CONSTRUCTION MATERIALS & MANAGEMENT

CONSTRUCTION MATERIALS

Structural Steel

In order to reduce the work involved in design computations, and to facilitate the use of the Indian Standard Code of Practice for Use of Structural Steel in General Building Construction [IS: 800-2007 (Revised)], it is proposed to make available a number of design handbooks showing typical designs of different types of structures.

Structural steel can be in the form of rolled steel, beam, channel and angle sections, metal strip, sheet, bars (round and square), flats and plate, tee bars, bulb angles. A no. of design codes are available according to the shape of the structural steel member.

Composition of Structural Steel

Steel is an alloy of Iron, Carbon, Chromium, Nickel and many other elements.

Following is a list of some important chemical elements used in structural steels:

Carbon (C) : It is the most important chemical element in steel. If the carbon content in the alloy is increased to a certain level then strength increases but ductility decreases. So, Structural steels, should have carbon contents between 0.15 to 0.30%; if the carbon content goes much higher, the ductility will be too low, and for magnitudes less than 0.15% the strength will not be satisfactory.

Manganese (Mn) : Manganese has a percentage ranging from about 0.50 to 1.70%. It has effects similar to those of carbon, and the steel producer uses these two elements in combination to obtain a material with the desired properties. Manganese is a necessity for the process of hot rolling of steel by its combination with oxygen and sulfur.

Aluminium (Al) : Aluminium is used as a deoxidizer in the material, and also helps to form a more fine-grained crystalline microstructure.

Chromium (Cr) : It is primarily used to increase the corrosion resistance of the material, and for that reason often occurs in combination with nickel and copper. Stainless steel contains 18% of nickel and 8% of chromium.

Copper (Cu) : Copper is another primary corrosion resistance elements. It is typically found in amounts not less than 0.20%, and is the primary anti-corrosion component in steel grades.

Molybdenum (Mo) : It increases the strength of the steel at higher temperatures and also improves corrosion resistance. Molybdenum has effects similar to manganese and vanadium, and is often used in combination with one or the other.

Nickel (Ni) : It enhances the corrosion resistance of steel, and also the low-temperature behavior of the material by improving the fracture toughness.

Silicon (Si) : Along with aluminum, silicon is one of the principal deoxidizers for structural steel. It normally appears in amounts less than 0.40%.

Material Properties

Properties of the steel depends upon its chemical composition, method of manufacture and process of fabrication. Some important properties of steel which are desired for its use as a structural material are :

(1) **Strength :** Tensile strength increases with increased hardness of the material.

(2) **Toughness :** It is the resistance to the impact loading against fracture. It is in the nature of all materials to contain some imperfections. In steel these imperfections take the form of very small cracks. If the steel is insufficiently tough, the 'crack' can propagate rapidly, without plastic deformation and result in a 'brittle fracture'. The risk of brittle fracture increases with thickness, tensile stress, stress raisers and at colder temperatures. The toughness of steel and its ability to resist brittle fracture are dependent on a number of factors that should be considered at the specification stage.

(3) **Ductility :** It is a measure of the degree to which a material can be strained or elongated between yield point to the fracture point under the effect of tensile loading. With the increase in carbon content of the steel, its strength increases but ductility decreases. Ductility is measured in tension tests by percent elongation over a given gauge length usually 2 or 8% reduction of cross-sectional area. Ductility is an important property because it permits redistribution of stresses in continuous members and at points of high local stresses.

(4) **Durability :** The ability to withstand wear and tear through weathering and corrosive attack etc. is referred as durability of steel. The increased distortion of planes and structure decreases the corrosion resistance of the material.

Behavior of Structural Steel

Structural steel has different behavior under different conditions. If the material is subjected to compression like in columns, it behaves differently as compared to its behavior under tensile stresses.

Steel columns are slender because of high strength of the material. As the compressive stress is gradually increased, a value is reached at which the column, instead of just axially shortening in length, buckles and deforms perpendicular to its axis. This value of load is called the buckling load. When a column reaches the buckling load, it has effectively failed as a structural element and is incapable of sustaining the load.

The structural steel, when used as a beam element, is represented by internal forces called bending moments and shear forces. The behavior is characterized by the magnitude and distribution of these forces. At any point in the beam, the internal shear force and the internal bending moment can be represented as pairs of forces.

Concrete

Constituents

Concrete a composite man-made material, is the most widely used material in the construction industry. It consists of a rationally chosen mixture of binding material such as lime or cement, well graded fine and coarse aggregates, water and admixtures (to produce concrete with special properties). In a concrete mix, cement and water form a paste or matrix which in addition to filling the voids of the fine aggregate, coats the surface of fine and coarse aggregates and binds them together. Freshly mixed concrete before set is known as wet or **green concrete** whereas after setting and hardening it is known as set or **hardened concrete**. The moulded concrete mix after sufficient curing becomes hard like stone due to chemical action between the water and binding material.

Constituents : A good quality concrete is essentially a homogeneous mixture of cement, coarse and fine aggregates and water which consolidates into a hard mass due to chemical action between the cement and water. Each of the four constituents has a specific function. The coarser aggregate acts as a filler. The fine aggregate fills up the voids between the paste and the coarse aggregate. The cement in conjunction with water acts as a binder. The mobility of the mixture is aided by the cement paste, fines and nowadays, increasingly by the use of admixtures.

Water-cement ratio : The water-cement ratio (w/c) is one of the major factors but not the only one influencing the strength of concrete. It is responsible mainly for the porosity of the hardened cement paste. Water-cement ratio is the water used to the quantum of cement in the mixture by weight. For proper workability the w/c ratio varies from 0.4-0.6. However, maximum strength is derived at w/c = 0.4 at which minimum capillary cavities are expected to form. It may be noted that for complete hydration of cement under controlled conditions the water requirement is about 38 per cent.

Concrete Mix Design : Conventional nominal mix proportioning (1:1:2; 1:2:4; 1:3:6, etc.) have limited significance as these are with little consideration for the materials that will be used. Since the quantity of fine aggregate is fixed irrespective of the cement and the maximum size of aggregate, considerable variations in quality are obtained by this method. Therefore, nominal mix proportions, arbitrarily fixed, have little use in concrete mix design. Another reason for increased use of the design mix concept is that the water-cement ratio is not specified for nominal mixes, and has to be kept as low as possible provided that the mix is fully compacted concrete.

Mix design should ensure that the concrete :

I. complies with the specifications of structural strength laid down, which is usually stated in terms of the compressive strength of standard test specimens.
II. fulfills the durability requirements to resist the environment in which the structure will serve throughout its functional life.
III. has capability of being efficiently mixed, transported and compacted.

Concrete mix proportions can be expressed in terms of volume or weight. The present trend is towards specifying mixes in terms of minimum strength requirements, rather than by volume proportions. For example, M 20 design mix should have a characteristic strength of 20 N/mm^2, M 25 mix shall have a characteristic strength of 25 N/mm^2, etc.

The Principles of Proportioning

The fundamental object in proportioning concrete or mortar mixes is the production of a durable material of requisite strength, watertightness, and other essential properties at minimum cost. To achieve these objectives, careful attention must be given to the selection of cement, aggregate, and water to the following considerations :

I. The mix must be workable so that it can be placed and finished without undue labour.

II. Since cement is the most costly ingredient in the mix, the proportion used should be as small as is consistent with the attainment of desired properties.

Before the engineer can begin to design a concrete mix the following information from the site of work is required :

I. Grade of concrete : The grade M 20, M 25 connotes characteristic strength, f_{ck} of 20 N/mm^2, 25 N/mm^2, respectively, and standard deviation based on the degree of control to be exercised on site.

II. Type of cement : The grade of Ordinary Portland Cement (OPC) such as 33, 43, or 53 grade. Portland Pozzolana Cement (PPC) to relevant IS specifications.

III. Type and size of aggregate : Natural sand, crushed stone, gravel etc. conforming to IS:383-1970, quoting the source of supply.

IV. Nominal maximum size aggregate (MSA) : 40 mm, 20 mm, 10 mm, as per IS:383-1970.

V. Maximum/minimum cement content (kg/m^3): This is required for durability/considerations.

VI. Type of mixing and curing water: Whether fresh potable water, seawater, ground water is to be used.

VII. Maximum free water-cement ratio by weight : This is required for considerations of strength and/or durability for different exposures and to meet appearance and other requirements.

VIII. Degree of workability of concrete : This is dependent on placing and compaction conditions.

IX. Air content : This is inclusive of entrained air.

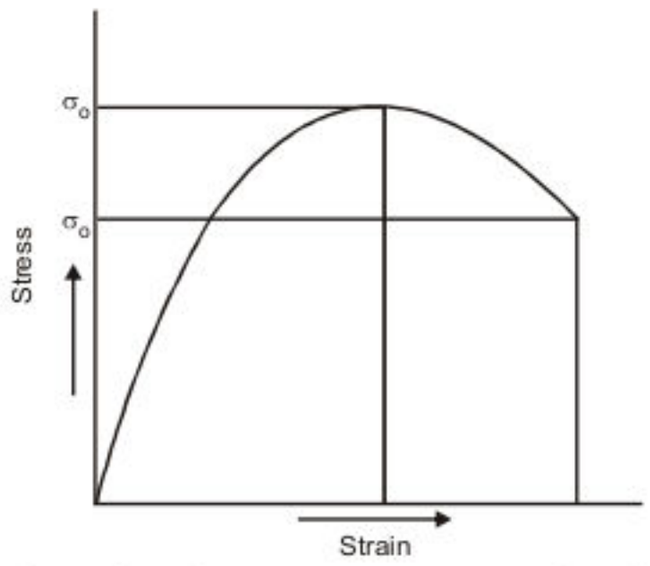
X. Type of admixture used.

XI. Maximum/ minimum density of concrete.

XII. Maximum/minimum temperature of fresh concrete.

Short-term and Long-term Properties of Concrete

1. **Stress Strain Curve of Concrete :** The true elastic curve for concrete in compression can be plotted by applying and releasing load until the set at zero loads becomes constant. By subtracting the set from the total deformation the elastic deformation for a given load is determined. Since mortar and concrete have no elastic limit, the modulus of elasticity for concrete must be the slope of the stress deformation curve at zero stress.



The elastic modulus of concrete in compression, $E_c = 5000\, f_{ck}$, where f_{ck} is the characteristic strength of concrete. The elastic modulus of concrete varies from 14×10^3 to 40×10^3 N/mm^2. Its value increases with the density and to some extent with age.

2. **Poisson's Ratio :** Under unit compression the unit lateral expansion of concrete is about 1/6th to 1/12th of the unit strain in the direction of the applied forces for the ordinary range of working stress. The ratio increases with the richness of the mix. The value of Poisson's ratio varies between 0.15 to 0.20 for normal concrete.

3. **Creep :** The continued deformation with time under applied load is creep. It may be defined as increase of strain in concrete with time under sustained stress. This is also known *as plastic flow or time yield*. The rate of creep decrease with time and the creep strains at five years are taken as terminal values. Creep increases rapidly with the stress, loading at an early age of concrete, broken ballast, soft and porous aggregate, poorly graded and improperly compacted concrete. Creep may be due to closer of internal voids, viscous flow of the cement paste and flow of water out of the cement gel. In reinforced concrete structures it is of advantage since it causes better distribution of stresses.

4. **Shrinkage :** Contraction of concrete in the absence of load is known as shrinkage. It may be plastic shrinkage-shrinkage of concrete due to absorption of water by aggregates, evaporation of water and bleeding, or drying shrinkage-the shrinkage taking place after the concrete has set and hardened. Shrinkage of concrete increases with high w/c ratio and high cement content. Shrinkage can be estimated by using Schorer's formula : $\varepsilon_s = 0.00125(0.90 - h)$

where ε_s = shrinkage strain and h is relative humidity expressed as a fraction.

The rate of shrinkage decreases with time.

Bricks and Mortar

Clay bricks are used for building-up exterior and interior walls, partitions, piers, footings and other load bearing structures. A brick is rectangular in shape and of size that can be conveniently handled with one hand. Brick may be made of burnt clay or mixture of sand and lime or of Portland cement concrete. Clay bricks are commonly used since these are economical and easily available. The length, width and height of a brick are interrelated as below :

- Length of brick = 2 × width of brick + thickness of mortar
- Height of brick = width of brick
- Size of a standard brick (also known as modular brick) should be 19 × 9 × 9 cm and 19 × 9 × 4 cm.
- When placed in masonry the 19 × 9 × 9 cm brick with mortar becomes 20 × 10 × 10 cm.

An indent called frog, 1-2 cm deep, is provided for 9 cm high bricks. The size of frog should be 10 × 4 × 1 cm. The purpose of providing frog is to form a key for holding the mortar and therefore, the bricks are laid with frogs on top. Frog is not provided in 4 cm high bricks and extruded bricks.

Classification of Bricks

Clay bricks are classified as first class, second class, third class and fourth class based on their physical and mechanical properties.

S.No.	First Class Bricks	Second Class Bricks	Third Class Bricks
1.	These are thoroughly burnt and are of deep red, cherry or copper colour.		
2.	The surface should be smooth and rectangular, with parallel, sharp and straight edges and square corners.		
3.	These should be free from flaws, cracks and stones.	Small cracks and distortions are permitted.	
4.	These should have uniform texture		These are light-colored.
5.	No impression should be left on the brick when a scratch is made by a finger nail.		These are soft.
6.	The fractured surface of the brick should not show lumps of lime.		
7.	A metallic or ringing sound should come when two bricks are struck against each other.		They produce a dull sound when struck against each other.
8.	Water absorption should be 12-15% of its dry weight when immersed in cold water for 24 hours.	A little higher water absorption of about 16-20% of its dry weight is allowed.	Water absorption is about 25% of dry weight.
9.	The crushing strength of the brick should not be less than 10 N/mm^2.	The crushing strength should not be less than 7.0 N/mm^2.	
10.	These are recommended for pointing, exposed face work in masonry structures, flooring and reinforced brick work.	These are recommended for all important or unimportant hidden masonry works and centering of reinforced brick and RCC structures.	These are used for building temporary structures.

Characteristics of Good Brick

The essential requirements for building bricks are sufficient strength in crushing, regularity in size, a proper suction rate, and a pleasing appearance when exposed to view.

1. The bricks should have uniform size and plane, rectangular surfaces with parallel sides and sharp straight edges.
2. The brick should have a uniform deep red or cherry colour as indicative of uniformity in chemical composition and thoroughness in the burning of the brick.
3. The surfaces should not be too smooth to cause slipping of mortar.
4. The brick should have precompact and uniform texture. A fractured surface should not show fissures, holes grits or lumps of lime.
5. The brick should be so hard that when scratched by a finger nail, no impression is made.
6. When two bricks are struck together, a metallic sound should be produced.
7. Water absorption should not exceed 20 % of its dry weight when kept immersed in water for 24 hours.
8. Crushing strength should not be less than 10 N/mm^2.
9. Raw material should be free from stones, kankars, organic matter, saltpetre, etc.

Ingredients of Good Brick

Silica	50-60%
Alumina	20-30%
Lime	10%
Magnesia	< 1%} Less than 20%
Ferric oxide	< 7% } Less than 20%
Alkalis	< 10%} Less than 20%
Carbon dioxide	Very small percentage
Water	Very small percentage

Test for Bricks

1. **Dimension test (IS 1077) :** 20 pieces out of selected pieces are taken and are laid flat. The tolerances on the sizes of bricks are fixed by giving maximum and minimum dimensions, not on individual bricks but on batches of 20 bricks chosen at random. It follows from this method of measurement that batches are likely to contain, bricks outside the prescribed limit of tolerance. Such lots should be rejected to avoid complaints about the variation of perpends.
2. **Water Absorption test (IS 3495 (part II)):** 24 hours Cold water test : Dry bricks are put in an oven at a temperature of 105° to 115°C till these attain constant mass. The weight (w_1) of the bricks is recorded after cooling them to room temperature. The bricks are then immersed in water at a temperature of 27° ± 2°C for 24 hours. The specimens are then taken out of water and wiped with a damp cloth. Three minutes, thereafter it is weighed again and recorded as w_2.

   The water absorption in $\%w = \dfrac{w_2 - w_1}{w_1} \times 100$

   The average water absorption shall not be more than 20 per cent by weight upto class 12.5 and 15 % by weight for higher classes.

   5 hours hot water test : The weight of the oven dried bricks (w_1) is recorded as above. Then the specimen is immersed in the water and boiled for 5 hours, followed by cooling down to 27° ± 2°C by natural loss of heat within 16-19 hours. The specimen is taken out of water and wiped with a damp cloth and the weight is recorded as w_3.

   The water absorption in %

$$\%w = \frac{w_3 - w_1}{w_1} \times 100$$

3. **Efflorescence test (IS 3495 (Part III)) :** The ends of the brick are kept in a 150 mm diameter porcelain or glass dish containing 25 mm depth of water at room temperature (20°-30°C) till the entire water is absorbed

or evaporated. The water is again filled to 25 mm depth in the dish and allowed to be absorbed by the brick or evaporated. Presence of efflorescence is classified as below.

I. Nil — When the deposit of efflorescence is imperceptible.

II. Slight — When the deposit of efflorescence does not cover more than 10 % of the exposed area of the brick.

III. Moderate — When the deposit of efflorescence is more than 10 per cent but less than 50% of the exposed area of the brick.

IV. Heavy — When the deposit of efflorescence is more than 50 per cent but the deposits do not powder or flake away the brick surface.

V. Serious — When the deposits are heavy and powder or flake away the brick surface.

4. **Compressive strength test (IS 3495 (Part I)) :** Six bricks are taken for the compressive strength test although it may be found that an individual brick varies by 20% or more from the average, the permissible stresses allowed for load bearing walls take account of this, being based on an average strength of six bricks. It is, therefore, both unnecessary and uneconomical to insist that every bricks is above a certain strength. As a criterion of structural strength for brick, the transverse failure in a wall or pavement is likely to occur on account of improper bedment. For testing bricks for compressive strength from a sample the two bed faces of bricks are ground to provide smooth, even and parallel faces. The bricks are then immersed in water at room temperature for 24 hours. These are then taken out of water and surplus water on the surfaces is wiped off with cotton or a moist cloth. The frog of the brick is flushed level with cement mortar and the brick is stored under damp jute bags for 24 hours followed by its immersion in water at room temperature for three days. The specimen is placed in the compression testing machine with flat faces horizontal and mortar filled face being upwards. Load is applied at a uniform rate of 14 N/m^2 per minute till failure. The maximum load at failure divided by the average area of bed face gives the compressive strength.

Mortar

The mortar composition is designed by the volume or weight of material in 1 m^3 of mortar or by the relative amount of materials with the amount of binding material taken as unity. For simple mortars composed of one kind of binding material and containing no mineral admixtures (e.g., cement mortar), the composition will be designated, say 1:4, i.e., one part (by weight or volume) of binding material (cement) and 4 parts of sand.

Some of the important uses of mortars are as follows :

1. In brick and stone masonry-it is used in the vertical joints and is spread over each layer to give bed and a binding medium for successive layers of masonry.
2. In plastering and pointing-to cover exposed walls and joints to protect against weathering besides better appearance.
3. As matrix in concrete.

Classification of Mortar

Mortars are classified on the basis of their bulk density, kind of binding material, applications and, physical and mechanical properties.

On the Basis of Bulk Density

Type of Mortar	*Bulk Density (kg/m^3)*	*Aggregate*
Heavy weight	> 1500	Heavy quartz or sand
Light weight	< 1500	Light porous sand from pumice, tuffa, slags, etc.

On the Basis of Binding Material

The governing factors in deciding a particular type of mortar for a specific structure depends upon the desired strength of masonry, resistance to penetration of rain water, immediate and long term appearance, hardening temperature, expected working conditions of the building and cost.

For most practical purposes a building mortar will fall in one of the following classes:

Cement mortars are prepared from Portland cement or its varieties, sand and water.

Lime mortars are mixture of air hardening lime or hydraulic lime, sand and water.

Gypsum mortars are prepared from gypsums or anhydride binding materials.

Mud mortars are prepared from clay nodules and are used in construction of houses for poor and temporary construction works.

Composite mortars may be surkhi-motar (surkhi, lime and water), lime-surkhi-sand mortar, cement-lime mortar and cement-clay mortar.

On the basis of Application

Brick laying mortars are intended for brick work.

Finishing mortars are intendend for architectural or ornamental parts , application of decorative layers on walls and panels.

Special mortars are intended for acoustics, X-ray shielding, plugging concrete at oil fields, etc.

On the basis of physical and mechanical properties

The basis of this classification is the strength of concrete which underlies the durability of concrete. Building mortars are subdivided into nine grades on the basis of compressive strength from 0.4 to 30.0 N/mm^2.

Characteristics of a Good Mortar

1. It should have ease of mobility and placeability.
2. It should possess enough resistance against water penetration.
3. Water retention- It is characterized by the ability of mortar not to stratify during transportation and to retain adequate humidity in a thin layer spread over a porous bed. Mortar may lose so much water that the amount left may be insufficient for its hardening and required strength.
4. It should possess strength to withstand the load. The strength of masonry depends upon both the mortar and the building unit.

Timber

The terms timber and wood are often used synonymously, but they have distinct meanings in the building industry. Wood is the hard, fibrous material that makes up the tree under the bark, whereas timber may be defined as a wood which retains its natural physical structure and chemical composition and is suitable for various engineering works.

Classification of timber is as per IS: 399, except the classification of timber based on grading which is given in IS: 6534.

Structure of Timber

A tree can be divided into three portions, crown-composed of branches and leaves, trunk, and roots. The trunk accounts for about 80 per cent of the total bulk of wood.

The structure of timber visible to naked eye or at a small magnification is called macro structure, and that apparent only at great magnifications, the micro structure. Macro structure of the timber can be studied by cutting the trunk in three directions. In the cross-sectional and radial ducts, the following main parts of a tree, e.g. bark, cambium, sap wood, heart wood and pith, become readily apparent. Each of the components has a specific function. The bark protects the wood against mechanical damage. Its inner layer, called bast conveys the nutrients from the crown downwards and stores them. The function of cambium is to grow wood cells on the inside and smaller bast cells on the outside. The sapwood assists in the life process of tree by storing up starch and conducting sap. The cells in the sap wood are active. The heart wood gives a strong and firm support to the tree. With the growth of tree, the cells in the inner older portion of trunk gradually become inactive and lifeless, but do not decay. This portion of the trunk is called heart wood. At the centre of the cross-section is the pith, a small area occupied by friable tissues consisting of thin walled, loosely connected cells called pith.

Defects in timber	Diseases of timer	Decay of timber
Checks is a longitudinal crack which is usually normal to the annual rings.	**Dry Rot** is decomposition of felled timber caused by the action of various fungi. The fungus reduces fibres to fine powder and the timber looses its strength.	**Due to fugal & Bacterial attack.** Bacteria do not cause any serious damage to timber, except for some discolourations. Fungi are a system of plant organism which live in and attack timber causing rot and decay.
Shakes are longitudinal separations in the wood between the annual rings. These lengthwise separations reduce the allowable shear strength without much effect on compressive and tensile values.	**Wet Rot** is set up by the access of water through wounds in the bark and causes the decomposition of sap and fibres of the tree. This may also occur when timber is seasoned by exposing it to moisture.	**Termites, or white ants** are the most destructive of all insect agencies. They are small, social insects which form vast colonies. They completely excavate the wood at the centre leaving the outer shell intact
Heart shake occurs due to shrinkage of heart wood, when tree is overmatured. Cracks start from pith and run towards sap wood.		**Beetles** are small insects and they cause rapid decay of timber by converting them into fine powder. Usually, the outer shell of timber remains intact and hence the timber looks sound from outside until it fails completely.
Cup Shake appears as curved split which partly or wholly separates annual rings from one another.		**Pin hole borers** are very common and attack structural timber, furniture and other wood work in house. They are less than 6 mm in size and attack both sapwood and heartwood.
Star Shake are radial splits or cracks wide at circumference and diminishing towards the centre of the tree.		**Death watch Beetles** are somewhat larger than the previous one and the tunnels made by these are also bigger and filled with bun-shaped pellets. They normally attack timber infested with fungi or otherwise decayed.
Rindgall is characterised by swelling caused by the growth of layers of sapwood over wounds after the branch has been cut off in an irregular manner.		
Upsets are caused by the crushing of fibres running transversely during the growth of the tree due to strong winds and unskilled felling consequently resulting in discontinuity of fibres.		

Bitumen

Bitumen is a non-crystalline solid or viscous material derived from petroleum, by natural or refinery process and substantially soluble in carbon-disulphide. It is asphalt in solid state and mineral tar in semi fluid state. Bitumen is brown or black in color.

It becomes soft at temperatures between 30°-100° C (no sharp melting point), and therefore must be protected from exposure to heat. It is insoluble in water and fairly resistant to most acids. Although bitumen is combustible, composite products, such as mastic asphalt, are not readily ignited.

Forms of Bitumen

1. Bitumen Emulsion
2. Blown Bitumen
3. Plastic Bitumen
4. Staight run Bitumen
5. Cut back Bitumen*

***Cut back Bitumen** is obtained by fluxing asphaltic bitumen in presence of some suitable liquid distillates of coal tar or petroleum. It is mainly used in road construction and in soil stabilization (2-4%). Cut-backs are commercially manufactured in the following three groups.

1. Rapid curing (RC) cut-backs containing naptha or gasoline.
2. Medium curing (MC) cut-backs containing kerosene.
3. Slow curing (SC) cut-backs containing light oils as fluxing agents.

Each of the above group of cut-backs is further subdivided into six categories from 0 to 5. The six different viscosities are named by numbers 0 to 5 in the increasing order of viscosity.

Uses of Bitumen

1. Bitumen is used for manufacture of roofing and damp proofing felts.
2. Plastic bitumen is used for leak stops, waterproof packing paper.
3. Pipe asphalt, joint filler, bituminous filling compounds are used for cable boxes, for sealing accumulators and batteries.
4. It is also used for fixing of roofing felts, dam proofing felts and for heat insulation materials for buildings, refrigeration and cold storage equipments.
5. When bitumen is used in hot applications, the process is known as hot mopping in which case a suitable flux is added. Fluxing is essentially a softening process. The flux is usually a heavy oil added primarily to control the final setting hardness, but may also serve to reduce the temperature at which a hot applied bitumen becomes workable.

CONSTRUCTION MANAGEMENT

The management of construction projects requires knowledge of modern management as well as an understanding of the design and construction process. Construction projects have a specific set of objectives and constraints such as a required time frame for completion. While the relevant technology, institutional arrangements or processes will differ, the management of such projects has much in common with the management of similar types of projects in other specialty or technology domains such as aerospace, pharmaceutical and energy developments.

"Project management is the art of directing and coordinating human and material resources throughout the life of a project by using modern management techniques to achieve predetermined objectives of scope, cost, time, quality and participation satisfaction."

Types of Construction Projects

1. Private Construction projects
2. State Construction projects
3. Federal Construction projects

Tender and Contract

Contract is an undertaking by a person or firm to do any work under certain terms and conditions. The work may be for the construction or maintenance and repairs, for the supply of materials, for the supply of labor, for the transport of materials, etc.

Types of Contract

(1) **Lump sum contract :** In this contract the contractor undertakes the execution or construction of a specific work with all its contingencies, to complete it in all respects within a specified time for a fixed amount.

(2) **Lump Sum & Schedule contract :** In this system the contractor undertakes the execution or construction of a work on the item rate basis. It includes quantities, rates and amounts for various items of work and total amount of contract, plans and detailed drawings, detail specifications and deposit of 10% security money, penalty, progress, date of completion and other conditions of contract.

Tender

Tender is and offer in writing to execute some specified articles at certain rates, within a fixed time under certain conditions of contract and agreement between the contractor and the department or owner or party.

Analysis of Rates and Specifications

The rates of a particular item of work depends on the following

(*i*) Specification of works & materials, quality of materials, proportion type of mortar method of constructional operation, etc.

(*ii*) Quantities of materials & their rates, number of different types of laborer and their rates

(*iii*) Location of the site of work and its distances from the sources of materials & the rates of transport, availability of water.

The analysis of rate is usually worked out for the unit of payment item of work under two heads:-

(*a*) Materials (*b*) Labor

Specifications

(*a*) General specification

(*b*) Detailed Specification

General specifications of a first class building

1. ***Foundation & Plinth :*** shall be of I-class brick work in lime mortar or 1 : 6 cement mortar over lime concrete or 1 : 4 : 8 cement concrete.
2. ***Damp proof course :*** D.P.C shall be 2.5 cm (1") thick cement concrete 1 : 1 ½ : 3 , mixed with one kg of impermo per bag of cement or other standard water proofing materials as specified.
3. ***Superstructure*** **:** shall be of I- class brick work with lime mortar or 1 : 6 cement mortar.
4. ***Roofing*** **:** shall be of R.C.C slab with an insulation layer and lime concrete terracing above.
5. ***Flooring*** **:** drawing room and dining room floors shall be of mosaic (terrazzo).

General specifications of second class building

1. ***Foundation & Plinth*** **:** shall be of 1st class brick work with lime mortar over lime concrete.
2. ***Damp proof course*** **:** D.P.C shall be of 2 cm (¾") thick cement concrete 1:2 mixed with 1 kg of imperno per bag of cement or other standard water proofing materials.
3. ***Super structure*** **:** shall be of 2nd class brick work in lime mortar.
4. ***Roofing*** **:** shall be of R.B. slab with 7.5 cm line concrete terracing above.
5. ***Flooring*** **:** shall be 2.5 cm (1") cement concrete over 7.5 cm (3") L.C.
6. ***Finishing*** **:** Inside & Outside walls be of 12 mm cement mortar plastered 1:6.
7. ***Doors & Windows*** **:** chaukhat shall be of R.C.C or well-seasoned sal wood, shutters of shisham wood or deodar wood 4 cm.
8. ***Miscellaneous*** **:** Rain water pipes shall be of cast iron finished paint.

General Specifications of a Third Class Building

1. ***Foundation & Plinth*** **:** shall be of 2nd class brick work in lime mortar over lime concrete.
2. ***Super structure*** **:** shall be of second class brick work in mud mortar.
3. ***Roofing*** **:** shall be of mud over tiles or bricks or planks over wooden beams.
4. ***Flooring*** **:** shall be of brick on edge over well rammed earth.
5. ***Finishing*** **:** Inside & Outside walls shall be plastered with lime mortar and white washed three coats.
6. ***Doors & Windows*** **:** shall be of salwood & shutters of chair mango or other country wood.

General Specifications of a Fourth Class Building

1. ***Foundation & Plinth*** **:** shall be of sun dried or kutcha bricks in mud mortar
2. ***Roofing*** **:** shall be of tile roof over bamboo & wooden supports
3. ***Flooring*** **:** shall be of tile roof over bamboo & wooden supports
4. ***Doors & Windows*** **:** shall be of chir or mango wood or country wood

Estimate

An estimate is the anticipated or probable cost of a work and is usually prepared before the construction is taken up. Before undertaking any work or project it is necessary to know its probable cost which is obtained or derived by estimating. The estimate is prepared by computing or calculating the quantities required and then calculating the cost at suitable rates, to get the expenditure likely to be incurred in the construction of the work or structure.

Data for Estimate

To make out an estimate for a work the following data are necessary-

1. Drawing
2. Specification
3. Rates

Types of Estimate

1. ***Preliminary Estimate or Approximate or Abstract or Rough Cost*** **:** Is required for preliminary studies of various aspects of a work or project, to decide the financial position and policy for administrative sanction by the administrative authority.
2. ***Plinth area estimate for building (P.A. Estimate)*** **:** Is prepare don the basis of plinth area of building, the rate being deducted from the cost of similar building having similar specification, heights and construction.
3. ***Cube rate estimate for a building*** **:** Is a preliminary estimate or an approximate, and is prepared on the basis of the cubical contents of the building the cube rate being deducted from the cost.
4. ***Approximate quantity method estimate*** **:** In this the total length of walls is found in running meter and this total length multiplied by the rate per running meter of wall gives a fairly cost.
5. ***Detailed estimate or item rate estimate*** **:** is an accurate estimate and consist of working out the quantities of each item of the works & working the cost.
6. ***Revised Estimate*** **:** should be accompanied by a comparative statement showing the variations of each items of works, its quantity, rate and cost under the original and revised, side by side the excess or saving and reason for variation.

Project Planning

Project

A project has a specific purpose, it starts at a specific and is assumed to be finished when all its objectives are fulfill.

Every project either big or small has three objectives :

(*i*) The project should be completed in minimum elapsed time.

(*ii*) The project should be completed within minimum capital investment

(*iii*)The available resources are judicially utilized in order to complete the project.

Project Cost

- The project cost includes material and construction cost
- The economy in completion of project can be brought by reducing the material cost and construction cost
- Material cost can be reduced by designing the advance design philosophy
- Construction cost can be reduced with the help of numerical methods like PERT, CPM

Elements of Project Management

1. ***Planning*** **:** It is one of the most important element of project management and defines the objective of the project.
2. ***Scheduling*** **:** In scheduling the layout of the actual activities of the project is done in timely order & allocation of the resources to each activity is also done.
3. ***Controlling*** **:** It involves the actual execution of planning and scheduling.

Techniques of Project Management

1 Bar Chart / Gantt Chart :

- A bar chart consists of 2 coordinate X & Y.
- X- coordinate is used to refer time and Y- coordinate is used to refer activity.
- The start and end point of the bar indicates the starting time & finish time of the activity, hence the length of the bar indicates the duration of the activity.

Limitation of Bar chart :

1. Lack of degree of details
2. Bar chart can be only used for simple and small project.
3. No interdependency between the activity is shown
4. It does not indicate critical & non-critical activities
5. Lack of project progress
6. Bar chart is suitable only for repetitive type of project, i.e., it cannot be used in research project.

2. Milestone Chart

- Milestone chart is the modification over the bar chart
- in milestone chart project progress can be shown with the help of hatched line having half the width of the bar
- in milestone chart details about the sub- activities forming an activity can also be shown with the help of vertical arrows indicating the completion of sub-activities.

3. Network Diagram

- the network diagram is a flow of diagram in which activities and events are connected logically and sequentially
- all the limitations of bar chart are removed in the network diagram

Elements of Network Diagram

Activity : Is the actual performance of ETH task requires both the time and resources and is represented by an arrow.

Types of activities

1. ***Successor activity*** **:** It is a type of activity which starts after the completion of some another activity.
2. ***Predecessor activity*** **:** Is the type of activity which occurs before the occurrence of some other activity.
3. ***Parallel activity*** **:** The activities which can be started simultaneously and are independent of the occurrence of each other.
4. ***Serial activity*** **:** The activities which can be performed after the another are known as serial activities.

Event

An event is the stage which marks the starting or finish of an activity and it neither requires time nor any resource

Types of events

(*a*) *Successor & Predecessor Events* : the events which occur after the occurrence of some other events are known as successor events. The events which occur before the occurrence of some another events are known as predecessor events

(*b*) *Tail event* : the event which marks the beginning of an activity is known as tail event & if this tail event marks the beginning of the project is known as initial event.

(*c*) *Head event* : the event which marks the finish of an activity is termed as head event and if this head event marks the end of the project it is termed as finish event.

Dummy Activity

Is an artificial activity which neither require time nor any resource but is used to establish the geometrical and logical relationship between two activities.

Rules to Eliminate Extra Dummy's From the Network

(*i*) If the dummy is the only activity emerging from a node it can be removed.

(*ii*) If the dummy is the only activity merging into the node, the dummy can be removed.

(*iii*) If the dummy activity represents the relationship which is already been established in the network it can be removed.

(*iv*) If the two different activities coming out of two separate nodes have the same set of predecessor activities, the concerned activities can be merged into a single node.

(*v*) If the two different activities are merging into two separate nodes having same set of successor activities, the concerned activity can be merged into a single node.

Rules for Numbering the Events

(*i*) Number the initial event as 1

(*ii*) Remove all the activities temporarily, emerging from the initial event

(*iii*) Number the new initial events sequentially

(*iv*) Repeat the step 2 until all the events are numbered

PERT (Programme Evaluation & Review Technique)

In PERT, 3 time estimates are done for each activity since it is based on probabilistic approach.

(*i*) Optimistic time (t_o) : it is the minimum time in which the activity may be expected to be completed under the most ideal condition.

(*ii*) Pessimistic time (t_p) : it is the maximum time in which the activity may be expected to be completed under the worst condition.

(*iii*) Most Likely time (t_1) : it is the normal time in which the activity may be expected to be completed under general conditions.

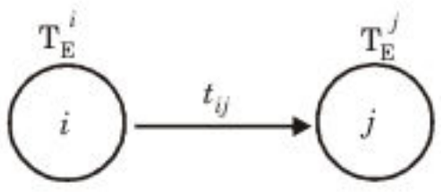
Expected Time (t_E)

- Expected time is calculated to simplify the analysis of PERT
- It represents the average time of completion of the activity which has a 50% chance of being executed in this given expected time
- Expected time is calculated by giving the weightage actor of '1' to both optimistic & pessimistic time & weightage factor of '4' to most likely time

$$t_E = \frac{t_o + 4t_L + t_P}{6}$$

Event Time

1. Earliest expected event occurrence time (T_E) :



$$T_E^j = T_E^i + t_{ij}$$

2. Latest allowable occurrence time (T_L) :

$$T_L^j = T_L^i - t_{ij}$$

Slack (S)

The slack of an event is the time by which it may be delayed without affecting the scheduled completion time of the project

$$S = T_L - T_E$$

(*i*) if $S > 0$, i.e., $T_L > T_E$
- If slack is negative, it signifies that an event may be delayed by the duration S, without affecting the scheduled completion time of the project.
- If slack is positive, it represents that the event ahead of schedule due to the availability of excess resources.

(*ii*) if $S = 0$, $T_L = T_E$
- If slack is 0, no delay is permitted in the event as any delay will cause the corresponding change in scheduled completion time of the project.
- 0 value of slack indicates that the event is on schedule due to the availability of adequate resources
- The event for which slack is zero are known as critical events & the path joining the critical events is known as critical path.

(*iii*) if $S < 0$, i.e., $T_L < T_E$
- The negative value of slack indicates that the event is behind of schedule due to lack of resources
- The events for which slack is negative are known as supercritical events and the path joining the supercritical events is known as 'supercritical path'.

Probability of Completion of the Project on Scheduled Time

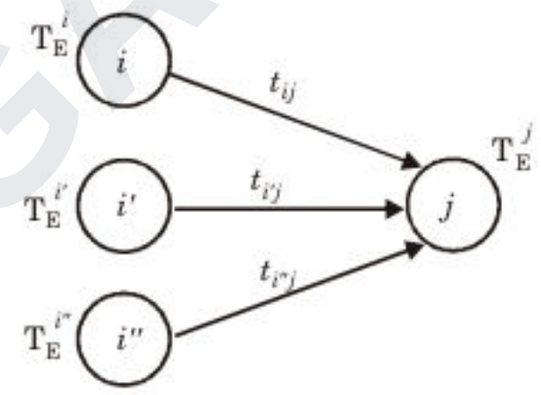
Probability of completion of the activity in scheduled time is equal to the ratio of area of probability distribution curve up to that given time to the total area of probability distribution curve,

$$P_r.t = \frac{A_t}{A} = \frac{\int_{-\infty}^{t} f(x)\cdot dx}{\int_{-\infty}^{\infty} f(x)\cdot dx} = \int_{-\infty}^{t} f(x)\cdot dx$$

CPM (Critical Path Method)

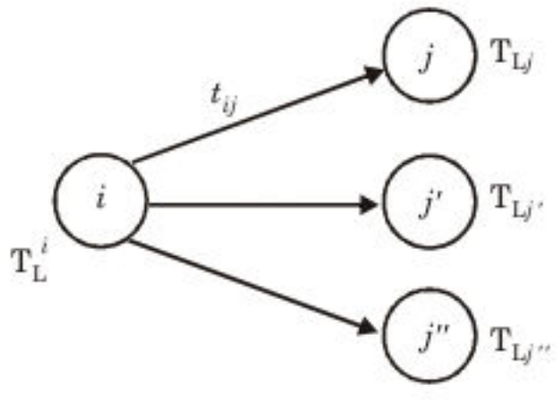
Event Time in CPM

(*a*) Earliest occurrence event time (T_E)



$$T_E^j = \left(T_E^i + t_{ij}\right)_{max}$$

(*b*) Latest Allowable Occurrence Time (T_L)



$$T_L^j = \left(T_L^j - t_{ij}\right)_{min}$$

Activity in CPM

(*a*) Earliest Start time (E.S.T)

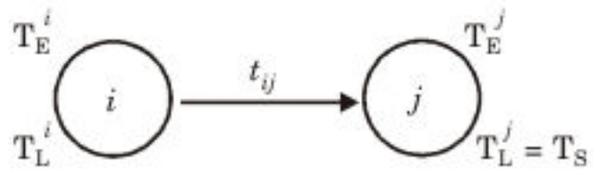
- It is the earliest time in which the activity may start.
- An activity starts when its tail event has occurred.

$$EST = T_E^i$$

(*b*) Earliest finish time (EFT)

$$EST = T_E^i + t_{ij}$$

(*c*) Latest Finish time (LFT)



$$LFT = T_L^i$$

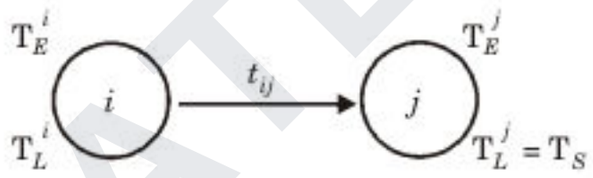
(*d*) Latest Start time (LST)

$$LST = T_L^i - t_{ij}$$

Float (F)

- Float in CPM is analogous to slack in PERT
- It is the time by which starting or finishing of an activity can be delayed without affecting the scheduled completion time of the project

Types of Float (F)



(1) Total Float : Is the time by which starting and finishing of an activity can be delayed without affecting the project completion

$$F_T = LFT - EFT$$

(2) Free float : Is the positive portion of total float which can be used by an activity without affecting the total float of succeeding activity

$$F_F = \left(T_E^j - T_E^i\right) - t_{ij}$$

(3) Independent float : Is the excess of minimum available time over the activity duration.

$$F_{ID} = \text{Head slack} - \text{Tail slack}$$

(4) Interfering float : Is just the another name given to head event slack.

EXERCISE – I

MCQ TYPE QUESTIONS

1. The carbon content in steel
(*a*) Decreases the ductility of steel
(*b*) Decreases the hardness of steel
(*c*) Increases the ductility of steel
(*d*) Increases the hardness of steel

2. Cavities of blow-holes steel are formed when :
(*a*) Being worked in cold state
(*b*) Being worked in hot
(*c*) A gas is the molten mass of the metal
(*d*) All of the above

3. Plates in the structural steelwork are used to
(*a*) Connect steel beams
(*b*) Serve as tension members of steel roof turns
(*c*) Form built- up sections of steel
(*d*) All of the above

4. Which of the following mechanical treatment is given to the steel to prepare wires and rods?
(*a*) Drawing
(*b*) Forging
(*c*) Pressing
(*d*) Rolling

5. The initial setting time of cement is increased by adding
(*a*) Al_2O_3 (*b*) $CaSO_4$
(*c*) MgO (*d*) Alkalies

6. Gunite is a mixture of :
(*a*) Cement and mortar
(*b*) Sand and mortar
(*c*) Cement and sand
(*d*) Cement, sand and motor

7. Match the following :

A. Pith	1. Recent growth
B. Cambium	2. Dead portion of tree
C. Heart Wood	3. Innermost central portion
D. Sap Wood	4. Thin layer of sap between sap wood and inner bark

Codes :

	A	B	C	D
(*a*)	1	2	3	4
(*b*)	4	3	2	1
(*c*)	3	4	2	1
(*d*)	2	1	4	3

8. The annular rings of heart wood and sap wood are held together with the help of :
(*a*) Cambium layer
(*b*) Inner bark
(*c*) Outer bark
(*d*) Medullary rays

9. Match the columns with the regard to defect in timber

A. Defect due to conversion	1. Warp
B. Defect due to fungi	2. Termites
C. Defect due to insect	3. Wet root
D. Defect due to natural forces	4. Torn Grain
E. Defect due to seasoning	5. Knots

Codes :

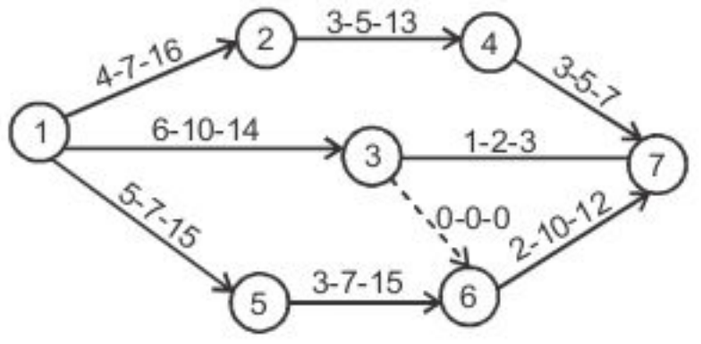
	A	B	C	D	E
(*a*)	1	2	3	4	5
(*b*)	4	3	2	5	1
(*c*)	4	3	1	4	5
(*d*)	2	3	2	4	1

10. The time estimates for 3 activities A, B & C are as follows :-

Activity	Optimistic Time	Pessimistic Time	Most Likely Time
A	10	12	14
B	5	10	12
C	6	8	12

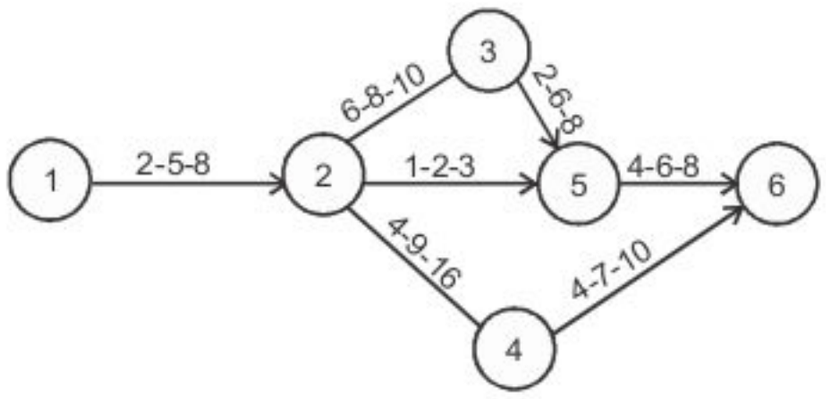
Then,
(*a*) Activity A is more reliable
(*b*) Activity B is more reliable
(*c*) Activity C is more reliable
(*d*) Cannot say about reliability

11. The critical path of the network shown in figure :



(*a*) 1-2-4-7
(*b*) 1-3-7
(*c*) 1-3-6-7
(*d*) 1-5-6-7

12. Calculate the earliest expected time of event 5 in the network shown in fig :



(*a*) 14.3
(*b*) 8
(*c*) 18.67
(*d*) 13

13. Radial shakes, a defect in timber occurs :
(*a*) Due to shrinkage of interior part of tree
(*b*) Due to non- uniform growth
(*c*) When tree is exposed to run for seasoning after being felled down
(*d*) All of the above

14. The timber is generally preferred for the buildings in the earthquake- proen regions because :
(*a*) It can be easily handled
(*b*) It combines light weight with strength
(*c*) It is easy to provide connections in timber
(*d*) All of the above

15. Magnesia in brick earth imparts :
(*a*) Plasticity to the earth
(*b*) Red colour to bricks
(*c*) Yellow tint to the bricks and decreases shrinkage
(*d*) Dark blue or blackish colour

16. The process of grinding clay with water and making it plastic is known as :
(*a*) Pugging
(*b*) Weathering
(*c*) Blending
(*d*) Digging

17. The bricks are crystallised and disintegrated during burning because of
(*a*) Excess lime
(*b*) The oxidation of iron pyrites
(*c*) Alkalies
(*d*) Vegetation & organic matter in brick earth

18. The presence of which of the following constituent of brick prevents cracking, shrinking and warping of raw bricks
(*a*) Alumina
(*b*) Silica
(*c*) Oxide of iron
(*d*) Magnesia

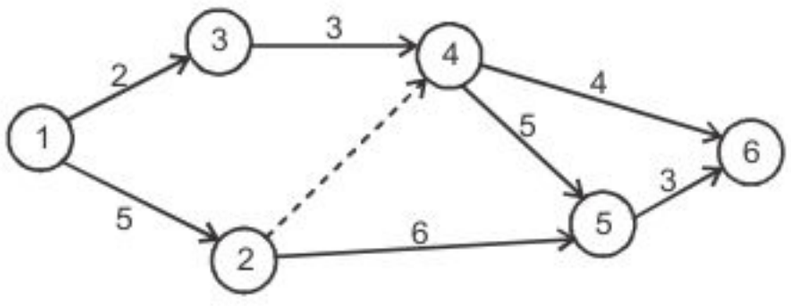
19. A bullnose brick is as brick moulded
(*a*) To the shape of a gutter
(*b*) With a rounded angle
(*c*) With a double bullnose on end
(*d*) All of the above

20. A queen closer is :
(*a*) Full brick
(*b*) Longitudinally ½ brick
(*c*) ¾ brick
(*d*) Crosswise ½ brick

21. The minimum compressive strength in timber is a direction :
(*a*) Inclined at 90° to the grains
(*b*) Inclined at 60° to the grains
(*c*) Inclined at 43° to the grains
(*d*) Parallel to the grains

22. When the bitumen s being distilled to a definite viscosity or penetration without further treatment, it is known as the
(*a*) Plastic bitumen
(*b*) Cut-block bitumen
(*c*) Straight run bitumen
(*d*) Blown bitumen

23. From the network shoe in the figure (the number on each arrow denotes the time duration of activity in days), the earliest start time, in days for activity 5-6 is :



(*a*) 5
(*b*) 11
(*c*) 14
(*d*) 6

24. For a particular activity of a project, time estimates received from two engineers X & Y are as following, state who is more certain about the time of completion :

	T_o	T_m	t_p
X	4	6	8
Y	3	5	8

(*a*) Engineer X is more certain
(*b*) Engineer Y is more certain
(*c*) Both are equally certain
(*d*) Cannot be determined

25. PERT calculation yield a project length of 50 weeks with a variance of 16, within how many weeks would you expect the project to be completed with the probability of 95%.
(*a*) 50 weeks
(*b*) 57 weeks
(*c*) 60 weeks
(*d*) 65 weeks

26. Strength and quality of concrete depends on
(*a*) aggregate shape
(*b*) aggregate grading
(*c*) surface area of the aggregate
(*d*) all of these

27. The lower water-cement ratio in concrete produces
(*a*) more density
(*b*) small creep and shrinkage
(*c*) more bond
(*d*) all of these

28. The entrained air in concrete
(*a*) increases workability
(*b*) decreases workability
(*c*) increases strength
(*d*) none of these

29. The property of fresh concrete, in which the water in the mix tends to rise to the surface while placing and compaction is called
(*a*) Bleeding
(*b*) Creep
(*c*) Segregation
(*d*) Shrinkage

30. Separation of ingredients from concrete during transportation is called
(*a*) Bleeding
(*b*) Creep
(*c*) Segregation
(*d*) Shrinkage

31. For making impermeable concrete, the process contains
(*a*) through mixing
(*b*) proper compaction
(*c*) proper curing
(*d*) all of these

32. After casting, an ordinary cement concrete on drying
(*a*) shrinks
(*b*) expands
(*c*) remains unchanged
(*d*) can expand or shrink

33. Workability of concrete can be improved by addition
(*a*) Iron
(*b*) Sodium
(*c*) Zinc
(*d*) Sulphur

34. Split strength of concrete can be determined by
(*a*) Brazilion test
(*b*) Vicat's apparatus
(*c*) Cube test
(*d*) Briquettes test

35. Workability of concrete can be improved by
(*a*) more sand
(*b*) more cement
(*c*) more fine aggregate
(*d*) fineness of coarse aggregate

36. Workability of concrete can be improved by
(*a*) increasing size of aggregate
(*b*) decreasing aggregate
(*c*) increasing fine aggregate
(*d*) increasing flaky aggregate

37. Compound that helps in obtaining early strength of cement concrete is
(*a*) Tricalcium silicate
(*b*) Dicalcium silicate
(*c*) Tri aluminate
(*d*) Dicalcium silicate

38. Workability of concrete is directly proportional to
(*a*) grading of the aggregate
(*b*) time of transit
(*c*) aggregate cement ratio
(*d*) none of these

39. Workability of concrete is inversely proportional to
(*a*) water cement ratio
(*b*) size of aggregate
(*c*) time of transit
(*d*) none of these

40. If compaction factor of a concrete is 0.90, then workability is
(*a*) very low
(*b*) low
(*c*) medium
(*d*) high

41. Strength of concrete is directly proportional to
(*a*) cement water ratio
(*b*) water cement ratio
(*c*) sand cement ratio
(*d*) water aggregate ratio

42. Strength of concrete increase with increase in
(*a*) water cement ratio
(*b*) size of aggregate
(*c*) aggregate cement ratio
(*d*) moisture content

43. Strength of concrete increase with
(*a*) increase in water cement ratio
(*b*) increase in fineness of cement
(*c*) decrease in curing time
(*d*) decrease in size of aggregate

44. Strength of concrete increases with
(*a*) increase in water cement ratio
(*b*) decrease in water cement ratio
(*c*) decrease in size of aggregate
(*d*) decrease in curing time

45. Poisson's ratio for concrete
(*a*) increases with richer mix
(*b*) decreases with richer mix
(*c*) remains constant
(*d*) none of these

46. Creep in concrete increases with
(*a*) increase in cement content
(*b*) decrease in curing time
(*c*) decrease in age of concrete at the time of loading
(*d*) all of these

47. At freezing point of water, concrete
(*a*) sets freely
(*b*) sets slowly
(*c*) set rapidly
(*d*) does not set

48. Coefficient of thermal expa-nsion of cement concrete is
(*a*) 3×10^{-4} per°C
(*b*) 3×10^{-5} per°C
(*c*) 3×10^{-6} per°C
(*d*) 3×10^{-8} per°C

49. A compaction factor of 0.85 for a cement concrete sample indicates
(*a*) low workability
(*b*) medium workability
(*c*) good workability
(*d*) very good workability

50. A concrete is said to be workable if
(*a*) its consistency is of a paste
(*b*) it can be easily mixed, placed and compacted
(*c*) bleeding and segregation is there
(*d*) laitance is formed

51. pH value of water for quality concrete shall not be less than
(*a*) 2
(*b*) 4
(*c*) 6
(*d*) 12

52. Bleeding in cement concrete is caused because of
(*a*) vibrating fresh concrete for long time
(*b*) finishing hard the fresh concrete
(*c*) transporting concrete by belt conveyor system
(*d*) both (*a*) and (*b*)

53. When cement content in cement mortar is reduced, then
(*a*) slump increases
(*b*) consistency decreases
(*c*) compressive strength decreases
(*d*) none of these

54. Factor of safety for steel as compared to concrete is

(*a*) same

(*b*) lower

(*c*) higher

(*c*) none of these

55. Factor of safety for steel is based on its

(*a*) yield stress

(*b*) ultimate stress

(*c*) both (*a*) and (*b*)

(*d*) none of these

NUMERICAL TYPE QUESTIONS

1. A bus takes no less than 25 mins to reach a destination and sometimes as much as 48 min. 35 min time is the most frequent time to reach the destination. If this task of the bus is an activity in PERT project, then the expected time to reach the destination by bus is _____ min

2. The crushing strength of a good building stobe should be at least _____ MPa

3. In PERT network, expected project duration is found to ne 38 days from the start of the project. The variance is four days, the probability that the project will be completed in 38 days is _____

4. Time estimate of an activity in PERT network are :

T_o = 12 days

T_e = 23 days

T_m = 15 days

The probability of completion of activity in 13 days is _____

5. Approximate ratio of strength of cement concrete at 3 months to that at 28 days of curing is _____

6. Approximate ratio of the strength of the cement conc of 7 days to that of 28 days (2/3) is _____

ANSWERS

EXERCISE – I

MCQ Type Questions

1. (*a*)	**2.** (*c*)	**3.** (*d*)	**4.** (*a*)	**5.** (*b*)	**6.** (*c*)	**7.** (*c*)	**8.** (*d*)	**9.** (*b*)	**10.** (*a*)
11. (*d*)	**12.** (*c*)	**13.** (*c*)	**14.** (*b*)	**15.** (*c*)	**16.** (*a*)	**17.** (*b*)	**18.** (*b*)	**19.** (*b*)	**20.** (*b*)
21. (*a*)	**22.** (*c*)	**23.** (*b*)	**24.** (*a*)	**25.** (*b*)	**26.** (*d*)	**27.** (*d*)	**28.** (*a*)	**29.** (*a*)	**30.** (*c*)
31. (*d*)	**32.** (*a*)	**33.** (*c*)	**34.** (*c*)	**35.** (*b*)	**36.** (*a*)	**37.** (*c*)	**38.** (*a*)	**39.** (*a*)	**40.** (*c*)
41. (*a*)	**42.** (*b*)	**43.** (*b*)	**44.** (*b*)	**45.** (*a*)	**46.** (*a*)	**47.** (*a*)	**48.** (*a*)	**49.** (*a*)	**50.** (*b*)
51. (*c*)	**52.** (*d*)	**53.** (*a*)	**54.** (*b*)	**55.** (*b*)					

Numerical Type Questions

1. (35.5) **2.** (100) **3.** (0.5) **4.** (0.15) **5.** (1.15) **6.** (0.75)

EXPLANATIONS

EXERCISE – I

MCQ TYPE QUESTIONS

10.

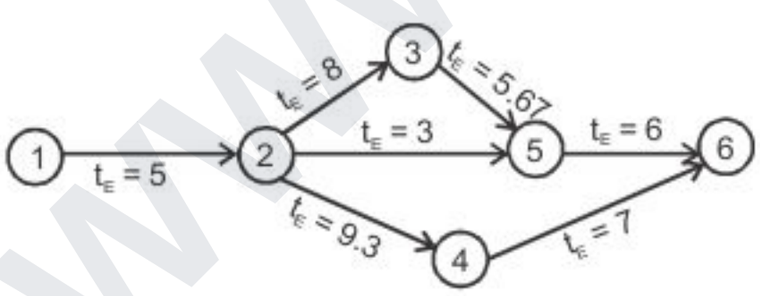
Activity	Optimistic Time	Pessimistic Time	Most Likely Time	$t_E = \frac{t_o + t_2 + t_p}{6}$	$\sigma^2 = \left(\frac{t_p - t_o}{6}\right)$
A	10	12	14	12	0.44
B	5	10	12	9.5	1.36
C	6	8	12	8.33	1

11.

Activity	t_E
1-2	8
1-3	10
1-5	8
2-4	6
3-7	2
3-6	0
5-6	7.67
6-7	9
4-7	5

Path	Σt_E
1-2-4-7	8 + 6 + 5 = 19
1-3-7	10 + 2 = 12
1-3-6-7	10 + 0 + 9 = 19
1-5-6-7	8 + 7.67 + 9 = 24.67

12.



Event	T_E
1	0
2	5
3	13
4	14.3
5	$\begin{bmatrix} 8 \\ 18.67 \end{bmatrix}$

Hence, T_E for event 5 = 18.67

23.

Event	1	2	3	4	5	6
Earliest Occurrence time	0	5	2	5	11	14

Earliest occurrence tail event = EST of the activity

$$EST_{5\text{-}6} = 11 \text{ days}$$

24.

$$\sigma_x^2 = \left(\frac{t_p - t_o}{6}\right)^2$$

$$= \left(\frac{8-4}{6}\right)^2 = 0.4356$$

$$\sigma_y^2 = \left(\frac{t_p - t_o}{6}\right)^2$$

$$= \left(\frac{8-3}{6}\right)^2 = 0.69$$

Engineer X's time have more uncertainty

25.

$$\sigma = \sqrt{16} = 4$$

$$z = 1.65$$

Now, $\frac{T_S - T_E}{\sigma} = Z$

$\therefore$ $T_S = \sigma Z + T_E$

$= 4 \times 1.65 + 50$

$= 56.6$

$= 57$ weeks

NUMERICAL TYPE QUESTIONS

1. Here, $t_o = 25$ min

$t_L = 35$ min

$t_p = 48$ min

$$t_E = \frac{25 + 4 \times 35 + 48}{6}$$

$= 35.5$

3.

$$\text{S.D} = \sqrt{\text{var}}$$

$$= \sqrt{4} = 2$$

$$z = \frac{\text{X} - \bar{\text{X}}}{\sigma}$$

$$= \frac{38 - 28}{2} = 0$$

$$\text{P}(0) = 0.5$$

Therefore, the probability that the project will be completed in 38 days is 50%

4.

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

$$= \frac{12 + 4 \times (15) + 23}{6} = 15.83$$

$$\text{S.D} = \frac{b - a}{6} = \frac{23 - 12}{6} = 1.83$$

$$z = \frac{\text{X} - \bar{\text{X}}}{\sigma} = \frac{13 - 15}{2} = -1$$

$$\text{P}(-1) = 0.1586$$

■■