SURA'S

DIPLOMA Standard

TNPSC

RECRUITMENT FOR THE POST OF

OVERSEER / JUNIOR DRAUGHTING OFFICER

PAPER-I

CIVIL ENGINEERING

(DETAILED THEORY - DIPLOMA STANDARD)

By

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TNPSC Junior Draughting Officer Exam. Original Question Paper 2021

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TNPSC

COMBINED ENGINEERING SUBORDINATE SERVICES EXAMINATION.

OVERSEER / JUNIOR DRAUGHTING OFFICER

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TNPSC – COMBINED ENGINEERING SUBORDINATE SERVICES EXAM.

Junior Draughting Officer – Civil Engineering (Diploma Std.)

Date : 18-09-2021
Duration : 3 hours

Original Question Paper

No. of Qns. : 200
Marks : 300

1. **The unsupported length of a R.C. column is 3.2 m, the effective length of the column, when both ends are held in position and restrained against rotation, is**
A) 1.08 m B) 3.20 m
C) 2.08 m D) 6.40 m **Ans. (C)**

2. **The slenderness ratio of the steel column is**
A) $\frac{l}{r_{min}}$ B) $\frac{L}{r_{xx}}$
C) $\frac{L}{r_{yy}}$ D) $\frac{KL}{r_{min}}$ **Ans. (D)**

3. **What are the following loads to be considered as vertical loads carried by lintels?**
a) Distributed loads from the dead weight of the lintel and the masonry wall above the lintel and any floor and/or roof
b) Dead and live loads supported by the masonry
c) Concentrated loads from floor beams, roof joists, and other members that frame directly into the wall

Select the correct answer :
A) (a) and (b) only B) (a) and (c) only
C) (a), (b) and (c) D) (b) and (c) only
Ans. (C)

4. **While designing the staircase with central stringer beam, the stringer beam is designed as**
A) simply supported beam
B) cantilever beam
C) fixed beam
D) T-beam **Ans. (B)**

5. **In the design of beams for shear, the nominal shear stress, τ_v is given by**
A) $\tau_v = \frac{V_u}{bD}$ B) $\tau_v = \frac{V_u}{bd}$
C) $\tau_v = \frac{V_u}{BD}$ D) $\tau_v = \frac{V_u}{Bd}$ **Ans. (B)**

6. **Young's modulus of concrete (E) is given by**
A) E = 1000 fck
B) E = 5000 times square root of fck
C) E = 5700 fck
D) E = 10000 times square root of fck
fck = characteristics strength of concrete
Ans. (B)

7. **For the simply supported beams and slabs, the basic value of span to effective depth ratio is**
A) 7 B) 10
C) 20 D) 26
Ans. (C)

8. **The maximum spacing of inclined stirrups (45°) in a beam is less than 300 mm and**
A) d B) 0.75 d
C) 1.25 d D) D
Ans. (B)

9. **If the Independent of footings of two columns are connected by a beam, called as**
A) Mat foundations
B) Combined footings
C) Strap footing
D) Spread footings
Ans. (C)

10. **Slump value recommended for ordinary R.C.C. work for beams and slabs is**
A) 20 to 30 mm
B) 50 to 100 mm
C) 12 to 25 mm
D) 75 to 150 mm **Ans. (B)**

11. **To compensate for the reduced workability .... are commonly added to high strength mixtures.**
A) Accelerators
B) Retarders
C) Air entraining Admixture
D) Super plasticisers
Ans. (D)

12. **Certain type of fungi feed on wood and during feeding, they attack on wood and convert it into dry powder form. This is known as**
A) Dry rot B) Blue stain
C) Heart rot D) Sap stain
Ans. (A)

13. **The insects which are usually responsible for decay of timber is**
A) Termites B) Grasshopper
C) Spider D) Dragonfly
Ans. (A)

14. **Wood is impregnated with creosote oil in order to**
A) Change its colour
B) Protect against fungi
C) Protect the annular layers
D) Fill up the pores
Ans. (B)

15. Fine Aggregates should pass through one of the following IS sieve
A) 2.35 mm B) 45 μ
C) 4.75 mm D) 75 μ
Ans. (C)

16. In aggregates, the percentage by weight of particles having least dimension less than three-fifth of their mean dimension is termed as
A) Elongation index B) Flakiness index
C) Fineness index D) Fineness modulus
Ans. (B)

17. In aggregates, the percentage by weight of particles present in it whose greatest dimension (length) is greater than nine-fifth of their mean dimension, is termed as
A) Elongation index B) Flakiness index
C) Fineness modulus D) Fineness index
Ans. (A)

18. Vicat's apparatus is used to determine the
A) Initial setting and final setting time
B) Soundness of cement
C) Tensile strength
D) Compressive strength
Ans. (A)

19. A bat is the portion of a
A) Wall not exposed to weather
B) Brick cut across the width
C) Wall between facing and backing
D) Brick cut in a such manner that its one long face remains uncut
Ans. (B)

20. Relative density of sand indicates
A) Density of sand compared with density of water
B) Bulk density of sand
C) Bulking of sand
D) Looseness of sand
Ans. (D)

21. Determination of percentage of individual grain size present in the soil is known as
A) Stability analysis
B) Compressability analysis
C) Strength analysis
D) Grain size analysis **Ans. (D)**

22. The ratio of unit weight of soil solids to that of water is called
A) Void ratio
B) Porosity
C) Specific Gravity
D) Degree of saturation
Ans. (C)

23. The Minimum Water content at which the soil will flow is known as
A) Water content B) Liquid limit
C) Shrinkage limit D) Plastic limit
Ans. (B)

24. A temporary structure constructed to exclude earth and water from workspot where foundation is to be laid within it is dry and open air is
A) Caisson B) Coffer dam
C) Cause way D) Cribs
Ans. (B)

25. The centre to centre distance between the end supports of a bridge is termed as
A) span B) clear span
C) total span D) effective span
Ans. (D)

26. The camber of a gravel road lies between
A) 1 in 15 and 1 in 20
B) 1 in 20 and 1 in 25
C) 1 in 25 and 1 in 30
D) 1 in 30 and 1 in 35
Ans. (C)

27. In transportation engineering, clover leaf is a type of
A) Regulatory signs
B) Traffic control devices
C) Traffic interruption
D) Interchanges **Ans. (D)**

28. The portion of road between the edge of the road formation and the edge of the pavement is called as
A) Kerb B) Guard stone
C) Median strip D) Berm
Ans. (D)

29. Well graded gravel is denoted by
A) GW B) GH
C) SH D) SW
Ans. (A)

30. Imhoff tank is used for the following purpose
A) Filtration
B) Chlorination
C) Sedimentation and sludge digestion
D) Softening
Ans. (C)

31. The free board to be provided above the top sewage line in the septic tank is
A) 0.2 - 0.3 m B) 0.1 - 0.2 m
C) 0.3 - 0.5 m D) 0.4 - 0.55 m
Ans. (C)

32. .... are placed directly below the road gutter and storm water directly enters them from top.
A) Curb inlet B) Manhole
C) Gutter inlet D) Drop man hole
Ans. (C)

33. A pipe conveying sewage from the plumbing system of a single building to a common sewer is called
A) Common sewer B) House sewer
C) Lateral sewer D) Outfall sewer
Ans. (B)

67. The permissible error in chaining for measurement with chain on rough or hilly ground is

A) 1 in 100 **B)** 1 in 250
C) 1 in 500 **D)** 1 in 1000

Ans. (B)

68. Yield of well is expressed in terms of

A) m^3/hr **B)** m^3/sec
C) m / sec **D)** N / m^2

Ans. (A)

69. The ratio of power output of the pump to the power input of the pump is known as

A) Overall efficiency
B) Mechanical efficiency
C) Manometric efficiency
D) Volumetric efficiency

Ans. (A)

70. The value of Chezy's constant (C) according to Manning's formula is (where, m = Hydraulic mean depth, N = Manning's constant)

A) $C = \frac{1}{N} m^{1/3}$ **B)** $C = \frac{1}{N} m^{1/6}$

C) $C = \frac{1}{N} m^{6}$ **D)** $C = \frac{1}{N} m^{3}$

Ans. (B)

71. In a most economical trapezoidal section, half of the top width is equal to

A) Bottom width of the channel
B) Depth of the channel
C) Sloping side of the channel
D) One-Third depth of the channel

Ans. (C)

72. The inlet length of a venturimeter

A) is equal to the outlet length
B) is more than the outlet length
C) is less than the outlet length
D) zero

Ans. (C)

73. Hydraulic Gradient Line (HGL) represents the sum of

A) Pressure head and kinetic head
B) Kinetic head and datum head
C) Pressure head, kinetic head and datum head
D) Pressure head and datum head

Ans. (D)

74. For the Laminar flow through a circular pipe

A) The maximum velocity = 1.5 times the Average velocity
B) The maximum velocity = 2.0 times the Average velocity
C) The maximum velocity = 2.5 times the Average velocity
D) The maximum velocity = Average velocity

Ans. (B)

75. The flow in which each liquid particles has a definite path, and the paths of individual particles do not cross each other, is called

A) Steady flow **B)** Uniform flow
C) Laminar flow **D)** Turbulant flow

Ans. (C)

76. The Capillary rise or fall of a liquid is given by

A) $h = \frac{\sigma \cos\theta}{4\rho g d}$ **B)** $h = \frac{4\sigma \cos\theta}{\rho g d}$

C) $h = \frac{8\sigma \cos\theta}{\rho g d}$ **D)** $h = \frac{\sigma \cos\theta}{8\ \rho g d}$

Ans. (B)

77. The point through which the weight is acting is called

A) Centre of pressure
B) Centre of gravity
C) Centre of buoyancy
D) Centre of pressure and gravity **Ans. (B)**

78. The pictorial representation of activity and events of a project is known as

A) Flow chart **B)** Flow Net
C) Algorithm **D)** Network

Ans. (D)

79. Personal banking services is also known as

A) Global banking **B)** Retail banking
C) Rural banking **D)** Urban banking

Ans. (B)

80. The following is indirect cost of accident

A) Money paid for treatment of worker
B) Compensation paid to worker
C) Cost of lost of time of injured worker
D) Contract value **Ans. (C)**

81. Strong room will be most essential for the .... building.

A) Residential **B)** School
C) Bank **D)** Public

Ans. (C)

82. A legal agreement made between the owner and contractor is called

A) Legal document **B)** An agreement
C) A tender **D)** A contract

Ans. (D)

83. PERT stands for

A) Programme Estimation and Reporting Technique
B) Process Estimation and Review Technique
C) Programme Evaluation and Review Technique
D) Planning Estimation and Resulting Technique

Ans. (C)

84. In PERT analysis, event means

A) Start (or) finish of a task
B) Time taken for a task
C) End of an activity
D) Work involved in the project

Ans. (A)

85. **Higher standard deviation means**
A) Higher uncertainity
B) Lower uncertainity
C) Nothing to do with uncertainity
D) Equal chance of uncertainity
Ans. (A)

86. **Bar chart is also called as**
A) Square chart B) Milestone chart
C) Gantt Chart D) Rectangular chart
Ans. (C)

87. **Bar charts are considered to be suitable for**
A) Minor works B) Major works
C) Dam construction D) Large projects
Ans. (A)

88. **Approximate cost for water supply arrangements is**
A) 4 to 5% of the estimated cost of the building works
B) 2 to 3% of the estimated cost of the building works
C) 3 to 4% of the estimated cost of the building works
D) 1 to 2% of the estimated cost of the building works
Ans. (B)

89. **Calculate the rough cost estimate for a 1^{st} class building having a plinth area of $500m^2$. Add a lump sum of 20% estimate for public health and electric services. Rate per m^2 of construction is ₹ 6,000**
A) ₹ 30 Lakhs B) ₹ 36 Lakhs
C) ₹ 33 Lakhs D) ₹ 72 Lakhs
Ans. (B)

90. **A property is said to have distress value when it can fetch .... value than market value**
A) Higher B) Lower
C) Equal D) Double
Ans. (B)

91. **The value of the property at the end of the useful life period is known as**
A) Scrap value B) Salvage value
C) Junk value D) Book value
Ans. (B)

92. **What is the unit of measurement used for supplying of bitumen?**
A) Kg B) Cubic metre
C) Tonne D) Square metre
Ans. (C)

93. **Actual size of standard modular brick Tile**
A) 19 c.m. × 9 c.m. × 4 c.m.
B) 19 c.m. × 9 c.m. × 9 c.m.
C) 20 c.m. × 10 c.m. × 10 c.m.
D) 20 c.m. × 10 c.m. × 5 c.m.
Ans. (A)

94. **For sanitary and water supply works and for electrification, the percentage of the estimated cost of the building works for the above works shall be**
A) 8% B) 10%
C) 12% D) 14%
Ans. (A)

95. **The unit of measurement for Random Bubble masonry is**
A) m^3 B) m
C) m^2 D) m^4
Ans. (A)

96. **The actual cost of a work is known as**
A) Cost after completion of the total work
B) Security deposit of the work
C) E.M.D.
D) Estimation
Ans. (A)

97. **Unit of dimension for aggregates**
A) cm B) mm
C) length D) breadth
Ans. (B)

98. **The compression members used in roof trusses and bracings are called as**
A) girders B) columns
C) struts D) beams
Ans. (C)

99. **The slenderness ratio of a tension member is defined as the ratio of its unsupported length (L) to its**
A) least radius of curvature
B) least radius of gyration
C) least of section modulus
D) least of polar modulus
Ans. (B)

100. **In a two-way reinforced rectangular footy, for reinforcement in short direction, the width of central band shall be**
A) half the width of footy
B) half the length of footy
C) width of footing
D) one-third the length of footy
Ans. (C)

101. **The effective length of column with one end fixed and the other end free shall be**
A) $\frac{l}{\sqrt{2}}$ B) $2l$
C) $\frac{l}{2}$ D) $1.0l$
Ans. (B)

102. **The horizontal upper portion of a step where the foot rests, is called as**
A) Tread B) Nosing
C) Riser D) Flight
Ans. (A)

103. **The bending moment value in the continuous slab is calculated by using**
A) $\frac{wl^2}{2}$ B) $\frac{wl^2}{8}$
C) coefficients D) $\frac{wl^2}{12}$
Ans. (C)

173. The discharge through the internal mouthpiece running full is given by

A) $0.5\, a\sqrt{2gH}$ **B)** $0.85\, a\sqrt{2gH}$

C) $0.707\, a\sqrt{2gH}$ **D)** $a\sqrt{2gH}$

Ans. (C)

174. The loss of pressure head for the Laminar flow through pipes varies

A) As the square of velocity

B) Directly as the velocity

C) As the inverse of the velocity

D) As the cubic of velocity

Ans. (B)

175. The coefficient of discharge of Internal Mouthpiece running full is given by

A) 0.707 **B)** 0.850

C) 0.500 **D)** 0.600

Ans. (A)

176. The loss of head due to sudden contraction of a pipe is equal to

A) $\left(\frac{1}{C_c}-1\right)^2 \frac{V_2}{2g}$ **B)** $\left(1-\frac{1}{C_c}\right)^2 \frac{V_2}{2g}$

C) $\frac{1}{C_c}\left(1-\frac{V_2^2}{2g}\right)$ **D)** $\frac{V_2^2}{2g}\left(\frac{1}{C_c}-1\right)^2$

Ans. (D)

177. The loss of head due to friction according to Darcy's formula is

A) $\frac{4flv^2}{gd}$ **B)** $\frac{4flv^2}{2gd}$

C) $\frac{4flv}{2gd}$ **D)** $\frac{4flv}{gd}$

Ans. (B)

178. Surface tension has the unit as

A) Force / unit area **B)** Force / unit length

C) Force / unit volume **D)** Area × Length

Ans. (B)

179. The pressure of a liquid measured with the help of a Piezo meter tube is

A) Vacuum pressure **B)** Gauge pressure

C) Absolute pressure **D)** Atmospheric pressure

Ans. (B)

180. Atmospheric pressure is also known as

A) Barometric pressure **B)** Intensity of pressure

C) Vacuum pressure **D)** Gauge pressure

Ans. (A)

181. The impact of disasters are indicated

A) Social

B) Economical

C) Social and economical

D) Social, economical and health

Ans. (D)

182. Present Value Index (PVI) =

A) Cash inflow – Cash outflow

B) $\frac{\text{Annual Return}}{\text{Investment}} \times 100$

C) $\frac{\text{Initial Investment}}{\text{Annual Return}}$

D) $\frac{\text{Present value of future cash inflow}}{\text{Present value of future cash outflow}} \times 100$

Ans. (D)

183. When rates are being fixed per unit quantity of each items of work and agreed by the contractor is called?

A) Lump sum contract

B) Lump sum and schedule contract

C) Unit rate contract

D) Service contract

Ans. (C)

184. Critical activity has

A) Maximum float

B) Minimum float

C) Zero float

D) Average float

Ans. (C)

185. Zero float for any activity means that the activity is

A) Super-critical **B)** Sub-critical

C) critical **D)** Not critical

Ans. (C)

186. What is the volume of cement required for $1m^3$ cement concrete with 1 : 5 : 10 proportion using 40 mm aggregate?

A) $0.095\ m^3$ **B)** $0.95\ m^3$

C) $0.475\ m^3$ **D)** $0.116\ m^3$

Ans. (A)

187. The administrative and technical head of each branch of engineering department

A) The Chief Engineer

B) The Superintending Engineer

C) The Minister

D) The Administrative Officer

Ans. (A)

188. Animation in construction management is a

A) Construction technology model

B) QC model

C) Simulation model

D) CPM model

Ans. (C)

189. The good planning of a civil engineering project depends on

A) Proper time keeping

B) Weather condition

C) Selection of huge number of labours

D) Proper design

Ans. (D)

190. The fundamental managerial functions which involves reviewing the difference between the schedule and the actual performance of the project

A) Project planning **B)** Project controlling
C) Project scheduling **D)** Project surveying

Ans. (B)

191. Calculate the quantity of plastering of wall (Two faces) having length as 4 m, and height as 3 m

A) 20 sq. m **B)** 24 sq. m
C) 18 sq. m **D)** 16 sq. m

Ans. (B)

192. Name the formula to calculate the volume of earthwork from contour plan for filling a depression or pond and for cutting a hillock

A) Trapezoidal formula
B) Prismoidal formula
C) Mean sectional Area method
D) Mid-sectional area method

Ans. (B)

193. Which of the following is known as general overhead ?

A) Losses on advance
B) Interest on investment
C) Travelling expenses
D) Aminity to the labour

Ans. (C)

194. The unit of measurement for Earthwork in hard soil is

A) m^2 **B)** Kg
C) m **D)** Cu. m.

Ans. (D)

195. What is the cement required in kg using thumb rule for cement mixture 1:6:1m^3?

A) 480 kg **B)** 360 kg
C) 288 kg **D)** 240 kg

Ans. (D)

196. The weight of one bag of cement is

A) 45 kg **B)** 50 kg
C) 60 kg **D)** 65 kg

Ans. (B)

197. Units of dimension for brick material in metric system is

A) Breadth **B)** Length
C) mm **D)** cm

Ans. (D)

198. The brick work is not measured in Cu.m in case of

A) One or more than one brick wall
B) Brick work in arches
C) Reinforced Brick work
D) Half brick wall

Ans. (D)

199. The quantity of wood for the shutters of the doors and windows is calculated in

A) m^2 **B)** lump-sum
C) m^3 **D)** m

Ans. (A)

200. What is the unit of measurement for 'half brick wall'?

A) Square metre **B)** Metre
C) Tonne **D)** Cubic metre

Ans. (A)

★★✦✦★★

CIVIL ENGINEERING

(Diploma Standard)

★ Construction Materials and Construction Practice

★ Hydraulics

★ Transportation Engineering

★ Surveying

★ Engineering Mechanics

★ Construction Management

★ Estimating and Costing

★ Environmental Engineering and Pollution Control

★ Mechanics of Structure

★ Structural Engineering

CONSTRUCTION MATERIALS & CONSTRUCTION PRACTICE

CONSTRUCTION MATERIALS

Introduction

The use of the construction materials depends on the nature and purpose of the structure to be built. There are many types of building materials used in construction such as Concrete, Steel, Wood and Masonry. Each material has different properties such as weight, strength, durability and cost which makes it suitable for certain types of applications.

The choice of materials for construction is based on cost and effectiveness to resist the loads and stresses acting on the structure.

Stones

- In many places, stones are more freely available than any building material. They are derived from rocks.
- The stones for construction works are obtained by quarrying rocks. Such stones are very irregular in shape and size. They are therefore dressed for proper bedding, thin joints and speedy construction. When such stones are laid with cement or lime mortar in a systematic manner, they form a structural mass which can resist load without disintegration.

Classification of Rocks

Rocks are classified into three types. They are,

1. Geological classification
2. Physical classification
3. Chemical classification

1. Geological Classification

According to this classification, rocks are of 3 types. They are:

1. Igneous rocks
2. Sedimentary rocks
3. Metamorphic rocks

- **Igneous Rocks :** Stones obtained from these rocks are very strong and durable. It is the result of cooling and consolidation of molten lava released from volcanoes. E.g. Granite, Basalt.
- **Sedimentary Rocks :** They are formed by gradual deposition of broken pieces of rocks which are disintegrated by atmospheric actions. It is transported from one place to another place and deposited at the bottom of rivers or lakes. These deposits harden due to water pressure. E.g. Limestone, Sandstone
- **Metamorphic Rocks :** Metamorphic rocks are a type of rock that have become changed by intense heat or pressure while forming. In the very hot and pressured conditions deep inside the Earth's crust, both sedimentary and igneous rocks can be changed into metamorphic rock. In certain conditions these rocks cool and crystallize into bands of crystals. Later they can become exposed on Earth's surface. The change in colour, structure and texture are due to either pressure or heat or both. Eg. Marbles, Slates.

2. Physical Classification

This classification is based on general structure of rocks. According to this classification, rocks are of three types. They are:

1. Stratified Rocks
2. Unstratified Rocks
3. Foliated Rocks

- **Stratified Rocks :** Sedimentary rocks are distinctly stratified rocks. They are formed by series of parallel layers. E.g. Limestone, Sandstone, Slates.
- **Unstratified Rocks :** Igneous and sedimentary rocks which are affected by movements of earth are of this type of rocks. They cannot be split into thin slabs. E.g. Granite, Marble.
- **Foliated Rocks :** These rocks have a tendency to split up in a definite direction. Such foliated structure is very common in metamorphic rocks. E.g. Gneiss.

3. Chemical Classification

This classification is based on their chief constituents. Chemically, rocks are of three types. They are :

1. Silicious Rocks
2. Calcareous Rocks
3. Argillaceous Rocks

- **Silicious rocks :** These rocks have silica or sand as their main constituent. They are hard and durable. E.g. Sand stone, Granite.
- **Calcareous Rocks :** These rocks have calcium carbonate as their main constituent. E.g. Lime stone, Marble.
- **Argillaceous Rocks :** In these rocks clay predominates. E.g. Slate, Laterite.

Uses of Stones

Stones are widely used in many permanent engineering works on account of their strength and durability. The principal uses of stone in construction are:

- As material for foundation
- As aggregate for concrete making
- As material for road construction
- As thin slabs for Pavings
- In Ornamental Works
- As Wall, Columns, Beams and Lintels in Buildings.
- Limestone for manufacture of cement
- As roofing tiles in the form of slates

Characteristics of Good Building Stones

Following are the characteristics of good building stone:

- **Crushing Strength :** For a good structural stone, the **crushing strength should be greater than 100 N/mm².**
- **Appearance :** The stones which are to be used for face work, should be decent in appearance and they should be capable of preserving their colour uniformly for a long time. The colour of the stones for face work should be chosen by keeping in mind the environmental condition of the surrounding area.
- **Durability :** A good building stone should be durable. The various factors contributing the durability of a stone are its chemical composition, texture, resistance to atmosphere and other influences, location of the structure, etc. The important atmospheric agency which affect the durability of a stone is alternate conditions of heat and cold due to difference in temperature.
- **Dressing of Stones:** Stones should be such that they can be easily carved, moulded out and dressed. Dressing of stones results in economy of construction.
- **Fracture :** For a good building stone, its fracture should be sharp, even, bright and clear with grains, well cemented together. A dull, chalkey and earthly fracture of a stone, reduces the life span of the building.
- **Hardness :** The co-efficient of hardness, as worked out in hardness test should be **greater than 17 for a stone to be used in road work. If it is between 14 and 17, the stone is said to be of medium hardness.**
- **Attrition :** In attrition test, if wear is more than 3%, the stone is not satisfactory. If it is equal to 3%, the stone is just tolerable.
- **Fire Resistance :** The minerals composing stone should be fire resistant in such a way that the shape is preserved when a fire occurs.
- **Seasoning :** The stones should be well seasoned before putting into use. The stones obtained freshly from a quarry, contain some moisture which is known as the quarry sap. The presence of this moisture makes the stone soft.
- **Specific Gravity :** For good building stone, the **specific gravity should be greater than 2.7 or so.**
- **Texture :** A good building stone should have compact, fine, crystalline structure free from cavities, cracks or patches of soft or loose material. These stones with such texture are strong and durable.
- **Water Absorption :** All the stones are more or less porous, but for a good stone, percentage of water absorption by weight s**hould not exceed 0.60 after 24 hours immersion in water.**

Crushing strength of common building stones

Name of Stone	Crushing Strength in N/mm²
Trap	300 to 350
Basalt	153 to 189
Granite	104 to 140
Slate	70 to 210
Marble	72
Sand stone	65
Lime stone	55
Laterite	1.8 to 3.2

Tests on Stones

To acertain the required properties of stones, the following tests can be conducted:

- crushing strength test
- water absorption test
- abrasion test
- impact test
- acid test.

Crushing Strength Test : For conducting this test, specimen of size 40 × 40 × 40 mm are prepared from parent stone. Then the sides are finely dressed and placed in water for 3 days. The saturated specimen is provided with a layer of plaster of paris on its top and bottom surfaces to get even surface so that load applied is distributed uniformly. Uniform load distribution can be obtained satisfactorily by providing a pair of 5 mm thick play wood instead of using plaster of paris layer. The specimen so placed in the compression testing machine is loaded at the rate of 14 N/mm² per minute. The crushing load is noted. Then crushing strength is equal to the crushing load divided by the area over which the load is applied. At least three specimen should be tested and the average should be taken as crushing strength.

Water Absorption Test : For this test cube specimen weighing about 50 grams are prepared and the test is carried out in the steps given below:

- Note the weight of dry specimen as W_1.
- Place the specimen in water for 24 hours.
- Take out the specimen, wipe out the surface with a piece of cloth and weigh the specimen. Let its weight be W_2.
- Suspend the specimen freely in water and weight it. Let its weight be W_3.
- Place the specimen in boiling water for 5 hours. Then take it out, wipe the surface with cloth and weigh it. Let this weight be W_4. Then,

Percentage absorption by weight

$$= \frac{W_2 - W_1}{W_1} \times 100 \qquad \text{..... (1)}$$

Percentage absorption by volume

$$= \frac{W_2 - W_1}{W_2 - W_3} \times 100 \qquad \text{..... (2)}$$

Percentage porosity by volume

$$= \frac{W_4 - W_1}{W_2 - W_3} \times 100 \qquad \text{..... (3)}$$

$$\text{Density} = \frac{W_1}{W_2 - W_1} \qquad \text{..... (4)}$$

$$\text{Specific gravity} = \frac{W_1}{W_2 - W_3} \qquad \text{..... (5)}$$

$$\therefore \text{ Saturation coefficient} = \frac{\text{Water absorption}}{\text{Total porosity}}$$

$$= \frac{W_2 - W_1}{W_4 - W_1}$$

Abrasion Test : This test is carried out on stones which are used as aggregates for road construction. The test result indicate the suitability of stones against the grinding action under traffic. Any one of the following test may be conducted to find out the suitability of aggregates:

1. Los Angeles abrasion test
2. Deval abrasion test
3. Dorry's abrasion test.

However Los Angeles abrasion test is preferred since these test results are having good correlation with the performance of the pavements.

Then Los Angeles value can be calculated as :

$$= \frac{\text{Weight of aggregate passing through sieve}}{\text{Original weight}} \times 100$$

The following values are recommended for road works:

For bituminous mixes – 30%

For base course – 50%

Impact Test : The resistance of stones to impact is found by conducting tests in impacting testing machine. It consists of a frame with guides in which a metal hammer weighing 13.5 to 15 kg can freely fall from a height of 380 mm.

Aggregates of size 10 mm to 12.5 mm are filled in cylinder in 3 equal layers; each layer being tamped 25 times. The same is then transferred to the cup and again tamped 25 times. The hammer is then allowed to fall freely on the specimen 15 times. The specimen is then sieved through 2.36 mm sieve. Then,

$$\text{Impact value} = \frac{W_2}{W_1}$$

where W_2 = weight of fines

W_1 = original weight.

The recommended impact values for various works are:

- ♦ for wearing course $\ngtr$ 30%
- ♦ for bituminous mechadam $\ngtr$ 35%
- ♦ for water bound mechadam $\ngtr$ 40%

Acid Test : This test is normally carried out on sand stones to check the presence of calcium carbonate, which weakens the weather resisting quality. In this test, a sample of stone weighing about 50 to 100 gm is taken and kept in a solution of one per cent hydrochloric acid for seven days. The solution is agitated at intervals. A good building stone maintains its sharp edges and keeps its surface intact. If edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate. Such stones will have poor weather resistance.

BRICKS

- ♦ Clay bricks were used by humans from very early dates. First, it was used without burning as sundried bricks. Burnt brick was a common building material among the Egyptians. Now a days, they are made from specially selected and matured brick earth. It is used to construct the building because of its good bearing capacity, long life and strength. Bricks are made up of blending a good clay, moulded to a rectangular shape of uniform size, dried and burned. As bricks are in uniform size they can be beautifully laid in masonry work.
- ♦ Bricks are obtained by moulding clay in rectangular moulds, then by drying and burning them. In places where stones are not easily available, bricks are used in construction. These are preferred because of its durability, strength, reliability, low cost, etc.

> - ♦ The earliest bricks were sun dried and made from mud.
> - ♦ It was used in 8000 BC in southern Turkey around the city of Jericho.
> - ♦ In Mesopotamia (modern Iraq) the first true arch of sun baked brick was made about 4000 BC.
> - ♦ Ceramic or fried (burned) bricks were used as early as 3000 BC in early Indus valley cities.

Size and Weight of Brick

- ♦ The Bricks are prepared in various sizes. The custom in the locality is the governing factor to decide the size of brick. Such bricks which are not standardised are known as traditional bricks.
- ♦ BIS has recommended the bricks of uniform size. Such bricks are known as Modular bricks. **The actual size of modular bricks is 190mm × 90mm × 90mm. With mortar thickness (10mm) the nominal size of modular brick is 200mm × 100mm × 100mm.**
- ♦ But practically to match with the beam width, a brick or block of width **230mm is used widely in construction industry. 115mm is considered for half brick. The brick of size 230 mm × 110mm × 110 mm or 230mm × 110mm × 76mm is generally used in construction industry.**
- ♦ **It is found that the weight of 1m³ of brick earth is about 1800 kg. Hence the average weight of brick will be about 3.0 to 3.5 kg.**
- ♦ The size of Indian brick, we are using is 228mm × 107mm × 69mm.

Brick Earth

Bricks are easily moulded from plastic clays also known as brick clay or brick earth.

- Hairpin bends should be avoided as far as possible. If unavoidable, they should be located on gentle hill slopes.
- The main object of a hill road is to gain elevation. Thus, alternate rise and fall should be avoided.
- Ridges should be crossed at the lowest elevation.

Road Network in India

The length of various categories of roads is as under:

- National Highways: 1,44,634 km
- State Highways: 1,86,908 km
- Other Roads: 59,02,539 km

National Highways play a very important role in the economic and social development of the country by enabling efficient movement of freight and passengers and improving access to market. MoRTH and its implementing agencies have implemented multiple initiatives in last 8 years to augment the capacity of the National Highway infrastructure in India.

As on 30 November 2022, the total length of National Highways in the country was 1,44,634 km. The pace of National Highways (NH) construction has increased consistently between 2014-15 and 2021-22 due to the systematic push through corridor-based National Highway development approach. In 2014-15, the pace of NH construction was about 12 km/ day which increased to about 29 km/ day in 2021-22.

Bharatmala Pariyojana : The Bharatmala Pariyojana was launched with the primary focus on optimizing the efficiency of the movement of goods and people across the country. The Phase I of the Bharatmala Pariyojana approved in October 2017, focuses on bridging critical infrastructure gaps through development of 34,800 km of National Highways. The Pariyojana emphasized on a "corridor based National Highway development" to ensure infrastructure symmetry and consistent road user experience. The key components of the Pariyojana are Economic Corridors development, Inter-corridor and feeder routes development, National Corridors Efficiency Improvement, Border and International Connectivity Roads, Coastal and Port Connectivity Roads and Expressways.

As part of Phase-I of the programme, 27 Greenfield corridors are planned with an overall length of 9,000+ kms. As a part of Bharatmala Pariyojana, India's largest expressway, i.e.,1,386 km long Delhi-Mumbai Expressway is being developed and some sections such as Delhi – Dausa (Jaipur), Vadodara – Ankleshwar sections of the Expressway are nearing completion. Other key corridors which have already been completed/nearing completion are Ambala – Kotputli Corridor & Amritsar – Jamnagar Corridor.

In Bharatmala Pariyojana, 60% projects on Hybrid Annuity Mode, 10% projects on BOT (Toll) Mode and 30% projects on EPC mode have been envisaged respectively.

Pradhan Mantri Gram Sadak Yojana : Pradhan Mantri Gram Sadak Yojana-I (PMGSY-I) was launched as a one-time special intervention to provide rural connectivity, by way of a single all-weather road, to the eligible unconnected habitations of designated population size as per Census 2001.

The scheme was launched on 25th December, 2000 to provide all-weather access to eligible unconnected habitations. The Pradhan Mantri Gram Sadak Yojana (PMGSY) phase 1 is a 100% Centrally Sponsored Scheme. For subsequent phases, the Union Government bears 90% of the project cost in respect of projects sanctioned under the scheme in North-Eastern and Himalayan States, whereas for other states the Union Government bears 60% of the cost.

PMGSY - Phase I:

PMGSY - Phase I was launched in December, 2000 as a 100 % centrally sponsored scheme.

Under the scheme, 1,35,436 habitations were targeted for providing road connectivity and 3.68 lakh km. for upgradation of existing rural roads in order to ensure full farm to market connectivity.

PMGSY - Phase II:

The Government of India subsequently launched PMGSY-II in 2013 for upgradation of 50,000 Kms of existing rural road network to improve its overall efficiency. While the ongoing PMGSY - I continued, under PMGSY phase II, the roads already built for village connectivity was to be upgraded to enhance rural infrastructure. The cost was shared between the centre and the states/UTs.

PMGSY - Phase III:

Phase III was approved by the Cabinet during July 2019. It gives priorities to facilities like:

Gramin Agricultural Markets (GrAMs) : GrAMs are retail agricultural markets in close proximity to the farm gate, that promote and service a more efficient transaction of the farmers' produce.

Higher Secondary Schools and Hospitals.

Under the PMGSY-III Scheme, it is proposed to consolidate 1,25,000 Km road length in the States. The duration of the scheme is 2019-20 to 2024-25.

Geometrical Design of Highway

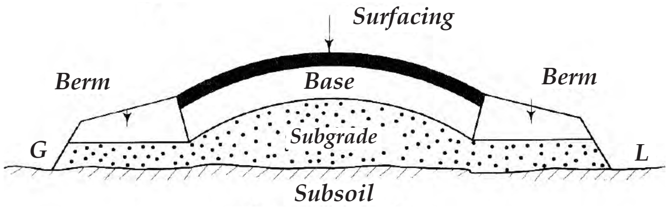
Road structure

Road structure consists of the following components as shown in the figure below :

- Sub soil
- Sub grade
- Base course
- Wearing course or Surface course
- Berm

Sub Soil:

This is the natural or prepared soil on which a road has to be formed which should be strong and stable to carry the road traffic and weight of road construction.



Cross section of road structure

Sub Grade:

The sub grade functions as a support to road surface and serves as a foundation. The life of a road primarily depends on the stability and dryness of sub grade. Therefore considerable attention should be paid in the preparation of the sub grade.

Base Course:

Base course is a layer made of granular material such as broken granite stone, natural gravel, and boulder stone. It is a layer immediately under the weaning course. It is an important structural part of the road. It should be strong enough to bear the loads of the traffic. The material in a base course must be of extremely high quality. It must be well compacted.

Functions of Base Course:

- It reduces the traffic stresses on the sub grade and protects it.
- Acts as a working platform for the construction of upper pavement layers.
- Acts as a drainage layer by protecting the sub grade from wetting up.
- Intercept the upward movement of water by capillary action.
- It acts as a separating layer between subgrade and surface course.

Wearing Course or Surface Course:

- Wearing course is the top most layer of a road which is in direct contact with the traffic. The purpose of the weaning course is to give a dense smooth riding surface with flexibility.
- It resists the pressure exerted by tyres and withstands wear and tear due to the traffic. It acts as a water tight layer and prevents percolation of water.

Right of Way

Right of way is the area of land acquired and reserved along its alignment for construction and development of a highway.

Land Width:

A minimum land width is prescribed for different categories of road. The below table gives the minimum width of right of way for different categories of road.

No.	Type of road	Plain and rolling terrain				Mountainous and steep terrain	
		Open areas		Built-up areas		Open areas	Built-up areas
		Normal (m)	Range (m)	Normal (m)	Range (m)	Normal (m)	Normal (m)
1.	NH and SH	45	30-60	30	30-60	24	20
2.	MDR	25	25-30	20	15-25	18	15
3.	ODR	15	15-25	15	15-20	15	12
4.	VR	12	12-18	10	10-15	9	9

Requirement of right of way

There are chances of developments along the route and when it becomes necessary to have the widening of road in future; it proves to be difficult and costly to acquire such developed lands along the boundary of road. Hence the appropriate width of land has to be acquired in the initial stage so that the road can be widened without serious difficulties when the occasion demands in future. The rights of ownership of road land are vested with the highway authority.

As a further precaution, restrictions are put up on the construction activities along the road and for this purpose, building lines and control lines are decided at suitable distance from the road boundary. The owner of land along highway route has to leave a certain set back or margin from road boundary and he can construct the building up to that line only in his plot. This line is known as building line.

A further set back in the form of control line has to be maintained by the private land owners along the highway route and the development between the portion covered by the building line and control line is restricted by the concerned highway authority.

The right of way mainly depends on the importance of road and it is decided in such a way that the following components of road are suitably accommodated:

- availability of funds;
- cost of acquisition of lands;
- drainage systems;
- height of embankment or depth of cutting;
- side slopes of embankment or cutting;
- visibility considerations on curves;
- width of formation;
- width of land required for future development; etc.

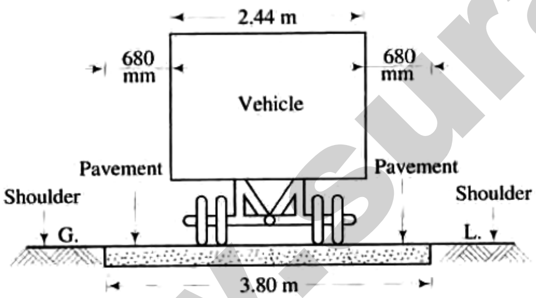
Width of Formation

The width of pavement or carriage way depends on the width of traffic lane and number of lanes. The carriage way intended for one line of traffic movement may be called as a traffic lane. The lane width is determined on the basis of the width of vehicle and the minimum side clearance provided for the safety. When the side clearance is increased, there is an increase in speed of the vehicles and hence in increase in the capacity of the pavement. **A width of 3.75 m is considered desirable for a road having single lane for vehicles** of maximum width 2.44 m. For pavement having two or more lanes, width of 3.5 m per lane is sufficient.

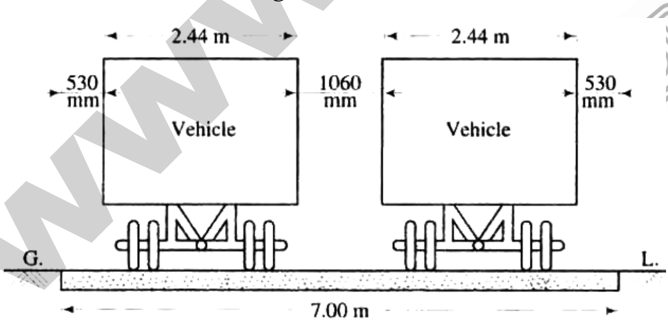
Widths of formation

Type of roadway	Formation width in (m)	
	Plain and rolling terrain	Mountainous and steep terrain
National and State Highways		
Single lane	12.00	6.25
Two lanes	12.00	8.80
Major district roads		
Single lane	9.00	4.75
Two lanes	9.00	–
Other district roads		
Single lane	7.50	4.75
Two lanes	9.00	–
Village roads Single lane	7.50	4.00

Road Classification and dimensions



Single lane road



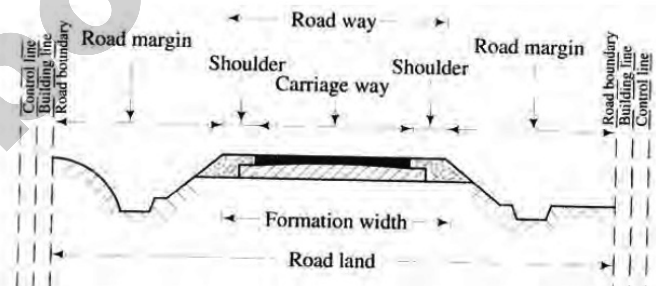
Two-lane road

Single and double lane Roadway

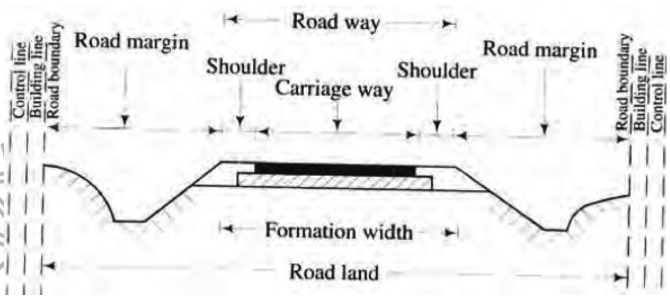
Class of Road	Width of the Carriage Way
Single lane	3.75m
Two lanes, without raised kerbs	7.0 m
Two lanes, with raised kerbs	7.5 m
Intermediate carriage way	5.5 m
Multilane pavement	3.5 m per lane

Shoulders : Shoulders are provided along the road edge to serve as an emergency lane for vehicles to be taken out of the pavement. These also act as service lanes for vehicles that have broken down. The minimum shoulder width recommended by the IRC is 2.5 m. The shoulders should have sufficient strength to support load even in wet weather. The surface of the shoulder should be rougher than the traffic lanes so that the vehicles are discouraged to use the shoulder as a regular traffic lane.

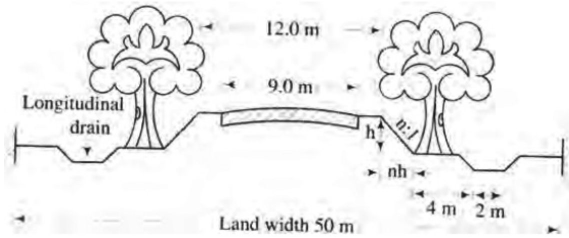
Cross Sections of Roads : The following figures shows the cross-section of road in embankment, cross-section of road in cutting, the typical cross-section of two-lane NH or SH in rural area, the typical cross-section of two-lane city road in Built up area. The carriage way intended for one line of traffic movement may be called a traffic lane. The pavement maybe of single lane, Two lane or multilane.



Cross section of road in cutting



Cross section of road in embankment



Cross section of two lane national highway

Road Camber :

Camber is the cross slope provided across the road to raise middle of the road surface to drain off rain water from road surface. The camber given is either a parabolic, elliptic or straight line shape in the cross section.

The objectives of providing camber are

- Surface protection of roads especially for gravel land bituminous roads
- Sub-grade protection by proper drainage
- Quick drying of pavement which in turn increases safety.

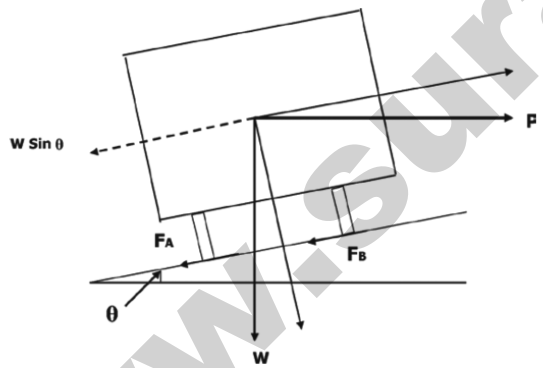
Camber is measured in 1 in n or n% (eg. In 1 in 50 or 2%) and the value depends on the type of the pavement and the amount of rainfall.

IRC Values for camber

Surface type	Heavy rain	Light rain
Concrete/Bituminous	2%	1.7%
Gravel/WBM	3%	2.5%
Earthen	4%	3.0%

Super Elevation

In order to counter act the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to inner edge, by providing a transverse slope throughout the length of the horizontal curve. This transverse inclination to the pavement surface is known as super elevation or cant or banking. The super elevation "e" is expressed as the ratio of the height of outer edge with respect to the horizontal width.



Super elevation is provided to counteract centrifugal force on moving vehicles at horizontal curves and it is calculated from the following formula:

$e = v^2/225\ R$

where, e = super elevation (%)

v = speed in km/hr

R = radius of curve in meters

Super elevation obtained from the above expression should, however be kept within limit mentioned below :

- Plain terrain - 7%
- Snow bound area - 7%
- Hilly area but not snow bound - 10%

Sight Distance

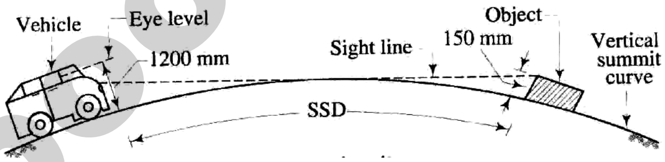
The safe and efficient operation of vehicles on the road depends very much on the visibility of the road ahead of the driver. Thus the geometric design of the road should be done such that any obstruction on the road length could be visible to the driver from some safe distance ahead so that the driver can stop the vehicle before the obstruction. This distance is said to be the sight distance.

Types of Sight Distance

Sight distance available from a point is the actual distance along the road surface, over which a driver from a specified height above the carriage way has visibility of stationary or moving objects. Three sight distance situations are considered for design:

Stopping Sight Distance (SSD) or The Absolute Minimum Sight Distance

Stopping sight distance (SSD) is the minimum sight distance available on a highway at any spot having sufficient length to enable the driver to stop a vehicle traveling at design speed, safely without collision with any other obstruction.



Intermediate Sight Distance (ISD)

It is defined as twice SSD

Overtaking Sight Distance (OSD) for safe overtaking operation

The overtaking sight distance is the minimum distance open to the vision of the driver of a vehicle intending to overtake the slow vehicle ahead safely against the traffic in the opposite direction. The overtaking sight distance or passing sight distance is measured along the center line of the road over which a driver with his eye level 1.2 m above the road surface can see the top of an object 1.2 m above the road surface.

Head Light Sight Distance

It is the distance visible to a driver during night driving under the illumination of head lights.

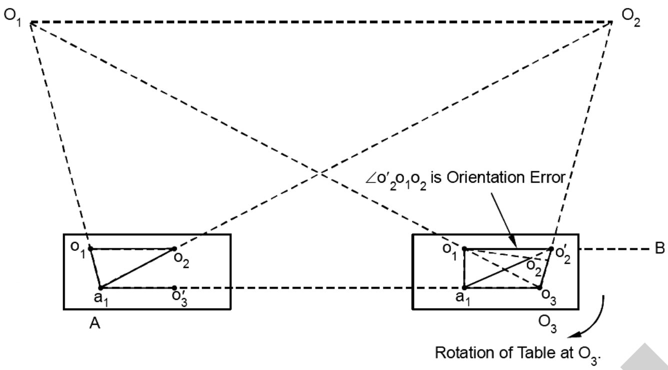
Safe Sight Distance to enter into an intersection

The most important consideration in all these is that at all times the driver traveling at the design speed of the highway must have sufficient carriageway distance within his line of vision to allow him to stop his vehicle before colliding with a slowly moving or stationary object appearing suddenly in his own traffic lane.

The computation of sight distance depends on:

1. Reaction time of the driver
2. Speed of the vehicle
3. Efficiency of brakes
4. Frictional resistance between the tyre and the road
5. Gradient of the road.

- The table is removed from A and set at O_3 with marked position of o_3 over O_3, properly levelled and similarly oriented. This is achieved by back sighting A from O_3.
- Now with table at O_3, keep alidade touching o_1 and sight O_1 and draw a back ray resecting the line a_1 o'_3 in o_3. Here o_3 is the point representing the station O_3 with reference to the approximate orientation made at A.
- With alidade touching o_3, sight O_2 and draw a ray to O_2. If the ray passes through the plotted point o_2, the orientation of the table is correct and o_3 is the correct position of O_3. Whereas, if this ray cuts the previously plotted line a_1o_2 at some other point, say o'_2, then the position o_3 is not the correct position of O_3.



Two-point problem

- The orientation error will be equal to $\angle o'_2o_1o_2$ between the lines o_1 o_2 and o_1 o_2'. This error can be eliminated by rotating the table through the angle $o_2'o_1o_2$. This table rotation can be achieved by taking the following steps.

(i) The alidade is placed along line o_1 o_2' and a ranging rod B is fixed in line with o_1 o_2', far away from the plane table.

(ii) Alidade is now kept along true line o_1 o_2 and table is rotated so that ranging rod B is bisected. The table is clamped in new position.

(iii) The true location of O_3 on map is now marked by:

(a) orienting alidade along o_1 O_1 and drawing the ray o_1 O_1, and

(b) orienting alidade along o_2 O_2 and drawing the ray o_2 O_2.

- The point of intersection of the two rays will give the correct position of O_3 (the new table position) on map.
- The new position of table station O_3 is, thus, correctly marked on map with the help of two previous table stations O_1 and O_2 already marked on map. The procedure followed is termed two-point problem in plane table survey.

Three-point Problem

The position of new plane table station on the map can be correctly located with the help of three well defined points on ground whose positions are already plotted on map. Such a procedure is called three-point problem. It is obvious that locating the position of table by this process is more accurate. However, it is more involved and complex.

Let there are three ground stations A, B and C whose positions are marked as a, b and c on the plan map and let these stations are visible from new table station O. It is required to plot the position of O on map as o. This can be achieved by any of the following methods :

(a) Mechanical

(b) Graphical

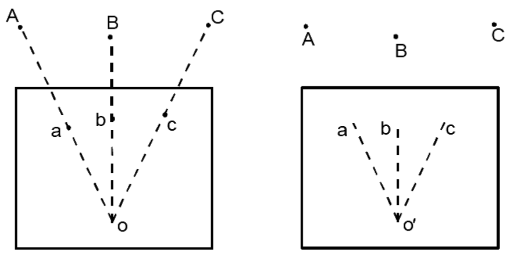
(c) Trial and Error

Mechanical or Tracing Paper Method

The process of mechanical method is applied using a tracing paper or cloth. The table is stationed, set and levelled at station O and is oriented as nearly as possible in its correct position either by visual judgment or by use of compass. A tracing cloth/paper is spread and stretched over the table. The position of O is guesstimated and fixed on the tracing to approximately locate the table station O on the map as o. With alidade centered at o, stations A, B and C are bisected and rays oa, ob and oc are drawn on the tracing. The tracing is then un-stretched and rotated until the three new drawn rays pass through plotted positions of a, b and c on the map. This will provide a new position of station O on map as o'. This is transferred to map by a pin of a fine needle point.

The alidade is then placed along o'a and station A is bisected by rotating the table and then clamping it in new position. Stations B and C are then sighted and rays drawn as check. The new rays shall pass through o' if new table orientation is correct. However, a small triangle of error may be formed as table orientation was only approximate.

The above process is then repeated by trial and error till the triangle of error vanishes.



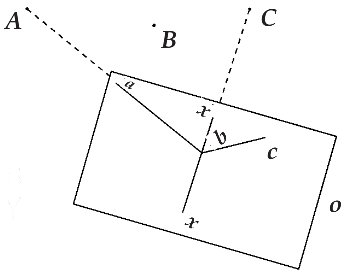
Mechanical or Tracing Paper Method

Graphical Method

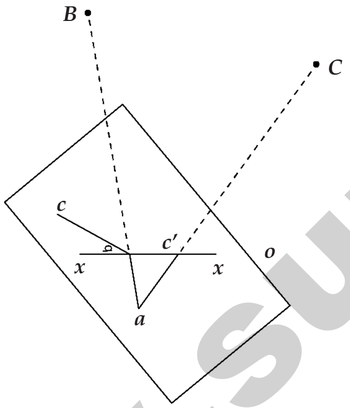
Several graphical methods are suggested to solve the three-point problem. However, the Bessel's solution is the most commonly used method in practice being the simplest. The Bessel's solution can be described in the following steps :

- The plane table is set up and levelled at new station O. The alidade is placed along known line (say ba on the map) and table is rotated until A is sighted with 'a' pointing towards A as shown in Figure below, clamp the table and sight C with alidade centered on b, draw a line *x–x* along alidade edge.

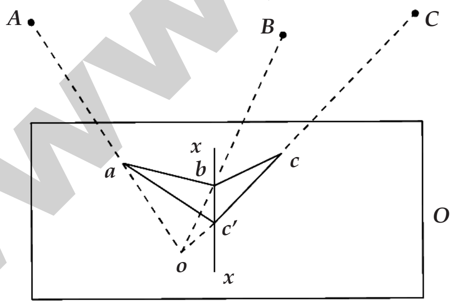
- The alidade is now placed along ab and table turned to bisect B with b towards B as in Figure below. Clamp the table and centre the alidade at a, bisect C by drawing the ray aC intersecting the previously drawn ray *x–x* at point c′ (say). Join cc′.
- Alidade is now placed along c′c as in Figure below and table turned till C is bisected and clamped in new position. The table is correctly oriented.
- The alidade is centered at b and B is bisected. Draw the ray to intersect cc′ in o. Similarly, if alidade is pivoted about a and A is sighted, the ray will pass through o if the process is accurate. Any minor error is corrected accordingly.



(a)



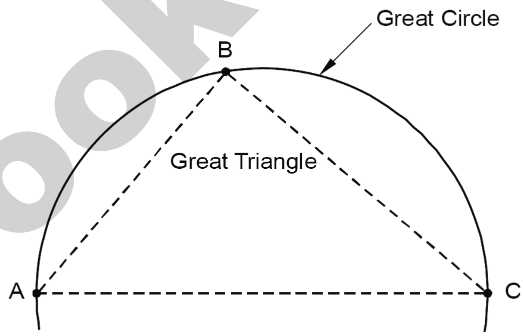
(b)



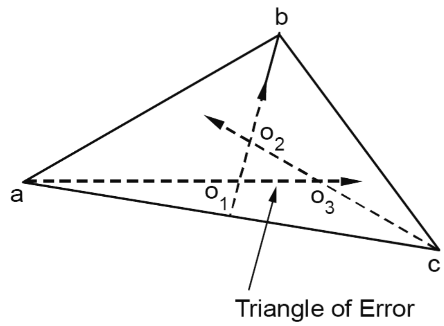
(c)

Trial and Error Method or Lehmann's Method

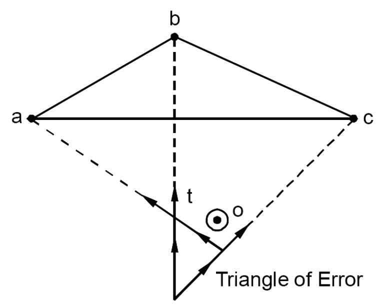
- This method is very commonly used in field and is quite quick and very accurate. The plane table is stationed, set and levelled at station O and is oriented as nearly as possible into correct position either by visual judgment or by use of compass.
- Rays Aa, Bb and Cc through plotted points a, b and c are drawn sighting stations A, B and C along aA, bB and cC respectively. If the table was oriented correctly to start with, all these rays will intersect at common point o on the map indicating correct position of station O. However, since the initial orientation was only approximate, a small triangle o_1 o_2 o_3 will be formed in place of a common point o. This triangle is called triangle of error and is shown in Figure below.
- This triangle is attempted to shrink to a point by trial and error, so that in final positions lines aA, bB and cC pass through a single point o. The process applied to achieve this object is known as Lehmann's rule. The triangle formed by joining stations A, B and C is termed great triangle while the circle passing through A, B and C as great circle.



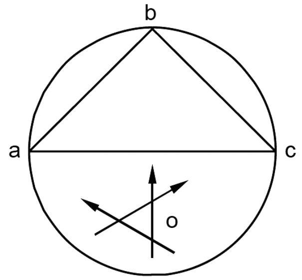
(a)



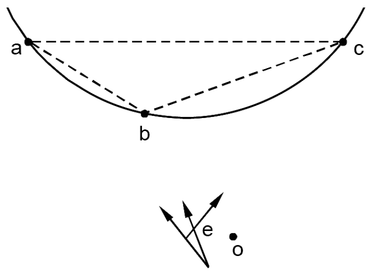
(b)



(c)



(d)



(e)

Lehmann's Rule

Lehmann's Rule

The Lehmann's rule can be stated as follow :

- The distance of true position of o from each of ray aA, bB and cC is proportional to the distance of O from ground stations A, B and C respectively.
- If we look in the directions of stations A, B or C, the true position of station O is on the same side of the three rays aA, bB or cC, i.e. if the table station O is outside the great triangle ABC, the triangle of error will be outside the triangle abc and o will be outside of abc. Similarly, if table station O is within the triangle ABC, the triangle of error will be inside abc and o will be inside the triangle of error.
- If the table station O is outside the great triangle but inside the great circle, the ray to middle station B, bB in Figure shown above lies between the true station position o and intersection of other two rays (i.e. aA and cC).
- When table station is outside the great circle, the table position O in Figure above is on the same side of ray towards most distant point (aA) as the intersection of other two rays, 'e'.

Using above rules, the triangle of error is sought to be shrunk to a point quickly. The first triangle of error is used to locate new trial position of O (say o_1) and placing alidade along o1 and the one of the known point (say a) and then rotating the table so that A is sighted. Clamping the table in new position, B and C are sighted and rays drawn. The new triangle of error is generated which is much smaller than the first triangle of error. New position of table station (say o_2) is marked using Lehmann's rules.

The process is repeated until all the rays aA, bB and cC intersect at single point o.

ERRORS IN PLANE TABLING

The main sources of errors in a plane table survey can be broadly classified as follows :

- Due to faulty instrument adjustments
- Due to quality of drawing paper used in map plotting
- Human errors of surveyor in centering and orienting the table
- Surveyor's error in observing and plotting.

Faulty Instrument Adjustments

The instrument, if not properly adjusted, will introduce many errors in plane table survey. These adjustments, which are normally required, their methods of testing and subsequently correcting must done with careful manner.

Quality of Drawing Paper

The drawing paper stretched on the plane table board for recording the survey details and plotting the plan shall be of good quality. The expansion, contraction and shrinking of paper due to temperature and moisture changes can cause errors in survey map reading even if it is prepared error free. The errors due to these can be minimized by using the plotted scale.

Surveyor's Errors in Table Setting

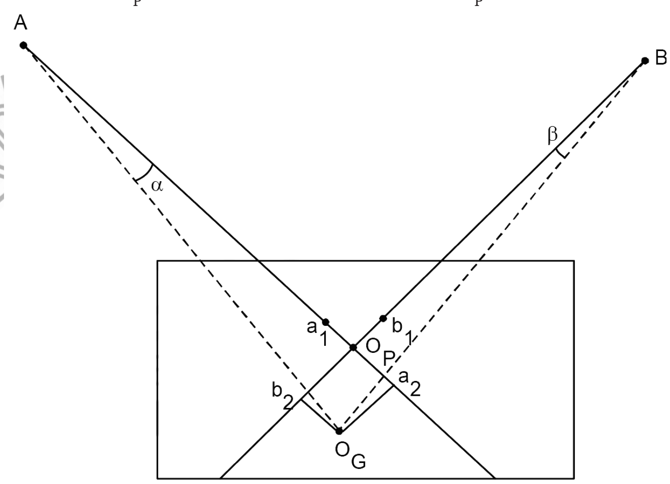
There can be primarily two types of errors which are :

(a) inaccurate centering of table, and

(b) inaccurate orientation of table.

Inaccurate Centering

- The position of instrumentation station on map shall be exactly over the station on ground it represents. The importance of accurate centering can be best emphasized by explaining the nature and impact of error on survey accuracy.
- Let O_G be the instrument station over which the instrument is required to be set up and O_P its plotted position on map plan as shown in Figure below. AO_GB is the desired angle to be plotted, while AO_PB is corresponding angle obtained by drawing rays AO_P and BO_P with alidade centered at O_P.



Effect of Inaccurate Centering

- The angular difference ($\angle AO_GB - \angle AO_PB$) represents the error introduced due to inaccurate centering. The magnitude of error will be inversely proportional to the distance of reference stations A and B from instrument station O_G. Instead of O_G and O_P being coincident, an angle α (= $\angle O_G AO_P$) is introduced and hence similarity an angle β (= $\angle O_G BO_P$) for station B. Let us also draw perpendiculars from O_G on ray O_PB at b_2 and on ray O_PA at a_2.

It can then be observed that

$$\sin\alpha = \frac{O_Ga_2}{O_GA}$$

$$\text{or,} \quad \alpha = \sin^{-1}\frac{O_Ga_2}{O_GA}$$

$$\text{and} \quad \sin\beta = \frac{O_Gb_2}{O_GB}$$

$$\text{or} \quad \beta = \sin^{-1}\frac{O_Gb_2}{O_GB}$$

The angular error $\angle AO_GB - \angle AO_PB$ would be equal to $\alpha+\beta$. It can also be observed that the position of A on the map marked as a_1 is not accurate. It will be some position 'a' on the map left of a_1. Similarly, the true position of B on the map represented by 'b' will be on the right of plotted position b_1. The deviations of positions of A and B would be $a_1a = \alpha \cdot a_1a_2$ and $b_1b = \beta \cdot b_1b_2$ respectively. These errors will depend on the scale of map chosen. Thus, if scale chosen is 1 cm on scale = n meters on ground, the plotted length

$$O_Pa_1 = \frac{AO_G}{n} \text{ cm}$$

$$\text{and} \quad O_Pb_1 = \frac{BO_G}{n} \text{ cms}$$

$$\text{Actual distance } aa_1 = \frac{AO_G}{n} \times \alpha \text{ cm} = e_1 (\text{say}), \text{ and}$$

$$\text{and} \quad bb_1 = \frac{BO_G}{n} \times \beta \text{ cm} = e_2 (\text{say})$$

Usually, during ploting, the maximum accuracy of plotting which can be achieved by even an experienced surveyor could be ¼ of a millimeter, i.e. (1/40) cm; hence deviation aa1 or bb_1 which could cause error in plotting would be noticeable only when it is equal to or more than (1/40) cm.

Thus, minimum value of $\frac{e}{n}$ to be noticed will be 1/40.

$$\text{or} \quad e = \frac{n}{40}$$

In other words, 'e' must not exceed n/40.

It can also be observed that normal size of the plane table is such that maximum area on drawing sheet used for plotting could be **100 cm × 60 cm.** Hence, in general, the perpendiculars OB_Ga_2 and O_Gb_2 cannot exceed 50 cm in *x*-direction and 30 cm in *y*-direction. From this, a table can be prepared for different length of sights to get an idea of angular error which can be introduced due to inaccurate centering.

Length of Sight (m)	Length of O_Ga_2 or O_Gb_2 (m)	Value of α or β	Angular Error $\alpha+\beta$
50	0.50	0°34´ 22.6″	1° 81′ 45.4″
100	0.50	0°17´ 11.3″	0° 34′ 22.6″
200	0.50	0°8´ 35.7″	0° 17′ 11.3″
500	0.50	0°3´ 26.3″	0° 6′ 52.5″
1000	0.50	0°1´ 43.1″	0° 3′ 26.3″

From the observations made above, it can be seen that if a smaller land area is being surveyed and plotted with scale factor 'n' of smaller magnitude, the error due to inaccurate centering of table will be more critical, the importance factor gradually decreasing with larger and larger values of n.

Inaccurate Orientation

When the table is set at new instrument station, the correct orientation is rather more important than correct centering. The position of instrument station should be accurately corresponding to its plotted position on the map. The survey details already plotted on the map from previous instrument stations can synchronize with details to be plotted on map from new instrument station only when the plane table is accurately centered and oriented in new position.

The correct orientation can be achieved by checking the orientation by two-point or three-point problem. Preferably the orientation of the table should be checked from as many stations as possible by sighting two distant and prominent reference stations which are already plotted on the map, thereby eliminating the triangle of errors. The orientation of table shall also be checked after observations, preferably after recording each observation to eliminate any chance rotation of table during the observation process due to improper clamping of table.

Surveyor's Error in Observing and Plotting

Human error can be introduced during observation and plotting of details by the surveyor. These could be due to

- objects not being sighted and bisected in sight vanes accurately,
- the centering of alidade on the desired station point on paper may not be accurate,
- the radiating ray towards the desired object may not be correctly drawn through the referred station point, and
- plotting of details may not be properly done or recorded.

DEPRECIATION	.....	₹ 25,000
INTEREST	.....	₹ 35000
TOTAL	.....	(₹ 1,20,000)
PROFIT BEFORE TAXES	.....	₹ 30,000
LESS : TAXES	.....	(₹ 9,000)
PROFIT AFTER TAXES	.....	₹ 21,000

It is to be noted that while the P&L Account gives cash flow from operations for a period, the Balance Sheet shows the position of assets and liabilities at a point of time. In practice, business is carried on both in cash and on credit. In such a situation, net profit will not equate cash inflow from operations. Computation of cash inflow will be, in that case, be made as illustrated below where certain items not involving movement of cash or payment outstanding out of receivables or payables have to be suitably adjusted from the Balance Sheet.

	Dec. 31, 2021	**Dec. 31,2022**
Debtors	₹ 50,000	₹ 47,000
Creditors	₹ 20,000	₹ 25,000
Outstanding expenses	₹ 1,000	₹ 1,200
Prepaid expenses	₹ 800	₹ 700
Income received in advance	₹ 300	₹ 250
Depreciation	-	₹ 7,500
Net profit for the year		₹ 1,20,000

Cash flow from operations out of above can be obtained as follows :

Cash Flow Statement

Sources (Decrease in Assets and Increase in Liabilities)

Net profit	₹ 1,20,000
Decrease in Debtors	₹ 3000
Increase in Creditors	₹ 5000
Increase in outstanding expenses	₹ 200
Decrease in prepaid expenses	₹ 100
Depreciation	₹ 7500
	₹ 15800
Total	₹ 1,35,800

Uses (Increase in Assets and Decrease in Liabilities)

Less : decrease in income received in advance (₹ 50)

Cash inflow from operations for the year 2022 ₹ 1,35,750

Cash Budget

Cash flow statement as a tool of the management does not give a step-by-step assistance in course of the year for which the needs to be broken up periodically in the form of a cash budget which is prepared in a manner as explained below :

Cash Budget

Particulars	**April 1998**	**May 2022**	**June 2022**
Opening Balance	₹ 20000	₹ 10000	₹ 36000
Receipt for Sales	₹ 60000	₹ 75000	₹ 50000
Sub-total	₹ 80000	₹ 85000	₹ 86000
Less : Cash Payments			
Purchases	₹ 40000	₹ 30000	₹ 40000
Wages	₹ 15000	₹ 14500	₹ 16000
Fund	₹ 10000	-	₹ 7000
Overhead	₹ 5000	₹ 4500	₹ 6000
Sub-total	(₹ 70000)	(₹ 49000)	(₹ 69000)
Closing Balance	₹ 10000	₹ 36000	₹ 17000

As shown earlier, cash flow for a period can be prepared from the, P&L Account after suitable adjustment for depreciation, non-tangible assets written off and other non-cash items. To this are added items like receipts from issue of shares, realisation from sale of assets, raising of' loans as sources of cash. Similarly, payment of loans, redumption of shares, purchase of assets, payment of dividends etc, are shown as application of cash.

Quality Control

Quality control and safety represent increasingly important concerns for project managers. Defects or failures in constructed facilities can result in very large costs. Even with minor defects, re-construction may be required and facility operations impaired. Increased costs and delays are the result. In the worst case, failures may cause personal injuries or fatalities. Accidents during the construction process can similarly result in personal injuries and large costs. Indirect costs of insurance, inspection and regulation are increasing rapidly due to these increased direct costs. Good project managers try to ensure that the job is done right the first time and that no major accidents occur on the project.

As with cost control, the most important decisions regarding the quality of a completed facility are made during the design and planning stages rather than during construction. It is during these preliminary stages that component configurations, material specifications and functional performance are decided. Quality control during construction consists largely of insuring conformance to these original design and planning decisions.

While conformance to existing design decisions is the primary focus of quality control, there are exceptions to this rule. First, unforeseen circumstances, incorrect design decisions or changes desired by an owner in the facility function may require re-evaluation of design decisions during the course of construction. While these changes may be motivated by the concern for quality, they represent occasions for re-design with all the attendant objectives and constraints. As a second case, some designs rely upon informed and appropriate decision making during the construction process itself. For example, some tunneling methods make decisions about the amount of shoring required at different locations based upon observation of soil conditions during the tunneling process. Since such decisions are based on better information concerning actual site conditions, the facility design may be more cost effective as a result.

Work and Material Specifications:

Specifications of work quality are an important feature of facility designs. Specifications of required quality and components represent part of the necessary documentation to describe a facility. Typically, this documentation includes any special provisions of the facility design as well as references to generally accepted specifications to be used during construction. Indian standard codes are list of codes used for civil engineers in India for the purpose of design and analysis of civil engineering structures such as buildings, dams, roads, railways, and airports. IS: 456 – code of practice for plain and reinforced concrete.

Quality Assurance as per ISO is defined as "all the planned and systematic activities, implemented within the organization for quality management, to provide adequate confidence that a product or service will satisfy given requirements for quality." Therefore, quality assurance is essentially a preventive activity and is therefore to be systematically planned in advance. The activity includes identification and planning of the checks, inspection and control of process as a part of quality control. Quality assurance also means establishment of a quality system which can demonstrate the requirements. Therefore, concept of quality assurance if not adopted over quality control by any organization, simple change of name will not lead to any improvement. Total Quality Management (TQM) is defined as "the management approach of an organization, centered on quality, based on the participation of all its members and aiming at long term success through customer satisfaction, and benefits to all members of the organization and to society." In fact, in this approach, customer is the person who accepts the product of any process. Suppose, cement is received by a person, then person receiving cement is customer. When cement is mixed with aggregate and concrete is produced in a mixer, the person receiving concrete at site becomes the customer and so on so forth. Thus, participation of all members is essential in TQM. Everybody must be involved, from all levels and across all functions. A culture of continuous improvement must be established.

Organization for Quality Assurance:

Both owner of the project (Department responsible for execution of work) and the contractor shall be responsible for quality of work. Roles and responsibilities of different engineers of the owner and contractor should be adequately predefined to ensure quality of work. The duties and responsibilities may vary from job to job, and should be laid down for each project and should be also part of the quality assurance plan.

Quality Assurance Engineer (QAE)

Quality Assurance Engineer shall remain responsible for all Quality Assurance and acceptance requirements of the project and will directly report to the Project Manager or project head. He will regularly supervise the activities of Asst. QA Engineer; QA Engineer will provide all necessary assistance to the construction team with reference to acceptance of all raw, manufactured, mixed materials used in the project. His responsibilities include the following:

- Preparation of Quality Assurance Plan.
- Providing inputs to Deputy Project Manager for preparation of work method statement.
- Setting up of field laboratories.
- Calibration of equipment.
- To maintain an effective documentation system for QA/QC throughout the project. To monitor and coordinate quality control activities on site.
- Ensure that tests are carried out as per relevant IS/applicable international code of practice.
- Maintain the test records for all the construction material/ Products used in the project.
- To verify the system for reporting and disposing non-conformance and corrective action requests.
- To perform internal quality audit on site in accordance with applicable procedure.
- Advising on, planning and organizing inspections, maintenance and repairs.

Types of Quality Control:

One of the most important tasks of the supervision during the execution of a construction work is technical quality control, i.e. control as to whether the materials and work supplied by the Contractor meet the technical requirements in the contract specifications. There are two types of quality control, which are described below:

Control of Methods: Method control is carried out by the field engineers whose job is to be on site and supervise the work of contractor during execution of the works. Method control is carried out according to the type of work. Where the work method is of considerable importance and requires constant supervision to achieve the quality, or where in some case, the quality is difficult to improve on, there should always be a field engineer on the site. Examples are concreting, water proofing, etc. Where work methods are of less importance or quality is constantly being achieved by the contractor, there may be no need for continuous surveillance. Examples are excavation etc.

Control of End-Results : End-result control includes field tests and a combination of field and laboratory tests. The frequency of end-result control depends on the quality parameters that are to be checked. Parameters which can vary considerably are continuously controlled. An example of this is the compaction control of earthworks where the achieved density is determined by means of a field test. As regards regulating laboratory tests the specification usually determines the number of tests. When the works are started and in cases where difficulties as regards compliance with quality requirements are encountered, laboratory testing will normally be intensified.

QUALITY AUDIT

Quality Audit - Objectives and Principles:

Audit is defined in ISO 9000-2015 as "Systematic, independent and documented process for obtaining objective evidence and evaluating it objectively to determine the extent to which audit criteria are fulfilled". The fundamental elements of an audit include the determination of the conformity of an object according to a procedure carried out by personnel not being responsible for the object audited. Audit criteria and audit evidence are defined as follows:

Audit criteria : Set of policies, procedures or requirements used as a reference against which the audit evidence is compared.

Audit evidence : Records, statements of fact or other information, which are relevant to the audit criteria and verifiable. The principles of auditing should ensure that an audit is an effective and reliable tool in support of management policies and controls, by providing information on which an organization can act in order to improve its performance. The principles as outlined in ISO:19011.2011 include the following: (i) Integrity, (ii) Fair presentation, (iii) Due professional care, (iv) Confidentiality, (v) Independence, (vi) Evidence-based approach.

DISASTER MANAGEMENT

Disaster is an event of nature or man-made which leads to sudden disruption of normal life society. It causes damage to life and property to a serious magnitude by which normal social and economic mechanisms available are insufficient to restore normally. World Health Organization defines 'disaster' as : **"Any occurrence that causes damage, economic disruption, loss of human life and deterioration in health and the health services on a scale sufficient to warrant an extraordinary response from outside and affected community or area". Hazard** and disaster are closely related. A hazard is a natural event while the disaster is its consequence. A hazard is a perceived natural event which threatens both life and property. A disaster is the culmination of such hazard.

Distinction Between Natural and Man Made Disasters

Disasters are classified under various groups when studied according to origin or from functional angle. Although both types of disasters (natural or man made) result in damage to life and property, their distinction can be identified by classifying into major groups :

NATURAL DISASTERS	*MAN MADE DISASTERS*
♦ Wind related – Storm, Cyclone, Tornado, Storm surge, Tidal waves ♦ Water related – Flood, Cloudburst, Flash flood, Excessive rains, Drought. ♦ Earth related – Earthquake, Tsunamis, Avalanches, Landslides, Volcanic eruptions	♦ Accidents : Road, Rail, Air, Sea, Building Collapse ♦ Industrial Mishaps : Gas leak, Explosion, Sabotage, Safety ♦ Fire : Building, Coal, Oil ♦ Forest Fire (In tropical countries, forest fires are often manmade) ♦ Contamination / Poisoning : Food, Water, Illiatliquor, Epidemics, Terrorist activities ♦ Ecological : Pollution (Air, Water, Noise), Soil degradation, Loss of Biodiversity, Global Warming, Sea level rise, Toxic Wastes, Nuclear accidents. ♦ Warfare : Conventional, Chemical, Nuclear

Tsunami

- A tsunami can kill or injure people and damage or destroy buildings and infrastructure as waves come forth and recede. A tsunami is a series of enormous ocean waves caused by earthquakes, underwater landslides, volcanic eruptions or asteroids. Tsunamis can travel 700-800 km per hour, with waves 10-30 meter high. It causes flooding and disrupts transportation, power, communications, and water supply. A killer Tsunami hit the south east Asian countries on the 26th of December, 2004. A massive earthquake with a magnitude of 9.1 - 9.3 in the Richter scale epicentre in the Indonesian island of Sumatra. It triggered one of the biggest Tsunamis the world had ever witnessed. The massive waves measuring up to 30 metres that killed more than 2,00,000 people of Asia. In India, over 10,000 people were killed by this disaster.
- Tamil Nadu alone accounted for 1,705 deaths. All the coastal districts were affected, Nagapattinam was the worst hit in the state of Tamil Nadu. Fishermen, tourists, morning walkers, children playing in beach and people living on the coast were unprepared for the waves. So they lost their life and the most of the loss of lives and damage to property was within 500 metres of the shore.
- After that the Indian government set up a Tsunami Early Warning System at Indian National Centre for Ocean Information Services (INCOIS), Hyderabad in 2007.

Riot

Thousands of people are killed in riots all over the world each year, and these riots erupt from a number of racial, religious, economic, political, or social causes that cannot be predetermined. As per Pew Research Center analysis of 198 countries on April 11, 2015. Syria tops in riot in the world followed by Nigeria, Iraq and India.

Fire

Wildfires occur when vegetated areas are set alight and are particularly common during hot and dry periods. They can occur in forests, grasslands, bush and deserts, and with blowing wind, can spread rapidly. Fires can lead to the destruction of buildings, wooden bridges and poles, power, transmission and telecommunication lines, warehouses containing oil products and other fuel. It causes injury to people and animals. The most common causes of fires are lightning strikes, sparks during arid conditions, eruption of volcanoes and man-made fires arising from deliberate arson or accidents.

A side-effect of wildfires which also threatens inhabited areas is smoke. Fires create large quantities of smoke, which can be spread far by wind and poses a respiratory hazard. On an average, in India, every year, about **25,000 persons die** due to fires and related causes. Female accounts for about 66% of those killed in fire accidents. It is estimated that about **42 females and 21 males die every day in India due to fire.**

FLOODS

Floods are high stream flows, which overlap natural or artificial banks of a river or a stream and are markedly higher than the usual flow as well as inundation of low land.

Types of floods

Flash floods : Such floods that occur within six hours during heavy rainfall.

River floods : Such floods are caused by Precipitation over large catchment areas or by melting of snow or sometimes both.

Coastal floods : Sometimes floods are associated with cyclone high tides and tsunami.

Causes of floods

- Torrential Rainfall
- Encroachment of rivers bank
- Excessive rainfall in catchment
- Inefficient engineering design in the construction of embankments, dams and canals

Effects of floods

- Destruction of drainage system
- Water pollution
- Soil erosion
- Stagnation of water
- Loss of agricultural land and cattle
- Loss of life and spread of contagious diseases.

Chennai flood – 2015 : Chennai is one of the largest metropolitan cities in India, which lies on the south eastern coast. The north east monsoon along with tropical cyclone hits Chennai every year and gives heavy cyclonic rainfall. In 2015, November and December due to heavy rain, the devastating floods that hit Chennai and other parts of Tamil Nadu claimed more than 400 lives and caused enormous economic damage. The Government of India and Tamil Nadu have taken a lot of action to reduce loss of life and minimize human sufferings.

Disaster Response

Disaster response entails restoring physical facilities, rehabilitation of affected population, restoration of lost livelihoods and reconstruction efforts to restore the infrastructure lost or damaged. The Response Phase focuses primarily on emergency relief : saving lives, providing first aid, restoring damaged systems (communications and transportation), meeting the basic life requirements of those impacted by disaster (food, water and shelter) and providing mental health and spiritual support and care.

First responders to disaster : On a daily basis, **police officers, firefighters, and emergency medical technicians** are a community's first responders, whether during fire, flood or acts of terrorism. Mental health professionals and the community's hospitals may also be activated in those early minutes and hours after disaster.

Disaster Management :

Disaster management includes Prevention, Mitigation, Preparedness, Response and Recovery. Disaster management involves all levels of government. Non-governmental and community based organizations play a vital role in the process. Modern disaster management goes beyond post-disaster assistance. It now includes pre-disaster planning and preparedness activities, organizational planning, training, information management, public relations and many other fields. Crisis management is important, but is only a part of the responsibility of a disaster manager. The traditional approach to disaster management has a number of phased sequences of action or a continuum. These can be represented as a disaster management cycle.

Disaster Management Cycle

- **Mitigation :** Minimizing the effects of disaster. Examples : building codes and zoning vulnerability analyses ; public education.
- **Preparedness :** Planning how to respond. Examples : Preparedness plans, emergency exercises / training, warning systems.
- **Response :** Efforts to minimize the hazards created by a disaster. Examples : Search and rescue ; emergency relief.
- **Recovery :** Returning the community to normal. Examples : temporary housing, grants, medical care.
- The Department of Ocean Development in Association CSIR Laboratories, has set up an Early Warning System for Tsunami and Storm Surges in the Indian Ocean.

$$= \frac{18 \times 10^5 \times 120}{24 \times 60 \times 60 \times 1000} = m^3 \text{ per second}$$

$$= 2.50 \, m^3 \text{ per second}$$

(2)W.W.F. $= Q = \frac{AIR}{360}$

$$= \frac{30000 \times 0.50 \times 15}{360} = 625 \, m^3 \text{ per second}$$

(2) Combined flow (Q) = DWF + WWF

$= 2.50 + 625 = 627.50 \, m^3/sec$

MINIMUM SIZE OF SEWER

Minimum size of sewers can be fixed depending upon the practice followed in the area. Normally the minimum size of sewer is 100 mm diameter for maximum length of 6 m. When the length of sewer is more, 150 mm is minimum diameter of sewer. It is desirable to lay duplicate sewer lines when sewer diameter exceeds above 3000 mm or so.

SHAPE OF SEWERS

The sewer sections are broadly classified into,

1. Circular sections
2. Non circular sections

Circular sections

Mostly circular in shape of sewer is used for all types of sewerage system. They are best suitable for diameter up to 1.5 m. Comparing to non-circular sections, they give least perimeter for a given area of flow and maximum hydraulic mean depth for running full and half-full conditions. They are very much useful in separate system, where the discharge is more or less constant.

Non-Circular sewer sections

These type of sewer sections are used in combined system. It gives more satisfactory velocity for both large and small flows. It has larger diameter and allows greater variations in flow.

Types

1. Standard Egg shaped sewer section
2. New egg shaped sewer section
3. Box or rectangular sewer section
4. Semi elliptical sewer section
5. Semi circular sewer section
6. Parabolic type sewer section
7. Horse shoe sewer section
8. Basket handle sewer section
9. U-shaped sewer section

MATERIALS USED FOR SEWERS

Based on cost, durability, resistance to abrasion and corrosion, strength and weight of the material, the following kinds are used.

- Asbestos cement sewers
- Brick sewers
- Cement concrete sewers
- Wooden sewers
- Cast-iron sewers
- Corrugated iron sewers
- Stoneware sewers
- Steel sewers
- Plastic sewers

Asbestos cement sewers

These are manufactured from a mixture of asbestos fibre and cement. They are available in sizes up to 900 mm diameter. It is light weight, easy to handle and durable against soil corrosion. They are easy to cut and join. The internal surface is smooth. They are brittle and cannot withstand impact forces.

Brick sewers

These are cast in sites. It is preferable for constructing large size combined sewers. It is particularly suitable for storm water drains. They are generally plastered on their outer surfaces so as to prevent the entry of tree roots and ground water through the brick joints and are lined with stone or ceramic blocks.

Cement concrete sewers

For small size sewers upto 600 mm diameter, plain concrete sewers may be used. Large sized cement concrete sewers may be reinforced. They can be prepared either at factory or at site. It should be free from cracks, fractures, etc., and of correct shape. It should give a clear ringing sound when struck with a hammer.

Wooden sewers

In olden days, wooden sewers were widely used. The construction and maintenance of wooden sewers are difficult. The life of wooden sewers is short and they are now rarely adopted as sewers.

Cast-iron sewers

Cast iron sewers are used when the sewers have to withstand high internal pressures and external loads. In valleys, where sewers are to be supported on piers, it is the most suitable type. They are strong enough to withstand the effects and vibrations. They are water tight and adopted under special circumstances.

Corrugated iron sewers

The corrugated iron sewers are used for storm sewers. They should be protected from the effects of corrosion by galvanizing or by bituminous coatings. It is made in varying metal thickness and in diameters upto 450 mm.

Stoneware sewers

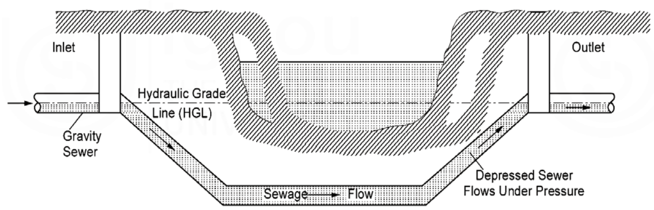
The stoneware sewers are also known as vitrified clay sewers. They are widely used for carrying sewage and drainage, house connections as well as lateral sewers. They are available in sizes of 50 mm increments from 100 to 300 mm and in 75 mm increments from 300 mm to 900 mm. They are however, rarely made in sizes bigger than 900 mm diameter. It is cheap, smooth, durable and strong enough to take the load of backfilling if laid properly. But, they are brittle and do not withstand high internal pressure.

Steel sewers

The steel sewers are mainly used at places where lightness, imperviousness and resistances to high pressure are required. They are flexible and absorb vibrations and shocks efficiently. They are generally used for main, out fall and trunk sewers. They are protected from corrosion by galvanizing or by bituminous coatings or by using special corrosion- resistant sewers.

INVERTED SIPHONS

An inverted siphon or depressed sewer is a sewer that runs full under gravity flow at a pressure above atmosphere in the sewer. Special feature of inverted siphon is that its profile is depressed below the hydraulic grade line. This is very useful when a sewer line has to be laid across a stream, a highway cut, or any other similar obstruction. When the profile laid below the ground, that portion of the sewer is known as inverted siphon (or, a depressed sewer).



An Inverted Siphon Carrying Gravity Flow under an Obstacle Along the Route

It is obvious that this section of sewer lies below the hydraulic grade line, flowing full and under pressure. In order to maintain appropriately higher velocities to disallow solids settling down in the sewer pipe, generally two or three different sizes of parallel pipes are provided to carry the minimum, average and peak flows. Since the siphon is subject to pressure, while flowing, ductile iron pipes or concrete encasement is provided in order to prevent leakage. The siphon may be constructed as a U shape with vertical or inclined legs.

True siphons are also used in sewerage practices depending upon the ground profile (topography). A true siphon is a sewer that flows full with the flow line above the hydraulic grade line, the pressure in the sewer being less than atmospheric.

Joints In Sewer Line

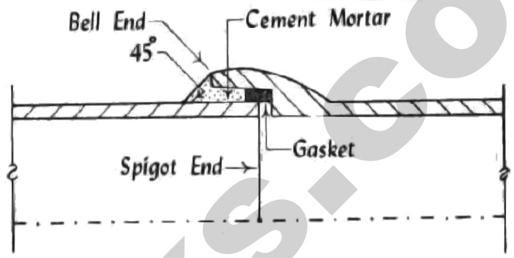
To make a continuous sewer line, joints are necessary. The pipe joint will be decided by considering the pipe material, internal pressure, external loads, etc. Depending upon the manner of making the joint, the joints classified as follows.

1. Cement mortar joints
2. Collar joints
3. Flexible or bituminous joints
4. Mechanical joints
5. Open joints

Cement mortar joints

In this type of joint, the cement mortar of proportion 1:1 or 1:2 is inserted between the space of bell end and spigot end. In order to maintain the alignment of sewers, the gaskets or packing pieces may be placed.

The mortar is filled in the annular space formed between bell and spigot ends and the joint is finished by applying cement mortar at an angle of about 450 on the outer face as shown in figure given below.



Cement mortar joint

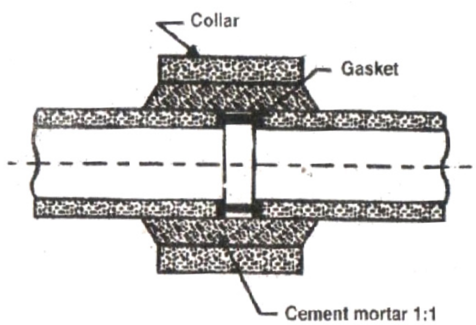
The cement mortar joints are widely used in the construction of sewers and they are found to be satisfactory.

However some of the difficulties encountered with this type of joints are as follows.

i. These types of joints are likely to be affected by corrosion.
ii. A subsequent movement in the joint results in the breakage of sewer joint.
iii. These types of joints require skilled workmanship for rigidly water tight.

Collar joints

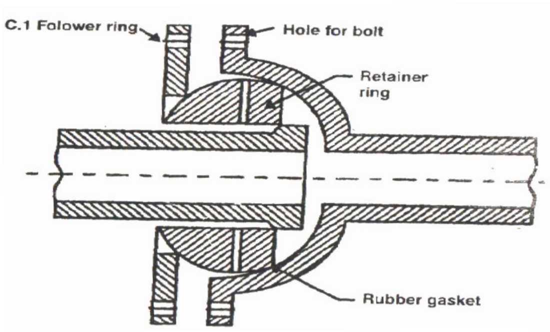
The ends of sewer are plain used in this type of joints. The ends of sewer are placed near each other and then a collar of slightly bigger diameter is placed over the ends of sewer. The annular space between collar and the ends of the sewer is then filled with CM 1:1. It is used for sewers of large diameters.



Collar joints

Flexible or bituminous joints

In this type of joint, the bitumen is used instead of cement mortar. These joints are flexible and they are adopted at places where there are chances of sewer settlement.



Flexible joints

Mechanical joints

In this type of joint, the mechanical devices such as rings, bolts, etc,. are used to keep the two ends of sewer together. Such type of joints is generally used for metallic sewer such as cast iron, steel, etc.

Open joints

In this type of joint, the ends of the sewer are placed together or in case of pipes with bell and spigot ends. Non filling materials are inserted in the annular space formed between bell and spigot ends. The open joints are adopted for the sewer passing through dry grounded. The joints are merely covered by tar paper or material like gravel to prevent the entry of earth particles in the sewer.

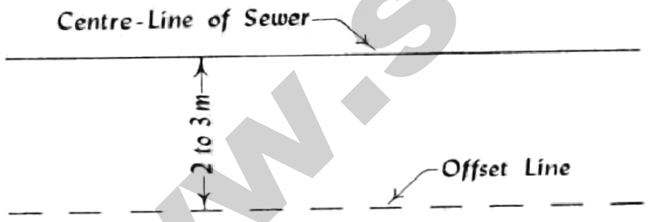
LAYING OF SEWER LINES

The following procedures are adopted for the laying of new sewer.

i) To know the nature of sub soil, trial holes or borings are dug along the proposed sewer line.

ii) The position of manholes are studied and located on the ground.

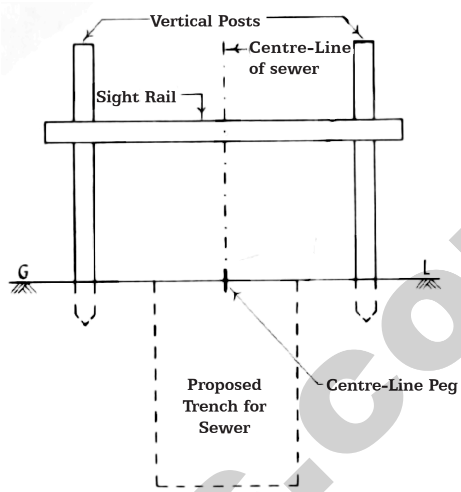
iii) The centre line pegs of the sewer line are driven at a distance of every 7.5 m to 15 m. The distance may be adjusted as per convenience.



iv) The center line of a sewer should be properly maintained by following the two methods.

1) In the first method, parallel line (offset) to sewer is marked at a distance of 2 m to 3 m. The offset helps in locating the sewer centre line when excavation is carried out to lay sewers.

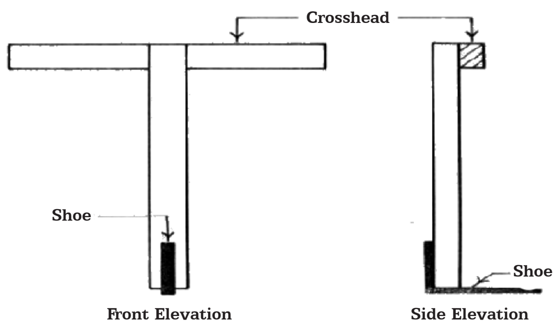
2) In the second method, two vertical posts are driven into the ground at a known distance from the centre line peg. One horizontal rail known as sight rail is fixed between these posts at a convenient height from the ground level as shown in Fig.



v) The modified levels of invert at each sight rail are given and these are marked on the sight rail. These levels may be marked by fixing nails on sight rails or the top the sight rails may be adjusted to the modified invert levels of sewer line. The modified levels of invert are obtained by adding a suitable vertical length to the invert levels mentioned on the longitudinal section. Thus, an imaginary line parallel to the proposed sewer line is obtained on the ground.

vi) Excavating trench is protected by timber on the sides. If necessary, dewatering is made in waterlogged area. The bedding layer of sewer line is required only for soft soil.

vii) The boning rod is used to check the invert levels of sewer in the process of construction. The boning rod consists of cross head at top and shoe at bottom are shown in Fig. The length of the rod is adjusted to the vertical length of trench. The verticality of boning rod is checked by using plump bob from top.



viii) The test for water tightness of joint is then carried out.

ix) The refilling of trenches is started after the sewer line is properly laid in position. The earth should be equally laid on either side of sewer and the filling should be carried out in layers of about 15 cm thickness. Each layer should be well watered and rammed.

TESTING OF SEWER LINES

1. Water Test

To test the water tightness of sewer line, water test carried out between two manholes is taken and the lower end of sewer line is provided with a plug.

In the manhole at upper end of sewer line, water is filled in and it is allowed to flow through the sewer line. The depth of water in the manhole is maintained at 150 cm. The sewer line is watched by moving along the trench and the joints which have sweated are repaired.

2. Obstruction Test

In this test, a smooth ball of diameter 13 mm less than the diameter of sewer bore is inserted at the high end of the sewer drain. In the absence of any obstruction, the ball rolls down at the invert of the pipe and emerges at the lower end.

3. Straightness Test

In this test, a mirror is placed at one end of the sewer line and a lamp is placed at the other end. If the pipe line is straight, the full section of the sewer is observed in the light. Otherwise this would be apparent. The mirror will also indicate any obstruction in the sewer barrel.

Ventilation of Sewer

Ventilation of sewer is necessary to avoid,

- Concentration of nuisance causing unpleasant odours.
- Accumulation of explosive and poisonous gases and vapours.
- Air locks.
- To relieve the air pressure above or below atmospheric pressure.

Methods of Ventilation

The following methods are adopted for ventilating sewers.

1. Proper construction of sewers
2. Proper design of sewers
3. Providing manholes with gratings
4. Providing ventilating columns or shafts
5. Providing manholes with chemicals
6. Providing unobstructed outlets
7. Providing forced draught

Proper Construction of Sewers

Sewers should be laid at such a gradient that will help in maintaining self-cleaning velocity in the sewer and preventing the chance of sewage staying at the point for a longer period.

Proper Design of Sewers

Always sewers are designed to run $\frac{1}{2}$ to $\frac{2}{3}$ full. The remaining space is reserved for the accumulation of gases. The proper design in sewers has the following advantages.

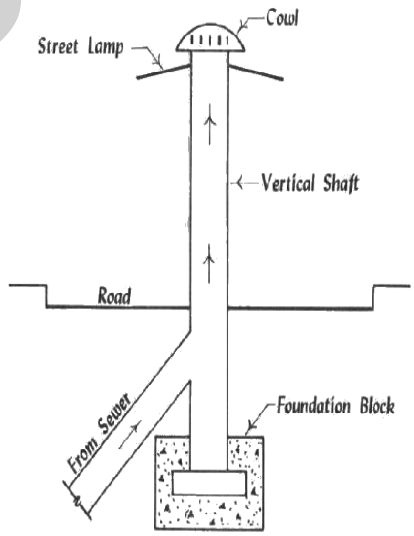
1. Minimize the corrosion of sewers.
2. Provide enough ventilation.
3. Avoid the pollution of underground water due to exfiltration.

Providing Manholes with Gratings

For the purpose of relieving the gases collected in the sewers, perforations are provided in the man hole cover. This method is very simple compared to other methods. But, it causes air pollution. This method is to be adopted in isolated places where air pollution does not cause any public nuisance. Unwanted things like sand, dust and storm water may also enter the sewer line through such manhole covers.

Providing Ventilating Columns or Shafts

To attain proper house drainage, the lateral sewers are ventilated independently at suitable places by ventilating shafts or columns. The diameter of ventilating column is preferably kept equal to $\frac{1}{3}$ of the diameter of sewer served by it. The ventilating column is placed at intervals of 60 to 150 m (take 100 m) apart and should be higher than the height of nearly structures. The top of ventilating columns should be covered with wired mesh called cowl to prevent anything directly falling into the pipe and to allow the escape of sewer gas.



Ventilating columns

Providing manholes with chemicals

In this method, the chemicals are placed in the manhole covers. These chemicals react with the sewer gases and make them harmless. This method is costly. Hence this method is rarely adopted.

Providing unobstructed outlets

In case of storm water drains, unobstructed outlets may act as ventilation in the sewers.

Providing forced draught

To expel out the foul gases from the sewer, forced draught is provided by exhaust fans.

(vii) Design torsion reinforcements at corners where two discontinuous edges meet.

Example 2 : Design a reinforced concrete slab for a room of clear dimensions 4 m × 5 m. The slab is supported all around on walls of width 300 mm. The slab has to carry a live load of 4 kN/m². and floor finish 1 kN/m². Use M20 concrete and Fe 415 steel. Assume corners are held down.

Thickness

Since $l_x > 3.5$,

$$\frac{l}{d} = 25 \text{ i.e., } d = \frac{l}{25} \text{ say } 160 \text{ mm}$$

$D = 180$ mm

Effective Span

Now $l_x = 4 + 0.16 = 4.16$ m

$l_y = 5 + 0.16 = 5.16$ m

$$\frac{l_y}{l_x} = \frac{5.16}{4.16} = 1.24 < 2$$

Hence two way slab is to be des igned.

Design Moment and Shear

Loads:

Self wt = 0.18 × 1 × 1 × 25 = 4.5 kN/m²	
Finishing	1 kN/m²
Live load	4 kN/m²
Total	9.5 kN/m²
Factored load	$w_u = 1.5 \times 9.5 = 14.25$ kN/m²

The slab is simply supported on all the four sides, (since it rests on walls). The corners are held down by providing torsional reinforcement. Hence moment coefficients are obtained from Table. (Table 26, IS 456), case 9:-

$$\alpha_x = 0.072 + 0.007 \times \frac{4}{10} = 0.0748$$

$$\alpha_y = 0.056$$

$$\therefore M_u = 0.0748 \times 14.25 \times 4.16^2 = 18.45 \text{ kN-m}$$

$$M_y = 0.056 \times 14.25 \times 4.16^2 = 13.81 \text{ kN-m}$$

$$V_u = 14.25 \frac{1.24^4}{1+1.24^4} \times \frac{4.16}{2} = 20.83 \text{ kN}$$

Design of Main Reinforcement

(i) Reinforcements in x - directions

$d = 160$mm.

$x_{u\,lim} = 0.48 \times 160 = 76.8$

$M_{u\,lim} = 0.36 \times f_{ck} \times b\, x_{u\,lim}\,(d - 0.42\, x_{u\,lim})$

$= 70.63 \times 10^6$ N-mm

$= 70.63$ kN-m.

$M_u < M_{u\,lim}$. Hence underre inforced section.

$$\therefore 18.45 \times 10^6 = 0.87 \times 415 A_{st} \times 160 \left[1 - \frac{A_{st}}{1000 \times 160} \times \frac{415}{20}\right]$$

$$319.38 = A_{st}\left[1 - \frac{A_{st}}{7710.84}\right]$$

$$\therefore A_{st}^2 - 7710.84 A_{st} + 319.38 \times 7710.84 = 0$$

$$A_{st} = \frac{7710.84 - \sqrt{7710.84^2 - 4 \times 319.38 \times 7710.84}}{2}$$

$= 333.83$ mm²

Using 10 mm bars,

$$\text{Spacing} = \frac{\pi/4 \times 10^2}{333.83} \times 1000 = 235.3 \text{ mm}$$

Hence provide 10 mm bars at 225 mm c/c.

(ii) Reinforcements in y-directions

These reinforcements will be placed above the reinforcements in x-direction. Hence in these case

$d = 160 - 8 = 152$ mm

From the relation,

$$M_u = 0.87 f_y . A_{st} . d \left[1 - \frac{A_{st} f_y}{b.d.f_{ck}}\right] \text{, we get}$$

$$13.81 \times 10^6 = 0.87 \times 415 A_{st} \times 152 \left[1 - \frac{A_{st}}{1000 \times 152} \times \frac{415}{20}\right]$$

$$251.64 = A_{st}\left[1 - \frac{A_{st}}{7325.30}\right]$$

$$A_{st}^2 - 7325.30 A_{st} + 251.64 \times 7325.30 = 0$$

$$A_{st}^2 = \frac{7325.30 - \sqrt{7325.30^2 - 4 \times 251.64 \times 7325.30}}{2}$$

$= 260.9$ mm²

Using 8 mm bars, spacing,

$$S = \frac{\pi/4 \times 8^2}{260.9} \times 1000 = 192.7 \text{ mm}$$

Provide 8 dia bars at 190 mm c/c.

It satisfies the prescribed maximum spacing clauses (i.e., 3 × d or 300 mm whichever is less)

Check for Shear

$$\tau_v = \frac{V_u}{bd} = \frac{20.83 \times 1000}{1000 \times 160} = 0.130$$

$$p_t = \frac{\pi/4 \times 10^2 \times 100}{225 \times 160} = 0.218$$

Permissible basic $\tau_c = 0.33$ N/mm²

Enhancement factor for slab of 180 mm thickness is 1.24 (Clause 40.2.1.1)

∴ Permissible shear = 0.33 × 1.24 = 0.409 N/mm²

$$\tau_{c\,max} = \frac{1}{2} \times 2.8 = 1.4 \text{ N/mm}^2$$

Thus $\tau_v < \tau_c$ and $< \tau_{c\,max}$

Hence shear reinforcements are not required.

Check for Deflections Criteria

$$\frac{L}{d} \text{ provided} = \frac{4.16 \times 1000}{160} = 26$$

$$\text{Basic } \frac{L}{d} = 20,\ P_t = 0.218,$$

$$f_s = 0.98 \times 415 \times \frac{A_{st}\text{ reqd}}{A_{st}\text{ provided}} = 240$$

$\therefore$ $F_1 = 1.60$

$\therefore$ $\frac{L}{d}\text{ max} = 20 \times 1.6 = 32$

Thus $\frac{L}{d}$ provided $<$ $\frac{L}{d}$ max.

$\therefore$ Deflection control is satisfactory.

Torsional Reinforcement at Corners

$$\text{Size of mesh} = \frac{l_x}{5} = \frac{4.16}{5} = 0.832\text{ m} = 832\text{ mm.}$$

$$\text{Size of wall} = 300\text{ mm}$$

$\therefore$ Provide mesh of size 300 + 832 = 1100 mm with side cover of 30 mm.

Area of torsional reinforcement

$$\frac{3}{4} \times 333.83 = 250.05\text{ mm}^2.$$

Using 8 mm bars

$$S = \frac{\pi/4 \times 8^2}{250.05} = 1000 = 201\text{mm c/c}$$

$\therefore$ Provide 8 mm mesh of 200 mm c/c.

Reinforcement in Edge Strip

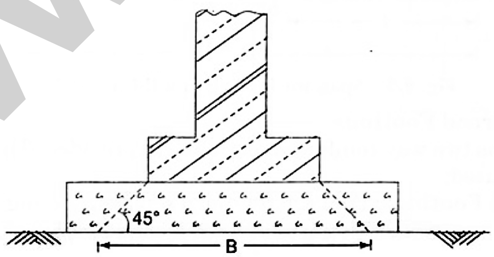
$$A_{st} = \frac{0.12 \times 1000 \times 180}{1000} \times 216\text{mm}^2$$

$$S = \frac{\pi/4 \times 8^2}{216} = 1000 = 232.\text{ Provide 8 mm @ 225 c/c.}$$

ISOLATED COLUMN FOOTINGS

Footings of walls and columns transfer the load of superstructure to soil. The footing may rest on soil directly or may transfer the load through piles. Load bearing capacity of masonry or concrete walls and columns is much higher than that of soil. Hence they can not be made to rest directly on the soil. The load from superstructure is to be spread to wider area so that load on soil is within the safe bearing capacity of the soil. The footing does this job of spreading the load over wider area. In doing this job, the footing itself is subjected to bending moment and shear force.

Footing may be of masonry. plain concrete or of R.C.C. In case of plain concrete footings the dispersion angle of load is 45° as shown in Figure below.



Dispersion in plain concrete footing.

TYPES OF R.C.C. FOOTINGS

There are mainly two types of footings

(a) One way reinforced footings

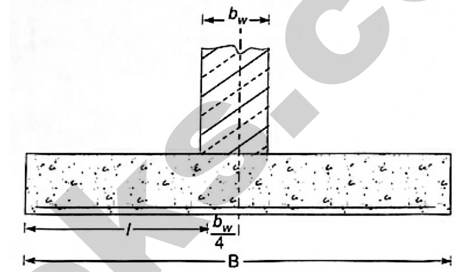
(b) Two way reinforced footing

(a) One Way Reinforced Footings

These footings are for walls. In case of masonry walls footing, the footing may be designed as a cantilever of span

$$l = \frac{B}{2} - \frac{b_w}{4}$$

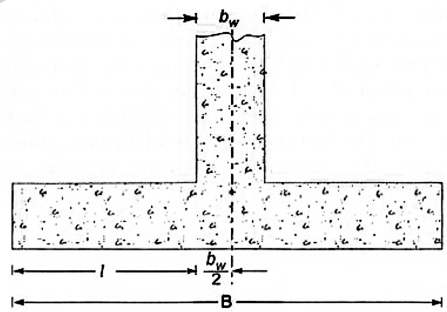
where B is the width of footing and b_w is width of wall as shown in Figure below.



Span for footing of a masonry wall.

In case of concrete walls, the footing is designed as a cantilever of span.

$l = \frac{B}{2} - \frac{b_w}{2}$, as shown in Figure below.

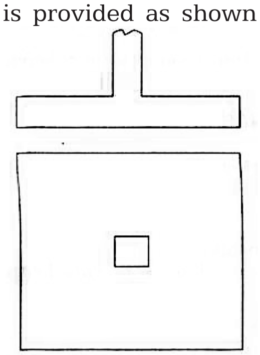


Span for footing of a R.C.C. wall.

(b) **Two Way Re inforced Footings**

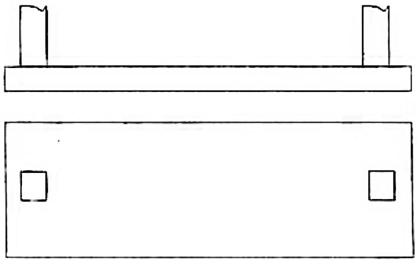
For all R.C.C. columns two way reinforced footings are provided. The following types of the footings are commonly used:

(i) **Isolated Column Footings:** For each column a separate footing is provided as shown in Figure below.



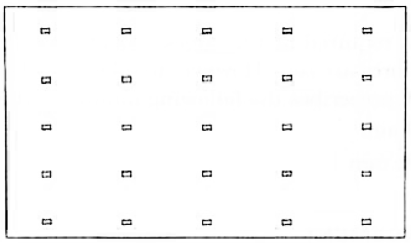
Isolated column footing.

(ii) **Combined Footings:** Common footing may be provided for two columns. This type of footing is usually preferred when the column is very close to boundary of the property and hence there is no scope to project footing much beyond the column face. Such footing is shown in Figure below.



Combined footing.

(iii) **Raft Foot ing:** If the load on the columns is quite high or when SBC of soil is low, the sizes of isolated columns may work out to such extent that the footings of adjacent columns overlap. In such cases for all columns a common footing may be provided as shown in Figure below. Such footings are known as raft footing.



Raft footing.

LOAD FOR FOUNDATION

The loads to be used to determine the size of the footings should be on the serviceability conditions and not on the limit state of collapse conditions. Thus for

(a) Dead load plus imposed case, 1.0 DL + 1.0 IL

(b) Dead load plus wind load case, 1.0 DL + 1.0 WL

(c) Dead + Imposed + Wind load case, 1.0 DL + 0.8 DL + 0.8 WL

10 per cent of load from column may be taken as self weight of footing for determining the area of footing required. However it is to be noted that self weight directly get transferred to soil without creating any bending moment and shear force in the footing.

In case of multistory buildings, one should take advantage of the allowable reduction in the live load for residential and office buildings.

DEPTH OF FOOTING

Rankine's formula is used to determine the minimum depth of foundation. The formula is as given below:

$$h = \frac{p}{w}\left[\frac{1-\sin\phi}{1+\sin\phi}\right]^2$$

where h = minimum depth
p = safe bearing capacity
w = unit weight of soil and
ϕ = angle of friction of soil

COVER

If plain concrete bed is provided, the minimum cover to main reinforcement shall be 50 mm. If plain concrete bed is not provided minimum cover to main reinforcement shall be 75 mm.

MINIMUM THICKNESS

Theoretically, the thickness required at the edges of footings is zero, since, at free edge the bending moment and shear force are zero. However to take care of accidental situations and the requirement of cover. IS 456 prescribes the following minimum thickness:

For footings on soil- 150 mm

For footings on piles - 300 mm

MINIMUM REINFORCEMENT

The minimum reinforcement described for slab and beams are applicable for footings also. Minimum diameter of bar to be used is 10 mm.

DESIGN OF ISOLATED COLUMN FOOTINGS SUBJECTED TO AXIAL LOADS

Isolated column footings are usually square or rectangular shape. They may have uniform thickness throughout or may have sloping top. The design procedure for footings is explained below.

Example 1 : Design a square footing for a short axially loaded column of size 300 mm × 300 mm carrying 600 kN load. Use M20 concrete and Fe 415 steel. SBC of soil is 180 kN/m². Sketch the details of reinforcement.

Solution.

1. Size of footing:

$$P = 600\text{kN}$$

$$\text{Self weight} = \frac{600}{10} = 60 \text{ kN}$$

$$\therefore \text{Total load} = 660 \text{ kN}$$

$$\text{SBC} = 180 \text{ kN/m}^2$$

$\therefore$ Area offooting

$$A = \frac{660}{180} = 3.667 \text{ m}^2$$

$\therefore$ Size of footing = 1.91 × 1.91 m

Provide 2 m × 2 m footing

2. Soil reaction for the facto red load:

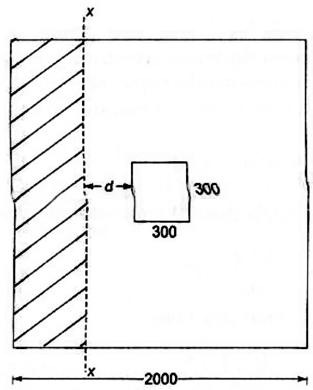
$$q_u = \frac{15P}{B\times B} = \frac{1.5\times 600}{2\times 2} = 225 \text{ kN/m}^2$$

$$= 0.225 \text{ N/mm}^2$$

3. Depth of footing:

From the consideration of shear, depth will be found and checked for two way shear and bending.

The critical section is at a distance 'd' from the face of the column as shown in Figure below.



V_u = Soil pressure from shaded area

$$= q_u B\left(\frac{B-b}{2}-d\right)$$

$$= 0.225\times 2000\left(\frac{2000-300}{2}-d\right)$$

$= 450[850 - d]$

Assuming 0.2% steel, for M20 concrete

τ_c = 0.32 N/mm^2

∴ Minimum depth required is

$0.32 \times 2000 \times d = 450\,[850 - d]$

d = 351 mm

provide d = 360 mm

Cheek for bending:

$M_{u\,lim} = 0.36 f_{ck}\, B\, x_{u\,lim}\,(d - 0.42\, x_{u\,lim})$

$$= 0.36 f_{ck} B \frac{x_{u\,lim}}{d}\left(1-\frac{0.42 x_{u\,lim}}{d}\right)d^2$$

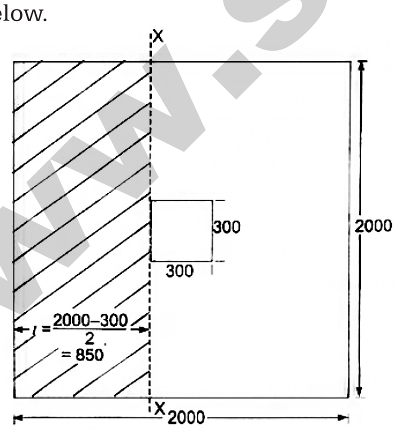
$$\frac{x_{u\,lim}}{d} = 0.48$$

∴ $M_{u\,lim} = 0.138 f_{ck}\, bd^2$

$M_{u\,lim} = 0.138 \times 20 \times 2000 \times 360^2$

$= 715.39 \times 10^6$ N-mm

M_u is to be calculated at the face of the column as shown in Figure below.



M_u = Moment of force under shaded area about section $x - x$.

$$= q_u \frac{(B-b)^2}{8}$$

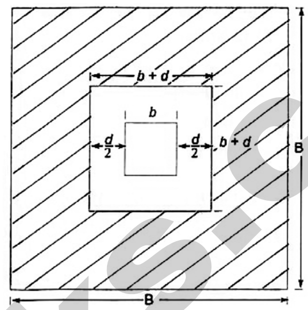
$$= 0.225\times 2000\frac{(2000-300)^2}{8}$$

$= 162.563 \times 10^6$ N-mm $< M_{u\,lim}$

∴ Depth provided is sufficient.

Check for two way shear :

Critical section is at a distance $\frac{d}{2}$ from the face of column as shown in Figure below.



∴ Perimeter of critical section

= 4 (b + d) = 4 (300 + 360) = 2640 mm

∴ Area of critical section = 2640 d = 2640 × 360

∴ Two way shear stress

$$= \frac{\text{Upward pressure in shaded area}}{\text{Area of Critical Section}}$$

$$= \frac{0.225(2000\times 2000 - 660\times 660)}{2640\times 360}$$

= 0.844 N/mm^2

Maximum shear stress permitted

$$= 0.25\sqrt{f_{ck}} = 0.25\sqrt{20}$$

= 1.118 N/mm^2

∴ Depth of 360 mm is sufficient from the consideration of two way shear.

Step 4:

$M_u = 162.563 \times 10^6$ N-mm over a width of 2000 mm

$$162.563\times 10^6 = 0.87\times 415\times A_{st}\times 360\left[1-\frac{A_{st}}{2000\times 360}\times\frac{415}{20}\right]$$

$$1250.7 = A_{st}\left[1-\frac{A_{st}}{34699}\right]$$

$$A_{st}^2 - 34699 A_{st} + 1250.7\times 34699 = 0$$

$$\therefore\ A_{st} = \frac{34699-\sqrt{34699^2 - 4\times 1250.7\times 34699}}{2}$$

= 1299 mm^2

Using 12 mm bars, spacing

$$S = \frac{\pi/4 \times 12^2}{1299}\times 2000$$

[since above area is required in 2000 mm width]

= 174 mm

Solution

Step 1 : Properties of I-section

HB 350, @ 0.674 kN/m section is used as a stanchion.

From steel section tables, the geometrical properties of the section are as follows :

Sectional area A = 8591 mm^2

Radius of gyration r_{xx} = 149.3 mm

Radius of gyration r_{yy} = 53.4 mm

Step 2 : Slendernes ratio, r_{min} = 53.4 mm

Unsupported length l = 4 metres

Slenderness ratio of the stanchion

$$\frac{l}{r_{min}} = \left(\frac{4 \times 1000}{53.4}\right) = 75$$

Step 3 : Safe load

From IS : 800–1984 for $\frac{l}{r}$ = 75.0, and the steel having yield stress, f_y = 260 N/mm^2, allowable working stress in compression

σ_{ac} = 109 N/mm^2 (MPa).

The safe load carrying capacity of the stanchion

$$P = (\sigma_{ac} - A) = \left(\frac{109 \times 8591}{1000}\right) = 936.42 \text{ kN}$$

DESIGN OF STEEL BEAMS

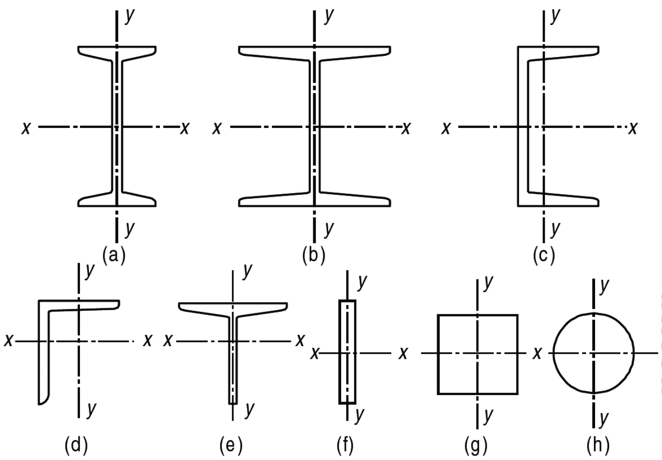
A beam is defined as a structural member subjected to transverse loads. The plane of transverse load is parallel to the plan of symmetry of the cross-section of the beam and it passes through the shear centre, so that the simple binding occurs. The transverse loads produce bending moments and shear forces in the beam at all the sections of the beam.

The term joist is used for beams of light sections. Joists support floor construction; they do not support other beams. The term subsidiary beam or secondary beam is also used for the beam supporting floor construction. Main beams are supporting joists for subsidiary beams: these are called floor beams in buildings. The term girder is most commonly used in buildings. Any major beam in a structure is known as a girder.

In the roof trusses, horizontal beams spanning between the adjacent trusses are known as purlins. The beams resting on the purlins are known as common rafter or simply rafters. In the buildings the beams spanning over the doors, windows and other opening in the walls are known as lintels. The beam at the outside wall of a building, supporting is share of the floor and also the wall up to the floor above it are known as spandrel beams. The beams framed to two beams at right angle to it, and usually supporting joists on one side of it; used at opening such as stair wells are known as headers. The beam supporting the headers is termed as trimmers. The beam supporting the stair steps are called as stringers. In the bridge floors, the longitudinal beams supported by the floor beams are also called as stringers. In the mill buildings, the horizontal beams spanning between the wall columns, and supporting wall covering are called as girts.

The beams are also called simply supported; overhanging cantilever, fixed and continuous depending upon nature of supports and end conditions.

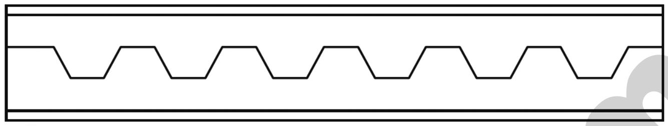
The rolled steel I-sections, channel, sections, angle sections, tee-sections, flat sections and bars as shown in the figure below are the regular sections, which are used as beams. The rolled steel I-sections as shown in the Fig. below are most commonly used as the beams, and as such these sections are also termed as beam sections. The rolled steel I-sections are symmetrical sections. In these sections, more material is placed near top and bottom faces, i.e., in the flanges as compared to the web portion. The rolled steel I-sections provide large moment of inertia about *xx*-axis with less cross-sectional area. The rolled steel I-sections provide large moments of compared to the other sections and such as these are most efficient and economical beams sections. The rolled steel wide flange beams as shown in Fig. below provide additional desirable features. As the name indicates, the flanges of the sections are wide. These sections provide greater lateral stability and facilitate the connections of flanges to other members. I-sections and wide flanges beam sections have excellent strength. The rolled steel channel sections as shown in Fig. below are used as purlins and other small structural members. The channel sections have reasonably good lateral strength and poor lateral stability. The channel sections are unsymmetrical sections about *yy*-axis. When the channel sections are loaded and supported by vertical forces passing through the centroid of the channel, then the channel sections bend and twist if these are laterally unsupported, except for the special case, wherein the loads act normal to the plane of web, causing bending in the weakest direction. The rolled steel angle sections as shown in Fig. below are also used as purlins and so other small structural members. The angle sections act as unsymmetrical sections about both *xx*-axis and *yy*-axis. The rolled steel tee-sections as shown in Fig. below are used as beams in the rectangular water tanks. The angles and tee-sections are used for light loads. The rolled steel flats and bars as shown in figure are very rarely used. These sections are weak in resisting bending. Most commonly the beams are loaded in the direction perpendicular to *xx*-axis, so that the bending of beams occurs about strong (*xx*-axis) and *xx*-axis becomes neutral axis. The beams are very rarely loaded in the direction perpendicular to *yy*-axis. In such cases, *yy*-axis becomes neutral axis.



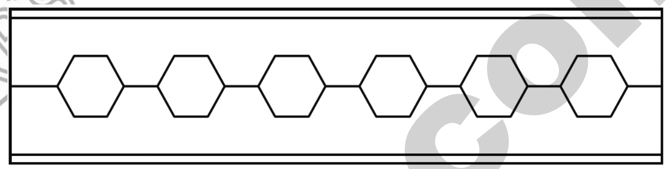
Rolled steel sections used as beams

In general, in cases of bending of the beam about one (single) axis the load is considered to be applied through the shear centre of the beam sections. In case, the loading passing through the shear centre, the sections may be analyzed for simple and binding and shear. The shear centre for the beam sections is at the centre of area, and this load position produces simple bending about either axis.

When the load does not pass through the shear centre as in channels, angles and some built-up sections, a torisonal moment is produced along with the bending moment and both are considered to avoid over stressing of the member. For such sections, a special load device may be used so that the load passes through shear centre of the section and the torisonal may be avoided. In addition to the above, expanded or castellated beams as shown in Fig. below are used. The castellated beams are light and these are economically used for the light construction. The castellated beams are made by splitting the web of rolled steel I-sections in a predetermined pattern as shown in Fig. The splitted portions are rejoined in such a manner as to produce a regular pattern of opening in the web. The modulii of sections of castellated beams increase without the increase of material and weight.



Splitting pattern



Castellated beams

BENDING STRESS

The bending stress is also termed as flexural stress. When beams are loaded, they bend and bending stress are set up all the sections. The established theory of bending is expressed in the following formula:

$$\left(\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}\right)$$

where, M = Bending moment

I = Moment of inertia

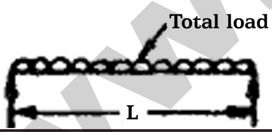
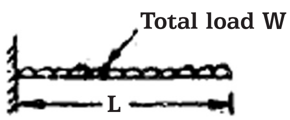
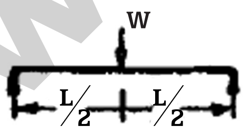
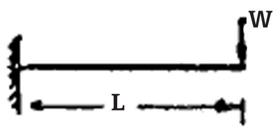
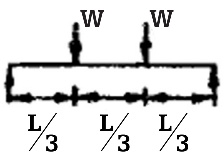
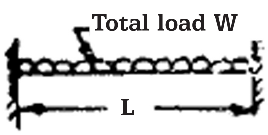
σ_b = Bending stress at any point

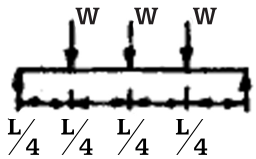
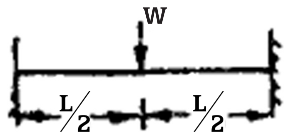
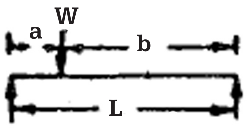
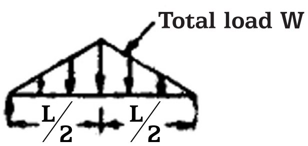
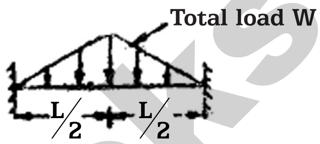
y = Distance from the neutral axis to the point under consideration

R = Radius of curvature of the beam.

Deflection of Beams

In the case of buckling failure the web is assumed to act as a column with reduced length and is to be dealt with according to the principles given in Unit section. However, normally a beam that is safe with respect to web crippling will be safe as well with respect to web buckling.

Beam loading	Coefficient of Maximum Deflection (k)	Beam Loading	Coefficient of Maximum Deflection (k)
	$\frac{5}{384}$		$\frac{1}{8}$
	$\frac{1}{48}$		$\frac{1}{9}$
	$\frac{23}{648}$		$\frac{1}{384}$

Beam loading	Coefficient of Maximum Deflection (k)	Beam Loading	Coefficient of Maximum Deflection (k)
	$\frac{19}{384}$		$\frac{1}{192}$
 a < b	$\frac{a}{9\sqrt{3}L}\left(1-\frac{a^2}{L^2}\right)^{3/2}$		
	$\frac{1}{60}$		$\frac{7}{1920}$

Limiting Deflections

Beam of Span L	Limiting $\frac{\delta}{L}$ Ratio
Beams supporting floors and false ceiling	$\frac{1}{325}$
Purlins and girders	$\frac{1}{200}$
Crane Girders supporting manually operated cranes	$\frac{1}{500}$
Crane Girders supporting EOT cranes (upto 500 kN)	$\frac{1}{750}$
Crane Girders supporting EOT cranes (more than 500 kN)	$\frac{1}{1000}$
Beams having other types of moving loads (e.g., changing cars)	$\frac{1}{600}$
Bridge girders with dead, live and impact loads	$\frac{1}{600}$
Bridge girders with live load plus impact	$\frac{L}{800}$

Example 1 :

Laterally Supported Beam

A simply supported beam of span 10 in is carrying a uniformly distributed load of 30 W m . Design a beam using standard I-sections, if the compression flange of the beam is laterally supported throughout its length.

Solution

$$\text{Maxm. B.M.} = \frac{wl^2}{8} = \frac{30\times10^2}{8} = 375 \text{ kNm}$$

Assuming f_y of steel = 250 MPa

In case of laterally supported beams, we have

$\sigma_{bc} = \sigma_{bt} = 0.66 f_y = 0.66 \times 250 = 165$ MPa

Required section modulus

$$Z_x = \frac{375\times10^6}{165} = 2.273\times10^6 \text{mm}^3 = 2273 \text{ cm}^3$$

Adopt ISMB 550 (wt = 103.7 kg/m) Z_x = 2359.8 cm^3

Assuming a maximum deflection of $\frac{L}{235}$ we must have a $\frac{L}{D}$ ratio of 17.9

Here L = 10000 mm, D = 550

$\therefore \frac{L}{D} = 18.18$ which slightly exceeds the limit but as it is a marginal case it may be accepted.

Check for shear

$$\text{Maxm. S.F.} \frac{10\times30}{2} = 150 \text{ MPa}$$

Permissible average shear stress 0.4 × 250 = 100 MPa

Effective web depth d_1 = total depth – 2 × fillet depth

= 550 – 2×19.3 = 511.4mm

Web thickness = 11.2 mm

Actual shear stress

$$\frac{150000}{511.4\times11.2} = 26.2 \text{ Mpa} < 100 \text{ Mpa} \quad \therefore \text{ safe}$$

Web Crippling

As the load is uniformly distributed, we shall check for support reactions.

Assuming support width (b) = 300 mm

Fillet depth (k) = 0.1 × 550 = 55 mm

Support reaction (r) = 150 kN

Effective web width B = $(b+\sqrt{3}\,h_2)$

$= (300+\sqrt{3}\times 55) = 395$ mm

$\therefore$ Crippling stress $= \dfrac{R}{Bt_w} = \dfrac{150000}{395\times 11.2} = 33.9$ MPa

Allowable bearing stress $\sigma_p = 0.75 f_y$

$= 0.75\times 250 = 187.5$ MPa > 33.9 $\therefore$ OK

Web Buckling

Slenderness ratio for web $= \dfrac{l}{r}$

$\dfrac{0.8\,D}{t}.\sqrt{3} = \dfrac{0.8\times 550}{11.2}\sqrt{3} = 68$

Corresponding $\sigma_{ac} = 114$ MPa (for steel $f_y = 250$)

Buckling stress $= \dfrac{150000}{395\times 11.2} = 33.9$ Mpa < 114 $\therefore$ OK

SLENDERNESS RATIO FOR TENSION MEMBERS

Slenderness ratio (λ) is defined as the ratio of the effective length (l) of a member to its least radius of gyration (r), i.e. $\lambda = \dfrac{l}{r}$

Slenderness ratio limitations are not as important in tension members as they are in compression members. This is since the tension member tends to straighten up under the axial pull. However, to prevent large lateral deflections and other practical structural considerations the following limitations are recommended.

Slenderness Ratio of Tension Members

Sl. No.	Types of Tension Member	Maximum Slenderness Ratio
1.	Tension member (other than pre-tensioned ones)	400
2.	Members normally acting as a tie in a roof truss or bracing system but subject to a possible reversal of stress resulting from wind or earthquake forces	350
3.	A member in which reversal of stress due to loads either wind or seismic forces occurs	180

COLUMN SPLICE

The length of structural steel members as available in the market or site is limited upto 15 m maximum, or even less. In multistoreyed buildings, for convenience of fabrication it is kept at about 5 m lengths. Also the cross sectional area of columns may vary from one storey to another. Due to these reasons columns are joined with each other along their lengths. Such joints are called column splices. The design of the splice depends upon the surface quality of the column ends at the joint. If the ends are machined and milled, so as to provide good contact area along the whole cross-section, the splice plates are free from any force transmitted. However, they have to be designed against tensile forces caused by lateral (wind/earthquake) loading and also due to erection stresses. If the ends of the columns are not milled, the forces from the upper column is transmitted to the lower one through the splices. This is to be designed to transmit all the forces to which they are subjected as a single cover butt joint welded or riveted as the case may be.

IS : 800 stipulates that column splices and butt joints of struts and compression members depending on contact for stress transmission shall be accurately machined and close butted over the whole section with a clearance not exceeding 0.2 mm locally at any place. The ends of shafts together with the attached gussets, angles, channels, etc. after riveting together should be accurately machined so that the parts connected butt over the entire surfaces of contact. (Reduction in thickness by machining should not be more than 2 mm.)