TASK-3

a)

The factors that you have considered in designing the geometry of the road. Lane width and No. of lanes should be proposed for this road with justification for the selected sizes.

Main steps of road and project.

New road project:

1. Feasibility study

To check the project validly usefulness, cost and effect to the environment, for the road project the client should be appointed a group to prepare the feasibility study.

Feasibility Study

Finacial Feacsbility

- Rough idea for about the budget.

from proposed

- The way of preparing the funds.
- Aid donated from would bank, ADB.
- Long term loan

Environmental Feacsbility

- To check the feature affect

Road to the environment.

2. Finding out the alignment of the road

- Short cut possible path.
- Cut and fill volume .balancing.
- Geological conditions (soil).
- Hydraulic conditions (river, lakes, and pounds).
- Important religion place (mosque, temple).

- ❖ Land value of the area.
- ❖ Instead of proposing one alignment two or three alignment can be proposed for feature discussion.

3. Cutting out land survey to prepare existing longitudinal section and cross section.

4. Road design

- ❖ Proposed longitudinal profile and cross profiles.
- ❖ Find out the cut and fill volume.
- ❖ Than select the final alignment.
- ❖ After finalizing final alignment road design work can be continuous according to the following different area.
    - a. Structural design.
    - b. Drainage design.
    - c. Material design.
    - d. Traffic design.

Alignment of the road

- i. Shortest path/length.
- ii. Avoid deep cut& fill.
- iii. Avoid historical places/environmentally concerned places.
- iv. Avoid ponds, resvoirs.
- v. Avoid main towns, railway crossings, highway crossings etc.

Normally 3 or 4 alignments are proposed and final decision should be taken after survey.

Road environment factors

a. Adverse road design.
   Ex: poor visibility

b. Adverse environment
   Ex: slippery road, lack of maintenance, weather condition.

c. Inadequate road furniture or markings.
d. Unexpected obstructions.

Construction process of sub base

Select the suitable soil consider.
max^{m} dry density of the soil (the bearing capacity mainly base on the dry density)
Conduct lab test to find out max^{m} dry density with optimum water content.

Proctor compaction test.

- Take soil sample to the soil tray.
- Mix water with soil.
- fill the half of cylinder with material and apply 35 blows with given rod. Fill the cylinder with 3 steps.

- Take the soil out of the cylinder,

  Weight the soil (W1)
  Wet density of soil = $W1/\pi r^2 h$
  Wet density = dry density (1+water content)

- Take three samples from the soil and weight it= W1, W2, W3 put the samples in to over for 24 hrs.

  After 1 day time, weight them = W1', W2', W3'

- Continue this process for 5, 6 steps by adding more water.

Cross section of the road

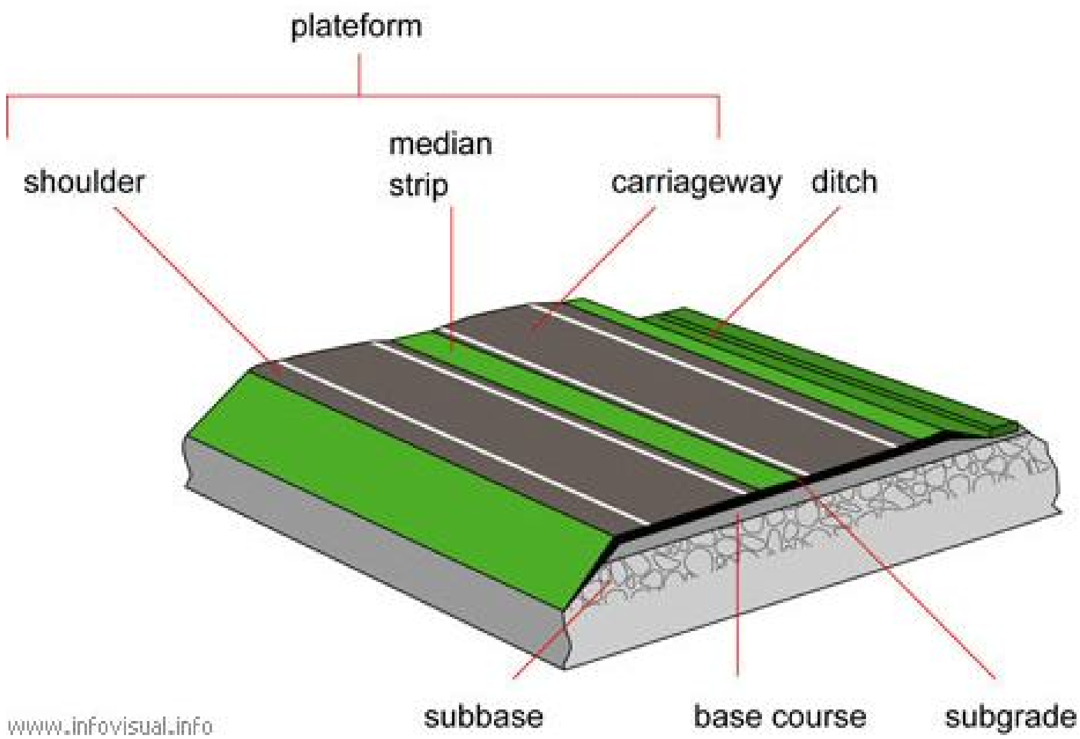


Fig-1

a. **Sub grade**: upper surface of a road. Repaired available ground with soil.
b. **Sub base**: lower surface of a road. Filling layer with soil.
c. **Aggregate base course**: middle surface of a road.
d. **Platform**: horizontal surface raised above the surrounding ground.
e. **Shoulder**: space between the roadway and the ditch.
f. **Median strip**: separation between two roadways.
g. **Carriageway**: central part reserved for vehicle traffic.
h. **Ditch**: channel that carries away water.

a. ROAD SUB GRADES

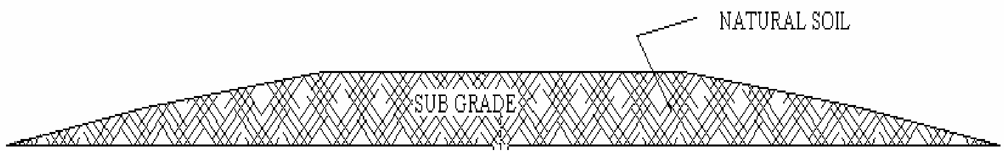


Fig -2 ROAD SUB GRADE

Before preparing the sub base layer, the earth work top soil, grassing, side ditches and drains for the section concerned is completed so that the section of embankment already constructed is protected against erosion and earth slipping. The sub grade soil poured and spread using backhoe and then it is shaped and compacted conformity completed.

Where the surface is high, it is trimmed and suitably compacted to achieve the tolerances. If the surface is low, the deficiency is corrected by scarifying the existing laying and adding fresh material.

b. ROAD SUB BASE

The sub base layer is a secondary load-spreading layer. . It will normally consist of natural ground.
The materials used for a sub base are,

- Natural gravel
- Mixture of the gravel
- Sand and clay

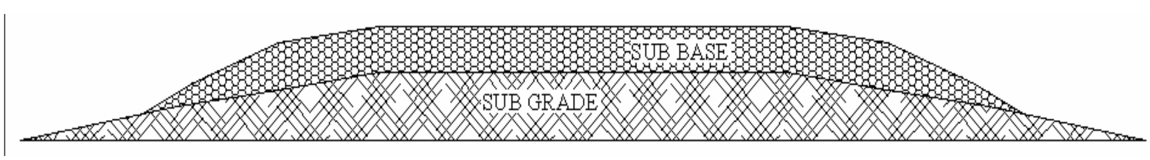


Fig -3ROAD SUB BASE

Specifications for sub base material usually limit the amount of liquid limit. The completed sub base shall contain no aggregate.
Degree of compaction > 98% of MDD.
(MDD is indicated “Maximum Dry Density”)

Fig -4Sub Base Constructions

Sub base preparation is a soil material lay on an existing pavement or prepared sub grade layer. Soil material is placed and spread with Motor grader to required design level. Then, the water is thoroughly mixed with the material and it compacted with Roller. When compacting, the dip is checked. If the dip is less than 250 mm, it should be filled with material otherwise it should be scarified.

The field moisture content is carried out to satisfied compaction. If the material is too wet, it shall be dried by aeration and if it is too dry, the material shall be sufficiently watered prior to compaction

c. ROAD BASE

This is the main load spreading layer of the pavement. Normally this project will consist of crushed stone (50mm). This is the upper layer of the pavement. It will normally consist of bituminous material.

Types

- Dry macadam – ABC – (aggregate base course)
- Water bounded macadam
- Cement bounded macadam

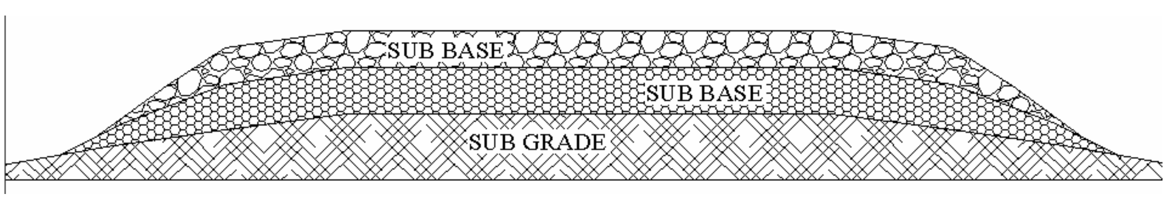


Fig -5ROAD BASE

AGGREGATE BASE COURSE (ABC)

Fig -6 AGGREGATE BASE COURSE AT CRUSHER PLANT

The Aggregate Base Course (ABC) layer is a main load-spreading layer. For a road construction normally the thickness of the ABC layer is 200 mm according to the design drawing. After the edge treatment the base materials shall be laid for the road.

Aggregate Base Course is a mixture of various sizes of aggregates and quarry dust in it. Normally aggregates of 37.5mm, 28mm, and 20mm… are included.

In this project the thickness of the ABC layer is 200mm and the graded crushed rock aggregate with nominal size 37.5 mm is used for this ABC layer the motor grader is used to laying ABC. Normally the road has a cross fall of 3% from the center the motor grader can be used to blade the road as required.

After placing it shall be compacted well using the rollers and the compaction shall be tested.

BASE COURSE CONSTRUCTION

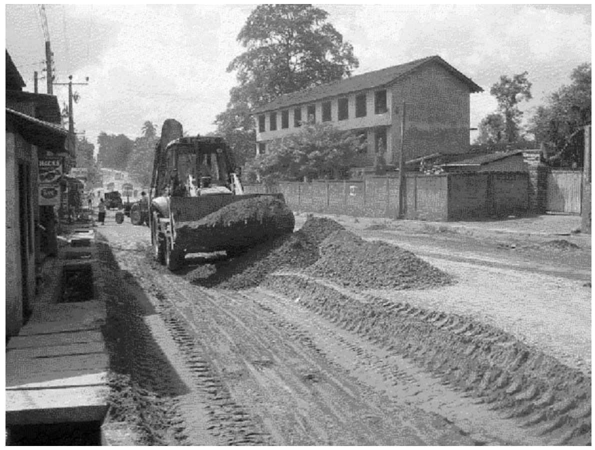


Fig -7 Base Course constructions

The Aggregate Base Course construction is an aggregate lay over the prepared sub base layer. After the unloading the ABC material, it is spread with Motor grader to required design height. Surveying gives the requirements of layer level. Then, small amount of water is added to the layer and it compacted with Tandem roller.

While rolling, the aggregate added or removed to required level. The rolling shall continued until the aggregate does not shift or wave in front of the roller. The in-situ dry density test is done to determine the compaction.

The degree of compaction of ABC layer should be above 98 % of Maximum dry density otherwise the compaction is failure. If the compaction is failure, that place to be re-compacted and re-tested. Sometimes the material has been more or less moisture content during that the layer is allowed to air dry or added more water and then it will compact.

In a rigid pavement surface layer is concrete. This kind of road speed is limited.
In a flexible pavement bituminous layer are place over the sub base and road base. Speed is not accuracy.

BASIC STRUCTURAL LAYERS OF A FLEXIBLE PAVEMENT

- Surfacing layer: This is the top most layers of the flexible pavement.
- The functions of the surfacing are to provide initial load distribution.
- To provide a safe and even running surface.
- To provide a weather proof finish.
- To provide a surface which removes surface water rapidly,

Surfacing, road base, sub base, sub grade.

The surfacing normally consists of two layers, wearing course and base course.

DRAINAGE OF ROADS

The objective in designing in a road drainage system is to provide drain or sewers with sufficient capacity to with the most sewer condition. These systems are gravity system and pumping system.

Gravity system-

Water entering in the drains will be conducted away from the road by gravity eventually discharging to the natural water course.

Care must be taken that is out fall to the water course is not enough to increase the level of water in water course.

This is the minimum velocity of flow at which slid particles will remain in suspension in water. This system is expensive.

Pumping system-

Very expensive.

There are two main drainage systems. These are,

- Storm water drainage
- Foul water drainage

Storm Water Drainage: The estimation of the quantity of storm water to the carried in sewer system is a difficult matter to determine as it is effected by,

a. Unpredictable variation of rate of intensity of rain fall.
b. Un predictable direction of movement of rainfall
c. the time taken for rain water to get in to the sewer after fouling in the ground

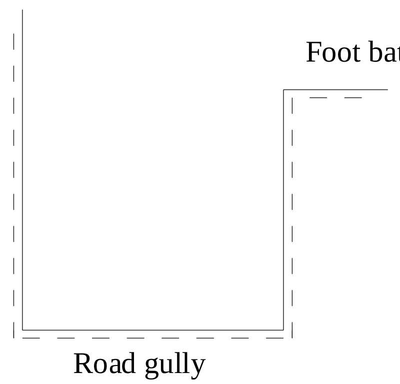


Fig 8

Foul Water Drains:
The emphasis in road work is on storm drainage but, some basic knowledge of foul water drainage as needed as these system will be encountered from time in carrying out road building and improvement system. The layout of a high way drainage system, with a foul drainage system is dependent upon the topography on the ground.

And, Trench is excavated by JCB back hoe loader or excavator to approximate dimension. Before the excavation reduced level of the trench bed and width of the trench is given by the surveyor. According to the dimension, the trench is excavated. After the excavation, the trench bed is smoothed according to the reduced level.

b)

Embankment construction work clearly stating the procedure to follow for achieving proper compaction.

Embankment Construction

All suitable material available from the roadway and other excavation can be used for embankment construction where additional material is necessary they can be obtained from approved borrow pits or other approved sources.

During borrow excavation the borrow areas should be kept drained as far as possible and all necessary precautions to prevent any erosion or interference with exiting drainage facilities. And also borrow operation should be carried out in a manner not to affect the stability or safety of any structures or cause any other damage to adjacent property.

Sub base construction

Sub bases

This works consists of laying and compaction of sub base material. Where the sub base is to be placed on an existing paved road, the bituminous crust removed by scarifying. The exposed surface suitably is compacted prior to laying of the sub base.

Material

Naturally occurring or blended gravels and sands or mixtures thereof and can not include highly plastic clays, silts, peat or other organic soils or any soil that is contaminated with top soil, vegetable and other deleterious matter. The material used for the top 150 mm of sub base is Type I sub base material and material used for the lower layers Type II sub base material.

1. Type I sub base material:
    - The 4 day soaked CBR of the soil 100 % maximum dry density under standard conditions of compaction shall not be less than 20 %.
    - The Plastic Index (PI) and Liquid Limit (LL) shall be less than 15 % and 40 % respectively.
2. Type II sub base material:
    - The 4 day soaked CBR of the soil 100 % maximum dry density under standard conditions of compaction shall not be less than 8 %.
    - The Plastic Index (PI) and Liquid Limit (LL) shall be less than 15 % and 40 % respectively.

Placing and compaction of sub base material

The sub base material normally is spread in layers not exceeding 225 mm for compaction using 8 to 10 tonne smooth wheeled roller or any other roller of comparable compaction effort. Where necessary the material may be spread in thicker layers with the use of heavier roller. Where the sub base is built up of more than one layer the layers to follow shall be placed only after the degree of compaction of the previous layers achieved.

The moisture content of the material has to be checked at the time of compaction. If the material is too wet it should be dried by aeration and if it id too dry, the material should be sufficiently wetted prior to compaction.

The rolling commences at the edge and proceeds towards the centre longitudinally except at super elevated sections where the rolling commence at the lower edge and proceed towards the higher edge.

Degree of compaction

The sub base is compacted to a density not less than 100% of the maximum dry density

Base construction

Aggregate bases

This work consists of the reconstruction of existing bitumen surfaced aggregate bases that require re-strengthening and re- shaping. Work can be carried out either by rebuilding the existing base along with added aggregate or by over laying with aggregate, penetration macadam or bitumen bound macadam.

Material

Aggregate for aggregate bases consists of 50 mm, 37.5 mm and 12.5 mm single sized aggregate and graded aggregate of maximum size of 37.5 mm, can conform to the following table.

Sieve size	Percentage passing			
mm	Nominal size			
µm	50	37.5	25	19
62.5	100	-	-	-
50	-	100	-	-
37.5	87 - 100	95 -100	100	-
25	-	-	85 – 100	100
19	53 – 85	58 - 92	70 – 95	85 – 100
9.5	33 – 65	38 -70	50 – 80	55 – 90
4.75	18 – 50	23 – 55	30 – 63	35 – 70
2.36	15 – 40	18 – 45	22 – 50	26 – 55
600	8 – 25	8 – 25	8 – 25	8 – 25
75	0 - 10	0 - 10	0 - 10	0 - 10

Retaining Wall

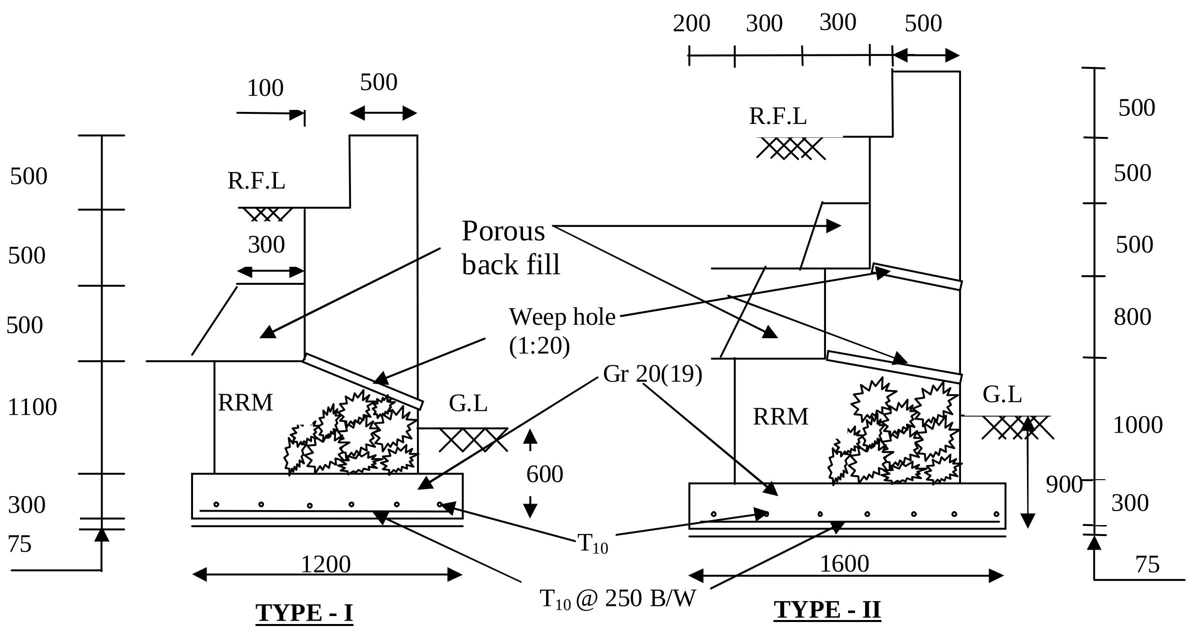
Retaining wall is another important structure. Retaining walls at:

- From CH 1 + 820 to CH 2 + 040 RHS.
- From CH 2 + 610 to CH 2 + 660 RHS.

For the construction of the retaining wall we had gone through the following sequence:

- The offset was marked from the centre line, then after the ground was excavated by JCB and it was trimmed very well in order to maintain a smooth surface for the screed. The reduced level of the screed bottom level had been checked in random points. (E.g. the screed bottom level for the retaining wall at the chainage from 2+610 to 2+660 is 94.620 m) If the reduced level is found to be correct then we were allowed to do proceed on our works.
- The thickness of the screed concrete is 75 mm with a mix proportion of 1:3:6(37.5). So for the retaining wall construction we have given the top level of the screed level by using the level instrument. (E.g. The reduced level is 94.620 + 0.075 = 94.695 m)
- Then the base concrete has been done. For the base concrete :
  - ✓ Reinforcement:
    - T10 @ 250 both ways.
    - Lap length = 50 x diameter of the bar. (I.e. 500mm)
  - ✓ Concrete
    - Grade 20 concrete 1:2:4 (20).
    - Cover block value was 25 mm.
- To lay the base concrete we gave the top level of the base concrete. For the above retaining wall the reduced level is 94.620 + 0.075 + 0.3 = 94.995 m. As the edges having permeable soil we have to place polythene sheets on either edge. Expansion joints should be provided at every 6 meters interval. To get the expansion joints we have used rig foam pieces. Sufficient application of poker has been applied to get rid of both desegregation and trapping of air voids.

- When the base concreting has been done we have placed tooth stones. These tooth stones have been placed to give better bonding between the base surface and the rubbles that we are going to use in our further constructions.
- Curing has been done as required.(for 7 days)
- Random rubble masonry has been commenced providing the threw stones. The levels of the rubble works were given. The levels were adjusted according to the road finished level at the certain points.(Inter polate / outer polate)
- Weep holes have been provided in the slope of 1:20. The diameter of the PVC pipe was 110 mm.
- Porous backfill to be done in order to dissipate the pore water pressure.
- The width of the base should be greater than 1/3 of the height of the retaining wall. It helps to prevent the propagation of the tensile stresses at the base of retaining wall.
- In our project there are two types of retaining walls. That is depends on the soil pressure.



The detail of retaining walls

Culverts

1. Pipe culverts
2. Box culverts

Pipe Culvert

This work shall consist of supplying, jointing, bedding of reinforced concrete pipes of the required type, diameter and length in the construction of culverts. The work also includes the construction of headwalls, Wing walls, aprons, catch pits and other ancillary items necessary for completion.

✓ *Materials*

Concrete for bedding can be of class c concrete.

(a) Reinforced concrete pipes and fittings
(b) Concrete bedding
(c) Cement mortar for pipe jointing

Materials used for construction of head walls, wing walls and other ancillary items shall conform to the following requirements.

✓ *R.R masonry*

a) Stones used in RR masonry can be obtained from approved quarry and should be hard, durable, fresh rock free from fractures and other imperfections. And maximum dimensions not exceeding 450 mm.
b) Cement mortar of mix proportions sand : cement = 5:1

✓ *Bedding of pipes using Concrete bedding*

The pipes shall be bedded in a continuous cradle of class c concrete, of mix proportion 1:3:6 (37.5) having a minimum thickness of 0.25 times the nominal diameter of pipe or 150mm, whichever is more. The concrete shall extend up the sides of the pipes to a height of at least 10 percent the external diameter. The minimum width of the cradle shall be constructed monolithically without horizontal construction joints. The cradle shall be such that the pipe can be seated fully in it. The pipe shall be laid on the concrete bedding before the concrete has set.

- ✓ **Laying of pipes**

Laying of pipes on prepared foundation shall be started at the outlet and proceeded towards inlets, with the abutting sections properly matched and fitted in. Where collars are used for jointing the pipes, cross trenches shall be excavated to accommodate the collar and to facilitate jointing. Ends of the pipe shall be carefully cleaned before they are placed. As each length of pipe is placed, the mouth of the pipe shall be protected to prevent entry of earth or bedding materials. Once laid the pipes shall be properly aligned.

- ✓ **Jointing**

Each pipe joint shall be sealed to prevent leakage and infiltration of water on to the bedding. In jointing pipes with tapered ends, the end with external taper of one pipe shall be joined with the end with internal taper of the other pipe, and the space between the pipes at the joint shall be patched with 1:2 cement sand mortar. In addition on this the joint shall be provided with a covering with cement mortar of the same composition having a minimum width of 100mm and minimum thickness of 25mm placed across, and running continuously round the pipe at the joint.

Box culvert

A structure including supports, erected normally over a water way, for carrying traffic, having a clear span between supports of more than 3.0 m measured along the centerline of the roadway is called a bridge. Although it is called as a box culvert, it is a kind of bridge because it has a clear span of greater than 3.0 m. It is the most important construction project in our site, because a lion share of money is used for this construction and the time taken for the construction is also comparatively, very high.

Poker vibrator had been used to get rid of the air voids by applying it for sufficient time. Here, more attention was paid to prevent from the application of poker vibrator to prevent the mix design from desegregation. Poker vibrator has been applied points at every 450 mm intervals.

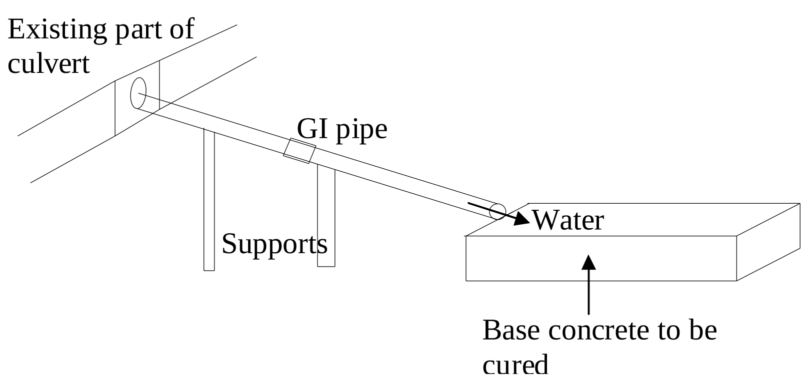


Fig- 9The arrangement made for curing purposes in the base of the box culvert

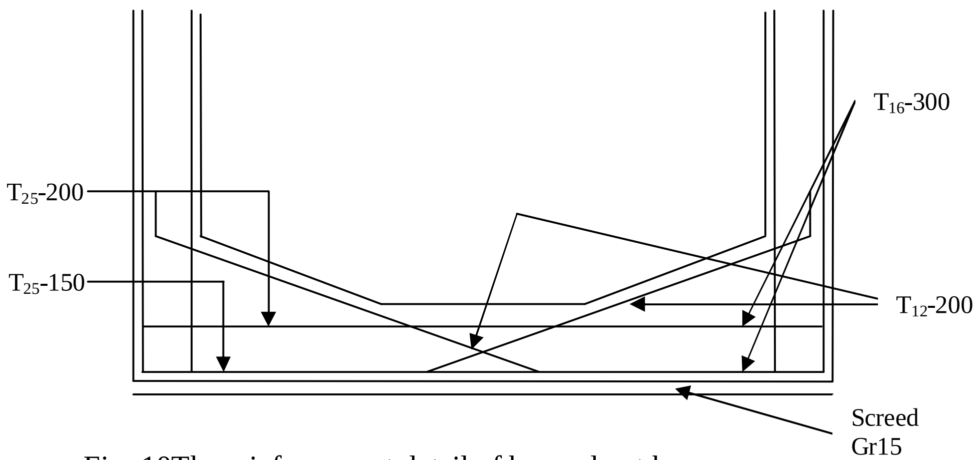


Fig -10The reinforcement detail of box culvert base

The first lift concrete works also have been done to the box culvert. For the second lifting, this time we have decided to do these works by using the man made concrete mixture. For the second lifting of concreting we have constructed an access bridge as shown as below.

Fig -11 The type of a access bridge which was constructed to the widening works of the box culvert

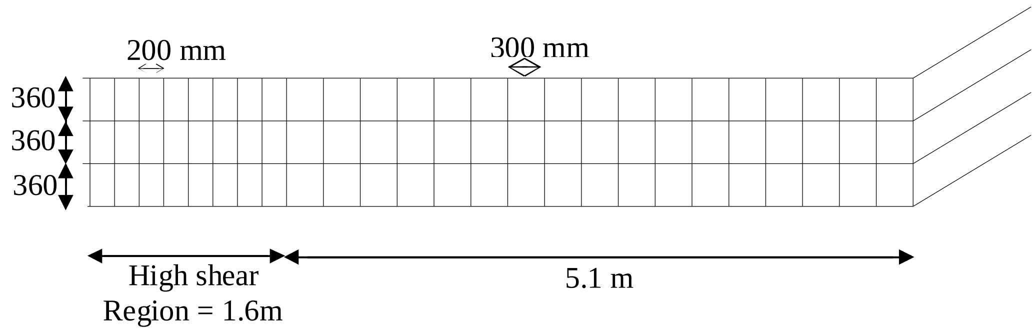


Fig-12 The reinforcement arrangement to the wing wall of the box culvert

In the either end of the box culvert we have high shear regions. It is obvious that high shear forces are expected near the supports. In the high shear panels we had the stirrups which had reinforcement details (T_{10}-200mm c/c) as shown as follows:

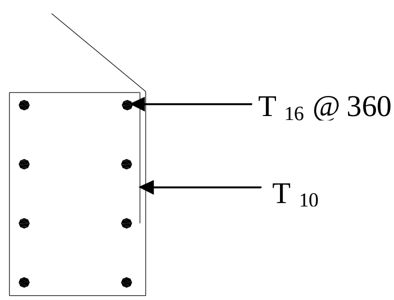


Fig -13The stirrups at the box culvert

We have provided the cover blocks of 50 mm thickness. The lap length of the reinforcement was found to be 50φ.

Where, φ is the diameter of the main reinforcement.

Hence the lap length $= 50 \times 16$

$= 800$ mm

The purpose of the construction of the wing wall is;

- To give the stability to the structure by preventing the erosion enhancing the function of the key wall.
- For an embankment it is preventing the collapse of the carriageway in excessive loading situations.

Normally, wing walls are constructed parallel to the road centreline, because it gives aesthetically good appearance to our works.

There is a protection wall in the existing culvert. As this is near to the river, the flow rate of the water is very high. So the erosion that occurs there can cause great challenges to the stability of the structure. In other words, key wall cannot control the erosion alone. So we have to construct a protection wall to provide more resistance to the erosion, hence the structure is protected well.

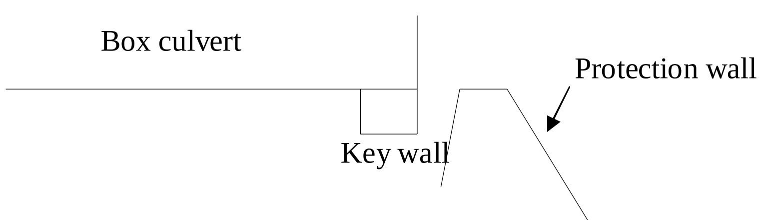


Fig-14

c)

Road safety arrangement that you expect to implement during construction and after finishing the road work in this project with suitable sketches.

<u>Safety protection.</u>

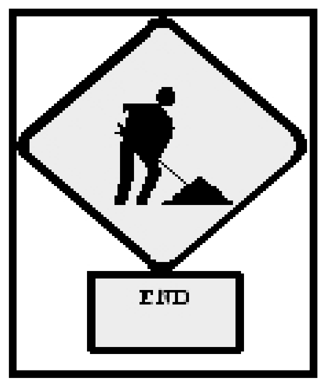
From the experience it is understood that the Engineer should ensure the safety of the valuable human lives engaged in the road construction works and as well as the people who use the road under construction. Not only he is responsible for the human lives, but also, he should pay his keen attention towards the careful usage of the plants and machineries of the site. The Engineers must consider safety in his site. When trenching of roads is in progress for laying underground utility services, it is essential that adequate safety measures be provided to ensure the safety of road users and workmen, during both day and night. The Engineer tried his best to provide the safety measures by instructing the labourers to wear the helmet, gloves and gum boots in necessary situations. When the road marking works were on progress the person who arranges the traffic cone and the person who holds the STOP board were instructed to wear the retroflective clothes.

The traffic control devices that could be used for ensuring road safety are:

- Traffic Signs
- Traffic Cones
- Barricade Boards
- Road Humps along with road markings

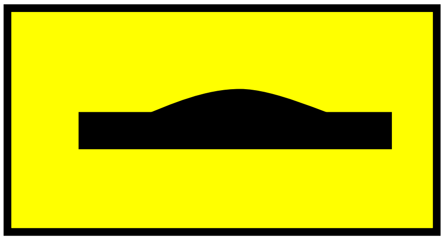
Traffic controlling

Some traffic signs



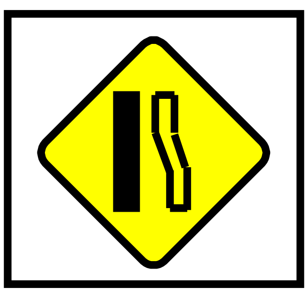
Road works ahead

End of road works

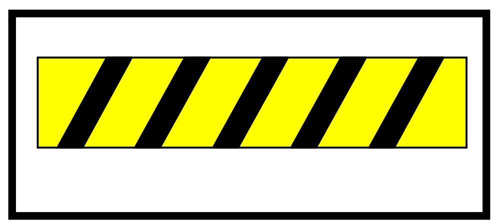


Humps

Traffic



Road narrows on the right side ahead



Barricade board

Fig-16

Road signals

For this highway Construction,
Fixing the traffic controlling signs at the work site is one of the most vital safety procedures in the highway constructions. Traffic controlling signboards must be fixing and maintain at the suitable places. And they must be fix clearly visible manner to the motorists.

Men at work

Fig -17 Men at work

Men at work sign is use to warn the motorists the men at work ahead of the road. Usually men at work sing board is fixes at seventy five meters to hundred meters ahead of the men working place. This signboard must be fix clearly visible manner to the motorists.

Men at work ends

Fig -18 Men at work ends

Men at work ends sign is use to warn the motorists the end of the men working area in road construction section.

Road narrow

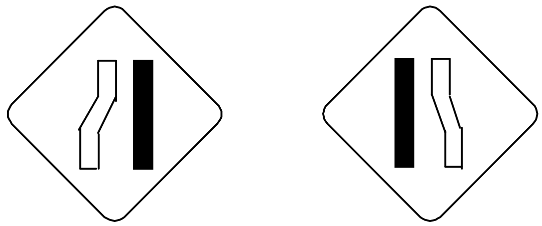


Fig -19 Road narrows

Road narrow sign is use to warn the motorists existing road width becomes restricted. According to the type of restriction we must decide the sign type of road narrow to be used. Road narrow sign normally fix at twenty five meters after the "Men at Work" signboard.

Pass this side

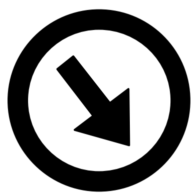


Fig -20 pass this side

Pass this side Sign is use to divert the motorists to the way they have to drive vehicle around road works. Pass this side sign is usually fix at a short distance ahead from the road construction section.

Barricades

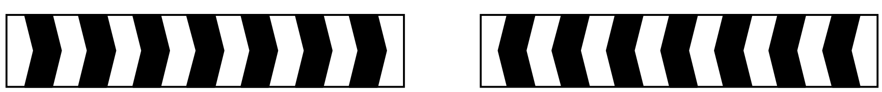


Fig -21 Barricades

Barricades sign is use for protections purpose therefore prevent vehicles and pedestrian entering the construction area. Barricades are two types. One is board and another one is long type. And they also use to separate the construction area from the trafficked areas.

Barrels and Drums

Fig -22Barrels and Drums

Barrels and Drums also use for protections purpose therefore prevent vehicles entering the construction area. And they also use to separate the construction area from the traffic areas. Barrels and Drums are placed between along the road construction area and the traffic area.

Hump

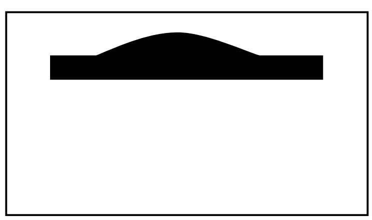


Fig-23Hump

Hump sign is use to warn the motorists hump is ahead and slow down the vehicle. The purpose of Humps make the vehicle speed to death slow at hazardous places so the vehicles must slow down their speed and accidents can be minimize. Humps must be constructing with hump ahead signboards fix both side of hump. Two hump ahead signboards fix thirty meters after and before the hump.

d)

Brief description of different type of bridges with suitable sketches illustrating major components.

Bridge

A bridge is a structure providing passage over an opening- gorge, road, railway, canal, river, creek etc. Without closing the same. The required passage may be for road, railway, canal, pipe line or pedestrians.

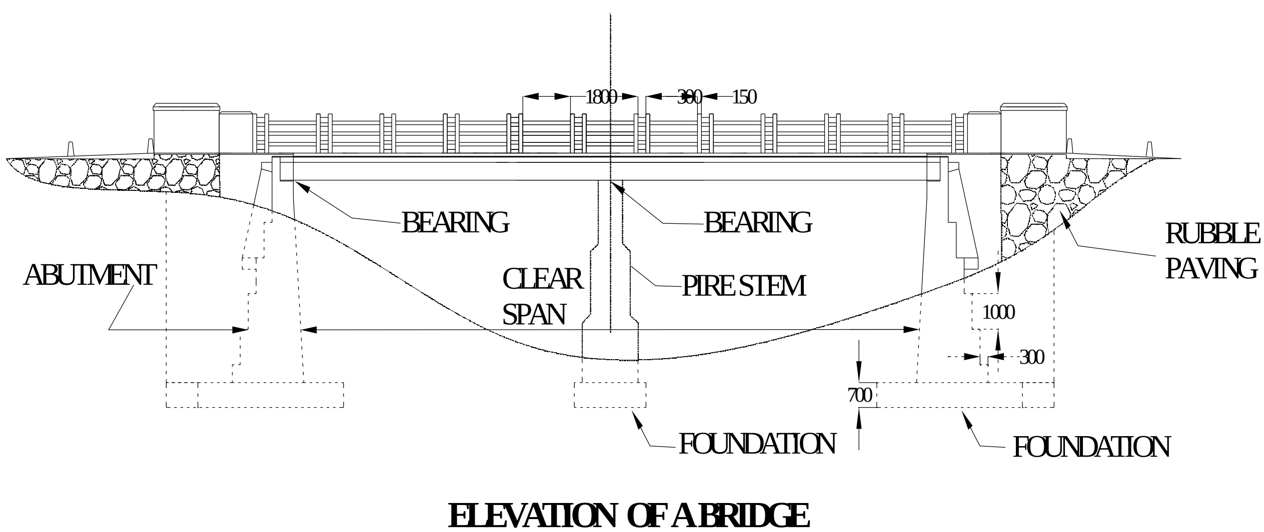


Fig-24

Components of bridges

The components of the bridge consist of:

1. Foundations for the abutments and piers or tower.
2. Abutments and piers or tower.
3. River training works like revetment for slopes of abutment aprons for beds upstream and downstream, guide bunds etc.
4. Approaches to the bridge to connect the road a railway to the bridge proper.
5. Decking consisting of girders or trusses.
6. Handrails guard stone etc.

   The structure below the bearing is known as a substructure and the portion of bridge above the bearing is superstructure

Type of bridges

Introduction

Bridges are structures which carry people and vehicles across natural or man-made obstacles. As early roads connected villages and towns, people traveled by foot or with carts and wagons. Although a person carrying a large bundle might be able to cross a stream by swimming or stepping on stones, as horse drawn vehicles with heavy loads needed to cross more dangerous terrain, permanent sturdy bridges became an important part of transportation systems.

Early bridges were made from local materials such as wood, stone and fibers. Today, most bridges have a concrete, steel, or wood framework with an asphalt or concrete roadway. Based on the length of the barrier to be crossed, the amount and type of traffic as well as forces of nature (wind, tide, and flood) different materials and shapes of bridges are used.

There are many types of bridges such as arch bridges, girder bridges, truss bridges, cantilever bridges, cable-stayed bridges, suspension bridges and moveable bridges. Many bridges are actually combinations of different types of bridges and no two bridges are identical! Most bridges are held up by at least two supports set in the ground called abutments. Some bridges have additional supports along the middle of the bridge called piers. A span is the distance between two supports, either two piers, a pier and an abutment or two abutments. Many short bridges are supported only by the abutments and are called single-span bridges. Longer bridges usually have one or more piers to support them and are known as multi-span bridges.

Bridge construction

Bridges are constructed in many different ways and are often identified by the materials they are constructed from and the method of construction. The methods of bridge construction vary from site and contractor to contractor. They are also dicted by many factors which include the size of the spans, the materials to be used, the restrictions imposed by the location of the site, its topography and access limitation, the structural design principles and usage of the area over which the bridge spans.
Whatever methods are used, they may be broken down into six distinct sections;

1. Founding the piers and abutments
2. Construction of those piers, abutments and portals
3. Provision of the structural span
4. Construction of the deck
5. Provision of the wearing surface
6. Incorporation of safety features and services

The founding of the abutments will depend on the nature of the strata, both of the banks of the stream bed. The construction of the abutment will affected by the velocity of the water flow, its change in level resulting from weather conditions, and the effects of scour action around any temporary works. In order to provide a dry area in which to construct the foundation, interlocking sheet- steel piles could be driven around the foundation area from the bank on one side of the stream, to a depth suitable to prevent water entry. The foundations may then be excavated and constructed in dry working conditions.

The abutment must not only support the bridge but must also act as a retaining wall to prevent the carriageway failing into the stream. This prevention must be not only along the line of the road but also at right angles to it, which may require the extension of the abutment for widths greater than those required for the carriageway construction, or the use of wing walls.

The abutments may be constructed of stone, brick or more usually in-situ reinforced concrete. In the latter case the in terlocking sheet piles could be used as permanent shuttering, thus saving costs and at the same time protecting the concrete below the level of the stream from various harmful effects such as scour, erosion and sulphate attack. A facing of other material may be applied to the concrete abutment in order to improve the appearance, while at the rear a protective coating of bituminous paint is applied to the vertical face and a land- drainage system is incorporated in order to reduce the horizontal thrusts due to wet backfill material against the retaining wall.

In the case of small-span bridges, the structural span consists of pre-cast, pre-stressed, concrete beam having various cross-sectional shapes. These beams are bought to the site by road and are lifted into position by a mobile crane. The tops of the abutments are rebated to form the bearing for the beams to seat on. Depending on the method of structural design, the bearing may incorporate facilities for movement, thus allowing for expansion, contraction, creep and flexure.

The deck generally comprises an in-situ reinforced-concrete topping to the precast beams. This topping provides the base for the carriageway construction as well as linking the beams into an integral unit, housing the various services (in ducts for ease of repair, maintenance, etc.) and providing anchorage for guard rails, barriers, lamp posts and traffic signs.

The wearing surfaces to both the carriageway and the footway are constructed in a similar manner to those detailed. Provision for surface water may be either to a sewer or, in appropriate cases, a direct discharge into the stream below. Where movement joints are incorporated into the structure there must be a similar facility in the wearing surface. This is provided by means of specially designed steel shoes which keep the two wearing surfaces apart while at the same time preventing the entry of dirt and water into the main structure.

Different type of bridge

There are six main types of bridges:

1. Beam bridge
2. Cantilever bridge
3. Arch bridge
4. Suspension bridge
5. Cable-Stayed bridge
6. Truss bridge

Beam Bridge

The beam type is the simplest type of bridge. The beam bridge could be anything as simple as a plank of wood to a complex structure. It is made of two or more supports which hold up a beam.

Consists of a horizontal beam supported at each end by piers. The weight of the beam pushes straight down on the piers. The farther apart its piers, the weaker the beam becomes. This is why beam bridges rarely span more than 250 feet.

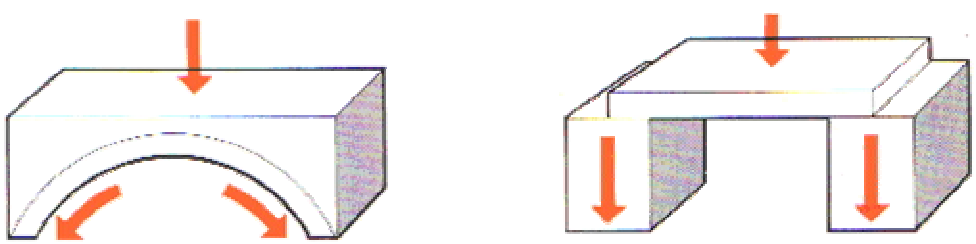


Fig-25

Girder Bridge

A girder bridge is perhaps the most common and most basic bridge. A log across a creek is an example of a girder bridge in its simplest form. In modern steel girder bridges, the two most common girders are I-beam girders and box-girders.

If we look at the cross section of an I-beam girder we can immediately understand why it is called an I-beam. The cross section of the girder takes the shape of the capital letter I. The vertical plate in the middle is known as the *web*, and the top and bottom plates are referred to as flanges. To explain why the I shape is an efficient shape for a girder is a long and difficult task so we won't attempt that here.

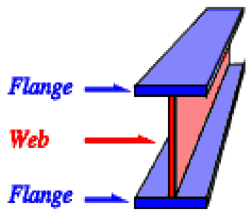


Fig-26 section

A box girder is much the same as an I-beam girder except that, obviously, it takes the shape of a box. The typical box girder has two webs and two flanges (illustration #2.) However, in some cases there are more than two webs, creating a multiple chamber box girder

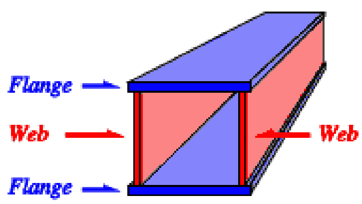


Fig-27 Box section

Other examples of simple girders include pi girders, named for their likeness to the mathematical symbol for pi, and T shaped girders. Since the majority of girder bridges these days are built with box or I-beam girders we will skip the specifics of these rarer cases.

Now that we know the basic physical differences between box girders and I-beam girders, let's look at the advantages and disadvantages of each. An I-beam is very simple to design and build and works very well in most cases. However, if the bridge contains any curves, the beams become subject to twisting forces, also known as torque. The added second web in a box girder adds stability and increases resistance to twisting forces. This makes the box girder the ideal choice for bridges with any significant curve in them.

Box girders, being more stable are also able to span greater distances and are often used for longer spans, where I-beams would not be sufficiently strong or stable. However, the design and fabrication of box girders is more difficult than that of I beam. For example, in order to weld the inside seams of a box girder, a human or welding robot must be able to operate inside the box girder.

Cantilever bridge

In the cantilever type of bridge, two beams support another beam, which is where the deck or traffic way is. The two beams must be anchored, and this must be done well.

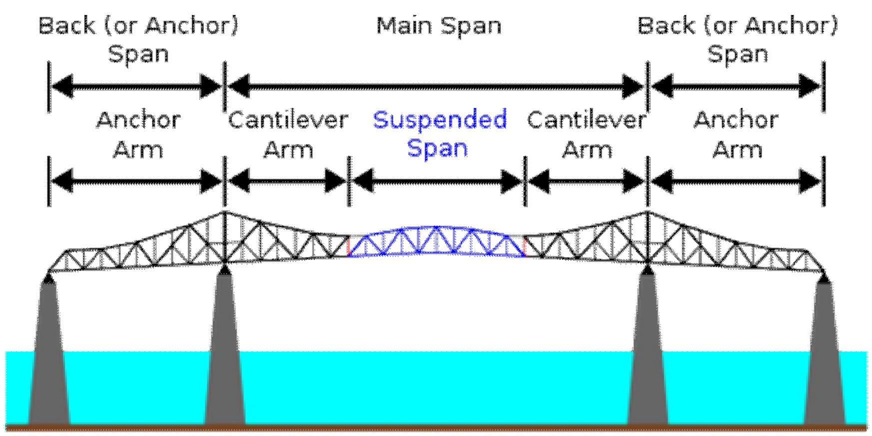


Fig-27

Arch bridge

After girders, arches are the second oldest bridge type and a classic structure. Unlike simple girder bridges, arches are well suited to the use of stone. Many ancient and well know examples of stone arches still stand to this day. Arches are good choices for crossing valleys and rivers since the arch doesn't require piers in the center. Arches can be one of the more beautiful bridge types.

Arches use a curved structure which provides a high resistance to bending forces. Unlike girder and truss bridges, both ends of an arch are fixed in the horizontal direction (i.e. no horizontal movement is allowed in the bearing). Thus when a load is placed on the bridge (e.g. a car passes over it) horizontal forces occur in the bearings of the arch. These horizontal forces are unique to the arch and as a result arches can only be used where the ground or foundation is solid and stable.

Like the truss, the roadway may pass over or through an arch or in some cases both Structurally there are four basic arch types hinge-less, two-hinged, three hinged and tied arches

The hinge-less arch uses no hinges and allows no rotation at the foundations. As a result a great deal of force is generated at the foundation (horizontal, vertical, and bending forces) and the hinge-less arch can only be built where the ground is very stable. However, the hinge-less arch is a very stiff structure and suffers less deflection than other arches.

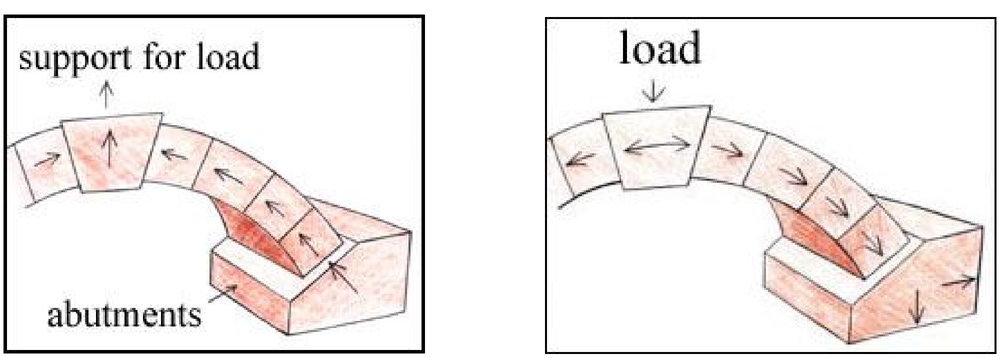


Fig-28

The two hinged arch uses hinged bearings which allow rotation. The only forces generated at the bearings are horizontal and vertical forces. This is perhaps the most commonly used variation for steel arches and is generally a very economical design.

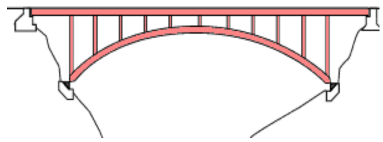


Fig-29 Two hinged arch

The three-hinged arch adds an additional hinge at the top or crown of the arch. The three-hinged arch suffers very little if there is movement in either foundation (due to earthquakes, sinking, etc.) However, the three-hinged arch experiences much more deflection and the hinges are complex and can be difficult to fabricate. The three-hinged arch is rarely used anymore.

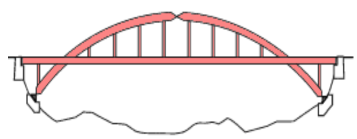


Fig-30

Three – hinged archThe tied arch is a variation on the arch which allows construction even if the ground is not solid enough to deal with the horizontal forces. Rather than relying on the foundation to restrain the horizontal forces, the girder itself "ties" both ends of the arch together, thus the name "tied arch."

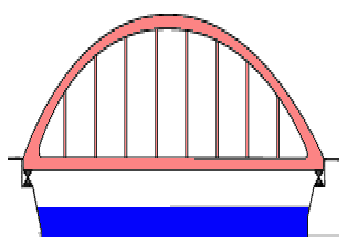


Fig-31Tied arch

Suspension bridge

Most suspension bridges have a truss system beneath the roadway to resist bending and twisting. The deck (traffic way) of a suspension bridge is hung by cables which hang from towers. The cables transfer the weight to the towers, which transfer the weight to the ground.

Of all the bridge types in use today, the suspension bridge allows for the longest spans. At first glance the suspension and cable-stayed bridges may look similar, but they are quite different. Though suspension bridges are leading long span technology today, they are in fact a very old form of bridge. Some primitive examples of suspension bridges use vines and ropes for cables.

The development of metals brought the use of linked iron bars and chains. But it was the introduction of steel wire ropes that allowed spans of over 500m to become a reality.

A typical suspension bridge is a continuous girder with one or more towers erected above piers in the middle of the span. The girder itself it usually a truss or box girder though in shorter spans, plate girders are not uncommon. At both ends of the bridge large anchors or counter weights are placed to hold the ends of the cables.

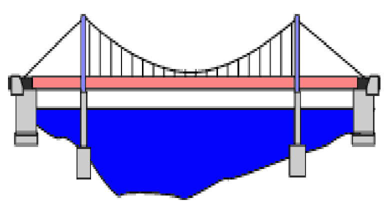


Fig-32 Suspension bridge

The main cables are stretched from one anchor over the tops of the tower(s) and attached to the opposite anchor. The cables pass over a special structure known as a saddle. The saddle allows the cables to slide as loads pull from one side or the other and to smoothly transfer the load from the cables to the tower.

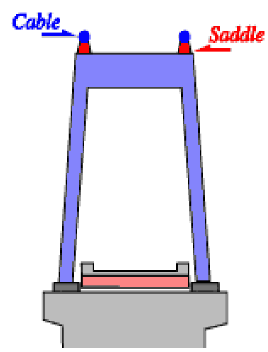


Fig-33 Tower

From the main cables, smaller cables known as hanger cables or hanger ropes are hung down and attached to the girder. Some suspension bridges do not use anchors, but instead attach the main cables to the ends of the girder. These self-anchoring suspension bridges rely on the weight of the end spans to balance the center span and anchor the cable.

Thus, unlike normal bridges which rest on piers and abutments, the girder or roadway is actually hanging suspended from the main cables. The majority of the weight of the bridge and any vehicles on it are suspended from the cables. In turn the cables are held up only by the tower(s), there is an incredible amount of weight that the towers must be able to support.

As explained in the cable stayed bridge section, steel cables are extremely strong yet flexible. Like a very strong piece of string, it is good for hanging or pulling something, but it is useless for trying to push something. Long span suspension bridges, though strong under normal traffic loads, are vulnerable to the forces of winds. Special measures are taken to assure that the bridge does not vibrate or sway excessively under heavy winds.

Cable-Stayed bridge

A typical cable stayed bridge is a continuous girder with one or more towers erected above piers in the middle of the span. From these towers, cables stretch down diagonally (usually to both sides) and support the girder.

Steel cables are extremely strong but very flexible. Cables are very economical as they allow a slender and lighter structure which is still able to span great distances. Though only a few cables are strong enough to support the entire bridge, their flexibility makes them weak to a force we rarely consider: the wind.

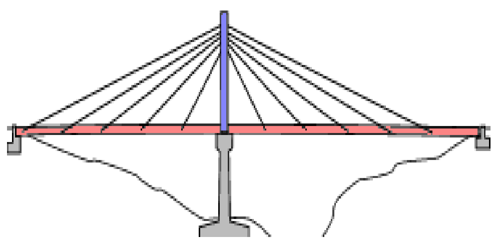


Fig-34Stayed Bridge

For longer span cable-stayed bridges, careful studies must be made to guarantee the stability of the cables and the bridge in the wind.

The lighter weight of the bridge, though a disadvantage in a heavy wind, is an advantage during an earthquake. However, should uneven settling of the foundations occur during an earthquake or over time, the cable-stayed bridge can suffer damage so care must be taken in planning the foundations. The modern yet simple appearance of the cable-stayed bridge makes it an attractive and distinct landmark.

The unique properties of cables, and the structure as a whole, make the design of the bridge a very complex task. For longer spans where winds and temperatures must be considered, the calculations are extremely complex and would be virtually impossible without the aid of computers and computer analysis. The fabrication of cable stay bridges is also relatively difficult. The cable routing and attachments for the girders and towers are complex structures requiring precision fabrication.

There are no distinct classifications for cable-stayed bridges. However, they can distinguish by the number of spans, number of towers, girder type, number of cables, etc. There are many variations in the number and type of towers, as well as the number and arrangement of cables. Typical towers used are single, double, portal, or even A-shaped towers

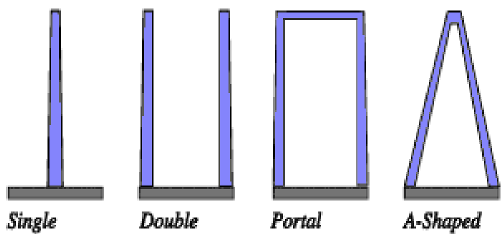


Fig-35 Typical Tower

Cable arrangements also vary greatly. Some typical varieties are mono, harp, fan, and star arrangements In some cases, only the cables on one side of the tower are attached to the girder, the other side being anchored to a foundation or other counterweight.

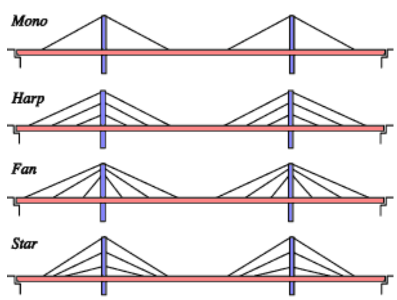


Fig-36 Cable Arrangement

Truss bridge

Consists of an assembly of triangles. Truss bridges are commonly made from a series of straight, steel bars. The Firth of Forth Bridge in Scotland is a cantilever bridge, a complex version of the truss bridge. Rigid arms extend from both sides of two piers. Diagonal steel tubes, projecting from the top and bottom of each pier, hold the arms in place. The arms that project toward the middle are only supported on one side, like really strong diving boards. These "diving boards," called cantilever arms, support a third, central span.

The truss is a simple skeletal structure. In design theory, the individual members of a simple truss are only subject to tension and compression forces and not bending forces.

Thus, for the most part, all beams in a truss bridge are straight. Trusses are comprised of many small beams that together can support a large amount of weight and span great distances. In most cases the design, fabrication, and erection of trusses is relatively simple. However, once assembled trusses take up a greater amount of space and, in more complex structures, can serve as a distraction to drivers

Like the girder bridges, there are both simple and continuous trusses. The small size of individual parts of a truss makes it the ideal bridge for places where large parts or sections cannot be shipped or where large cranes and heavy equipment cannot be used during erection. Because the truss is a hollow skeletal structure, the roadway may pass over or even through the structure allowing for clearance below the bridge often not possible with other bridge types.

Trusses are also classified by the basic design used. The most representative trusses are the Warren truss, the Pratt truss, and the Howe truss.

The Warren truss is perhaps the most common truss for both simple and continuous trusses. For smaller spans, no vertical members are used lending the structure a simple look For longer spans vertical members are added providing extra strength Warren trusses are typically used in spans of between 50-100m.

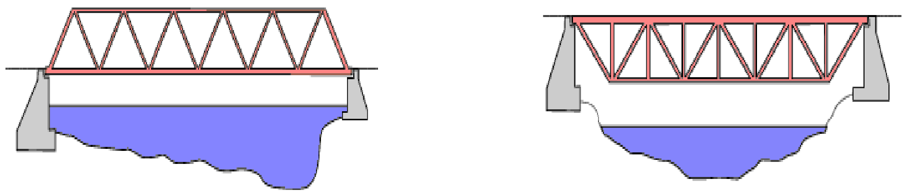


Fig-37 Warren Truss

The Pratt truss is identified by its diagonal members which, except for the very end ones, all slant down and in toward the center of the span. Except for those diagonal members near the center, all the diagonal members are subject to tension forces only while the shorter vertical members handle the compressive forces. This allows for thinner diagonal members resulting in a more economic design.

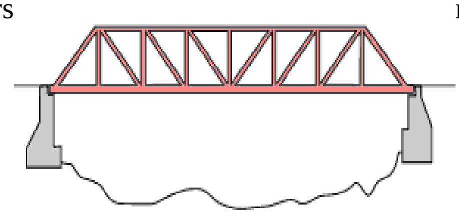


Fig-38 Pratt truss

The Howe truss is the opposite of the Pratt truss. The diagonal members face in the opposite direction and handle compressive forces. This makes it very uneconomic design for steel bridges and its use is rarely seen.

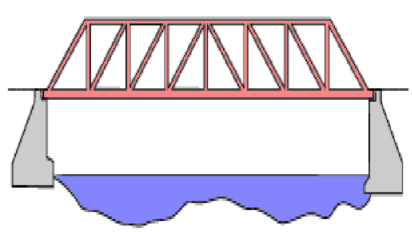


Fig-38 Howe truss

Bridge components

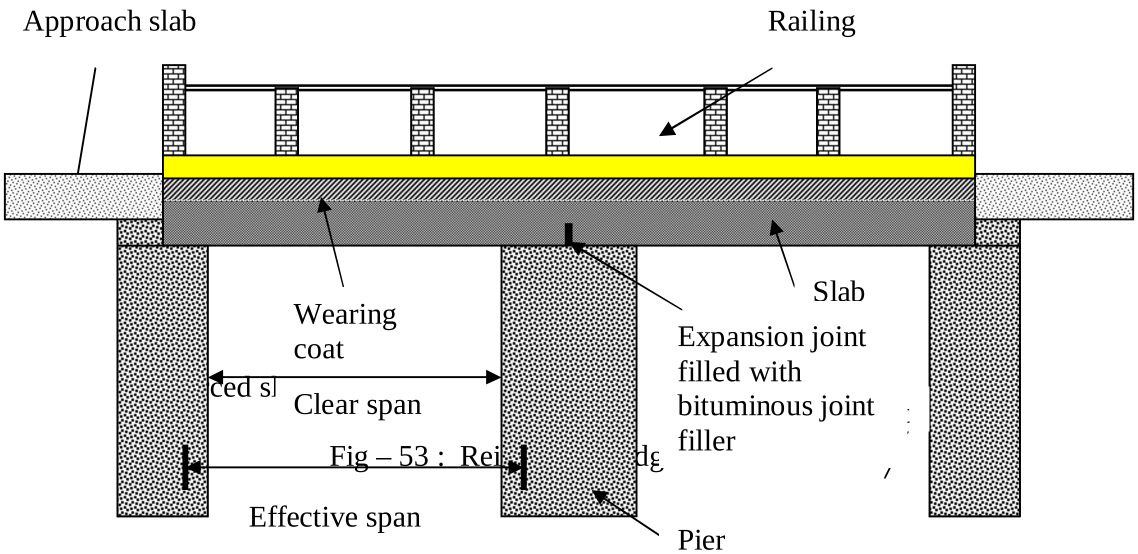


Fig-39

e)

description of main components of proposed pre-stressed beam bridge with suitable sketches.

Pre stressing

Pre stressing is a method of reinforcing different kinds of structural elements. It was based off of the use of rebar in concrete as reinforcement, with the main distinction being that an induced stress changes the properties of the concrete (PTI). In most applications, pre stressing is used to overcome a materials' weak tensile strength. A highly tensile steel strand or rod passes through the material, is pulled into tension and anchored on both ends to couple their properties. This pre stressing applies a compressive stress on the material, which offsets the tensile stress the material might face under loading.

In pre-tensioning system, the high-strength steel tendons are pulled between two end abutments (also called bulkheads) prior to the casting of concrete. The abutments are fixed at the ends of a pre stressing bed.

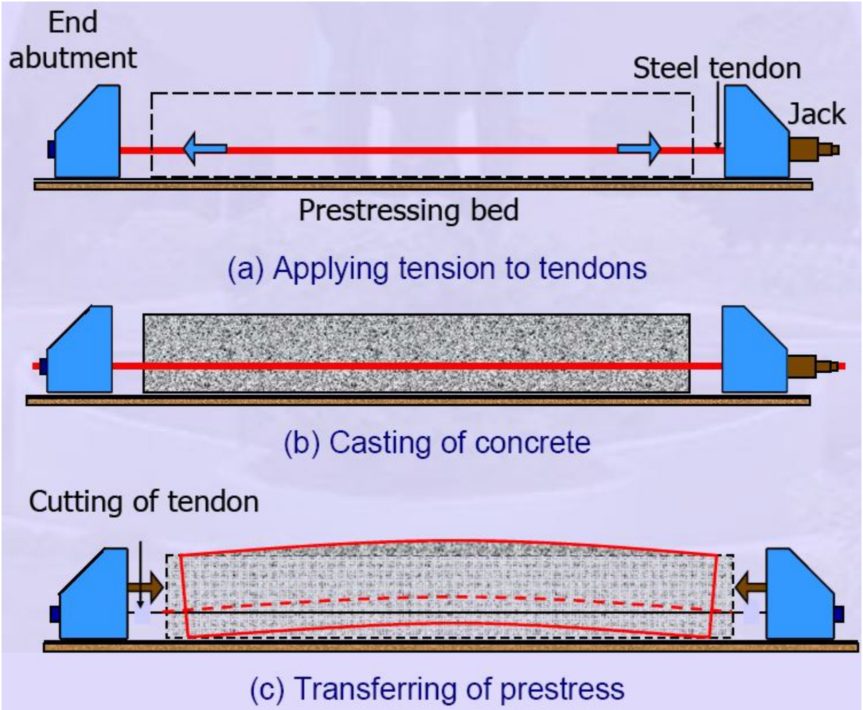
Once the concrete attains the desired strength for pre stressing, the tendons are cut loose from the abutments.

The pre stress is transferred to the concrete from the tendons, due to the bond between them. During the transfer of pre stress, the member undergoes elastic shortening. If the tendons are located eccentrically, the member is likely to bend and deflect (camber). The various stages of the pre-tensioning operation are summarized as follows.

1) Anchoring of tendons against the end abutments
2) Placing of jacks
3) Applying tension to the tendons
4) Casting of concrete
5) Cutting of the tendons.

During the cutting of the tendons, the pre stress is transferred to the concrete with elastic shortening and camber of the member.

The stages are shown schematically in the following figures



Stages of pre-tensioning

Fig -40 Post-tensioning on a highway overpass

Ice of Abutment

Current practice is to make decks integral with the abutments. The objective is to avoid the use of joints over abutments and piers. Expansion joints are prone to leak and allow the ingress of de-icing salts into the bridge deck and substructure. In general all bridges are made continuous over intermediate supports and decks under 60 metres long with skews not exceeding 30° are made integral with their abutments.

Open Side Span With Bank Seats

Solid Side Span with Full Height Abutments

Fig-41

Usually the narrow bridge is cheaper in the open abutment form and the wide bridge is cheaper in the solid abutment form. The exact transition point between the two types depends very much on the geometry and the site of the particular bridge. In most cases the open abutment solution has a better appearance and is less intrusive on the general flow of the ground contours and for these reasons is to be preferred. It is the cost of the wing walls when related to the deck costs which swings the balance of cost in favour of the solid abutment solution for wider bridges. However the wider bridges with solid abutments produce a tunnelling effect and costs have to be considered in conjunction with the proper functioning of the structure where fast traffic is passing beneath. Solid abutments for narrow bridges should only be adopted where the open abutment solution is not possible. In the case of wide bridges the open abutment solution is to be preferred, but there are many cases where economy must be the overriding consideration.

Design Considerations

Loads transmitted by the bridge deck onto the abutment are :

i. Vertical loads from self weight of deck
ii. Vertical loads from live loading conditions
iii. Horizontal loads from temperature, creep movements etc and wind
iv. Horizontal loads from braking and skidding effects of vehicles.

These loads are carried by the bearings which are seated on the abutment bearing platform. The horizontal loads may be reduced by depending on the coefficient of friction of the bearings at

The movement joint in the structure. However, the full braking effect is to be taken, in either direction, on top of the abutment at carriage level.

In addition to the structure loads, horizontal pressures exerted by the fill material against the abutment walls is to be considered. Also a vertical loading from the weight of the fill acts on the footing. Vehicle loads at the rear of the abutments are considered by applying a surcharge load on the rear of the wall. For certain short single span structures it is possible to use the bridge deck to prop the two abutments apart. This entails the abutment wall being designed as a propped cantilever.

Choice of Pier

Wherever possible slender piers should be used so that there is sufficient flexibility to allow temperature, shrinkage and creep effects to be transmitted to the abutments without the need for bearing at the piers, or intermediate joints in the deck. A slender bridge deck will usually look best when supported by slender piers without the need for a downstand crosshead beam. It is the proportions and form of the bridge as a whole which are vitally important rather than the size of an individual element viewed in isolation.

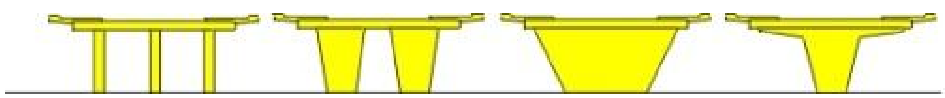


Fig-42 **Different Pier Shapes**

Design Considerations

Loads transmitted by the bridge deck onto the pier are :

i. Vertical loads from self weight of deck
ii. Vertical loads from live loading conditions
iii. Horizontal loads from temperature, creep movements etc and wind
iv. Rotations due to deflection of the bridge deck.

The overall configuration of the bridge will determine the combination of loads and movements that have to be designed for. For example if the pier has a bearing at its top, corresponding to a structural pin joint, then the horizontal movements will impose moments at the base, their magnitude will depend on the pier flexibility. Sometimes special requirements are imposed by rail or river authorities if piers are positioned within their jurisdiction. In the case of river authorities a 'cut water' may be required to assist the river flow, or independent fenders to protect the pier from impact from boats or floating debris. A similar arrangement is often required by the rail authorities to prevent minor derailments striking the pier. Whereas the pier has to be designed to resist major derailments. Also if the pier should be completely demolished by a train derailment then the deck should not collapse.

Pre-stressed Concrete Decks

There are two types of deck using prestressed concrete :

i. Pre-tensioned beams with insitu concrete.
ii. Post-tensioned concrete.

1. The term pre-tensioning is used to describe a method of prestressing in which the tendons are tensioned before the concrete is placed, and the prestress is transferred to the concrete when a suitable cube strength is reached. Post-tensioning is a method of prestressing in which the tendon is tensioned after the concrete has reached a suitable strength. The tendons are anchored against the hardened concrete immediately after prestressing.

There are three concepts involved in the design of prestressed concrete :

1. Prestressing transforms concrete into an elastic material. By applying this concept concrete may be regarded as an elastic material, and may be treated as such for design at normal working loads. From this concept the criterion of no tensile stresses in the concrete was evolved.

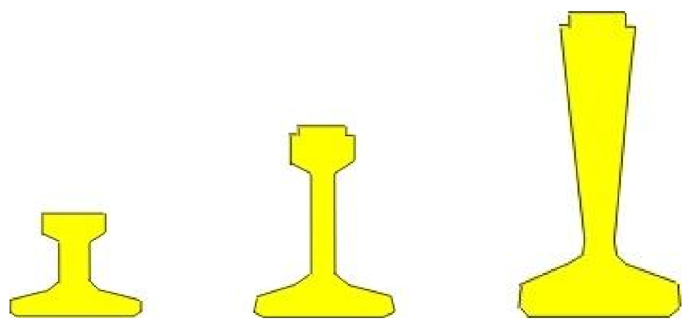
In an economically designed simply supported beam, at the critical section, the bottom fibre stress under dead load and prestress should ideally be the maximum allowable stress; and under dead load, live load and prestress the stress should be the minimum allowable stress.

> Therefore under dead load and prestress, as the dead load moment reduces towards the support, then the prestress moment will have to reduce accordingly to avoid exceeding the permissible stresses. In post-tensioned structures this may be achieved by curving the tendons, or in pre-tensioned structures some of the prestressing strands may be deflected or de-bonded near the support.

2. Prestressed concrete is to be considered as a combination of steel and concrete with the steel taking tension and concrete compression so that the two materials form a resisting couple against the external moment. (Analogous to reinforced concrete concepts) This concept is utilized to determine the ultimate strength of prestressed beams.

3. Prestressing is used to achieve load balancing. It is possible to arrange the tendons to produce an upward load which balances the downward load due to say, dead load, in which case the concrete would be in uniform compression.

Pre-tensioned Bridge Decks



T-Beam M-Beam Y- Beam

Fig-43

Types of beams in common use are inverted T-beams, M-beams and Y beams. Inverted T-beams are generally used for spans between 7 and 16 metres and the voids between the beams are filled with insitu concrete thus forming a solid deck. M-Beams are used for spans between 14 and 30 metres and have a thin slab cast insitu spanning between the top flanges. The Y-beam was introduced in 1990 to replace the M-beam. This lead to the production of an SY-beam which is used for spans between 32 and 40 metres.

Post-tensioned Bridge Decks

Post-tensioned bridge decks are generally composed of insitu concrete in which ducts have been cast in the required positions.

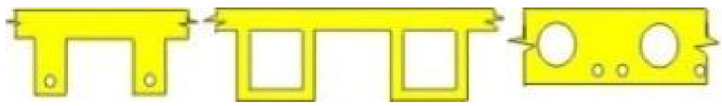


Fig-44

When the concrete has acquired sufficient strength, the tendons are threaded through the ducts and tensioned by hydraulic jacks acting against the ends of the member. The ends of the tendons are then anchored.

Tendons are then bonded to the concrete by injecting grout into the ducts after the stressing has been completed.

It is possible to use pre-cast concrete units which are post-tensioned together on site to form the bridge deck.

Generally it is more economical to use post-tensioned construction for continuous structures rather than insitu reinforced concrete at spans greater than 20 metres.

For simply supported spans it may be economic to use a post-tensioned deck at spans greater than 20 metres.

Choice of Deck Joint

Current practice is to make decks integral with the abutments. The objective is to avoid the use of joints over abutments and piers. Expansion joints are prone to leak and allow the ingress of de-icing salts into the bridge deck and substructure. In general all bridges are made continuous over intermediate supports and decks under 60 metres long with skews not exceeding 30° are made integral with their abutments. Where it is intended not to use road salts, or the deck and substructure have been designed to incorporate deck joints then the following guidance is given in BD 33/94 for the range of movements that can be accommodated by the various joint types: