सत्यमेव जयते

FOREST ENGINEERING

বন বিভাগ
পশ্চিমবঙ্গ সরকার

DIRECTORATE OF FORESTS
GOVERNMENT OF WEST BENGAL

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PREFACE

In their normal functions the Foresters have to design, construct and maintain buildings and forest roads. In order that they are able do so with reasonable efficiency, it is necessary that the Foresters should have some basic knowledge in Civil Engineering. The present course materials deal with basic elements of building and forest roads in ten lessons. Under the JICA project on 'Capacity Development for Forest Management and Training of Personnel' being implemented by the Forest Department, Govt of West Bengal, these course materials on Forest Engineering have been prepared for induction training of the Foresters and Forest Guards. The object of this training manual is to help the frontline forest personnel have a better perception about basic principles and procedures involved in the construction and maintenance of buildings and roads.

The subjects covered in these materials broadly conform to the syllabus laid down in the guidelines issued by the Ministry of Environment of Forests, Govt of India, vide the Ministry's No 3 -17/1999-RT dated 05.03.13. In dealing with some of the parts of the course though, the syllabus has been under minor revision to facilitate better understanding of the subjects and to provide their appropriate coverage. The revised syllabus, with such modifications, is appended.

The contents of the course material have been compiled and edited by A Basu Ray Chaudhuri, IFS (Retd). Many books and literature including those available on the internet have been made use of in preparing this course material and references of such books and documents have been cited in the respective lessons. Shri A Basu Ray Chaudhuri is indebted to many forest officers who have helped in the preparation of this material. A special word of thanks is due to

Shri Judhabahadur Chetri WBFS (Retd) for providing valuable reference material, (2) Shri Prabir Kr Guha Roy Forest Ranger (Retd) for his contribution to preparation of Lesson one, and (3) Shri Udit Kr Roy Forest Ranger (Retd) for providing valuable inputs to other lessons.

The efforts that have gone into making this course material will be best rewarded if the frontline staff of the forest department finds it useful in their day-to-day work.

Kolkata, 2015

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Syllabus (Revised)
Forest Engineering

Forest engineering (10* hours), excursion 1 day		
1.Building materials & their measurements	-stone -bricks-size -lime, cement sand and metal -mortar -cement concrete-RCC	1 hour
2.Building construction	-site selection -ground tracing – Components of building* -Foundation –Plinth course or basement* – Damp proof course* Super structure –walls* –scaffolding* –brick masonry* –stone masonry* –sills* –lintels* –R.C.C column* –R.C.C beam* Carpentry and Joinery -Doors and windows –roof* –flooring –plaster* –pointing* –whitewash, colourwash, distemper, painting*	4* hours
3.Water supply	Source of water –surface source* –underground source –springs* -wells-dug well, tube well, artesian well* –sinking of wells* –cleaning and protection of wells* Purification of water –sedimentation* -filtration –disinfection by chlorination*	1 hour
4. Road	-Types of forest roads –Road structure –Road design Carriageway*, shoulder*, camber, gradient, super Elevation, road curves, retaining wall*, breast wall*, road drainage -Alignment in plains and hills -Preparation of road estimate	3* hours

	– Road construction For- est Bridges* –cross drainage works* –culverts* –bridges*	
Practical	Study of parts of a building in the campus	1 hour
Field study	Study of various types of forest roads and their parts during tour/ excursions	

* These are modifications to the MoEF-prescribed syllabus, indicating revision/addition of topics and lesson hours.

5	• Lesson Plan • Building construction (contd.) Superstructure (contd.) Roof Flooring Plaster Pointing Whitewash, colour wash, distemper, painting	34 - 40
6	• Lesson Plan • Water Supply • Source of Water Surface source Underground source • Sinking of well • Purification of water	41 - 46
7	• Lesson Plan • Forest Roads Types of Forest Roads Road structure Road design	47 - 54
8	• Lesson Plan • Forest Roads (contd.) Forest Road Alignment Preparation of road estimate Road construction	55 - 60
9	• Lesson Plan • Forest Roads (contd.) • Forest Bridges Types of cross drainage works Culverts Bridges	61 -67
10	• Lesson Plan • Practical Parts of a building in the campus – Briefing – Inspection and Measurement – Drawing of plan and Elevation	68 - 69

Lesson Plan Time 1 hour

Lesson 1

Objective: To study

- **Building Materials and their measurements**
  - Stone
  - Bricks
  - Sand
  - Lime
  - Cement
  - Mortar
  - Mass Concrete
  - Reinforced cement concrete (RCC)

Backward Linkage- Nil
Forward Linkage- Details of building construction described in subsequent lessons **Training materials required:** Copy of Lesson 1 to be circulated beforehand **Allocation of Time**

- Stones – 7 mts
  - Classification
  - Characteristics of good building stone
  - Measurement
- Bricks- 9mts
  - Classification of bricks
  - Characteristics of good bricks
  - Treatment before use
  - Size
  - Mode of measurement of brick wall
- Lime 5 mts
  - Uses
  - Source
  - Manufacture
- Sand 4 mts
  - Characteristics of good sand
  - Bulking
- Cement 5 mts
  - Composition
  - Properties of good cement
  - Storage
- Mortar 8 mts
  - Quantities required
  - Types of mortar
  - Specifications for mortar
  - Application

- Mass concrete
  - Ingredients
  - Proportioning of aggregates
  - Application
- Reinforced cement concrete (RCC) 7 mts
- Discussion/ Miscellaneous 5 mts

1.0. **Building Materials and their Measurements:**

1.1. **Stone:** Stones used in construction are derived from the rocks forming the crust of the earth surface.

1.1.1. Classification of rocks:

1.1.1.1. According to geological formation:-

a) **Igneous Rocks or Unstratified rocks**, e.g. Granite, Basalt, Trap etc.

b) **Sedimentary or Aqueous or Stratified rocks**; e.g. Sand stone, Lime stone, Shale etc.

c) **Metamorphic rocks;** e.g. Gneiss, Schist, Quartzite, Clay, Slate etc.

1.1.1.2. According to chemical composition:-

a) **Silicious Rocks;** e.g. Granite, Trap, Sand stones etc.

b) **Calcareous Rocks**; e.g. Lime stone, Marble etc.

c) **Argillaceous Rocks;** e.g. Slate, Laterite etc.

1.1.1.3. According to physical structure:-

a) **Stratified Rocks;** e.g. Gneiss, Mica, Slate, Sand stone etc.

b) **Unstratified Rocks;** e.g. Granite, Blue Basalt, Trap etc.

1.1.2. Characteristics of good structural stone:

1. Strong against crushing:

2. Durability: It depends upon the following:-

a) Atmosphere

b) Chemical composition

c) Physical Texture: Crystalline stone is hard and compact. Stone with fine crystals is stronger than one with coarse crystals.

d) Physical Structure: It depends on the origin of the stone.

e) Position or place in the structure:

3. Appearance: Stones with lighter shades are preferable to those of deeper shades. Appearance in relation to design is of great importance from architectural point of view.

4. Availability: Large size block of stones should easily be available and it should be cheap.

10 mts

1. Stones should have ability to receive polish and paint when used for faceworks.
2. Stones should have facility to dress easily.
3. Stones should be resistant to fire.

1.1.1. Measurements:-

When placed in stack, depending on the size of the stone, the solid volume and the void will be as follows.

S.No.	Aggregate	Solid %	Void %
1.	Ballast ¾" and down gauge	67	33
2.	Ballast stone 1" and down gauge	54	46
3.	Broken stone 1½" and down gauge	59	41
4.	Broken stone 2" and down gauge	55	45
5.	Broken stone 2½" and down gauge	59	41

As per West Bengal P.W. Department:-
Unless specifically mentioned otherwise in the description of the item itself, measurement for supply and / or carriage shall be taken as soon after the stacks are made as possible. The height and the shape and size of stacks shall be as per direction; but in no case the height of the stacks be less than the minimum as indicated below:-

MATERIALS	Minimum height of stacks	Allowance to be deducted for sinkage and / or shrinkage
Stone metal ballast, chips, shingles or gravel.	60 cm.	1/13
Stone metal boulders and Laterite boulders 15cm. or above size.	60 cm.	1/7
Stone boulders below 15 cm size	60 cm.	1/9

1.2. **Bricks**. It is the artificial block of burnt clay used for building purposes.

1.2.1. **Classification of Engineering bricks**:-
Bricks are classified according to the state of burning. They are categorized as under:-

Category (i): Just burnt – commonly called 1st class. Possesses all the qualities of good bricks. Used in high class construction.

Category (ii): Underburnt – commonly called 2nd class. Used in ordinary structures of less importance.

Category (iii): Overburnt – commonly called 3rd class or Jhama bricks. Not used in construction works. Generally used as an aggregate in foundation or crushed to powdered form to be used as surkhi in mortar.

1.2.2. **Characteristics of good bricks: - (Field Test) –** a good brick should

a) be thoroughly burnt.
b) give a ringing sound when struck with another brick.
c) not break easily when thrown on ground or against other bricks.
d) be free from flaws like stones, vegetation, holes etc. Examination of fracture should show homogeneous close grained structure.
e) regular in size; true in shape; even surfaces; uniform in colour.

1.2.3 Treatment before use: Bricks must be soaked well before setting in mortar (say 2 hrs.), Otherwise moisture in mortar is absorbed by bricks and joints remain weak and open due to non-setting of mortar in absence of chemical action.

1.1.4. Size of Bricks:- According to WB PWD Schedule general specifications, the brick size will be as furnished below:-

Type of brick	Size
a) Standard Modular	19cm x 9cm x 9 cm
b) Traditional bricks	9¾"x 4¾"x 2¾"

1.1.5. The mode of measurement for wall thickness for traditional bricks 10" x 5" x 3" (Nominal size, i.e. size with mortar):-

Thickness of wall stated in the estimate for the purpose of calculation is known as nominal thickness.

Giving allowance of ¼ inch for mortar joint, the nominal thickness of brick wall made with -

a) One brick laid on edge (with the long side parallel to the length of the wall i.e. for 3" walls) shall be measured as 7.5 cm.

b) One brick laid flat (with the long side parallel to the length of the wall i.e. for 5" Walls) shall be measured as 12.5 cm.

c) One brick thick walls (with the length of brick parallel to the thickness of the wall i.e. for 10" walls) shall be measured as 25 cm.

1.2.6.1 Giving allowance of 1cm for mortar joint the nominal size of modular brick will be 20cm x 10cm x 10cm.

1.3. **Lime.**

1.3.1. Uses:- Used in building

a) as a matrix for concrete;
b) in preparing plastic mortar for stones or bricks in wall;
c) plastering and white washing walls, embedding tiles on roofs and floors.

1.3.2. Source:- CaCO3 (Calcium Carbonate) either pure or mixed with impurities is the source of all lime.

1.3.3. Manufacture of Lime:-

By burning limestone (termed as Calcining), the *CO2* (Carbon di oxide) is driven out and oxide of Ca (*CaO*) is obtained which is *Quick Lime.* This Quick lime when treated with water is converted into Slaked Lime [*Ca(OH) 2*]. When this slaked lime is mixed with definite volume of water, it hardens. This process of hardening is termed as *"Setting".*

1.4. **Sand:**

Natural sand is weathered and worn out particles of rocks of various sizes and grades.

In concrete work, it is termed as 'fine aggregate'. It is found in its natural state from

(1) Pits, suitable for road works only;
(2) Rivers, clean but rounded, used in mortars; and
(3) Sea shores, used in underwater works.

1.4.1. Characteristics of good sand:

i) It should be of uniform texture.
ii) It should be free from clay and other impurities.
iii) It should be free from acids, alkalis, and salts.
iv) It should be sharp.
v) It must be compact.
vi) It should be of durable minerals.

1.4.2 Bulking of sand:

When sand absorbs moisture up to 5%, it increases its volume by 20 – 25% and when moisture increases beyond 10% the sand gets back to its original volume. This temporary increase in volume of moist sand is known as Bulking of sand and has a great bearing on the quantity of sand to be used in mortars and concretes. When sand is wet, slightly more sand should be used than indicated by the proportion of mortar.

1.5 Cement: It is a calcareous substance similar to strong hydraulic lime.

1.5.1 Normal Portland cement: Lime-stone and clay burnt to a clinker and finally ground to a fine powder. (Composition: CaO – 63%, SiO2 – 21%, Al2O3 – 6%, Fe2O3 – 4%).

1.1.2. **Properties of cement:**

a) Good Portland cement should be gray / greenish gray in colour.
b) Weight of well-burnt cement should be 50 kg (112 lbs) per bag (1 bag = 35dm3 or 1.25 cu.ft.).
c) It should not form nodules.
d) It should be cool to the feel when a hand is introduced into a bag of cement
e) Smaller lumps in the cement bag indicate that the cement has been affected by the atmosphere and the bag should be rejected for works.

1.1.3. **Storage of cement**:

Cement bags shall be placed in stacks on raised platforms (at least 4 cm from ground), dry and impervious to water and at least 30 cm clearance from any wall. The stacks shall not be more than 12 bags high to prevent lumping of cement under pressure as also chances of injury to any workman. Where bulk handling of cement is undertaken protective masks should be provided for the workmen.

1.6. **Mortar:**

It is a mixture of lime or cement with sand /surkhi (brick dust) or cinder and water used in a plastic state for binding individual bricks, stones or tiles etc.into one solid mass.

1.6.1. **Quantity of Mortar Required:**

Estimated quantities are given below.
1. For 1 m^3 of brick works, mortar required is 0.25 m^3 .
2. For 100 cu.ft. of brick work mortar required is 25 cu.ft

1.6.2. **Types of mortar:**

1. Mud Mortar: It is made from stiff clay suitable for brick making, broken into fine powder and thoroughly cleaned of grass, pebbles etc. It is then mixed with water and well tempered before use. Sometimes chopped straw is well mixed with mud mortar to prevent heavy shrinkage. Mud mortar is used only in inferior and cheap works.

2. Lime Mortar: It is a mixture of lime and sand with water used in plastic state to provide an even bedding and adhesive material in masonry, brick work and concrete or for plastering and pointing. Hydraulic lime (lime which sets through hydration) only should be used in mortar.

3. Cement Mortar: It is a mixture of cement and sand with water used in plastic state to provide an even bedding and adhesive material in masonry, brick work and concrete or for plastering and pointing.

1.1.3 **Specification for Cement Mortar:**

1. Water: Water used for mortar should be free from oils, acids, alkalis, salts, sugar and vegetable matters.

2. Sand and Cement: Cement conforming to I.S.I. specification should be used. Cement which has partially set shall not be used. Sand shall be used as specified by the officer- in-charge and shall be clean, sharp, free from dirt and other foreign matter.

3. Proportioning:
Cement mortar to be used should be as per approved specifications. However, some standard specifications of **proportions by volume** are given below.

Srl. No	Purpose	Proportion
		Cement : Sand
1.	Ordinary masonry or Brick work	1 : 4 to 6
2.	Water-tight masonry or brick work	1 : 3
2.	125 mm thick brick work	1 : 3 to 4
3.	Plastering Building walls	1:5
4.	Pointing	1:3 to 4
5.	For water proofing cement plastered surface (e.g. Neat Cement Punning)	1 : 0

4. Consistency: The minimum quantity of water shall be added to ensure that the mixed mortar can be used easily. It should be firm enough as not to run out of joints and should be capable of easy spreading.

1.1.4 **Application**
Only that much of mortar should be prepared which can readily be used. Mortar shall be used as soon as possible after mixing and before it has begun to set and in any case within 30 minutes after the water is added to the dry mixture. Curing should be done for at least 7 days after laying cement / lime mortar in position.

1.7. **Mass Concrete**
Concrete is a mixture in which a paste of binding material and water binds fine and coarse material known as aggregates into a rock like mass as the paste hardens, through the chemical action of binding material and water. The binding material may be cement (which gives cement concrete), or lime (which gives lime concrete). When unqualified, concrete would mean cement concrete.

1.7.1 **Ingredients**

Cement concrete has the following ingredients –

- cement
- Aggregates – These are inert materials used principally to increase the mass and reduce the cost. They are subdivided as –

 Fine aggregates – 3/16" to 100 mesh, example sand; object is to fill all voids in coarse aggregates, should not contain more than 5% of clay and silt, and should be free from organic matter.

 Coarse aggregates – 2.5" to 3/16", viz. broken stone (granite, gneiss, hard crystalline lime stone, gravel etc). The aggregates should be hard, strong, durable pieces free from injurious quantities of soft, friable, thin, elongated or flaky pieces, alkali, and organic matter.

- Water – Water acts as lubricant for the aggregates and cement. It combines chemically with cement to form the hardened paste. Water should be free from oily or greasy substance, organic impurities, acids and alkalis. Quantity of water should be such that the concrete mass remains plastic and workable. Strength of concrete depends on water/cement ratio. According to PWD (WB) Schedule 2014, the quantity of water to be used for each mix of 50 kg. Cement to give the required consistency shall not be more than 34 litres for 1:3:6 mix, 32 litres for 1:2:4 mix, 30 litres for 1:1.5:3 mix and 27 litres for 1:1:2 mix.

1.7.2 **Proportioning of Aggregates**

The most popular and common use is to take one unit of cement and to this fine and coarse aggregates are added arbitrarily in the **proportion by volume of 1: n: 2n.** That is to 1 part of cement is added n parts of fine aggregates (sand) and 2n parts of coarse aggregates (stone chips). The value of n varies with the class of work. **Proportions by volume** used for some common works are given below.

- R.C.C Work – 1 : 2 : 4
- Medium quality of works such as foundation of walls, arches, ordinary floors, stairs etc. – 1 : 2.5 : 5 to 1 : 3 : 6.
- Water tight construction – 1 : 1.5 : 3

1.7.3 **Application**

The concrete should be placed in forms within 30 minutes from the time water is first added. The concrete should be deposited in layers of uniform depth not exceeding 6"-8". The surface should be brought to required smoothness with as few strokes of trowelling as possible. Curing of concrete works should be continued for at least 10 days.

1.8. **Reinforced Concrete**

Mass concrete is good in resisting compression but is very weak in resisting tension. The weakness in tension prohibits its use where tensile forces are developed, for example, in beams, slabs, long columns etc. Hence reinforcement is provided in the concrete wherever tensile stress is expected. The best reinforcement is steel, since tensile strength of steel is quite high and the bond between steel and concrete is good. As the elastic modulus of steel is high, for the same extension, the force resisted by steel is high compared to concrete. However in tensile zone, hair cracks in concrete are unavoidable.

1.8.1 **Reinforcement details**

- Diameter – Generally M.S (Mild Steel) round bar of diameter between 5 mm and 50 mm is used as steel reinforcement in RCC works. However, with a little more cost, the twisted bar can be used, which increases the tensile strength about 50% more than the ordinary M.S bar.
- Length- The available lengths of steel bars are from 6m to 15 m. Short length bars should be avoided.
- Cover – It is the distance from the outside of reinforcement rod to the surface of concrete. Minimum cover for the following are :

Slab – 2cm Beam -3 to 4 cm
Column – 4 to 5 cm

1.8.2 **Formwork or Shuttering**

It is a temporary structure constructed to consolidate the concrete mass into desired shape. It is generally made of light but strong wood.

1.1.3. **PWD (WB) guidelines (Excerpts)**

Shuttering may be of approved dressed timber true to line, not less than 25 mm. thick. Surface to be in contact with concrete is to be planed smooth except where otherwise stated. In timber shuttering the joints must be perfectly closed and the entire shuttering surface shall be covered with polythene sheets of approved quality. It shall be so constructed that it may be removed without shock or vibration to the concrete. Before the form work is stripped, the concrete surface shall be exposed where necessary in order to ascertain that the concrete has hardened sufficiently. In normal weather and with ordinary cement, **vertical or side shuttering** may be removed **after three days** and the **bottom shuttering** of horizontal members **after fourteen days in case of slabs** and **twenty one days in case of beams and cantilevers etc**. from the date of placing the last portion of the concrete in the structure. The above are the minimum and may be extended if found necessary.

Reference Materials

1. Lecture notes on Forest Engineering – I by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- I by M.V. Achar, Forest Rangers' College
3. PWD (WB) Schedule of Rates 2014
4. N.J Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun
5. http://www.civilengineeringx.com/concrete-category/reinforced-cement-concrete-r-c-c/

Lesson 2

1 hour

Lesson Plan

Objective: To study

- **Building Construction**
  - Site selection
  - Ground Tracing
  - Foundation
  - Plinth Coarse or basement
  - Damp proof coarse
  - Anti-termite measures

Backward Linkage – Building materials discussed in lesson 1

Forward Linkage - Building construction described in subsequent lessons **Training materials required –** Copy of Lesson 2 to be circulated beforehand **Allocation of time**

- Selection of Site – Preparation of site — 8 mts
- Setting out building/ ground tracing — 6 mts
- Components of building- Foundation and super structure
  - Foundation — 26 mts
    - Object
    - Causes of failure
    - Safe bearing capacity of soil
    - Angle of Repose
    - Design of foundation- width and depth
    - Methods of securing safe foundation
- Plinth course or basement — 10 mts
  - Damp proof course
  - Anti termite measures
- Discussion / Miscellaneous — 10 mts

1. BUILDING CONSTRUCTION:-

Forest managers are required to construct different types of building like office building, staff quarters, rest houses etc in various localities. Hence the design, construction and maintenance of such buildings are very important aspects of their jobs which should be carried out properly and in systematic manner.

1.1 **Selection of site:-** The Selection of sites for building is important and the following factors are to be considered carefully:-

i. **Good water supply facility**:- Availability of sufficient quantity of good quality water for construction and domestic use.

ii. **Nature of soil**:- Select site with compacted sandy or gravelly soil, avoiding black cotton soil or clayey soil.

iii. **Situation**:- To be situated centrally with regard to all sorts of facilities.

iv. **Drainage**: -The site should be slightly raised to provide natural drainage for keeping the place dry and healthy.

v. **Elevation**:- To command a good view of surrounding, elevated site is preferable.

vi. **Accessibility**: - To be selected by the side of village for easy access in general use.

vii. **Climatic aspect**: - Not to be exposed to cold or hot wind, snow, etc.

1.2 **Preparation of site:-** The site should be cleared of undergrowth. If removal of trees is considered unavoidable, the same should be done on observance of due formalities. The site should be free from termite, and provided with suitable drainage system around the building to provide natural drainage.

1.3 **Setting out building / Ground Tracing: -** Setting out building also called ground tracing is the process of laying down the centre lines and excavation lines on the ground before the excavation is started. It is based on the following processes:-

i. Centre line of the main wall forming the biggest rectangle is to be laid on the ground.

ii. Pegs to be driven at corners of rectangles and strings are stretched across them. The right angles and diagonals to be checked properly. (See fig. 2.1)

iii. The centre lines of the intermediate walls are laid and the right angles of all these lines and their corresponding diagonal lines are checked.

iv. Big pegs or small brick pillars platform in continuation of these centre lines about 1.0 mt to 1.5mt away from the edge of trenches are to be erected or constructed. The top levels of these platforms should be equal.

v. Nails are driven on the top of these pegs or platforms to indicate the centre lines, foundation width lines etc. Lines for excavating the foundation trenches are marked with lime or chalk powder.

vi. Lines for foundation trenches are to be scored out on ground with pickaxe and then excavation is started.

1.4 **Components of building: -** Building consists of two basic components:-

i. **Substructure or foundation**: - The portion below the ground level is called substructure or foundation which transmits the load of super structure to subsoil.

ii. **Superstructure: -** The portion above the ground level which serves the purpose of construction is called superstructure. The part of superstructure in between ground level and floor level is known as '**plinth'.**

A building has the following components:-

a) Foundation

b) Walls and columns

c) Floors

d) Doors, windows and other openings

e) Lintel and sills
f) Roofs
g) Staircases
h) Fire places and chimneys

1.5 **Foundation: -**Foundation is an artificially built lower portion of the building located below the ground level which is in direct contact with the ground over which the loads are transmitted. The soil immediately below the base of foundation is called '**sub-soil'** and the portion of foundation in direct contact with the sub-soil is called **'footing'** and the projection of footing is called '**offset'**. The minimum offset on each side is usually 5cm in brick work and 7.5 cm in stone masonry. The number of offsets depends upon the increase in width required.(See fig 2.2).

1.1.1 **Object of foundation: - F**oundation serves the following purposes:-

i. **Reduction of load intensity**: - To distribute the load of superstructure to a large area so that intensity of the load at base does not exceed the safe bearing capacity of the soil.
ii. **Even distribution of load**: - To distribute non-uniform load of superstructure evenly to subsoil by the combined footing of columns carrying uneven load.
iii. **Provision of level surface**:- To provide level and hard surface.
iv. **Lateral stability**: - To anchor the superstructure with the ground for imparting lateral stability.

v. **Safety against undermining**: - To provide structural safety against undermining and scouring.
vi. **Protection against soil movement**: - Special measures prevent / minimize the distress or cracks in superstructure due to expansion and contraction of sub soil owing to moisture movement.

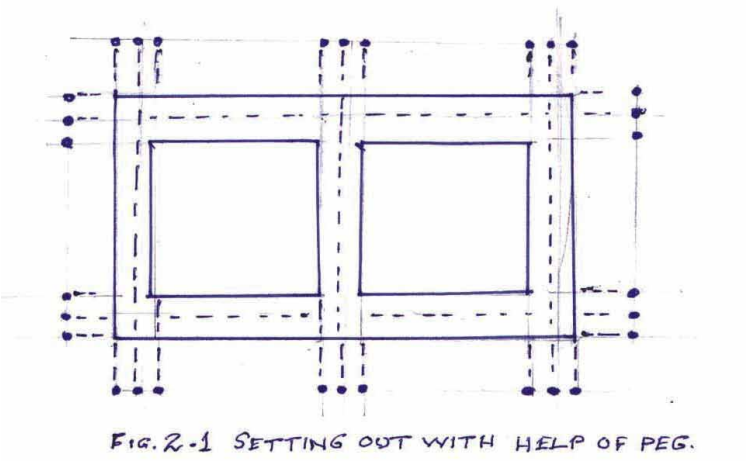


FIG. 2-1 SETTING OUT WITH HELP OF PEG.

(Source:Lecture notes on Forest Engineering – I by K. Muniamuthu, State forest Service College, Coimbatore)

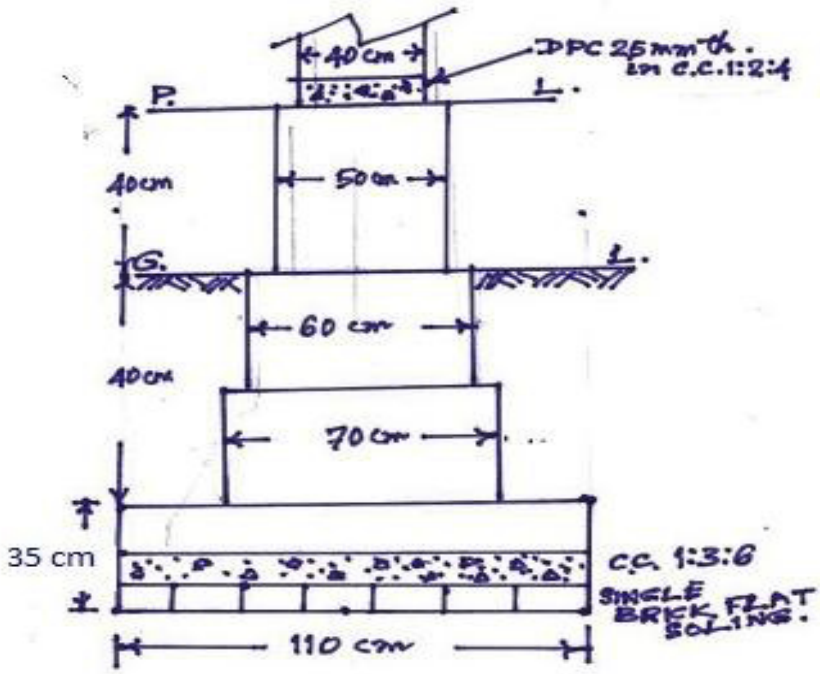


FIG 2.2 FOUNDATION

1.1.2 **Causes of failure of foundation and its remedial measures: -** The foundation may fail due to the following reasons:-

i. **Unequal settlement of subsoil:-** It is caused due to non-uniform nature of subsoil, unequal load distribution and eccentric loading. This may be avoided by resting the foundation on hard strata and appropriate design of footing.

ii. **Unequal settlement of masonry:-** This happens due to weak masonry materials and improper mortar joint, insufficient curing and non-restriction of height of masonry construction per day.

iii. **Subsoil moisture movement:-** The subsoil water level fluctuates causing swelling and cracking the subsoil.

iv. **Lateral pressure of the wall:-** The lateral pressure from pitched roof or arch, or wind action may be the causes of failure by overturning. Special precaution is needed.

v. **Lateral movement of subsoil:-** Granular soil is very soft and liable to move out laterally under vertical load especially on sloping ground which causes failure of foundation. Sheet piles should be driven to prevent lateral movement.

vi. **Weathering of subsoil due to trees and shrubs:-** The root of trees and shrubs penetrates underneath of footing and absorbs moisture resulting void and weathering. Such roots should be cut/uprooted.

vii. **Atmospheric action:-** Sun, wind and rains could affect the foundation and may be a cause for its failure. Proper filling of foundation trenches with good soil and compacting is to be made.

1.1.3 **Safe bearing capacity of soil:-**The supporting power of soil or rock is referred to as its bearing capacity and hence the foundation should be designed accordingly. The **safe bearing capacity (S.B.C.)** of soil may be defined as the maximum pressure which the soil can carry safely without any risk or shear failure. S.B.C. varies from soil to soil. The S.B.C. is expressed in tonnes per square metre.

1.1.4 **Angle of repose:-** If any type of soil is excavated and left exposed to weather in a conical shape, its sides will slip and will gradually attain stability without further slide. The angle between the horizontal and the slope so formed is termed the natural **'angle of repose'** of soil denoted by **φ**. The unit weight (kg/cu.m) and angle of repose vary from soil to soil depending upon grain size, compaction and moisture contents etc.

1.1.5 **Design of foundation: -** The design of foundation for a building consists of design of width and depth of foundation and design of thickness of concrete bed.

i. **Design of width of foundation: -** B=W/q where B=width of foundation in metre, W= total load at base in tones per running metre, q= safe bearing pressure in tonnes per square metre. As a thumb rule, the width of foundation at concrete bed should be either (i) twice the width of the wall + 30 cm, or (ii) 100 cm, whichever is higher.

ii. **Design of depth of foundation:-**
Sometimes, the top soil may be good and compact, and may have adequate bearing capacity. In that case it is desirable to keep the minimum depth of foundation given by Rankines formula:

$$D_{min} = \frac{q}{\gamma}\left[\frac{1-\sin\phi}{1+\sin\phi}\right]^2$$

Where Ø is the angle of repose,
Dmin is the depth of foundation in metres, and

q = Intensity of load at the base of footing (t/m^2 or kN/m^2))

γ = Unit weight of soil (t/m^3 or kN/m^3).

A minimum depth of 60 to 100 centimeter below ground level should be provided in any soil to keep foundation beyond the effect of weathering.

iii. **Design of thickness of concrete bed: -** As a thumb rule thickness of concrete bed block should not be less than 5/6 of thickness of main wall or a minimum of 20 cm.

1.1.6 **Method of securing safe foundation in Soft soil:-** For improving safe bearing pressure the following methods may be adopted:-

i. Increasing depth of foundation
ii. Compacting the soft soil
iii. Draining the dampness
iv. Confining the soft soil
v. Grouting the soft soil
vi. By chemical treatment

Any of the following methods may be adopted to secure safe foundation in soft soil: -

i. The area at the base of the foundation may be increased by R.C.C. raft foundation etc.
ii. By driving piles about 1 to 2 meters centre to centre.
iii. By well foundation or building piers.

1.6 **Plinth course or Basement: - Plinth** is defined as the portion of the structure situated between the ground level and the floor level. The level of the floor is known as '**plinth level'**. The construction built up is known as '**plinth course'** and the built up area is known as '**plinth area'**. The height of plinth course should be 50cm to 75cm above ground surface in dry localities and more in marshy area. It is made in stone masonry or brick masonry in cement mortar. The plinth slab at top level is projected slightly outside to throw off rain water. The steps from ground level to floor level should have a rise of 15cm to 20cm with a tread of 20cm to 30cm. In black cotton soil, the existing soil is to be removed up to a depth of minimum of 60cm from the plinth area and to be filled with good red soil, gravel

etc.

1.6.1 Damp proof course: - The building should be free from moisture and remain dry. Dampness creates unhygienic condition and reduces strength of structural components. Dampness rising from ground can be prevented by a damp-proof course at plinth level, damp coming in through walls may be checked by providing the outside of the wall with rich cement-sand (1:3) plaster or by constructing hollow wall, and dampness percolating from above can be prevented by a damp-proof course immediately below the cornice course.
The damp proof course may consist of: -

i. A layer of hot asphalt 12mm thick or a sheet of lead or bitumen as damp course to cover the full thickness of wall at plinth level.
ii. Two courses of slate stone in cement mortar 1:3 with joints suitably staggered may be used.
iii. Fine C.C. 1:2:4 with water proofing compound may be used.

1.6.2 Anti-termite treatment: - Termite popularly known as white ant causes considerable damage to walls especially to wood work. Anti-termite treatment is necessary by adopting the following steps: -
i. **During site preparation: -** Materials favoured by the termite should be destroyed and removed from the site. Insecticides solution like D.D.T., B.H.C., Aldrin etc may be used.
ii. **During soil treatment: -**
a) A 10cmthick layer of sand, crushed stone dust shall be applied below the flooring.
b) To spread 1cm thick layer of asphalt over the plinth area at plinth level.
c) A layer of sand, hot coal tar mixed with mortar may be applied below floor.
d) The emulsion prepared with Aldrex 30 E.C. mixed with water in 1:59 may be applied over the entire plinth surface
e) 25gm of C.U.S.O. added with 1litre of water may be mixed with concrete / mortar.

Reference materials

1. Lecture notes on Forest Engineering – I by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- I by M.V. Achar, Forest Rangers' College
3. PWD (WB) Schedule of Rates 2014
4. N.L Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun
5. http://www.abuildersengineer.com/2012/11/depth-of-footings-foundations.html

Lesson 3

Building construction (contd.)

1 hour

Objective: To study

- **Super structure**
  - **Walls-** Different kinds based on materials
    - Mud wall, Bamboo mat walls, wooden walls, brick walls, stone walls
    - Thickness of load bearing walls
    - Scaffolding
- **Brick Masonry**
- **Stone Masonry**

- Common terms in brick works
- Bonds in brick masonry-types
- Construction of brick masonry

- **Sills**
- **Lintels**
- Rubble masonry-Random rubble, dry stone rubble, concrete rubble
- Construction of stone masonry

Backward Linkage – Materials of lesson 1 & 2

Forward Linkage – Building construction dealt with in subsequent lessons **Training Materials required –** Copy of Lesson 3 to be circulated beforehand **Allocation of time**

Walls- Different kinds based on materials 9mts

- Mud wall, Bamboo mat walls, wooden walls, brick walls, stone walls

Thickness of load bearing walls 5mts

Scaffolding 3 mts

Brick Masonry 20 mts

- Common terms in brick works
- Bonds in brick masonry-types
- Construction of brick masonry

Stone Masonry 10 mts

- Rubble masonry-Random rubble, dry stone rubble, concrete rubble
- Construction of stone masonry

Sills 3 mts

Lintels 5 mts

Discussion/Miscellaneous 5mts

1.1 Superstructure: - The upper parts of the building above ground level are known as 'Superstructure'. It consists of wall, column, sill, lintel, arch, floor, roof, door, window, staircase etc.

1.2 Wall: - It is the most essential component of a building. The function of a wall is to enclose and divide the space of the building. The walls are of different kinds on the basis of materials used:-

i. Mud wall
ii. Bamboo mat wall
iii. G.C.I. Sheet wall
iv. Wooden wall
v. Brick wall
vi. Stone wall

The masonry wall is both load bearing and non load bearing. The load bearing walls are designed to carry the superimposed load in addition to their own weight. The non-load bearing walls carry their own weight only. Partition wall of thickness 10cm to 20cm is generally non load bearing wall.

1.2.1 Thickness of load bearing wall: - The thickness of wall is designed in such a way to carry the superimposed load, dead load, wind load and load due to earthquake. It is designed as follows:-

T= W/P, Where 'T' is thickness of masonry in metre, 'W' is total load in tonnes per running metre, 'P' is safe permissible load in tones per square metre.

Thickness of all walls should be designed as per the load acting on it. However, for small buildings following thickness are generally used.

Mud wall: - minimum thickness 60cm upto a height of 4mt, and 100cm for the height of wall between 4mt and 10mt.

Wooden wall: - boarding should be more than 25mm thick.

G.C.I. Sheet wall: - Sheet should be between 22 and 26gauge.

Masonry wall: -

Floor wall	Wall thickness	
	Stone masonry(cm)	Brick masonry(cm)
Single floor upto 4mt height	40	20
Double storey up to 10mt height	50	30
Three storied up to 15mt height	60	40

The thickness of walls in lower floor should be more than the walls in upper floor. No wall should be constructed higher than 15 m without being stiffened by cross walls or buttresses.

1.3 Scaffolding: **-** When the height of wall exceeds 1.5mt, a reasonably stable supporting frame of temporary nature where the workmen can sit, stand and carry on work should be constructed. Commonly it is made of bamboo / timber, pole / steel pipe. Such structure is called '**Scaffolding**'. Vertical members are called '**Standard**'; horizontal members are called '**Ledger'**. Standards are braced diagonally. The transverse members called '**Putlogs**' are placed at right angle to wall. Bamboo mat/planks **boarding** is placed on putlogs for the workmen to work.

1.3 **Brick work or Brick masonry: -** It is made of brick unit bonded together in mortar and its strength depends upon:-

i. Quality of brick
ii. Quality of mortar
iii. Method of bonding

1.1.1 **Common terms in brick works: -**

i. **Stretcher: -** Longer face of a brick (19cm x 9cm) when laid.
ii. **Header:** - Shorter face of a brick (9cm x 9cm) when laid.
iii. **Course:** - One complete horizontal layer of bricks.
iv. **Lap:**- Horizontal distance between the vertical joints in two successive courses.
v. **Bat:** - A portion of brick cut across the width.
vi. **Bed:** - The lower surface of brick when laid flat.
vii. **Quoin:** - A corner or external angle on the face side of wall.
viii. **Closer:** - A portion of brick with the cut made longitudinally and used to close up bond at the end of course.
ix. **Queen closer:** - A half brick cut longitudinally placed next to the corner quoin in a header course.
x. **Bond:** - The method of arranging bricks to tie the bricks together.
xi. **Frogs:** - The identification of bricks provided to form a key for holding the mortar. The bricks are laid with frogs on top.
xii. **Racking back:** - Stepping of the unfinished end of the wall masonry. Each alternate course is reduced by the length of one brick.
xiii. **Toothing:** - A method of leaving or preparing a brick wall to enable other brickwork to be added later. It consists of projecting every alternate course over the course below it by one lap.

1.1.2 **Bonds in brick masonry or Brick work:**- Bond is the arrangement of brick work in such a manner so that the vertical joints do not occur continuously either on the face or inside the wall. Proper bonding helps in distributing the concentrated load over a large area.

1.1.3 **Types of bond: -** The bonds are of the following types:-

(i) **Stretcher bond:** - In this bond all the courses are stretcher courses and the overlap which is usually half-brick is obtained by commencing each alternate course with a half bat. This pattern is used in partition wall, compound wall , cavity wall etc. (See fig 3.1)

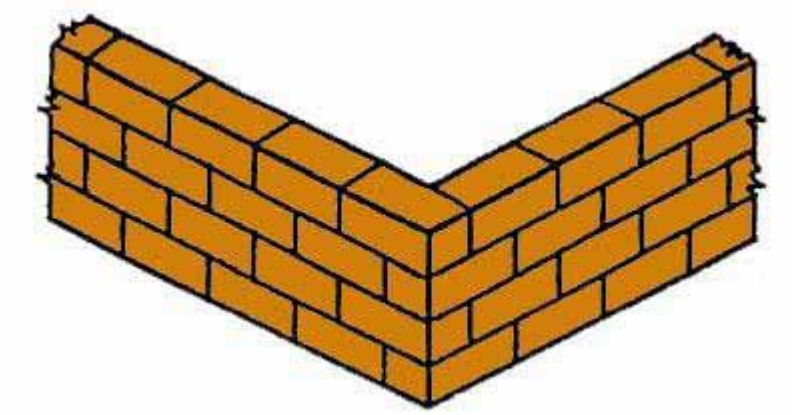


Fig.3.1 Stretcher Bond (Isometric View)
(Source: http://www.civilprojectsonline.com/civil-projects/types-of-bonds- in-brickwork-stretcher-and-header-bond/)

(ii) **Header bond:** - The facing of this bond has all the courses as headers only and the overlap which is half the width of the brick is obtained by introducing a three-quarter bat in each alternate course at the quoins. This pattern is used in case of wall of one brick thickness (See fig 3.2).

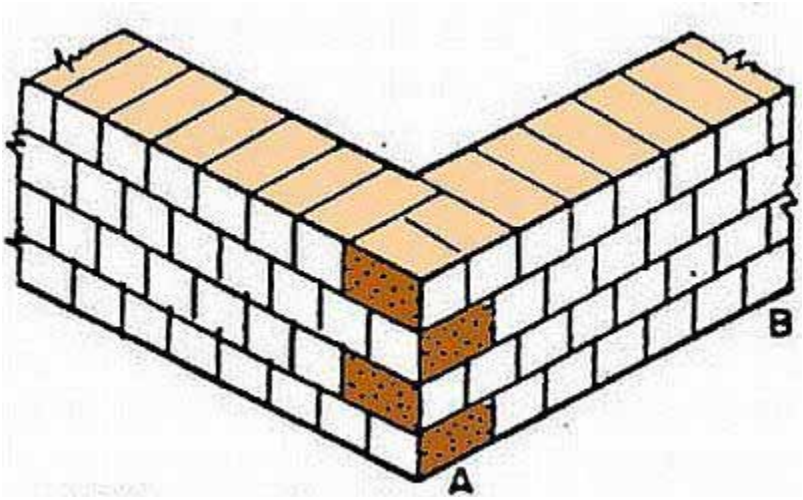


Fig.3.2 Header Bond (Isometric view)
(Source: http://www.civilprojectsonline.com/civil-projects/types-of-bonds-in-brickwork- stretcher-and-header-bond/)

(iii) **English bond:** - The bricks in the facing are Iaid in alternate courses of headers and stretchers. The header course is commenced with a quoin header followed by a queen closer and continued with successive headers. The stretcher course is formed of stretchers having a minimum lap of one- quarter their length over the header. The bond contributes substantially to the strength of brickwork, and may be particularly suitable for walls carrying heavy loads (See fig 3.3).

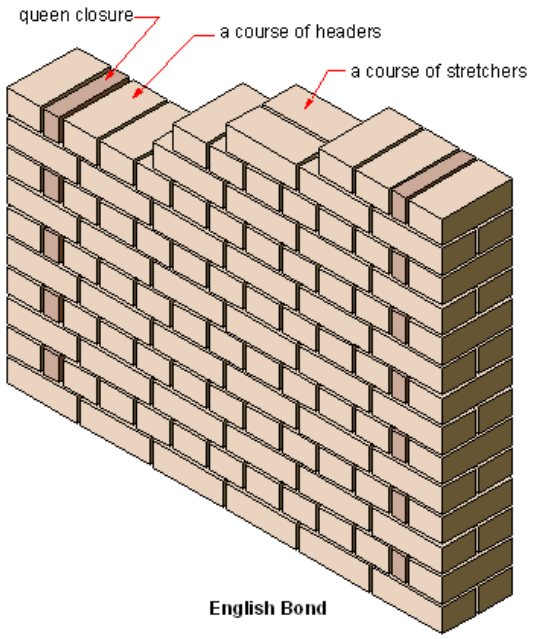


Fig. 3.3 English Bond
(Source: http://www.builderbill-diy-help.com/english-bond.html)

(iv) **Flemish bond:** - When alternate header and stretcher are laid in same course. Every alternate course starts with quoin header followed by a queen closer to develop face lap. (See fig 3.4). Every header will obtain a location that is central with respect to the stretcher above or below.

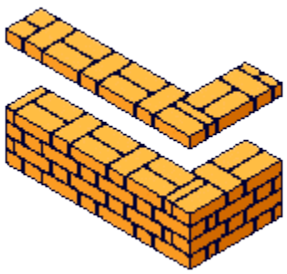


Fig.3.4 Flemish Bond
(Source: http://www.fatbadgers.co.uk/Britain/Brick%20Bonding.htm)

1.1.4 **Brick work or brick masonry construction: -** Brick work is a great art. Bricks are laid systematically with respect to bonding, jointing and finishing. Construction to be done in the following manners: -

i. Bricks should be soaked thoroughly in water.

ii. Mortar is spread upto a depth 1.5cm to 2 cm.

iii. Corners of walls to be constructed first. Corner's quoin brick is pressed in hard and then queen closer is covered with mortar.

iv. The level, alignment and offsets are to be checked.

v. After completion of first course, mortar is to spread over the course up to 1.5cm to 2cm deep.

vi. The masonry work should be kept wet for one to two weeks.

1.5 Stone wall or Stone masonry: - Stone wall or Stone masonry is made of stone blocks as building unit bonded together with mortar. Stones like granite, lime stone, sand stone, marble, slate, laterite etc are used for stone masonry construction.

1.5.1 Kinds of stone masonry wall: - It is classified mainly into two classes: -

i. **Ashlar masonry**: - It consists of stone blocks of accurately dressed stones with extreme fine bed and joints. The height of stone varies from 20cm to 30cm..

ii. **Rubble masonry: -** They are of many types: -

a) Random rubble uncoursed: - Stones of all sizes and shapes are used. Space between stones is filled with stone chips and flushed with mortar. Bond is obtained by interlocking of stones.

b) Random rubble coursed: - Stones of the same kind as random ruble uncoursed are used. But at every 12 to 18 inch height, coursed are levelled to obtain a fairly horizontal joint.

c) Squared rubble uncoursed: - The masonry work uses stones of all sizes but dressed to have horizontal and vertical sides.

d) Squared rubble coursed:- Stones of same size and shape as in squared rubble un-coursed masonry are used, but courses are leveled off at 15 to 18 inch height**.**

e) Regular coursed rubble:- Hardest and well dressed stones are used. Course height should be between 6 inch and 9 inch. No course should be greater in height than course below. Joints should be ¼ inch thick.

f) Dry stone rubble masonry – It is the ordinary rubble masonry made to course, in which mortar is not used in the joints. It is suitable for retaining and breast walls.

g) Dry stone revetment or Pitching: - To protect the earthen cutting or embankment from scouring action of water, dry stone walls are laid in layers which are called 'Dry stone pitching'**.**

1.5.2 Stone masonry construction: - The following main principles are to be observed:-

i. The stone used is to be hard, tough, durable, well soaked and washed.

ii. The stone should be properly dressed and placed on its natural bed.

iii. Bond should be used at regular intervals.

iv. Faces should be truly vertical and masonry should be raised uniformly.

v. The exposed joints should be pointed in cement mortar in 1:3.

vi. The work should be cured for 2 to 3 weeks.

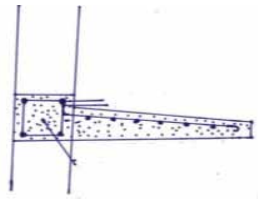
1.6 Sill: - It is the horizontal member provided at the bottom of window opening. The bottom horizontal part of the door is also called **'sill'**. The objects of sill at bottom of the opening are-

i. To afford protection to the wall below the window.

ii. To fit shutter tightly over the window frame. The sill is made of stone, brick, tile, wood and concrete.

1.7 Lintel: - The opening of door, window, cupboard etc should be bridged over so as to support the load of the wall above them. This may be done either by a lintel or an arch. The lintel is convenient in all respect. A lintel is a horizontal member provided over the openings of doors, windows, cupboards etc. The lintel supports the structure and its loads above opening and then transmits the loads to the adjacent walls. The width of the lintel will be same as that of the wall and the thickness is to be designed considering the load coming upon it. On the basis of mate-

rial used, the common types of lintel are: - wooden lintel, stone lintel, brick lintel, steel lintel and R.C.C. lintel. The R.C.C. (with 1:2:4 to 1:3:6 cement concrete) lintel is widely used now-a-days. The R.C.C. lintel is projected outside upto a minimum width of 45 cm and the depth at end is minimum of 5 cm to make a sloping over surface for easy discharge of water. This extended portion is called 'Sunshade' or 'Chajja'. (See fig 3.5).



Reference Materials:

1. Lecture notes on Forest Engineering – I by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- I by M.V. Achar, Forest Rangers' College
3. PWD (WB) Schedule of Rates 2014
4. N.J. Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun

Fig.3.5 R.C.C Lintel with Sunshade

Battened Ledged Door

5. Brick works-code of practice 1991 BUREAU OF INDIAN STANDARDS.
6. (http://theconstructor.org/tips/design-and-detailing-of-rcc-beams/7472/)
7. Websites cited in the Lesson.

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Lesson 4

Time 1 hour

Building construction (contd.)

Lesson Plan Objective: To study

- **Building Construction (contd.)**
- **R.C.C column**
- **R.C.C Beam**
- **Carpentry and Joinery**
  - Qualities of Good structural timber
  - Principles of joining timber work
  - Common types of joints
- **Doors**
  - Common sizes
  - Door frames
  - Types of doors
- **Windows**
  - Common sizes,
  - Window frame
  - Types of Windows

Backward Linkage – Materials of previous lessons
Forward Linkage – Building construction dealt with in subsequent lessons **Training materials required –** Copy of Lesson 4 to be circulated beforehand **Allocation of time**

1.1.C **Column – R.C.C Beam**	15 mts
Carpentry and Joinery	15 mts
Qualities of Good structural timber	
Principles of joining timber work	
Common types of joints	
Doors	10 mts
Common sizes	
Door frames	
Types of doors	
Windows	10 mts
Common sizes,	
Window frame	
Types of Windows	
Discussion/Miscellaneous	10 mts

BUILDING CONSTRUCTION: - (CONTD.)

1. **R.C.C. column -** Columns are important vertical members of building and their function is to support beams which in turn support walls and slabs. Foundation works for both brick and R.C.C. column are to be designed and constructed in such a manner so that the column can resist the load coming upon it. The column size and section should be as per approved plan. The columns are located at the corners of rectangular or square superstructure and at such places as indicated in the plan. In case of R.C.C column the height should be extended slightly above the roof level to facilitate extension for anchoring of steel bars with the existing bars. In R.C.C column, necessary reinforcement should be placed properly as per design. A typical design of R.C.C column is shown in Fig.4.1

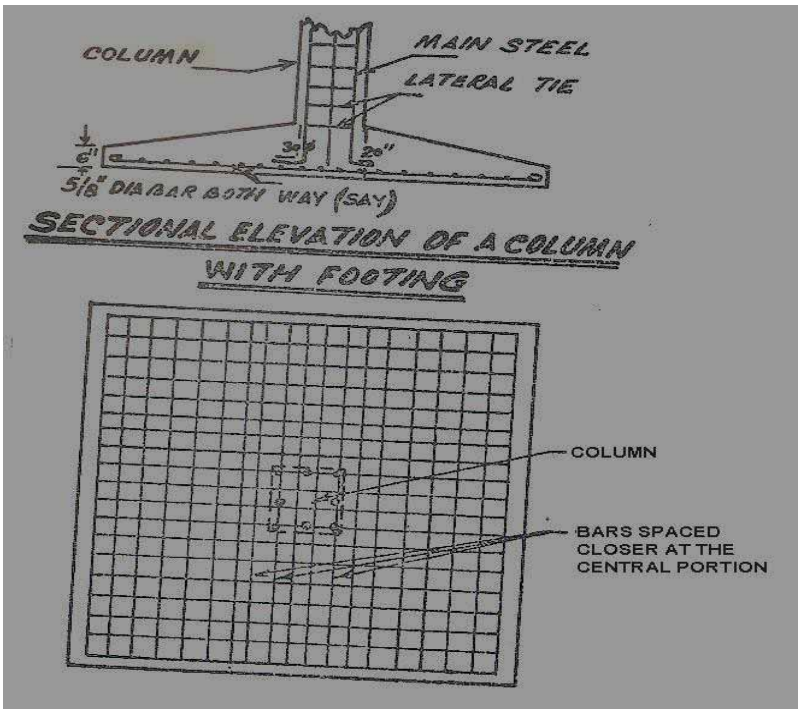

Fig 4.1 Reinforcement of a column and its footing

(Source : Redrawn from Forest Engineering without Tears by N.J.Masani)

2. **R.C.C. Beam:-**

RCC beams structural elements are designed to carry transverse external loads that cause bending moment, shear forces and in some cases torsion across their length. Concrete is strong in compression and very weak in tension. Steel reinforcement is used to take up tensile stresses in reinforced concrete beams. Mild steel bars of round section have been traditionally used in RCC work. But with the introduction of deformed and twisted bars, the use of mild steel bars has declined.

2.1 **Location of reinforcement**

- Simply supported R.C.C Beam, R.C.C Lintels and R.C.C Slabs – The tensile reinforcement is at the bottom, since tension develops at the bottom.
- Cantilever R.C.C Beam and Slab – The tensile reinforcement is near the top surface, since tension develops near the top of the beam.
- Continuous R.C.C beam or fixed beam – The reinforcement is at the bottom of the beam near the centre, and at top of the beam near supports.

2.2 R.C.C beam to be constructed should be as per approved design and plan. Typical reinforcement designs of simple R.C.C beam and cantilever beam are shown in Fig. 4.2

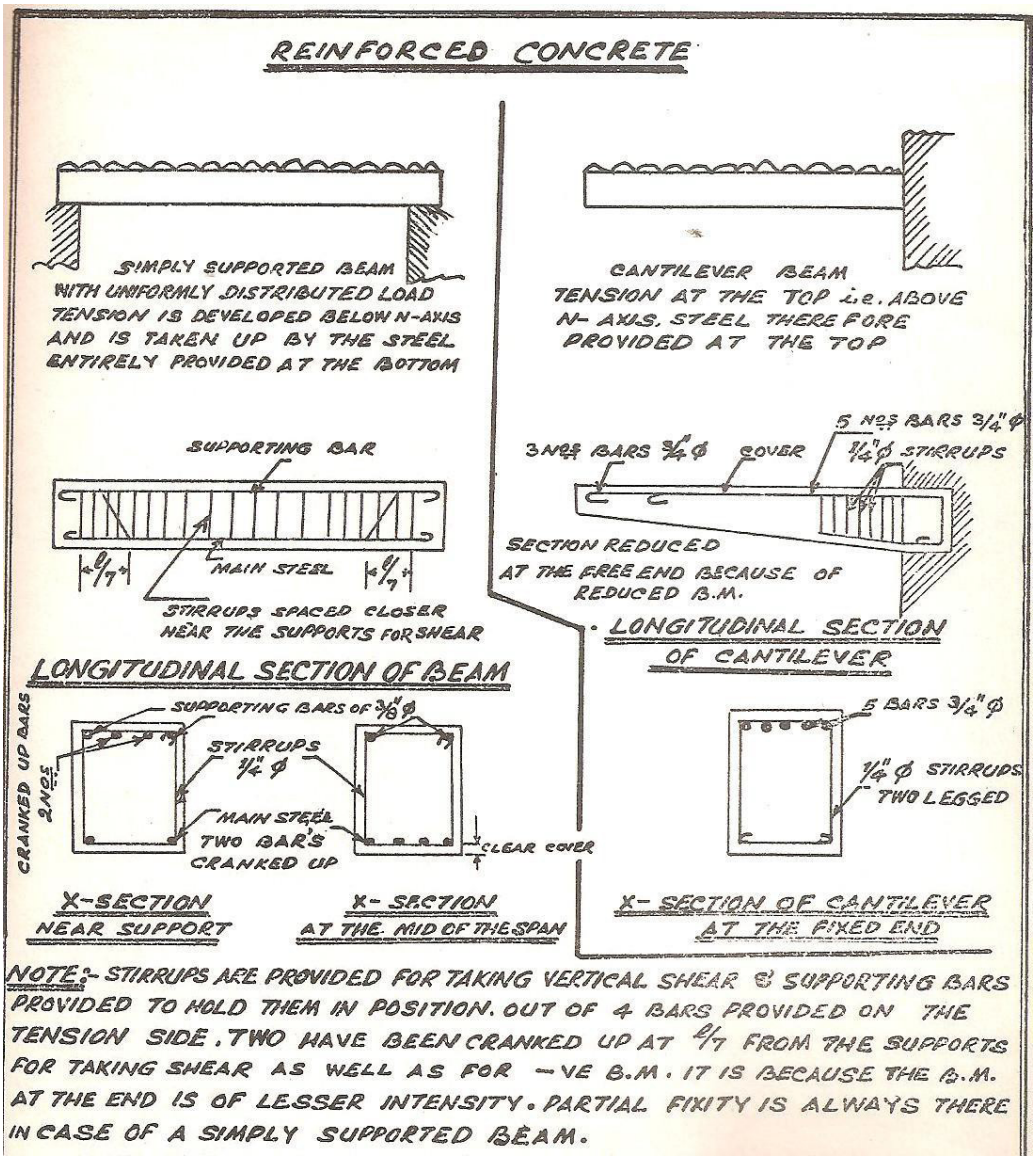

Fig. 4.2 Simply supported beam and cantilever beam
(Source : Forest Engineering without Tears by N.J.Masani)

3. **Carpentry and Joinery: -** The timber obtained from depot is rough and cannot be used as structural members or otherwise in building works. So it needs be dressed, planed, framed and placed in position. This is the combined work of carpentry and joinery.

4. **Qualities of good structural timber: -** The qualities and features of good structural timber are the following: -

i. Heavier specimens are generally strong and durable.
ii. Dark in colour.
iii. Timber which has slower growth and narrow annual rings.
iv. Freshly cut timber with sweet smell.
v. Timber with straight fibres and free from dead knots, flaws, shakes etc.
vi. Timber should not bow, wrap or split in shape during conversion and seasoning.
vii. Should give out clear ringing sound.

5. **Principles of joining timber work: -** Joints are the weakest parts of timber structure and the following principles are to be followed:-

i. Joints should be simple as far as possible.
ii. Joints should be cut and placed in such a manner that it weakens the connecting members to the minimum.
iii. Each abutting surface of a joint should be so designed to bear maximum compressive / tensile stress.
iv. The surface of a joint to be formed and fitted accurately so that there is even distribution of pressure.
v. Fastenings should be proportioned so that they may be of equal strength with the pieces which they connect.
vi. Fastenings should be designed and placed in such a manner as to avoid failure of joints by shear or crushing.

6. **Common types of joints:-**

i. **Lengthening Joint**: - To increase the length of wooden members of shorter length by the method of Lapped Joint, Butt Joint etc.
ii. **Widening Joint**: - To increase the width of smaller planks or boards by the method of Butt Joint, Rebated Joint etc.
iii. **Bearing Joint**: - Provided when two wooden members meet at right angle. The usual bearing joints are Halved Joint, Notch Joint etc.
iv. **Framing Joint: -** To make frame of door, windows etc. The method of cutting grooves and tongues in the members of the frame is suitably altered to obtain the desired form of joint.

7. **Doors**

Door is a fitting in a structure for an opening into it by which persons enter. A door consists of door frame and door shutters, either one or two leaves, hung to the door frame by means of hinges.

7.1 **Doors** should preferably be placed in the corner of a room for privacy and for maximum use of accommodations. In case of more than one door, they are to be placed in the opposite wall to facilitate ventilation and cause least interference.

7.2 **Common sizes of doors**

In general height of a door should be 1.8mt to 2.1mt. The width should be such that two persons can pass trough.

7.3 **Door frame**

It is an assembly of horizontal and vertical members forming an enclosure. Two vertical members on each side are called **'posts'** fitted with walls by clamps, and the horizontal member is called **'head'**. Generally there is one head. If another horizontal member is fitted at bottom, it is called '**sill'.** The sectional size of members is generally 8cm × 10cm, or 10cm

× 12cm. (See fig 4.3)

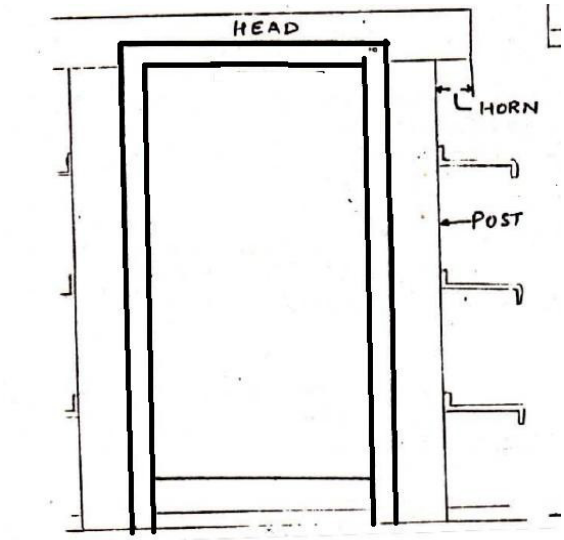

Fig. 4.3 Door Frame

(Source: Redrawn from Lecture Notes on Forest Engineering I by K. Muniamuthu, State Forest Service College Coimbatore)

1.4 **Types of doors**

The common types of doors are classified depending upon (a) materials used, b) arrangements of different components of the door, c) methods of construction, and d) nature of working operations.

Some of the types are described below.

i. **Battened and ledged door**: - it is made with vertical narrow bonds known as **'battens'** fitted with horizontal support named as **'ledges'**. (See Fig.4.4)

ii. **Battened, ledged and braced door**: - An improved version of battened and ledged door, it has additional members named **'braces'** fixed diagonally.

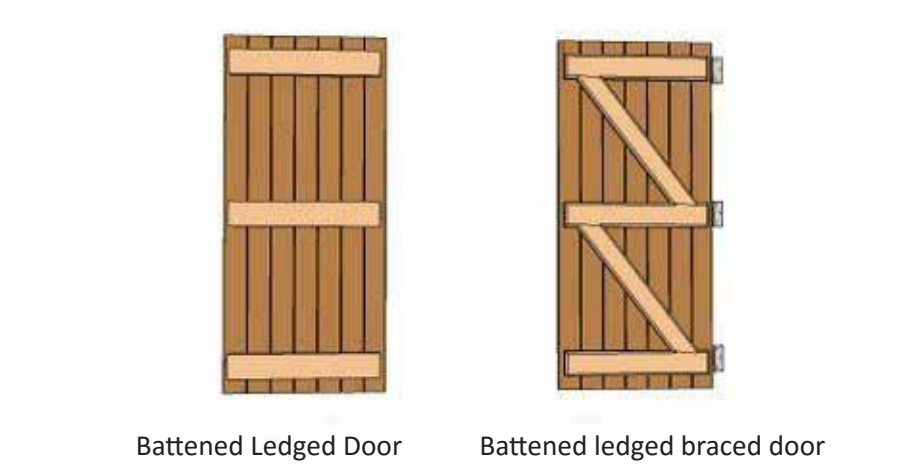

Fig.4.4 Battened Ledged door, battened ledged braced door (Source: http://www.secrets-of-shed- building.com/building_a_shed_door.html)

iii. **Battened, ledged, braced and framed door**: - As modification of battened, ledged and braced door, it has two additional vertical members called **'styles'**.

iv. **Framed and panelled door**:- It consists of a frame work of vertical members called **'style'** and horizontal members called **'rails', which are** grooved along the inner edge of the frame to receive **'panels'** . This type of door is widely used.

v. **Glazed and sash door**: - It is made of either fully glazed, or partly glazed and partly paneled. In the latter case, the bottom one third height is panelled and top two third height is glazed.

vi. **Flush door**: - this door consists of either entire solid or semi solid skeleton or core covered on both sides with plywood, face veneers etc.

vii. **Louvered or Venetian door**: - Louvered doors permit free ventilation through louvers and also maintain the privacy of the room. The door may be either louvered fully or partly louvered and partly paneled. This type of door is generally used for bath room.

viii. **Wire-gauged door**: - Wire mesh is provided in the panels to permit free passage of air. The door is formed of a wooden frame consisting of verticals styles and horizontal rails and the panel openings are fitted with fine galvanized wire-gauge mesh.

ix. **Swing door**: - The door has its leaf attached to door frame by means of double action spring hinges so that the shutter can move both inward and outward. Generally it has a single leaf but two leaves can also be provided.

x. **Revolving door**: - It consists of centrally placed vertical members to which four radiating shutters are attached. The vertical member is supported on ball bearings at bottom and bush bearings at top to facilitate rotation.

8. **Window**

Windows are provided to admit air and light to the rooms as well as to give a view of the outside. Window consists of two parts: -

a) Window frame secured to the wall opening with the help of holdfast.

b) Window shutters held in position by window frame.

The window should be located on opposite wall facing the door or opposite to another window for cross ventilation. The total area of window opening varies from 10 to 20 percent of the floor area of the room. The window should be generally located about 75 cm above the floor level, and all sills in a room should be at the same level. The heights of the windows should be adjusted so that lintels above door and window openings remain at the same level.

8.1 **Sizes of windows**

The size and number of windows should be designed on the basis of distribution of lights, control of ventilation and privacy of the occupants. The common sizes are 60 cm × 130 cm, 90 cm × 130 cm, 105 cm × 130 cm, 120 cm × 130 cm and 150 cm × 130 cm.

8.2 **Window frame**

Window frame should be made of scantling having a cross section of 8 cm × 10 cm to 10 cm × 12 cm and is fitted to the opening with suitable holdfasts. It is also provided with iron bars at a spacing of 10 cm to 15 cm. It may also be provided with grills in place of iron bars. Shutters are fitted with frame by means of hinges.

1.3 **Types of windows**

On the basis of nature of operational movement of shutter, materials used for construction, manner of fixing, and their location, windows are classified into the following types that are normally used:-

a) Casement windows: - It is the common type. The shutters of windows open like shutters of door. The shutters consist of styles, top rails, bottom rails, intermediate rails thus dividing it into panels. The panels may be glazed, or unglazed, or partly glazed and partly unglazed.

b) Fan light: - It is additional opening placed on top of door or window frame. It is intended for light and ventilation. The horizontal member separating the door or window is called '**transome**', hence it is sometime called '**transome light'**.

c) Sky light: - It is generally a glass frame pressed parallel to the sloping roof surface. The common rafters are suitably trimmed and the light is erected on a curb frame.

d) **Clere-storey window: -** It is similar to the ordinary ventilator and is provided above the lean-to-roof but below the main roof to provide light and ventilation. The shutter swings in such a way that upper part opens inside and the lower part opens outside, to exclude rain-water.

e) **Dormer window:** - It is a vertical window provided on the sloping roof. It is provided for ventilation and lighting to the enclosed space below the roof.

f) **Ventilators:** - It is a small window fixed at a greater height than the door and window, generally about 30cm to 50cm below roof level. The ventilator has a frame and shutter generally glazed and horizontally pivoted. The common sizes are 60 cm × 45 cm, 75 cm × 45 cm, 60 cm × 60 cm, 100 cm × 60 cm and 120 cm × 60cm.

Reference Materials:

1. Lecture notes on Forest Engineering – I by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- I by M.V. Achar, Forest Rangers' College
3. PWD (WB) Schedule of Rates 2014
4. N.J. Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun

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Lesson Plan Objective: To study

Lesson 5

Building construction (contd.)

Time 1 hour

- **Superstructure (contd.)**
  - **Roofs**
    - Flat roofs- RCC roof
    - Pitched or slopping roofs
      - Single roofs, double or purlin roofs, trussed roofs
      - Roof covering
  - **Flooring**
  - **Plaster –** Materials and methods
  - **Pointing-** Materials and methods
  - **Whitewash, colour wash, distemper, painting-** materials and methods

Backward Linkage – Materials of previous lessons

Forward Linkage – Building construction dealt with in subsequent lessons

Training materials required – Copy of Lesson 5 to be circulated beforehand; demonstration of tools used in plaster.

Allocation of time Roofs

Flat roofs- RCC roof	8 mts
Pitched or slopping roofs	11 mts
Single roofs, double or purlin roofs, trussed roofs Roof covering	
Flooring	10 mts
Plaster – Materials and methods	8mts
Pointing- Materials and methods	8 mts
Whitewash, colourwash, distemper, painting- materials and methods	10 mts
Discussion/ Miscellaneous	5 mts

Building construction- Superstructure (contd.)

1. **Roof**

Roof is the uppermost part of a building constructed to protect the interior of building from atmospheric elements like rain, wind, heat, snowfall etc. It consists of structural elements such as rafter, purlin, truss, slab etc. and roof covering. This structure should have adequate insulation against heat and sound.

2. **Types of Roof**

Based on shape, roofs may be mainly divided into two categories, namely, (1) Flat or terraced roof, and (2) Pitched or sloping roof.

2.1 Flat or Terraced Roof :- This type of roof is constructed for any shape and size in such a locality where there is moderate rainfall and no snowfall. It is either horizontal or with a little slope less than 10^0. Depending upon the materials used and the arrangement of rafters, joist, beam etc. the flat roof is of **four types** (a) Mud terraced roof, (b) Madras terraced roof, (c) Jack arch roof, and (d) R.C.C. roof.

2.1.1 R.C.C. Roof :- It is invariable in modern building because of the inherent advantages of R.C.C. It is stronger in compression and its weakness in tension is reinforced with mild steel bar. The method of construction is also easy. The thickness of R.C.C. roof is thinner than that of other types of roof. The quantity of reinforcement steel required depends on the maximum amount of tensile stress. Reinforcement should be placed uniformly on the tensile zone with clear concrete cover as per approved plan and design. Provision for shear, bond, anchorage and laps in bars are to be considered during design. After the centering, shuttering and placing of reinforcement are completed, cement concrete paste preferably in 1:2:4 is to be put in such a way that their will be no void. This may be done by jerking and thrusting, but preferably by a vibrator. On the next day a cement wash is to be applied over the work and after drying of cement wash, the top of roof is to be flooded with water and to be kept wet at least for 15 days. The shuttering is to be dismantled when the concrete mass becomes solid. Thereafter a course of cement concrete in 1:2:4 with smaller size of stone chips mixed with water proofing compound to a thickness of 3 to 5cm may be put on top of the above work in a turtle shape or water proofing solution may be applied.

2.2 Pitched or Slopping Roof :- A roof with slopping surface generally 30^0 or a rise equal to $^1/3$ to $^1/4$ of span is known as pitched roof. The slopping of pitched roof has three forms or directions namely, (a) **Lean-to-roof** (see **fig 5.1**), (b) **gabbled roof** (see **fig 5.2**), and (c) **hipped roof** (see **fig 5.3**). The lean-to-roof has one slopping surface and is provided for a small span. The gabbled roof has two slopping surfaces one opposite to other. The hipped roof has four slopping surfaces forming triangles in four directions.

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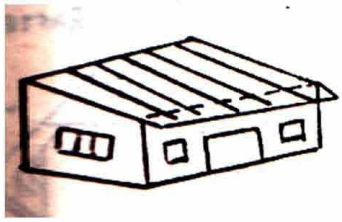

Fig. 5.1 LEAN TO ROOF

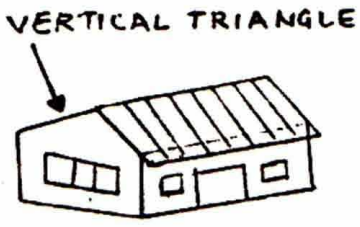

Fig. 5.2 GABBLED ROOF

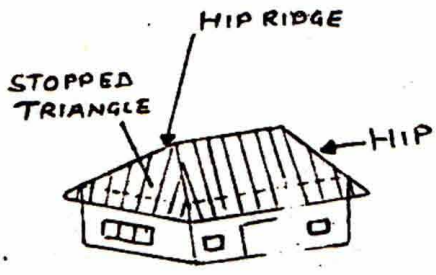

Fig. 5.3 HIPPED ROOF

(Source: Lecture Notes on Forest Engineering I by K. Muniamuthu, State Forest Service College Coimbatore)

Permeable

On the basis of structural members used such as rafter, purlin, truss etc., **the pitched roof** is broadly classified into **three types** as under :-

a). **Single roof or only common rafter roof** :- This type is used when the span is limited to five meter. It is again subdivided into four sub-divisions :- 1) Lean-to- roof, 2) Couple roof, 3) Couple closed roof, and 4) Collar beam roof.

b). **Double or Purlin roof** :- Double roof have two structural elements namely Purlin and common rafter. The Purlins are supported on end-walls and the Purlins give intermediate support to the common rafters. Thus each common rafter is supported at three points, i.e. at lower end on a wall plate, at the centre on a purlin and at the top with a ridge piece.

c). **Trussed roof :-** When the span of roof exceeds five meter and where there is no inside wall to support the Purlin, a framed roof structure known as **'truss'** is provided at suitable intervals of 2 to 3 meter along room length. In this truss system, there are three structural elements namely truss, purlin and common rafter. The important types of roof trusses in common use are 1) Kingpost Truss (See Fig.5.4), 2) Queenpost Truss, and 3) Steel Truss.

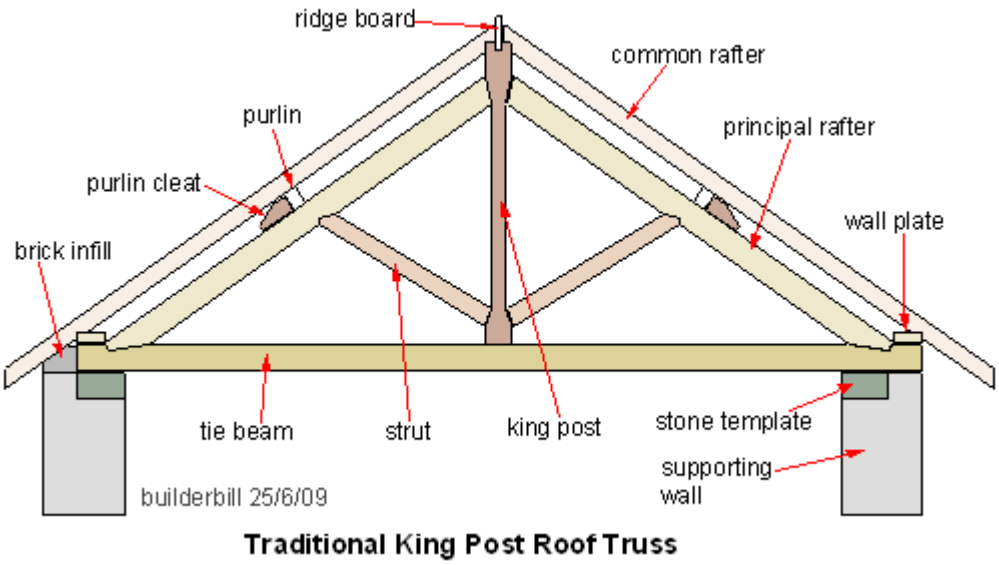

Fig. 5.4

(Source:http://www.builderbill-diy-help.com/king-post-truss.html)

3. **Roof Covering for Pitched Roof**

Selection of materials for roof covering depends upon the type of building, frame work, roofing materials and climatic condition. The various roof covering materials used are :- 1) Thatch, 2) A.C. sheet, 3) C.G.I. sheet, 4) Tiles, 5) Slate, 6) Wooden shingles. A stable and durable frame work is to be made over which roof covering materials to be placed with proper and tight binding by means of required binding materials like rope, twine, nails, J- bolts etc.

4. **Flooring**

Floor is a level surface which takes the load of occupants of building, furniture, equipments etc. The floor resting in ground surface is called **'ground floor'** while the other floor of each storey is called **'upper floor'**. It should be strong, durable, fire resistant, damp resistant, sound and thermal insulated. The flooring work is carried out after filling up of foundation trench and basement. The floor is of six types depending upon the materials used :- a) Mud flooring, b) Brick flooring, (c) Tiled flooring, d) Stone flooring, e) Cement concrete flooring, f) Wooden flooring.

4.1 Foundation trench and basement filling

After masonry work in foundation is over, the gaps left in foundation trenches to be filled with the existing soil, and with extra soil if needed, up to original ground level. The filling should be made in layer not exceeding 20cm thick. The filling is to be rammed and dressed with an outer ward gentle slope. The filling of basement is to be made with morrum or good red soil or sand free from mud etc. Filled up materials should be watered thoroughly, rammed and dressed properly to a perfect level and the verandah floor should be given an outward slope.

4.2 Cement Concrete Flooring

It is the most common flooring and easy to construct. The concrete flooring consists of two components, namely, (1) base concrete course and (2) wearing surface or topping. The base course normally consists of lean concrete mix 1:4:8 to a thickness of 7.5 cm to 10 cm. The base course is laid over the whole area and leveled to a rough surface. After the base course has fully set and hardened its surface is thoroughly cleaned and the floor area is divided into square or rectangular panels, each side being 1m to 2m, by glass strips or wooden battens, with their depth equal to flooring thickness. The surface of the base course should be made damp and applied with a coat of neat cement slurry prior to applying the wearing course. The wearing surface or topping of required thickness is then laid over the base course in alternate panels. The cement concrete is spread evenly using a straight edge, and then thoroughly floated with wooden floats until the mortar comes up to the surface which can then be finished off smooth with a steel trowel. The battens used for forming the panels may be removed the next day and topping concrete laid in alternate panels.

4.2.1 When laying concrete is completed, the surface is cured for 7 to 14 days. When the concrete has set, the surface may be rubbed with hard polishing stones to provide a fine polish to the floor.

5. **Plastering**

The objects of plastering wall are to give a plane, hard and finished surface, to protect the bricks and the stone from weathering and to prepare the surface for receiving white wash, distemper and paint etc.

5.1 The plastering is of three kinds depending upon the materials used, namely, (1) **Lime Plastering**, (2) **Cement Plastering**, and (3) **Mud Plastering**.

5.2 Lime Plastering – It is done with lime mortar. The proportion of lime and sand is 1:2 for one coat of plaster; 1:2.5 for second coat of plaster and for third coat, only lime is used. One coat of plaster is ordinarily sufficient for brickwork. Rough stone masonry requires two coats. Stone wall where painting is to be carried out on plaster would require three coats. The rough coat or the first coat is normally ½ inch thick. When two coats are applied the thickness is (5/8" + 1/8") or ¾ inch. That is, the first coat will be 5/8" thick and the second coat will be laid 1/8" thick. For three coats, the combined thickness will be (5/8" + 5/16" + 1/16") or 1 inch.

5.2.1 Procedure: Mortar joints in new stone or brick masonry should not be raked but left rough and projecting. For uniform thickness of plaster, rough casting screeds of plaster, 6" wide, are prepared at intervals of 4 feet across walls. The surface between these ledgers is covered up with plaster and leveled up from screed to screed.

1.3 **Cement Plastering –** Cement mortar of varying proportion – 1:2 to 1:8 – is used. Cement plaster is applied to required thickness in one coat only and well rubbed and polished. The surface is prepared as described for lime plaster. Usual thickness of plaster is

- ¾" for rubble masonry,
- ½" for brickwork on smooth side and 5/8" on rough side, and
- 3/8" to 5/8" for concrete walls.

1.4 **Mud Plastering** – It is done with a mixture of stiff clay and chopped straw. The clay should be fine, and the mixture thoroughly mixed and flooded with water and left for 10 days. It is then applied to surfaces in thin coats only. Subsequent coats are applied when previous coats are still wet. Plastered surface is smoothened with wooden float. Cracks appearing on drying may be filled with liquid cow dung.

6. **Pointing**

Pointing is the treatment of exposed joints of brickwork or stone work with lime or cement mortar. Rich mortar is used for pointing –

- Cement mortar – 1:1 to 1:3
- Lime mortar – 1:1

6.1 It is done

- where building materials (brick, stone etc) can stand action of water;
- where workmanship is neat and good;
- where natural beauty of materials and workmanship is exhibited to view.

6.2 Types of Pointing

a) Flush Pointing - Pointing is flush with the face of the wall. It is most commonly used.

b) Keyed-Joint Pointing – Same as flush pointing but depression is made with an iron tool of half round edge drawn along the centre of joints.

c) Flat Joint V-shaped grooved pointing – Similar to flush pointing, but an iron tool (called jointer) with 'V' like face drawn along the centre of joints

d) Weather Pointing- Mortar is raked out 1/2" to ¾" before it has set. Pointing is done with a vertex of 'V' projecting beyond the surface.

e) Tuck or Raised Pointing :- A ridge raised 1/8" beyond face of wall.

f) Struck Pointing – Consists of keeping upper side of the joint ½" inside the face of masonry and lower side of joint flush with masonry.

7. **Whitewashing: -** Fresh burnt white lime is slaked by adding it to water in a vessel, constantly stirred and is allowed to stand for two days. Then it is again thinned with water to the consistency of cream and strained through clean coarse cloth. To the wash is added glue, blue and mixed thoroughly.

7.1 The surface to be whitewashed should be cleaned of all dirt and thoroughly dried. The whitewash is to be applied with a brush, each coat consisting of one vertical followed by one horizontal stroke. Each coat should be allowed to dry before the next coat is applied. Three coats will be necessary on new work.

8. **Colour-washing :-** Strained white wash is mixed with desired colour pigments and applied to the surface by the method as done in white washing.

9. **Distempering: -** It is a kind of paint in which water or oil-in-water emulsion is the carrier. It consists of pigment, glue and carrier. Oil bound distemper is washable. Before distempering, one coat of priming made by boiling glue in water may be applied and then distempering done as per the application method as in white washing.

10. **Painting: -** Paint is an impervious coat laid in building materials for decorative purpose and for protection from the effects of atmosphere. A paint consists of (1) a base (generally lead or zinc oxide), (2) an inert filler , (3) a vehicle or carrier, generally linseed oil, (4) a drier,

(5) the pigment, and (6) a solvent. Ready mixed paint is available in the market. The surface to be painted should be smooth and dry. For re-painting on old surface the old paint should be scrapped, cleaned before application of fresh paint.

Reference Materials:

1. Lecture notes on Forest Engineering – I by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- I by M.V. Achar, Forest Rangers' College
3. PWD (WB) Schedule of Rates 2014
4. N.J. Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun
5. Websites cited in the lesson

Lesson 6

Water Supply

Time 1 hour

Lesson Plan

Objective: To study

- **Source of Water**
  - Surface source – River, lakes, ponds, reservoir
  - Underground source – Springs , wells Sinking of wells
    - Cleaning and protection of wells
  - Purification of water
    - Sedimentation Filtration
    - Disinfection by chlorination

Backward Linkage - Nil

Forward Linkage – Inspection of wells in the campus

Training materials required – Copy of Lesson 6 to be circulated beforehand.

Allocation of time

- **Source of Water**

Surface source – River, lakes, ponds, reservoir 8 mts Underground source – Springs, wells (dug well, tube wells, artesian well) 10 mts
Sinking of wells – selection of site, depth of wells, lining/steining 12 mts
Cleaning and protection of wells 8 mts

- **Purification of water** 12 mts
  - Sedimentation Filtration
  - Disinfection by chlorination
- **Discussion / Miscellaneous** 10 mts

1. **Sources of Water Supply**

Water is necessary for all living beings and no life can exist without water. So, the water needs to be good and free from impurities. The original source of all supplies of water is either rainfall or snowfall. Some part of rainfall runs out as surface water into streams and rivers and a part infiltrates into the ground. Sources of water are classified into two types namely :-

i. **Surface source :-** Sources of these types are :- (a) **River or Streams**, (b) **Lakes**, (c) **Ponds**, (d) **Reservoirs**. Water from stream coming through upper catchment is generally safe for drinking. But if there are villages on the catchment area, and the villagers use the area as latrine, the water coming through that area will be contaminated. Stream or river water becomes more polluted during the onset of monsoon or floods. This is the time when streams bring down all the contaminated surface deposits on the banks. Proper boiling of water is necessary for use as drinking water. When using water from shallow and small stream in dry weather, it is advisable to dig a shallow well about a metre deep below the bed level near its bank and draw water from the well. Water of small pond is stagnant water and hence it should not be used directly for drinking purpose. However, large lakes and reservoirs, if located in uninhabited mountainous country, may be safe for human consumption, but should be used only after due chemical and bacteriological analysis.

ii. **Underground source :-** It is of two types namely :-

(a) **Springs :-** Spring water is supposed to be uncontaminated owing to the fact that water has filtered through a considerable thickness of porous soil before emerging in the form of a spring. However, the spring water may carry sulphar and calcium compound from rocks through which it has passed and as such, the water is to be analyzed before use.

(b) **Wells :-** Wells are made to supply water for domestic use and for minor irrigation purpose. Mainly there are five types of well –

1) **Shallow Well :-** This is sunk into superficial permeable bed overlaying an impermeable strata (**see fig 6.1**) and it obtains water from rainfall in the vicinity. Water in shallow well is polluted because of surface drainage and soaking into the ground.

2) **Deep Well :-** This is sunk through at least one impermeable stratum into water bearing permeable stratum (**see fig 6.2**). The water of this type of well is filtered by passing through a thick layer of soil and so it is usually of good quality. The superficial polluted water is excluded by the intervening impermeable stratum. The surface flow to the well can be prevented by lining up to a few meters below the ground level.

3) **Tube Well :-** A tube well is a type of water well in which a long 100– 200 mm (4 to 8 inch) wide stainless steel tube or pipe is bored into an

underground aquifer. The lower end is fitted with a strainer, and a pump at the top lifts water for irrigation. The required depth of the well depends on the depth of the water table. It is generally used in sandy bed of stream when water level goes deep down.

4) **Artesian Well** :- An artesian aquifer is a confined aquifer containing ground water under positive pressure. The aquifer is confined between impermeable rocks or clay which causes this positive pressure. This pressure causes the water level in a well to rise to a point where hydrostatic equilibrium has been reached. A well drilled through the super imposed impermeable layer into such an aquifer is called an **artesian well**, and if water reaches the ground surface under the natural pressure of the aquifer, the well is called a flowing artesian well (See fig 6.3). An aquifer is a geologic layer of porous and permeable material such as sand and gravel, limestone, or sandstone, through which water flows and is stored.

The water from deep well and tube well is relatively safe for drinking.

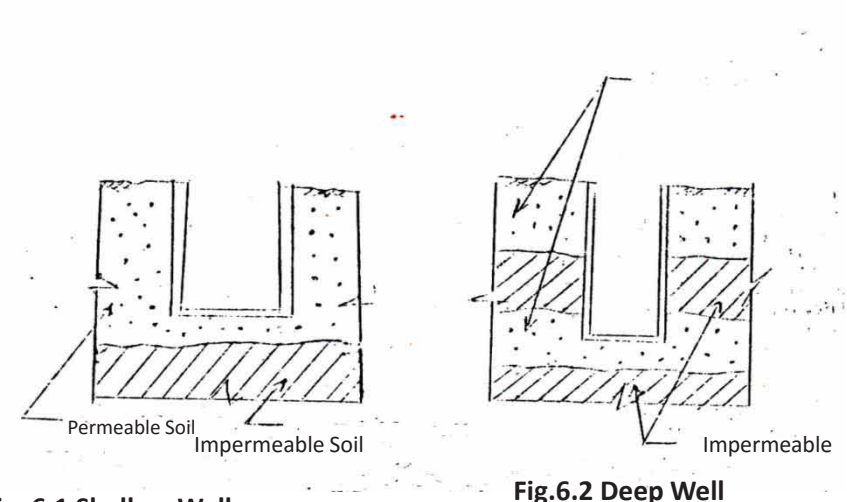

Fig. 6.1 Shallow Well

Fig.6.2 Deep Well

(Source: Lecture notes on Forest Engineering – I by K. Muniamuthu, State forest Service College, Coimbatore)

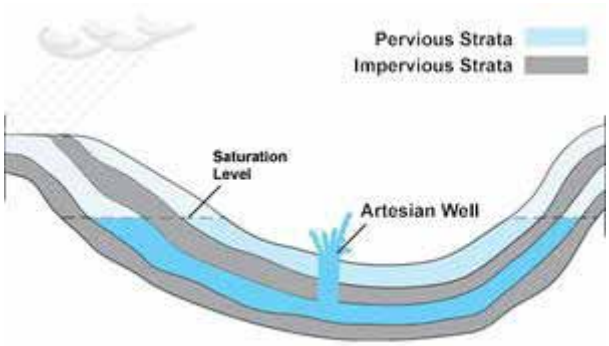

Fig.6.3 Artesian Well

(Source: http://en.wikipedia.org/wiki/Artesian_aquifer)

2. Sinking of Well

The factors to be considered are the soil condition, depth of water table, zone of saturation and ground water rate of flow. So, selection of site for sinking well has a great importance.

1.1 **Selection of site for sinking of a well**

Selection parameters are as follows :-

- **a)** Area where grass remains green and verdant.
- **b)** In summer, insects hover over damp spot.
- **c)** Where dense vapor rises from the part of the surface where springs lie underneath.
- **d)** Spring are often found at the junction of a transverse valley with the principal one.
- **e)** Reasonably away from latrine, cattle shed, burial ground, stagnant pool and other contaminated places.

1.2 **Depth of well**

The depth of well to be sunk to obtain required quantity of water may be sometimes decided by comparing the depth of other well in the locality or by careful study of geological structure of strata. The latter is an expert's job. A well sunk near the bank of a slow-flowing stream at a depth a little below the low-water level of the stream may often reach the permanent water strata.

1.3 **Lining or Steining**

The wall lining is called **'steining'** which keeps the sides from falling and prevent surface drainage and sewage from entering into well. Steining may be done of masonry brick work,

R.C.C. well-ring or timber. In case of well for temporary use, timber is used but for permanent use, brick masonry work, R.C.C. rings are used. Small wells upto 1.5 m diameter may be lined with 10 cm brick wall. For walls of bigger diameter lining with 20 cm brick wall is necessary. The space between the face of excavation and steining is filled with good puddle clay.

1.1.1 **Well curb**

It consists of a flat ring made of timber or iron having an external diameter slightly larger than that of the well steining to be constructed. The upper surface of the curb is flat on which the brick or stone lining will be built. The lower surface of the well curb is beveled and shod with mild steel plates to form a sharp cutting edge to facilitate sinking of well.

1.1.2 **Sinking of steining wall**

The well curb is to be placed on ground and over the curb brick work is started. The steining above ground level for about 1 to 1.5 m is built. Care is taken to build simultaneously diametrically opposite points so that curb is loaded uniformly all around and the well sinks in true vertical manner by the superimposed weight. Earth is scooped out from under the curb to ensure one course is completely sunk before the next steining course is built. The process is continued until the desired depth is reached.

1.1.3 **R.C.C ring well**

In the sandy soil steining with R.C.C. ring is preferable. R.C.C rings are generally 1m in diameter, 40-60 cm high and 5 to 10 cm thick. After placing one ring on the sandy ground, the sand inside is dug out. The ring is caused to sink by pressure from above and excavating the sand beneath. When the top of the ring is nearly level with the ground, a second ring is placed on the rim of the first ring and excavation is continued. More and more rings are sunk as the process progresses.

2.4 Cleaning & Protection of well

The well is to be used regularly otherwise the water becomes unfit for drinking. The well should be covered properly to prevent falling of undesirable substances. The well should be properly cleaned every year specially in the dry season. Total water is to be bailed out and the well is cleaned thoroughly by taking out deposition of clay etc. Time is allowed for the well to replenish with fresh water. When water level becomes high during rain, lime, bleaching powder as required mixed with water may be applied.

2.4.1 No cattle shed should be allowed to exist nearby. Surface drainage, sewage and industrial waste should be prevented from entering into well. The steining wall should be raised above ground to protect cattle and humans from falling in the well. No tree should be allowed to grow near the well as roots are likely to damage the stein wall. A concrete platform is to be provided around the well, sloping away from the well so that the water used for washing, bathing may not flow back to well.

2. **Purification of Water**

The various methods adopted for purifying raw water for domestic use are described below. The methods to be adopted will depend on quality of water to be purified.

i. **Screening :-** The big and longer visible objects such as tree branches, vegetation, fish, moss etc. may be removed by **'screening'**.
ii. **Sedimentation :-** Water is allowed to stand or velocity reduced in a basin or tank so that heavy suspended matters settle at the bottom as sediment. Sedimentation is assisted by addition of alum.
iii. **Filtration :-** The water from sedimentation tank is drawn to other tank filled with layers of clean gravels and sand with an outlet at bottom of tank. The water so filtered is to be passed to the chlorination tank for disinfection.
iv. **Disinfection by Chlorination :-** Chlorination has been found to be the most convenient and economic method of disinfection**.** Chlorination is the process of killing harmful bacteria by the use of chlorine gas or bleaching powder. Chlorination is applied at different stages as per requirements.
    (a) Pre chlorination – application of chlorine before sedimentation and filtration;
    (b) Post chlorination – after filtration;
    (c) Double chlorination – means chlorinated twice, pre and post chlorination;
    (d) Break-point chlorination – indicates extent of chlorination beyond which addition of chlorine will appear as free residual chlorine;
    (e) Super chlorination – indicates application of excessive amount of chlorine, which may be required in some special cases.

Reference Materials:

1. Lecture notes on Forest Engineering – I by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- I by M.V. Achar, Forest Rangers' College
3. PWD (WB) Schedule of Rates 2014
4. N.J. Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun
5. Websites cited in the lesson

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Lesson Plan Objective: To study

LESSON-7

Time 1 hour

- **Types of Forest Roads**
  - Classification
- **Road structure**

Lesson 7 Forest Roads

- **Road design**

Sub-grade or formation, Foundation or soling, Base course, Wearing course
Cross section of roads in plains Cross section of roads in hills

Roadway/road width, Carriageway, Shoulders/ berms, camber, gradients
Road curves- Super elevation, widening of roads at curve, sight distance or clear vision
Retaining wall Breast walls
Road drainage- plain road, hill road

Backward Linkage - Nil

Forward Linkage – Inspection of road works during tour, and study materials in subsequent Lessons

Training materials required – Copy of Lesson 7 to be circulated beforehand

Allocation of time

- **Types of Forest Roads** **10** mts
- **Road structure** 15 mts
- **Road design** 30 mts
- **Discussion / Miscellaneous** **5** mts

Forest Roads

1. **Definition**

A road is a way over which vehicles and other traffic may lawfully pass. Forest roads are made for transporting timbers, fuel and other forest produces and to provide communication from one place to the other. Good communication enhances efficiency and saves time.

2. **Classification of Forest Roads**

The forest roads are classified as under :-

i. **Based on Terrain :-** They are of two types :
   a) **Plain Road :-** It is constructed on plains; construction and maintenance are easy and economic.
   b) **Hill Road :-** It is constructed on hilly terrain; construction and maintenance are more difficult which are to be done carefully.

ii. **Based on nature of traffic and its function :-** They are of four types :
   a) **Inspection Path :-** Narrow paths of 60 to 100 cm width to facilitate inspection of interior forests, where vehicles cannot access or situation demands inspection on foot.
   b) **The Bridle Path :- N**arrow paths of100 to 200cm width to form a quick and direct root for laden animals from place to place and have a steeper gradient than that of cart road.
   c) **The Feeder Cart Road :-** It is mainly for exporting commodities from interior to main cart road. It is usually earth road and in some cases it may be metalled road.
   d) **Main Cart Road :-** It is a wide road and is used throughout the year for carrying of forest produce from depot to market or rail yard. It is generally a metalled road and should be straight and direct as far as possible, and must be well drained. The gradient should be low and long slopes are avoided.

iii. **Based on duration :-** The road is of three types :
   a) **Temporary Road :-** It is required for one or at most two working seasons for extracting timber from the felling site to the existing cart roads. The spurs and obstacles are avoided in alignment to minimize expenses.
   b) **Fair Weather Road :-** This type of road is made for use over a number of years but the road is not open to traffic during monsoon.
   c) **Permanent Road :-** This type of road is aligned and constructed with great care. The road should be straight, direct, and consistent with

easy gradients with shallow cuttings and low embankments. It is to be raised above the general ground level and provided with side drains.

iv. **Based on materials used :-** The roads are of six types namely :

a) **Earth Road :-** Most of the forest roads like inspection path, bridle path, feeder road are earth roads. All the temporary and fair weather roads in the forests are also earth roads. Earth roads are made with existing and borrowed earth.

b) **Gravel and moorum Road :-** They are constructed when gravels and moorum are available along or near the alignment of road..

c) **Metalled Road :-** it Is a road made with stone metal for foundation and wearing surface, and is called **Water Bound Macadam (WBM)** road. This type of road consists of road metal, and gravel or kankar bound together with water in the wearing course.

e) Bituminous Road :- The metal road when bitumen, asphalt are used as binder.

f) The Plank Road :- In very soft, marshy or swampy ground, planks, if available in plenty, are used to make such road.

3. **Road structure**

The road structure (Fig. 7.1) consists of the following parts –

- **Sub-grade or Formation** – It is the soil surface on which the entire road structure rests.
- **Foundation or Soling** – It is the layer of hard material resting on formation level. The function of the foundation is to distribute the weight of traffic to the formation.
- **Base Course** - The **'base** course' is composed of stone aggregate or road metal well consolidated.
- **Wearing Course** - The **'wearing course'** is the uppermost part of the road structure. It minimizes the abrasion of the road by traffic and acts as an impervious layer.

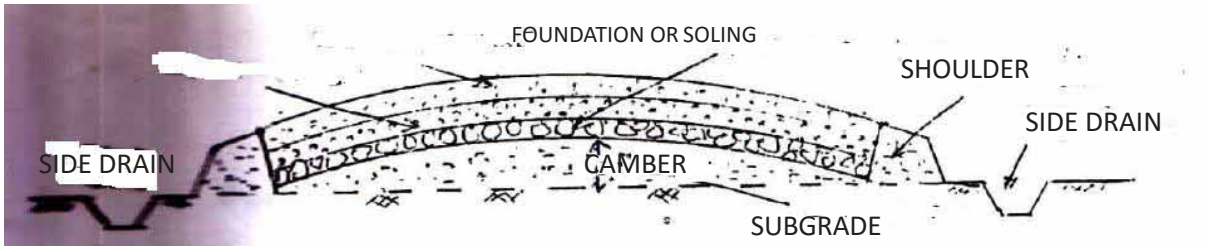

Fig.7.1 Road Structure

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

1.1. **Cross Section of Road in Plains**

It consists of –

- **Carriageway** – It is the portion of the road used for traffic.
- **Shoulder or Berm –** Portion between edge of the carriageway and the road drain.
- **Side drains –** Also called ditch; it is designed to collect and remove water from the formation and the adjacent side slope. The side drains could be trapezoidal shaped or 'V' shaped.
- **Camber – I**t is the rise of the centre of the road above its edges. The function of camber is to prevent stagnation of rain water on the road surface.
- **Super-elevation** – Transverse slope or inward tilt imparted to curves.

1.2. **Cross Section of Road in Hills (Fig.7.2)**

It is provided with transverse profile, gutter, catch water drain, camber, super elevation at curves, retaining wall and breast wall. Regarding transverse slope there are different opinions. Many engineers prefer uniform slopes towards the inner uphill side edge with a gutter, while others prefer an outward slope. In either case, the transverse slope should not exceed 1:20 to avoid heavy erosion. In case of rain fall exceeding 500mm, the slope should be given inward towards hill. On steep gradient, camber should be increased.

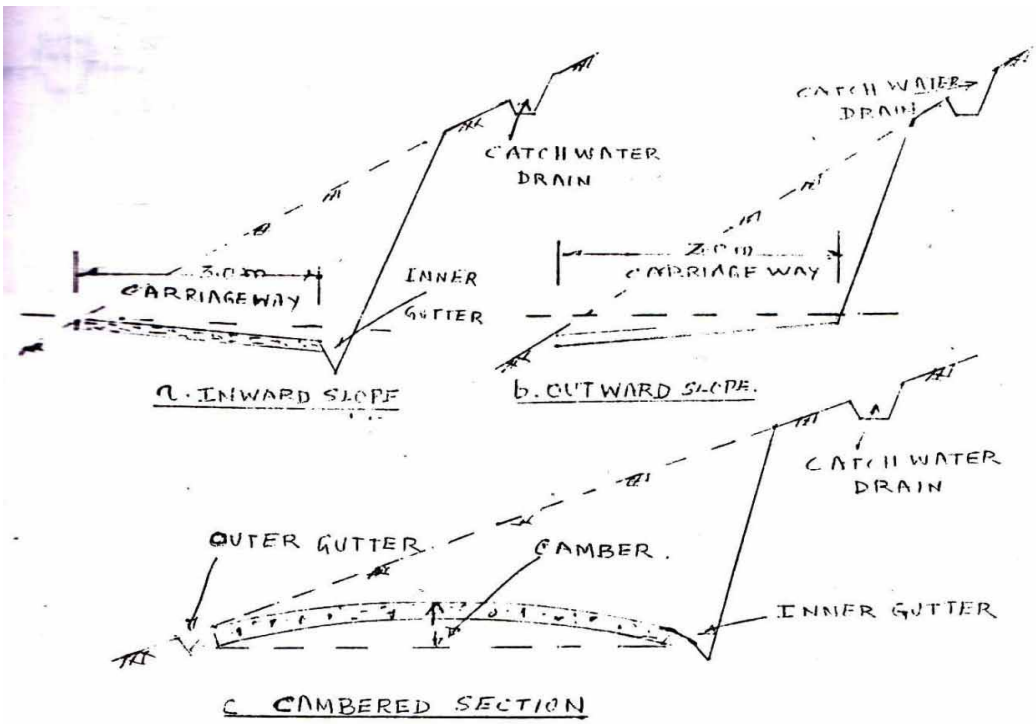

Fig.7.2 Hill Road Cross Section

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

1.3. **Stone Metalling of Roads.**

As the road made with earth and gravel is unable to take heavy traffic load, stones as road metal are used. The system of stone metalling of road is mainly of three types :- (a) **Telford system, (b) Macadam system, (c) Modern system.**

1.1.1 **Modern Roads or Water Bound macadam Road**

- The formation or sub-grade is cut to camber.
- 10-20 cm thick rubble stone or brick foundation is laid on formation as soling course and base course.
- Over the base course is laid the wearing course of 10 cm thick layer of hard material like stone chips of about 5 to 8 cm gauge.
- Binding course of 1 to 1.5 cm thick of moorum or clean gravel is laid on wearing course.
- The surface is covered with a sealing coat of 5 mm layer of sand or fine bajri.

4. **Road Design**

The elements of forest road design are :

i. **Land width :-** It includes other parts of road elements like carriageway, berms on either side, drainage arrangement, space for storing materials, equipment, borrow-pits, provision for future widening etc. To cover all these for cart roads, land width should be 20 to 25m.

ii. **Road way or road width :-** The road width includes berms, side drains and the carriage way itself. The normal road width is 1m for inspection path, 3m for bridle path and 5 to 7m for cart road.

iii. **Carriageway: -** It is also called **'wearing surface'**. The width of forest cart road should have a minimum of 3m carriage way for single lane and 4 m for double lanes.

iv. **Shoulders or berms :-** A minimum width of 60 cm to 100 cm should be provided on either side of carriageway.

v. **Camber :-** It is the convexity given to the cross section**.** It is generally expressed in terms of transverse slope of the road.

Example: 1/20 road camber will mean the centre of the road is raised above its edge by an amount equal to 1/20 of half the width of the road.

If the road width is 3.0 m, the centre of the road will be raised by (in this example of camber of 1/20)

Camber varies from road to road. In W.B.M road, camber of 1 in 30 to 1 in 48 is generally adopted.

vi. **Gradient :-** Road gradient is the longitudinal slope along center line of the road way. It is expressed as a ratio of rise or fall to the corresponding road length. Thus a road gradient of 1 in 20 means a rise or fall of 1 metre for 20 m horizontal distance.

Types of Gradients :- The various types of gradient provided in a road length considering rise and fall of terrain area are

(a) **Maximum Gradient** – it is the gradient which must never be exceeded on any part of the road.

(b) **Ruling Gradient**- It is the gradient within which an engineer will endeav or 7.5 cm our to design the road, but may be sometimes forced to exceed it to the maximum gradient.

c) **Average Gradient** – Total rise or fall on the road divided by total length of the road.

vii. **Road Curves :-** Road curves are provided in order that change of direction is gradual. Road curves are of two types :

a) **Horizontal Curve** – It allows change of direction of road,

b) **Vertical Curve** – It is introduced wherever there is change in gradient, that is, depressions and elevations.

The curves on forest roads are generally circular curves. The design of road curves depends on speed of vehicle, allowable friction, maximum permissible super elevation and permissible centrifugal force.

Hairpin Curves – They are very sharp curves (see fig 7.3) on a hill slope changing direction by 180 degree. Hairpin bends are provided, when absolutely necessary, on gentle hill slope.

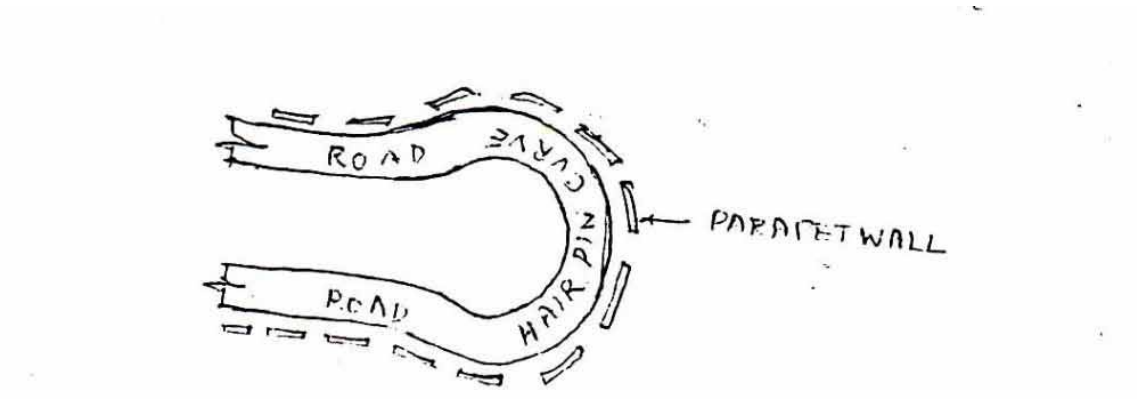

Fig. 7.3 Hairpin Curve

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

viii. **Super Elevation :-** It is provided at all the curves in order to counter-act the centrifugal force acting on the vehicle. It prevents skidding outward of fast moving vehicle. Super elevation is provided by raising outer edge of the road by half the required amount above the centre line of the road and by lowering the inner edge as necessary.

ix. **Widening of Road at Curves :-** When the vehicle passes through a horizontal curve, the front wheels turn sideways, and the rear wheels do not follow the path of the front wheels and occupy more width of the carriage way than on straight portion of the road. Hence the road width is to be increased on the inside over the entire portion of curve.

x. **Sight Distance or Clear Vision :-** It is defined as the distance measured along centre of the road over which the driver of a vehicle should see the opposite object on road surface so as to react and avoid any collision or accident. A minimum sight distance or clear vision of 50 m should be provided for the drivers.

xi. **Retaining Wall** (see fig 7.4) :- The wall constructed to support the earth filling with a surface slope much steeper than its natural angle of repose is known as **'retaining wall'**. The abutments, abutment return walls and wing walls of culverts and bridges, the curtain and drop walls of causeways, the walls constructed on the downhill side of hill roads to support the embankment, etc. are some examples of retaining walls.

xii. **Breast Wall** (see fig 7.4) **:-** The Breast wall is constructed on the uphill side of a road in cutting to support extra thrust caused by changes in the angle of repose and change of humidity of the atmosphere. It is similar to retaining wall but smaller in dimension.

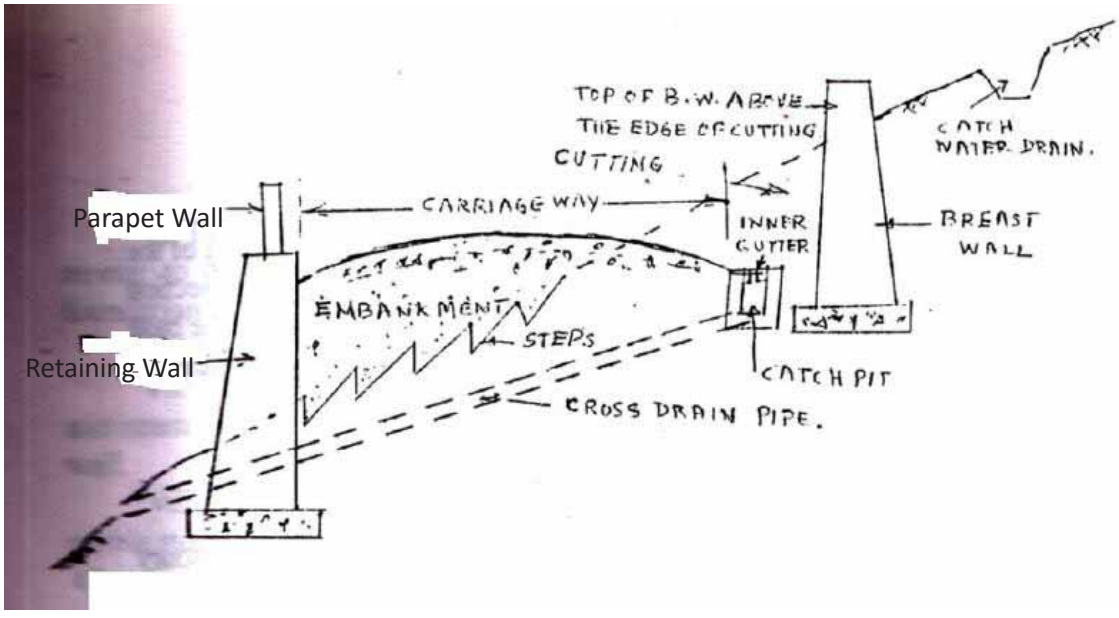

Fig. 7.4 Retaining wall and Breast Wall

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

xiii. **Road Drainage :-** Good drainage increases the efficiency and life of road. Water enters the road structure (i) from top wearing course, (ii) from surface water on the pavements, and (iii) from sub-soil seepage from the under side of the pavements. Function of road drainage is to collect and dispose surface water and sub-soil water. The design and construction of drains are to be made accordingly.

a. Plain Road Drainage :- The rainwater from the surface of road is led to the side drains by providing necessary camber, and the side drains have gradient so that water quickly flows into a cross drainage. Generally, the side drains have 60 to 100 cm top width, 30 to 50 cm bottom width, depth of about 30 cm, and a bed slope of 1 in 100.

b. Hill Road Drainage (Fig. 7.2) :- For efficient service and low maintenance cost, sufficient surface drainage should be provided for hill roads. The drainage in hill roads are mainly by

(i) Inner gutter provided on uphill side;

(ii) Outer gutter provided on the downhill side;

(iii) Catch water drain, provided about 5 to 10 m above the edge of cutting on the uphill side of the road to intercept rain water running down hill slope;

(iv) Road water tables – small oblique cross bunds placed on steep hill cart road to divert water into side gutters;

(v) Pole drain – consists of poles placed obliquely across the road to divert water to side gutters. It can be used only on earth roads.

Reference Materials:

1. Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- II by M.V. Achar, Forest Rangers' College
3. N.J. Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun

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Lesson 8

Time 1 hour

Forest Roads (contd.)

Lesson Plan

Objective :
To study

- **Forest Road Alignment**
  - Alignments in the plains
  - Alignments in hills
  - Road alignment survey
- **Preparation of road estimate**
  - Items of work in road estimate
- **Road construction**
  - Clearing of Roadway
  - Formation of road
    Formation of cuttings Formation of embankment
  - Masonry structure
  - Surface dressing
  - Construction of earth roads
  - Construction of water bound macadam

Backward Linkage – Materials in Lesson number 7
Forward Linkage – Subsequent lessons on Forest road
Training materials required – Copy of Lesson 8 to be circulated beforehand
Allocation of time

- **Forest Road Alignment** 10 mts
- **Preparation of road estimate** 15 mts
- **Road construction** 25 mts
- **Discussion / Miscellaneous** 10 mts

LESSON-8

1. Forest Roads Alignment

Locating the center line of the proposed road following some principles of road design is called road **'alignment'**. A survey is to be undertaken for determining the centre line of the proposed road and collection of some information for this purpose.

1.1 Alignment of roads in plains

The following points are to be considered during alignment :-

- **i.** The alignment should be short and straight as practicable.
- **ii.** Existing road is to be utilized as far as possible.
- **iii.** Main road should be located centrally in the area.
- **iv.** Avoid unnecessary crossing of streams and natural drainages.
- **v.** Avoid swamp and low lying area and heavy rock cut.
- **vi.** High ground should be selected where possible.
- **vii.** Slight deviation from straight line trace should be made to break the monotony of a very long straight road.
- **viii.** Private land should be avoided as far as possible.
- **ix.** Small streams may be bridged but for bigger stream, the road may be diverted to get stable land for a good bridge site.
- **x.** For development of the locality, a small deviation from original alignment may be allowed to touch stone quarry, bazaar, rest house etc.

1.2 Alignment of roads in hills

The following points may be brought into consideration during alignment:

- **i.** To start from higher obligatory points to lower obligatory points. {Obligatory points are those through which the road must pass]
- **ii.** To avoid unnecessary ascent and descent.
- **iii.** Sunny side of a valley or the side exposed to drying winds should be chosen for road position wherever practicable.
- **iv.** Try to keep the center line within the ruling gradient.
- **v.** Gradients of the road should be most carefully maintained. In no case it should exceed maximum gradient. Same gradients should be maintained, if practicable, for at least 400 metres, though long stretches of the same gradient should be avoided.
- **vi.** To avoid area of heavy rock cut and places liable to landslide.
- **vii.** To avoid hair pin curves and zigzags.

viii. To provide halting and water arrangement at intervals in case of continuously rising road.

ix. To avoid carriage way dipping towards downhill and to take the road on the slope dipping into the uphill.

x. To select wooded slope of valley.

xi. While selecting the approaches to bridges, the following factors to be considered –

a) The approach road should be straight for at least about 50 meter on either side.

b) The deep cutting at bridge site should be avoided to improve visibility and avoid drainage problems.

c) The approach road should be above high flood level.

d) The gradient on the bridge should be easy, if level stretch of road is found impossible.

1.3 **Road alignment survey :-** The road alignment survey consists of the following :-

i. **Reconnaissance Survey** :- It is a rough and rapid survey over the area where the road will be constructed. The objective is to produce a report and a rough map covering details like all reasonable obligatory points, features of the country, gradients anticipated, existing paths, culverts etc, rough elevations, positions of wells, perennial stream etc, requirement of local traffic, market places etc.

ii. **Preliminary location survey** :- The preliminary survey is done with equipments like Prismatic compass, Abneys level, Ghat tracer, Chain etc. The located routes are pegged out at uniform distance of 20 meters including pegging at curves. Then the route map will be prepared.

iii. **Final location Survey** :- It is conducted in details taking leveling along center line of the traced route and at right angles to the traced route. Levels are taken along the centre line at each peg, and notes are taken of rock, jungles, drainage lines, sites for bridges, culverts etc. In short stretches of forest roads, the operation of leveling is avoided; levels of the pegs are calculated with Abney level or Ceylone Ghat Tracer.

iv. **Construction survey or demarcation** :- It is done for setting out the road. The process begins after alignment is pegged but completes before the estimate is approved and the work started. After sanction is accorded, the temporary pegs are replaced by permanent ones.

2. **Preparation of Road estimate :-** Road estimate gives the probable cost of road construction. It is important to know the probable cost before undertaking the work**.** The accuracy in preparing the estimate is a vital factor for which one has to go into the details of each work item, namely :-

i. Preliminary road alignment survey work, preparation of drawing and estimate.

ii. Cleaning of jungles, uprooting of stump and removing the debris.

iii. Earthwork for cutting and embankment including blasting rock. The volumes of cutting and filling should be separately estimated.

iv. Surface dressing to provide camber, super elevation etc.

v. Metalling work, if required, including soling, wearing, binding etc.

vi. Drainage works such as side drains, gutters, catch water drains etc.

vii. Masonry cross drainage work such as bridge, culvert, retaining wall, breast wall etc.

The detailed proposal and estimate should be prepared giving

- A report with detailed drawings
- Brief specifications of the job
- Description of work items with detailed specifications
- For each item of work, volume of work in units to be specified.
- Amount of cost separately for each item on the basis of approved schedule of rates.
- Total cost along with an Abstract Cost giving break ups item wise. In addition to the consolidated amount of estimated cost, an amount of extra cost, being a small percentage of the total cost, say 5%, is added as contingencies to meet unforeseen expenses.

4. Road construction :- When the project is finalized and the drawing, specification and estimate are approved, the execution of road construction may be taken up.

The construction consists of the following works :

i. **Organization of labourers** :- When the work is taken up departmentally the laborers like skilled, semi skilled and ordinary are to be arranged for proper completion of the work.

ii. **Tools and machineries** :- In case of work taken up departmentally, supply of all types of tools and machineries required for the job are to be arranged.

iii. **Cleaning of roadway** :- The line of alignment should be cleared at 30cm wide on both ends and the pegs if removed may be driven again. The area of roadways should be cleaned by cutting jungles, bushes, tree etc. The trees and bamboos should be except on steep hill slopes.

iv. **Earth work** :- To get the formation of road, earthwork in cutting and in filling should be started –

a) **Formation of cutting** :- Central rectangular portion is first cut out and the correct slide slopes may be formed. A conical shape pillar known as **'Dead-man'** or **'Witness pillar'** must be left until the measurement of the earth work is taken. The depth of cutting is known as **'lift'** and the distance carried to deposit the earth is known as **'lead'**. Excavated earth, not required for making embankment, is formed into **'Spoil Bank'** to be located at least 3 m away from the edge of the cutting on downhill side. The Spoil banks are not continuous and a gap of about 3 m is left after every 30 m of spoil bank.

b) **Formation of embankment** :- The materials like gravel, singles and sand are known to be the best materils for embankment. When earth from nearby cutting is not available, the earth is to be collected from borrow pit and such pit should be located 3 meter away from the edge of the road on uphill side and should not be deeper than 1 m. There may be separate pits of 30 meter length with a space of 5 meter between

two pits. The best way of raising the embankment is to put the earth in layers of about 30 – 50cm thickness with the provision of watering, ramming and rolling before the next layer is laid.

v. **Masonry structures in road** :- Important bridges exceeding 6 meter span are built up simultaneously with commencement of road works. However, small works like Irish bridge, culvert, retaining and breast wall etc. are carried out as the work in progress. Approaches to bridge and culvert should be taken up well ahead to allow settlement.

vi. **Surface dressing of road** :- Surface of the road is to be dressed as sub grade to provide required camber by raising the center of the road by adding extra earth. The surface is also dressed at curves to provide super elevation by raising the outer edge and lowering the inner edge.

vii. **Construction of earth road :-** Preparation of formation either by cutting or embankment is to be done first and formation width of road all through is to be maintained. The sub-grade is given a camber of 1 in 24. The gradient at regular interval is to be checked. A layer of 10cm graded soil is spread evenly over the sub grade and rolled with optimum moisture by roller. It is to be watered for 4 – 5 days for curing and then the surface is sprinkled with water for 10 – 15 days. In case of road constructed with clay, the carriage way is dressed with sand for a better road. The road so made is generally **'fair weather road'**.

viii. **Construction of water bound macadam road :-** When the intensity of traffic increases,, the road is required to be metalled to make the road surface harder and more durable. The broken stone metal, gravel and stone are to be procured and stacked at site. Spreading of materials evenly, consolidation by roller in a moist condition, and maintaining camber (1 in 30 to 1 in 48), super elevation as well as gradient are done as per requirement.

ix. Maintenance of road is very vital for better service facilities and longer life of the road. Salient features of road maintenance are

- Frequent removal of mud and dust from carriageway;
- Efficient drainage
- Maintenance of shoulder
- Complete renewal of the surface

Reference Materials:

1. Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- II by M.V. Achar, Forest Rangers' College
3. N.J. Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun

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Lesson 9

Time 1 hour

Forest Roads (contd.)

Lesson Plan

Objective:

To study

- **Forest Bridges**
  - Types of Cross-drainage works
    - The Ford
    - The Irish bridge
    - The causeways
  - Culverts
    - Pipe culvert, slab culvert
  - Bridges
    - Timber / wooden bridges
    - Cantilever bridge
    - Suspension bridge

Backward Linkage – Materials in Lesson number 8

Forward Linkage – Inspection of cross drainage works during tour

Training Materials required - Copy of Lesson 9 to be circulated beforehand

Allocation of time

Forest Bridges

Types of Cross-drainage works	20 mts
• The Ford The Irish bridge The causeways	
Culverts	
• Pipe culvert, slab culvert	10 mts
Bridges	
• Timber / wooden bridges	10 mts
• Cantilever bridge	8 mts
• Suspension bridge	7 mts
Discussion/Miscellaneous	5 mts

LESSON-9

Forest Bridges

1. **Introduction :-** Forest bridges need only be strong enough to carry loaded carts, timber lorries and elephants. Forest roads are mainly **'fair weather'** roads. Mostly Irish Bridges and causeways are used for cross drainage in forest roads.

2. Types of Bridges

Depending on the condition of stream, traffic condition etc. the following types of cross drainage works are generally used in the forest road :-

i. **The Ford** (See fig 9.1) :- The banks on both sides are cut down at a gentle slope so that carts and lorries can get down and up easily. The river bed is cleared of any projecting boulders etc, pot-holes filled up, and fairly leveled so that traffic can be passed over the gap during the dry season. It should be located in the straight reaches of the stream.

ii. **The Irish Bridge** (See fig 9.2) :- The Irish Bridge is a paved dip in the surface of the road not exceeding 6 meter in span. The full width of the formation is dropped to follow the bed of the shallow water courses, and provided with normal cross-slope of 1 in 12 in hill sections to 1 in 30 in flat ground. The edges of the Irish bridge are rounded off to avoid sharp dips in the road. The road surface may be paved with dry stones, or stone in cement mortar, or cement concrete. Irish bridge is preferable to culvert in hill section where large boulders come down from upwards and block the culvert vents.

iii. **The Cause Way** (See fig 9.3) :- The cause way is similar to Irish Bridge and may be constructed for a length more than 6 meter. Causeways are preferable to culverts and bridges where a depth of 30 cm is not likely to last for more than 24 hours at a time, and the consequent interruption to traffic is negligible. A causeway should be constructed at right angles to the flow of water. The curtain and drop walls should be taken below the scour depth, the ends being sloped up at 1 in 15, and carried into the banks well above flood level. The foundation for curtain wall on upstream side should be 0.5d + 50 cm, minimum 100 cm, and that of drop wall on downhill side should be 1.5d +1 m, minimum being 2d, where d is the maximum depth of water over the causeway at high floods. The cross slope on causeway surface should be the same as that of the stream, subject to a maximum of 1 in 30. The causeway surface is provided with a stone soling and a cement concrete pavement.

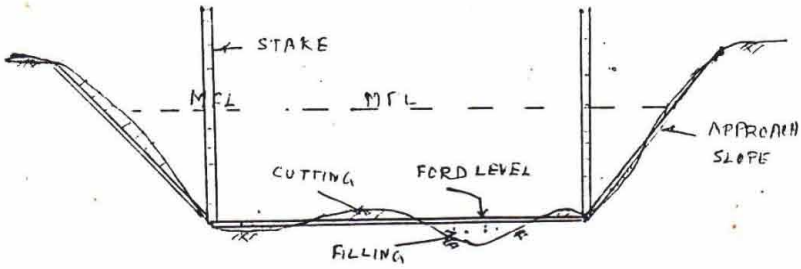


FIG. **9.1** THE FORD ACROSS A STREAM

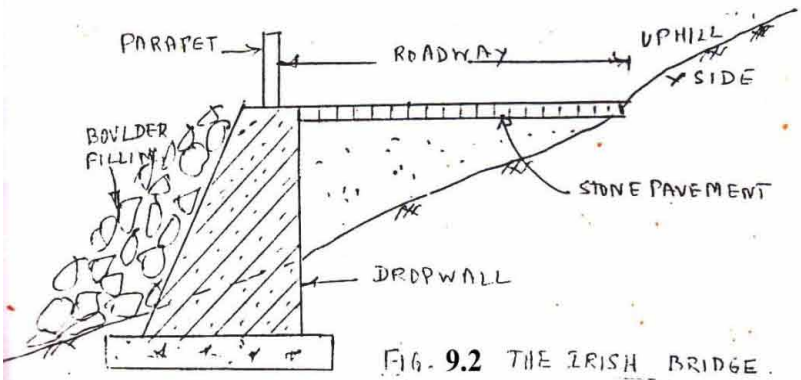
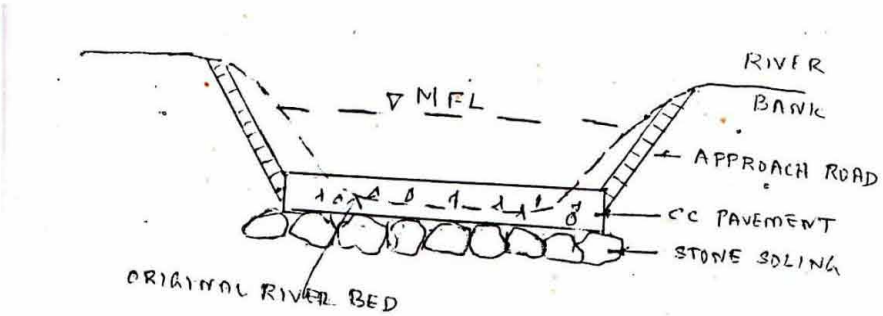


FIG. **9.2** THE IRISH BRIDGE.



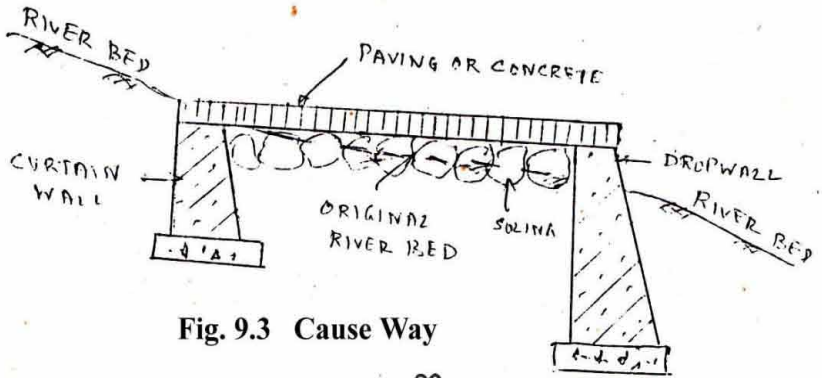


Fig. 9.3 Cause Way

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

2. **Culverts**

Culvert is a small bridge with one or two opening or span. In forest roads it is generally of single span and constructed up to a maximum span of 6 meter. The common types used in the forest road are :-

i. **Pipe Culvert** (**See fig 9.4**) :- It is generally made with Hume pipe or RCC pipe or stone ware pipes. In a forest road the construction of pipe culvert consists in simply
   - laying the pipes in position across the road on a stable foundation of cement concrete;
   - filling soil in the gaps, and providing a minimum earth cushion of 60 cm over the pipe;
   - constructing road over the earth cushion;
   - protecting each end of the pipe culvert by a head wall and wing wall. The exact number of pipes and diameter of pipes are determined by the quantity of maximum water discharge.

ii. **Slab Culvert** (**See fig 9.5**) :- Masonry culvert with stone slab is very common in forest road. The slab may be of RCC, stone or timber sleeper. It is advisable to provide independent foundation for individual abutment, and a rough stone flooring for the culvert. The thickness of slab cover is designed on the basis of span, load etc.

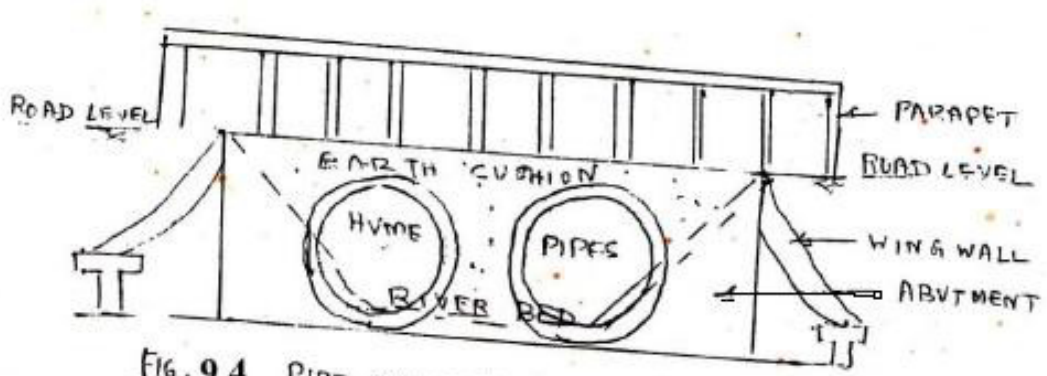


FIG. 9.4 PIPE CULVERT.

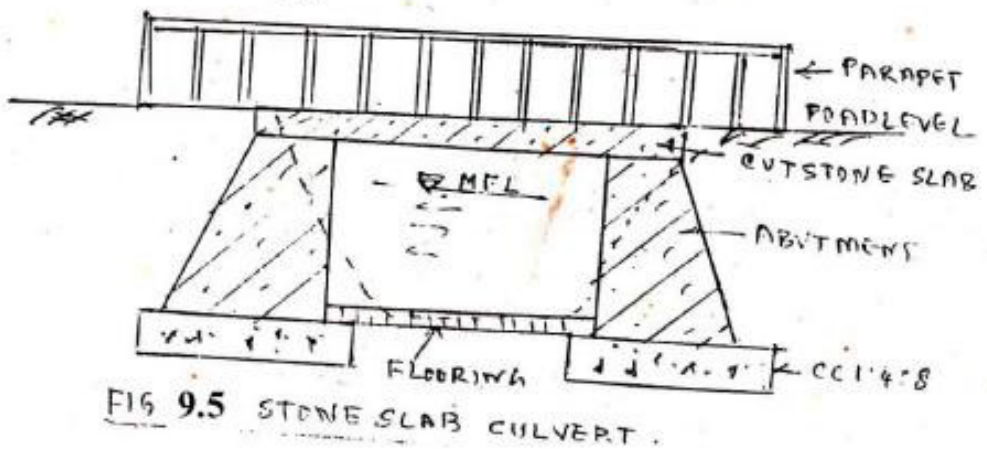


FIG 9.5 STONE SLAB CULVERT.

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

3. **Bridge**

To allow the water of stream from one side of road to the other with waterways of more than 2 sq.m and the span opening over 6 meter, bridge is constructed in forest road. The forest bridges are of the following types :-

i. **Timber Bridge** (See fig 9.6) :- Wooden bridge is very common on account of abundance and accessibility of timber. It consists of masonry or timber posts for abutment. Transoms are placed over the abutment posts. The longitudinal beams, called **'road bearer'** spanning the gaps, are placed over the transoms. The roadway over these beams consists of suitable thick planks nailed onto them. The simple wooden bridge can be used only up to 6 meter span. Where gap exceeds 6 meter, piers are to be provided, and when the span exceeds 10 meter, trussed girder with top and bottom booms to take compressive and tensile stress are to be built up.

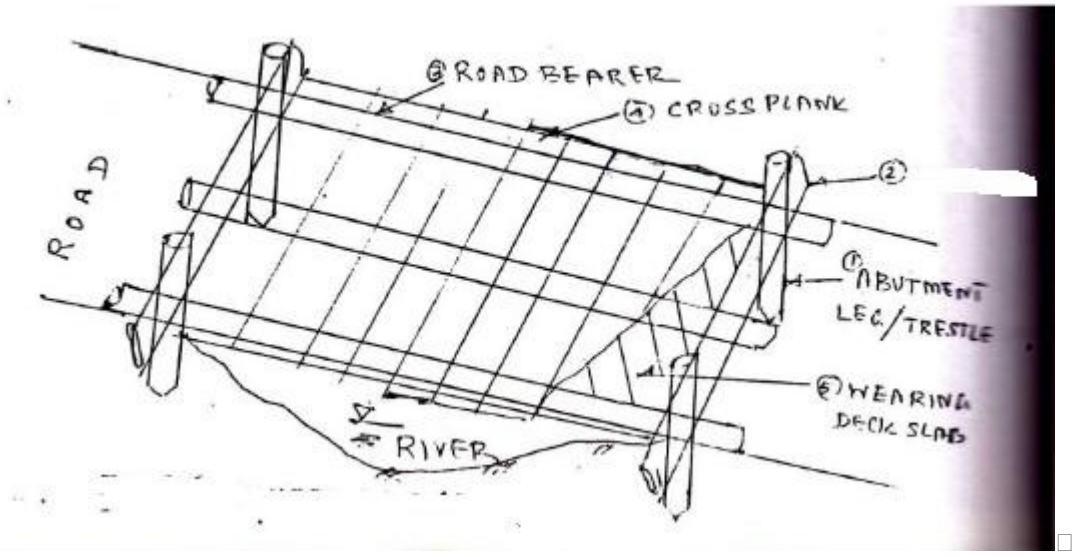


Fig.9.6 Timber Bridge

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

ii. **Cantilever Bridge** (See fig 9.7) :- In a stream where pier could not be constructed due to deep gorge and timber is available in plenty, timber cantilever bridge is very suitable. Timber logs are embedded with rubble stone in the side banks in layers. Next top layer of timber logs should be projected in such a way that the center of gravity of each system cantilever falls well within the middle third of the base of bottom layer. This procedure is to be continued till a gap of 4 – 5 meter is left in the middle. Road bearers are laid over this gap and the surface is leveled with earth and stone boulders. This type of construction is cumbersome and wasteful and hence it is being replaced by more easily built suspension bridge.

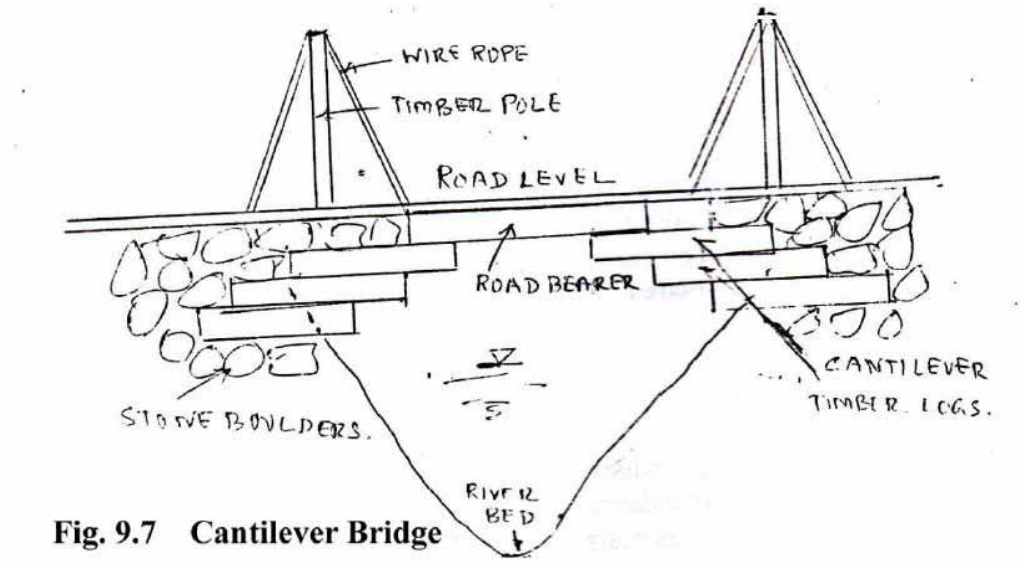


Fig. 9.7 Cantilever Bridge

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

iii. **Suspension Bridge** (See fig 9.8) :- Suspension bridge can be constructed across large openings which do not admit intermediate piers either on account of swift flowing of water or being a deep gorge. This type is rarely used for heavy traffic but may have to be constructed for carrying laden animals, men or jeep.

A common suspension bridge consists of a roadway suspended by cables passing over the tops of piers and connected to anchorage on either bank. The roadway is suspended from the cables by means of wire rope slings or specially made hanger rods. The stability of the whole bridge depends upon the strength of the anchorage. The site should be so selected that the anchorage may be constructed in solid rock or hard soil. The cable generally consists of steel wire rope but for light, temporary bridge cordage, fibers or even country rope may be used. The piers are made of timber frame work or of steel girder or masonry pillars with RCC or steel beams. The roadway consists of transoms, road bearer, decking, wheel guides and railings attached to the transoms.

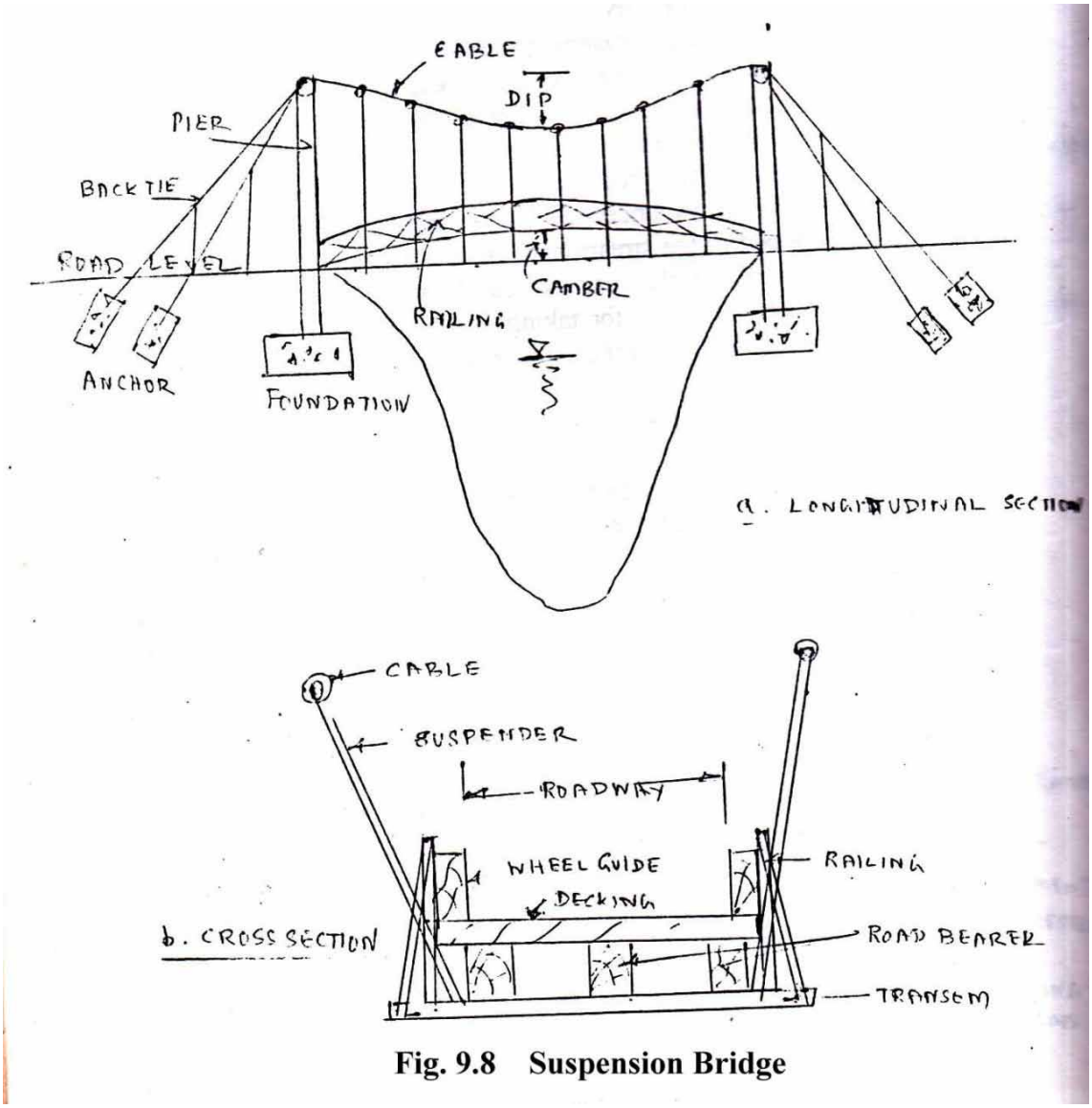


Fig. 9.8 Suspension Bridge

(Source: Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore)

Reference Materials:

1. Lecture notes on Forest Engineering – II by K. Muniamuthu, State forest Service College, Coimbatore
2. Lecture Notes on Engineering Part- II by M.V. Achar, Forest Rangers' College
3. N.J. Masani 1980 Forest Engineering Without Tears Natraj Publishers Dehra Dun

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Lesson 10

Time 1 hour

Practical

Lesson Plan

Objective:
To study

- **Parts of a building in the campus**

Backward Linkage – Materials of Lessons 2, 3, 4 and 5

Forward Linkage – Nil

Training materials required – Chain, Measuring tape, Drawing instruments

Allocation of time

- Briefing 10 mts
- Inspection and measurement 25 mts
- Drawing of plan and elevation of a part of the building 25 mts

Procedure:

- The class may be divided into groups – each group consisting of 3-4 members.
- Each group may be assigned a part of a building in the campus. The parts should preferably be those of incomplete building or buildings under construction so as to permit better visibility and access. The parts assigned may be small and simple requiring only a few measurements.
- Each group may be briefed
  (1) on what they should draw as plan and elevation,
  (2) that the drawing may be sketch plan and elevation, and
  (3) about lengths or dimensions they should take measurement of.
- After briefing the groups will be asked to take measurements and finally draw sketch plan and elevation of the relevant part of a building.

Procedure:

- The class may be divided into groups – each group consisting of 3-4 members.

- Each group may be assigned a part of a building in the campus. The parts should preferably be those of incomplete building or buildings under construction so as to permit better visibility and access. The parts assigned may be small and simple requiring only a few measurements.

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(1) on what they should draw as plan and elevation,

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