rails:** Hand rails should be provided at a convenient height of a normal person which is from 850 mm to 900 mm.
(g) **Location**: stair should be so located that it provide easy access to the occupants, should be well lighted and ventilated.
(f) **Materials of construction**: the material used for the construction of stair should be such as to provide sufficient strength and fire resistance.

According to NBC 206:2003 the following should be fulfilled while designing a stair:

1) The minimum tread shall be 250 mm excluding nosing and the maximum riser will be 175 mm for all buildings except for internal staircases of Apartments, which can be permitted up to 190 mm.
2) Handrails shall be provided in all open staircases
3) The maximum number of risers shall be limited to 15 per flight.

4) The minimum headroom under a staircase shall not be less than 2000 mm measured vertically from the nosing of the tread to the soffit plane above.

Types of Stairs

The stairs may be built with wood, concrete masonry or with cast iron. Wooden stairs are not safe, because of the danger of fire. However they are used in unimportant buildings to access to small areas in the upper floors. Cast iron or steel stairs in the spiral forms were used commonly to reduce stair case area. In many residential buildings masonry stairs are also used. Reinforced concrete stairs are very commonly used in all types of buildings.
Based on the shapes stairs may be classified as:

(*a*) Straight stairs
(*b*) Dog legged stairs
(*c*) Well or open-newel stairs
(*d*) Geometrical stairs
(*e*) Spiral stairs
(*f*) Turning stairs.

(*a*) **Straight Stairs:** If the space available for stair case is narrow and long, straight stairs may be provided. Such stairs are commonly used to give access to porch or as emergency exits to cinema halls. In this type all steps are in one direction. They may be provided in single flight or in two flights with landing between the two flights .

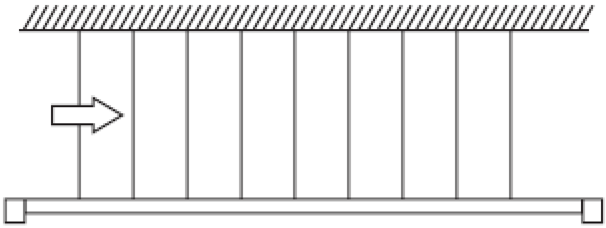


Fig. 8.35. Straight stairs

(*b*) **Dog Legged Stairs:** It consists of two straight flights with 180° turn between the two. They are very commonly used to give access from floor to floor. Figure 8.36 shows the arrangement of steps in such stairs.

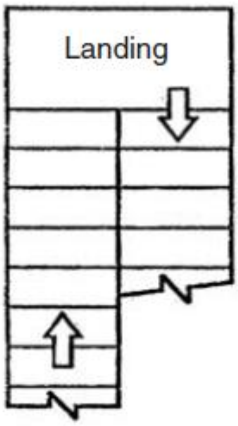


Fig. 8.36. Dog legged stair

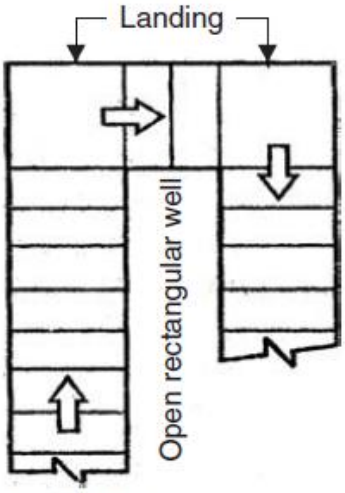


Fig. 8.37. Open well (newel) stair

(*c*) **Well or Open-newel Stairs:** It differs from dog legged stairs such that in this case there is 0.15 m to 1.0 m gap between the two adjacent flights. Figure 8.37 shows a typical open newel stair.
(*d*) **Geometrical Stair:** This type of stair is similar to the open newel stair except that well formed between the two adjacent flights is curved. The hand rail provided is continuous.[Ref. Fig. 8.38]

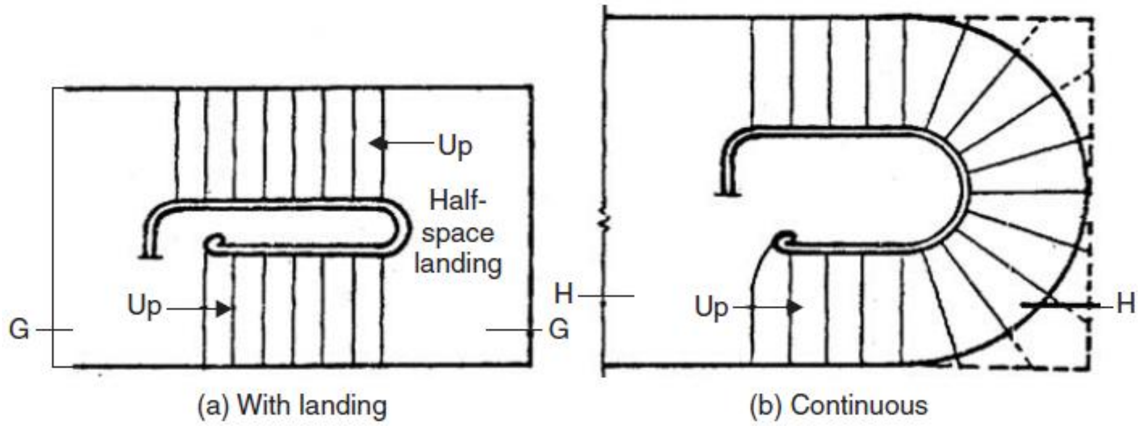


Fig. 8.38. Geometric stairs

(*e*) **Spiral Stairs:** These stairs are commonly used as emergency exits. It consists of a central post supporting a series of steps arranged in the form of a spiral. At the end of steps continuous hand rail is provided. Such stairs are provided where space available for stairs is very much limited. Figure 8.39 shows a typical spiral stair. Cast iron, steel or R.C.C. is used for building these stairs.

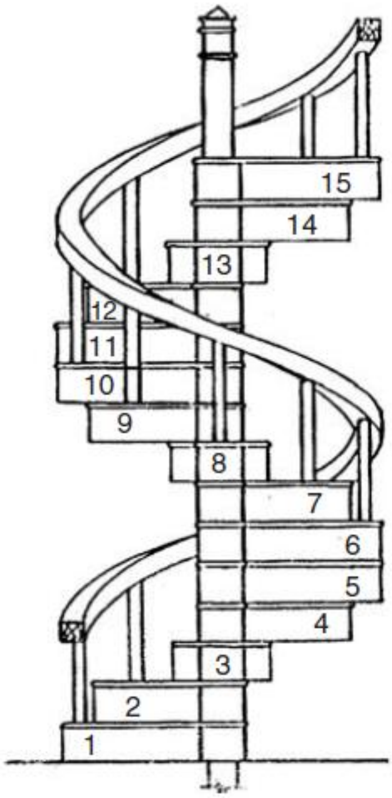


Fig. 8.39. Spiral stairs

(f*)* **Turning Stairs:** Apart from dog legged and open newel type turns, stairs may turn in various forms. They depend upon the available space for stairs. Quarter turned, half turned with few steps in between and bifurcated stairs are some of such turned stairs. Figure 8.40 shows a bifurcated stair.

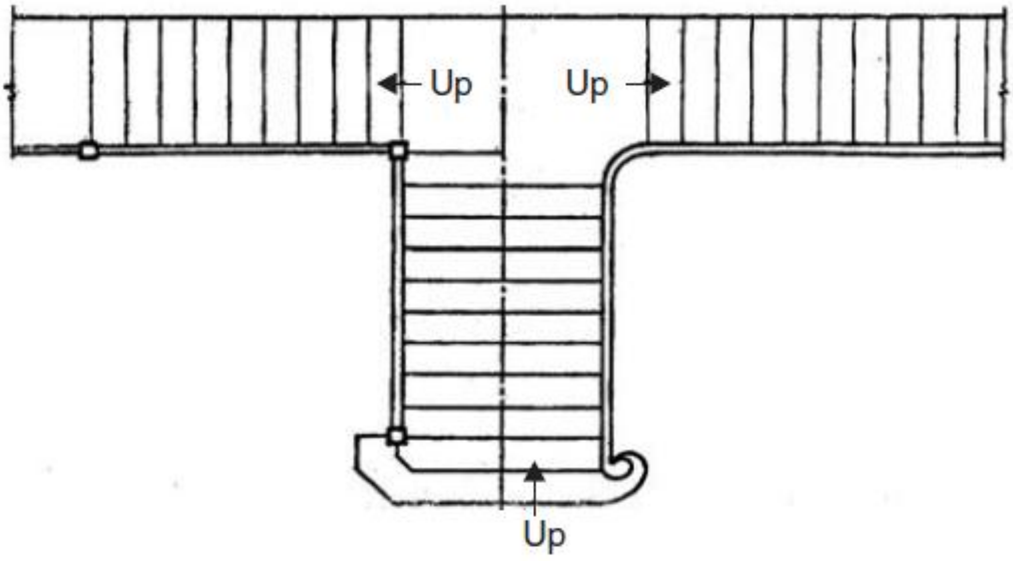


Fig. 8.40. Bifurcated stairs

The following points should be considered in locating stairs in a building:
(*a*) They should be located near the main entrance to the building.
(*b*) There should be easy access from all the rooms without disturbing the privacy of the rooms.
(*c*) There should be spacious approach.
(*d*) Good light and ventilation should be available.

Design of staircase:

Types of bldg.	Riser (mm)			Tread (mm)			Slope		Unobstructed width of stair
	Min.	Opt.	Max.	Min.	Opt.	Max	Opt.	Max	Min. (mm)
Residential	100	175	190	225	250	350	35^0	40^0	800
Semi-public (Factory, office, school, shop)	100	165	190	250	275	350	31^0	38^0	1000
Public (cinema, theatre, stadium, hospitals)	100	150	280	280	300	350	270	330	1000 1200 for hospitals

Design procedure:

- Given the level difference between two floors (ceiling height plus thickness of floor slab).
- Assume the types of building and stair and accordingly the size of riser(R).
- Find the number of risers by NR = (level difference/size of riser).
- Find the number of treads by NT = (NR - 1).
- Assume the size of tread (T).
- Assume the width of the stair.
- Consider the size of landing (L) equal to width of stair.
- Assume the entry space (E), generally equal to landing).
- Find the total length of stair = (NT * T) + L +E.
- Adjust the size of riser and tread if required.

5.3 Ladders, ramps, Lifts & Escalators

Ladders

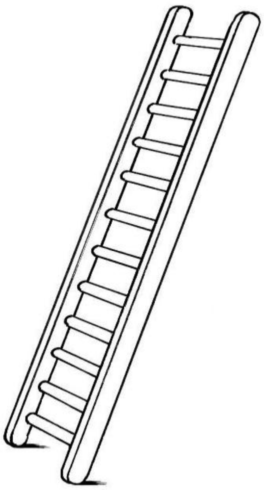
A ladder is a vertical or inclined set of rungs or steps.

There are two types of ladders:

- Rigid ladders that can be leaned against a vertical surface such as a wall. The vertical members of a rigid ladder are called stringers or rails (US) or stiles (UK). Rigid ladders are usually portable, but some types are permanently fixed to buildings. They are commonly made of metal, wood, or fiberglass, but they have been known to be made of tough plastic.
- Rope ladders that are hung from the top. These types of ladders are traditionally used for honey hunting, painting works etc.

The most common injury made by ladder climbers is bruising from falling off a ladder and so for safety, a rigid ladder should be leaned at an angle of about 15° to the vertical. In other words, the distance from the foot of the ladder to the wall should be about one quarter of the height of the top of the ladder. At steeper angles, the ladder is at risk of toppling backwards when the climber leans away from it. At shallower angles, the ladder may lose its grip on the ground. Ladder stabilizers are available that increase the ladder's grip on the ground.

A ladder standoff, or stay, is a device fitted to the top of a ladder to hold it away from the wall. This enables the ladder to clear overhanging obstacles, such as the eaves of a roof, and increases the safe working height for a given length of ladder



Ramps

A wheelchair ramp is an inclined plane installed in addition to or instead of stairs. Ramps permit wheelchair users, as well as people pushing strollers, carts, or other wheeled objects, to more easily access a building.

A wheelchair ramp can be permanent, semi-permanent or portable. Permanent ramps are designed to be bolted or cemented in place. Semi-permanent ramps rest on top of the ground or cement pad and are commonly used for the short term. Permanent and semi-permanent ramps are usually of aluminum, concrete or wood. Aluminum ramps are more durable than wooden ramps and can be moved or reconfigured. Portable ramps are usually aluminum and typically fold for ease of transport. Portable ramps are primarily intended for home and building use but can also be used with vans to load an unoccupied mobility device or to load an occupied mobility device when both the device and the passenger are easy to handle.

Lifts

Lift (also known as elevator in USA) is a hoisting or lowering mechanism, designed to carry passengers or freight, and is equipped with a car and platform that typically moves in fixed guides and serves two or more landings. The lifts can be broadly classified as either electric traction type or hydraulic type:

- Traction lifts have an elevator car and counterweight attached to opposite ends of hoist ropes. The hoist ropes pass over a driving machine that raises and lowers the car. Traction elevators run on load-bearing rails in the elevator hoist way. Traction elevators are most often used in mid-rise and high-rise buildings with five or more floors.

- Hydraulic lifts, on the other hand, are raised by forcing pressurized oil through a valve into a steel cylinder located above ground or underground. The pressure forces a piston to rise, lifting the elevator platform and car enclosure mounted on it. The car is lowered by opening the valve and allowing the weight of the car to force oil from the cylinder in a controlled manner. When the valve is closed the car is stopped. Since the weight of hydraulic elevator cars is borne by the piston, there is no need for a structural framework or load-bearing rails. Hydraulic elevators are commonly found in low-rise buildings with two to five floors.

The main design considerations for choosing either electric traction drive or hydraulic for a particular project are the number of floors, the height of the building, the number of people to be transported, desired passenger waiting times and frequency of use.

Escalator

Around 1900, Charles Seeberger, who designed the forerunner of the modern escalator, came up with the name that finally stuck. His term "escalator" is a combination of "elevator" and "scala," the Latin word for steps. The other mode of vertical building transportation is "Escalator". It can be described as moving stairs typically used to carry large number of people at high volumes through a limited no of floors. These are commonly used in high density areas or where sudden traffic surges are expected at times; for example at discharge times from offices, railways underground stations, airport terminals, theaters, shopping malls and departmental stores. In such applications, escalators will provide shorter travel time than elevators because elevator cars are limited in size and passengers have to wait longer for the service.

CHAPTER-6 Doors and windows

6.1 Doors: frames, shutters and their fixing details

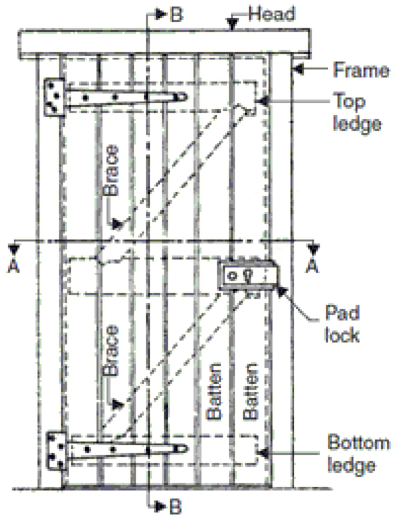
The function of a door is to give access to building and to different parts of the building and to deny the access whenever necessary. Number of doors should be minimum possible. The size of the door should be of such dimension as will facilitate the movement of the largest object likely to use the doors.

In case of the residential buildings, the size of the door should not be less than 0.9 m × 2.0 m. larger doors may be provided at main entrance to the building to enhance the aesthetic view. Minimum sized doors are used for bath rooms and water closets. The size recommended is 0.75 m × 1.9 m. As a thumb rule height of door should be 1 m more than its width.

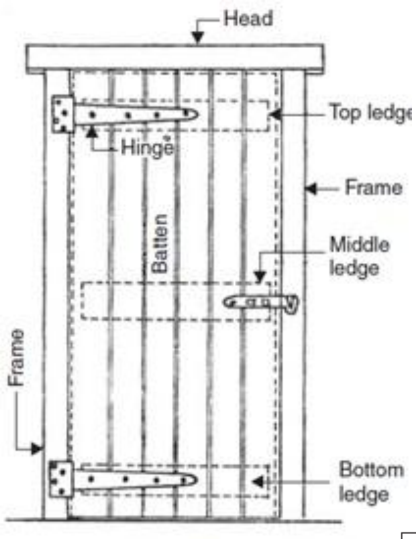
Types of Doors

Various types of doors are in use which may be classified on the basis of arrangement of shutters, method of constructions, principles of working operations and materials used. Commonly used doors are briefly explained below:

1. **Battened and Ledged Doors:** Battens are 100 mm to 150 mm wide and 20 mm thick wooden boards. Their length is that of door opening. The battens are connected by horizontal planks, known as ledges of size 100 to 200 mm wide and 30 mm thick. Usually three ledges are used one at top, one at bottom and the third one at mid-height. This is the simplest form of door and the cheapest also. Battens are secured by tongued and grooved joint.



Battened, ledged and braced door



Battened and ledged d

2. Battened, Ledged and Braced Doors: If doors are wide apart from using battens and ledges diagonal members, known as braces, are provided to strengthen the door. Figure below shows a typical battened, ledged and braced door.

Sometimes above two types of shutters are provided within wooden frame work and in those cases they may be called as *battened, ledges and framed doors.*

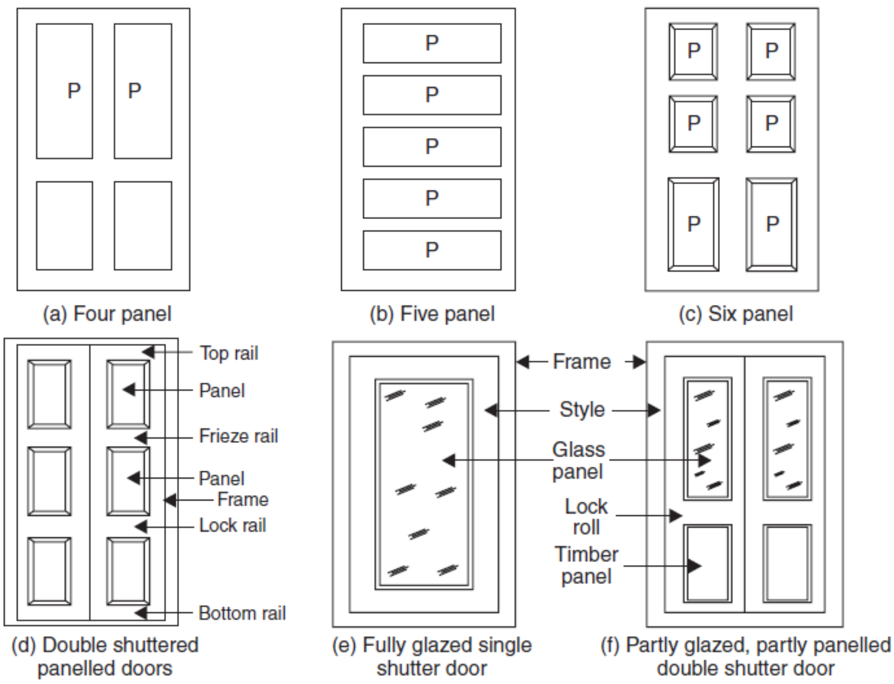


Fig. 8.23. Panelled and lazed doors

3. Framed and Panelled Doors: This type of door consists of vertical members, called styles and horizontal members called rails. The styles and rails are suitably grooved to receive panels. The panels may be of wood, A.C. sheet, glasses etc. The panels may be flat or of raised type to get good appearance. These are very commonly used doors. They may be of single shutter or of double shutter. If glass panels are used they may be called as glazed doors.

4. Flush Doors: The shutters of these doors are made of plywood or block boards. They are of uniform thickness. These shutters are available with different attractive veneer finishes. The time consumed in making such doors at site is quite less. These doors are suitable for interior portion of a building. Nowadays flush doors are commonly used in residential and office buildings. Figure 8.24 shows typical flush door.

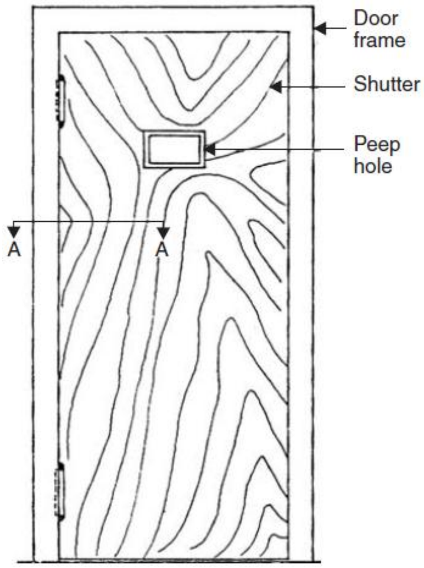


Fig. 8.24. Flush door

5. Louvered Doors: Whenever privacy as well as ventilation is required such doors can be used. Louvers are the glass, wooden or A.C. sheet strips fixed in the frame of shutter such that they prevent vision but permit free passage of air. The doors may be fully or partially louvered. Such doors are commonly used for public bathrooms and latrines. [Fig.8.25]

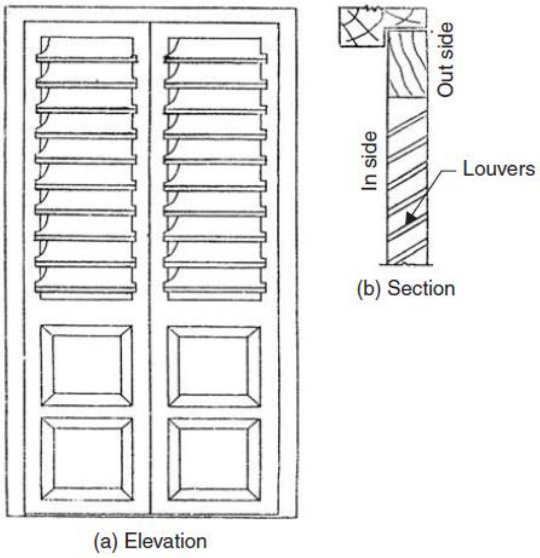


Fig. 8.25. Louvered door

6. Revolving Doors: It consists of a centrally placed pivot to which four radiating shutters are attached. The central pivot is supported on ball bearing at the bottom and has a bush bearing at the top. The shutters may be partly or fully made-up of glass. A circular space of entrance is provided within which shutters rotate. As shutters rotate they give entrance on one side and exit on other side. These doors are preferred in public buildings like stores, banks, hotels, theatres where continuous use of doors is necessary. They are very much required in entrance to air conditioned public buildings. Figure 8.26 shows a typical revolving door.

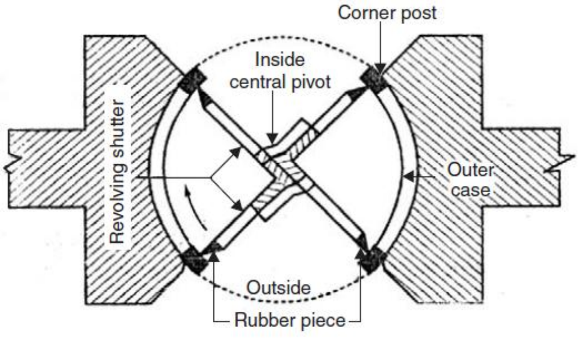


Fig. 8.26. Revolving door

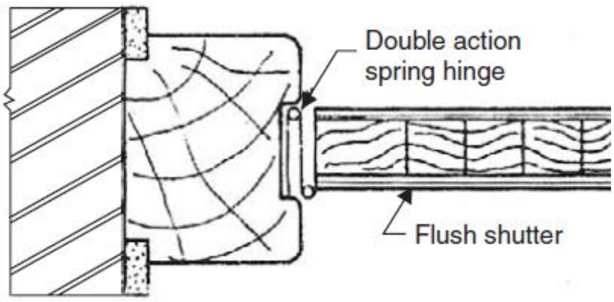


Fig. 8.27. Plan of swing door

7. Swing Doors: Swing door has its shutter attached to the frame by means of double action springs. Hence shutter can move both inward and outward. They may be single shuttered or double shuttered. Such doors are preferred in offices and banks. Since these doors can open on both sides it is desirable to provide glass panels or peep holes to enable user to see the persons from other side. [Fig. 8.27]

8. Sliding Doors: In this type of doors, shutter slides on the sides. For this purpose runners and guide rails are provided. Sliding shutters may be one, two or even three. Such doors are used in banks, offices etc. The arrangement of such shutters in plan is shown in Fig. 8.28

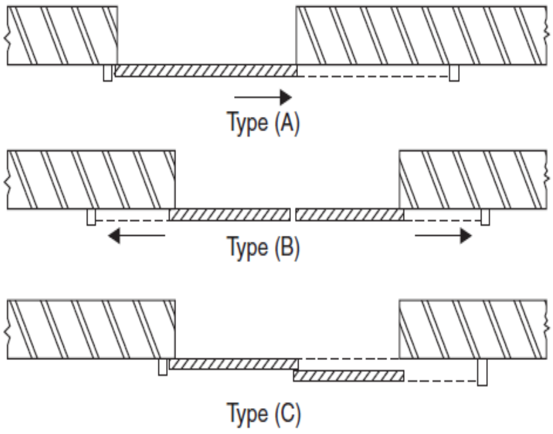


Fig. 8.28. Plan of sliding door

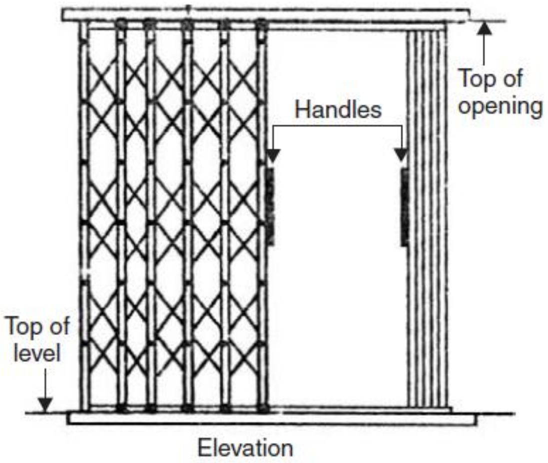
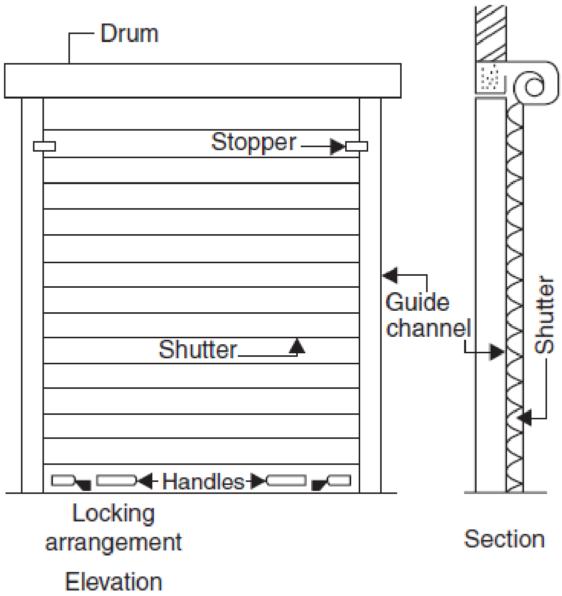


Fig. 8.29. Collapsible steel door

9. Collapsible Doors: Steel channels 16 to 20 mm wide are used as verticals. They are placed with 12 to 20 mm gap. Steel flats 16 mm to 20 mm wide and 5 mm thick are hinged to them as shown in Fig. 8.29. The rollers are provided at their top as well as at bottom so that shutter can be pulled or pushed sideways with slight force. There may be single or double shutters. Usually these doors are used for additional safety. They are commonly used for front doors, bank locker rooms, school and college entrance doors.

10. Rolling Shutters: Figure show a typical rolling shutter door. It consists of a frame, a drum and a shutter made of thin steel plates. The width of the door may vary from 2 to 3 m. The shutter moves on steel guides provided on sides and can easily roll up. For this counterbalancing is made with helical springs on the drum. The shutter can be easily pulled down. This type of doors is commonly used as additional doors to shops, offices, banks, factory, and buildings from the point of safety.



6.2 Windows & ventilators: types and their fixing details

A window is an opening formed in a wall or roof to admit daylight through some transparent of translucent material fixed in the window opening. As the window is the part of a wall or roof envelope to the building, it should serve to exclude wing and rain, and act as a barrier to excessive transfer of heat, sound and spread of fire in much the same way that the surrounding wall of roof does.

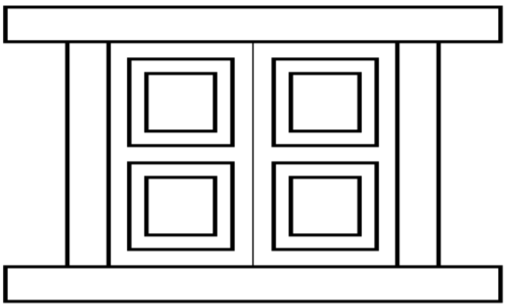
Windows are located at a height of 0.75 m to 0.90 m from the floor level. In hot and humid regions, the window area should be 15 to 20 per cent of the floor area. It is preferable to have at least two openings in two different walls. Another thumb rule used to determine the size of the window opening is for every 30 m^3 inside volume there should be at least 1 m^2 window opening. For adequate natural light, the total area of glass panes in windows should be at least 8% of the floor area.

Design of windows:

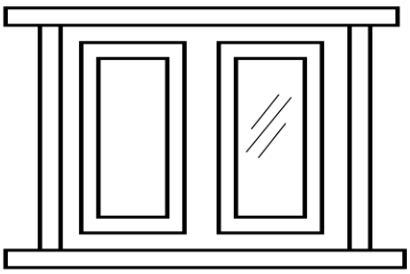
1. The size and number of windows should be sufficient to provide adequate light and ventilation in the room.
2. Windows should be located opposite to each other wherever possible. Windows provided on Northern side permit maximum day light without glare.
3. The shutter of windows in external walls should open outside.
4. All external windows, specially the one's on ground floor, should be provided with mild steel round or square bars or steel grills to safe guard against theft.
5. Windows in external wall should be provided with chajja projections to prevent the entry of the rain water in the room.

Types of windows:

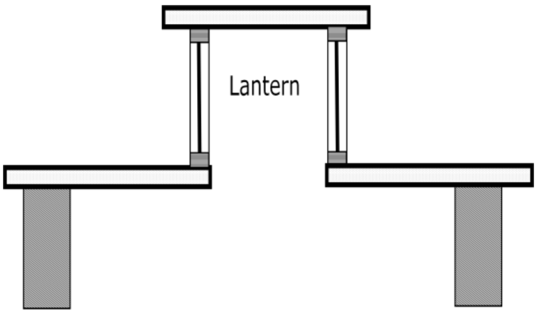
- **Based on materials use**
  1. Timber
  2. Steel
  3. Aluminum
  4. PVC windows
  5. Others
- **Based on uses and Shutter**
  1. Casement/ordinary window
  2. Glazed/sash window
  3. Louvered window.
  4. Pivoted window
  5. Corner window
  6. Double hung window
  7. Gable window
  8. Dormer window
  9. Bay window
  10. Clarestorey window
  11. Lantern light window
  12. Sky light window
  13. Sliding window
  14. Venetian shutter
  15. Ankhi-Jhyal
  16. Deshemaru-jhya etc.

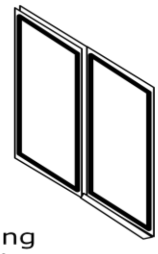


Ordinary window

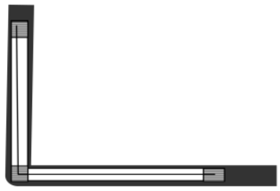


Glazed window

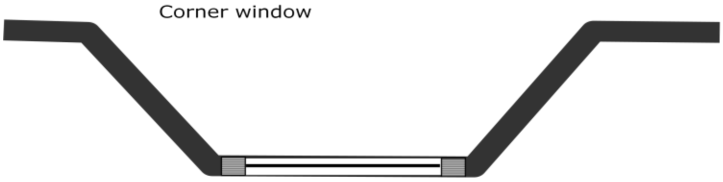




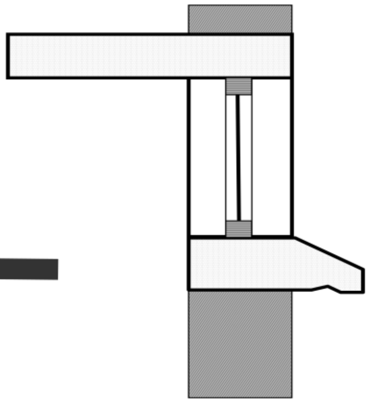
Sliding window



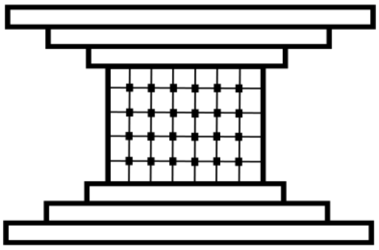
Corner window



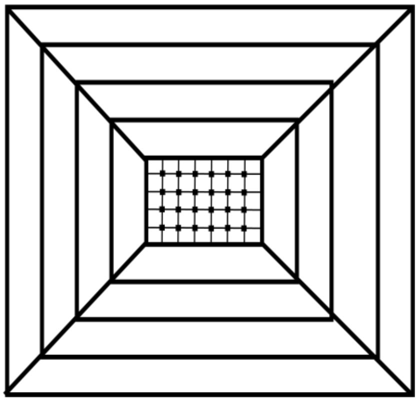
Bay window



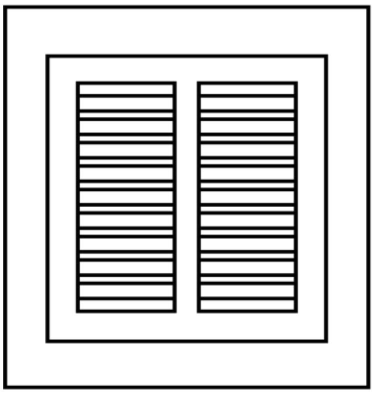
Clerstorey window



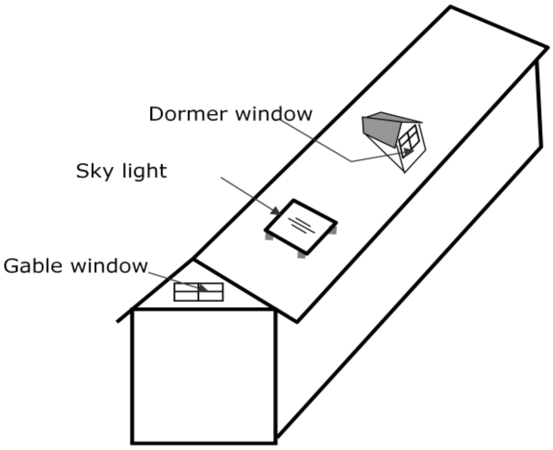
Ankhijyal



Desemarujya



Louvered window



Ventilators:

Ventilation may be defined s supply of fresh air into an enclosed space or the removal of inside air from the enclosed space. In other words, ventilation is the removal of all vitiated air from a building and its replacement with fresh air. Ventilation may be achieved either by natural or by artificial mean.

Ventilators are small windows, fixed at a greater height than the window, generally about 30 to 50 cm below roof level or ceiling level. The ventilator has a frame and a shutter, generally glazed, which can be opened or closed. Ventilators may also be provided in continuation of a window or a door, at its top. Such a ventilator is also known as a fan light.

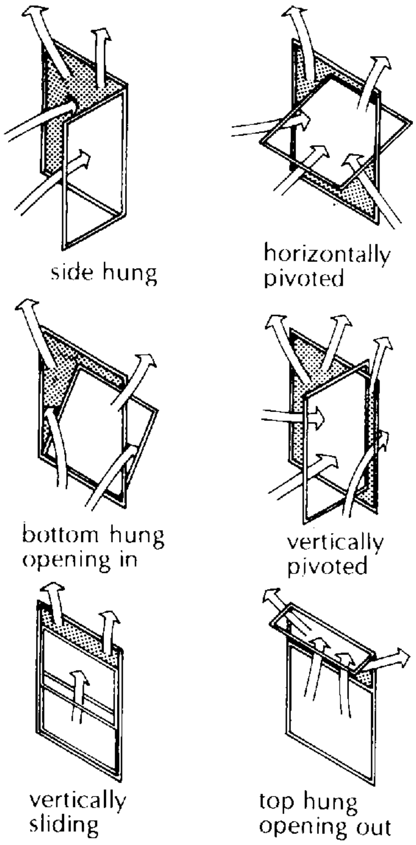


Fig. 11 Ventilation.

Points to be considered for door, window and ventilation:

Frames shall have smooth, well-plane (wrought) surfaces except the surfaces touching the walls, lintels, sill etc., which may be left clean sawn.

Rebates, rounding or moulding shall be done before the members are jointed into frames. The depth of the rebate for housing the shutters shall be 15 mm, and the width of the rebates shall be equal to the thickness of the shutters.

In frames a tolerance of ± 2 mm shall be permitted in the specified finished dimensions of timber sections.

Fixing of Frames:

(a) Before fixing a position the fames shall be got approved by the Engineer-in-Charge.
(b) The surface of the frames abutting masonry or concrete and the portions of the frames embedded in floors shall be given a coating of coal tar.
(c) Frames shall be fixed to the abutting masonry or concrete with holdfasts or metallic fasteners as specified. After fixing the jamb posts of the frames shall be plugged suitably and finished neat.
(d) Vertical members of the door frames shall be embedded in the floor for the full thickness of the floor finish and shall be suitably strutted and wedged in order to prevent warping during construction.
(e) A minimum of three hold fasts shall be fixed on each side of door and window frames one at centre point and other two at 30 cm from the top and bottom of the frames.
(f) In case of window and ventilator frames of less than 1 m in height two hold fasts shall be fixed on each side at quarter point of the frames. Hold fasts and metallic fasteners shall be measured and paid for separately.

CHAPTER 7 Flooring

7.1 Flooring and its types

Floor are the horizontal elements of a building structure which divide the building into different level for the purpose of creating more accommodation within a restricted space one above the other and provide support for the occupants, furniture, equipment etc. of a building. Floor system is the building's primary horizontal planes which support both live and dead loads. Structurally the floor system must transfer these loads laterally to either beams or columns or to the bearing walls while providing at the same time lateral support for adjacent walls.

- A floor consists of the following two components :

A Sub-floor (or Base Course, or Floor Base)

The purpose of this component is to impart strength and stability to support floor covering and all other superimposed loads. For ground floor, its purpose is also to prevent settlement and to provide damp resistance and thermal insulation.

Floor Covering (or Paving, or Flooring)

This is the covering over the sub-floor and is meant to provide a hard, clean, smooth, impervious, durable and attractive surface to the floor.

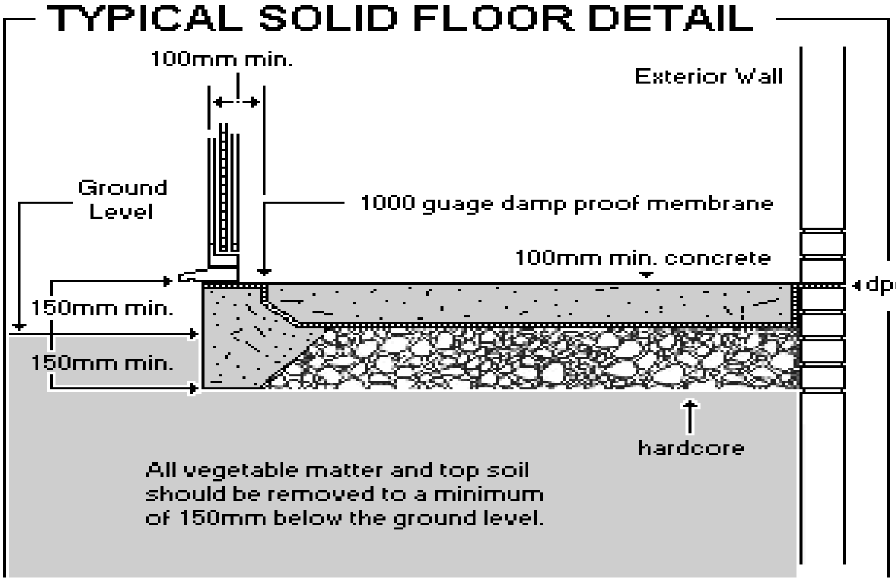
PURPOSE OF FLOORING

- Provide level surface with sufficient strength
- Supporting the occupants of building
- Exclude passage of water and water vapor
- Provide resistance to heat loss through the floor
- Provide adequate fire resistance
- Provide sound insulation
- Provide thermal insulation

Ground Floor

Apart from giving good finished surface, these floors should have good damp resistance. The ground surface is rammed well and a layer of red earth or sand is placed which is compacted. A layer of broken bricks, stones etc. is provided up to 150 mm below floor finish level and rammed. While ramming the surface is kept moist to get good compaction. Then 1: 4: 8 concrete of 100 to 150 mm thickness is provided as base course. Over this bed floor finish is laid.

The ground floors that rest directly on the ground are known as **solid floors** while the floors supported above the ground level are called **suspended floors**. Suspended floors are generally made of timber.



Basement floor

A floor when provided for the accommodation below the natural ground level is termed as basement floor. A basement floor is similar to ground floor except its location.

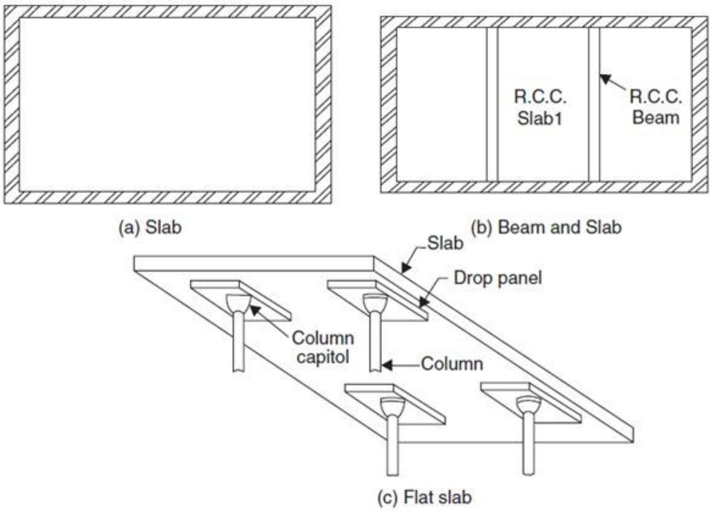
Upper Floors

An upper floor is basically a principal structural element, and the general structural design of a building will greatly influence the choice of the type of floor. Upper floors are supported either on the walls or on beams. In olden days upper floors were made of *timber floors* or *steel joist and stone slabs*.

Nowadays *R.C.C. floors* are commonly used. It may consist of *only slab*, if span is less or it may be *beam and slab flooring*. In halls of hotels and assembly, many provide *flat slabs i.e.* slabs directly supported over columns. The columns are provided with widened portion called column head. They give elegant look to halls, particularly when the head room is high. R.C.C. floors need proper thickness and reinforcements. They are arrived at by structural design engineers. Figure below shows typical R.C.C. slabs.

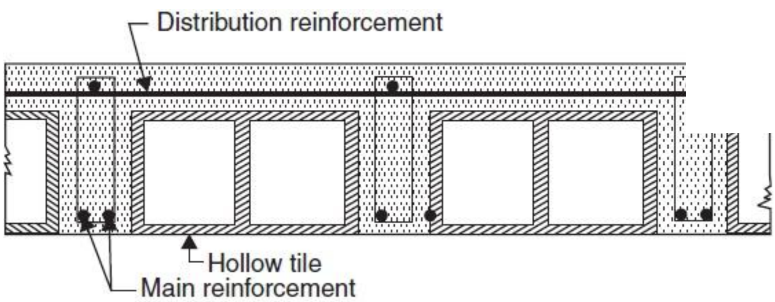
In R.C.C., concrete is used to resist compression and steel to resist tension. Hence the concrete in tension zone do not contribute in resisting the load. It just keeps the steel at required position.

In *ribbed or hollow tiled flooring*, the concrete in tension portion is replaced by hollow tiles.



R.C.C. floors

In precast concrete floor panels may be used which helps in avoiding form works, storing of sand, coarse aggregates etc. at the site and also curing. Factories manufacture these units which are to be placed over supports in the structure.



Ribbed or Hollow tiled flooring

7.2 Special types of floor finishing

1. Mud and moorum
2. Brick
3. Flag stone
4. Cement concrete
5. Terrazo
6. Mosaic
7. Marble
8. Tiles
9. Timber
10. Rubber
11. P.V.C.

1. Mud and Moorum Flooring: These floorings are used in low cost housing, especially in villages. Over the hard layer of earth filling mud or moorum layer is provided. In order to prevent formation of cracks after drying, chopped straw in small quantity is mixed with the moist earth before ramming. The floor needs a thin wash of cow dung at least once a weak. They are cheap, hard, fairly impervious, easy in construction and easy in maintenance. They remain warm in winter and cold in summer.

2. Brick Flooring: This is also a cheap floor construction. It is commonly used in warehouse and factories. Bricks are laid flat or on edges. Bricks of good quality should be used for the construction. Brick layer is provided on sand bed or on lean concrete (1: 8: 16) bed. In both cases joints are rendered flush and finished with cement mortar. It is durable, hard, cheaper than cement concrete, non slippery and easily repairable. But it is absorbent.

3. Flag Stone Flooring: Laminated sand stones or slates of 20 mm to 40 mm thick in the form of slabs of 300 mm × 300 mm or 450 mm × 450 mm or in the form of rectangles of size 450 mm × 600 mm are used as floor finishes. The stone slabs are laid on 20 to 25 mm thick mortar spread over concrete bed. The joints are to be finished with rich mortar. It is hard, durable, resistant to wear and tear, easy in construction but its usage is not comfortable. Its uses are limited to workshops, garages and store houses etc.

4. Cement Concrete Floors: It is modestly cheap and durable floor and hence commonly used in residential, commercial and industrial buildings. It consists of two courses-base course and wearing coat. Base course is laid over well compacted soil. Its thickness is usually 75 mm to 100 mm. It consists of lean cement concrete mix (1 : 4 : 8) or lime concrete containing 40% of 1 : 2 lime mortar and 60% of coarse aggregate of 40 mm size. After base course is hardened wearing coat of 40 mm is laid. It consists of panels of 1 m × 1 m, 2 m × 2 m or 1 m × 2 m. Alternate panels are laid with 1: 2: 4 concrete using wooden, glass or asbestos strip separators of 1.5 mm to 2.0 mm thickness. To get good bond between base coarse and wearing coat cement slurry wash is given before laying wearing coat panels. After 3–4 days of laying of one set of panel, another alternate panels are laid. Top of these panels are finished by tamping the surface with wooden floats and tapping with trowels, till cement slurry appears on top. It needs curing for 7 to 14 days. To get good appearance many times red-oxide finishing coat is provided. It is non-absorbent and thus very useful for water stores, durable, smooth, pleasing in appearance, economical and possesses good wearing properties.

5. Terrazo Flooring: Terrazo finishing coat is applied over concrete flooring to get pleasing appearance. Terrazo finish consists of 75 to 80% of surface marble chips embedded in cement mortar. Marble chips are mixed in cement in the proportion 1: 1.25 to 1: 2 and about 6 mm terrazo topping is laid. The top is tamped and rolled. Additional marble chips are spread during tamping to get proper distribution of marble chips on the surface. After drying it for 12 to 20 hours, it is cured for 2–3 days.
Then grinding is made in the following three steps:
Ist grinding—Using coarse grade (No. 60) carborundum stones.
IInd grinding—Using medium grade (No. 120) carborundum stones.
IIIrd grinding—Using fine grade (No. 320) carborundum stones.
Plenty of water is used during grinding. After each grinding, cement grout of cream-like consistency is applied and cured for 6–7 days. After final grinding and curing the floor is washed with plenty of water and then with dilute oxalic acid solution. Then floor is finished with polishing using machines and wax polish.

6. Mosaic Flooring: It consists of a finishing coat of small pieces of broken tiles of China glazed or of marble arranged in different patterns set in lime-surkhi or cement mortar. The base course is concrete flooring and on it 30 to 40 mm mortar layer is provided. On this mortar layer broken pieces of China glazed or marble are set to get different attractive patterns. After 20 to 24 hours of drying the top is rubbed with carborundum stone to get smooth and polished surface.

7. Marble Flooring: Marble slabs are cut to get marble tiles of 20 to 25 mm thickness. They are laid on floors similar to other tiles. With power driven machine surface is polished to get even and shining surface. This type of flooring is widely used in hospitals and temples.

8. Tiled Flooring: This is an alternative to terrazo flooring, used commonly used in residential, office and commercial buildings. Tiles of clay, cement or terrazo of standard sizes are manufactured in factories under controlled conditions. On the concrete base, 25 mm to 30 mm thick mortar is laid and these tiles are placed and pressed with trowel or wooden mallet. Before placing tiles care is taken to see that, neat cement slurry is applied to bottom side and sides of tiles to get good bond. Next day joints are cleaned of loose mortar and raked up to 5 mm depth. Then that is filled with coloured cement slurry to get uniform colour on the top surface. After curing for 7 days grinding and polishing is made as in the case of terrazo flooring.

9. Timber Flooring: Timber flooring is used in dancing halls and in auditoriums. Timber plates may be directly placed on concrete bed or may be provided over timber frame work. In latter case it is necessary to provide proper ventilation below the floor. This flooring is costly.

10. Rubber Flooring: Tiles or sheets of rubber with fillers such as cotton fibres, asbestos fibre or granulated cork are manufactured in variety of patterns and colours. These sheets or tiles may be fixed to concrete or timber floors. These floors are attractive and noise proof. However they are costly.

11. P.V.C. Flooring: Poly-Vinyl-Chloride (PVC) is a plastic which is available in different colour and shade. Nowadays tiles of this material are used widely. Adhesives are applied on concrete base as well as on bottom of PVC tiles. Then the tile is pressed gently with 5 kg wooden roller till the oozing of adhesive is seen. The oozed out adhesive is wiped and the floor is washed with warm soap water. The floor finish is smooth, attractive and can be easily cleaned. However it is slippery and costly.

7.3 Floor and wall ties

The floor and wall connection should be such that when overloaded it should fail in a ductile manner. There are two general method of connection for a tensile connection between walls and floors. If such connection are going to fail at all, it is desirable that the failure be in the tie element and be a ductile failure.

In the first method reinforced bars are precast in the wall elements at regular spacing adjacent the intended final position of a floor slab. Each bar is bent out at right angles to the wall and one end is tied to the floor slab.

The second method incorporates a screw thread elements attached reinforced rod within the wall elements. A thread bar is attached to the screw threaded element and tied to the floor slab. This overcomes the difficulty of the first method but is more expensive method of connection. Also within the presence of screw thread if failure occurs, one cannot readily get ductile failure of the metal element.

CHAPTER 8.0 Temporary construction

8.1 Scaffolding and its types

Scaffolding:

This is temporary rigid structure for the purpose of facilitating masons as "platform to work" as the building increases its height. When the height of wall or column or other structural member of a building exceeds about 1.5 m, temporary structures are needed to support the platform over which the workmen can sit and carry on the constructions. These temporary structures, constructed very close to the wall, are in the form of timber or steel framework, commonly called scaffolding.

Component parts:

Standards: These are the vertical members of the framework, supported on the ground or drums, or embedded into the ground. These vertical members are spaced at 2.4-3.0 m.

Ledgers: These are horizontal members running parallel to the wall.

Braces: Bracing members are tied diagonally to stiffen the scaffolding. Braces are the poles tied by ropes.

Putlogs: Horizontal member firmly fixed in the standard and support putlog is called ledger, vertically spaced at 1.2-1.5m.

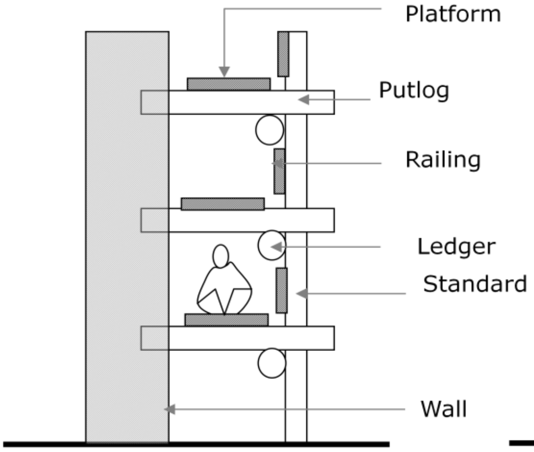
Boarding: These are horizontal platform to support workmen and material: these are supported on the putlogs.

Guard Rail: This is a rail, provided like a ledger, at the working level.

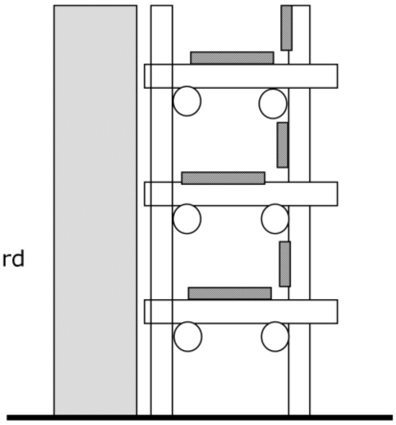
Transoms: These are those putlogs whose both ends are supported on ledgers.

Types of Scaffolding:

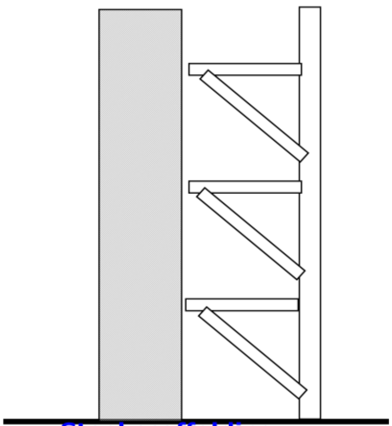
1. **Bricklayers or Single Scaffolding**
2. **Masons or Double Scaffolding**
3. **Steel/Tubular Scaffolding**
4. **Needle or Cantilever Scaffolding**
5. **Wooden gantries**
6. **Trestle Scaffolding**



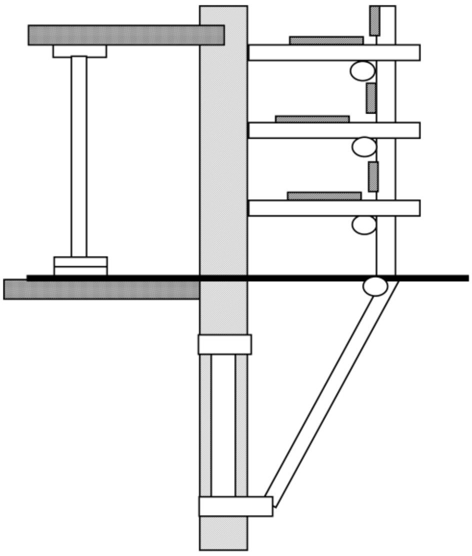
Bricklayers scaffolding



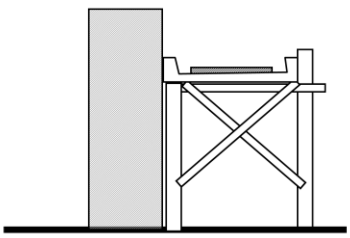
Mason's scaffolding



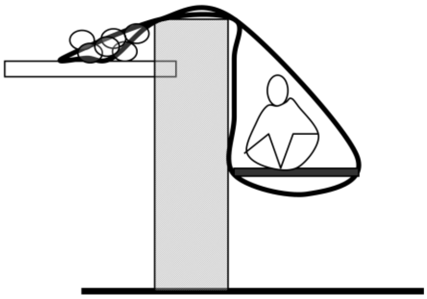
Steel scaffolding



Needle scaffolding



Gantry



Trestle scaffolding

Brick layers or Single Scaffolding:

This consists of a single frame work of standards, ledgers, and putlogs etc, constructed parallel to the wall at a distance of about 1.2 meters. This type of scaffolding is erected by driving into the ground a single row of standards at 1.5-3.0 meters c/c (usually 2.4 meters c/c). it is cheap and common for wall construction. Ledgers are connected to the standards and are provided at a vertical interval of 1.2 to 1.5 m. Putlogs are placed with one end on the ledgers and other end in the hole left in the wall, at an interval of 1.2 to 1.5 m. Cross braces are also used for strength and stability. Such scaffolding is commonly used for brick lying, and is also called putlog scaffolding.

Double or masons scaffolding:

This type of scaffold is normally used where the cheap single type of scaffolding cannot be used, as for example in stone masonry work; it is difficult to leave holes in the walls for inserting the putlogs. In that case, more strong scaffolding is used consisting of two rows of scaffolding. Each row thus forms a separate vertical framework. The first roe is placed at 20 to 30 cm away from the wall, while the other framework is placed at 1 m distance from the first one. The two rows are secured by ledgers to which are secured the transoms (which fulfill the same function as the 'putlogs' in single scaffold). In addition, diagonal braces, raking shores are used to prevent slippage of scaffold. This type of scaffolding is also called independent scaffolding.

Cantilever or needle scaffolding:
Cantilever scaffolding is used under the following circumstances:

- Ground is weak to support standards.
- Construction of upper-part of the wall is to be carried out
- It is required to keep the ground, near wall, free for traffic etc.

Steel scaffolding:
Steel scaffolding is practically similar to timber scaffolding except that wooden members are replaced by steel tubes and rope lashings are replaced by steel couplets or fittings. Such scaffolding can be erected and dismantled rapidly. It has greater strength, greater durability and higher fire resistance. Though its initial cost is more but its salvage value is higher.

Trestle scaffolding:
Such type of scaffolding is used for painting and repair works. The working platform is suspended from roofs by means of wire ropes or chains etc. The platform can be raised or lowered at any desired level.

8.2Formwork:

Formwork or shuttering is a temporary construction used as a mould for the structure, in which concrete is placed and in which it hardens and matures. The construction of formwork involves considerable expenditure of time and cost in building work, and even higher in bridges.
Forms are classified as wooden, plywood, steel, combined wood-steel, reinforced concrete and plain concrete. Timber is the most common material used for formwork. The disadvantage of wooden formwork is the possibility of warping, swelling and shrinkage of the timber.

Characteristics of formwork:

i) They must be strong enough to carry the weight of wet concrete, resist the impact due to consolidation, and carry the load of the workmen etc.
ii) They should be braced rigidly to prevent slippage, sagging etc.
iii) They should be such that erection and dismantling is easily accomplished.
iv) The formwork should be watertight to prevent loss of fine materials, especially cement slurry, through gaps, which, if found, should be closed with clay/plaster of Paris, but which in practice are simply covered by plastic/polythene sheets.
v) Formwork should be clean before pouring.

Requirements of formworks:
A good formwork should satisfy the following requirements:

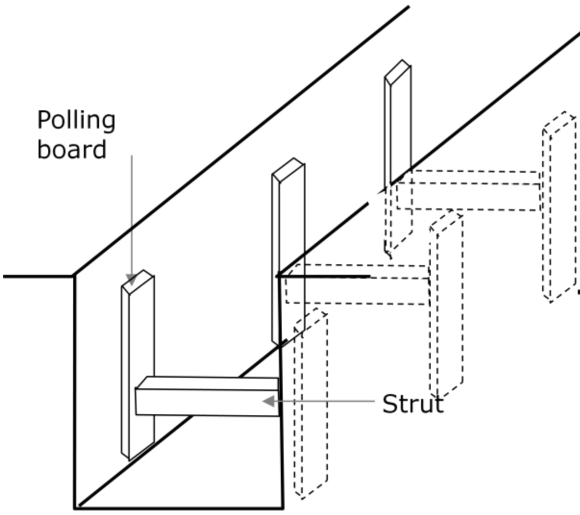
(i) The material of the formwork should be cheap and it should be suitable for re-use several times.
(ii) It should be practically water proof so that it does not absorb water from concrete. Also, its shrinkage and swelling should be minimum.
(iii) It should be strong enough to withstand all loads coming on it, such a dead load of concrete and live load during its pouring, compaction and curing.
(iv) It should be stiff enough so that deflection is minimum.
(v) It should be as be light as possible.
(vi) The surface of the formwork should be smooth, and it should afford easy stripping. All joints of the formwork should be stiff so that lateral deformation under loads is minimum

Formworks for excavation and trenches:

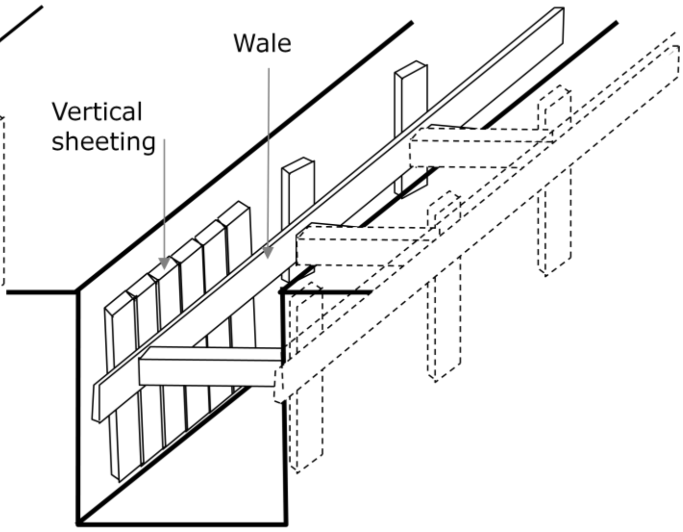
Timbering of trenches: This is the arrangement of timber planks in the trenches to prevent collapsing of sides. When the depth of trench is large, or when the sub-soil is loose, the sides of the trench may cave in. the problem can be solved by adopting a suitable method of timbering.

Methods:

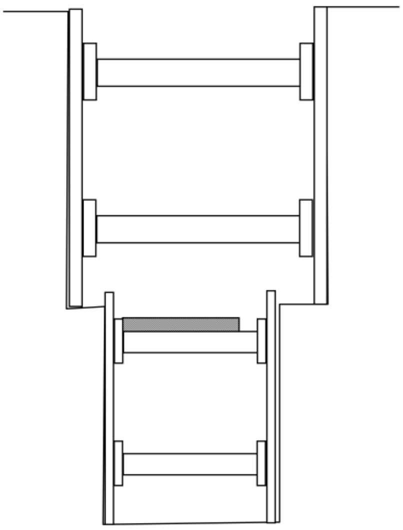
1) Stay Bracing
2) Box Sheeting
3) Vertical Sheeting
4) Runners
5) Sheet Piling



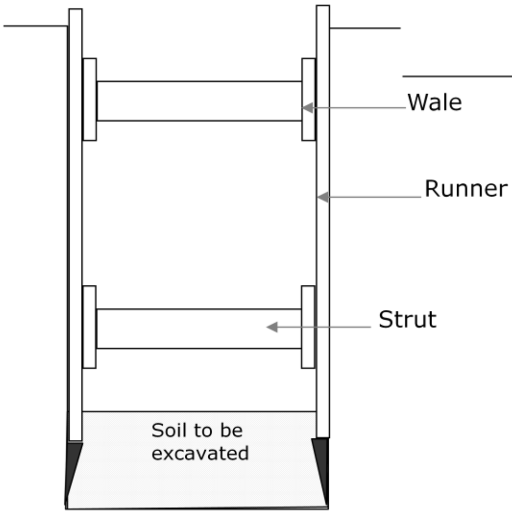
Stay bracing



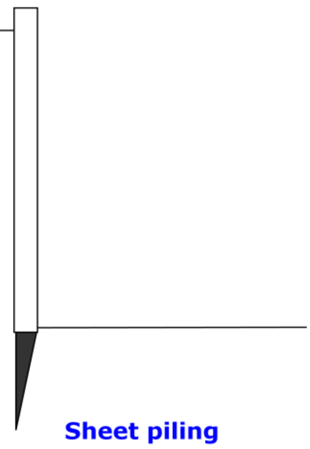
Box sheeting



Vertical sheeting



Runner system



Sheet piling

1) **Stay bracing:** This method is used for supporting the sides or a bench excavated in fairly firm soil, when the depth of excavation does not exceed about 2 meters. The method consists of placing vertical sheets or polling boards opposite each other against the two walls of the trench and holding them in position by one or two rows of struts. The sheets are placed at an interval of 2 to 4 meters and generally, they extend to the full height of the trench. The polling boards may have width of about 200 mm and thickness of 40 to 50 mm.

2) **Box sheeting:** This method is adopted in loose soils, when the depth of excavation does not exceed 4 meters. The method consists of vertical sheets placed very near to each other (sometimes touching each other) and keeping them in position by longitudinal rows (usually two) of wales. Struts are then provided across the wales.

3) **Vertical sheeting:** This system is adopted for deep trenches (up to 10 m depth) in soft ground. The method is similar to the box sheeting except that the excavation is carried out in stages and at the end of each stage, an offset is provided, so that the width of the trench goes on decreasing as the depth increases. Each stage is limited to about 3 m in height and the offset may vary from 25 to 50 cm per stage. For each stage, separate vertical sheeting, supported by horizontal wailings and struts are provided.

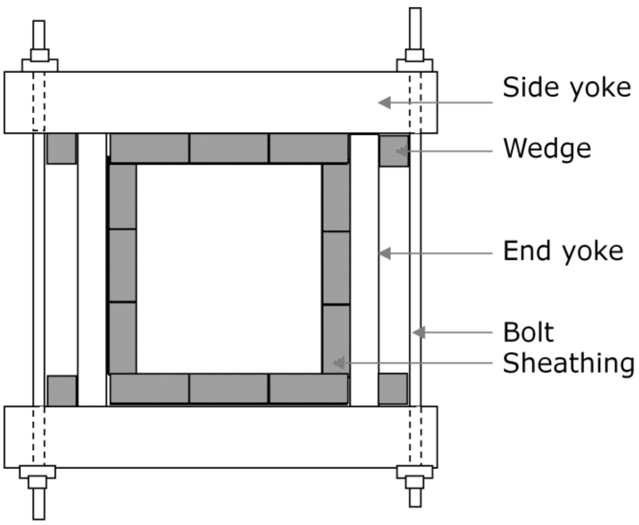
4) **Runners:** This system is used in extremely loose and soft ground, which needs immediate support as excavation progresses. The system is similar to vertical sheeting of box system, except that in the place of vertical sheeting, runners, made of long thick wooden sheets or planks with iron shoe at the ends, are provided. Wales and struts are provided as usual. These runners are driven about 30 cm in advance of the progress of the work, by hammering.

5) **Sheet piling:** This method is adopted when
(i) Soil to be excavated is soft or loose
(ii) Depth of excavation is large
(iii) Width of trench is also large and
(iv) There is sub-soil water.

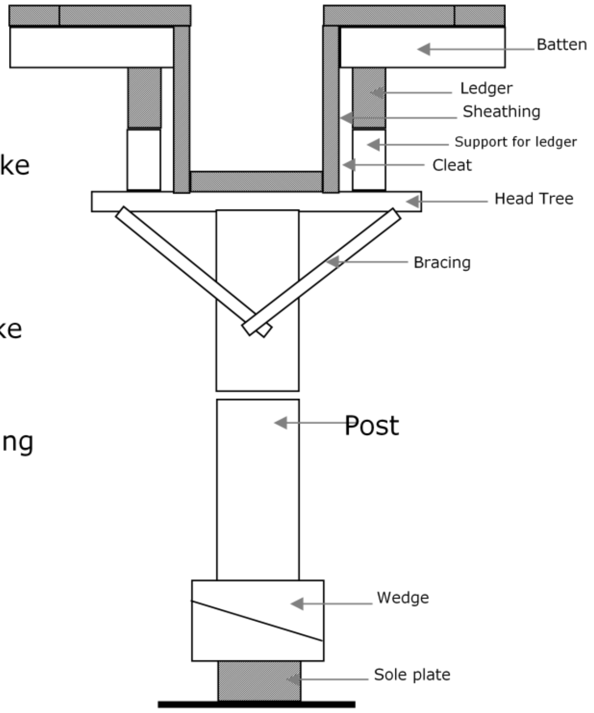
Sheet piles are designed to resist lateral earth pressure. These are driven in the ground by mechanical means (pile driving equipment). They can be used for excavating to a very large depth.

Precaution to timbering:
(i) Possibility of slip of earth
(ii) Testing of timbering elements
(iii) Safety of adjacent structure
(iv) Traffic in the surrounding
(v) Provision of ladders
(vi) Safety helmet
(vii) Supervision
(viii) First aid box
(ix) Fencing and light

Formworks for RCC construction:
Sheathing: vertical timber plank used on column.
Yokes: bracing members to tie up sheathing.
Wedges: wooden piece used to tighten various elements of framework.
Cleats: wooden piece fixed to the sides of beam.
Joists/battens: wooden member supporting decking.
Ledgers: horizontal wooden piece nailed to cleats and form bearing of joist.
Bottom sheathing: bottom plank of beam (thicker).
Head tree: horizontal beam connected at top of vertical post (props) through inclined cleats or beams.



Formwork for column



Formwork for Beam & Slab

Propping for centering of formwork:
The props may be of timber, steel or even brick pars in mud mortar. Spacing of the props is usually 1 o 1.2 m c/c. these props should rest squarely on wooden sole plate, 40 mm thick with a minimum bearing area of 10 cm2 laid either directly on firm ground or 40 cm X 40 cm brick masonry pillars in mud mortar of height not exceeding 40 cm. double wedges should be provided for tightening. In case brick masonry pillars of adequate section are used instead of wooden props, wooden sole plates should be provided at the top and double wedges inserted between the sole plate and the bottom of the formwork.
Removal of centering:
All formwork should be removed in such a way that concrete is not damaged due to shock, vibration. Wedges are slackened gradually and forms eased carefully in order to prevent the load being transferred suddenly to concrete. A rough guide as to whether the form can be removed or not is to strike the concrete with a light hammer. If there is a hard metallic sound, it indicates that the concrete has hardened sufficiently for forms to be removed for forms to be removed.

8.3 Shoring and its types:
Shoring is the temporary structure used as support to the unsafe structure. It may be used in all cases of strengthening any parts of the building and to give support to the building at risk. These render lateral support to walls and are used under the following circumstances:
1) When a wall shows a signs of bulging out due to bad workmanship.
2) When a wall cracks due to unequal settlement of foundation and the cracked wall needs repairs.
3) When and adjacent structure is to be dismantled
4) When openings are to be made or enlarged in the wall.

Materials of shoring: **Timber, steel or both**

Objectives of shoring:
- ✓ To give support to walls, which are at risk (bulging or leaning outwards etc.)
- ✓ To avoid failure of boundary wall caused by removal of adjacent support
- ✓ To give support to adjacent building during demolition works
- ✓ To support upper part of wall during formation of larger opening
- ✓ To give support to a floor or roof to enable a support wall to be removed and replaced by a beam

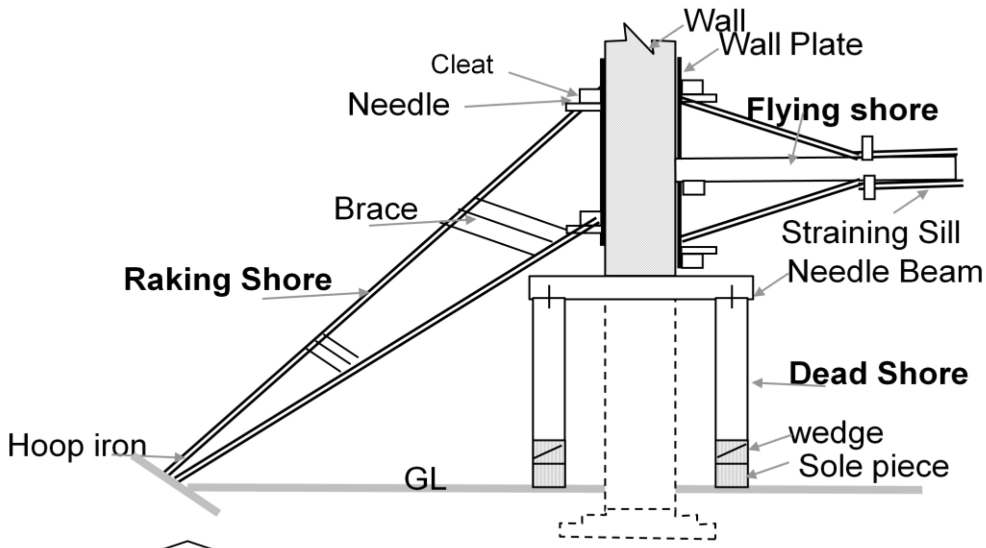
Types of shoring:
- Raking shoring (slant or sloped shore)
- Flying shoring (horizontal shore)
- Dead shoring (vertical shore)

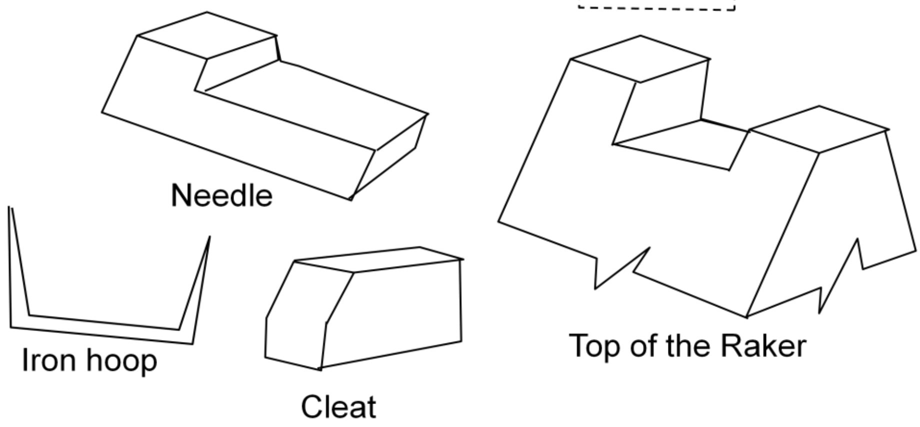
Raking shoring:
In this method, inclined members, called rakers are used to give lateral support to the wall, as shown in fig. A raking shore consists of the following components:
i) Rakers or inclined members
ii) Wall plate
iii) Needles
iv) Cleats
v) Bracing and
vi) Sole plate

The wall plate, about 20 to 25 cm wide and 5 to 7.5 cm thick is placed vertically along the face of the wall and is secured by means of needles of 10 cm X 7.5 cm section. In order that the needles do not get sheared off due to the thrust of the raker, the needles are further strengthened by means of cleats which are nailed directly to the wall plate. Rakers are fixed against the needles in such a way that the centre line of the raker and the wall meet at the floor level. The rakers are inter-connected by struts, to prevent their buckling. The feet of rakers are connected to an inclined sole plate, embedded into the ground by means of iron dogs.

The following points should be kept in mind while shoring is placed:

- Rakers should be inclined to the ground by 45 degree, to make them more effective. However, in practice, the angle may vary from 45 to 75 degree. The top raker should not be inclined steeper than 75 degree.
- For tall buildings, the length of raker can be reduced by introducing rider raker.
- The size of the rakers should be decided on the basis of anticipated thrust from the wall.
- The centre line of a raker and the wall should meet at floor level.
- If longer length of the wall needs support, shoring may be spaced at 3 to 4.5 m spacing, depending upon the requirements.





Flying or horizontal shoring:
Such shores are used to give horizontal support to two adjacent, parallel party walls which have become unsafe due to removal or collapse of the intermediate building. All types of arrangements of supporting the unsafe structure in which the shores do not reach the ground fall under this category. When the distance between the walls is up to 9 m single flying shore can be constructed. Whereas the distance between the walls is more, double flying shore may be provided.
The following points should be kept in mind while erecting the flying shores:
The centre lines of flying shore and struts and those of the walls should meet at floor levels of the two buildings, if the floor levels are different, the horizontal shore should be placed either mid-way between the levels of the two floors of equal strength, or it should be placed at the level of weaker floor.
The flying shores should be spaced at 3 to 4.5 m c/c, along two walls, and horizontal braces should be introduced between adjacent shores.
The struts should preferably be inclined at 45 degree. In no case should this inclination exceed 60 degree.
Flying shores are inserted when the old building is being removed, and should be kept in position till the new unit is constructed.
Dead or vertical shoring:
Such type of shoring consists of vertical members known as dead shores supporting horizontal members known as needles. The needles transfer the load of the wall to the deal shores.
Such shoring is provided to serve the following purposes:

- To rebuild the defective lower part of the wall
- To rebuild or deepen the existing foundation
- To make large opening in the existing wall at lower level

The following points are note worthy.
The section of needles and dead shores should be adequate to transfer the load, which can be estimated with fair degree or accuracy.
The needles are spaced at 1 to 2 m. A minimum of three needles should be used for an opening.
If the opening is made in an external wall, the length of outer dead shores will be greater than the inner ones.
If the external wall is weak, raking shores may be provided, in addition to the dead shores.

Shores should be removed only when the new work has gained sufficient strength, but in no case earlier than 7 days of the completion of new work.
The sequence of removal should be needles, strutting from opening, floor strutting inside and raking shore if any.

8.4 Underpinning and its procedures

Underpinning is the method of excavating under the building without making any harm to the existing foundation helpful to increase the depth of the foundation to increase the capacity of the foundation in order to transfer the increased load.

Necessity of underpinning

Underpinning is necessary if the excessive settlement has occurred due to:

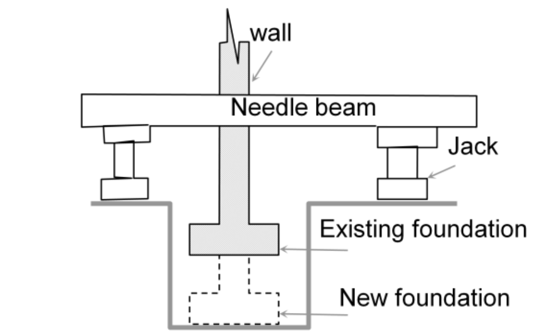
- uneven loading,
- unequal settlement of subsoil,
- Action of subsoil water,
- Action of tree roots etc.

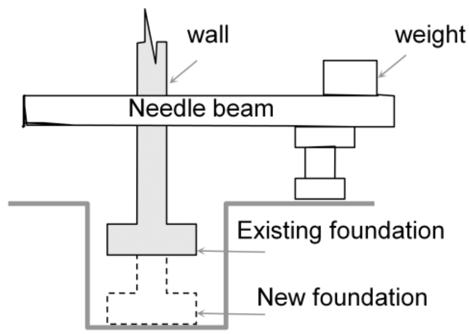
Objectives of Underpinning:

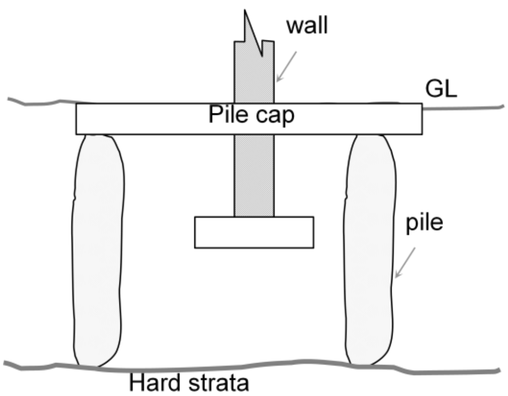
1) To strengthen the shallow foundation of existing building when a building with deep foundation is to be constructed adjoining it.
2) To strengthen existing foundation this has settled and caused cracks in the wall.
3) To deepen the existing foundation (on poor strata) so as to rest it on deeper soil strata of higher bearing power.
4) To construct a basement in the existing building.

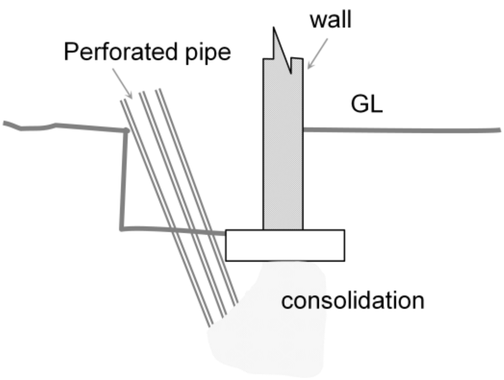
Methods of underpinning:

1. Pit method(ordinary and cantilever)
2. Pile method









Pit method:

In this method, the entire length of the foundation to be underpinned is divided into sections of 1.2 to 1.5 m lengths. One section is taken up at a time. For each section, a hole is made in the wall, above the plinth level, and needle is inserted in the hole. Needles may be either of timber or steel section. Bearing plates are placed above the needle to support the masonry above it. Needle is supported on either side of the wall on crib supports and screw jacks. The foundation pit is then excavated up to the desired level and new foundation is laid. If an interior strong column exists, or if the foundation is to be extended only to one side, cantilever needle beams may be used in the place of central needle beam as shown in fig.

Pile method:
In this method, piles are driven at regular interval along both sides of the wall. Generally, bore hole piles or under-reamed piles may be used. The piles are connected by concrete or steel needles, penetrating through the wall. These beams incidentally act as pile caps also. This method is very useful in clayey soils, and also in water-logged areas. The existing foundation is very much relieved of the load.

Underpinning of foundation of existing building:

The process of underpinning

- carried out making holes at regular intervals usually at 1.2-1.8m
- the entire load of the wall is transferred to the needles inserted into the cut holes which rest on the sole pieces or jacks at ground level
- the load is carried out for a short duration and hence the foundation could be strengthened or further deepen
- When the foundation of a wall is to be replaced, only 90 to 120cm longer part is cut and the new construction work is carried out
- When longer walls are to be underpinned, the work starts from the central part of the wall and is gradually expanded towards both the ends
- removed after setting up the newly constructed structure is finally set with full strength and there is no danger of further damages

The sequential stages of underpinning

Stage 1: suitable holes are driven through the walls for inserting the needle beams, one end of which is resting on the wooding block resting on a small concrete block and the longer end is left largely unsupported for a small temporary support near the wall on the side.

Stage 2: Excavation is carried out under the unsupported end of needle beams to the desired depth and the sides are held in place by adequate timbering. The unsupported needle beam is supported by a wooden post which rests on a concrete block. The temporary support provided to support the longer end is removed.

Stage 3: Excavation trench is widened so that the trench goes under the foundation to be underpinned. The offsets of the existing foundation are cut off.

Stage 4: The new foundation is laid and a new wall is built up to the underside of the old foundation.

CHAPTER 9 Finishing works

9.1 Cladding (types, fixing process)

In building construction, the material applied on the surface of wall is cladding. Cladding does not necessarily have to provide a water-proof condition but is instead a control element only serving to safely direct water or wind in order to control run-off and prevent infiltration into the building structure. Cladding applied to windows is often referred to as window capping.

All forms of cladding must fulfill following functions

- Be self supporting between the framing members,
- Provide necessary resistance to rain penetration,
- Be capable of resisting both positive and negative wind pressures,
- Provide necessary resistance to wind penetration
- Give required degree of thermal/sound insulation,
- Give required degree of fire resistance,
- Provide sufficient openings for admittance of natural daylight and ventilation,
- Be constructed in suitable size,

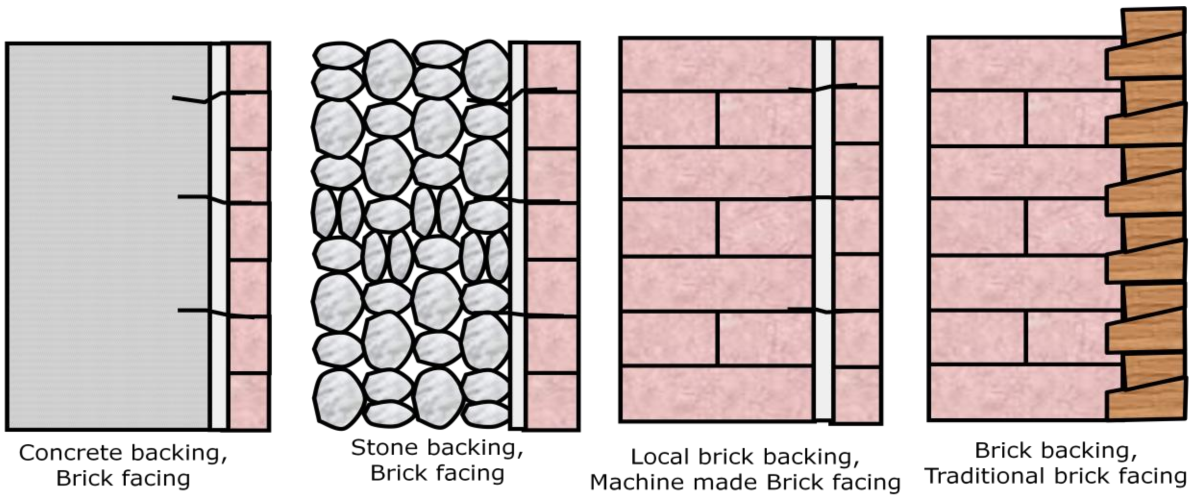
Load bearing and non-load bearing cladding

- Claddings are fundamentally non-load bearing, but they may be both **load bearing and non-load bearing.**

Load bearing Concrete Panels ~ this form of construction uses storey height load bearing precast reinforced concrete perimeter panels. The width and depth of the panels is governed by the load(s) to be carried, the height and exposure of the building. Panels can be plain or fenestrated providing the latter leaves sufficient concrete to transmit the load(s) around the opening. The cladding panels, being structural, eliminate the need for perimeter columns and beams and provide an internal surface ready to receive insulation, attached services and decorations. In the context of design these structures must be formed in such a manner that should a single member be removed by an internal explosion, wind pressure or similar force progressive or structural collapse will not occur. Load bearing concrete panel construction can be a cost effective method of building.

Brick Cladding (Brick Facing)

Brick is a popular construction material in Nepal. Most of the buildings in Kathmandu are constructed in brick. **Machine cut bricks** (Chinese) are more common for exposed brick **facades** and works as load bearing cladding. The framed structured buildings mostly have bricks for partitions as well as the **cladding material**. **Bricks tiles** in different **shape, size** and **color** are available in the market, which



are used for brick facing. They are held in place with plaster and mortars or sometimes clamps.

Requirements

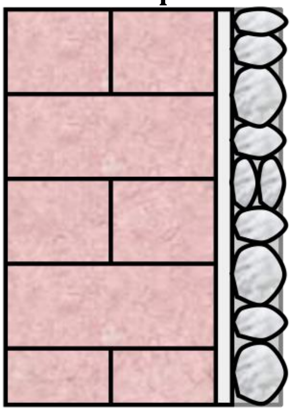
- It should fulfill the functional requirements of the claddings. The construction is such that the panels are supported at each structural floor and tied at vertical edges.

Method of tying to the vertical structural members:

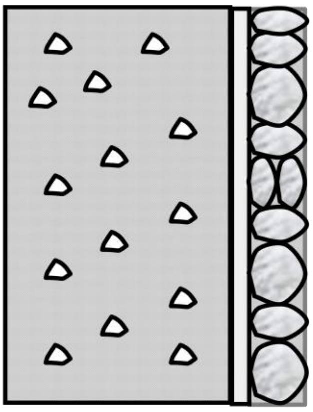
Butterfly wall ties are cast in to the column and built in to the brick joints at every fourth course. Galvanized pressed steel dovetail slots are cast in to the column and dovetail anchors are used to form the tie.

Stone cladding

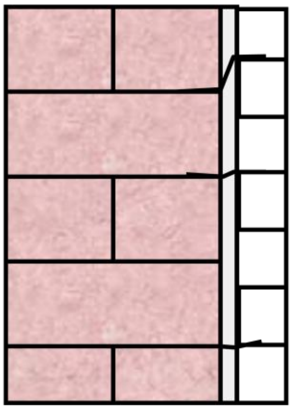
Stone are also a popular **cladding material**. They are either pasted or held in place with the help of **dowels** and **clamp**.



Brick backing, Stone facing



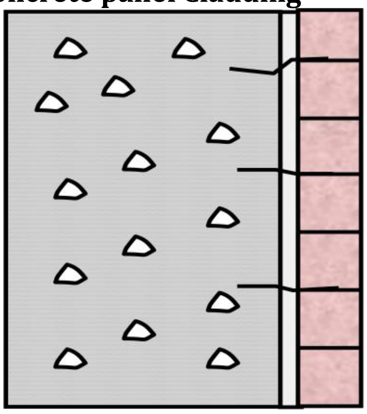
Concrete backing, Stone facing



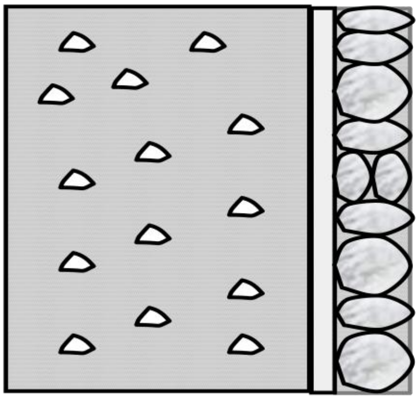
Brick backing, Stone facing

- These are the thin layers of stone.
- They may be slate stone or any other sedimentary rocks.
- Normally, stone clad are small in size and have cement mortar bedding on the wall.
- This kind of cladding may be applied on the normal brick backing or random ruble stone backing.
- This can also be laid on the concrete backing as well.

Concrete panel Cladding



Concrete backing, Brick facing



Concrete backing, Stone facing

These are common in **large construction** mass housing, industries, and high-rise buildings, retaining structures. They are usually **pre-fabricated** concrete panels with textured face fixed over the original surface to provide the desired face. These are mostly used in high risk reasons from weather or miscreant.

The under sill type spans horizontally from one column to another and are used where a high *wall/window* ratio is required, combination of both are also possible.

Requirements

- Concrete panels are constructed of dense concrete with suitable steel reinforcements. When designing a concrete panel following points are taken in to account;
  - ✓ Column or beam spacing,
  - ✓ Lifting capacity of the plant,
  - ✓ Joining methods,
  - ✓ Exposure conditions,
- Any special planning requirements as to the finish or texture
- There can also be a cladding of concrete on the brick or stone backing

9.2 Partitions & Suspended ceilings

A partition wall may be defined as a wall or division made up of bricks, timber, glass or other such materials are provided for the purpose of dividing one room or portion of a room from another.

Advantages

1. Divides the whole area into number of rooms.
2. Thin in section and therefore occupy less floor area.
3. Offers privacy for both sight and sound.
4. Easy in construction in any position

Requirements of good partition

- Thin in section to utilize max. floor area.
- Provide adequate privacy in rooms for both sight and sound.
- Use of durable, light and strong material.
- Simple, easy and economical in construction
- Fire resistance
- Heat and damp resistant.
- Resistant to insect and fungus attack.

Types of Partition

1. Loading bearing partition
2. Non-load bearing partition

Types according to use of materials

1. Brick partitions- plain, reinforced brick
2. Glass partition
3. Concrete partition- plain or reinforced
4. AC sheet or CGI sheet partitions
5. Timber partitions
6. Hollow blocks partitions
7. Aluminum partitions
8. Gypsum board partitions

Loading bearing partitions

Load bearing partition is designed and construction to receive superimposes loads and transferring to the foundation. It supports the joists of floor, purlins and ceilings joist of the roof.

Non –load bearing partitions

Non –load bearing partitions neither receive superimposed loads nor transmit any structural loads to the structural member below. This partition has only its own weight to hold in position. It also carries fixtures and fittings necessary in the room. It is obvious that it must be able to resist impact loading on its face and also vibration caused from any reason.

Suspended ceiling

A suspended (false) ceiling is the construction below the roof slab. It is the false structure mean not load bearing in overhead of the room below the roof or slab. It has a framework suspended (supported) from the main structure, usually in the roof slab and covering material is then fixed on the frame. It forms void between the ceiling and the roof/slab.

Light fixtures, air diffusers and other equipment are usually integrates into the linear pattern. Acoustic material may be supported above the ceiling material. Depending upon the purpose, plaster boards, straw-boards, etc are secured to ceiling.

Uses

- For attractive appearance.
- Space for housing utilities pipes, electrical wires, telephone wires, channel wires etc.
- Sound and heat insulation.

Types of ceilings

According to use of materials

1. Timber
2. RCC
3. Metal
4. Composite
5. Gypsum board
6. Straw boards
7. Glass
8. Paper

According to construction

- Joint less
- Jointed
- Open

Joint less

The ceiling that is monolithic in appearance and no joints can be seen on the surface is term as joint less ceiling. This can be done by applying plaster on the ceiling board/expended metal lathing etc

Jointed ceilings

- Are very commonly used in practice.
- The joints on the ceiling may be made in decorative appearance.
- The frame is made according to desired shape and size ceiling boards.
- Ceiling materials may be fixed with spring clip, nail or screws.

Open ceiling

- In the open ceiling, the frame is fixed in such a way that voids are formed to give virtual effect.
- Voids are largely provided
- For decorative purpose.

Procedure for ceiling fixing

- Ceiling joists are fixed on desired height from the floor.
- If necessary, vertical struts are fixed to set joists.
- Battens are then fixed on the joists.
- Ceiling materials like planks, plywood, metal sheets, etc is fixed on the battens

Finally, painting and finishing is done.

9.3 Plastering & Pointing (types and process of application)

PLASTERING

Applying mortar coats on the surfaces of walls, columns, ceiling etc. to get smooth finish is termed as plastering. Mortar used for plastering may be lime mortar, cement mortar or lime-cement mortar. Lime mortar used shall have fat lime to sand ratio of 1: 3 or 1: 4. If hydraulic lime is used mix proportion (lime: sand) is 1: 2. Cement mortar of 1: 4 or 1: 6 mix is very commonly used for plastering, richer mix being used for outer walls. To combine the cost effectiveness of lime mortar and good quality of cement mortar many use lime-cement mortar of proportion (cement: lime: sand) of 1: 1: 6 or 1: 1: 8 or 1: 2: 8.

The *objectives of plastering are*:

1. To conceal defective workmanship
2. To give smooth surface to avoid catching of dust.
3. To give good look.
4. To protect the wall from rain water and other atmospheric agencies.
5. To protect surfaces against vermit.

Requirement of good plaster are:

1. It should adhere to the background easily.
2. It should be hard and durable.
3. It should prevent penetration by moisture
4. It should be cheap.

Types of plasters

- Lime plaster (lime, sand, water)
- Cement plaster (cement, sand, water)
- Mud plaster (earth, sand, straw etc , water)
- Surkhi plaster (Surkhi, sand, water)
- Bajra plaster (dal, lime, earth, water)

Method of plastering

1. Preparation of surface background
2. application of rendering coat
3. Application of final coat

Preparation of surface background

• Before plastering, the mortar joints should be raked to a depth of 10-15mm so that the plaster can easily catch to the wall.
• All dust should be removed from wall by using stiff wire brush.
• Any uneven should be removed so that which make easier for plastering.
• The level of wall or component of plastering from one end to other end should not be more than 15mm.
• The wall should be uniformly wet before plastering.
• After that dots are placed of the interval of 2m×2m with the equal level or thickness of about generally 12mm.
• This type of dots are provided on the wall where plastering operation being operating.
• After that the whole wall is cover by plaster by the help of gauging tool(trowel), float and floating rule.

Trowel

float

floating rule

Defects in plaster work

• Cracking .Falling out of plaster
• Blistering of plaster- formation of small patches of plaster swelling out beyond the plaster surface and making due to improper slaking of lime particles in the plaster.
• Efflorescence-whitish crystalline substance, presence of salt in plaster making materials
• Flaking- formation of very loose mass of plastered surface due to poor bond between successive coat

POINTING:
Instead of plastering entire surface of the masonry, special mortar finishing work is done to the exposed joints. This is called pointing. It consists of raking the joints to a depth of 10 mm to 20 mm and filling it with richer mortar mixes. In case of lime mortar pointing mix used is 1 : 2 and in case of cement mortar pointing mix used is 1 : 3. Pointing is ideally suited for stone masonry because stones are having attractive colours and good resistance to penetration by water. Pointing gives perfection to weaker part of masonry (*i.e.* to joints) and it adds to aesthetic view of the masonry.
The table below gives the comparison between plastering and pointing.

Comparison between plastering and pointing		
S.NO	PLASTERING	POINTING
1	It is applied to entire surface	It is provided only at exposed joints.
2	It provides smooth surface.	It doesn't provide smooth surface.
3	It conceals defective workmanship.	It is used for beauty of masonry work.
4	It provides base for applying white/colour washing	White washing or colour washing are ruled out.

Purpose of pointing
- Protecting joints from adverse effect of atmosphere
- Give better appearance
- Preventing entry of water in to wall through joints
- Economy to plaster

Pointing procedure
- Joints are raked to 13 mm depth.
- Raked joints are cleaned by using brushes.
- Joints are kept wet for few hours.
- Mortar is applied on the joints by means of small trowel.
- Applied mortar is given the shape of desired type of pointing.
- Curing is done for 3-10 days.

Types of pointing

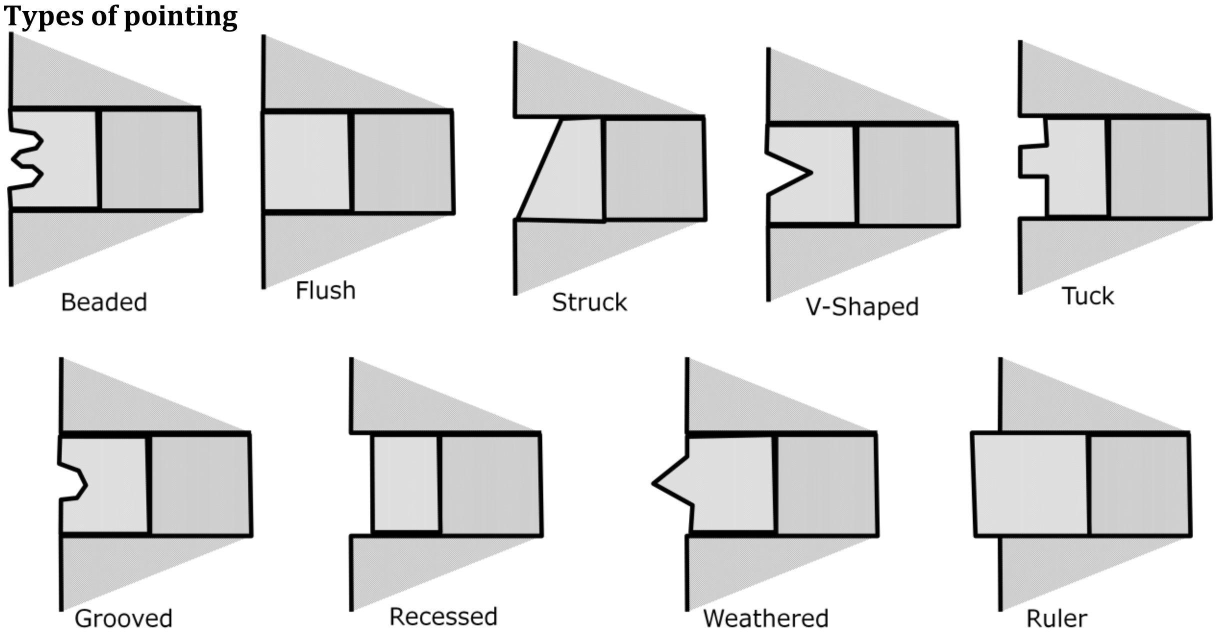


Fig:-types of pointing

- ✓ **Beaded pointing** - steel rod of suitable size giving groove is applied on joint, good appearance.
- ✓ **Flush pointing** - raked joint is filled with mortar and leveled.
- ✓ **Struck/cut pointing** - mortar is pressed in joint such that upper side is more pressed.
- ✓ **V-grooved pointing** - steel rod is used to form V-groove.
- ✓ **Tuck-pointing** - mortar is flushed to joints, mortar is cut to form raised ruler outside
- ✓ **Keyed/grooved pointing** - steel rod of 6mm dia. Used to form circular groove.
- ✓ **Recessed pointing** - mortar is pressed inside of joint by 6 mm by suitable tool.
- ✓ **Weathered (V) pointing** - V-shaped projection of mortar in joints.
- ✓ **Ruler pointing** – mortar is raised in the joint.

9.4 Painting works in wooden, metal and masonry surfaces

Paints

- ✓ It is the liquid material applied on timber, metal or masonry surfaces.
- ✓ It acts as protective or decorative on applied surface.
- ✓ It is composed of two main components; pigment and organic binders

Constituents of oil paint

- ✓ **Base -** metallic oxide in the form of powder, chief ingredient of paint, keep surface opaque
- ✓ **Extender or inert filler -** cheap pigment for volume
- ✓ **Pigment for color** - mixed to give desired color,
- ✓ **Vehicle** - liquid that acts as binder, makes paint fluid & spread ingredient uniformly
- ✓ **Thinner or solvent -** liquid that makes the paint thin & evaporates after applying paint
- ✓ **Drier** - material containing metallic compound, accelerates the drying of paint

Characteristics of good paint

1. Well stick to the surface & seal the pores thereby.
2. Consistency to easy workability.
3. Adequate thickness of paint for good protection and decoration of surface.
4. Rapid drying of paint.
5. Paint film be able to stand the adverse weather effects.
6. Resistance to cracking, flaking etc.
7. Possessing moisture resistance.
8. Giving permanent color.

Types of paints

- **Aluminum paints** - used for woodwork and metal surface.
- **Anticorrosive paints** - metal protective paint.
- **Asbestos paints** - for patch works in metal roof, it controls leakage.
- **Bituminous paints** - for water proofing on roof and DPC.
- **Bronze paints** - for metallic surface.
- **Cellulose paints** - made from celluloid sheets & amyl-acetate substitutes, superior type of paints.
- **Casein paints** - protein substance milk, curd etc
- **Cement paints -** available in powder form, water is vehicle, used on masonry surface.
- **Enamel paints** - base material-lead, white zinc etc., vehicle-varnish
- **Rubber base paints** - rubber with chlorine gas, applied on cement surfaces.
- **Emulsion paints** - contains synthetic resins & polyvinyl acetate.
- **Graphite paints** - of black color and used in mines.
- **Plastic paints** - plastic in suspension and gives pleasing shades.
- **Silicate paints** - mixing of calcium and silicate with resinous materials.
- **Luminous paints** - mixing calcium sulfide with varnish, it is very shiny.

Painting on wood work

a) Painting process on new wood work

1. **Preparation of surface**

   – Wood work is properly seasoned.
   – The surface is clean, dry and free from dust.
   – The surface is made smooth by rubbing with sand /glass paper.

2. **Knotting**

This is the process of sealing the knots (resin flows from it & destroy paint).

- **Patent knotting-**Applying of one or more coats of Shellac or aluminum varnish on the knots
- **Size knotting-**Applying of first coat of mixture of red lead in water with glue and is hot on knots, Applying of second coat of mixture of red lead in oil thinned with boiled oil & turpentine on dried first coat
- **Lime knotting-**The knot is covered by hot lime for 14 hours, the lime is than scrapped off & knot be treated by size knotting.

3. **Priming**

The surface is painted by first coat of primer before fixing wood work and fills all pores on it.

4. **Stopping**

   – Nail holes, cracks, and open joints are filled up with putty.
   – It is than rubbed by sand paper to make smooth surface.
   – The putty used is the chalk powder mixed to linseed oil.

5. **Second and succeeding coats** (under coats)

   – First coat of paint with desired color is applied on priming coat.
   – If necessary, second coat of paint is than applied after the first coat is dried.

6. **Finishing coat**

The last coat of desired colored paint is applied to give smooth & good surface.

b) Painting on old wood work

1. **Preparation of surface**

Old painting if blistered & flaked should be completely removed.

- **Removing of old paint by blow lamp**
  – The paint is softened by heat (from blow of lamp).
  – Thus softened paint is removed by stripping knife.
- **Removing of old paint by paint removers**
  - Paint removers are available in the market and are applied on the painted surface.
  - The old paint lifts up, wrinkles, and can be easily removed by sharp knife etc.
  - Caustic soda solution is also useful for removing old paint. The solution of caustic soda and water is applied on the surface and it is made wet for 48 hours.
  - Old paint is softens and can be easily scraped off.

2. **Coating of paint**

- First coat of desired paint is applied on the clean and smooth surface of woodwork. If necessary, second coat is also applied.

- Final coating is applied to give smooth, uniform, and pleasing surface.

Knotting and priming do not require in the painting of old woodwork. However, the stopping may be required if holes, cracks and opens are seen on the surface.

Painting on Metal

a) Painting new iron and steel work

- The surface is clean off rust by scrapping or brushing with steel wire brushes. oil, grease etc is removed by washing the surface with petrol, benzene or lime water
- The clean surface is treated with a film of phosphoric acid. This protects the surface from rusting and provides better adhesive surface for the paint.

- The prime coat or first coat is applied with a brush.
- After the prime coat has dried two or more under-coats are applied either with a brush or with spray gun.
- After the under-coat has dried, the final coat of the desired type of paint is applied. The finishing coat should present smooth finish.

b) Repainting old iron and steel work

- Before repainting, the old surface is thoroughly cleaned by application of shop water. The grease, if any may be removed by washing the surface with lime and water.
- However, if the old paint has cracked, it has to be removed by flame-cleaning.
- The surface is then scrapped with wire brush and wash with solution of caustic soda and fresh slaked lime.
- After the surface is thus prepared, painting is carried out as for the new surface.

Painting works on masonry

Step 1 - Clean the Surface

- Once you've done your shopping, it's time to get to work. As with most painting projects, preparation is the biggest key to your success. If at all possible, power washes the surface. This is the fastest way to remove old paint. Use the power washer with some bleach or mildewcide if a lot of mold or algae are present. You may be working inside, or in a place where the mess of a power washer isn't appropriate. If that's the case, tackle that old loose paint with a scraper and a wire brush.
- After all of the loose paint has been removed, make sure that the substrate is clean. Any oil or grease on the masonry surface will bleed through the paint, causing discoloration, and possibly interfering with the longevity of the paint job. Use tri-sodium phosphate, also simply known as TSP, to clean the concrete surface before applying any product. Mix it up in a bucket and scrub it into to the surface with a scrub brush to remove any grease or oil, ensuring that your paint will stick well.

Step 2 - Make any Repairs

- If you have any major defects in the surface to repair, use a simple, ready mix concrete patch to make those repairs after you clean it. Refer to the manufacturer's recommendations when trying to assess how long the patch should dry before being painted.

Step 3 - Seal and Prime

- Almost any masonry surface needs to be both sealed and primed before the paint is applied. The sealer is often clear, but keeps moisture from coming through the concrete. This is especially true in basements, which tend to hold moisture anyway. If you are not sure whether your basement has been sealed or not, tape all four sides of a square of plastic kitchen wrap onto the floor and leave it for 24 hours. If the floor hasn't been sealed, you will see condensed water between the plastic wrap and the floor that has evaporated up through the concrete.
- Check with the national paint store or your local home improvement store’s paint department when selecting your products. Buy a quality masonry sealer and a primer that complements it. Use the two step process of sealing and priming to build a strong, water resistant foundation for your paint.

Step 4 - Paint the Surface

- After your sealer and primer coats are completely dry, now apply the paint. Use a paint brush to do detail work around windows and trim if you are working on the outside of your home. You also need a brush for cutting in along the walls when painting a concrete floor. Use a roller to do the bulk of the painting. Make sure to read the manufacturer's recommendations as to what size nap to use. At least ¾-inch or 1-inch nap is recommended. Buy at least two covers, as the primer will most likely ruin the first one.

- Apply several thin coats, rather than trying to apply one very thick coat, as paint actually forms a harder surface when thin coats are laid on top of each other. One thick coat often results is a gummy or soft surface. This drying thoroughly is often called "curing." It means that the paint has dried through all the layers down to the original surface. Paint dries to different thicknesses, or "mils," depending on its sheen and makeup. The thicker the mil of the paint, the longer this process can take. Paint applied to floors or walls in basements may have a longer curing cycle.
- When choosing your paint, the most important thing to keep in mind is location. Where is the paint going to be applied? The need for interior and exterior paints is fairly self-explanatory. Additionally, many manufacturers make specific masonry paints. Some are even designated as floor paints, so you shouldn't have a hard time finding what you need. There are also additives for your floor paint that give it a little bit of texture or grip. This material is inexpensive and doesn't change the color, but does prevent the slip that can occur when wet feet hit a slippery floor. Some kits come with decorative chips that are added as the paint is applied.
- If you are using an oil based paint and primer, you need mineral spirits or paint thinner to clean your brushes, and most likely yourself.
- After your final coat of paint is applied, allow the paint to cure for the recommended time. If the paint is on the floor and you don't let it dry long enough, it may dry with footprints that will never go away.

Painting on plastered surface

- The free alkalis present in fresh plaster should dry before painting. It takes about 12 months.
- They affect paint adversely in drying, color etc. and leave patches.
- Surface is cleaned by pumice stone and holes are repaired by paris/putty or cement and again rubbed.
- Surface is washed with dilute solution of zinc sulfate to neutralize free lime on wall surface.
- Priming coat of mixture of equal parts of white and red lead in boiled linseed oil is applied on the surface.
- First coat of desired paint is applied on the surface.
- Final coat of the desired paint is applied on the dried first coating.

Varnish

It is the clear and pale solution of resinous substance dissolved in either oil turpentine or alcohol. The solution on drying forms a hard, transparent glossy film on the varnish surface.

- **Importance of varnish**
  - The varnish applied on the decorative surfaces enhances the appearance of the paint.
  - Safeguards the wood work from atmospheric agents.
  - Increases the durability of paint.
- **Types of varnish**
  - **Oil varnish-**Oil & resin dissolved in volatile liquid (takes 24 hours to dry).
  - **Spar varnish-**Used in spar & other parts of ship, weather resistance.
  - **Flat varnish-**Dull appeared varnish, addition of more wax, metallic soap etc.
  - **Asphalt varnish-**Dissolving asphalt in linseed oil & gives black color, used for metal.
  - **Spirit varnish-**Resin dissolved in volatile liquid (spirit) and fast to dry.

CHAPTER 10 CAUSES AND PREVENTION OF CRACKS IN BUILDINGS

Cracks in buildings are of common occurrence. A building component develops cracks whenever stress in the component exceeds its strength. Stress in a building component could be caused by externally applied forces, such as dead, live, wind or seismic loads, or foundation settlement or it could be induced internally due to thermal variations, moisture changes, chemical action, etc.

Cracks could be broadly classified as **structural** or **non-structural**.

Structural cracks are those which are due to incorrect design, faulty construction or overloading and these may endanger the safety of a building. Extensive cracking of an RCC beam is an instance of structural cracking.

Principal causes of occurrence of **structural cracks** in buildings are as follows:

a) <u>Faulty design</u> **b) <u>Faulty construction</u>** **c) <u>Overloading</u>**

Non-structural cracks are mostly due to internally induced stresses in building materials and these generally do not directly result in structural weakening. In course of time, however, sometime non-structural cracks may, because of penetration of moisture through cracks or weathering action, result in corrosion of reinforcement and thus may render the structure unsafe. Vertical cracks in a long compound wall due to shrinkage or thermal variation is an instance of non-structural cracking.

Principal causes of occurrence of **non structural cracks** in buildings are as follows:

a) Moisture changes,
b) Thermal variations,
c) Elastic deformation,
d) Creep,
e) Chemical reaction,
f) Foundation movement and settlement of soil,
g) Vegetation.

Moisture Changes

Building materials expand on absorbing moisture and shrink on drying. These are generally reversible. Shrinkage in concrete or mortar depends on a number of factors

- **Cement concrete:** Richer the mix greater is the drying shrinkage.
- **Water content**: More water in mix induces greater shrinkage
- **Aggregates :** Large aggregates with good grading has less shrinkage for same workability as less water is used
- **Curing:** If proper curing starts as soon as initial set has taken place and continued for 7 to 10 days shrinkage is comparatively less
- **Excessive fines**: More fines in aggregate requires more water for same workability and hence more shrinkage.
- **Temperature:** Concrete made in hot weather needs more water for same workability and hence results in more shrinkage.
- **Initial Expansion-**An example of cracks of wall due to initial expansion of bricks is given in fig

Some Measures for controlling shrinkage

- Shrinkage in plastering can be reduced by ensuring proper adhesion. The plastered should not be stronger than the back ground.
- Shrinkage cracks in masonry can be minimized by avoiding use of rich cement mortar and by delaying plastering till masonry has dried after proper curing and has undergone most of its initial shrinkage.

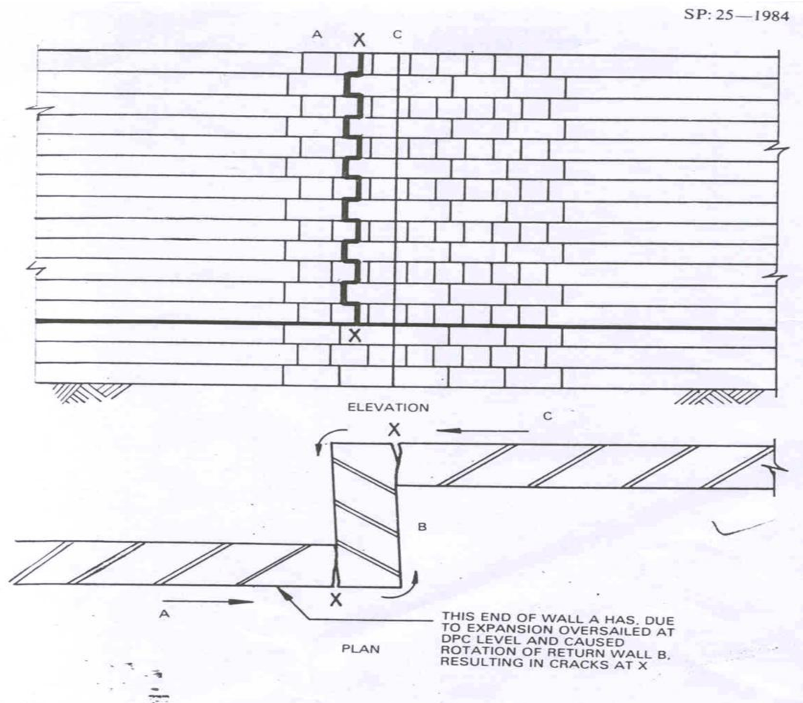


Fig. 9 Cracking Due to Expansion of Brickwork

Thermal Movement

The cracking of a typical structure due to thermal movement is given in fig

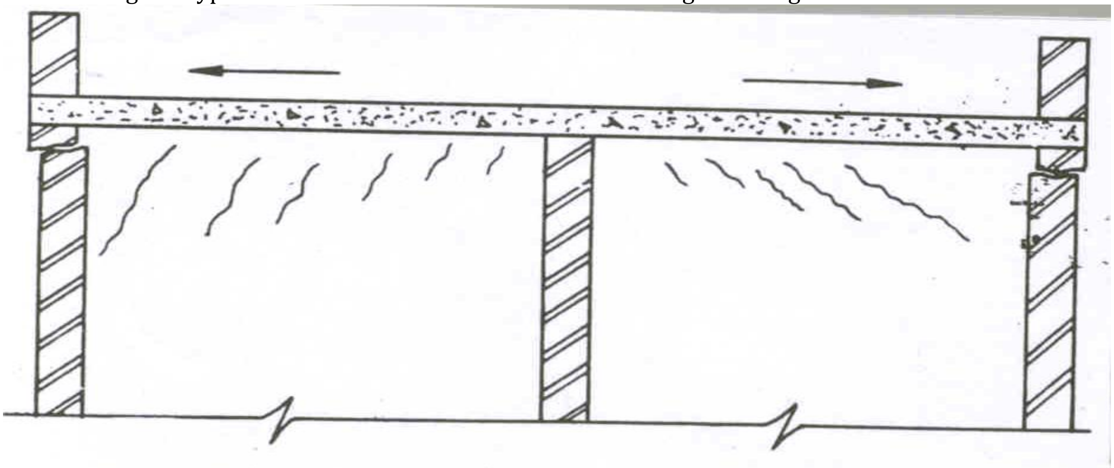


Fig. 11 Cracking in Top Most Storey of a Load Bearing Structure

In case of framed buildings due to thermal movement frames are distorted and cracks may appear as shown in fig

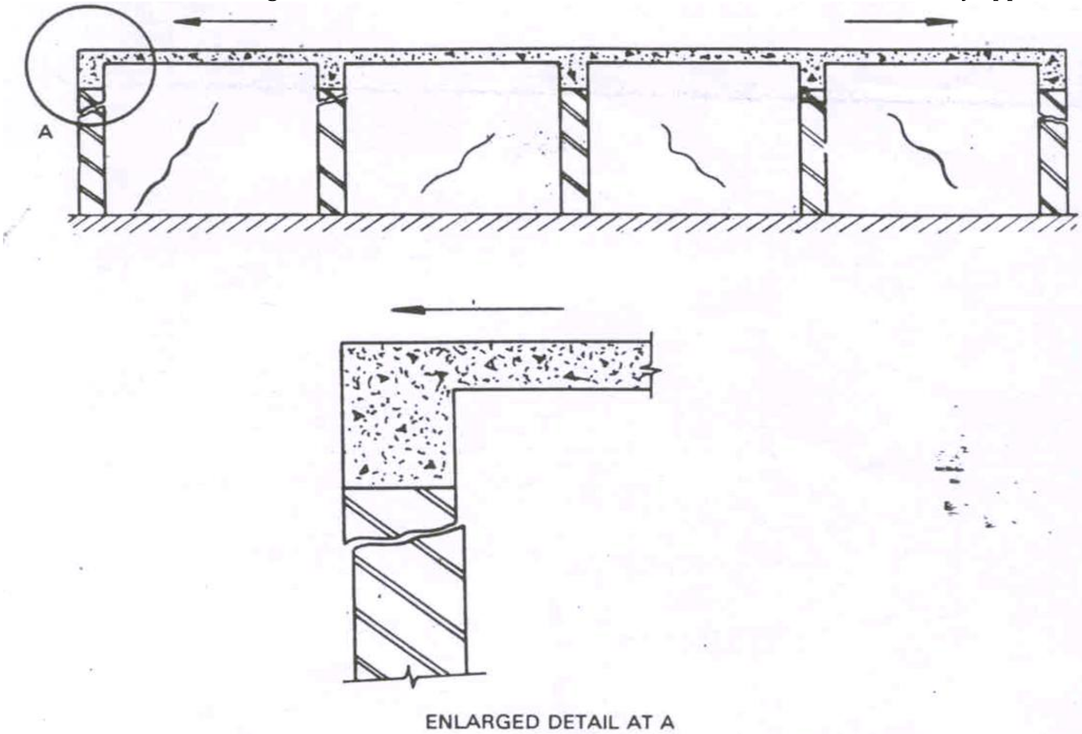


Fig. 13 Cracking in Cladding and Cross Walls of a Framed Structure

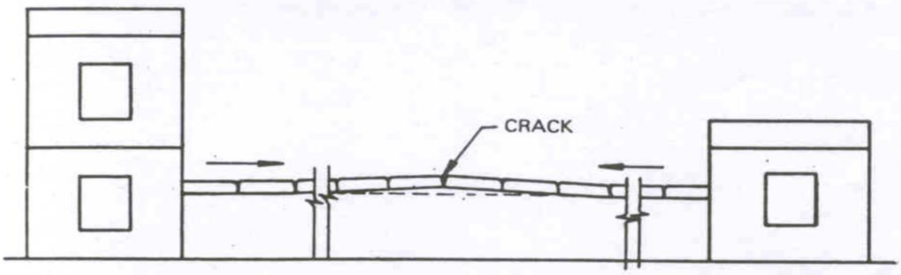


Fig. 14 Arching up and Cracking of Coping Stones of a Long Garden Wall

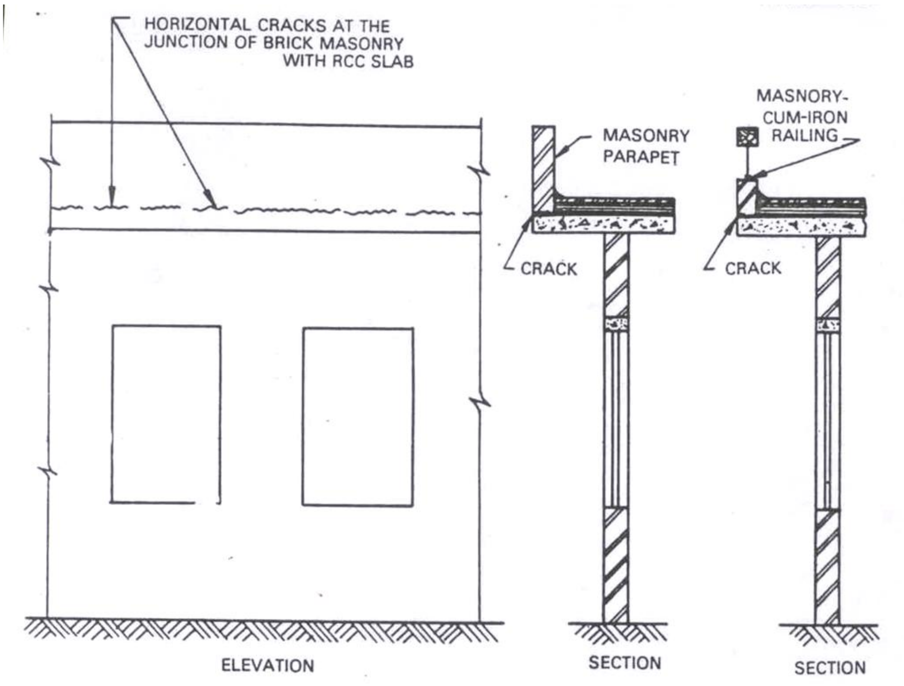
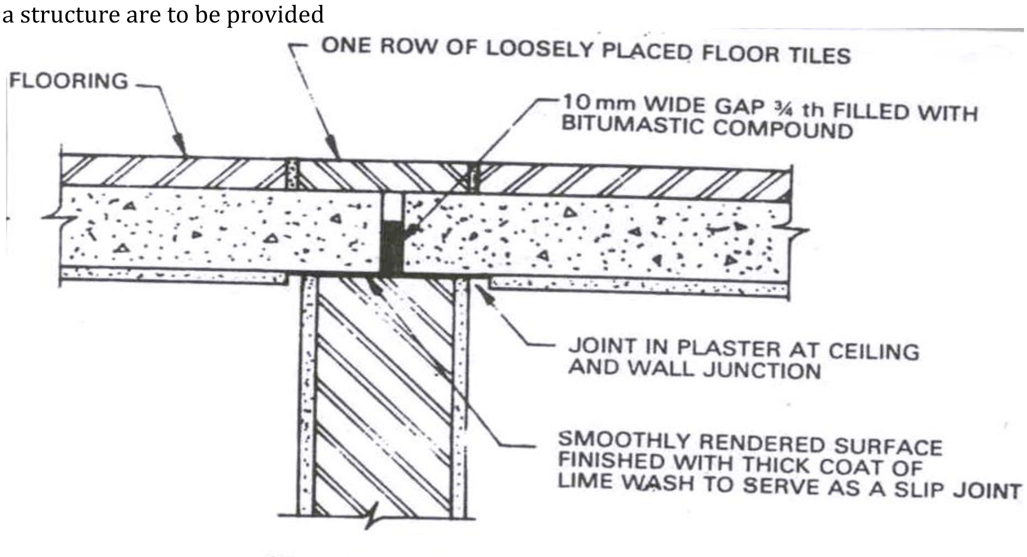


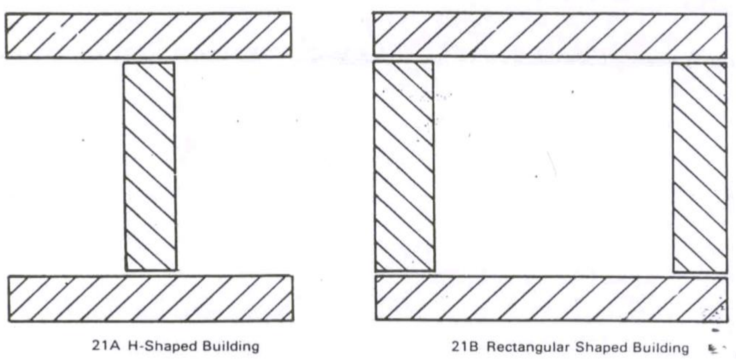
Fig. 15 Horizontal Crack at the Base of Brick Masonry Parapet (or Masonry-cum-Iron Railing) Supported on a Projecting RCC Slab

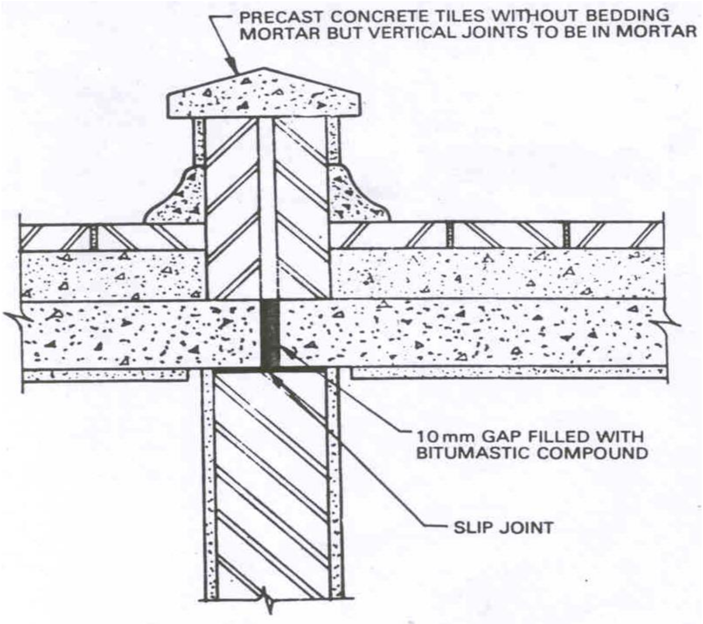
Prevention of Thermal Cracks

To prevent thermal cracks expansion joints, control joints and joints in case of change of shape and direction of wing in a structure are to be provided



17A Joint in floor slab





17B Joint in roof slab

General guide lines to provide movement joints

S.N.	TYPE OF STRUCTURE	MOVEMENT OF JOINTS
1	RCC roof slab	Provide 20to 25 mm wide, joint at 10-20m apart
2	Supports for RCC slabs 4-6m length	Provide slip joint between slab and bearing wall
3	RCC framed structure, other load & bearing structure	Provide 25 to 40 mm wide expansion joints at 30 to 40m interval
4	Junction between old and new structure	Provide vertical slip joints
5	Compound walls	Expansion joint 5 to 8mm wide at 5-8m interval and change of direction
6	Concrete pavement	Provide 20to 25mm wide joints at 25m-40m interval with control joints at 5 to 8m.
7	chajja	Provide expansion joint 5-8mm wide at 4 to 6m interval
8	RCC Railing	Provide expansion joints 5-8mm wide at 6 to 9m interval

Elastic Deformation

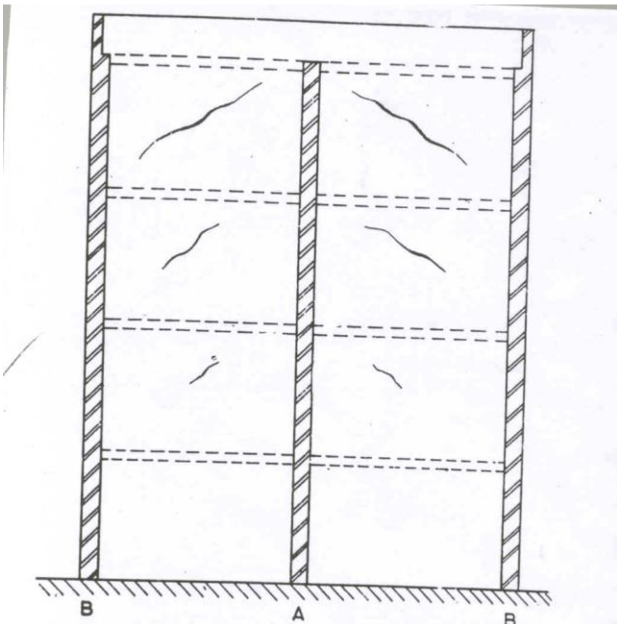


Fig. 25 Diagonal Cracks in Cross Walls of Multi-Storied Load Bearing Structures

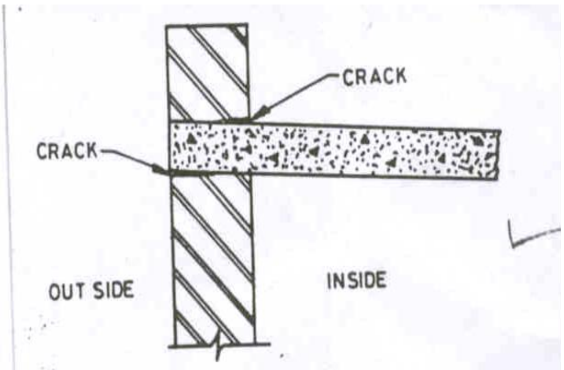


Fig. 27 Horizontal Cracks in a Wall at Supports Due to Excessive Defletion of a Slab of Large Span

Creep
Building items such as concrete and brick work when subjected to a sustained load not only undergo elastic strain but also develop gradual and slow time dependent deformation known as creep or plastic strain. The creep in brick work may stop after 4 months but the same in concrete continue upto a year or so. The creep in concrete may be 2 to 3 times of the elastic deformation and hence has to be fully carefully considered.

General measures for avoidance reduction of cracks due to elastic strain, creep and shrinkage
- Water cement ratio is to be controlled.
- Reasonable pace of construction adopted.
- Brick work over load bearing RCC members should be done after removal of shutting giving a time gap.
- Brick walls between columns should be deferred as much as possible.
- Plastering of areas having RCC and brick members should be done after sufficient time gap say one month or suitable groves provided in junction.
- Shutting should be allowed stay for a larger period say 30 days or so for cantilevers which are bound to defect appreciably.

Movement due to chemical reaction
- Certain chemical reaction in building materials result is appreciable change in volume of resulting products and internal stresses are set up which may result in outward thrust and formation of cracks.
- Soluble sulphate reacts with tricalcuium aluminate in cement and hydraulic lime and form products which occupy larger volume and ends in developing cracks. An example of cracking of a floor due to coming in contact of the sub base made of brick with heavy sulphate content and water can be seen in fig

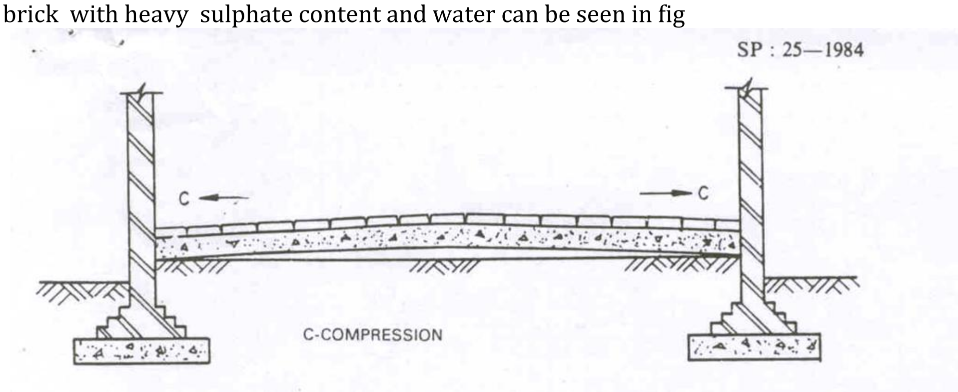
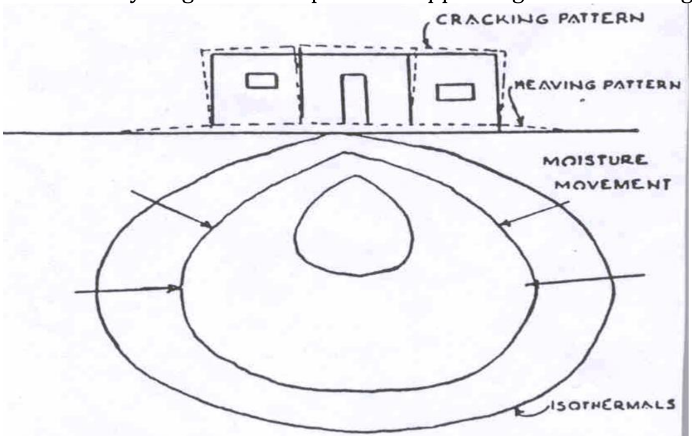


Fig. 39 Cracking and Upheaving of a Tile Floor Due to Sulphate Action in Base Concrete (Brick aggregate)

Prevention
- If sulphate content in soil is more that 0.2 % or in ground water more than 300 ppm, use rich mix of concrete.
- Avoid bricks containing too much soluble sulphates (more than 5 %) and use rich mortar in such cases.
- Use expansion and control joint at closure intervals
- Corroded reinforcement expands and cracks the concrete cover. To avoid this phenomenon rich mix of concrete using proper quality of water and adequate cover should adopted.
- Buildings on expansion clays are extremely crack prone. The soil movement in such clay is more appreciable upto a depth of 1.5 to 2M and this cause swelling and shrinkage and results in crack in the structure. The cracks due to settlement are usually diagonal in shape. Crack appearing due to swelling is vertical Fig



DIAGRAMATIC SKETCH OF THERMO-OSMOTIC HEAVING OF BUILDINGS ON DESICCATED CLAY SOILS.

• Large trees growing in the vicinity of buildings cause damage in all type of soil conditions. If the soil is shrinkable clay cracking is severe

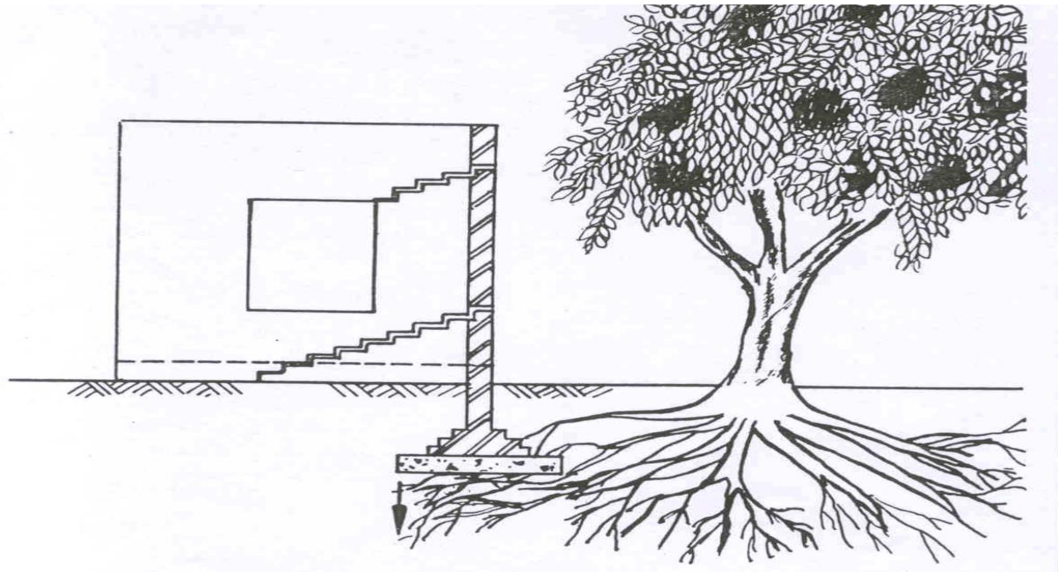


Fig. 45 Trees Growing Close to a Building on Shrinkable Soil may Cause Cracks in the Walls

Repair:

The repair for cracks may be undertaken after ascertaining the reasons for the appearance of the crack. A few basic principles if followed will be more effective

1. Rendering of minor crack less that 1m wide may be done after observing the crack for some time and then sealing it with weak mortar of cement, lime and sand.
2. Cracks where width change with season should be filled up with elastic fillers like silicon or polyurethane compound.
3. Where shear crack are observed shear keys made of RCC concrete with at least 1.5 percent steel vein forcemeat may be provided at 1 to 1.5m intervals.
4. If cracks are due to movement of soil in black cotton once, prevention of moisture penetration in the surrounding areas has to be ensured by providing a waterproof blanket around the plinth. The masonry wall below ground level should also be separated from the adjoining soil by replacing the existing soil with coarse grain material.

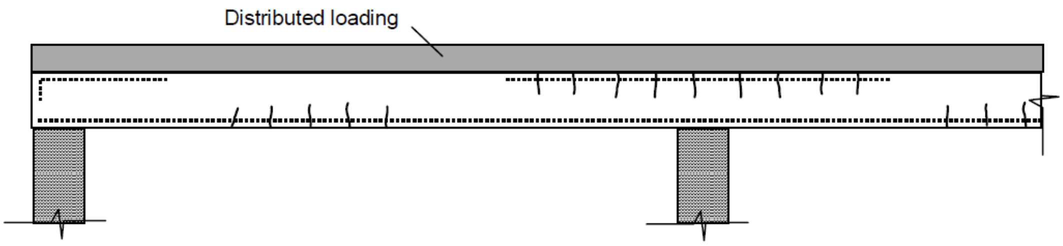


Fig. 10.14 Typical flexural cracks in a continuous one-way slab due to gravity loading

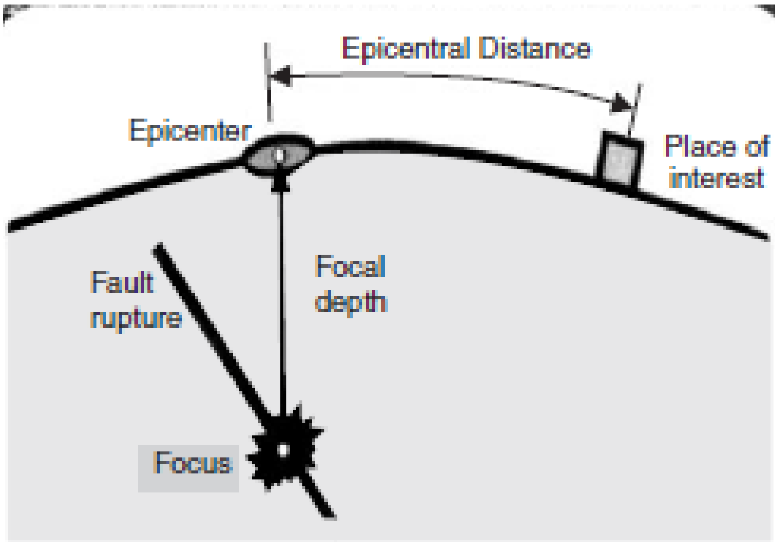
CHAPTER 11 Earthquake protection & Retrofitting in building

An earthquake is a sudden, rapid shaking of the earth surface caused by the breaking and shifting of rocks beneath. During earthquake, ground motion occurs in a random fashion in all directions radiating from a point within earth crust, called epicentre. It causes vibrations of structures and induces inertia forces on them. As a result structure may collapse resulting into loss of property and lives. Earthquakes do not kill people, vulnerable buildings do so. Hence there is need of designing earthquake resistant buildings, especially in the earthquake prone areas.

Depending upon the possible causes, the earthquakes may be classified as:
1. **Natural earthquake**
2. Earthquakes due to induced activities.

Natural earthquakes may be due to **(*i*) active faults (*ii*) movement of tectonic plates or (*iii*) due to volcanic eruptions**.

In earth's crust there are some faults which are not yet settled. The displacement of rocks along faults cause earthquake. Tectonic means large scale process affecting the structure of the earth crust. This process causes gradual movement of material within the crust of earth. Sometimes it shakes the earth crust.
Volcano is a mountain or hill having a crater through which lava, rock fragments, hot vapour and gas are or have been erupted from the earth's crust. Occasionally the volcanoes become active and create earthquake near the mountain crater.



TERMINOLOGY
1. Focus: The point on the fault where slip starts is the focus. It is also known as hypocentre
2. Epicentre: The point vertically above the focus on the surface of the earth is the epicentre.
3. Focal Depth: The depth of focus from the epicentre is called the focal depth.
4. Epicentral Distance: Distance from epicentre to any point of interest on the surface of earth is called epicentral distance

MAGNITUDE AND INTENSITY
Magnitude is a quantitative measure of the actual size of the earthquake. Professor Charles Richter proposed the scale of magnitude that goes from 0 to 9. It is a geometric scale. Now this scale is known as Richter scale. It is obtained from the seismograph. It depends on waveform amplitude on epicentral distance. It is denoted by letter M followed by the number. An increase in magnitude by 1 implies 10 times higher waveform amplitude and about 31 time higher energy released. Thus energy released in M6 and M5 earthquake have the ratio 31, and M8 to M5 have the ratio 31 × 31 × 31. There are other magnitude scales, like the Body Wave Magnitude, Surface Wave Magnitude and Wave Energy Magnitude.

Intensity is a qualitative measure of the actual shaking at a location during an earthquake. Hence for the same earthquake, it has different values at different places, highest value being at epicentre. This is a linear scale. It is assigned as Roman Capital Numbers from I to XII.
Intensity depends upon
1. Amount of source energy released
2. Distance between the source and the place of interest
3. Geographical features of the media of travel and importantly on the type of structure.

Modified Mercalli Intensity (MMI) scale is commonly used to express the intensity. MMI scale is as given below:
I. Very slight, felt only by instruments
II. Felt by people resting
III. Felt by passing traffic
IV. Furnitures and windows rattle

V. Can be felt outdoors, clocks stop, doors swing
VI. Furnitures move about, cracks appear in walls
VII. People knocked over, masonry cracks and falls
VIII. Chimneys and monuments fall, buildings move on foundations
IX. Heavy damage to buildings, large cracks open on ground
X. Most buildings destroyed, landslides occur, water thrown out of lakes
XI. Catastrophic, railway lines badly bent
XII. Utter catastrophic, no building is left standing.

11.1 Earthquake Protection of Buildings

- **IMPROVING EARTHQUAKE RESISTANCE OF SMALL BUILDINGS**

The earthquake resistance of small buildings may be increased by taking some precautions and measures in site selections, building planning and constructions as explained below:

1. Site Selection: The building constructions should be avoided on
(*a*) Near unstable embankments
(*b*) Sloping ground with columns of different heights
(*c*) Flood affected areas
(*d*) Subsoil with marked discontinuity like rock in some portion and soil in some portion.

2. Building Planning: Symmetric plans are safer compared to asymmetric. Hence go for square or rectangular plans rather than L, E, H, T shaped. Rectangular plans should not have length more than twice the width.

3. Foundations:

- Width of foundation should not be less than 750 mm for single storey building and not less than 900 mm for storeyed buildings.
- Depth of foundation should not be less than 1.0 m for soft soil and 0.45 m for rocky ground.
- Before foundation is laid remove all loose materials including water from the trench and compact the bottom.
- After foundation is laid back-fill the foundation properly and compact.

4. Masonry:
In case of stone masonry:

- Place each stone flat on its broadest face.
- Place length of stones into the thickness of wall to ensure interlocking inside and outside faces of the wall.
- Fill the voids using small chips of the stones with minimum possible mortar.
- Break the stone to make it angular so that it has no rounded face.
- At every 600 to 750 mm distance use through stones.

In case of brick masonry:

- Use properly burnt bricks only.
- Place bricks with its groove mark facing up to ensure better bond with next course.

In case of concrete blocks:

- Place rough faces towards top and bottom to get good bond.
- Blocks should be strong.
- Brush the top and bottom faces before laying.

In general walls of more than 450 mm should be avoided. Length of wall should be restricted to 6 m. Cross walls make the masonry stronger. It is better to build partition walls along main walls interlinking the two.

5. Doors and Window Openings:

- Walls with too many doors and windows close to each other collapse early.
- Windows should be kept at same level.
- The total width of all openings in wall should not exceed 1/3 rd the length of wall.
- Doors should not be placed at the end of the wall. They should be at least at 500 mm from the cross wall.
- Clear width between two openings should not be less than 600 mm.

6. Roof:

- In sloping roofs with span greater than 6 m use trusses instead of rafters.
- Building with 4 sided sloping roofs is stronger than the one with two sided sloping, since gable walls collapse early.

7. Chajja:

- Restrict chajja or balcony projections to 0.9 m. For larger projections use beams and columns.

8. Parapet: Masonry parapet wall can collapse easily. It is better to build parapet with bricks up to 300 mm followed by iron railings.

9. Concrete and Mortar: Use river sand for making mortar and concrete. It should be sieved to remove pebbles. Silt should be removed by holding it against wind. Coarse aggregates of size more than 30 mm should not be used. Aggregates should be well graded and angular. Before adding water, cement and aggregates should be dry mixed thoroughly.

10. Bands: The following R.C. bands should be provided

(*a*) Plinth band
(*b*) Lintel band
(*c*) Roof band
(*d*) Gable band.

For making R.C. bands minimum thickness is 75 mm and at least two bars of 8 mm diameters are required. They should be tied with steel limbs of 6 mm diameter at 150 mm spacing. If wall size is large, diagonal and vertical bands also may be provided.

11. Retrofitting: Retrofitting means preparing a structure in a scientific manner so that all elements of a building act as an integral unit.

IMPROVING EARTHQUAKE RESISTANCE OF TALL BUILDINGS

Tall buildings are subjected to heavy horizontal forces due to inertia during earthquake. Hence they need shear walls. A shear wall is a R.C.C. enclosure within the building built to take shear forces. It is usually built around lift room. These shear walls must be provided evenly throughout the buildings in both directions as well as from bottom to top. Apart from providing shear walls, the following techniques are also used for making tall buildings earthquake resistant:

1. **Base Isolation**
2. **Using Seismic Dampers.**

Base Isolation

The idea behind base isolation is to detach (isolate) the building from the ground in such a way that earthquake motions are not transmitted up through the building, or at least greatly reduced. The concept of base isolation is explained through an example of building resting on roller [Fig. 20.3]. When the ground shakes, the roller freely roll but the building above does not move. If the gap between the building and the vertical wall of foundation pit is small, the vertical wall of the pit may hit the wall.

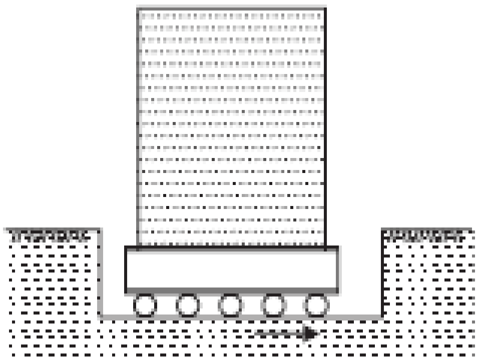


Fig. 20.3. Hypothetical building

Hence 100% frictionless rollers are not provided in practice. The building is rested on flexible pads that offer resistance against lateral movements [Fig. 20.4].

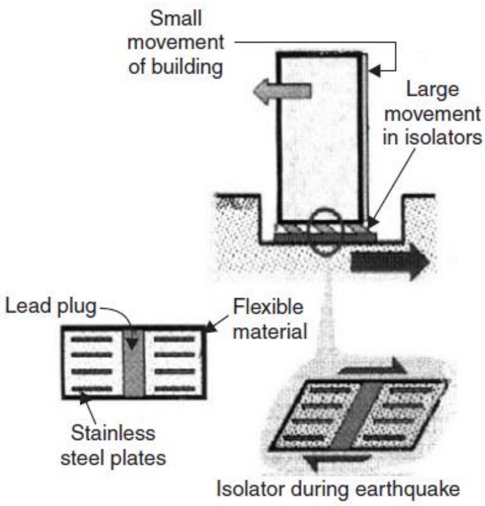


Fig. 20.4. Base isolated building

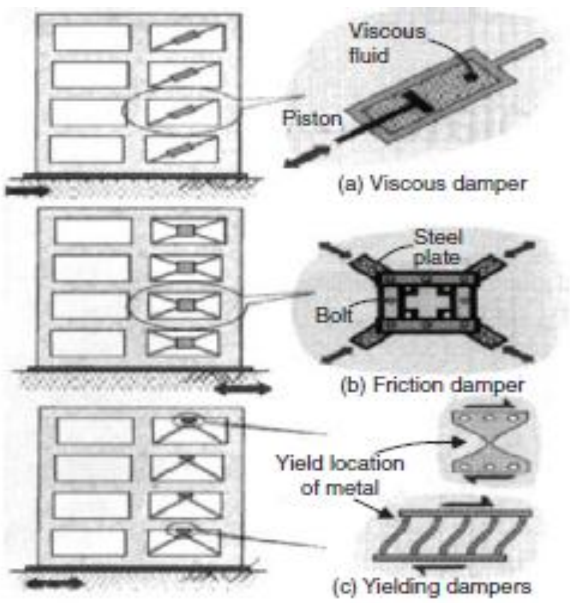


Fig. 20.5. Seismic dampers

This reduces some effect of ground shaking to the building. The flexible pads are called base-isolators, whereas the structures protected by means of these devices are called base-isolated buildings.

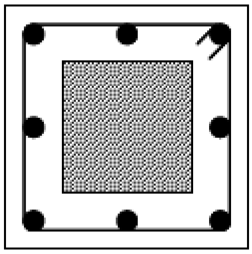
Seismic Dampers

Another approach for controlling seismic damage in buildings is by installing seismic dampers in place of structural elements, such as diagonal braces. When seismic energy is transmitted through them, dampers absorb part of it, and thus damp the motion of the building. Figure 20.5 shows the following types of seismic isolation bearings:
(*a*) High density rubber bearings (*b*) Laminated rubber bearings and (*c*) Friction pendulum bearings.

11.2 Techniques of Retrofitting and Retrofitting materials

Retrofitting: Retrofitting means preparing a structure in a scientific manner so that all elements of a building act as an integral unit.

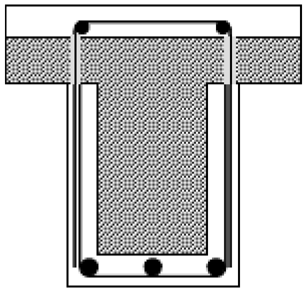
Retrofitting of existing structures, with insufficient seismic resistance accounts for a major portion of the total cost of hazard mitigation. Thus, it is of critical importance that the structures that need seismic retrofitting are identified correctly, and an optimal retrofitting is conducted in a cost effective fashion. Once the decision is made, seismic retrofitting can be performed through several methods with various objectives such as increasing the load, deformation, and/or energy dissipation capacity of the structure (FEMA, 2000). Conventional as well as emerging retrofit methods can be applied as described below.



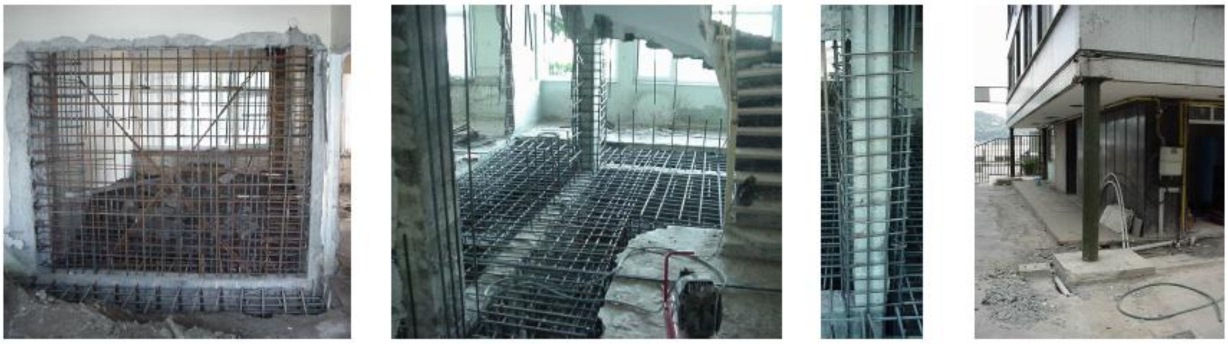
(b) Column jacketing

Conventional Strengthening Methods of retrofit

Conventional retrofitting methods include addition of new structural elements to the system and enlarging the existing members. Addition of shear walls and bracings is the most popular strengthening method due to its effectiveness, relative ease, and lower overall project cost compared to column and beam jacketing. Post-cast shear walls and steel braced frames are the most effective strengthening techniques. Although the latter is more effective due to its much higher ductility, post-cast concrete shear walls are the most commonly applied method due to their lower cost and familiarity of the construction industry with the method. Design of additional shear walls is performed to resist a major fraction of the lateral loads likely to act on the structure. This reduces the demand on the beams and columns, hence increasing their safety. Those still likely to be overstressed are strengthened through concrete or steel jacketing, which are relatively more laborious applications. Fig. 2 shows applications of various conventional strengthening methods such as post-cast shear wall (a), additional foundation to support the shear walls to be constructed around the stairs (b), concrete jacketing of a column (c), and addition of column members to remedy vertical irregularities (d).



(c) Beam jacketing



(a) additional shear wall (b) additional foundations (c) jacketing (d) additional columns

Fig. 2 Applications of conventional strengthening methods

Retrofit of Structures Using Innovative Materials

Base Isolation

The seismic base isolation technology involves placing flexible isolation systems between the foundation and the superstructure. By means of their flexibility and energy absorption capability, the isolation systems reflect and absorb part of the earthquake input energy before this energy is fully transmitted to the superstructure, reducing the energy dissipation demand on the superstructure. Base isolation causes the natural period of the structure to increase and results in increased displacements across the isolation level and reduced accelerations and displacements in the superstructure during an earthquake. This not only provides safety against collapse, but also largely reduces damage,

which is crucial for facilities that should remain operational after severe earthquakes such as emergency response centres, hospitals, and fire stations. Base isolation can also be used in seismic retrofitting of historic structures without impairing their architectural characteristics by reducing the induced seismic forces.
Base isolation is generally suitable for low to medium rise buildings, usually up to 10- 12 stories high, which have their fundamental frequencies in the range of expected dominant frequencies of earthquakes.

Supplemental Energy Dissipation and Structural Control

An alternative and often more cost efficient retrofitting strategy compared to base isolation is installation of supplemental energy dissipation devices in structures as a means for passive or active structural control. The objective of structural control is to reduce structural vibrations for improved safety and/or serviceability under wind and earthquake loadings. Passive control systems reduce structural vibration and associated forces through energy dissipation devices that do not require external power. These devices utilize the motion of the structure to develop counteracting control forces and absorb a portion of the input seismic energy. Active control systems, however, enhance structural response through control forces developed by force delivery devices that rely on external power to operate. The actuator forces are controlled by real time controllers that process the information obtained from sensors within the structure. Semi-active control systems combine passive and active control devices and are sometimes used to optimize the structural performance with minimal external power requirements. Fig. 7 shows the basic principles of various control systems commonly used to control wind and seismic forces acting on building structures.
The severity of seismic demand on a structure is proportional to its stiffness and inversely proportional to its damping or energy dissipation capacity. Thus, installing supplemental energy dissipating devices in the structure reduces the seismic demand and results in increased safety of the structure and its contents from the damaging effects of earthquakes. In recent years, considerable attention has been paid to research and development of structural control devices, with particular emphasis on improving wind and seismic response of buildings and bridges.

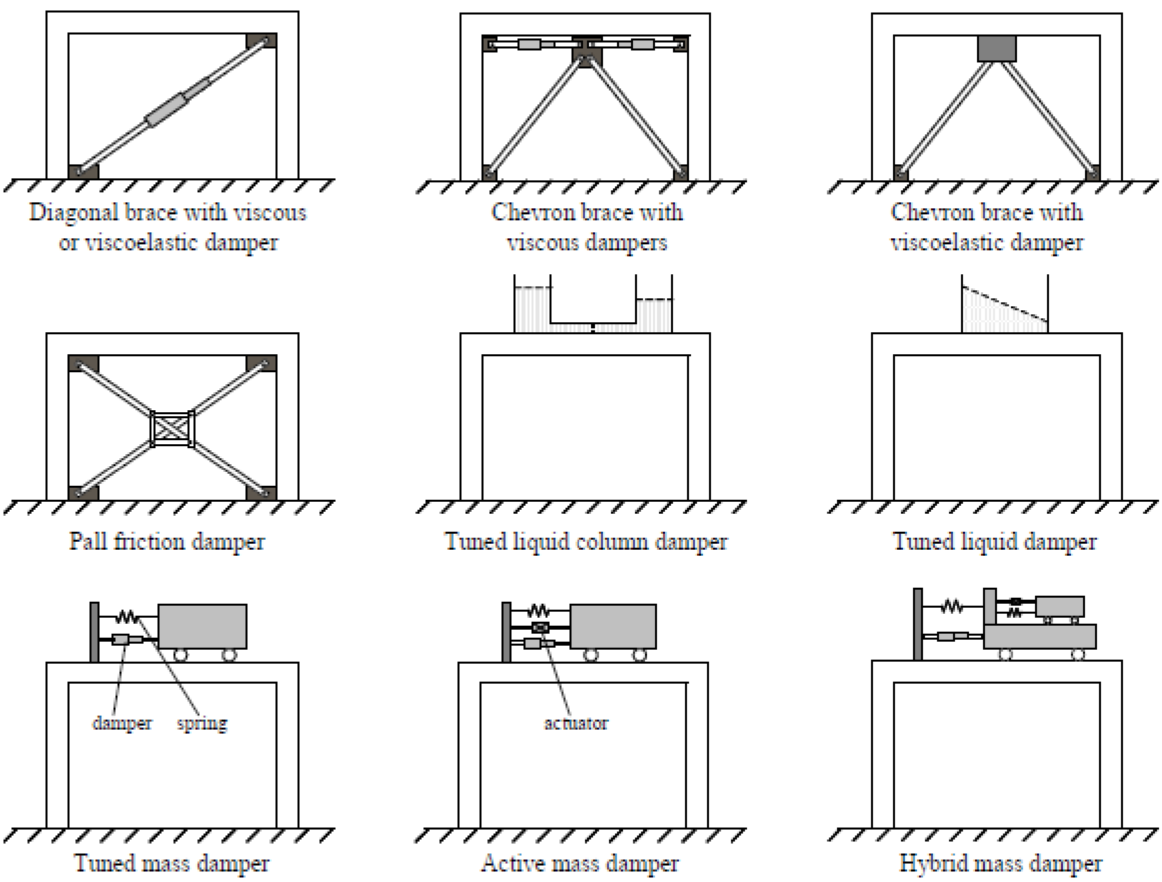


Fig. 7 Supplemental energy dissipation devices

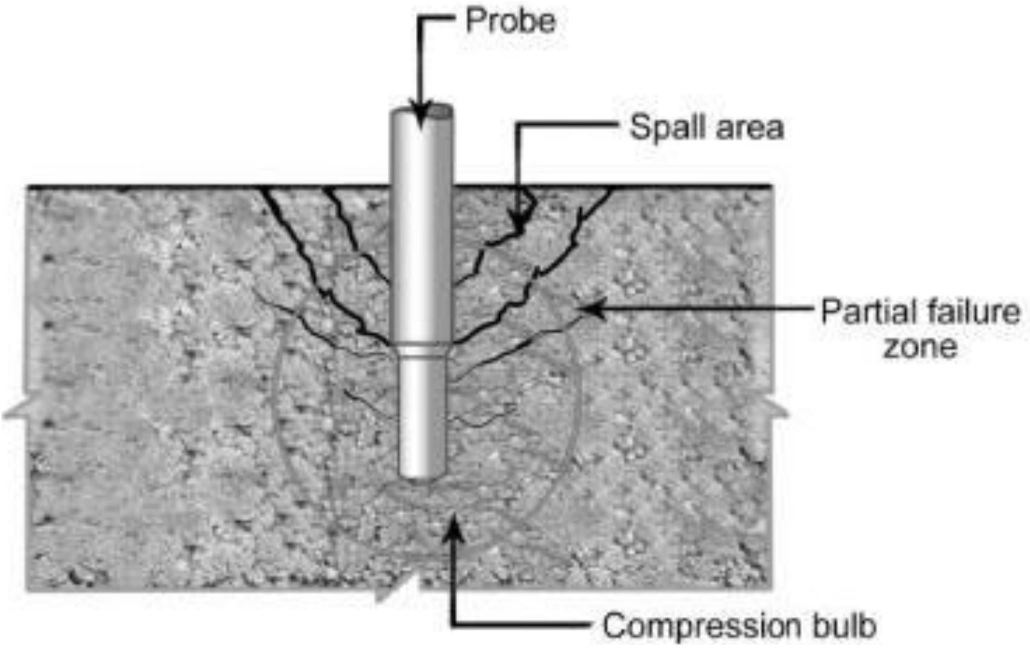
11.3 Destructive and non-destructive tests in buildings

DESTRUCTIVE TESTS

These are surface zone tests, which require access to one exposed concrete face and cause some localized damage. This damage is sufficiently small to cause no loss in structural performance. The strength of concrete is estimated with the help of correlation charts, which are sensitive to lesser number of parameters compared to the surface hardness and ultrasonic pulse velocity tests. Hence reliability of these tests is higher. The advantage compared to core test is that these are faster and less disruptive and damaging. Different tests in this category are based on penetration resistance, pull-out pull-off and break-off.

- *Penetration Resistance*

In penetration resistance testing, a specially designed bolt is fired into concrete with the help of a standardized explosive cartridge. A consistent correlation of the depth of the penetration with the strength of concrete has been found.



- Pull-out Testing

In pull-out testing, the force needed to pull a bolt or some similar device embedded into concrete is measured and correlated with the strength of concrete. This correlation has been shown to be unaffected by the mix characteristics and the curing history. The bolt may be inserted at the time of casting of the concrete or it may be epoxy grouted into a hole drilled into hardened concrete. The testing has high reliability and it is accepted by a number of public agencies in some countries as equivalent to cylinders for acceptance testing. The details of insert and failure zone are shown in Fig.18.

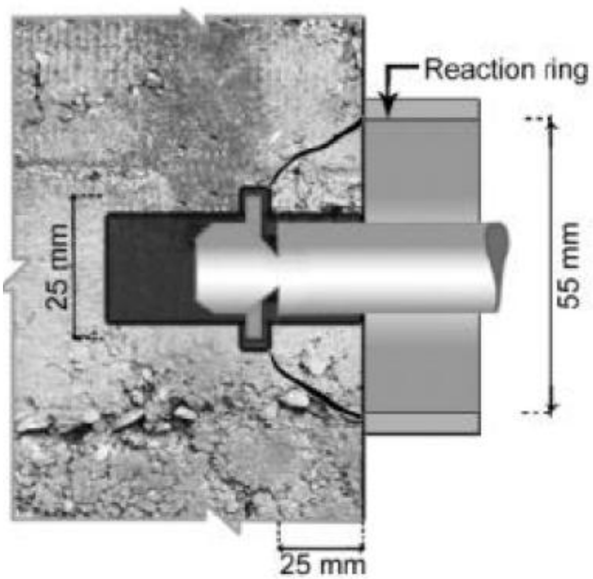


Fig.18:- (a) Pull – out test

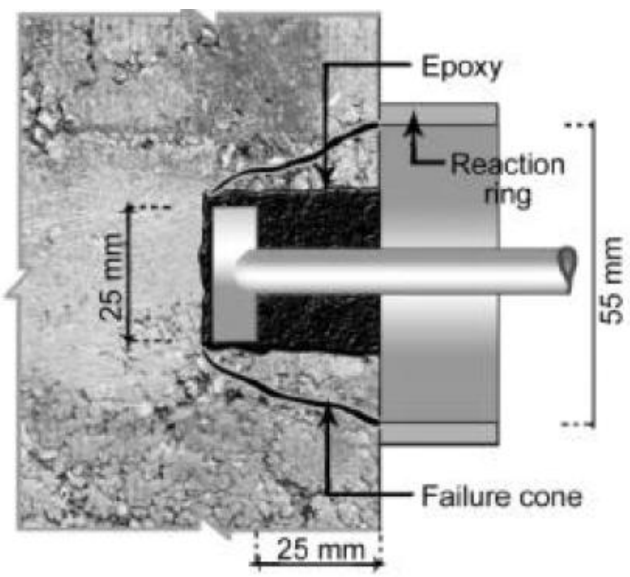
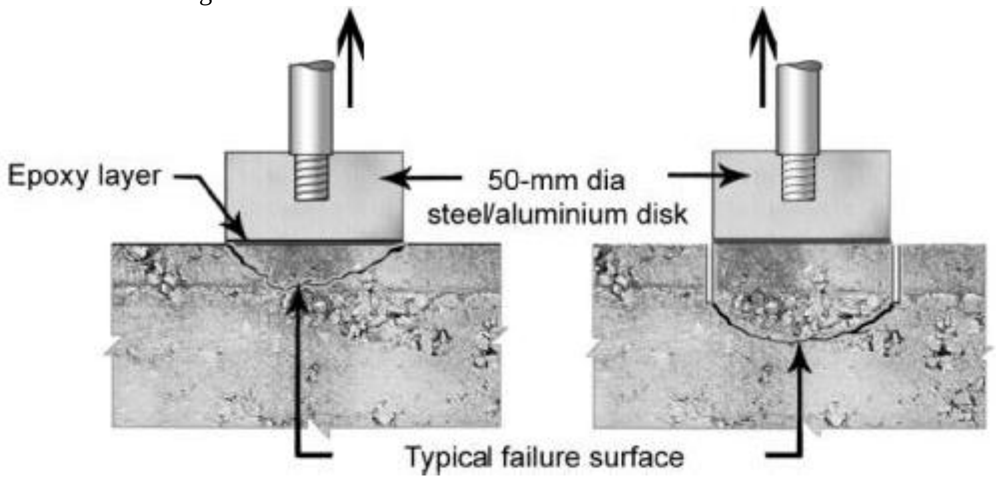


Fig. 18:- (b) CAPO test

- *Pull – off method*

The pull-off method is based on the measurement of in-situ tensile strength of concrete. The compressive strength of concrete is well known to be related with the tensile strength. Another application of the test is in testing of the bond between original and new concrete in repairs and strengthening. The details of the test are shown below. Two versions of the test are possible. In first case a metallic disk is glued directly to the surface of concrete and pulled off to measure the force necessary to pull a piece of concrete away from the surface. In the second case partial coring is done with a standard diameter of 75mm and the above procedure is repeated by gluing the disk at the top of the partial core. For assessing the bonding strength of the repairs with the original concrete, the depth of the partial coring should be below the surface of the original concrete.



Methods of non destructive tests (NDT):

These tests are based on indirect measurement of strength through measurement of surface hardness and dynamic modulus of elasticity. Calibration curves relating these properties with the strength of are available. For surface hardness rebound of an impact from the concrete surface is measured.
The most commonly adopted NDT methods for assessment of strength of concrete and their principles are given in the following:

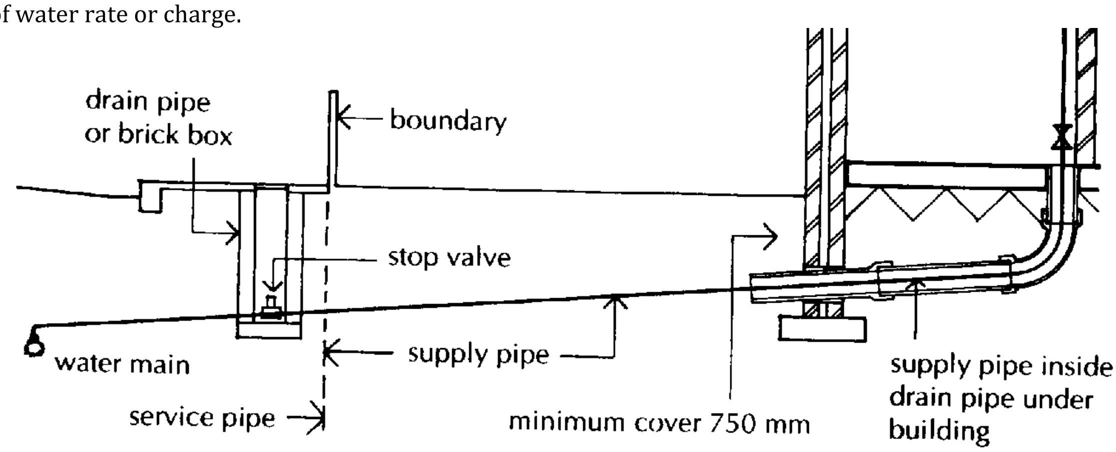
Table: NDT methods and principles

Rebound Hammer	Spring-driven mass strikes surface of concrete and rebound distance is given in R-values. Surface hardness is measured and strength estimated from calibration curves, keeping in the limitations.
Ultrasonic pulse velocity	It operated on principle that stress wave propagation velocity is affected by quality of concrete. Pulse waves are induced in materials and the time of arrival measured at the receiving surface with a receiver. Ultrasonic pulse velocity is influenced by elastic modulus and strength of concrete.
Penetration resistance	Probes are gun-driven into concrete, depth of penetration converted to estimates of concrete strength by using calibration curves.
Pull off testing	Circular steel probing is bonded to concrete. Tensile force is applied using portable mechanical system until concrete fails. Compressive strength can be estimated using calibration chart.
Core testing	Drilled cylindrical core is removed from structure, tests may be performed on core to determine compressive and tensile strength, Torsional properties, static modulus of elasticity, etc.

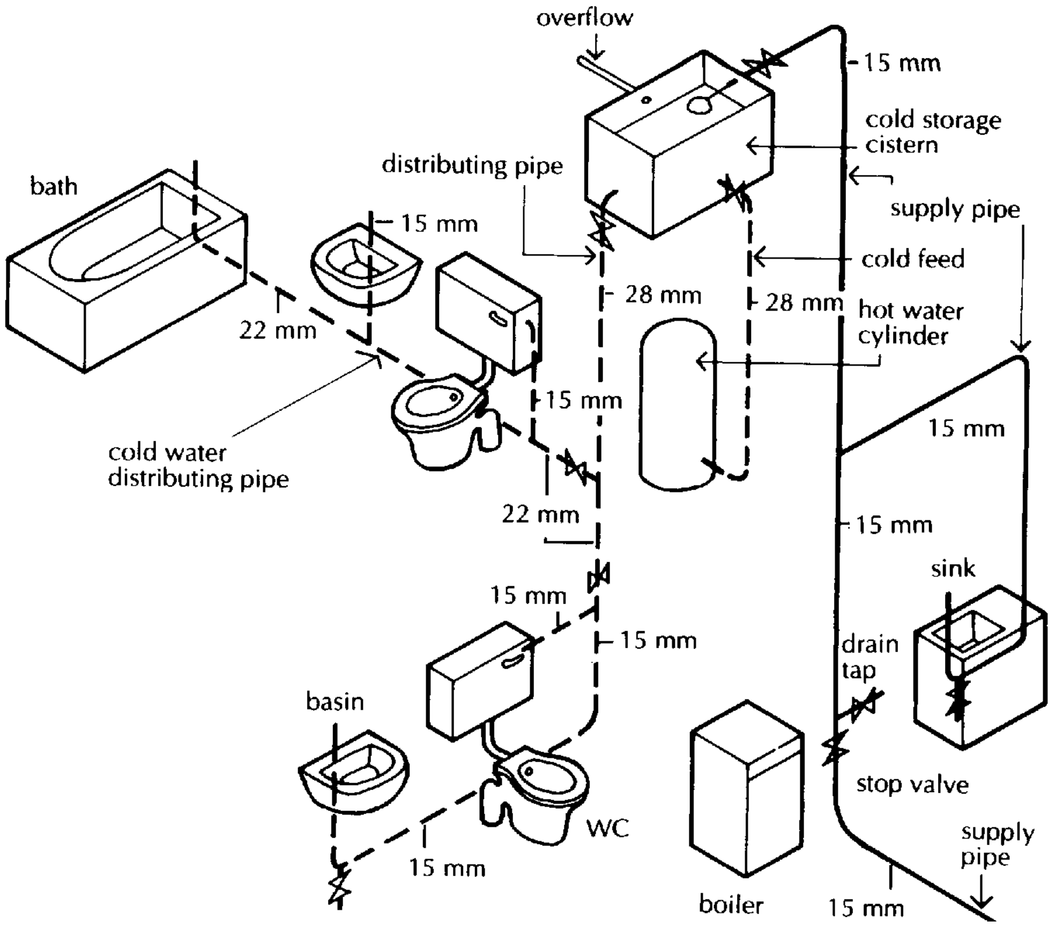
CHAPTER 12 Other services in building

12.1 Water supply & sanitation

The services like water supply, drainage, sanitation etc. are known as plumbing services.
Enough water to meet the needs of occupants must be available for all buildings. Further water needs for fire protection, heating; air conditioning, and possibly process use must also be met.
Water is supplied by the statutory water undertaker required to supply a constant, potable supply of water for which service cost is charged by units of consumption. Water is supplied, under pressure, through pipes laid under streets, roads or pavements.
Connections to the existing main are made by the water undertaker. The house or building service pipe connection is made to the main and the service pipe is run to a stop valve near to the site boundary of the building to be served. The stop valve is situated either immediately outside or inside the boundary. The purpose of the stop valve is to enable the water undertaker to disconnect the water supply where there is a waste of water in the building served, or nonpayment of water rate or charge.



The pipe that is run from the stop valve to and into the building is termed a supply pipe. For convenience it is usual to run the supply pipe into the building through drain pipes to facilitate renewal of the pipe if need be. At the point that the supply pipe enters the building there should be a stop valve to disconnect the supply for repair and maintenance purposes.



The intermittent supply of water necessitated the use of a water storage fixed at high level in each building to maintain a

constant supply of cold water, to allow for interruption in the supply.
A distribution pipe is any pipe (other than an overflow or flush pipe) that conveys water from a storage tank.

For residential buildings IS code recommends that a water requirement of 135 litres per head per day may be assumed. Out of this, 90 litres may be taken for domestic purposes while the balance 45 litrres are taken for flushing requirements.

Requirements in residential buildings	135 li/day/head
Requirements in other than residential buildings	
-Factories (with bath)	45 li/day/head
(without bath)	30 li/day/head
-Hospitals- (up to 100 beds)	340 li/day/bed
(More than 100 beds)	450 li/day/bed
-Nursing homes (with quarters)	135 li/day/head
-Students hostels	135 li/day/head
-Hotels (per bed)	180 li/day/bed
-Offices	45 li/day/head
-Restaurants	70 li/day/head
-Cinema hall (per seat)	15 li/day/seat
-School (day scholars)	45 li/day/head
(boardings)	135 li/day/head

House drainage

The arrangement provided in a house or building, for collecting and conveying waste water through drain pipes, by gravity, to join either a public sewer or a domestic septic tank, is termed as house drainage or building drainage.
House drainage is provided to:

- To maintain healthy conditions in the building
- To dispose of waste water as early and quickly as possible
- To avoid the entry of foul gases from sewer of septic tank
- To facilitate quick removal of foul matter
- To collect and remove waste matters systematically

Principles of house drainage

1. The lavatory block should be so located that the length of drainage line be minimum. In the case of multi-storeyed building they should be located one above the other. At least one wall of the lavatory block should be an outside wall, to facilitate the fixing of soil and vent pipe.
2. The drainage pipe should be laid by the side of building rather than below the building.
3. The slope of the drain should be sufficient to provide self cleansing velocity.
4. The size of the drain should be sufficient to handle the maximum discharge.
5. The drainage system should contain sufficient number of traps at suitable locations.
6. The house drainage should be disconnected from the public sewer by the provision of intercepting trap.
7. All the connections should be water tight.
8. The entire drainage system should be properly ventilated from the starting point to the final point of disposal.
9. All the materials and fittings should be non –absorbent type and resistant to corrosion.

<u>Pipes and traps used for drainage system:</u>

<u>Pipes</u>: soil pipes, waste pipes, vent pipe, rain water pipe, anti-siphoning pipe
<u>Traps:</u> a trap is a depressed pipe which, when provided in a drainage system, always remains full of water, thus maintaining water seal. It prevents the passage of foul air or gas through it, though it allows the sewage of waste water to flow through it.

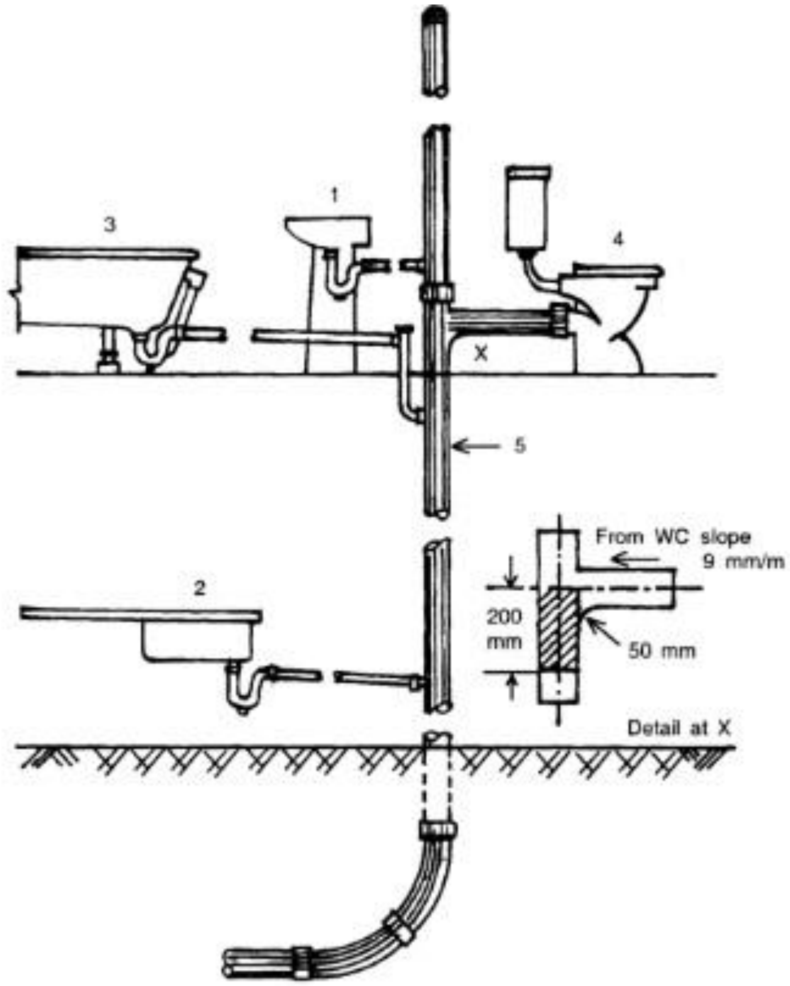
<u>For more detail on water supply system refer water supply engineering.</u>

<u>Sanitation</u>

Water discharged from waste appliances (such as washbasins, sinks, showers, etc.) is called waste water or grey water. The water discharged from soil appliances (such as water closets, urinals, etc) is called sewage. The wastewater from sewage is called foul water. The wastewater and foul water have to be collected safely and disposed of from the building. This system of collection and disposal is known as sanitation in a building. There are three types of sewerage system that can be designed to collect the foul water- combined system, partially separate system and separate system.

Combined system: in this system, all the foul water(waste and sewage) is carried away by the same drain.
Partially separate system: in this system, the whole of the sewage and a part of the waste water are carried off by the same system. The rest of the wastewater is carried off separately.
Separate system: in this system, the wastewater and the sewage are carried away separately. The wastewater is carried off and recycled or seeped into the ground. Sewage is to be drained to the sewer or to the septic tank.

The collection and disposal of foul water is treated in two ways- drainage above ground and drainage below ground level.



Single-stack drainage system without vent pipes: 1. Washbasin, 2. Kitchen sink, 3. Bath, 4. Watercloset, 5. Stack pipe.

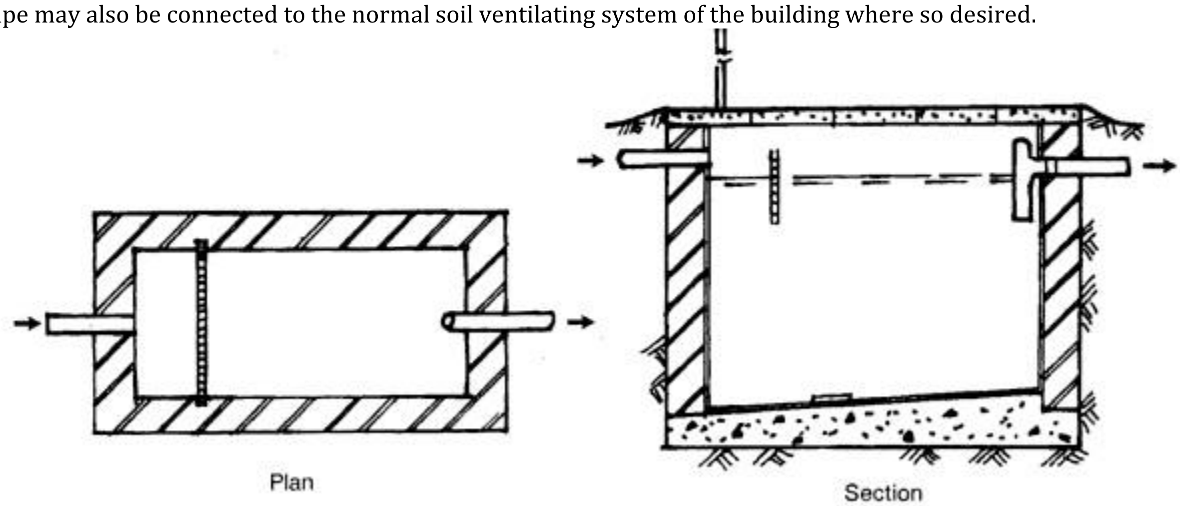
SEPTIC TANK

In un-sewered area, every house shall have arrangement for its sewage being treated in septic tank, effluent from which should be given secondary treatment either in a biological filter or on the land, or in a sub-surface disposal system.
Surface and sub-soil water should be excluded from finding way into the septic tank. Waste water may be passed into the septic tank provided the tank and the means for effluent disposal are designed to cope up with this extra liquid.
Depending on the location of the water table and the nature of the strata, the type of disposal for the effluent from the septic tank shall be decided.
Septic tanks shall have minimum width of 75 cm, minimum depth of one meter below water level and a minimum liquid capacity of the one cubic meter. Length of tanks shall be 2 to 4 times the width. Suitable sizes of septic tanks for use of 5, 10, 15, 20 and 50 persons based on certain assumptions are given in table.

No. of users	Length m	Breadth m	Liquid depth (Cleaning interval of) m	
			1 year	2 year
05	1.5	0.75	1.0	1.05
10	2.0	0.90	1.0	1.40
15	2.0	0.90	1.3	2.00
20	2.3	1.10	1.3	1.80

Note:
1. The capacities are recommended on the assumptions that discharge from only WC will be treated in the septic tank.
2. A provisions of 300 mm should be made for free board.
3. The sizes of septic tanks are based on certain assumptions, while choosing the size of septic tank exact calculation shall be made.

Every septic tank shall be provided with C.I. cover of adequate strength. The cover and frames shall be 500 mm dia (M.D.) minimum or 610 mm x 455 mm (LD). The specification for frames and cover given in 22.3.1 shall apply.
Every septic tank shall be provided with C.I. ventilating pipe of at least 50 mm diameter. The top of the pipe shall be provided with a suitable cage of mosquito proof wire mesh.
The ventilating pipe shall extend to a height which would cause no smell nuisance to any building in the area. Generally the ventilating pipe may extend to a height of about 2 m, when the septic tank is at least 15 m away from the nearest building and to a height of 2 m. above the top of the building when it is located closer than 15 metres. The ventilating pipe may also be connected to the normal soil ventilating system of the building where so desired.



(a) Simple type for a residence with two chambers

The sludge from septic tanks may be delivered into covered pit or into a suitable vehicle for removal from the site. Spreading of sludge on the ground in the vicinity shall not be allowed.

Before the tank is commissioned for use, it shall be tested for water-tightness by filling it with water and allowing it to stand for 24 hours. It shall then be topped up, if necessary, and allowed to stand for a further period of 24 hours during which time the fall in the level of the water shall not be more than 1.5 cm.

The tank shall be filled with water to its outlet level before the sewage is let into the tank. It shall, preferably, be seeded with small quantities of well digested sludge obtained from septic tanks or sludge digestion tanks. In the absence of digested sludge a small quantity of decaying organic matter, such as digested cow-dung, may be introduced.

The effluent from septic tank shall be disposed of by soak pit or dispersion trench depending on the position of the sub-soil water level, soil and sub- soil conditions and the size of the installation.

DESLUDGING OF SEPTIC TANKS
Septic tank shall be desludged periodically, the intervals of desludging, depending up to the design of the septic tanks and the capacity in relation to its users. Desludging may be done when the sludge level reaches a predetermined level. A portion of the sludge may be left in the tank to seed the fresh deposits.
De-sludging shall preferably be carried out by hydrostatic head or by using a portable pump. Manual handling of sludge shall be discouraged.

SOAK PITS 2.5 M DIA X 3 M DEEP

Construction

The earth excavation shall be carried out to the exact dimensions as shown in the figure. In the soak pit shall be constructed a honey-comb dry brick shaft 45 x 45 cm and 292.5 cm high. Round the shaft and within the radius of 60 cm shall be placed well burnt brick bats. Brick ballast of size from 50 to 80 mm nominal size shall be packed round the brick bats up to the radius of 90 cm. The remaining portion shall be filled with brick ballast of 40 mm nominal size. The construction of shaft and filling of the bats and the ballast shall progress simultaneously.

Cover and Drain

Over the filling shall be placed single matting which shall be covered with minimum layer of 7.5 cm earth. The shaft shall be covered with 7.5 cm thick stone or R.C.C. slab 10cm wide and 10 cm deep brick edging with bricks of class designation 40 shall be provided round the pit. The connection of the open surface drain to the soak pit shall be made by means of 100 mm diameter S.W. pipe with open joints.

DISPERSION TRENCH

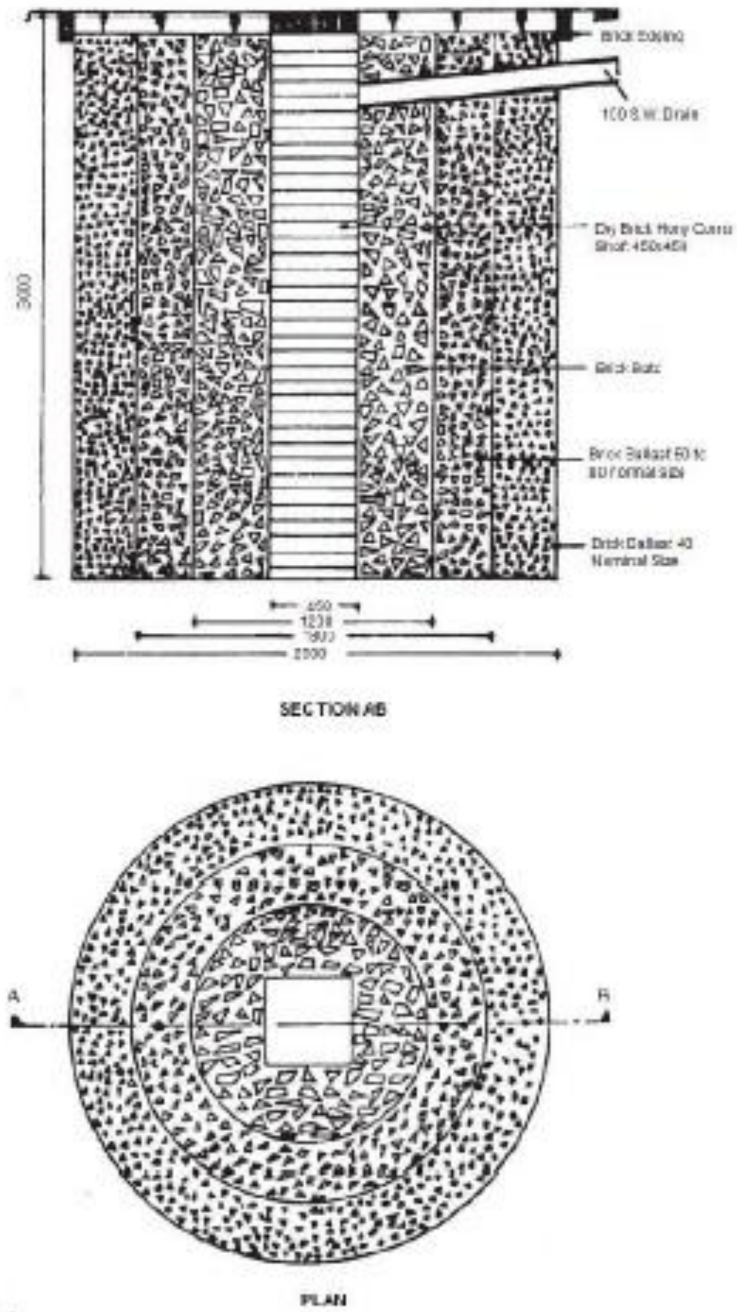
It shall be provided when the sub-soil water level is within 180 cm from the ground level. Dispersion trenches are not recommended in areas where fibrous roots of trees or vegetation are likely to penetrate the system and cause blockages.

Construction

Dispersion trenches shall be 50 to 100 cm deep and 30 to 100 cm wide, excavated to a slight gradient and shall be provided with 15 to 25 cm of washed gravel or crushed stones. Open jointed pipes placed inside the trench shall be made of unglazed earthenware clay or concrete and shall have minimum internal diameter of 75 to 100 mm. Each dispersion trench should not be longer than 30 m and trenches should not be placed closer than 1.8m.

The covering for the pipes on the top shall be with coarse aggregate of uniform size to a depth of approximately 15 cm. The aggregate above this level may be graded with aggregates 12 to 15 mm to prevent ingress of top soil while the free flow of water is no way retarded. The trench may be covered with about 30 cm of ordinary soil to form a mound and turned over. The finished top surface may be kept at least 15 cm above ground level to prevent direct flooding of the trench during rains.

SOAK PIT



12.2 Electrification, CCTV and Telephone network

In Nepal, electricity is generated in generating stations as alternating current at 50cycles per second. It is transmitted to the high voltage national grids by 132 KV high voltage lines to reduce the transmission losses. This electricity is stepped down at electric substations to 11kV, 3 phase, 50hz, which is considered economical for local transmission. This supply voltage is further reduced to 230volts between phase and neutral and 400 volts between phases. The supply agency (NEA) is responsible for the cables upto and including the electric meter. A system of fuse of 5, 16, 30, 100 amp capacity is installed between the supply inlet and the electric meter board by the supply agency to isolate the main supply from the building. From the fuses, the wires are led to the meter and from there, to the consumer unit, from where, the electricity is distributed to the various parts of the building. The owner of the building is responsible for the wiring from the meter to the distribution board and the other parts of the building.

For distribution of electricity from the consumer control unit to other points in an ordinary building, the supply is divided into the following types of circuits:

1. Lighting circuit of low capacity- 6amp
2. Power circuit through ring circuit
3. Fixed appliance circuits.

Generally, red wires are used for the live wire and fuse is placed in live wire. The neutral is black or blue and earthing is green or stripped green and yellow.

<u>Consideration for home lighting:</u>
The major three factors to be considered in lighting are nature of work, age of the person and the distance between the light source and the person using it.

- Living and dining rooms: we combine light fittings which provide good strong light (for reading, sewing, etc.) with decorative light fittings such as floor standing or table lamps. A one needs fairly good lighting over the dining table, we use single or multiple pendent(which should be able to take at least a 100 w lamp) directly over the table.
- Bedrooms: the lights should be so positioned that we will not be looking at the glaring light when lying in bed. This is particularly important as we may have to swish the light on suddenly in the middle of the night in the room where more than one person may be sleeping and ht switching on should be not disturb others. So one strong and another weak light will be ideal.
- Kitchen: it should be remembered that kitchen is normally a hot place and hence, cool lighting is the best.
- Bathroom: here the lighting should be of uniform level throught.

GENERAL PRECAUTIONS WHILE USING ELECTRICITY:

- No live naked wire should be touched
- No touch to man coming in contact with live naked wire before switch off
- Attempt to be made to detach live wire from man by means of dry timber stick (bad conductor)
- Safety belt must be used while working on the pole
- No touch to live electric gazette
- Strong cable insulator
- No touch to overhead line
- Switch off before changing fuse
- No live wire to be touched to earth
- Earthing must be made for all electrical equipments
- Live wires always connected to switches

<u>CCTV</u>
Closed Circuit Television Cameras (CCTV) have become important crime prevention and security measure in modern life. They are situational measures that enable a locale to be kept under surveillance remotely. In many parts of the world CCTV coverage is found in both public and private buildings such as hospitals, colleges, buses, homes and on the streets.
Closed-circuit television (CCTV) is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. It differs from broadcast television in that the signal is not openly transmitted, though it may employ point to point (P2P), point to multipoint, or mesh

wireless links. Though almost all video cameras fit this definition, the term is most often applied to those used for surveillance in areas that may need monitoring such as banks, casinos, airports, military installations, and convenience stores.

In industrial plants, CCTV equipment may be used to observe parts of a process from a central control room, for example when the environment is not suitable for humans. CCTV systems may operate continuously or only as required to monitor a particular event. A more advanced form of CCTV, utilizing digital video recorders (DVRs), provides recording for possibly many years, with a variety of quality and performance options and extra features (such as motion-detection and email alerts). More recently, decentralized IP-based CCTV cameras, some equipped with megapixel sensors, support recording directly to network-attached storage devices, or internal flash for completely stand-alone operation. Surveillance of the public using CCTV is particularly common in many areas around the world including the United Kingdom, where there are reportedly more cameras per person than in any other country in the world.[3] There and elsewhere, its increasing use has triggered a debate about security versus privacy.

Uses of cctv:

- Prevention of crime
- Video surveillance system
- Traffic police to monitor traffic

<u>Telephone network</u>

A telephone network is a telecommunications network used for telephone calls between two or more parties.

There are a number of different types of telephone network:

- A fixed line network where the telephones must be directly wired into a single telephone exchange. This is known as the public switched telephone network or PSTN. The Public Switched Telephone Network (PSTN), also known as **Plain Old Telephone Service (POTS)**, is the wired phone system over which landline telephone calls are made. The PSTN relies on **circuit switching**. To connect one phone to another, the phone call is routed through numerous switches operating on a local, regional, national or international level. The connection established between the two phones is called a **circuit**.
- A wireless network where the telephones are mobile and can move around anywhere within the coverage area.
- A private network where a closed group of telephones are connected primarily to each other and use a gateway to reach the outside world.

Public telephone operators (PTOs) own and build networks of the first two types and provide services to the public under license from the national government. Virtual Network Operators (VNOs) lease capacity wholesale from the PTOs and sell on telephony service to the public directly.

<u>Fire Protection</u>

A building may be made more fire resistant by minimizing use of combustible materials, protecting steel by fire resistant paints and providing stairs at suitable positions and protecting them from fire.

Various members of buildings can be made fire resistant as follows:
Walls: A Brick wall with cement plaster gives better fire resistance.
Roof: R.C.C. flat roofs have good fire resistance. Hence they should be preferred.
Ceiling: Ceilings should be made up of cement plaster, asbestos cement board or fibre boards.
Floors: R.C.C. floor is very good fire resisting floor.
Doors and Window Openings: All these openings should be protected against fire by taking the following precautions:
(a) The thickness of shutters should not be less than 40 mm.
(b) Instead of wooden, aluminium or steel shutters should be preferred.
(c) They should be provided with fire proof paints.
Stairs: Wood should be avoided in the stair cases. To minimize fire hazard, stairs should be centrally placed in the buildings so that people can approach them quickly. More than one stair case is always preferable. Emergency ladder should be provided in the building.
Structural Design: It should be such that under worst situation, even if part of the structure collapses, it should be localised and alternate routes are available for escape.

Fire Alarm System and Fire Extinguishers: All important buildings should be provided with fire alarm system. Alarm may be manual or automatic. Automatic alarm senses the smoke and activates bells.

Fire extinguishers should be provided at all strategic points in the buildings. The common fire extinguishers are as follows:
(a) Manual: Carbon dioxide type portable fire extinguishers are commonly used. Sometimes buckets of water, sand and asbestos blankets are kept ready at all possible places where fire is likely to catch.
(b) Internal Hydrant: The hydrant should be located in and around the buildings so that water is available easily for fire fighting.
(c) Automatic Water Sprinkler: In the buildings vulnerable for fire like textile mills, paper mills automatic water sprinklers are installed. As the fire takes place the sprinkling of water is automatically activated from the piping system containing water under pressure.

According to NBC107 some of the precautions are as follows:

- All buildings having a kitchen should be provided with a fireplace and a chimney in order to reduce the possibilities of the occurrence of accidental fire. Open hearths should be discouraged and eliminated wherever possible. Timber construction should not be placed near the fire place, nor should it remain exposed in the vicinity of fire. Such surfaces should remain encased by plaster, whether of mud or other binders, suitable for the purpose.

- Occupants are encouraged to install appropriate portable fire extinguishers in their building.
- Where open hearth or kerosene stoves are used for cooking, sufficient water should be stored in containers for emergency use in case of fire.
- **Provision of a Proper Access**: Every building should have an access as defined by Architectural Design Requirements (NBC 206) and should be wide enough to enable the fireman to easily approach to the building site.
- **Provision of Wide Doors**: The entry door shall be as defined by Architectural Design Requirements (NBC 206) and should be sufficiently wide and tall so that easy access in available to the fire man.
- **Provision of Fire Escape Ways**: All buildings should have sufficient ways as defined by Architectural Design Requirements (NBC 206) so as to allow the rapid evacuation of all occupants in the event of fire, if any. In addition to the main entrance, the side and/or rear entrance shall be incorporated in the design.
- **Provision of Open Space**: The front entrance should have enough open space as defined by Architectural Design Requirements (NBC 206) so that a number of people can gather and contribute in extinguishing the fire, if any.

Stairs

- The number of stairs in any building, especially when it exceeds 500 square metres in plinth area, shall be a minimum of two, one internal and the other an external fire escape. Additional stairs shall be provided in proportion to any increase in the plinth area.
- In the case of residential buildings, the minimum width of the stairs shall be 90 cm. For other buildings, the minimum width shall be 1.5 m. The distance from any point in a passageway to a staircase in a building shall not exceed 20 metres.

Fire Escapes

- Every building more than five storeys high shall have a separate fire escape having a minimum width of 75 cm. The fire escape shall have a minimum tread width of 20 cm and each riser shall be not more than 19 cm high. The number of risers per flight shall not be more than 15. Such a fire escape shall carry users towards an open space.

Exit Doors

- Exit doors shall open to a passageway or to a corridor.
- They should open outwards, but without restricting the movement of people passing outside the door.
- The maximum distance of such an exit doorway from any point in a passage shall be 20 m.
- The exit doorway shall neither be smaller than 90 cm in width, nor 180 cm in height.

The following factors are adopted in order to limit fire spread in homes:
1.Fire fighting equipment
2.Materials of construction
3.Means of escape
4.Protection of openings
5.Subdivision

- Fire fighting equipment:

The suitable equipments for detecting, extinguishing, and warning of fire should be placed in the buildings. These equipments should be located at such places that they are easily accessible.

- Materials of construction:

The structural and non structural elements of the buildings such as floors, partitions, roofs, walls, doors , windows etc should be constructed of fire resisting materials.

- Means of escape:

Suitable means of escape should be provided when fire occurs in the buildings. The means of escape are mainly considered in the designs of cinemas, theatres, town halls, factories, etc.

- Protection of openings:

The openings should be sufficiently protected by using fire resistant doors and windows to limit the fire.The area of the openings should not be excessive.

- Subdivision:

It is desirable to subdivide large buildings into small compartments to reduce the chances of spreading the fire into the whole building. In case of industrial buildings, high risk areas should be isolated from others

Rainwater harvesting

To supplement the ever growing shortage of protected, Pure and safe water supply for human consumption rainwater is an ideal source which can be conserved and used in a useful manner by the people. The amount of rainfall available varies from region to region. Each area has to develop its own method and system to conserve, store and use it to suit its requirement and local conditions. There are several methods by which rain after can be stored, used and conserved. Each system depends on the amount of precipitation, the period in which the rainfall occurs in year and the physical infrastructure for example, space available to store the water, etc.

From where to harvest rain:-

Rain water harvesting can be harvested from the following surfaces:

(A) Rooftops: If building with impervious roofs is already in place, the catchment area is effectively available free of charge and they provide a supply at the point of consumption.

(B) Paved and unpaved areas i.e., landscapes, open field, parks, storm-water drains, roads and pavement and other open areas can be effectively used to harvest the run off. The main advantage in using ground as collection surface is that water can be collected from a larger area. This is advantageous in area of low rainfall.

(C) Water bodies: - the potential lakes, tanks and ponds to store rainwater are immense. The harvested rainwater can not only be used to meet water requirement of the city, it also recharges ground water aquifers.

(D) Strom-water drains: Most of the residential colonies have proper network of storm-water drains. If maintained neatly, these offer a simple and cost effective means for harvesting rainwater.

COMPONENT OF A RAINWATER HARVESTING SYSTEM

A rainwater harvesting system comprises components of various stages- transporting rainwater through pipes or drains, filtration, and storage in tanks for reuse or recharge. The common components of rainwater harvesting system involved in these stages are illustrated here.

1) Catchments: The catchments of a water harvesting system are the surface which directly receives the rainfall and provides water to the system. It can be a paved area like a terrace or court yard of building, or an unpaved area like a lawn or open ground. A roof made of reinforced cement concrete (RCC), galvanized iron or corrugated sheet can also be used for water harvesting.

2) Coarse mesh at the roof to prevent the passage of debris.

3) Gutters:

Channel all around the edge of a sloping roof to collect and transport rainwater to the storage tank. The size of gutter should be according to the flow during the highest intensity rain. It is advisable to make them 10 to 15 percent oversize. Gutters need to be supported so they do not sag or fall off when loaded with water. The way in which gutters are fixed depend on the construction of the house it is possible to fix iron or timber bracket into the wall, but for houses having wider eaves, some method of attachment to the rafters is necessary.

4. Conduits

Conduits are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Conduits can be of any material like polyvinyl chloride (PVC) or galvanized iron (GI) material that are commonly available.

5. First flushing

A first flush device is a valve that ensures that runoff from the first spell of rain is flushed out and does not enter the system. This need to be done since the first spell of rain carries a relatively larger amount of pollutants from the air and catchment surface.

6. Storage facility

There are various options available for the construction of storage tanks with respect to the shape, size and the material of construction.

Shape: cylindrical, rectangular and square.

7. Recharge structures

Rainwater may be charged into the ground water aquifers through any suitable structure like dug wells, bore-wells, recharge trenches and recharge pits.

Various recharge structures are possible – some which promote the percolation of water through soil strata at shallower depth (e.g. recharge trenchers, permeable pavements) where other conduct water to greater depths from where it joins the groundwater(e.g. recharge wells). At many locations, existing structure like well, pits and tanks can be modified as recharge structure, eliminating the need to construct any structures afresh.

There are two board approaches to harvesting water:-
(a) Storing rainwater for direct use
(b) Recharging groundwater aquifers

Rainwater harvesting method for urban areas:-
(a) Recharge pit
(b) Recharge Trench
(c) Tube well
(d) Recharge Well

Care to taken in rain water harvesting
Water conservation technique discussed above shall be constructed with due care taking following precautions:
1. No sewage or waste water should be admitted into the system.
2. No waste water from areas likely to have oil, grease or other pollutants should be connected to the system.
3. Each structure / well shall have an inlet chamber with a silt trap to prevent any silt from finding its way into the sub soil water.
4. The well should be terminated at least 5 m above the natural static sub soil water at its highest level so that the incoming flow passes thorough the natural ground condition and prevents contamination hazards.
5. No recharges structure or a well shall be used for drawing water for any purpose.

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