# DESIGN OF BOX TYPE MULTIBARREL SKEW CULVERT


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**June 2008**

**Major project**

**On**

# DESIGN OF BOX TYPE MULTIBARREL SKEW CULVERT

Submitted in partial fulfillment of the requirements

For the degree of

**Master of Technology in Civil Engineering**
**(Computer Aided Structural Analysis & Design)**

By

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**June 2008**

# CERTIFICATE

This is to certify that the Major Project entitled "Design of Box Type Multibarrel Skew Culvert" submitted by Mr. Chudasama Vishal K. (06MCL002), towards the partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) of Nirma University of Science and Technology, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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## ACKNOWLEDGEMENT

Any fruitful work in a new work needs a direction and guiding hands that shows the way. It is proud to privilege to bring out indebt ness and warm gratitude to respected Mr. Jitendra S. Thakur, Executive Engineer, Irrigation Department, Sachivalaya, Gandhinagar, and Mr. Sunil Prajapati, Executive Engineeer, Minor Irrigation Department, for his support during thesis work. It gives me great pleasure to present this report entitled "Design of Multibarrel Box Type Skew Culvert". I take this opportunity to express my sincere thanks to all who contributed to make this task of project a success.

I would like to express my sincere thanks to my co-guide. Mr. Dhaivat Parikh, Lecturer, Nirma University, for his support during my thesis work.

My special thanks to Prof. G.N. Patel, Professor, and Department of Civil Engineering for getting best out of me. I would like to express my special thanks to Dr. P. V. Patel, Professor and Department of civil engineering for his fruitful involvement and guidance. I am also thankful to Prof. C. H. Shah, Structural Consultant, Mr. Bharat Rupera, Structural Consultant and Mr. B. N. Suthar, structural consultant for their guidance, motivational words and continual encouragement throughout the Major Project.

I express my gratitude to all faculty members of Civil Engineering Department, Nirma University, Ahmedabad for their special attention and suggestions towards the project work.

And lastly I am grateful to my friends who gave us the moral support directly or indirectly in the times of difficulties.

And last but not the least I would like to express my heartiest thanks to my parents who readily accepted my work and did not make me worry about other matters.

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# ABSTRACT

As the numbers of bridges comes up it has become healthy to provide box type multibarrel skew culvert where traffic moves on the top of continuous slab and water flows through barrels underneath it. Present situation of traffic requirements demand straight alignment of road in view of the fast traffic and this in turn necessities the use of skew crossings. By providing this type of alternatives, bridge span is in direction of road, we can directly provide skew culvert. So there is no need for provide approaches on both side in form of curve which will solve land acquisition problem and project becomes faster and economical.

Modeling and analysis of the skew bridge deck and box is to be done in Staad-Pro and/or in SAP. For single cell analysis STAAD PRO is used and for multibarrel box with SAP 2000 is used. For single cell analysis separate worked out in spread sheet with considering all load combination guided in IRC-6.

The problem consisting of two lane road width (7.5m) and span of 20m. Each barrel is dimension has 5m by 5m. For dead load, live load, earth pressure, water pressures are considering and for various load combination it will be analyzed and for critical design will be made. For analysis of single cell with skew angle of 25 degree generalized spread sheet was made and accordingly analysis processed. Culvert is designed for 25 degree skewness and for four barrels. Further comparative study is carried out for different skew angles 20 degree, 25 degree, 30 degree, 40 degree.

Parametric study also done for the give problem statement by considering various skew angles for comparing twisting moments. Another study done for different soil bearing capacity comparing to the bending moment for the base slab. Also parametric study done for different support condition on base slab which shows for even smaller height structures when we incorporating the soil structure interaction with soil stiffness, base moment will reduce and so that obtaining less thickness and less steel for base slab which economize the project cost.

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## ABBREVIATION NOTATION AND NOMENCLATURE

| | |
|---|---|
| *a* | A constant having values depending on B/L values |
| A | Area under load |
| A | Constant 4.5 for RCC bridges Discrete Fourier Transform |
| $A_h$ | Horizontal seismic coefficient |
| $A_v$ | Vertical seismic coefficient |
| B | Constant, 6 for RCC bridges |
| b | vertical height (internal clearance) |
| $b_1$ | Width of dispersion |
| $b_{eff}$ | Width of slab over which the load is effective |
| d | Thickness of top slab |
| E | Effective width of dispersion |
| e | Thickness of bottom slab |
| f | Thickness of outer side wall |
| FS | Factor of safety |
| g | Thickness of inner side wall |
| I | Importance factor |
| I.F. | Impact factor |
| Ka | Active lateral earth pressure |
| $k_s$ | Stiffness of soil or modulus of subgrade reaction |
| l | Effective span of simply supported slab |
| L | Span in meter |
| m | Modular ration |
| ML | Moment in longitudinal direction |
| MT | Moment in transverse direction |
| ø | Angle of internal friction |
| P | Direct load |
| P | Footway loading |
| P | Wheel load |
| $q_{ult}$ | Ultimate soil bearing capacity |
| R | Response Reduction factor |
| te | Width of tyre contact area parallel to span |
| tp | Width of dispersion parallel to span (Along the span) |
| ts | Effective depth of slab |
| tw | Thickness of wearing coat |

| | |
|---|---|
| u | Dispersion along transverse direction |
| v | Dispersion along longitudinal direction |
| w | Clear width |
| W | Width of footway in meters |
| W’ | Concentrated vertical loads |
| x | Distance of centre of gravity of the concentrated load from nearest support |
| Z | Section modulus |
| z | Zone factor |
| $\gamma'$ | Submerged density of water |
| $\gamma w$ | Density of water |
| $\theta$ | Skew angle |
| $\sigma_c$ | Permissible flexural compressive stress for concrete |
| $\sigma_{st}$ | Permissible tensile stressing flexure for steel |
| $\Delta q$ | Load applied on to the soil |
| $\Delta\delta$ | Deflection under loading |

# 1. INTRODUCTION

## 1.1 GENERAL

A bridge structures provide passage over an obstacle without the way closing beneath. The required passage may be for a road, a railway, pedestrians, a canal or a pipeline. The obstacle to be crossed may be river, a road, or a valley. A bridge is a structure which maintains communication such as the road and railway traffic and other moving loads over an obstacle, namely channel, a road, a railway, or a valley. The structure is termed as a bridge when it carries a road and railway traffic or pipe line over a channel or a valley and an Overbridge when it carries the traffic or pipeline over a communication system like roadways or railways. A viaduct is also bridge constructed over a busy locality to carry the vehicular traffic over the area keeping the activities of the area below the viaduct uninterrupted.

## 1.2 CLASSIFICATION OF BRIDGES

The classification of bridge structures with reference to the size has been done differently by road and rail alignment. The Indian railways consider structures with a total waterway more than 18 lineal waterway or one having any span of clear waterway of 12 m or over as a major bridge and those below as a minor bridge. They have also one more classification viz. important bridges which refer to those major bridges which have a total waterway of 18 lineal meters and more, or more than $110m^2$. For the purpose of investigation and cross drainage structures can be grouped into three categories viz.

1. Culverts and minor bridges (lineal waterway up to 30 m).
2. Major bridges (those with a lineal waterway over 30 m but on stable rivers and canals).
3. Important bridges (those with a lineal waterway over 30 m but on major rivers or tributaries which are shifting in nature or which presents some problems of stability).

## 1.3 INVESTIGATION OF CULVERTS AND MINOR BRIDGES

On any road or rail line project, a large number of culverts and bridges will have to be provided. It will be very time consuming and expensive if very detailed investigations have to be made for same and entire project study will be prolonged. A certain amount of risk can be taken in their construction, since repairs or replacement in case of inadequacy can be done wit minimum dislocation and cost.

### 1.3.1 Silting

When water flows through culverts, soil particle which flows through the culverts, because of heavier specific gravity it becomes settled and the open space area for flowing water will decrease. It is called silting effect.

A culvert can be defined as a crossing with a total length not exceeding 6 m between the faces of abutments or extreme vent way boundaries when measured at right angles to the axis of vent way. Such minor drainage works cab be made up of pipes, arches, RCC boxes, or reinforced concrete slabs on piers and abutments for draining local pockets or over minor man made channels/streams. Pipes and arch culverts are provided where the bank is fairly high or where sufficient cushion is available. Pipes are cheapest and quickest form to construct and are provided for low discharges, say up to $10m^3/s$. Box culverts are provided in multiple units, individual spans ranging from 1 to 4 m. Arches and slab culverts are suitable for span ranges 2 to 6 m.

In any investigation for any major road or rail line, the survey is conducted along the centerline of the proposed alignment and the details are collected by the plane table survey for about 100 m on either side of the alignment. In the other case of culverts across minor natural streams, the investigating engineer will have to see if there is any possibility of the diversion. Otherwise, details that will have to be noted during investigations will be the catchments area, soil characteristics, the nature of the stream, the high flood level, the low water level slope, navigational requirements if any. If the flow can be modified or trained to run normal to the alignment, a normal (90 degree) crossing can be provided. A normal crossing provides the shortest length of the bridge span as well as the length of the pier and abutments. It provides for a smooth flow and facilitates construction of segmental wing walls and return walls with minimum sharp angled structures that would cause no eddies and cross currents. Hence, it is always preferred. If a normal crossing is not possible, a skew crossing can be provided with minimum adverse effects on the flow through the bridge.

### 1.3.2 Catchments Area

The catchments area for any drainage crossing cab be obtained by directly measuring on a large scale map, provided contours are available. For small crossings, it may mostly be possible to work out the area from the prepared survey plan itself, covering details up to 100 m on either side.

### 1.3.3 Soil Particulars

For culverts, a simple soil investigation will suffice. The depth to which such an investigation has to be conducted will have to be decided by the engineer with reference to the type of foundation proposed, the level up to which the foundation is to be taken and the anticipated velocity of flow of water during the rime of flood. If any deep scour is anticipated, it is contra indication for pipe and box culvert. For culverts and minor bridges, it will be necessary to obtain only a qualitative idea of the various layers of the soil. In the absence of rock, representative sample of rocks can be taken from borings approximately 1.5 to 2 meters intervals which depending upon whether the same type of soil continuous of changes.

### 1.3.4 Hydraulic Particulars

The condition of highest flood levels should be ascertained from inquiries from the oldest of local residents. The highest flood level marked on each cross section. The type of bed and bank material and the condition should be noted for judging the rugosity coefficient in calculating the velocity of flow. The design flood discharge will have to be worked out making use of the various methods available and the choice made. Based on this, the waterway required for the bridge has to be worked out and the span arrangement decided upon.

Bridges and culverts form an important part of a road or rail or any other communication network, and the major part of the cost of the project goes into the construction of these structures. In order to provide a reliable and at the same time an economic structure, detailed investigations are necessary to correctly locate the structure, determine the type of structure and its correct size, and design of foundations. Thus a detailed investigations covering the topography, flood flow characteristics, soil profile etc. necessary before an ideal and economic site can be fixed.

Investigations are to be done in three stages viz. Feasibility study, Techno economic study and detailed survey and Project report preparation. For this purpose, the cross drainage work can be divided into three types, viz. culverts and minor bridges, and important or major bridges. The quantum of details to be collected the different for different types of structures. The simplest is for a culvert or major bridge which covers a total waterway of length up to 30 m.

## 1.4 COLLECTION OF PRELLIMINARY DATA FOR SELECTION OF BRIDGE SITES

The bridge site shall satisfy the following the requirements and as such the preliminary data for the selection alternative bridge sites shall be collected accordingly. If all requirements is not satisfied there may be some compromise for the less important ones.

- The channel is well defined and narrow.
- The river course is stable and has high and stable bank
- The river has large average depth compared to localized maximum depth to ensure uniform flow.
- The bridge site shall be far away for the confluence of large tributaries especially at the upstream so that the site remains beyond the distributing influence of them.
- Whether the river meanders and if so locate the nodal points of the river course which are not affected by the meandering. Such nodal points may be a possible bridge site.
- The site shall have a straight approach and a square crossing. Curves in the immediate approaches to the bridge shall be avoided. Skew crossing may be acceptable in unavoidable circumstances where curve in immediate approaches to the bridge has to be accepted if square crossing has to be adopted.
- The site is easily approachable from all sides and will give maximum service to the locality for which the bridge will be constructed.
- The proposed bridge will connect the road alignment, existing or proposed, with shortest approach.

- The site shall avoid curves at the immediate approach to the bridge. Curvature in the bridge proper shall also avoid unless forced by site conditions.

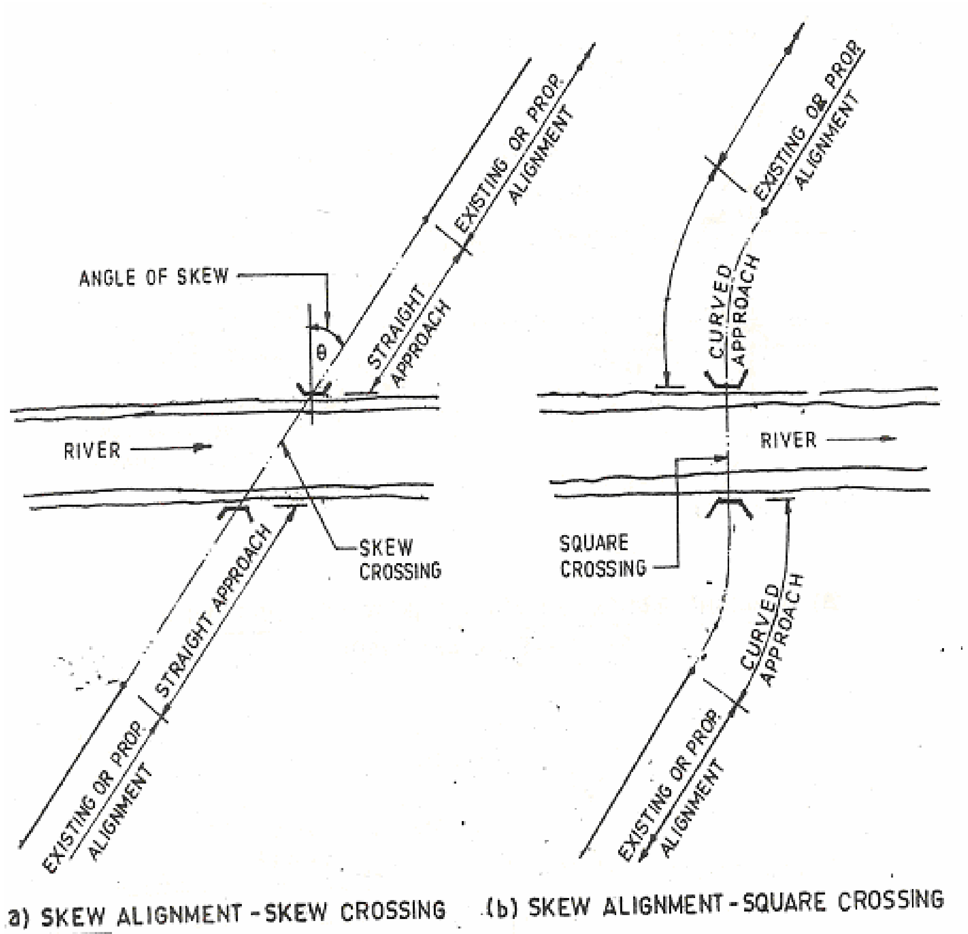



Fig 1.1 Skew and square Bridges

- One such example is shown in Figure in which the bridge was connect the new road with existing road running on one of the banks of the canal. A curved bridge was required to be constructed over the canal in order to introduction of S curve in one of the approaches in addition to building a skew bridge. Square crossing is as per alternative proposal number 1 would have made the approaches worse than alternative proposal number 2. Curves may not perhaps be avoided in many bridges of the hill roads for shortage of space in the approaches.
- The bridge site shall be such that there shall be no need for costly river training works.

- The site shall be sound from geological consideration.
- Material and construction required for the construction of the bridge shall be available as much as possible in the vicinity of the bridge site.

## 1.5 CHOICE OF BRIDGE TYPE

The choice of an appropriate type of bridge and planning of its basic features usually constitute a crucial decision to be taken by the engineer. The design must be consider all the preliminary data made available to him from the detailed investigation before arriving at a solution. The entire complete structure should be the most suitable to carry designed traffic, adequately strong to support the incident loads, economical and aesthetically pleasing. Some of the factors influencing the choice of the bridge type and its basic features are the following:

- The need to economize on the overall construction cost to the community by combining the railway and highway requirements may be necessitate a road cum rail bridge in two tiers across a very wide river
- Large navigational clearances required may dictate the use of the particular types such as arches, cantilever bridges, and cable stayed construction or suspension bridges.
- Long and high approaches may be too costly at plain coastal area for a railway line with low volume of traffic and it may be desirable to have a low level structure with a movable span to cater to navigation
- A high level structure with uninterrupted traffic as on national highway and the need to reduce the number of piers may be necessitate a cantilever bridge or a cable stayed bridge or a series of simply supported truss.
- The climatic and environmental conditions would preclude the use of some types and require some other. For example, the corrosive atmosphere has dictated the use of cantilever construction with precast segments for the prestressed concrete navigation span for the road bridge.
- Deck bridges are preferred to through bridges for highway traffic because of the better view of the surrounding scenery.
- The topographic and soil conditions at a site may limit the choice to a few general possibilities
- Weak subsoil conditions may lead to the use of simply supported spans instead of continuous spans

➢ Shortage of funds may necessitate the adoption of submersible bridge instead of a high level bridge on a road with low volume of traffic, and this in turn may result in reinforced concrete slab decking.

➢ The type of traffic may restrict the choice of bridge type. For railway traffic, steel trusses or steel can cantilever types are preferable to suspension bridges.

➢ The personal preference or company specialization of the designer/construction firm may influence the type the bridge finally adopted, especially when competitive tenders are obtained for long bridges with freedom to submit alternative designs. A firm specializing in prestresssed concrete cantilever construction and another firm specializing in cable stayed steel bridges will offer different designs for the same bridge site, each design emphasizing the specialization of the concerned firm.

## 1.6 NEED OF SKEW BRIDGE :

The simple skew bridge plan drawing shown in Fig1.

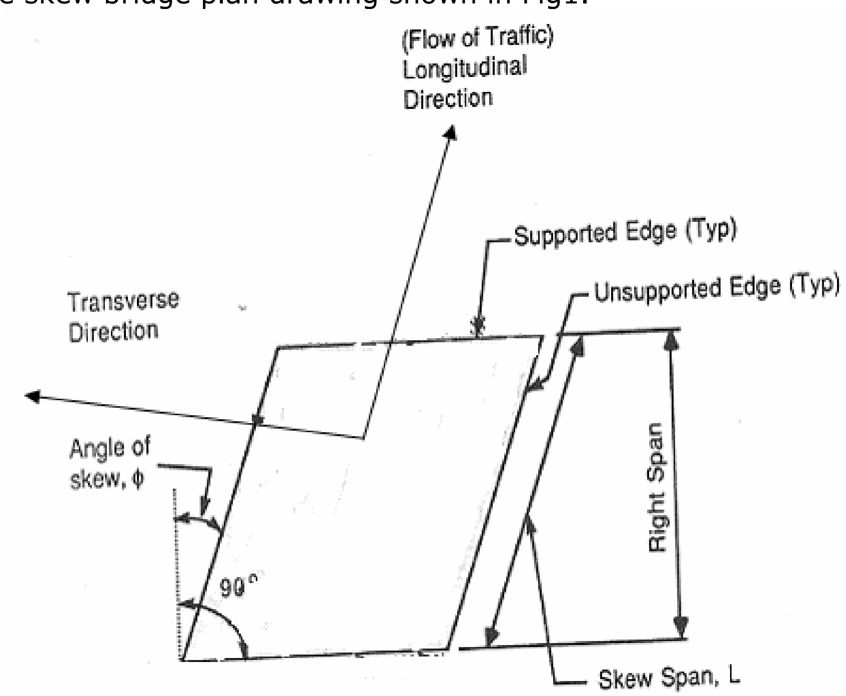



Fig 1.2 Plan of skew bridge

As the numbers of bridges are comes up it has become handy to provide box type skew bridges where traffic moves on the top of continuous slab and water flows through barrels underneath it. Skew bridges are necessary when a stream crosses the road at an angle different from 90 degree. Present situation of traffic requirements demand straight alignment of road in view of the fast traffic and this in turn necessities the use of skew crossings. Bridges in plane form is a parallelogram; the angle obtained subtracting the acute angle of parallelogram from 90 degree is termed as skew angle. The effect of skew in deck slabs having skew angles up to 20 degrees is not so significant and in designing such bridges, the length parallel to the centre line of the roadway is taken as the span. When skew angle varies from 20 degrees to 50 degrees, the skew effect becomes significant and slab tends to span normal to the supports. In this cases the slab thickness is determined with shortest span but reinforcement worked out on the basis of shortest span are multiplied by $\sec^2 \theta$ ($\theta$ being a skew angle) and are placed parallel to the roadway. The thickness of slab and reinforcement are calculated with this span lengths and the reinforcement are placed parallel to the centre line of roadway. The distributions are placed parallel to supports as usual.

## 1.7 HIGHWAY BRIDGE LOADING

A comparative analysis of loadings specified in different countries has been reported by Thomas. It is found that the IRC loading is the most severe for a single-lane bridge, but it is less severe than British, French, West German and Japanese loadings for a two-lane bridge. It has been reported by victor that IRC loadings have little relation to the vehicles currently in use in the country and certain basic anomalies have been observed in the prescribed loadings. In addition, application of class 70R, class AA and class A loadings in design is complicated. Simplified and more realistic standard loadings have been developed by Victor and Thomas. However the present IRC loadings have to be adopted in designs until the Indian Road Congress revises their standards.

The loadings in the different countries vary considerably both qualitatively and quantitatively. The IRC loadings appear to be the heaviest for single lane. However they are lighter than type HA loadings when two lanes are considered. In the view of the wide variations in Highway loadings specified in various countries, there is a need for a systematic survey of vehicular loads on bridge for rationalization of Highway Bridge loading standards.

- Local Wheel Load Effects:

In dealing with the analysis and design of bridge structures subjected to groups of concentrated loads we have so far only considered the distribution of the load to the primary structure of the bridge the main longitudinal beams and the transverse diaphragms. In addition to this distribution there will also be a local stress distribution in the top slab, or running surface, for each of the individual wheel loads; this stress distribution will, in general, be restricted to that portion of the top slab which spans between the longitudinal webs and transverse diaphragms. Being a secondary stress distribution, it may be superposed on the stress distribution produced in the bridge as a whole to give the resultant.

Due to overall deflection of bridge structure, the longitudinal webs, while having the same form for their longitudinal deflections, profiles, do not deflect equally and neither do the transverse diaphragms. The boundary conditions for the top slab spanning between these members are therefore complex, to simplify the problem from an analytical point of view, it is usually assumed that the boundaries of the top slab are simple, unreflecting supports and a factor introduced to take account of continuity over the supports. On this basis, the stresses due to the wheel loads may be derived by either of two procedures due to Piegaurds and Westergards.

The following forces shall have to be considered in the design of road bridges and all members shall be designed to sustain safely the effect of various loads, forces and stress that may act together.

- Dead load
- Live load
- Impact load
- Water current
- Earth pressure including live load surcharges
- Seismic forces

### 1.7.1 Dead load

The unit weight of various materials shall be assumed in the design as shown in table 1.1.

Table 1.1 Unit weights of various materials

| SR. NO. | MATERIALS | UNIT WEIGHT IN $t/m^3$ |
|---|---|---|
| 1 | Brick work in lime mortar | 1.8 |
| 2 | Brick work in cement mortar | 1.9 |
| 3 | Brick work in cement mortar(Pressed) | 2.2 |
| 4 | Stone masonry in lime mortar | 2.4 |
| 5 | Coursed rubble stone masonry in cement mortar | 2.6 |
| 6 | Cement concrete (plain) | 2.2 |
| 7 | Cement concrete (reinforced) | 2.4 |
| 8 | Cement concrete (plain with plums) | 2.3 |
| 9 | Cement concrete (prestressed) | 2.5 |
| 10 | Lime concrete with brick aggregate | 1.9 |
| 11 | Asphalt concrete | 2.2 |
| 12 | Compacted earth | 2.2 |
| 13 | Sand (loose) | 1.8 |
| 14 | Sand (wet compressed) | 1.4 |
| 15 | Gravel | 1.9 |
| 16 | Macadam (binder premix) | 1.8 |
| 17 | Macadam (rolled) | 2.2 |

### 1.7.2 Live load

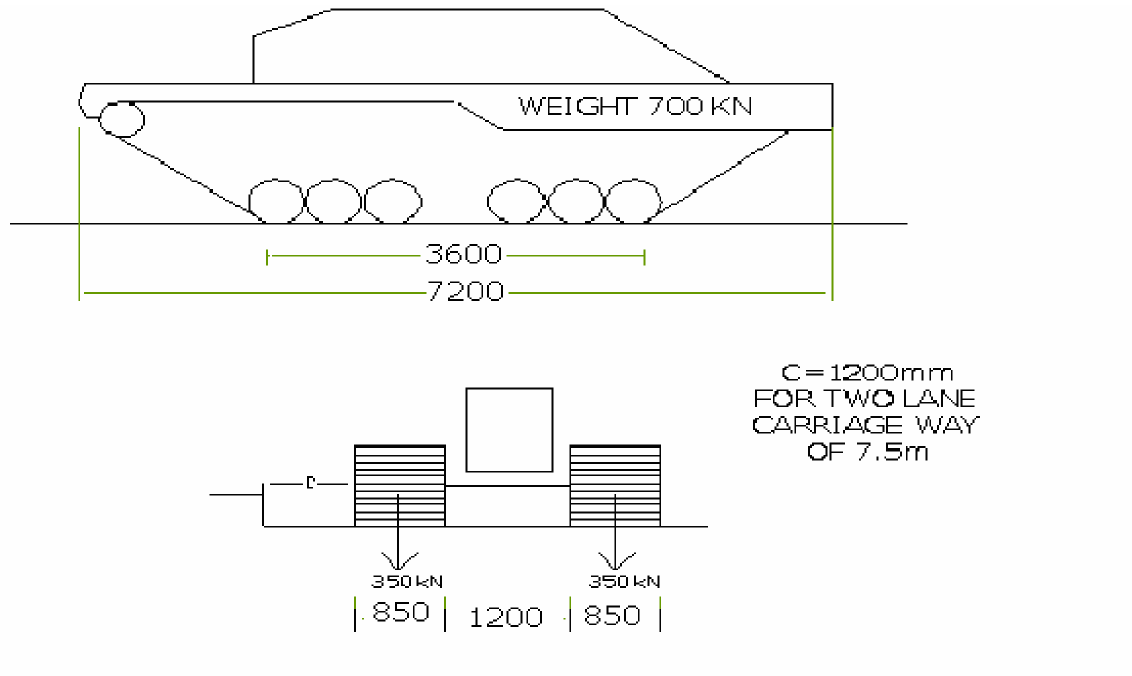
All the bridges in India shall be designed as per Indian Roads Congress loadings which consist of three classes of loading viz. I.R.C. class AA, I.R.C. class A, I.R.C. class B loading. For bridges to be built in certain municipal limits, industrial areas and on certain specified highways, single lane of class AA or two lanes of class A whichever produces worse effect is to be considered. All other permanent bridges shall be designed with two lanes of class A loading while two lanes of class B loading is applicable to bridges in specified areas or to the temporary type of structure such as timber bridges etc.

Fig1.3 to Fig 1.8 shows I.R.C. loadings. These loads shall be assumed to travel along the longitudinal axis of bridges and may be located anywhere on the deck for the consideration of worst effect produced in the section provided the distance between the wheel and the road kerb, the distance between axles and wheels and the distance between the adjacent vehicles as shown in the loading diagram are not encroached upon.

All the axles of standard vehicles or train shall be considered as acting simultaneously and the space left uncovered by the standard train shall not be assumed as subject to any additional load. The trailers attached to the driving unit are not to be considered as detachable. All the new bridges shall be one - lane, two-lane or four-lane width. For four-lane bridges or multiple of two-lane bridges, at least 1.2 m wide central verge shall be provided.

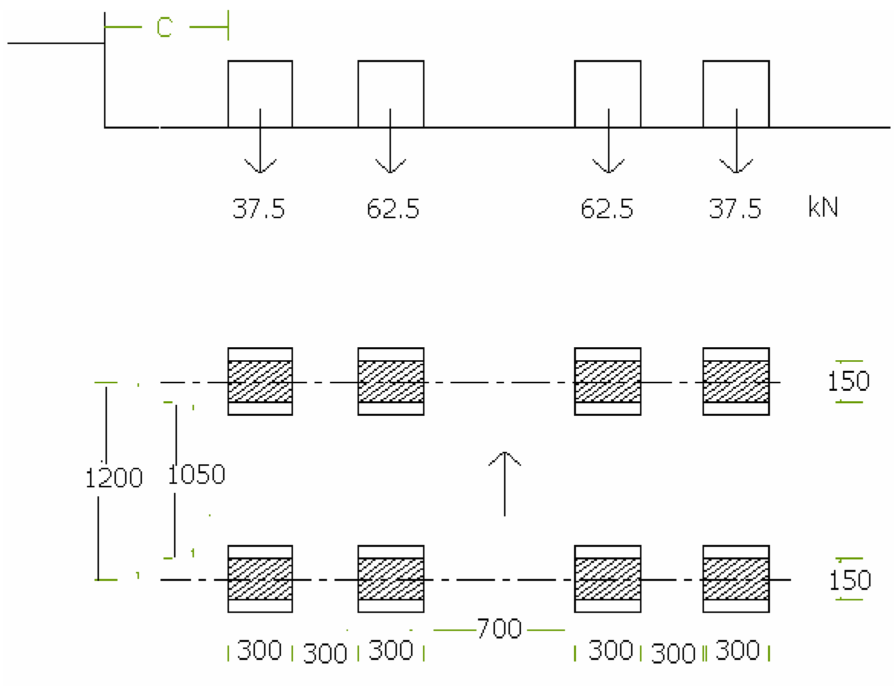
#### 1.7.2.1 IRC Class AA loading

IRC Class-AA loading comprises either a tracked vehicle of 700kN or vehicle of 400kN loads. Fig1.3 and Fig 1.4 shows the class-AA tracked vehicle and Fig.I.4 shows the class-AA wheeled vehicle. The tracked vehicle simulates the combat tank used by army. The ground contact length of vehicle is 7.2m. The nose to tail spacing between two successive vehicles shall not be less than 90 m. For multi lane bridges and culverts, one train of class AA tracked or wheeled vehicles whichever creates severer conditions shall be considered for every two lane width. No other live load considered on any part of the above two lane carriageway. When the class AA trains of vehicles is on the bridge. The class AA loading is to be adopted for bridges located within certain specified municipal localities and along specified highways. All bridges located on National highways and State highways have to be designed for this heavy loading.




All dimensions are in mm

Fig 1.3 IRC Class AA loading Tracked Vehicle




All dimensions are in mm

Fig 1.4 IRC Class AA Loading Wheeled Vehicle

#### 1.7.2.2 IRC Class-70R loading:

This loading was originally included in the appendix to the bridge code for use for rating for existing bridges. In recent years there is an increasing tendency to specify this loading in place of class AA loading. This loading consists of a tracked vehicle of 700 kN or a wheeled vehicle of total load of 1000 kN. This consists of a tracked vehicle of 700kN or a wheeled Vehicle of total load is 1000 kN. The tracked vehicle is somewhat similar to class AA, except that the contact length of truck is 4.87m, the nose to tail length of the vehicle is 7.92m and specified minimum spacing between successive vehicles is 30m. The wheeled vehicle is 15.22m long and has seven axles with the loads totaling to 1000kN. A bogie loading of 400 KN is also specified with wheel loads of 100 kN each. In addition, the effects on the bridge components due to a bogie loading of 400 kN are also to be checked. The dimensions of class 70 R loading is shown in Fig1.5. The specified spacing between vehicles as measured from the rear most point of ground contact of the leading vehicle to the forward most point of found contact of the following vehicle in case of tracked vehicle; for wheeled vehicle, it is measured from the centre of the rear-most wheel of the leading vehicle to the centre of the first axle of the following vehicle.

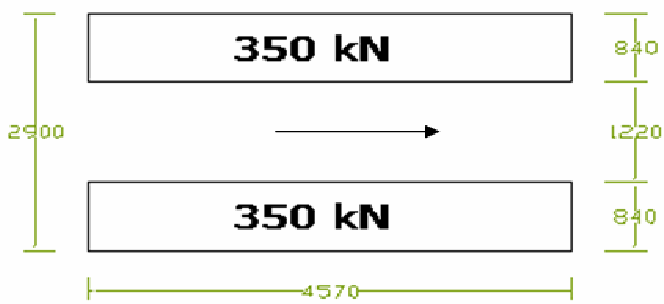



Fig 1.5 IRC Class 70R Tracked Vehicle (Plan)

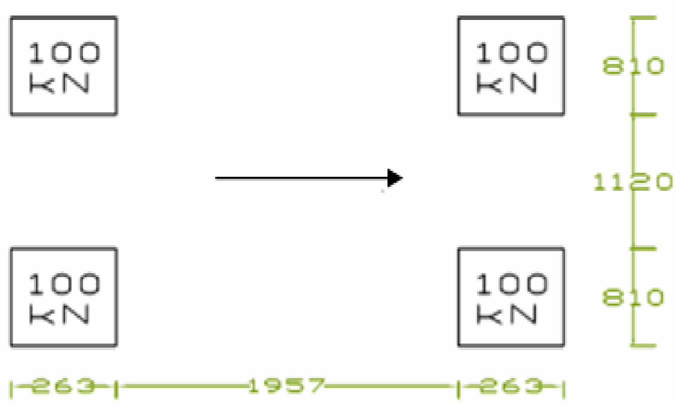
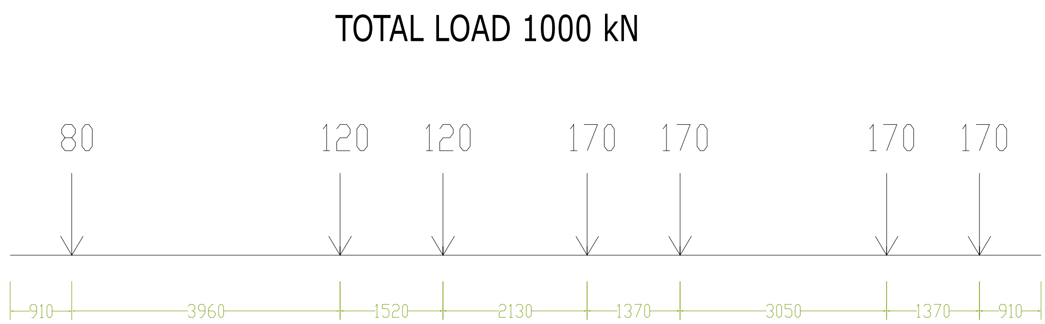



Fig 1.6 IRC Class 70 R Bogie Axle Type Vehicle




All dimensions are in mm

Fig 1.7 IRC Class 70 R Wheeled Vehicle

#### 1.7.2.3 IRC Class-A Loading:

IRC Class-A loading consist of a wheel load train comprising a truck with trailers of specified axle spacing and loads as detailed in Fig.1.8. This type of loading is adopted on all roads on which permanent bridges and culverts are constructed. Class A loading consists of a wheel load train composed of a driving vehicle and trailors of specified axle spacing and loads as shown in Fig.1.8. The nose to tail spacing between two successive trains shall not be less than 18.5m. No other live load shall cover any part of the carriage way when a train of vehicles (or trains of vehicles for multi lane bridge) is on the bridge. The ground contact for different wheels and minimum specified clearance are indicated in the Figure 1.8.

#### 1.7.2.4 IRC Class-B Loading:

Class B loading comprises a truck and truck and trailers similar to that of class A loading but with lesser intensity of wheel loads. The axle loads of class B loading is shown in Fig 1.8. This type of loading is adopted for temporary structures and timber bridges for bridges in the specified areas.

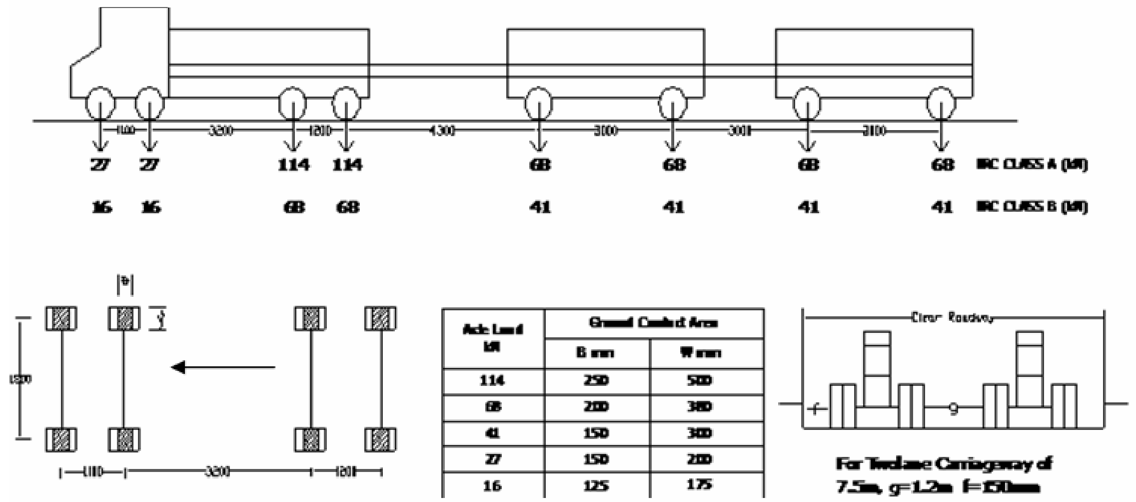



Fig 1.8 IRC Class A and Class B Type Vehicle

The standard loads are arranged in such a manner as to produce the severest bending moment or shear at any section considered. The loading vehicles are aligned so as to travel parallel to the length of the bridge. When these vehicles are on the span, no other live load need be considered as acting over the unoccupied area. Vehicle s in adjacent lanes is to be assumed to be moving in a direction producing maximum stresses.

#### 1.7.2.5 Reduction of stresses due to live load being on more than two traffic lanes simultaneously

The load intensity may be reduced by 10 percent for each additional traffic lanes in excess of the two lanes subject to a maximum reduction of 20 percent and subject also to be condition that the load intensities as thus reduced are not less than the intensities resulting from a simultaneous loading on two lanes.

### 1.7.3 Footway loading

For effective span of 7.5 m or less, 400 kg/m$^2$ for bridges near a town or centre of pilgrimage or large congregational fairs. For effective span over 7.5 m but not exceeding 30 m, the load intensity shall be calculated according to the following equation:

$$P = P' - \frac{40L - 300}{9}$$

For effective span of over 30 m, the intensity of footway shall be determined according to the following formula:

$$P = [P' - 260 + (4800/L)]\,[(16.5 - W)/15]$$

Where P = footway loading in kg per $m^2$

P' = 400 $kg/m^2$ or 500 $kg/m^2$ as the case may be.

L = effective span of the main girder in meters

W = Width of footway in meters

The footway shall be designed to withstand load of 4 tonnes inclusive of impact distributed over an area having 300 mm diameter. In such case the permissible stresses may be increased by 25 percent to meet this provision. Where the vehicles cannot mount the footway, this provision need not be made.

### 1.7.4 Impact loading

In order to account for the dynamic effects of the sudden loading of a vehicle on to a bridge structure, an impact factor is used as a multiplier for loads on certain structural elements. From basic dynamics we know that a load that moves across a member introduces larger stresses than those caused by a standstill load. However, the basis of impact factors predicted by IRC is not fully known. It has been felt by researchers that the impact factor to a large extent depends on weight of the vehicle, its velocity, as well as surface characteristics of the road. It is pertinent to note that the live load increases on account of the consideration of the impact effect. For example, a span which is 9 m long would yield an impact factor of 0.10 (10%) and an impact multiplier of 1.10. The IRC specifications for impact factors are computed as mentioned below.

For IRC Class A or Class B loading

I.F. = A / (B+L)

Where

I.F. = impact factor

A = constant, 4.5 for RCC bridges, 9.0 for steel bridges

B = constant, 6.00 for RCC bridges, 13.50 for steel bridges

L = span in m.

For spans less than 3 meters, the impact factor is 0.5 for reinforced concrete bridges and 0.545 for steel bridges. When span exceeds 45 meters, the impact factor is taken as 0.154 for steel bridges and 0.088 for for reinforced concrete bridges.

For IRC Class AA and 70R loading

1. Spans less than 9 m
   (a) Tracked vehicle 25%- for spans up to 5 m linearly reducing to 10% for spans up to 9 m.
   (b) Wheeled vehicle 25%- for spans up to 9 m.
2. Spans greater than 9 m
   (a) Tracked vehicle- for RCC bridges, 10% for spans up to 40 m and as per graph for spans greater than 40m. For steel bridges 10% for all spans.
   (b) Wheeled vehicle- for RCC bridges, 25% for spans up to 12 m, and in accordance with graph for spans exceeding 12 m. For steel bridges, 25% for spans up to 23 m and as per graph (IRC 6) for spans exceeding 23 m.

### 1.7.5 Earth pressure

The earth pressure for which earth retaining structures are to be designed shall be calculated in accordance with any rational theory. Coulomb's earth pressure theory may be used subject to modification that the resultant earth pressure shall be assumed to act at a height of 0.42H from base, where H is the height of the retaining wall. The minimum intensity of horizontal earth pressure shall be assumed to be not less than the pressure exerted by a fluid weighing 480 kg per cum. All the abutments shall be designed for a live load surcharge equivalent to 1.2m height of earth fill. For designing the wing and return walls, the live load surcharge shall be taken as equivalent to 0.6m height of earth fill.

The fills behind the abutments, wings, and return walls which exert the earth pressure shall be composed of granular materials. A filter media of 600 mm thickness with smaller size towards soil and bigger size towards the wall shall be provided over the entire surface of the abutments, wing or return walls. Adequate numbers of weep holes shall be provided in the abutments, wing or return walls above the low water level for the drainage of accumulated water behind the walls. The spacing of the weep holes shall not exceed one meter in both horizontal and vertical directions. The size of the weep holes shall be adequate for proper drainage and the weep holes shall be placed at a slope towards outer face.

### 1.7.6 Seismic force

All bridges in zone V shall be designed for seismic forces as specified. All major bridges with total lengths more than 60 m shall also be designed for seismic forces in zone III and IV. The vertical seismic force shall be considered in the design of bridges to be built in zone IV and V which the stability is the criterion for the design. The vertical seismic coefficient shall be taken as half of the horizontal seismic coefficient as given.

Horizontal seismic forces shall be taken to act at the centre of gravity of loads under consideration. The direction of seismic forces shall be such that the result effect of the seismic force and the other forces produces maximum stress in the structure. The seismic force for live loads shall not be considered when acting in the direction of traffic but shall be considered in the direction of perpendicular to traffic. The portion of the structure embedded in the soil shall not be considered to produce any seismic effects.

## 1.8 STANDARD SPECIFICATIONS FOR ROAD BRIDGES

The Indian road congress has formulated standard specifications and codes of practice for road bridges with a view to establish a common procedure for the design and construction of road bridges in India.

### 1.8.1 Width of carriage way

The width of carriage way required will depend on the intensity and volume of traffic anticipated to use of the bridge. The width of carriage way is expressed in terms of traffic lanes, each lane meaning the width required to accommodate one train of Class A vehicle. Except on minor village roads, all bridges must provide for at least two-lane width. The minimum width of carriageway is 4.25m for a one lane bridge and 7.5m for two lane bridges. For every additional lane a minimum of 3.5m must be allowed. Bridges allowing traffic on both directions must have carriageways of two or four lanes or multiple lanes of two lanes. Three lane bridges should not be constructed, as they will be conductive to the occurrence of accidents. In case of wide bridge, it is desirable to provide a central verge at least 1.2 m width or in order to separate the two opposing lines of traffic; in such a way that, the individual carriage way on either side of the verge should provide for a minimum of two lanes of traffic. If the bridges are to carry a tramway or railway in addition, the width of the bridge should be increased suitably. From consideration of safety and effective utilization of carriageway, it is desirable to provide footpath pf at least of 1.5m width on either side of the carriageway for all bridges. In urban areas, it may be necessary also to provide for separate cycle tracks besides the carriageway.

### 1.8.2 Clearances

The horizontal and vertical clearances required for highway traffic are given in this topic. Where in the maximum width and depth of moving vehicle are assumed as 3300 mm and 4500 mm respectively. The left half sections of each diagram shows the main fixed structure between end posts/ on arch ribs, whereas the right half section shows the intermediate portions. For a bridge constructed on a horizontal curve with super elevated surface, the minimum vertical clearance is to be measured from the super elevated level of the roadway. The horizontal clearance should be increased on the inner side of the curve by an amount equal to 5 m multiplied by super elevation.

## 1.9 OBJECTIVE OF THE STUDY

The aim of topic is to obtain the analysis and design of box type skew bridges. By providing these alternatives as bridge span is in the direction of road, we can directly provide these skew bridges. So there is no need for provide approaches on both the side in form of curves and that’s why project becomes economical. The design becomes very modular and construction is very speedy which will helpful for earlier utility of the bridge. The problem which consisting of two lane road (7.5 m road width) and span is considered 20 m for four nos. of barrels, 15 m for three nos. of barrels, 10 m for two nos. of barrels and 5 m for one barrels.

## 1.10 SCOPE OF WORK

Looking to above objective of the study scope of work decided as,

1) For performing analysis take various loads like dead load, live load, earthquake load, water pressure and earth pressure.
2) Analysis and design of top slab

3) Analysis and design of vertical walls
4) Analysis and design of bottom slab considering beams on elastic foundation.
5) Box consisting of single barrel and multibarrel of 4 nos.
6) Analysis for different angles of skew from 20 degree, 25 degree, 30 degree and 40 degree.
7) Analysis performing in SAP and in STAAD.
8) Parametric study done for different soil bearing capacity, with different support condition on bottom slab and for different skew angles
9) Preparation of drawing for 25 degree skew span.

## 1.11 ORGANIZATION OF MAJOR PROJECT

Chapter 1 includes the introductory part of thesis, collection of preliminary data for site selection, classification of bridges, choice of bridge types, standard specification for road bridges, objective, scope, various types of loading considering in IRC for analysis and designing of all components of culverts and organization of major project

Chapter 2 contains the literature review regarding information of various type of papers related to skew slab and box culvert

Chapter 3 includes introduction to skew and box bridges. Definition of skew angle, effects of skew angle on bridge, behavior of skew bridge, reaction on support, effect of heavy skew, arrangement of reinforcement in skew slab. It also includes box culvert design and general aspects, various load cases and analysis of deck slab by effective width method.

Chapter 4 covers loading calculations for the assigning problem statement. It includes different types of loading calculations like dead load , live load calculations considering class 70 R vehicle, breaking force calculations, soil pressures from side wall when soil is two different condition, one when soil is dry and another when soil is saturated, seismic force calculations according to IRC 6. This chapter also includes analysis and design concepts for designing bottom slab. It covers importance of foundation, types of foundations, shallow foundations and designing of bottom slab considering beams on elastic foundations.

Chapter 5 includes Excel work sheet consisting of single barrel

Chapter 6 includes analysis of multibarrel skew box culvert - 3 Dimensional analyses using software. Analysis was carried out in SAP 2000 version 10. It includes sample features of calculations and modeling techniques which is considering finite element model analysis with shell elements. These chapter shows how to modeled box type skew culvert with four numbers of barrels in SAP. It also covers the analysis results i.e. bending moment and torsional moment diagram considering different loading conditions and its deformed shape.

Chapter 7 covers complete design of different components of box which includes top and bottom slab designing and same time design of vertical wall considering column through moment area transformed method. The design was carried out through excel worksheet. It also includes single cell box culvert with right span and skew span bridge comparison detailed drawings and design detail drawings of multibarrel box type skew culvert of four barrels

Chapter 8 includes parametric study for comparing twisting moment for different skew angles, various soil bearing capacity, various support conditions.

Chapter 9 covers conclusion of the thesis work and further scope of work.

# 2. LITERATURE SURVEY

## 2.1 GENERAL

In the present chapter, various papers related to skew bridges and box types of bridges are included. The study includes the detailed information on topics related to bridge model, grillage analogy method, orthogonal seismic method for skew bridges, deck modeling for seismic analysis of skew bridges is studied. This is used to predict analysis and design of skew type box bridges.

## 2.2 LITERATURE REVIEW

In the study carried out by **Junyi Meng et al.** [13] on analytical and experimental study of a skew bridge model at Highway Administration Truner-Fairbank Highway Research center. The objectives of the studies are 1) to perform pilot studies on design 2) to provide experimental data to validate 3D modeling in FEM developed for skew bridge 3) to conform the applicability of a simplified bridge model developed for dynamic analysis of skew bridges. In this paper, the design, construction, instrumentation, testing and data processing of a skew steel bridge model were described with primary objective of verifying the numerical results obtained using FEM modeling. Experience and knowledge gained from this test will prove useful for further research activities. Proper instrumentation and data processing can only be achieved if the experimenter has through knowledge of how the test structure behaves under loads. For complex structural systems, this knowledge can be gained through analytical studies. The bridge was tested both statically and dynamically. The static test was performing to determine stiffness characteristics of the model as well as to conform its anti-symmetry. Dynamic excitations in form of a sinusoidal force generated by a shaker and an impact force generated by an impact hammer.

A comparison of the results obtained form these tests with those obtained numerically from a finite element analysis and analytically from dual stick bridge model shows that good correlation is obtained. The dynamic test was conducted to obtain damping and mode shapes.

**H. Zeng** [16] was done analysis on skew bridge interaction using grillage method. Field test was carried out on Walnut Creek Bridge on Interstate 35 near

Purcell, Oklahoma for vehicles to exert peak dynamic loads 1.3 – 1.7 times their static weights on the bridge. The bridge model was assembly of grillage analysis of longitudinal and transverse torsion beams. The FEM includes 205 nodes and 425 elements. The vehicle model has 7 degree of freedom planar representation that for both heaves and pitches. The equation of two sub systems is solved separately by Runge-Kutta interaction method in static space. The compatibility equations at the interface between the vehicles tires and bridge deck are satisfied by an iterative procedure. The comparison between numerical and experimental results gives reasonably good agreement. A response of typical point of bridge has a peak error of 8.2% and an RMS error of 12.4% for the quasi-static case, and a 17.6% peak error and a 24.5% RMS error for the dynamic case, respectively.

**Jun Yi Meng et al.** [11] carried out study on, seismic analysis and assessment of a skew highway bridge, using Finite element techniques. The effects of superstructure flexibility, substructure boundary conditions, structural skewness and stiffness eccentricity are assessed spectral analysis. The results show that the internal forces and displacements of the supporting columns as well as the displacement of the deck will be underestimated if one neglects the flexibility of the bridge deck. The study also demonstrates that seismic response of the bridge is affected quite noticeable by the boundary conditions of the bridge columns and the overall skewness of the bridge. Based on this study, theory was explained to the failure of the bridge.

The effect of superstructure flexibility is important and should not be ignored in dynamic analysis. The displacement of the deck is also underestimated by the simplified models. Proportioning of abutment seat size based on displacements computed for simplified models. Boundary condition of supporting columns plays an important role in the seismic behavior of skew bridges. Different boundary conditions lead to drastically different results. Skewness play an important role in dynamic behavior of bridge. Large skewness is likely to induce vibratory modes such as torsion and lateral flexure, which may cause an increase in axial forces, shears, moments and torque in the supporting columns as well as displacement in the columns. It was noted that boundary conditions of the columns had a more pronounced effect than skewness of the deck.

**Shrevin Maleki** [12] provided information on seismic analysis of slab girder single span skewed bridges is greatly simplified if one can assumed the concrete deck to be rigid in its own plane. In effect, deck can be replaced with a rigid bar and this will eliminate many degrees of freedom associated with the superstructure. A parametric study was performed on bridges with skews ranging from 0 to 60 degree and with span up to 30 m. It is assumed that bridges are elastically supported with elastomeric or pinned bearings in the longitudinal directions, and cross frames in the skew direction at each end. Linear finite element response spectrum analysis is performed on bridges with deck model as rigid and flexible shell elements. The effects of deck stiffness on the translational and torsional periods of vibration are noted. Stresses for flexible decks are evaluated and shown to be negligible.

It was noticeable that maximum cross brace shear occurs when response spectrum is applied in the Y direction in all cases and for all skew bridges. It was also seen that reactions are practically same and independent of skew angle for all bridges with elastomeric bearings and with skew angles up to 45 degrees. It was concluded that for elastically supported bridges there is no difference in support shear for all spans and skew angles, based on the deck rigidity assumptions. However, results reveals that for pin supported bridges the difference in support shear can be substantial. This difference can reaches up to as high as 26% for 30 degree skew and 30 m span. This difference can be reduced to 20% on the conservative side if we limit the span length up to 20 m and skew angles to 30 degrees. It was noticeable that for all elastically supported bridges, the maximum longitudinal shear occurs when the response spectrum is applied in Y direction.

**J. Y. Meng** [14] had carried out study on refined stick model for dynamic analysis of skew highway bridges. Stick models are widely employed in the dynamic analysis of bridges when only approximate results are desired or when detail models are difficult or time consuming. The properties of stick girders are determined in such a way that their static and dynamic analysis closely resembles those of the real deck. The validity of the model is demonstrated by comparison with numerical solutions obtained for skew plates and finite element results obtained for actual skew bridges. The model provides reasonably accurate results in predicting natural frequencies and mode shapes of the bridge, as well as in estimating the relative magnitudes of the displacements for superstructure and internal forces in the substructure. Because of the simplicity and ease of application, the model is a valuable tool for the preliminary analysis and seismic assessment of skew bridge response to dynamic loadings.

**E. M. Lui** [13] provides triple reinforced concrete box standards, barrel sections and bell joints. Study will involve developing details and quantities of 336 different ox culverts.Seven different triple box culvert was design from sixze of 101 x 81 to 121 x 121, with 12 different fills and 4 different skew headwalls.

**Tarek alkhardeji** [18] presents overview of the design, construction and laboratory field testing of box Culvert Bridge reinforced with glass FRP bars. A concrete pre-cast fabricated the box culvert units that were reinforced entirely with GFRP bars pre bend and cur to size by the manufacturer. Deformation and reinforcement strains were measured throughout the test. Test results wee compared with theoretical values. The insitu load test of the bridge indicated that bridge deflections were very small. Elastic deflection of the box units located under the west wheel path was higher than those obtained under the cast wheel path under similar conditions. Variation in the elastic response of box units under similar loading condition was related to the presence of minor cracks. After load was removed there was no residual deflection. Results obtained from this test will be used a s benchmark.

**Julian H kang** [17] presents a development of web application to improve process of a box culvert design and document management using XML and SVG. Box culvert is simple structures for road construction although parametric computer applications have demonstrated a significant amount of time savings I designing simple and repetitive structures, circulating resultant electronic document along project participants has not been fully integrated with these applications. As present in the simple box design, engineer should be able to design simple and repetitive strictures over the web without installing any structural analysis packages of CAD packages in the client computer. Web based design automation system that can be available by hourly change may help small design firms, which are often in charge of designing simple and repetitive structures, reduce their investment on computer systems and eventyally increase their profit. The public sector in the construction industry may also be benefited by the web based design automation. New information generated in the process of repairing the box culvert may be appended to the legacy database and utilixed for future maintenance. The parametric web based design automation system may have a potentially to shift the process of designing the repetitive simple structures from a stand alone computing to an internet based collaborative computing.

**S. Maleki** [15] presents orthogonal effects in seismic analysis of skewed bridges. He derived that in seismic analysis of bridges, the designer chooses the direction of applied earthquake forces arbitrarily. This paper investigates the effects of seismic force direction on the responses of slab-girder skewed bridges in response spectrum and time history linear dynamic analysis. The combination rules for orthogonal earthquake effects, such as the 100/30, 100/40, percentage rules and the SRSS method are also examined. It is concluded that either the SRSS or the 100/40 percentage rule in the skew direction should be used in the response spectrum analysis of skewed bridges. For time history analysis none of the combination rules provide conservative results. In this case, the application of paired acceleration time histories in several angular directions is recommended.

In his analysis he is modeled with rectangular shell elements. The girders are modeled with frame elements at each joint. They are free to rotate but restrained vertically at each end. This will capture girder’s weak axis moment of inertia to the superstructure stiffness for transverse loading. In the longitudinal direction, the ends of the girders are attached to a spring representing the elastomer’s lateral stiffness. The modeling of the superstructure is consistent with the recommendations of Mabsout et al [1997]. For single span bridges the abutment stiffness is not considered in the analysis. In the transverse direction abutments are much stiffer than the cross frames. As modeled in springs in series, the abutment wills not contributing the overall stiffness and only the effect of cross-frame stiffness is considered.

The translational free vibration modes of skew bridges that are supported elastically are very close to the parallel and perpendicular to the abutment. The directions of input motion for such bridges in response spectrum and time history analysis were examined. The peak responses were obtained by common combinations rules and compared. It is concluded that for response spectrum analysis of skewed bridges the 100/40 combination of input motion applied in the n, t direction produces reasonably results. The responses are very close to the results obtained form the SRSS method that is independent of the input axes.

In the time history analysis of commonly chosen input axes, such as x, y and n, t and combination rules, such as 100/30, 100/40 and SRSS, non produces the maximum responses for all skew angles and span lengths. The critical input angle must be obtained by trial and error applying a pair of ground motions in various orthogonal directions. Based on the three earthquake records considered in this study, a sinusoidal pattern of response variation with input angle was observed. It is recommended that time history analysis of the skewed bridges a pair of ground accelerations, with atleast three input angles of 0, 60 and 120 degree is considered. The maximum error found in responses was in the order of 13%. This is deemed practical for design purposes.

## 2.3 SUMMARY

In this chapter, review of relevant literature is carried out. In the literature review, concepts of box type skew bridge analysis for seismic design and parametric study for different skew angles were presented. These concepts are useful to understand the behavior of analysis and design of box type skew bridge.

# 3. SKEW TYPE BOX CULVERT

## 3.1 GENERAL

If a road alignment crosses over a river or other obstruction at an inclination different from 90 degree, a skew crossing may be necessary. In earlier days of slow traffic, attempts were made to have a square crossing for the bridge portion and suitable curves were introduced in the approaches. With the present day fast traffic, safety requirements demand reasonably straight alignment for the road, necessity a skew bridges. The inclination of the center line of traffic to the normal to the center line of river in case of a river bridge or other corresponding obstruction is called skew angle. The analysis and design of a skew bridge is very complicated than those for the right bridge.

The number of bridges which are built on the skew is very considerable and is greater than the number of the right bridges. Hence skew is very considerable importance in design, particularly so in the short and medium range of spans up to about 60 feet where the width of the bridge is of the same order as the span. The effect of skew in simply supported bridges can, in general, be neglected up to about 20 degrees of skew, the skew angle being defined as the inclination of the abutment to the perpendicular between the free edges. In these cases a normal distribution procedure will suffice.

## 3.2 DEFINITION OF SKEW ANGLE

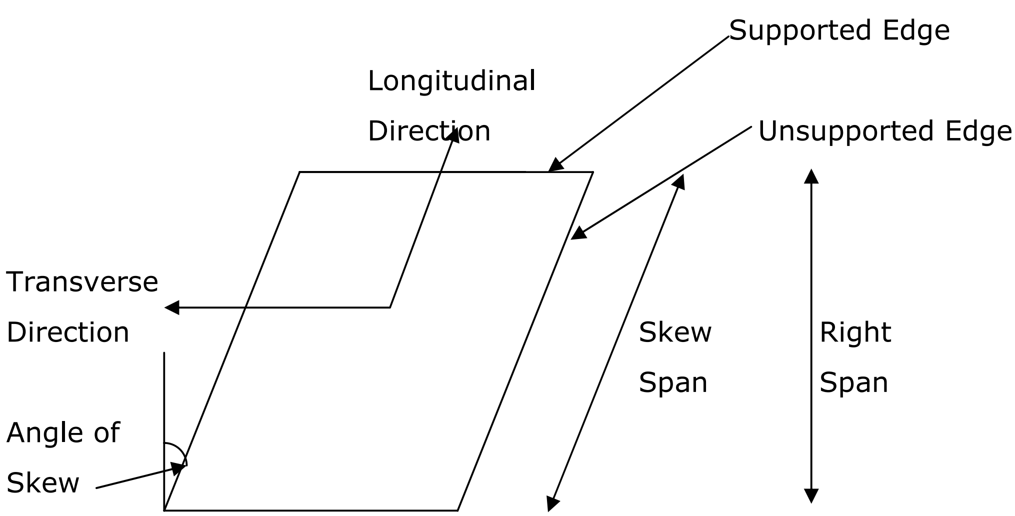



Fig 3.1 Plan of skew slab

For bridges in which the plane form is a parallelogram, the angle obtained by subtracting the acute angle of the parallelogram from 90 degree is called skew angle of the bridge. The simple plan of skew slab is shown in Fig 3.1. Non skew bridges i.e. those with zero angle of skew, are called right bridges. The span of a skew bridge measured along an unsupported edge of the bridge in plan is called the skew span and the perpendicular distance between the two lines of support is called right bridges. The directions parallel with and perpendicular to the flow of traffic on the bridge are called the longitudinal and transverse direction respectively.

## 3.3 EFFECT OF SKEW ANGLE ON BRIDGE

With the increase in the skew angle, the stresses in the skew slab differ significantly from those in the straight slab. A load applied on the slab travels to the supports in proportion to the rigidity of the various possible paths, hence a major part of the load tends to reach the supports in a direction normal to the faces to the abutments and piers. As a result, the planes of maximum stresses are not parallel to the center line of the road way and slab tends to be warped. The reactions at the obtuse angled end of the slab support are larger than the other end, the increase in value or average value ranging from 0 to 50 percent for skew angle of 20 to 50 degrees. The bearing reactions tend to change to uplift in the acute angle corners with increase in the skew angle.

For skew angle greater than 15 degree, a more rigorous analysis is desirable, but it is complicated. Analytical and experimental methods have been attempted. Based on extensive tests on skew slab models made of gypsum plaster, Rusch and Hergenroder have presented influence surfaces for bending moments and torsional moments at critical points of skew slabs under a concentrated load placed anywhere on the slabs for various span/width ratios and angles of skew. The Ministry of Surface Transport has prepared a standard designs for skew slabs of clear spans of 5,6 and 8 m and angles of skew of 15 degree, 30 degree, 45 degree, and 60 degree, on the basis of above data applied to IRC loadings suitable for two-lane traffic without footpaths on National Highways.

## 3.4 BEHAVIOUR OF SKEW BRIDGES

The behaviors of skew bridges differ widely from that of normal bridges and therefore, the design of skew bridges needs special attention. In normal bridges, the deck slab is perpendicular to the supports and as such the load placed on the deck slab is transferred to the supports which are placed normal to the slab. Load transference from a skew slab bridge, on the other hand, is a complicated problem because there remains always a doubt as to the direction to which the slab will span and the manner in which the load will be transferred to the support.

It is believed that the load travels to the support in proportion to the rigidity of the various paths and since the thickness of the slab is the same everywhere, the rigidity will be maximum along shortest span. i.e. along the spans normal to the faces of the piers or abutments. In Fig 3.2. Though the span of the deck is the length BC or DE, the slab will span along AB or CD being the shortest distance between the supports. Therefore, the planes of maximum stresses in a skew slab are not parallel to the centre line of roadway and the deflection of such slab produces a warped surfaces.

The effect of skew in deck slabs having skew angles up to 20 degrees is not so significant and in designing such bridges, the length parallel to the centre line of the roadway taken as the span. The thickness of the slab and the reinforcement are calculated with this span lengths and the reinforcement are placed parallel to the centre line of the roadway. The distributions are, however, placed parallel to the supports as usual.

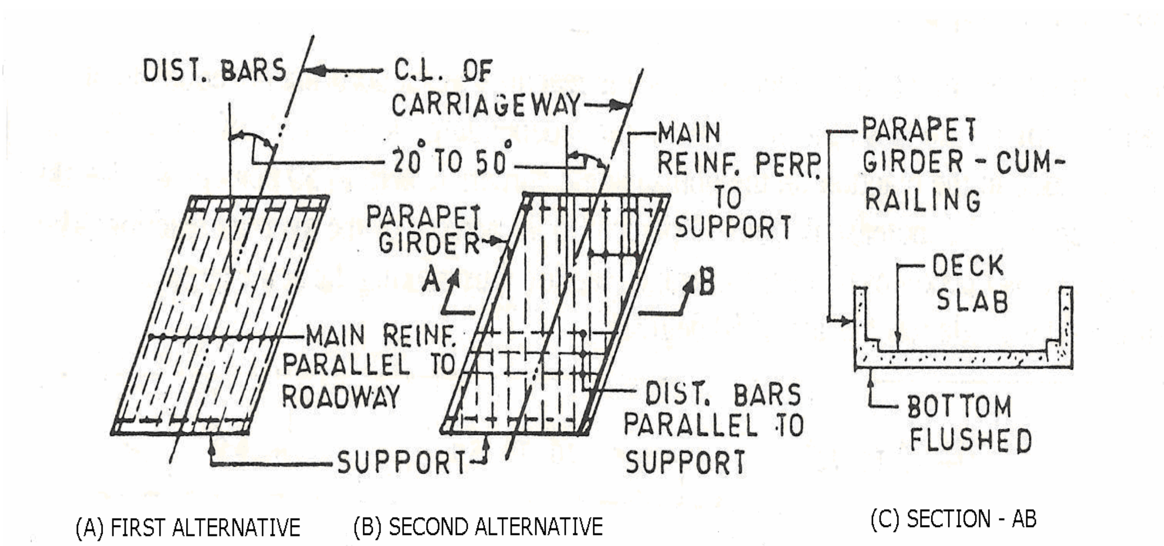



Fig 3.2 Arrangement of Reinforcement in Slab with Skew Angle from 0 to 50 Degrees

When the skew angle varies from 20 degrees to 50 degrees, the skew effect becomes significant and the slab tends to the supports. In such a cases, the slab thickness is determined with shortest span but the reinforcement worked out on the basis of shortest span are multiplied by $\sec^2 \theta$ ($\theta$ being the skew angle) and are placed parallel to the roadway as shown in Fig.3.1 the distribution bars being placed parallel to the supports as usual.

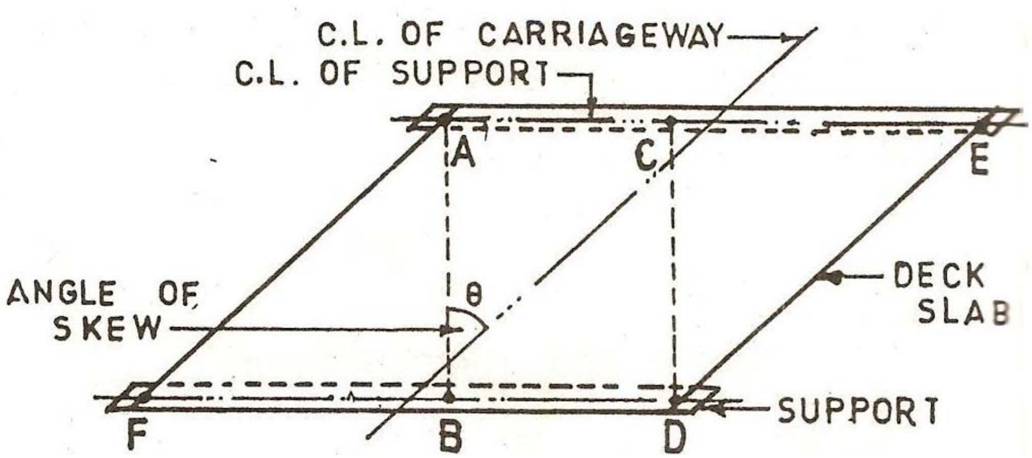



Fig 3.3 Plan of Skew Deck Slab

It is also common practice to place the reinforcement perpendicular to the support when the skew angle lies between 20 degrees to 50 degrees. The thickness and the reinforcement are determined with span normal to the support but since in placing the reinforcement perpendicular to the supports, the corner reinforcement within the area ABF to CDE in Fig.3.3 do not get any support on one side to rest on, the slab below the footpath (for bridges with footpath) or below the kerb (for bridges without footpath) shall be provided extra reinforcement to act as concealed beam. Alternatively, parapet girders as shown in Fig 3.2 may also be provided along the edge of the slab. Such parapet girders are made flush with the bottom of the slab and extended above the slab to the required height to form the solid parapet. This sort of deck of deck requires less quantity of steel in slabs but parapet girders need additional cost.

## 3.5 EFFECT OF HEAVY SKEW

For bridges of skew angles more than 50 degrees, girders should be used even though the spans are comparatively less. Where the width of the bridge is not much, the girders may be placed parallel to the roadway and the slab thickness and the reinforcement may be designed with the spacing of the girders as the span. The reinforcement is placed normal to the girders. In wider multilane skew crossings with large skew angles, however, it is preferable to use the girders at right angles to the supports. In these cases, again the triangular portions need parapet girders to support one end of the girders.

For larger degrees of skew the primary factor is the span to breadth ratio; for large span/breadth ratio, the moment trajectories and principal moments at mid span are effectively parallel to and perpendicular to the free edges and hence a distribution analysis based upon the skew span and right width is sufficiently accurate for design purposes. For all small span/breadth ration, the bridge will tend to span in a direction perpendicular to the abutments and hence at the centre of bridge the principal moments will be approximately parallel to and perpendicular to the abutments. In these cases distribution analysis of a type considered previously cannot yield the distribution of moments with a sufficient degree of accuracy.

No rigorous analytical procedure has been derived either a skew isotropic plate or a skew orthotropic plate; therefore alternative methods of analysis must be used if an elastic solution is required. We will consider here the application of finite differences to the solution of the governing differential equation and show how in certain cases, the distribution of moments may be derived.

## 3.6 REACTION AT SUPPORT

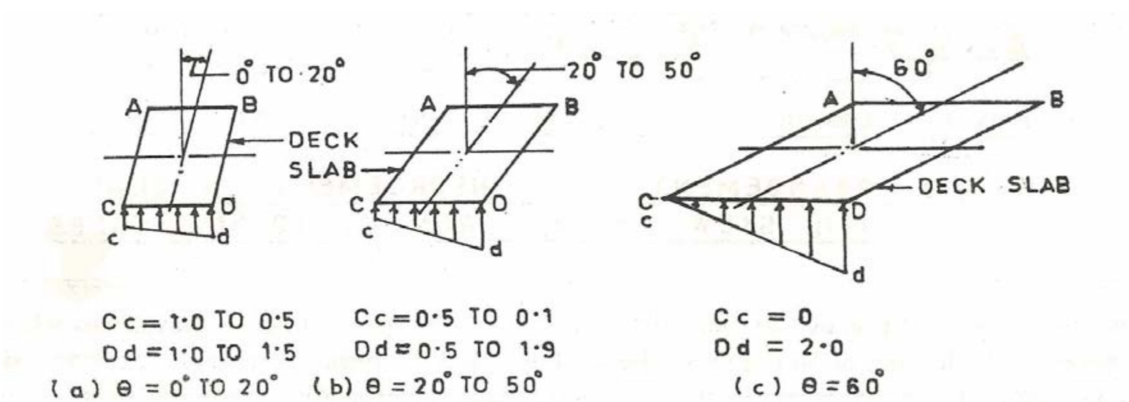



Fig 3.4 Variation Of Reaction On Supports For Slabs Having Various Angles Of Skew

Fig 3.3 shows reaction at supports for the skew slab. It was observed that due to the effect of skew, the reactions at supports are not equal but the same is more at obtuse angle corners and less at acute angle corners depending on the angle of skew. For skews up to 20 degrees, the increase in the reaction on the obtuse angle corners is zero to 50 percent and for skews from 20 degree to 50 degrees, the increase is form 50 percent to 90 percent of the average reaction. The reaction on the obtuse angle corner becomes twice the average reaction thus making the acute angle corner a zero pressure point when the skew angle reaches about 60 degrees.

### 3.6.1 Arrangement of reinforcement in skew slab

Reinforcement details for skew slab are shown in Fig 3.4 and Fig 3.5

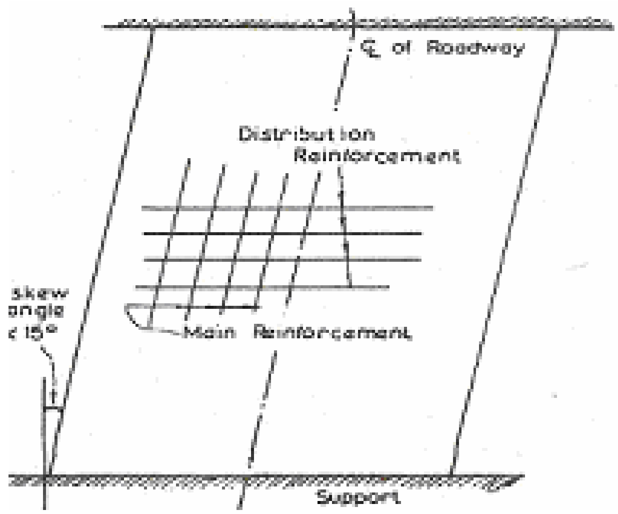



Fig 3.5 Reinforcement Layouts In Slabs (Small Skew Angles)

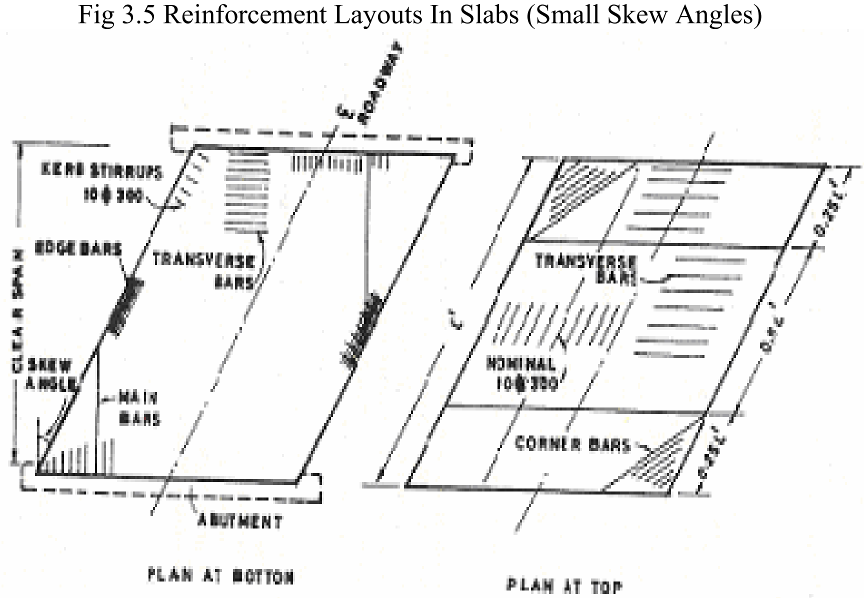



Fig 3.6 Layout Of Reinforcement In Skew Slab

Typical reinforcement details are suitable for skew slab culverts carrying two lane traffic of IRC loadings are shown in Fig 3.4 and Fig 3.5. The main reinforcements are placed perpendicular and parallel to the supports at the bottom of slab. Nominal reinforcements are provided at the top of the slab in a directional parallel to the centre line of road.

## 3.7 BOX BRIDGES

A box bridge (culvert) is a cross drainage work whose length (total length between the inner faces of wall) is less than 6m. In any highway or railway project, the majority of cross drainage works fall under this category. Hence, culverts collectively are important in any project, though the cost of individual structures may be relatively small. Culverts are classified according to function as highway or railway culvert. The loading and structural details of the superstructure would be different for these two classes. Based on the construction of the structure, they can be of the following types.

- Reinforced concrete slab culvert
- Pipe culvert
- Box culvert
- Stone arch culvert
- Steel girder culvert for railways

As stipulated in clause 112.1 of IRC-5 2000, for culverts and minor bridges of total length less than 60m, the width between the outermost faces of the bridge should be the full formation width of the approaches, subject a minimum of 12 m for roads other than hill roads and other district roads. Though these stipulations are intended to be applicable mainly to National Highways, it may be adopted for State highways if sufficient funds are available.

### 3.7.1 Box Culvert

If the discharge in a drain or channel crossing a road is small, and if the bearing capacity of the soil is low, then a box culvert is an ideal bridge structure. A box culvert is consisting of an RCC box of square or rectangular opening with span or generally restricted to 4 m. The top of the box is road level or it may be at a depth below the road level if the road is an embankment. If the design discharge is considerable, a single box culvert becomes uneconomical because of the higher thickness of the slab and walls. In such cases, more than one box is cast side by side monolithically.

Box culvert is economical for the reasons mentioned below:

- The box is a rigid frame structure and both the horizontal and vertical members are made of a solid slab, which is very simple in construction.
- In case of high embankments and ordinary culvert will require very heavy abutments that will not only be expansive but also transfer heavy loads to the foundations.
- The box type of structure is suitable for non-perennial streams where scour depth is not significant but subgrade soil is weak.
- The dead load and superimposed load are distributed almost uniformly over a wider area as the bottom slab serves as a raft foundation, thus reducing pressure on soil.

### 3.7.2 General Aspects

Box culvert consisting of two horizontal and two vertical slabs built monolithically are ideally suited for a road or a railway bridge crossing with high embankments crossing a stream with a limited flow. Reinforced concrete rigid frame box culverts with square or rectangular openings are used up to spans of 4 m.

Box culverts are economical due to their rigidity and monolithic action and separate foundations are not required since the bottom slab resting directly on the soil, serve as raft slab. For small bridges, single celled box culvert is used and for large discharges, multicelled box culverts can be employed. The barrel of the box culvert should be sufficient length to accommodate the carriage way and the kerbs.

### 3.7.3 Design Aspects

The design of single box culvert is done by treating the culvert as a rigid frame. The moment distribution method is generally adopted for determination of final moments at joints of the frame. The culvert is analyzed for critical load combinations.

### 3.7.3.1 Components

Reinforced concrete rigid frame box culverts are used for square or rectangular openings with spans up to about 4 m. The top of the box section can be at the road level or can be at a depth below road level with a full depending on the site conditions. The box culvert is consisting of following components:

- Barrel of box section of sufficient length to accommodate the carriageway and the kerbs.

- Wing walls splayed at 45 degree to retain embankments and also to guide the flow of water into and out of the barrel.

### 3.7.3.2 Loading Cases

The loading conditions to be considered in the design of the barrel (per unit length of the barrel) may be classified in to the following categories:

- Concentrated vertical loads due to wheel loads

This is computed from equation:

$$W = PI / b_e$$

where P = Wheel load

I= Impact factor

$b_e$ = effective width of dispersion

The reaction at the foundation is assumed to be uniform.

All different loading cases which is acting on box will be shown in Fig 3.6

- Uniform vertical load

The track load and the weight of wearing coat and deck slab occur as uniform load. The loading case may also be used for consideration of uplift on the bottom slab.

- Weight of walls (also for the case of uplift)

The weights of two side walls are assumed to cause uniform reaction at foundations. This loading case may also be used for consideration of uplift on the bottom slab.

- Pressure from contained water

The barrel is assumed to be full with water at the top of the opening. A triangular distribution of pressure is assumed.

➢ Traingular lateral load

The earth pressure computed according to Coloumb's theory is applied to both sides. The earth pressure is applied alone when the live load surcharge is neglected or in combination of case 6, when considering live load surcharge also.

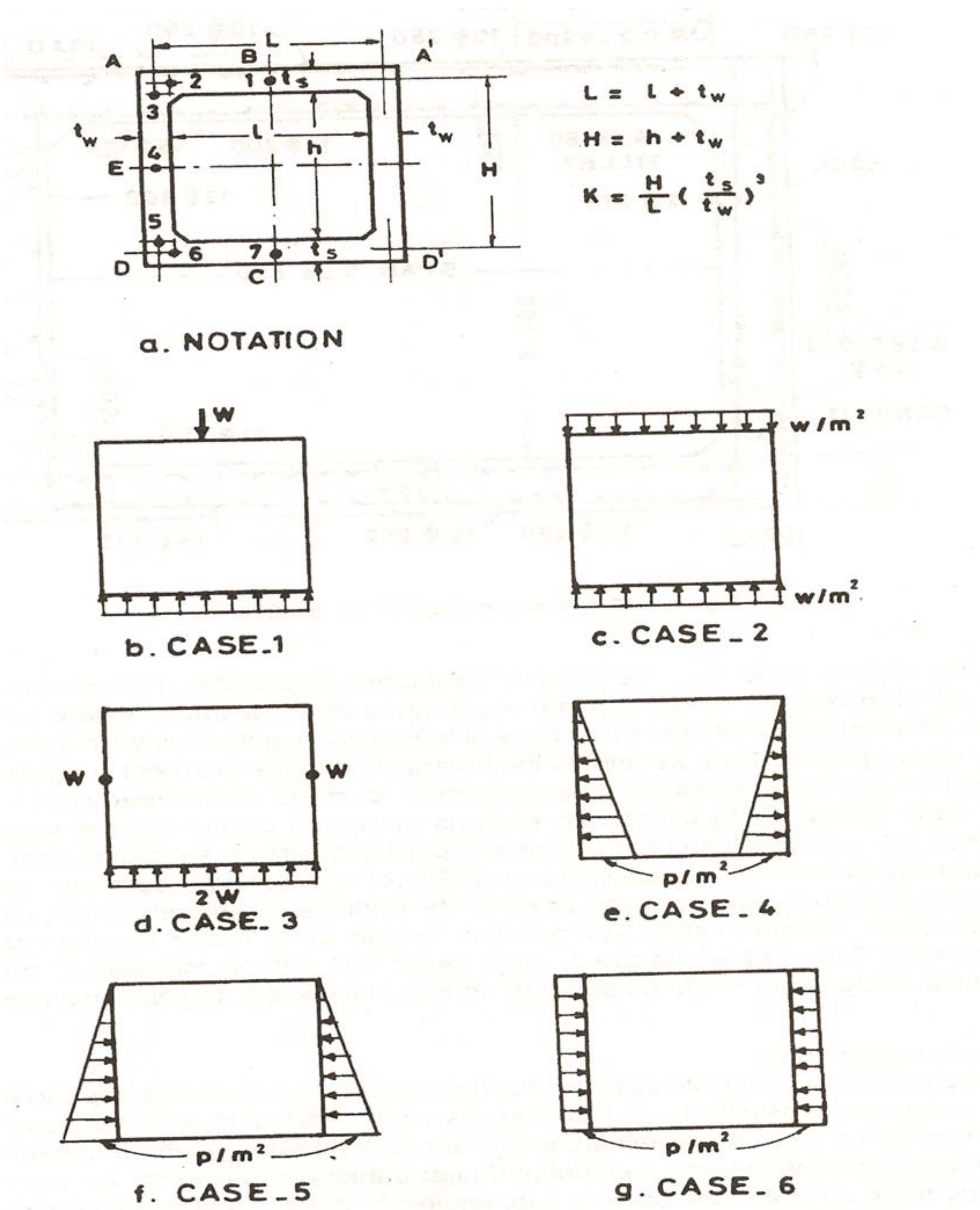



Fig 3.7 Loading Cases For Box Culverts

Case 1 : Concentrated loads

Case 2 : Uniform distributed load

Case 3 : Weight of side walls

Case 4 : Water pressure inside culvert

Case 5 :Earth pressure on vertial side walls

Case 6 : Uniform lateral load on side walls

- Unifrom lateral load

The effect of live load surcharge when acting alone will be a uniform lateral load. This loading is considered uniform on both sides. When combined with case 5, the effect of trapezoidal loading will be obtained.

The loading cases are shown schematically in Fig.3.6.

### 3.7.4 Hydraulic Design

The design of vent way would depend on the discharge to be catered for. Except in the case of buried barrel, the maximum flood level will be below the bottom of top slab allowing a vertical clearance. In this case, the designs of vent way similar to that for a culvert with R.C. slab deck. The design of the vent way for a buried barrel will be similar to that for a pipe culvert. Usually, the ratio of span to height of opening lies between 1:1 to 1.5:1. The top of bottom slab will be at bed level.

### 3.7.5 Structural Design

3.7.5.1 Design moments, shears and thrusts

The box culvert is analyzed for moments, shears and axial thrusts developed due to various loading conditions by any of the classical methods such as moment distribution, slope-deflection or column analogy procedures. Alternatively, coefficients for moments, shears and thrusts compiled by D.J. Victor are useful in the computation of the various force components for the different loading conditions.

3.7.5.2 Design of Critical Sections

The fixed end moments developed for the six different loading cases. The maximum design moments resulting from the combination of different loading cases are determined. The moments at centre of span of top and bottom slabs and the support sections and at the centre of the vertical walls are determined by suitably combining the different loading patterns. The maximum moment generally developed for the following load conditions

1. When the top slab supports the dead and live load and the culvert is empty.
2. When the top slab supports dead and live loads and the culvert is running full.
3. When the sides of the supports do not carry the live load and culvert is running full.

The slabs of the box culvert is reinforced on both faces with fillets at the inside corners. It becomes very tedious to use the same procedure for designing a multiple box culvert. For designing multiple box culverts, the interpolation formula may be used as this is also accepted by Ministry of Shipping and Trasnport (Road Wing). In this method, the design moments for any box culvert with a span range of 3 – 9 m can be evaluated with reference to some known values of loads and moments for box culverts of standard or known dimensions.

## 3.8 ANALYSIS OF DECK SLAB

- Effective width method (for one way slabs)

### 3.8.1 Effective Width Method (Slabs Spanning In One Direction)

As mentioned earlier, this method is applicable where one way action prevails. For this, the slab needs to be supported on only two edges, however, a very long slab may be supported on all four edges. This method is based on the observation that, it is not only the strip of the slab immediately below the load that participates in taking the load *but* also a certain width of the slab. This width of the slab over which the action of the load prevails is known as the effective width of dispersion. The extent of the effective width depends on the location of the wheel load with reference to support and dimensions of the slab. Thus, the concentrated load virtually transforms into a uniformly distributed load-distributed along some length (dispersed length along the span) and width (effective width). This is shown in Figure. IRC 21 recommends formulae for computing the effective width for two types of slabs,

[1] Simply supported slabs (supported on opposite edges)

[2] Cantilever slabs

➢ **Slab Supported on Two Edges (Simply Supported Slabs)**

(A) Dispersion of load perpendicular to span (Solid span spanning in one direction):

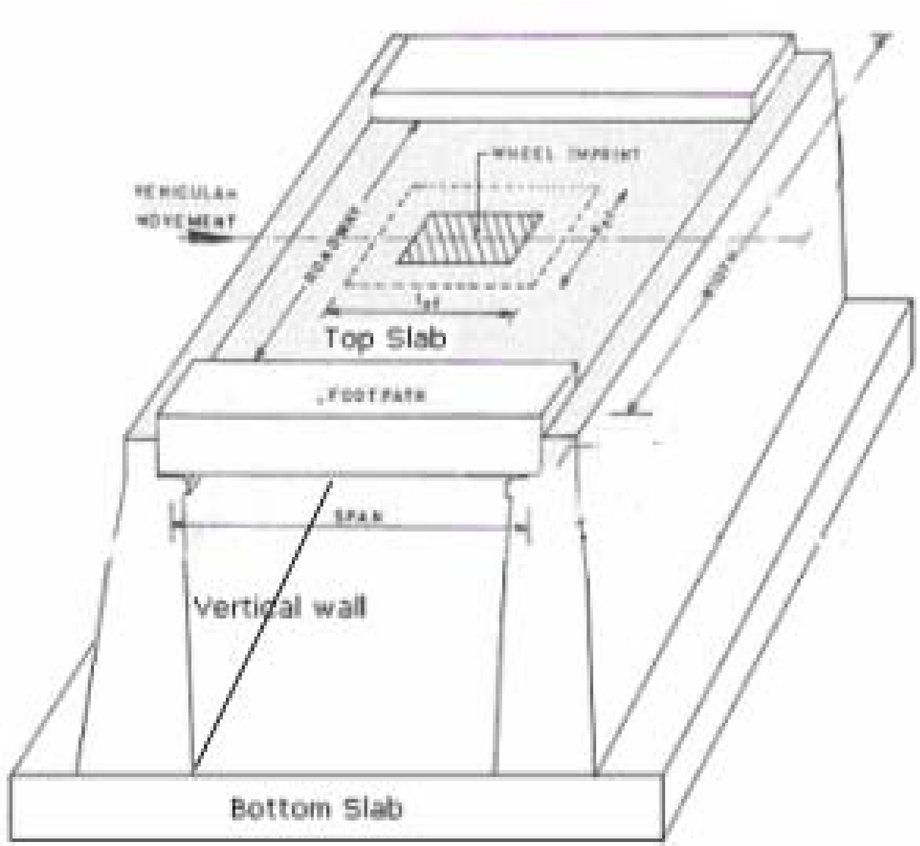



Fig 3.8 Load Dispersion on Slab

For the slab supported on two edges and carrying concentrated loads, the maximum live load bending moment is calculated by considering the effective width of the slab. This effective width also called the effective width of dispersion is measured parallel to the supporting edges of the slab (Fig. 7.2). The effective width of dispersion can be estimated by using the following formula:

$b_{eff} = \alpha x\left(1-\frac{x}{l}\right)+b_1$

Where

$b_{eff}$ = width of the slab over which the load is effective

l = effective span of the simply supported slab (clear span in case of continuous slabs)

x = distance of the centre of gravity of the concentrated load from the nearest support

α = a constant having values depending on B/L values

$b_1$ = width of the dispersion

For two or more concentrated loads in a line in the direction of the span, the bending moment per meter width shall be calculated separately for each load according to its approximate effective width.

For two or more loads across the span, if the effective width of the slab for one load overlaps the effective width of the slab for an adjacent load, the resultant effective width of slab for the two loads shall be taken as equal to the sum of the respective effective width for each load.

(B) Dispersion of load along span: The effective length of slab on which a wheel load or track load acts shall be taken as equal to the dimensions of the tyre contact area over the wearing coarse of the slab in the direction of the span plus twice the overall depth of the slab inclusive of the thickness of the wearing coat.

# 4. LOADING CALCULATION FOR BOX CULVERT

## 4.1 GENERAL

Bridge Deck provides the surface on which traffic passes. The deck slab and vertical walls are providing supporting member of bridge deck system.

## 4.2 PROBLEM STATEMENT

For the sample calculation of analysis deck slab is considered in spanning in one direction. For sample calculation only single barrel box culvert is considered. For both right bridges as well as skew type of bridges analysis and design is carried out.

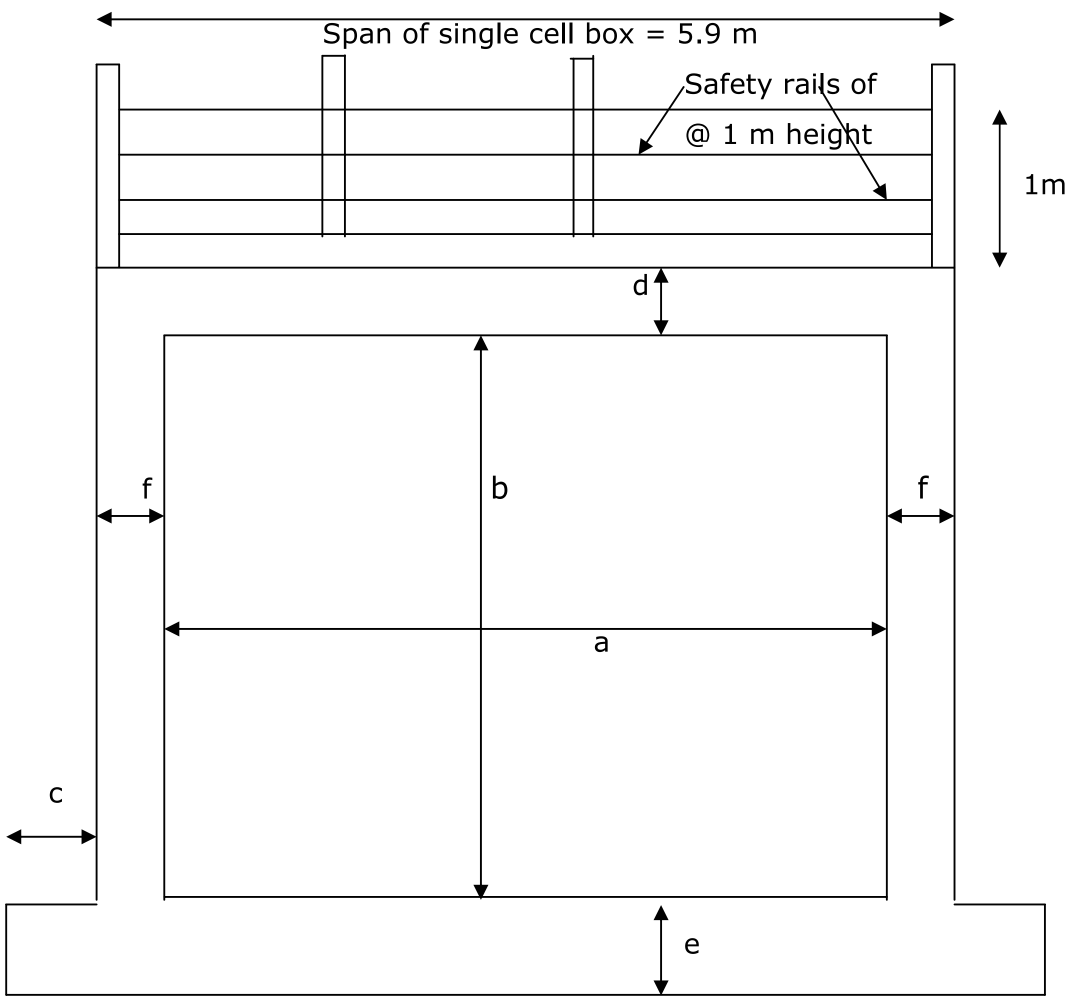



Fig 4.1 Dimension of box culvert of single cell and its elevation

- **Problem : Slab Spanning in one direction**

  Data:
  - Span = 5 m
  - Width of carriage way = 7.5 m
  - Foot path = 250 x 1250 mm
  - Height of box, a = 5000 mm
  - Width of box, b = 5000 mm
  - Top Slab thickness top, d = 500 mm
  - Bottom Slab thickness, e = 700 mm
  - Projection of bottom slab on each side, c = 500 mm
  - Thickness of wall, f = 450 mm
  - Wearing coat = 80 mm

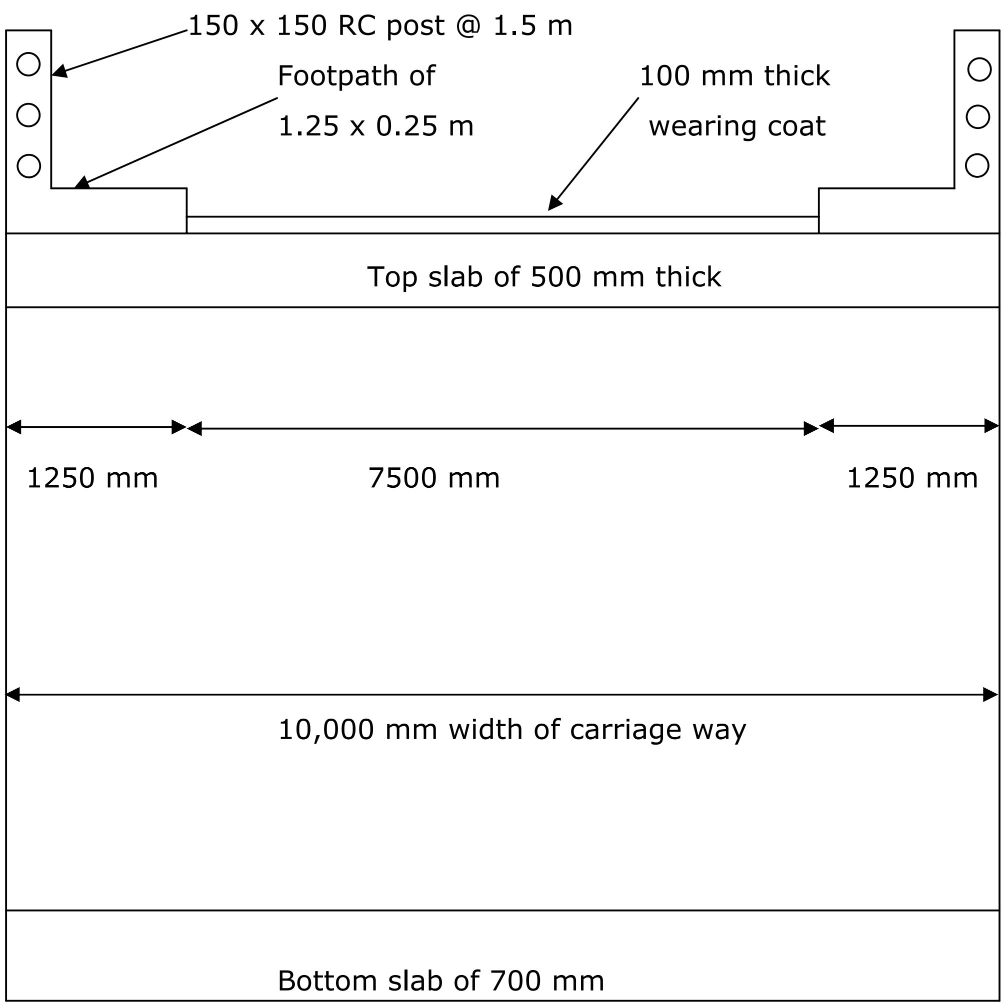



Fig 4.2 Cross section of bridge deck for single cell box culvert

## 4.3 LOADING CALCULATIONS

### 4.3.1. Dead Load

For the calculation of self weight of bridge density of concrete is considered as 24 kN / $m^{3}$.

### 4.3.2 Super Imposed Dead Load(SIDL)

In the SIDL load of railing, wearing coat and crash barrier is considered on top of the slab and load of soil of 0.3 m depth is considered on bottom slab.

Weight of wearing coat = 0.150 x 2.2 = 0.33t/m say 0.25 t/m
= 2.5 kN/m

Weight of crash barrier = 0.40 x 2.4 = 0.96 t/m say 1 t/m
= 10 kN/m

Weight of footpath = 0.38 x 2.4 = 0.9 t/m say 1t/m
= 10 kN/m

Footpath live load = 1 x 0.5 = 0.5 t/m
= 5 kN/m

(Clause 209.4, IRC:6 – 2000)

Weight of soil on bottom slab = 0.3x1.8 = 0.54 t/m=5.4kN/m, When soil is dry

Weight of soil on bottom slab=0.3x1 = 0.3 t/m = 3kN/m,When soil is submerged

### 4.3.3 Live Load :

The bridge is designed for the 70R tracked load and 70 R wheeled loading as per IRC: 6 -2000, and impact factor is considered is also calculated for the different types of loadings.

**Live Load calculation for class 70 R vehicle:**

Impact factors for bridges for reinforced concrete bridges = 0.25 x 1

(Clause 211.3 (A)(1) and clause 211.66, IRC 6 -2000)

Dispersion of live load by effective width method:

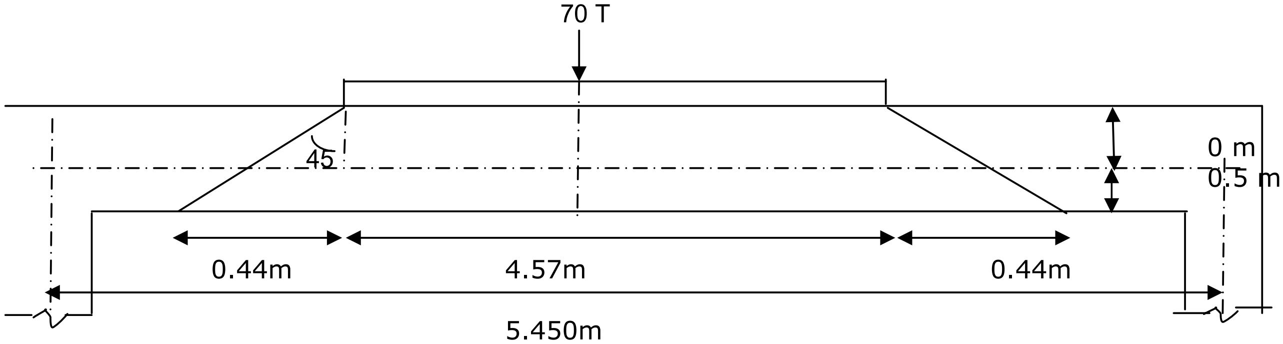



Fig 4.3 Dispersion of Live load along longitudinal direction
( Clause 305.16.3, IRC: 21 -2000)

**Calculation of effective width**

(i) LL starting from edge of box, i.e. cg of live load 2.73 m from outer wall

$a$ = 2.73 m

$l_o$ = 5.45 m

$b$ = 7.50 m

$b / l_o$ = 1.38

$\alpha$ = 2.4609

$b_1$ = 0.84 + (2 x0.100)= 1.04 m

$b_{ef}$ = α x a (1-a / lo)+ $b_1$ =2.46 x 2.73 x (1-2.73/5.45)+1.04
= 4.39 m

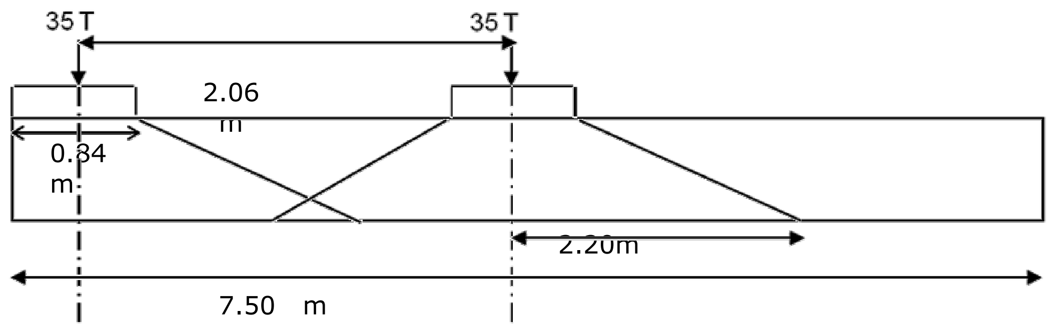



Fig 4.4 Dispersion of Live load along transerve direction
( Clause 305.16.2, IRC: 21 -2000)

Along transerve direction u = 0.42 + 2.20 + 4.39 - 2.06 =4.95 m

Here, Width of box = 7.5 m > 4.95 m

Hence take u = 4.95 m

Live load intensity = (70 x 1.25) / (5.45 x 4.95) = 3.24 t / m$^2$
= 32.4 kN / m$^2$

Live load intensity per m width = 3.24 x 1 = 3.24 t/m = 32.4 kN/m

### 4.3.4 Breaking Force

Breaking force is considered for 20% of the total live load in horizontal direction.

= 87.50 x 0.2 / 7.50 = 2.33 t

### 4.3.5 Soil pressure from side wall (When soil is dry)

When soil is dry, the soil pressure on side wall is calculated as follows:

Assuming $\Phi$ = 30
Ka = = $(1-\sin\Phi)/(1+\sin\Phi)$ =0.333

Lateral pressure at top due to

( i ) Live load surcharge of 1.2 m and ( ii ) Earth Cushion of 0.00 m height

= ( 0.333 x 1.8 x 1.2)+( 0.333 x 1.8 x 0.0 ) = 0.72 $t/m^2$ =7.2 $kN/m^2$

Lateral pressure at bottom due to soil
( i ) Live load surcharge of 1.2 m ( ii ) Earth Cushion of 0.00 m height
and ( iii ) Back fill of soil

= ( 0.333 x 1.8 x 1.2)+ (0.333 x 1.8 x ( 0.00+0.50+5.00 ) ) = 4.02 $t/m^2$

= 40.2 $kN/m^2$

### 4.3.6 Soil pressure from side wall (When soil is submerged)

Lateral pressure at top due to soil = $K_a\ \gamma'\ h + \gamma_w\ h$

Assuming submerged unit weight of soil $\gamma'$ = 1.2 $t/m^3$ =12 $kN/m^3$
Unit weight of water
$\gamma_w$ = 1 $t/m^3$ = 10 $kN/m^3$

Assuming $\Phi$ = 30

Ka = $(1-\sin\Phi)/(1+\sin\Phi)$ = 0.333

Lateral pressure at top due to
( i ) Live load surcharge of 1.2 m and ( ii ) Earth Cushion of 0 m Height

= ( 0.333 x 1.8 x 1.2 ) + ( 0.333 x 1.2 x 0.0 ) + ( 1 x 0 ) = 0.72 $t/m^2$

Lateral pressure at bottom due to
( i ) Live load surcharge of 1.2 m ( ii ) Earth Cushion of 0 m Height

And ( iii ) Back fill of soil

= ( 0.333 x 1.8 x 1.20 ) + ( 0.333 x 1.2 x ( 0.0+0.50+5.00 ) ) + ( 1 x ( 0.0+0.5+5))

= 8.42 $t/m^2$ = 84.2 $kN/m^3$

#### 4.3.7 Seismic force calculations ( From Modified Clause 222 of IRC 6 : 2000)

| | | |
|---|---|---|
| Zone factor Z | = | 0.36 |
| Importance factor I | = | 1.50 |
| Sa / g | = | 2.50 |
| Response reduction factor R | = | 2.50 |

Horizontal seismic coefficient $Ah_{Longitudinal}$ $= \dfrac{[Z/2]\ [Sa/g]}{[R/I]} = 0.270$

Horizontal seismic coefficient $Ah_{Transverse}$ = 0.270

Vertical seismic coefficient Av = Ah / 2 = 0.135

## 4.4 BOTTOM SLAB

### 4.4.1 General

The design of foundation is an important part of the overall design for a bridge and affects to a considerable extent the aesthetics, the safety, and the economy of the bridge. The purpose of any foundation is to transfer the load from the superstructure to the earth in a such a manner that the stresses on the soil are not excessive and the resulting deformations are within permissible limits. The design demands a detailed knowledge of hydraulics, soil mechanics and structural analysis.

Foundation engineering is as much an art as a science. The engineer will have to gather data on soil profile at the site and on the waterway characteristics. Since the soil at any place is not on of one uniform type, the design of a suitable foundation would involve exercise of considerable judgment. In order to design the foundation for a bridge, the designer must determine the following reasonably and accurately:

1. The maximum likely scour depth,
2. The minimum grip length required,

3. The soil pressure at the base,
4. The stresses in the structure constituting the foundation

The foundation should be taken to a depth which is safe from scour, and is adequate from considerations of bearing capacity, settlement stability and suitability of strata at the founding level.

### 4.4.2 Importance of bridge foundation :

The function of bridge foundation is to distribute the loads coming from the superstructure through the piers or abutments over the foundation materials so that these are able to take the loads without failure either due to excessive shear or excessive settlement of foundations materials. In the former case, the soil or rock layer over which the foundation rests is sheared off from the surrounding medium and the structure fails as a whole due to shear failure. On the other hand excessive settlement of the soil induces undue stresses in the structure itself supported over the foundation and though the structure does not show any sign of total failure due to failure of the medium, the undue stresses caused by the settlement produces cracks in the structure and the structure therby is damaged. The former is known as bearing capacity failure and latter one is known as settlement failure.

The factor of safety against a bearing capacity failure is normally kept as 3 over the ultimate bearing capacity but if the foundations are designed for the extreme loading conditions, a factor of safety considered as 2 may sometimes be allowed.

The slight settlement is allowed in many structures but this allowable settlement depends on the type of structures. In freely supported or balanced cantilever type superstructures, allowable settlement may be more than that in continuous or rigid frame or arch bridges. Uniform settlement is not harmful but if it occurs simultaneously throughout the structure. Differential settlement, even if lesser in magnitude, produces more serious effects than the uniform settlement does.

### 4.4.3 Types of Foundations:

The foundations used in bridge structure may be broadly classified as:

1. Shallow foundations and
2. Deep foundations

The selection of foundation system for a particular site depends upon many considerations, including the nature of subsoil, the presence or otherwise in the subsoil of boulders, buried tree trunks, etc. and the availability expertise and equipment with the contractors operating in the regions where the bridge work is located. Generally, piles would be suitable when a thick stratum of soft soil overlays a hard soil.

### 4.4.4 Shallow Foundations:

Shallow foundations cab be laid using open excavation by allowing natural slopes on all sides. This is normally convenient above the water table and is a practicable up to a depth of about 5 m. For larger depths and for work under water, it would be necessary to use shoring with sheet piles or to resort to the provision of cofferdams. The purpose of shoring and cofferdams permits excavation with minimum extra width over the foundation width and to facilitate working no the foundation in the dry, using suitable water pumping arrangements. In case of shoring, sheathing with timber planks supported by wales and struts is provided as the excavation proceeds. The size of the excavation at the bottom should be sufficiently large to permit adequate space for fixing form work around the footing and leave the working space of about 300 mm all around. The limiting depth of cofferdams is normally about 10 m. When excavation reaches a foundation level, the exposed area of the bottom of the pit is leveled and compacted by ramming. In case of pumping of water is necessary, a sump is provided to drain the water. A leveling course of about 150 mm thickness with lean concrete (1:3:6 or 1:4:8 by volume) is laid. The plan of the pier is marked on the top of the leveling course and construction is commenced.

A shallow foundations is usually consists of spread footings in concrete or coursed rubble masonry. The bottom most footing over the leveling course is of plain concrete 1:3:6 mix or og reinforced concrete of suitable thickness. The depth of foundation should be such that the foundation rests on soil with adequate bearing capacity. The maximum pressure on the foundation should be checked to ensure adequate factors of safety for different combinations of loads as specified in the IRC code.

A shallow foundation sometimes defined as one whose depth is smaller than its width. Normally a shallow foundation is taken as one which cab be prepared by open excavation, and deep foundation would be referred as on one which cannot be prepared by open excavation. Footings and rafts are examples of the shallow foundations. Shallow foundations transfer the load to ground by bearing at the bottom of the foundations. In case of deep foundations, the load transfer is partly by point bearing at the bottom of foundation and partly by skin friction with the soil around the foundation along its embedment in the soil.

### 4.4.5 Bottom slab resting on elastic foundation

When the soil bearing pressure is low say 25 kN /$m^2$ or less and if the deformation of the mat surface can be tolerated, the mat may be designed as an inverted flat slab, using heavy beams from column to column.

When footings are designed as flexible members, the computation takes some form of the solution of beam on an elastic foundation. The experience has indicated that the solution obtained is generally reliable when the data are satisfactory. Possibly the reasons, as to why the methods have not been widely used in the past, are ease if making conventional solution, which have been generally satisfactory and usually not much different from elastic solution, Second reason is that the soil data are generally obtained using the standard penetration test for which no straight forward conversion to a value of modulus of sub grade reaction exists.

The modulus of subgrade reaction is a conceptual relationship between soil pressure and deflection that is widely used in the structural analysis of foundation members. It is used for continuous footings and mats, the basic equation is using plate-load test data is

$$K_s = \Delta q/\Delta\delta$$

Where, $k_s$= the modulus of subgrade reaction (subgrade reaction or subgrade reaction)

$\Delta q$ = Load applied on soil and $\Delta\delta$ = Settlement caused by applied load.

Joseph Bowl had suggested that value of modulus of subgrade reaction with safe bearing capacity by the relation

$$K_s = 40 \times \text{Factor of safety} \times q_a \quad (\text{Units in kN/m}^3)$$

Where $q_a$ is in kN/m$^2$ and equation is based on that the ultimate pressure is at differential settlement. These can be established in this way.

These data can be obtained from a plate or footing load test data and a plot drawn by q versus δ curve. This plot is generally a not linear, and one must be obtained ks as the slope of the either tangent or secant line. Usually, initial values are used i.e. through the origin; however, one can choose any tangent point or an averaged value using the two points cut by a secant line along the curve. The secant slope defined by the origin (δ=0) and at δ=0.0254m (25mm or 1 inch) which giving Δδ = 0.0254m is recommended as initial selection. If considering 3 as a factor of safety than

$k_s = q_{ult} / \Delta\delta$

$= FS \times (q_{ult} / \Delta\delta) / \Delta\delta$

$= FS \times (q_a / \Delta\delta)$

$= FS \times (q_a / 0.0254)$

$= 40 \times FS \times q_a$

$= 40 \times 3 \times q_a$

$= 120 \times q_a$

For allowable bearing capacity 25 T/ m$^2$ = 250 kN/m$^2$

Ks = 120 x 250 = 30000 kN/m$^3$

Rigidity of base slab is selected in the preliminary design has tremendous effect on the stresses actually developing in the raft slab. Soil pressure distribution under the raft is neither uniform non linearly varying. This depends upon the relative rigidity of foundation and soil. For a known value of soil rigidity, there is a value of raft rigidity which would make the soil pressure more or less uniform. There are however no exact methods available to determine the rigidity of soil or soil pile system. Rigidity of raft can also not be determined exactly as it is affected by super-structure from the top and the soil below.

Modulus of subgrade reaction, which is measure of soil rigidity, is a function of the nature and properties of the soil below and behavior of structure above. There are methods available starting from empirical approximate ones on one hand to those taking into account the soil nature and soil properties below. All these methods make number of assumptions. Even the latest methods assume horizontal layers of soil having uniform soil properties in given area below the raft. This situation does not exist. It is quite common experience that the soil layers are rarely horizontal, and the properties of soil determined by bore holes varies to large extent from one bore hole to one another. For the soil properties empirical methods given in the literature gives different values so much so that value determined by one method is 6 to 7 times that determined by another method. Accurate determination of value of modulus of subgrade reaction is, therefore, not possible. Variation in the bending moments for same value of rigidity of raft with varying values of modulus of subgrade reaction is also considerable.

A designer can adopt any of thickness and value of subgrade reaction with in the ranges considered in these studies. The extent of variations that cab be expected on the values of the bending moments would be much high. Variation in stresses due to change in rigidity or soil modulus is smaller for the rafts which are symmetrical in plan and more uniform loaded. These shows that raft of a given thickness may behave as a rigid with poor soils and flexible with hard soils or rocks.

# 5. PROBLEM DFORMULATION THROUGH EXCEL SHEET

## 5.1 GENERAL

In the present chapter, all the loading calculation which is considering in the box type skew culvert is presented. The detailed plan and section is given in chapter 4.

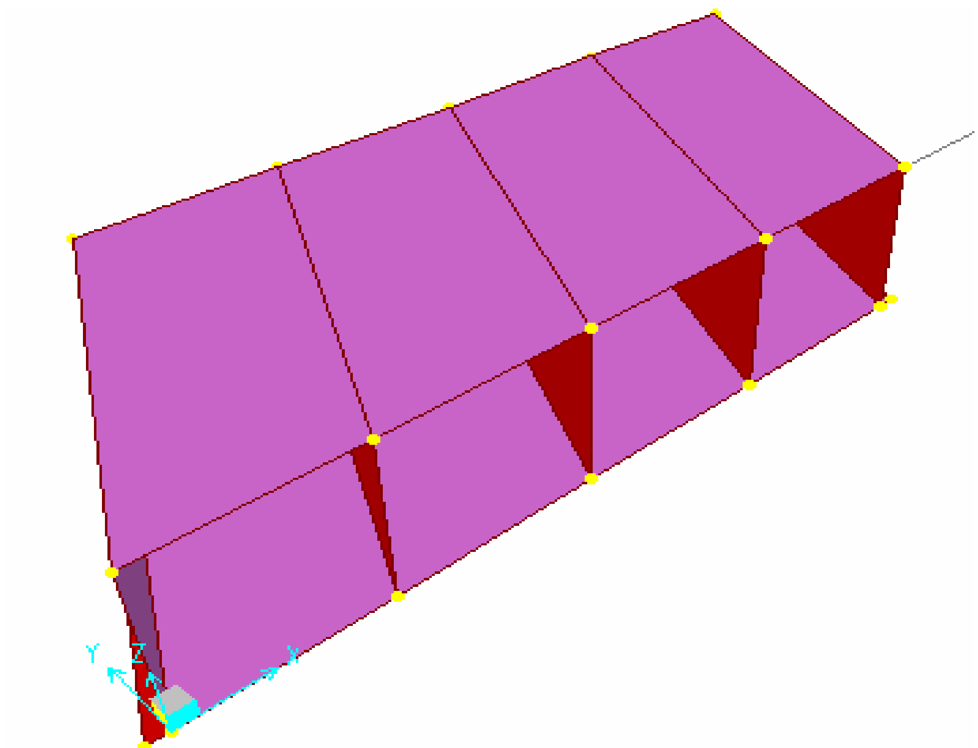



Fig 5.1 Box type multibarrel (four cell) skew culvert

Fig 4.2 shows box type multibarrel of four cell skew culvert. It consisting of three different main components. First is top skew slab which is resting on five vertical walls. The second components of vertical walls which is resting on bottom slab. Bottom slab is resting on soil. Projection is also provided on bottom slab on outer side of box. Water flows through these barrels and traffic moves form top of slab.

- Span = 5 m
- Width of carriage way = 7.5 m
- Foot path = 250 x 1250 mm
- Height of box, a = 5000 mm
- Width of box, b = 5000 mm

- Top Slab thickness top, d = 500 mm
- Bottom Slab thickness, e = 700 mm
- Projection of bottom slab on each side, c = 500 mm
- Thickness of wall, f = 450 mm
- Wearing coat = 80 mm

In this chapter, all the loading calculation for box type skew culvert is given in form of excel work sheet. The calculation flows through this pattern. Dead load and super imposed dead load calculations. Then two types of live load, Class 70R wheeled vehicle and class 70 R tracked vehicle are considered in the calculation. In live load case two different position of live load is considered, fist one is when live load starting from edge of the box and second one when live load is placed centrally. Soil pressure from side wall is calculated fro when soil is dry condition and when soil is submerged condition i.e. in drawdown condition. Seismic force calculation is also done. For the foundation, soil pressures for different cases are calculated.

All the loading calculation will be applied in to staad pro for single cell analysis and from that reference 3 dimensional analyses for four barrel cell was performed in SAP 2000 v 10.01, which is given in the chapter 6.

Fillate size of **150 150** mm

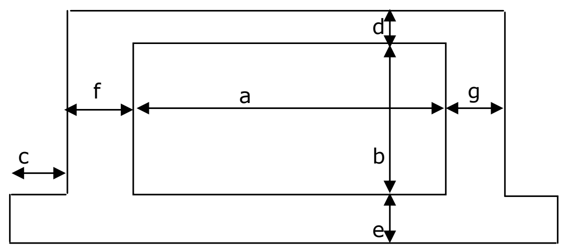
**BASIC DESIGN DATA :-** Culvert

| | | | |
|---|---|---|---|
| Nos of Cell | = | 1 | |
| Clear width W | = | 5.90 | m |
| Vertical height b | = | 5.00 | m |
| Th. of bottom slab,e | = | 0.50 | m |
| Th. of top slab d | = | 0.50 | m |
| Th. of outer side wall f | = | 0.45 | m |
| Proj of bottom slab c | = | 0.50 | m |
| Earth Cushion | = | 0.00 | m |
| Live Load surcharge | = | 1.20 | m |
| Th. of inner side wall g | = | 0.45 | m |
| Grade of concrete | = | 25 | $N/mm^2$ |
| Grade of Main steel | = | 415 | $N/mm^2$ |
| Grade of Distribution steel | = | 415 | $N/mm^2$ |
| Permissible flexural compressive stress for concrete $\sigma_c$ | = | 10 | $N/mm^2$ |

Total Length of structure = 7.5 m

Where, Inner width of cell a = 5.0 m

Zone of earthquake region = V




| Allowable Pmax | Normal | Seismic |
|---|---|---|
| $t/m^2$ | **25** | 31.25 |
| **Designed** | **Pmax** | **Pmin** |
| | **$kN/m^2$** | **$kN/m^2$** |
| Normal | 131.94 | 36.72 |
| Seismic | 35.34 | -18.77 |

| | | | |
|---|---|---|---|
| Permissible tensile stress in flexural for Main steel $\sigma_{st}$ | = | 200 | $N/mm^2$ |
| Modular ratio m | = | 10 | |

$$k = \frac{1}{1 + \frac{\sigma_{st}}{m \times \sigma_c}} = 0.333$$

$$j = 1 - \frac{k}{3} = 0.889$$

$$Q = 0.5 \times k \times j \times \sigma_c = 1.481 \ N/mm^2$$

Permissible tensile stress in flexural for Distribution steel $\sigma_{st}$ = 200 $N/mm^2$

$$k = \frac{1}{1 + \frac{\sigma_{st}}{m \times \sigma_c}} = 0.333$$

$$j = 1 - \frac{k}{3} = 0.889$$

$$Q = 0.5 \times k \times j \times \sigma_c = 1.481 \ N/mm^2$$

| | | | |
|---|---|---|---|
| Width of top slab | = | 7.500 | m |
| Thickness of wearing coat | = | 0.100 | m |
| Provision for future overlay of wearing coat | = | 0.050 | m |
| Width of bottom slab | = | 7.500 | m |
| Area of Crash Barrier | = | 0.40 | $m^2$ |
| Area of Footpath | = | 0.38 | $m^2$ |

**LOAD CALCULATION:-**

**1. Dead Load (Self weight of Bridge) :-**

For the calculation of self-weight of bridge density of concrete is considered as 2.4 t/m$^3$.

**2. Superimposed dead load (SIDL) :-**

In the SIDL load of railing, wearing coat and crash barrier is considered on top slab, while load of soil of 0.3 m depth is considered on bottom slab

| | | | | | | |
|---|---|---|---|---|---|---|
| Wt. Of wearing coat | = 0.150 x 2.2 | 0.33 t/m | Say | 0.25 t/m | 2.5 kN/m | |
| Wt. Of Crash Barrier | = 0.40 x 2.4 | 0.96 t/m | Say | 1 t/m | 10 kN/m | |
| Wt. Of Footpath | = 0.38 x 2.4 | 0.9 t/m | Say | 0 t/m | 0 kN/m | |
| Footpath Live load | = 1 x 0.5 = | | | 0.50 t/m = | 5 kN/m | |
| | | | | ( Clause 209.4, IRC: 6 -2000) | | |
| Wt. of soil on bottom slab | = 0.3 x 1.8 = | 0.54 t/m | Say | 0.6 t/m | | When soil is dry |
| | | | | = 6 kN/m | | |
| | = 0.3 x 1.0 = | 0.3 t/m | Say | 0.3 t/m | | |
| | | | | = 3 kN/m | | |
| | | | | When soil is submerged | | |

**3. Live Load: -**

The bridge is designed for the 70R Wheeled and 70R tracked loading as per IRC: 6-2000. And impact factor is also calculated for the different types of loading.

**(a) Class 70 R Wheeled Vehicles (40 ton Boggie),**

Impact factor for reinforced concrete bridges = 0.25*1 (From cl.211.3(a)(ii) and cl.211.6,
= 0.25 IRC: 6 -2000)

Dispersion of Live load

Tyre contact area over road surface = Actual max tyre load / Max tyre press = (20x500)/5.273
= 1896 cm$^2$

Tyre width perpendicular to span IRC:6-2000, Appendix 1,note-3 = (410 - 50) = 360.00 mm

Width of dispersion parallel to span (Along the Span)

tp = te + 2 x (tw + ts)

te = Width of tyre contact area parallel to span
= (1,896.45 x 100 ) / 360 = 526.79 mm

tw = Thickness of wearing coat 100.00 mm

ts = Effective depth of slab 500.00 mm

tp = 526.79+2x(100+500+0) 1,726.79 mm > 1220

Alogn longitudinal direction v = 1,726.79 + 1220 = 2946.79 mm < 5450 mm

Hence take v = 2.947 m

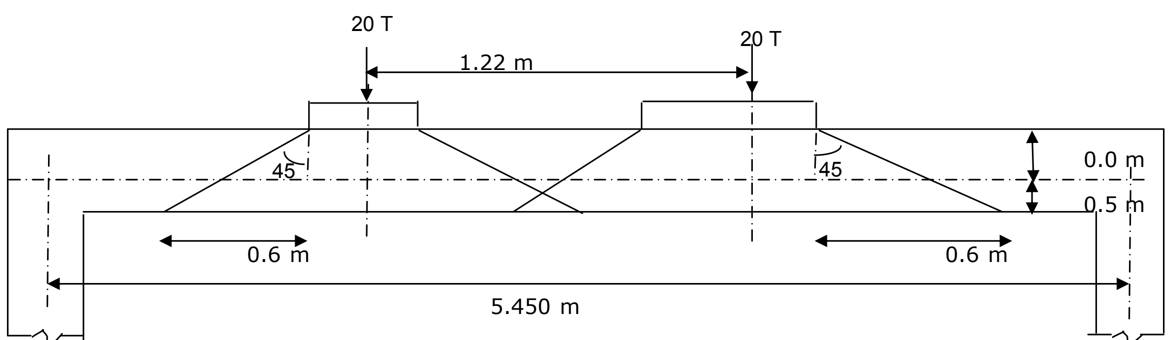



Fig 5.2 Dispersion of Live load along longitudinal direction
( Clause 305.16.3, IRC: 21 -2000)

**Calculation of effective width**

Now, $b_{ef}$ = a x a x (1-a / lo) + $b_1$ (From cl.305.16.2, IRC: 21 -2000)

Where $b_{ef}$ = the effective width of slab on which the load acts

$l_o$ = the effective span

a = the distance of centre of gravity of the concentrated load from the nearer support

$b_1$ = the breath of concentrated area of the load

a = a constant depanding upon the ratio b / $l_o$

b = the width of the slab

**(i) LL starting from edge of box, i.e. cg of live load 1.47 m from outer wall**

a = 1.47 m

$l_o$ = 5.45 m

b = 7.50 m

b / $l_o$ = 1.38

a = 2.4609

$b_1$ = 0.36 + (2 x0.100) = 0.56 m

$b_{ef}$ = a x a x (1-a / lo) + $b_1$ = 2.4609 x 1.47 x ( 1 - 1.47/5.45) + 0.56

= 3.21 m

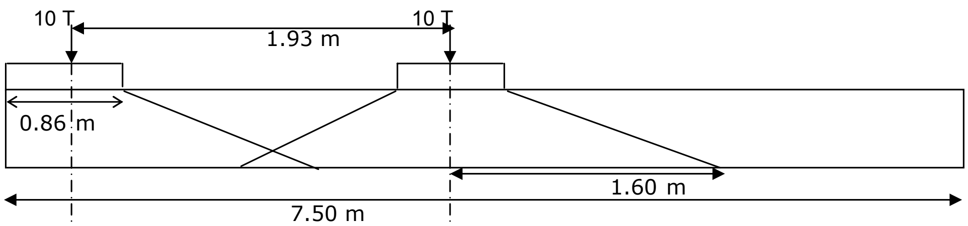



Fig 5.3 Dispersion of Live load along transerve direction
( Clause 305.16.2, IRC: 21 -2000)

Alogn transerve direction u = 0.43 + 1.60 + 3.21 - 1.28 = 3.96 m

Here, Width of box = 7.50 m > 3.96 m

Hence take u = 3.96 m

Live load intensity = ( 40 x 1.25 ) / ( 2.95 x 3.96) = 4.28 t / $m^2$ = 42.817 kN / $m^2$

Live load intensity per m width = 4.28 x 1 = 4.28 t / m = 42.817 kN / m

**(ii) LL centrally placed on span, i.e. cg of live load 2.73 m from outer wall**

a = 2.73 m

$l_o$ = 5.45 m

b = 7.50 m

b / $l_o$ = 1.38

a = 2.4609

$b_1$ = 0.36 + (2 x0.100) = 0.56 m

$b_{ef}$ = a x a x (1-a / lo) + $b_1$ = 2.4609 x 2.73 x ( 1 - 2.73/5.45) + 0.56

= 3.91 m

Alogn transerve direction u = 0.43 + 1.96 + 3.91 - 1.93 = 4.37 m

Here, Width of box = 7.50 m > 4.37 m

Hence take u = 4.37 m

Live load intensity = ( 40 x 1.25 ) / ( 2.95 x 4.37) = 3.88 t / $m^2$ = 38.832 kN / $m^2$

Live load intensity per m width = 3.88 x 1 = 3.88 t / m = 38.832 kN / m

Transverse moment = (40 x 1.25) x (3.75 - 1.40) = 117.75 tm = 1177.5 kNm

**(b) Class 70 R Tracked Vehicles ,**

Impact factor for reinforced concrete bridges = 0.25*1 (from cl.211.3 (a)(i)
= 0.25 and cl.211.66,IRC: 6 -2000)

Dispersion of Live load

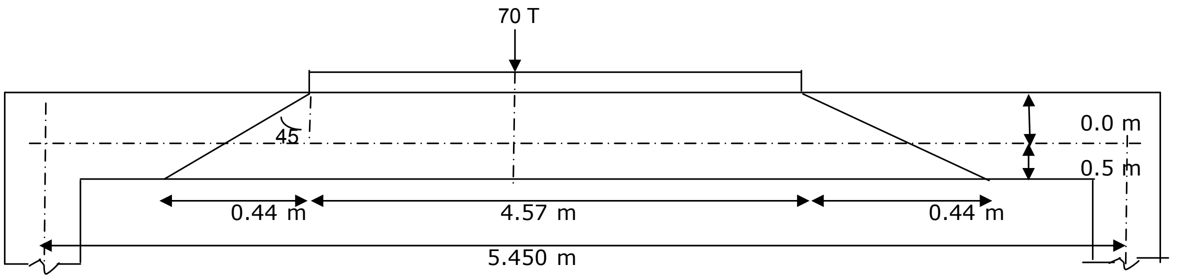



Fig 5.4 Dispersion of Live load along longitudinal direction
( Clause 305.16.3, IRC: 21 -2000)

Alogn longitudinal direction v = 0.440 + 4.6 + 0.440 = 5.45 m

**Calculation of effective width**

**(i) LL starting from edge of box, i.e. cg of live load 2.73 m from outer wall**

a = 2.73 m

$l_o$ = 5.45 m

b = 7.50 m

b / $l_o$ = 1.38

a = 2.4609

$b_1$ = 0.84 + (2 x0.100) = 1.04 m

$b_{ef}$ = a x a x (1-a / lo) + $b_1$ = 2.4609 x 2.73 x ( 1 - 2.73/5.45) + 1.04
= 4.39 m

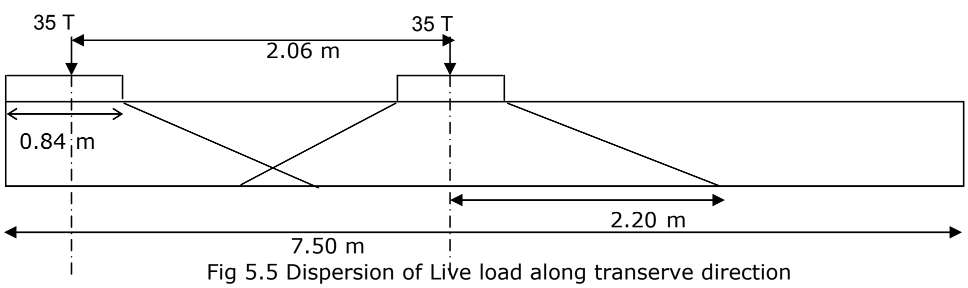



Fig 5.5 Dispersion of Live load along transerve direction
( Clause 305.16.2, IRC: 21 -2000)

Alogn transerve direction u = 0.42 + 2.20 + 4.39 - 2.06 = 4.95 m

Here, Width of box = 7.50 m > 4.95 m

Hence take u = 4.95 m

Live load intensity =(70 x 1.25) / (5.45 x 4.95) = 3.24 t / $m^2$ = 32.438 kN / $m^2$

Live load intensity per m width = 3.24 x 1 = 3.24 t / m = 32.438 kN / m

**(ii) LL centrally placed on span, i.e. cg of live load 2.73 m from outer wall**

a = 2.73 m
$l_o$ = 5.45 m
b = 7.50 m
b / $l_o$ = 1.38
a = 2.4609
$b_1$ = 0.84 + (2 x0.100) = 1.04 m

$b_{ef}$ = a x a x (1-a / lo) + $b_1$ = 2.4609 x 2.73 x ( 1 - 2.73/5.45) + 1.04
= 4.39 m

Along transerve direction u = 0.42 + 2.20 + 4.39 - 2.06 = 4.95 m
Here, Width of box = 7.50 m > 4.95 m
Hence take u = 4.95 m
Live load intensity =( 70 x 1.25 ) / ( 5.45 x 4.95)= 3.24 t / $m^2$ = 32.438 kN / $m^2$
Live load intensity per m width = 3.24 x 1 = 3.24 t / m = 32.438 kN / m
Transverse moment = (3.24x4.95x5.45) x (3.75-(0.42+1.03) 201.25 tm = 2012.5 kNm

**Hence from above, IRC Class 70R Tracked Vehicles loading will govern**

**<u>4. Braking force :-</u>**

Bracking force is considered 20% of the total live load in horizontal direction.
= 87.50 x 0.2 /7.50 = 2.33 t = 23.33 kNm

**<u>5. Soil Pressure From Side Wall: - ( When soil is dry )</u>**

When soil is dry , the soil pressure on side wall is calculated as follows:

Assuming Φ = 30

Ka = (1-Sin Φ) / (1+Sin Φ) = 0.333

Lateral pressure at top due to
( i ) Live load surcharge of 1.2 m and ( ii ) Earth Cushion of 0.00 m height
= ( 0.333 x 1.8 x 1.2)+( 0.333 x 1.8 x 0.0 ) = 0.72 t / $m^2$

Lateral pressure at bottom due to soil
( i ) Live load surcharge of 1.2 m ( ii ) Earth Cushion of 0.00 m height
and ( iii ) Back fill of soil
= ( 0.333 x 1.8 x 1.2)+ (0.333 x 1.8 x ( 0.00+0.50+5.00 ) ) = 4.02 t / $m^2$ = 40.2kN/m

**<u>6. Soil Pressure From Side Wall: - ( When soil is submerged, in drawdown condition )</u>**

When soil is submerged , the soil pressure on side wall is calculated as follows:

Lateral pressure at top due to soil = Ka γ' h + $\gamma_w$ h

Assuming submerged unit weight of soil γ' = 1.2 t / $m^3$

Unit weight of water $\gamma_w$ = 1 t / $m^3$ = 10 kN / $m^3$

Assuming Φ = 30

Ka = (1-Sin Φ) / (1+Sin Φ) = 0.333

Lateral pressure at top due to
( i ) Live load surcharge of 1.2 m and ( ii ) Earth Cushion of 0.00 m height
= ( 0.333 x 1.8 x 1.2 ) + ( 0.333 x 1.2 x 0.0 ) + ( 1 x 0 ) = 0.72 t / $m^2$
= 7.2 kN/ $m^2$

Lateral pressure at bottom due to
( i ) Live load surcharge of 1.2 m ( ii ) Earth Cushion of 0.00 m height
and ( iii ) Back fill of soil
= ( 0.333 x 1.8 x 1.20 ) + ( 0.333 x 1.2 x ( 0.0+0.50+5.00 ) ) + ( 1 x ( 0.00+0.50+5.00 ) )
= 8.42 t / $m^2$ = 84.2 kN / $m^2$

**7. Seismic force :-** ( From Modified Clause 222 of IRC 6 : 2000)

Zone factor Z = 0.36

Importance factor I = 1.50

Sa / g = 2.50

Response reduction factor R = 2.50

Horizontal seismic coefficient $A_{h\ \text{Longitudinal}}$ $= \dfrac{[Z/2]\,[Sa/g]}{[R/I]}$ = 0.270

Horizontal seismic coefficient $A_{h\ \text{Transverse}}$ = 0.270

Vertical seismic coefficient Av = Ah / 2 = 0.135

TABLE 5.1 Load calculation for seismic force (Moment at base)

| Sr No | Component | Direct Load | Seismic Force | | cg from base of footing | Moment @ base of footing | |
|---|---|---|---|---|---|---|---|
| | | | Long.= Ah x Load | Transverse | | Longitudinal | Transverse |
| | | kN | kN | kN | m | kNm | kNm |
| | Top slab<br>0.50 x 2.4 x 5.90 x 7.50 | 531.00 | 143.37 | 143.37 | 5.50 | 789 | 789 |
| | Outer sude wall (on earth pressure side)<br>0.45 x 2.4 x 5.00 x 7.50 | 405.0 | 109.35 | 109.35 | 2.50 | 273 | 273 |
| | Outer sude wall (opposite to earth pressure side)<br>0.45 x 2.4 x 5.00 x 7.50 | 405.0 | 109.35 | 109.35 | 2.50 | 273 | 273 |
| | Live load<br>0.50 x 70 | 350.0 | - | 94.50 | 5.50 | - | 520 |
| | **Total** | | **362.07** | **456.57** | | 1335 | **1855** |

**8. Soil pressure from foundation: -**

Soil pressure will act at the bottom slab of the box to resist the penetration of box in to the soil. The pressure acting on bottom slab of the box is calculated as follows:

**(a) When the box is full of water and LL is present**

Total vertical Load due to DL + SIDL +LL + Wt. of Earth + Wt. of Water

| | | | | |
|---|---|---|---|---|
| Wt. of top slab | = 0.50 x 2.4 x 5.90 x 7.50 | = | 53.1 t = | 531.0kN |
| Wt. of bottom slab | = 0.50 x 2.4 x 6.9 x 7.50 | = | 62.1 t = | 621.0kN |
| Wt. of side wall | = 0.45 x 2.4 x (5.00 + 0.50) x 2 x 7.50 | = | 89.1 t = | 891.0kN |
| Wt. of live load | = 87.50 | = | 87.5 t = | 875.0kN |

Wt. of SIDL = Wt. Of Wearing Coat + Wt. Of Crash Barrier + Wt. of soil on bottom slab
= ( 0.100 x 2.2 x 5.90 x 7.50) + (0.4 x 2.4 x 5.90 x 7.50) + ( 0.3 x 1 x 5.00 x 7.50) = 63.5 t
= 634.7 kN

Wt. of Eath Cushion = 1.2 x 0.00 x 5.90 x 7.50 = 0.0 t
= 0.0 kN

Wt. of Eath on projection of bottom slab = 1.2 x 5.5 x 1.00 x 7.50 = 49.5 t
= 495.0 kN

Wt. of Water = 1 x 5.00 x ( 5.00 - 0.6 ) x 7.50 = 165.0 t
= 1650 kN

Upward bouyant force = (0.50 x 6.9 x 7.50) + (0.45 x (5.00 + 0.50) x 2 x 7.50) = 63.0 t
= 630 kN

P / A =(53.1 + 62.1 + 89.1 + 87.5 + 63.5 + 0.0 + 49.5 + 165.0 - 63.0) / (6.9 x 7.50) = 9.79 t / m$^2$
= 97.93 kN / m$^2$

Total longitudinal moment due to Live load ( IRC Class 70R Tracked Vehicles), Breaking force

**(i) LL starting from edge of box, i.e. cg of live load 2.73 m from outer wall**

Live load intensity per m width = 3.24 t / m = 32.44 kN / m

Along longitudinal direction, dispersion of Live load = 5.45 m

Total Live load in longitudianl direction = 3.24x5.4 = 17.68 t = 176.79 kN

Eccentricity of Live load from center of base slab = (6.4 / 2 ) - (0.50 + (0.45/2) + 2.73)
= -0.25 m

Longitudinal moment due to Live load = 17.68 x -0. = -4.42 tm (Overturning moment)
= -44.20 kNm

Longitudinal moment due to Breaking = 2.33 x 5.5( = 12.83 tm (Overturning moment)
= 128.33 kNm

Net moment M @ centre of base slab = -4.42 - 12.83 = -17.3 tm = -172.5 kNm

P1 = P/A + ML/Z + MT/Z = 9.79+((6x-17.25)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2)) 12.61 t / m$^2$
= 126.14 kN / m$^2$

P2 = P/A + ML/Z - MT/Z = 9.79+((6x-17.25)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2)) 6.39 t / m$^2$
= 63.92 kN / m$^2$

P3 = P/A - ML/Z + MT/Z = 9.79-((6x-17.25)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2)) 13.19 t / m$^2$
= 131.94 kN / m$^2$

P4 = P/A - ML/Z - MT/Z = 9.79-((6x-17.25)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2))= 6.97 t / m$^2$
= 69.714 kN / m$^2$

**(ii) LL centrally placed on span, i.e. cg of live load 2.73 m from outer wall**

Live load intensity per m width = 3.24 t / m

Along longitudinal direction, dispersion of Live load = 5.45 m

Total Live load in longitudianl direction = 3.24x5.4 = 17.68 t = 176.79 kN

Eccentricity of Live load from center of base slab = (6.4 / 2 ) - (0.50 + (0.45/2) + 2.73)

= -0.25 m

Longitudinal moment due to Live load = 17.68 x -0. = -4.42 tm (Overturning moment)

= -44.20 kNm

Longitudinal moment due to Breaking = 2.33 x 5.5( = 12.83 tm (Overturning moment)

= 128.33 kNm

Net moment M @ centre of base slab = -4.42 - 12.83 = -17.25 tm

= -172.5297 kNm

P1 = P/A + ML/Z + MT/Z = 9.79+((6x-172.53)/(7.50x6.90^ 2 ))+((6x201.25)/(6.90x7.50^ 2 12.61 t / $m^2$

= 126.14 kN / $m^2$

P2 = P/A + ML/Z - MT/Z = 9.79+((6x-17.25)/(7.50x6.90^ 2 ))-((6x201.25)/(6.90x7.50^ 2)) 6.39 t / $m^2$

= 63.92 kN / $m^2$

P3 = P/A - ML/Z + MT/Z = 9.79-((6x-17.25)/(7.50x6.90^ 2 ))+((6x201.25)/(6.90x7.50^ 2)) 13.19 t / $m^2$

= 131.94 kN / $m^2$

P4 = P/A - ML/Z - MT/Z = 9.79-((6x-17.25)/(7.50x6.90^ 2 ))-((6x201.25)/(6.90x7.50^ 2)) 6.97 t / $m^2$

= 69.714 kN / $m^2$

**(b) When the box is full of water and LL is not present**

Total vertical load due to DL + SIDL + Wt. of Earth + Wt. of Water

| | | | | |
|---|---|---|---|---|
| Wt. of top slab | = 0.50 x 2.4 x 5.90 x 7.50 | = | 53.1 t = | 531.0kN |
| Wt. of bottom slab | = 0.50 x 2.4 x 6.9 x 7.50 | = | 62.1 t = | 621.0kN |
| Wt. of side wall | = 0.45 x 2.4 x (5.00 + 0.50) x 2 x | = | 89.1 t = | 891.0kN |
| Wt. Of SIDL | = Wt. Of Wearing Coat + Wt. Of Crash Barrier + Wt. of soil on bottom slab = ( 0.100 x 2.2 x 5.90 x 7.50) + (0.4 x 2.4 x 5.90 x 7.50) + ( 0.3 x 1 x 5.00 x 7.50) | = | 63.5 t / m = | 635kN/m |
| Wt. of Eath Cushion | = 1.2 x 0.00 x 5.90 x 7.50 | = | 0.0 t / m = | 0kN/m |
| Wt. of Eath on projection of bottom slab | = 1.2 x 5.5 x 1.00 x 7.50 | = | 49.5 t / m = | 495kN/m |
| Wt. of Water | = 1 x 5.00 x ( 5 - 0.6 ) x 7.50 | = | 165.0 t / m | |
| | | = | 1650.00 kN/m | |
| Upward bouyant force | = (0.50 x 6.9 x 7.50) + (0.45 x (5.00 + 0.50) x 2 x 7.50) | = | 63.0 t = | 630.0kN |
| P / A | =(53.1 + 62.1 + 89.1 + 63.5 + 0.0 + 49.5 + 165.0 - 63.0) / (6.9 x 7.50) | = | 8.10 t / $m^2$ = | 81kN/m2 |

Total longitudinal moment due to Live load ( IRC Class 70R Tracked Vehicles) and Breaking force

As here LL is not present, moment M @ centre of base slab = 0.00 tm

Net moment M @ centre of base slab = 0.00 = 0.00 tm

P1 = P/A + ML/Z + MT/Z = 8.10+((6x0.00)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2))= 11.21 t / $m^2$

= 112.13 kN / $m^2$

P2 = P/A + ML/Z - MT/Z = 8.10+((6x0.00)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2))= 4.99 t / $m^2$

= 49.91 kN / $m^2$

P3 = P/A - ML/Z + MT/Z = 8.10-((6x0.00)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2))= 11.21 t / $m^2$

= 112.13 kN / $m^2$

P4 = P/A - ML/Z - MT/Z = 8.10-((6x0.00)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2))= 4.99 t / $m^2$

= 49.91 kN / $m^2$

**(c) When the box is empty and LL is present**

Total vertical load due to DL + SIDL +LL + Wt. of Earth

| | | | | |
|---|---|---|---|---|
| Wt. of top slab | = 0.50 x 2.4 x 5.90 x 7.50 | = | 53.1 t = | 531.0kN |
| Wt. of bottom slab | = 0.50 x 2.4 x 6.9 x 7.50 | = | 62.1 t = | 621.0kN |
| Wt. of side wall | = 0.45 x 2.4 x (5.00 + 0.50) x 2 x | = | 89.1 t = | 891.0kN |
| Wt. of live load | = 87.50 | = | 87.5 t = | 875.0kN |
| Wt. of SIDL | = Wt. Of Wearing Coat + Wt. Of Crash Barrier + Wt. of soil on bottom slab<br>= ( 0.100 x 2.2 x 5.90 x 7.50) + (0.4 x<br>2.4 x 5.90 x 7.50) + ( 0.3 x 1.8 x 5.00 | = | 72.5 t = | 724.7kN |
| Wt. of Eath Cushion | = 1.8 x 0.00 x 6.8 x 7.50 | = | 0.0 t = | 0.0kN |
| Wt. of Eath on projection of bottom slab | = 1.8 x 5.5 x 1.00 x 7.50 | = | 74.3 t = | 742.5kN |

P / A =(53.1 + 62.1 + 89.1 + 87.5 + 72.5 + 0.0 + 74.3) / (6.9 x 7.50) = 8.47 t / $m^2$

84.74 kN / $m^2$

Total longitudinal moment due to Live load ( IRC Class 70R Tracked Vehicles), Breaking force

**(i) LL starting from edge of box, i.e. cg of live load 2.73 m from outer wall**

Live load intensity per m width = 3.24 t / m = 32.44 kN/m

Along longitudinal direction, dispersion of Live load = 5.45 m

Total Live load in longitudianl direction = 3.24x5.4 = 17.68 t = 177 kN

Eccentricity of Live load from center of base slab = (6.4 / 2 ) - (0.50 + (0.45/2) + 2.73)

= -0.25 m

Longitudinal moment due to Live load = 17.68 x -0. = -4.42 tm (Overturning moment)

= -44.20 kNm

Longitudinal moment due to Breaking = 2.33 x 5.5( = 12.83 tm (Overturning moment)

= 128.33 kNm

Net moment M @ centre of base slab = -4.42 - 12.83 = -17.25 tm

= -172.5297 kNm

P1 = P/A + ML/Z + MT/Z = 8.47+((6x-17.25)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2)) 11.29 t / $m^2$

= 112.95 kN / $m^2$

P2 = P/A + ML/Z - MT/Z = 8.47+((6x-17.25)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2))= 5.07 t / $m^2$

= 50.73 kN / $m^2$

P3 = P/A - ML/Z + MT/Z = 8.47-((6x-17.25)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2))= 11.87 t / $m^2$

= 118.75 kN / $m^2$

P4 = P/A - ML/Z - MT/Z = 8.47-((6x-17.25)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2))= 5.65 t / $m^2$

= 56.53 kN / $m^2$

**(ii) LL centrally placed on span, i.e. cg of live load 2.73 m from outer wall**

Live load intensity per m width = 3.24 t / m

Along longitudinal direction, dispersion of Live load = 5.45 m

Total Live load in longitudianl direction =3.24x5.4 = 17.68 t = 176.79 kN

Eccentricity of Live load from center of base slab = (6.4 / 2 ) - (0.50 + (0.45/2) + 2.73)

= -0.25 m

Longitudinal moment due to Live load = 17.68 x -0. = -4.42 tm (Overturning moment)

= -44.20 kNm

Longitudinal moment due to Breaking = 2.33 x 5.5( = 12.83 tm (Overturning moment)

= 128.33 kNm

Net moment M @ centre of base slab = -4.42 - 12.83 = -17.25 tm

P1 = P/A + ML/Z + MT/Z = 8.47+((6x-17.25)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2)) 11.29 t / $m^2$

= 112.95 kN / $m^2$

P2 = P/A + ML/Z - MT/Z = 8.47+((6x-17.25)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2))= 5.07 t / $m^2$

= 50.73 kN / $m^2$

P3 = P/A - ML/Z + MT/Z = 8.47-((6x-17.25)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2))= 11.87 t / $m^2$

= 118.75 kN / $m^2$

P4 = P/A - ML/Z - MT/Z = 8.47-((6x-17.25)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2))= 5.65 t / $m^2$

= 56.53 kN / $m^2$

**(d) When the box is empty and LL is not present**

Total vertical load due to DL + SIDL + Wt. of Earth + Wt. of Water

| | | | | |
|---|---|---|---|---|
| Wt. of top slab | = 0.50 x 2.4 x 5.90 x 7.50 | = | 53.1 t / m = | 531.0kN |
| Wt. of bottom slab | = 0.50 x 2.4 x 6.9 x 7.50 | = | 62.1 t / m = | 621.0kN |
| Wt. of side wall | = 0.45 x 2.4 x (5.00 + 0.50) x 2 x 7.50 | = | 89.1 t / m = | 891.0kN |
| Wt. of SIDL | = Wt. Of Wearing Coat + Wt. Of Crash Barrier + Wt. of soil on bottom slab<br>= ( 0.100 x 2.2 x 5.90 x 7.50) + (0.4 x 2.4 x 5.90 x 7.50) + ( 0.3 x 1.8 x 5.00 | = | 72.5 t | |
| | | = | 724.7 kN | |
| Wt. of Eath Cushion | = 1.8 x 0.00 x 6.8 x 7.50 | = | 0.0 t / m | |
| | | = | 0.0 kN/m | |
| Wt.of Eath on projection of bottom slab | = 1.8 x 5.5 x 1.00 x 7.50 | = | 74.3 t / m | |
| | | = | 742.5 kN/m | |
| P / A | = (53.1 + 62.1 + 89.1 + 72.5 + 0.0 + 74.3) / (6.9 x 7.50) | = | 6.78 t / m $^2$ | |
| | | = | 67.83 kN / m $^2$ | |

Total longitudinal moment due to Live load ( IRC Class 70R Tracked Vehicles) and Breaking force

As here LL is not present, moment M @ centre of base slab = 0.00 tm

Net moment M @ centre of base slab = 0.00 = 0.00 tm = 0 kNm

| | | | |
|---|---|---|---|
| P1 = P/A + ML/Z + MT/Z | = 6.78+((6x0.00)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2)) = | 9.89 | t / m $^2$ |
| | = | 98.94 | kN / m $^2$ |
| P2 = P/A + ML/Z - MT/Z | = 6.78+((6x0.00)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2)) = | 3.67 | t / m $^2$ |
| | = | 36.72 | kN / m $^2$ |
| P3 = P/A - ML/Z + MT/Z | = 6.78-((6x0.00)/(7.50x6.90^ 2))+((6x201.25)/(6.90x7.50^ 2)) = | 9.89 | t / m $^2$ |
| | = | 98.94 | kN / m $^2$ |
| P4 = P/A - ML/Z - MT/Z | = 6.78-((6x0.00)/(7.50x6.90^ 2))-((6x201.25)/(6.90x7.50^ 2)) = | 3.67 | t / m $^2$ |
| | = | 36.718 | kN / m $^2$ |

**Table 5.2 Summary of Maximum & Minimum pressure at base of box**

| Sr No | Load case | Pmax kN / $m^2$ | Pmin kN / $m^2$ |
|---|---|---|---|
| **(a)** | **When the box is full of water and LL is present** | | |
| | (i) LL starting from edge of box | 131.94 | 63.92 |
| | (iii) LL centrally placed on span | 131.94 | 63.92 |
| **(b)** | **When the box is full of water and LL is not present** | 112.13 | 49.91 |
| **(c)** | **When the box is empty and LL is present** | | |
| | (i) LL starting from edge of box | 118.75 | 50.73 |
| | (iii) LL centrally placed on span | 118.75 | 50.73 |
| **(d)** | **When thebox is empty and LL is not present** | 98.94 | 36.72 |

**9. Weight of Earth Cushion : -**

The weight of Earth Cushion acting on top slab of the box, and it is calculated as follows:

= 1.8 x 0.00 = 0 t / m

The weight of backfill acting on projection of bottom slab of the box, and it is calculated as follows:

**(i) When soil is dry**

= 1.8 x 5.5 = 9.9 t / m = 99 kN/m

**(ii) When soil is submerged**

= 1.0 x 5.5 = 5.5 t / m = 55 kN/m

**10. Water pressure : -**

The water pressure will act horizontally on side wall

The water pressure intensity will vary from zero at HFL level to maximaum at invert level of box

Assume free board = 0.6 m

Water pressure intensity at HFL level = 0 t / $m^2$ = 0 kN / $m^2$

Water pressure intensity at invert level of box = $\gamma_w$ h = 1 x ( 5.00 - 0.6 ) = 4.4 t / $m^2$

= 44 kN / $m^2$

Water pressure intensity per m width ,
At HFL level = 0 t / m

At invert level of box = 4.4 t / m = 44 kN/m

The box should be designed to remain safe for the following cases :

**Case 1 : -** DL + SIDL + LL starting from edge of box + Breaking + Earth pressure, when soil is dry and box is empty

**Case 2 : -** DL + SIDL + LL starting from edge of box + Breaking + Earth pressure, when soil is submerged and box is full of water

**Case 3 : -** DL + SIDL + LL starting from edge of box + Breaking + Earth pressure, when soil is submerged and box is empty (drawdown condition)

**Case 4 : -** DL + SIDL + LL centrally placed on span + Breaking + Earth pressure, when soil is dry and box is empty

**Case 5 : -** DL + SIDL + LL centrally placed on span + Breaking + Earth pressure, when soil is submerged and box is full of water

**Case 6 : -** DL + SIDL + LL centrally placed on span + Breaking + Earth pressure, when soil is submerged and box is empty (drawdown condition)

**Case 7 : -** DL+ SIDL + Earth pressure, when soil is dry and box is empty

**Case 8 : -** DL + SIDL + Earth pressure, when soil is submerged and box is empty

# 6. ANALYSIS OF MULTIBARREL SKEW BOX CULVERT (3 DIMENSIONAL) BY USING SOFTWARE

## 6.1 GENERAL

In present study consists of four barrel of box type skew culvert for analysis and designing. The modeling is done in SAP 2000 Version 10

## 6.2 INTRODUCTION TO SAP 2000.

SAP 2000 is very efficient finite element based powerful tool to analyze any kind of structure for different type of loading. SAP 2000 is an extremely versatile and powerful programme with many features and functions.

SAP 2000 is user-friendly software with graphical interface. Modeling of any kind of geometry in SAP is very easy. For modeling, SAP includes object based graphical interface, area and solid objects with internal meshing, editing with move, merge, mirror and replicate tools, accurate dimensioning with guidelines and snapping, powerful grouping and selection option. Application of loading is also very user friendly in SAP 2000.

The analysis procedure in SAP 2000 includes, static Analysis with frame and shell objects, multiple solvers for analysis optimization, generalized joint constraints including rigid bodies and diaphragms, layered shell elements, moving loads and multi step static loads.

Display of SAP 2000 includes 3D perspective Graphical Displays, Static Deformed and Mode Shapes, OpenGL viewer and Lane Loading and influence surface Displays.

The advantage of SAP 2000 is that it is very simple to import and export data file from various format files like in form of excel spread sheet with different output like as joint reactions, base reactions, displacement, assembled joint masses, element forces-Area shells, Element joint forces-Areas, Element joint stresses-Area Shells, objects and elements areas, objects and elements-joints.

### 6.2.1 Finite Element Model

For analysis in SAP2000 the finite element model is used**.** In finite element the structure is discretized in number of small elements, i.e. structure is idealized as an assembly of various elements. In finite element method, mathematical model is formulated and solved to achieve results.

Types of Element can be used,

- Frame Element
- Shell Element
- Solid Element

In present study bridge modes is analyzed by using shell elements. All the components of box type skew culvers are Top slab, Vertical walls and Bottom slab are assumed as shell element.

- **Shell Elements:**

The general idea of shell element is given in Fig.6.1. For modeling shell element can be taken with 5 degree of freedom. Shell element can be four node quadrilateral or three node triangular elements. It can be taken as membrane or plate bending element as per forces and modeling requirement. The Figure 6.1 shows the forces acting on shell element and the degree of freedom for shell element.

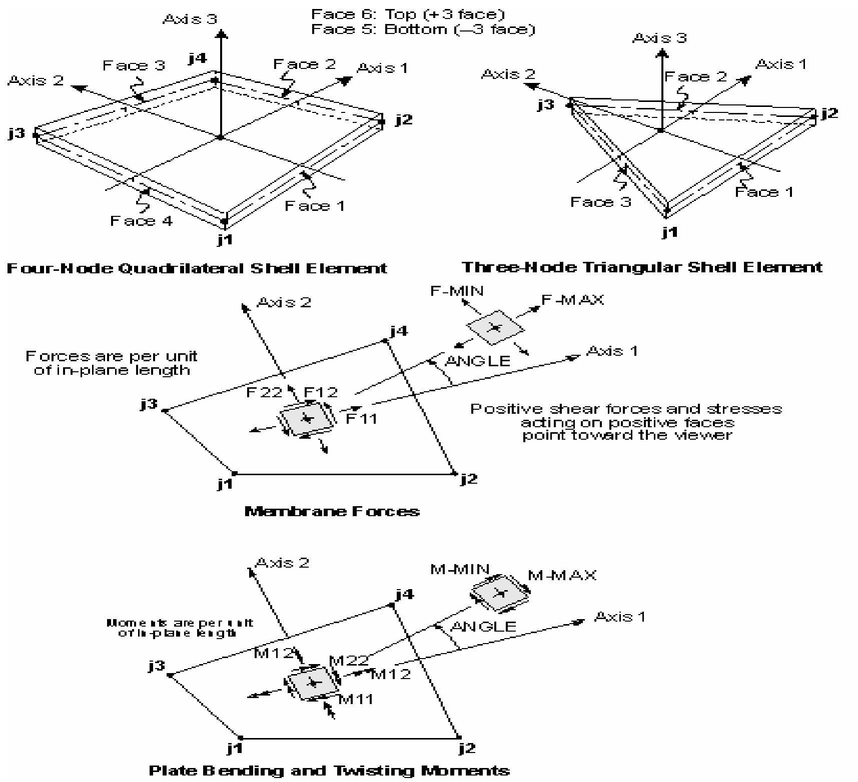



Fig 6.1 Shell Element Internal Forces

### 6.2.2 Modeling of Bridge Superstructure in SAP 2000

SAP 2000 wizard is having nice facility to Model Bridge very easily. It is having step by step bridge modeling option with many standard cross sections of bridge superstructure. To generate vehicular load is also very simple in this software.

First select the units in which all the loads to be given and same time direction to be chosen. Here for three dimensional modeling global system is selected and kN, m units selected. Then geometry of the modeling will be started.

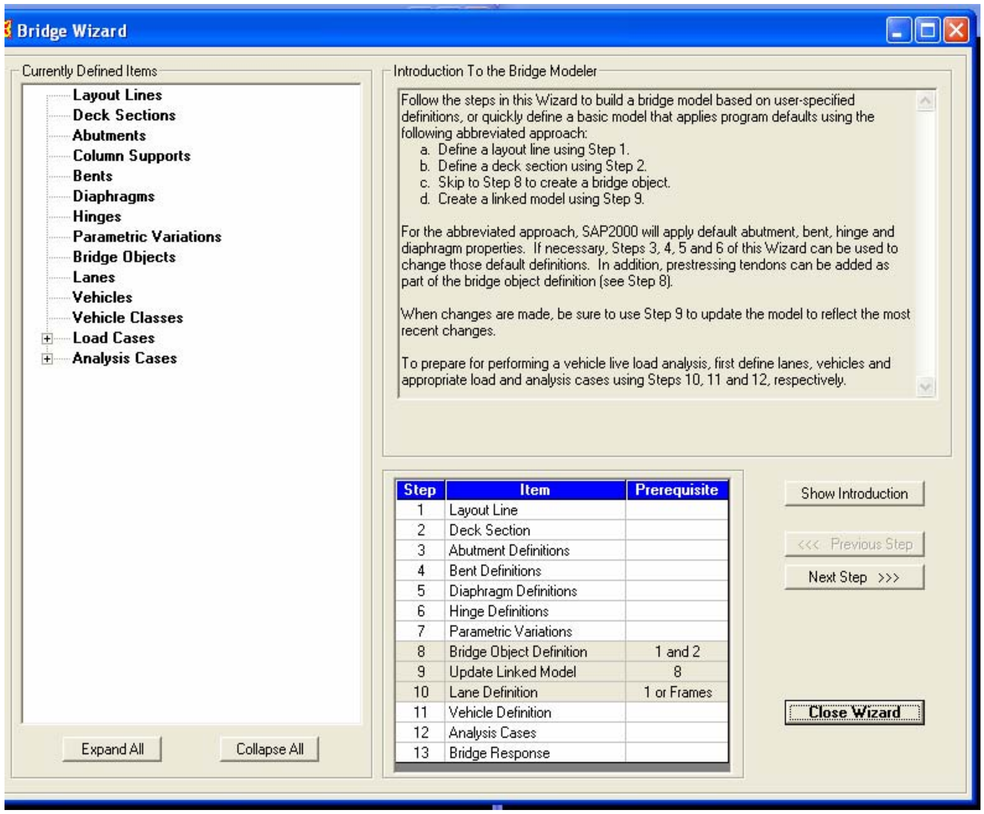



Fig 6.2 Bridge Wizard in SAP 2000

Fig 6.2 shows the bridge wizard in SAP 2000. to save time from repetitive preparation of model, in present study For analysis of all alternative one standard input file is prepared in excel worksheet, which can be directly imported in SAP 2000.

Modeling can be generated in another way, first of all in two dimensional plane generate four bay frame and then according two skew angle lines can be modified. After that joining the ordinates according to skew angles and then prepared two dimensional plane frames. These can be done by editing grid data in x, y and z direction. After two dimensional modeling, giving height according to the height of the culvert. So that three dimensional whole multibarrel skew culvert can be generated. These can been seen in Fig 6.3

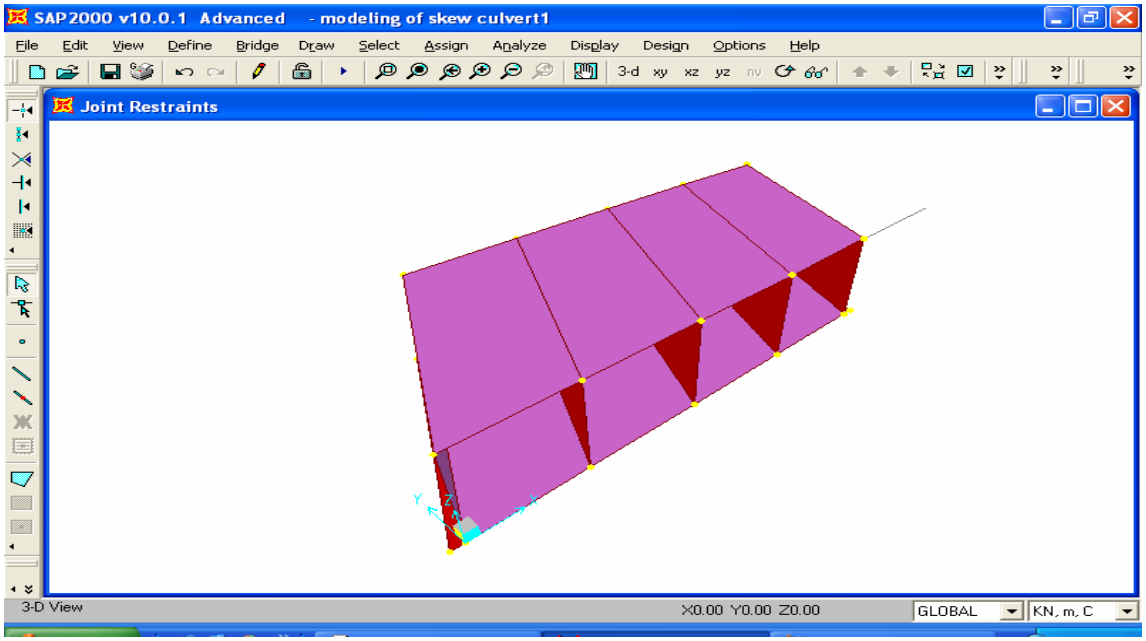



Fig. 6.3 Geometry developments for box type skew culvert

## 6.3 BRIDGE REFERENCE LINEFOR DEFINING LANES

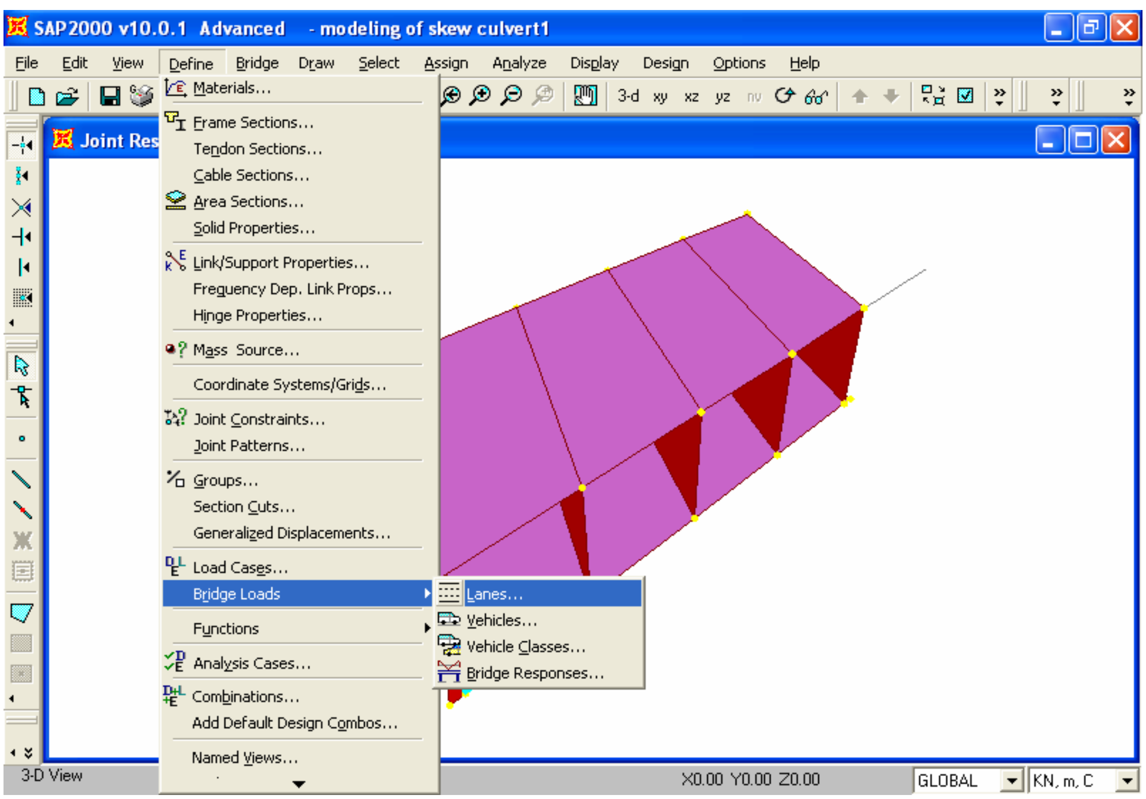



Fig. 6.4 Defining reference line for bridge

For any bridge structure, live load can be only given in SAP 2000 after defining the reference line. Here reference line can be defined at outside edge of the superstructure, from where particular offset given according to the centre line of vehicle and clearance as given in the Indian Road Congress.

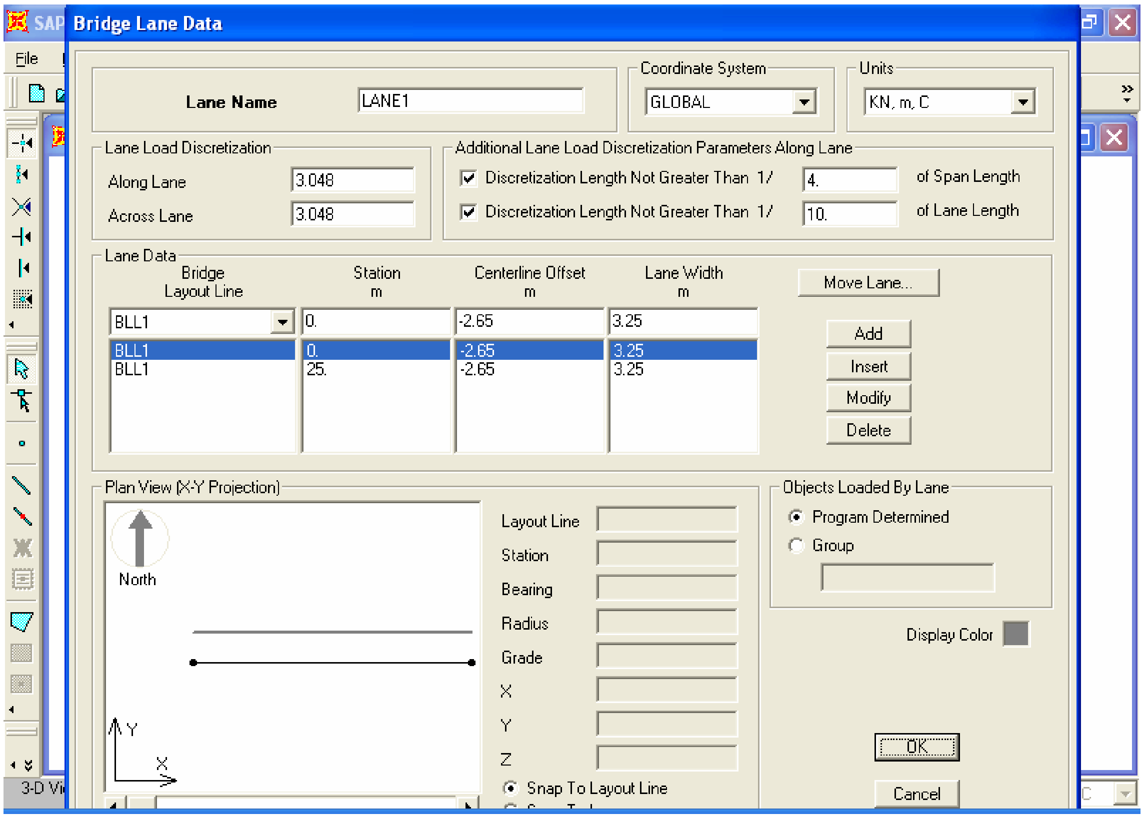



Fig. 6.5 Defining bridge lanes

For Class AA Tracked vehicle as clearance is 1.2 m from the edge of footpath. Particular offset is given as 2.65m from reference line.

For this type of skew culvert two lanes can be represented in form of two lanes. Here two different lanes can be shown by two different colours which can easily distinguish from one another.

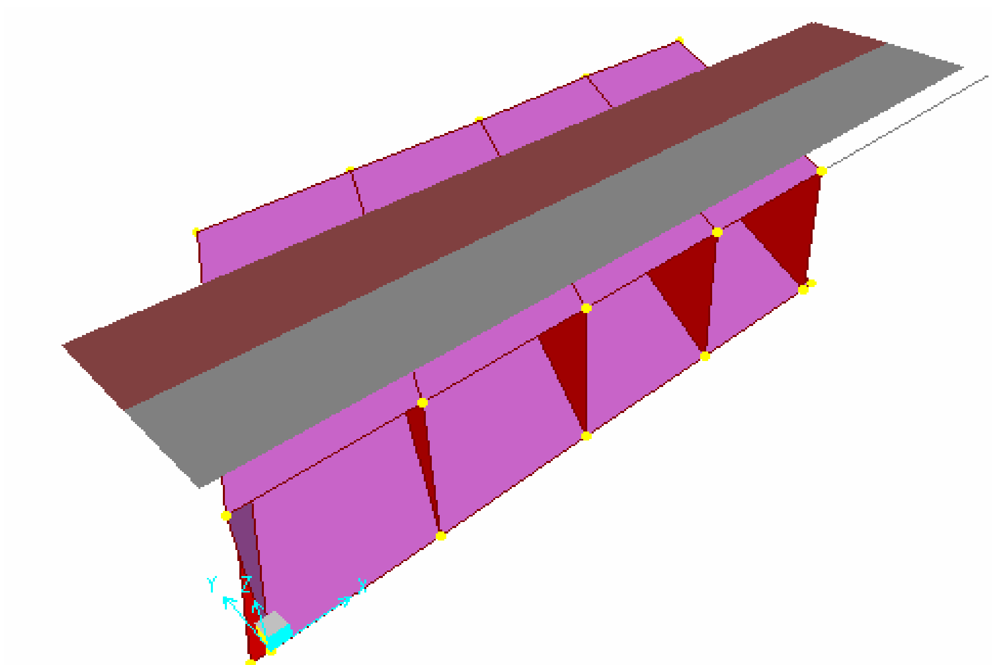


Fig. 6.6 Two lanes for the box type skew culvert

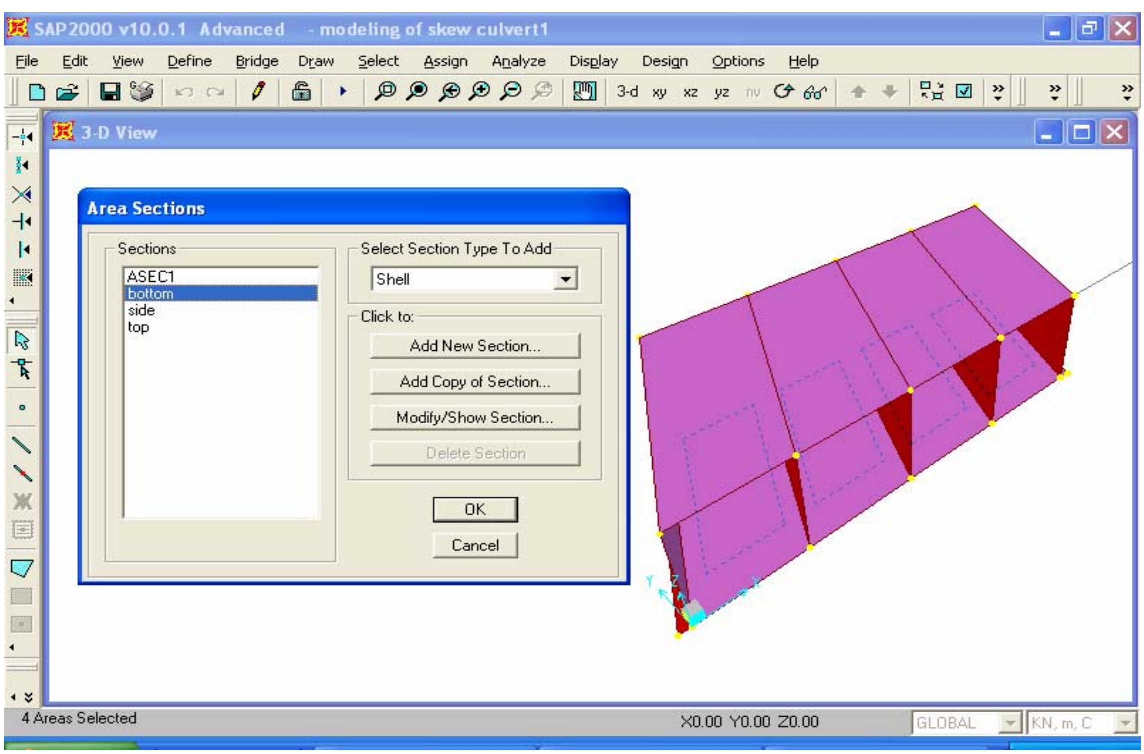



Fig. 6.7 Assignments of section to different culvert components

For these components meshing is to be done. For meshing can be generated as shown in Fig 6.8. According to meshing size which we required, feeding to the divide is in to the maximum size in longitudinal and transverse direction. These things can be seen in Fig 6.9 that all the elements are meshed according to the given sizes.

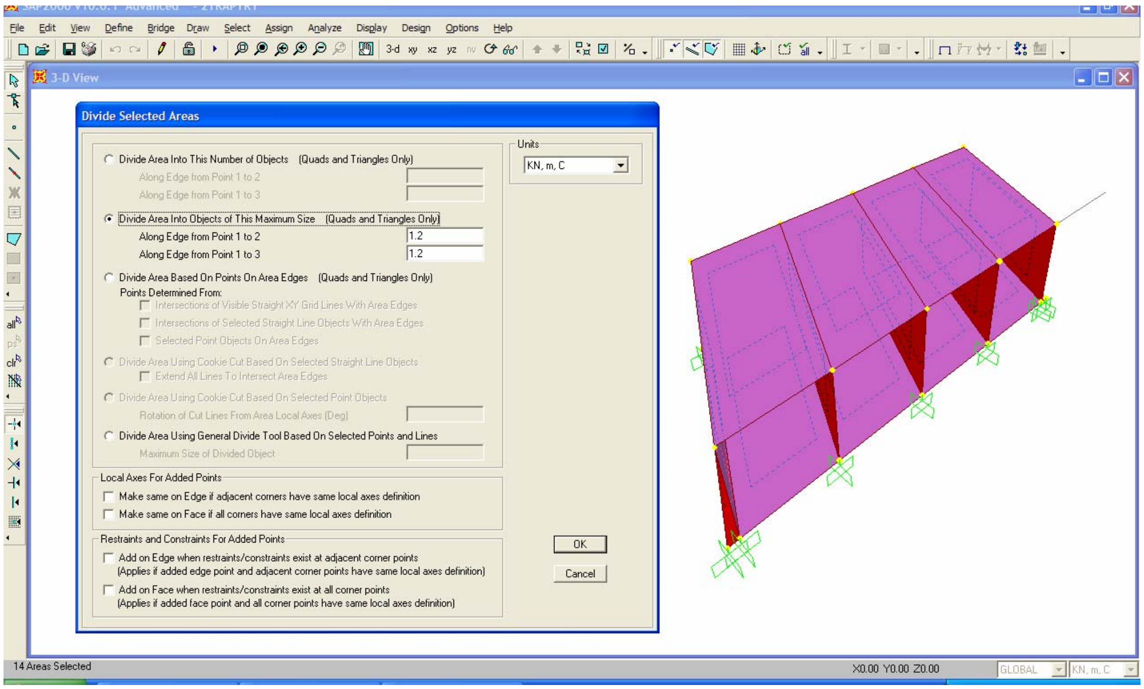



Fig 6.8 How to generate meshing for all elements

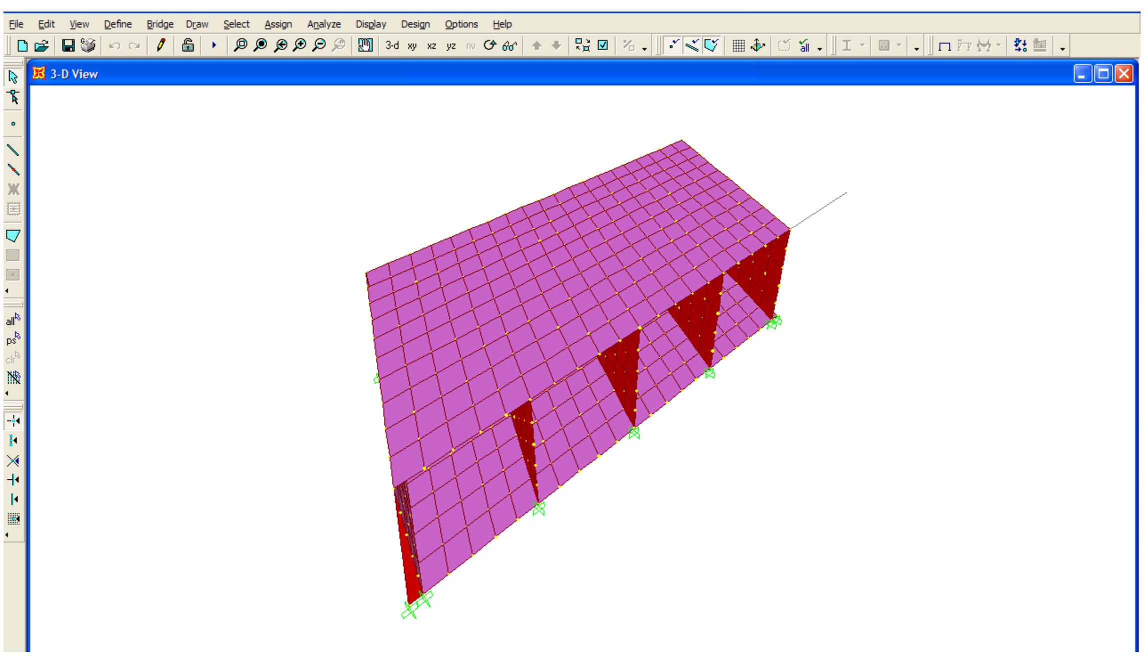



Fig. 6.9 Generation of meshing for all elements

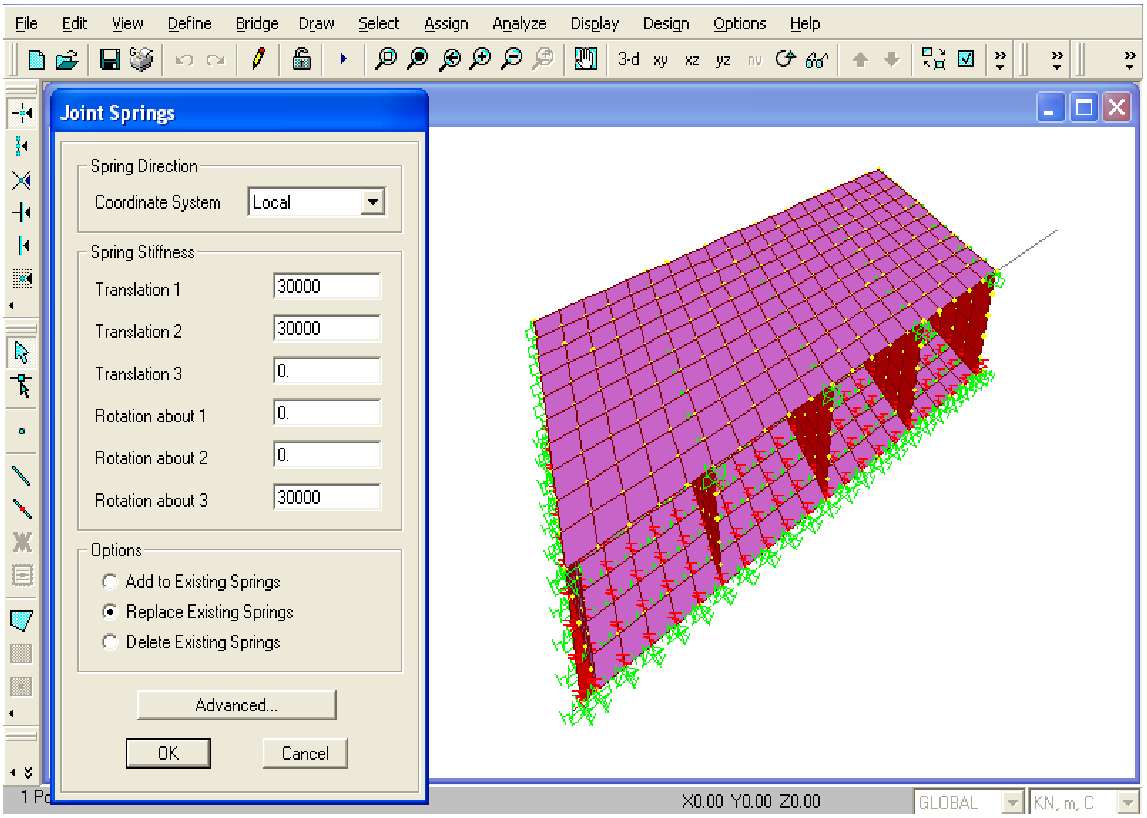



Fig. 6.10 Assignments of spring supports at base slab

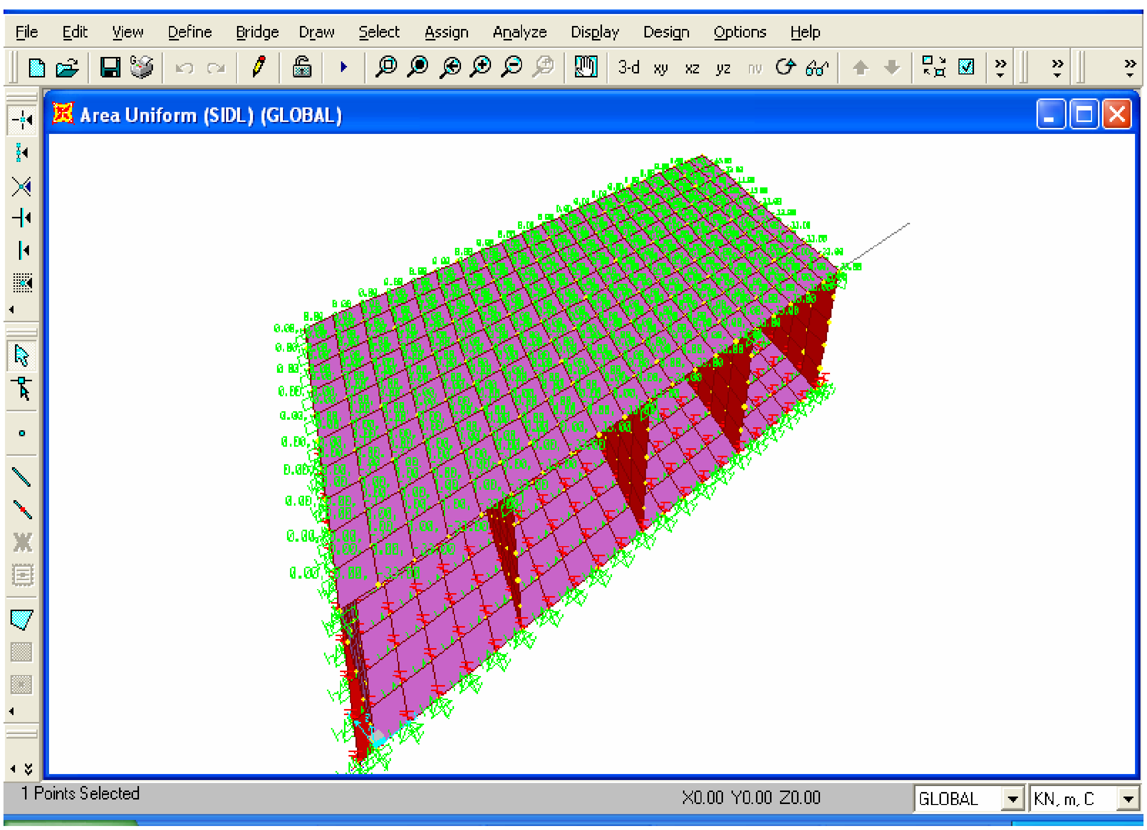



Fig 6.11 Assignments of Super Imposed Dead load to Top Slab

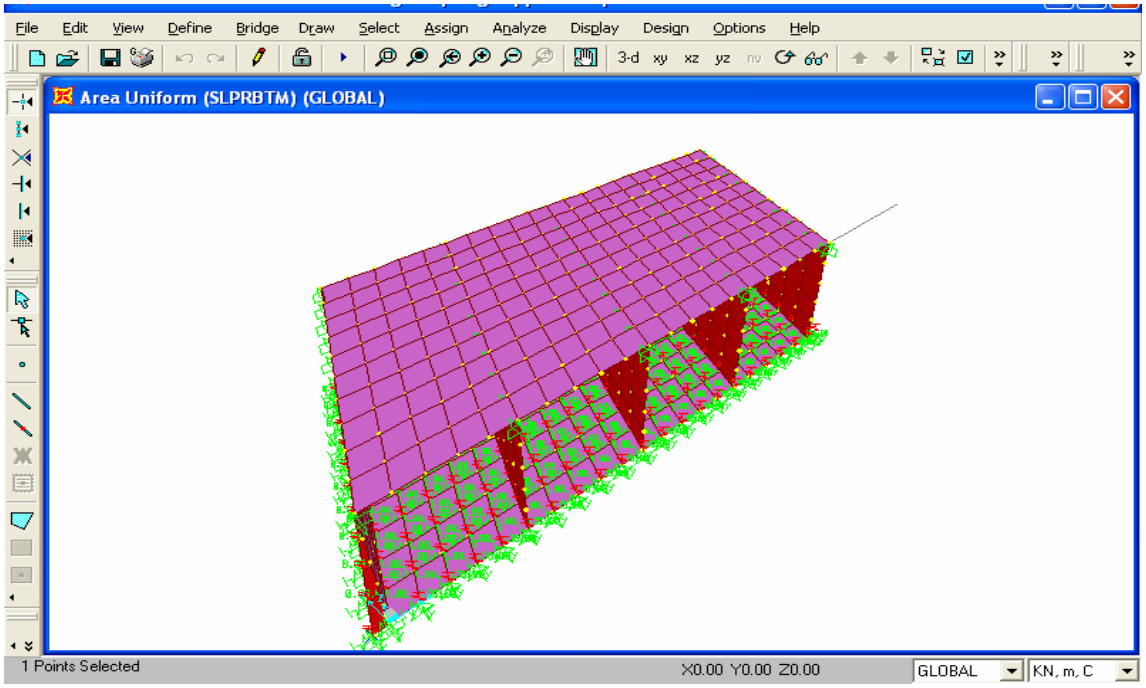



Fig. 6.12 Assignments of Soil pressure to Bottom slab

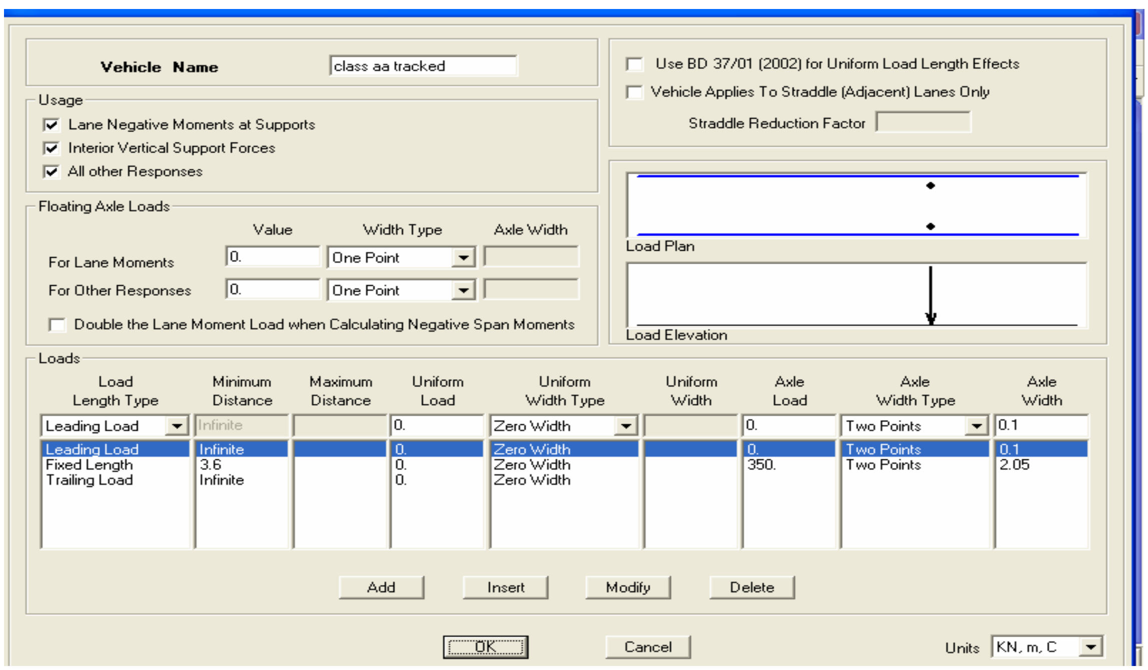



Fig. 6.13 Assignments of Live load (Class AA Tracked Vehicle)

After meshing completed for all the boundary element support condition is to be provided. Here we are considering fixed support at the junction of top slab and vertical walls. So that due to fixity at support mid span moment can be reduced. As bottom slab is resting on soil, we can consider these cases as foundation on spring support or beams on elastic foundation.

In these case stiffness of soil can be considered and it will be assigning to the support which could be enhanced the actual site condition and values of bending moment is well within the acceptable range and so that bottom slab thickness can be reduced.

## 6.4 ASSIGNMENTS OF SECTION AND LOADS

All the components of the skew culvert, top slab, bottom slab and vertical walls can be defined as shell elements. According to these elements top slab as assign for 0.5m thick slab, 0.45m thick vertical walls and bottom slab assigned as 0.7m thick. Assignment for all components can be given and it can be seen in Fig. 5.7.

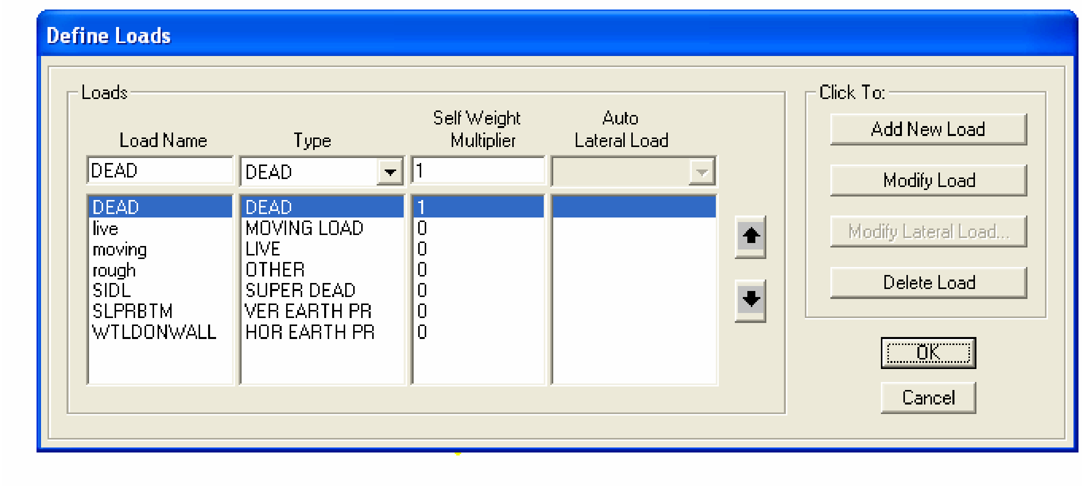



Fig 6.14 Assignments of loads

After assigning of support conditions and loads and their combinations, run the analysis.

## 6.5 ANALYSIS RESULTS

After completion of analysis, obtained the maximum bending moments in longitudinal direction and torsional moments in top slab for all load cases, but critically observed that the value is maximum on the live load case. Similarly for bottom slab, the maximum bending moment will be occurring at the soil pressure at bottom case. So taking all the critical values for designing different components.

For top slab designing class AA Tracked vehicle moment is governing so for designing of top slab considering longitudinal and transverse moment. For designing vertical walls considering higher axial load comes from top and longitudinal and transverse moments. For designing of bottom slab considering that slab is resting on elastic foundation and modulus of subgrade of reaction will come in to picture and its value becomes predominant. Here all the bending moment in longitudinal moment, transverse moment and torsional moment is considering for designing of various components and all diagrams are shown as below.

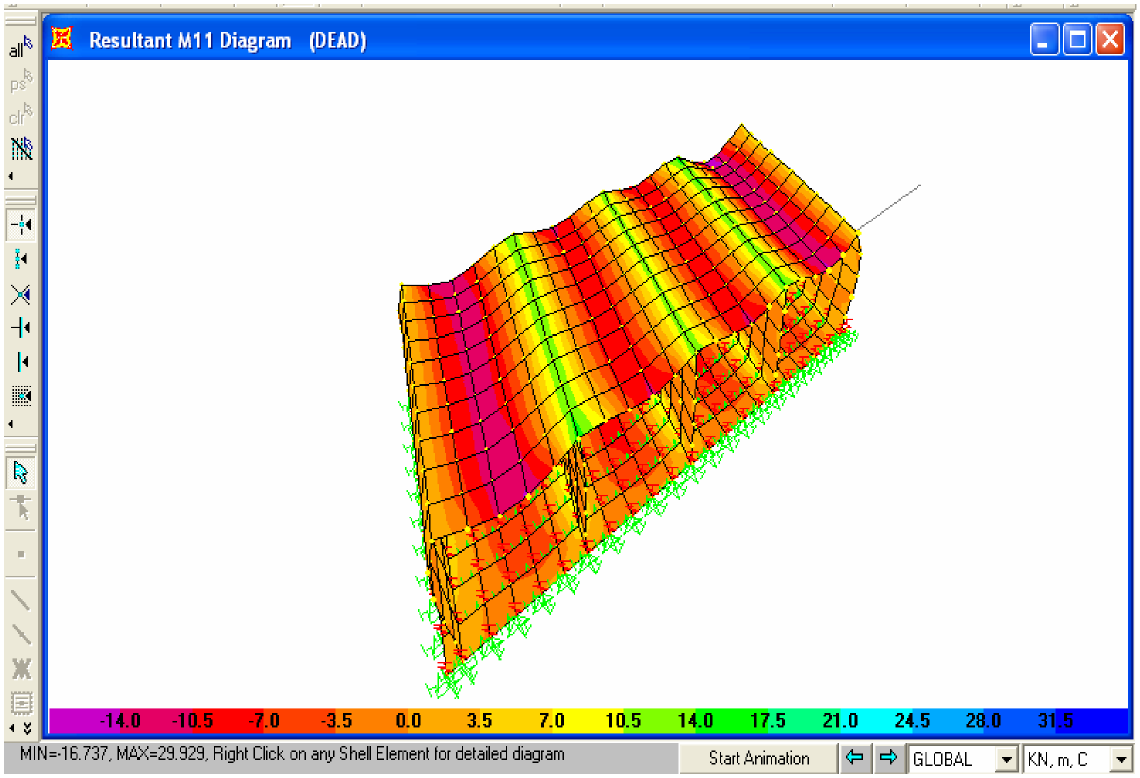



Fig 6.15 Longitudinal moment diagram for top slab and its deflected shape for dead load case

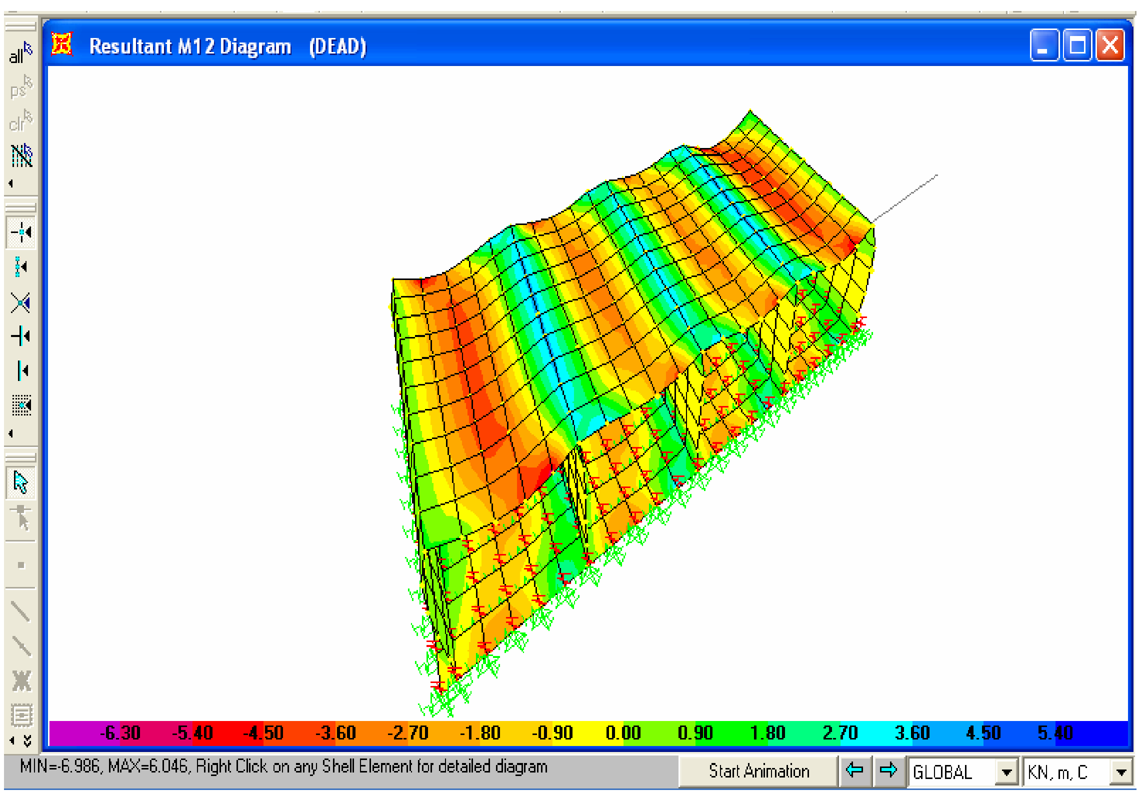



Fig 6.16 Transverse moment diagram for top slab and its deflected shape for dead load case

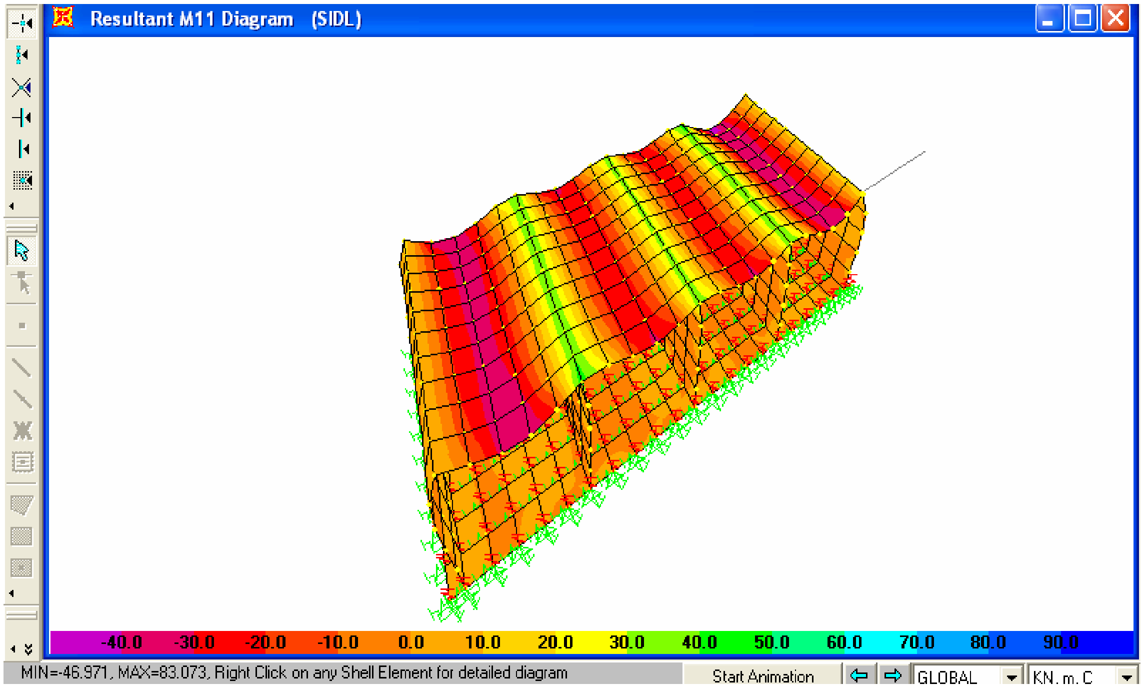



Fig 6.17 Longitudinal moment diagram for top slab and its deflected shape for super imposed dead load case

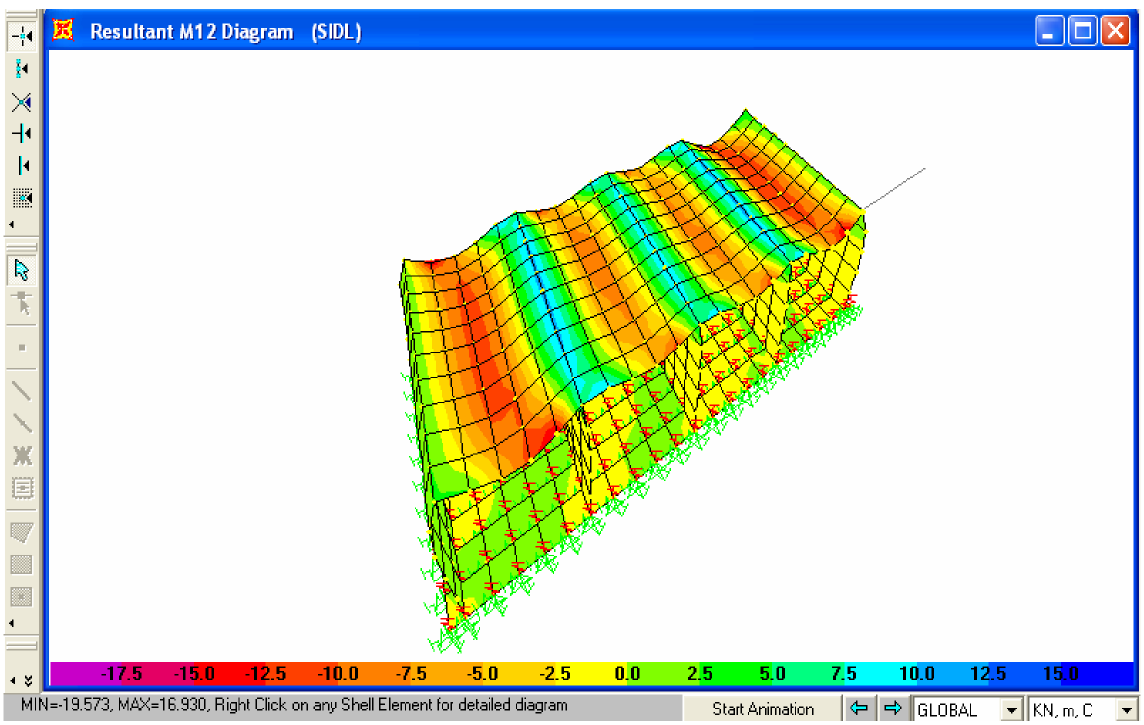



Fig 6.18 Torsional moment diagram for top slab and its deflected shape for super imposed dead load case

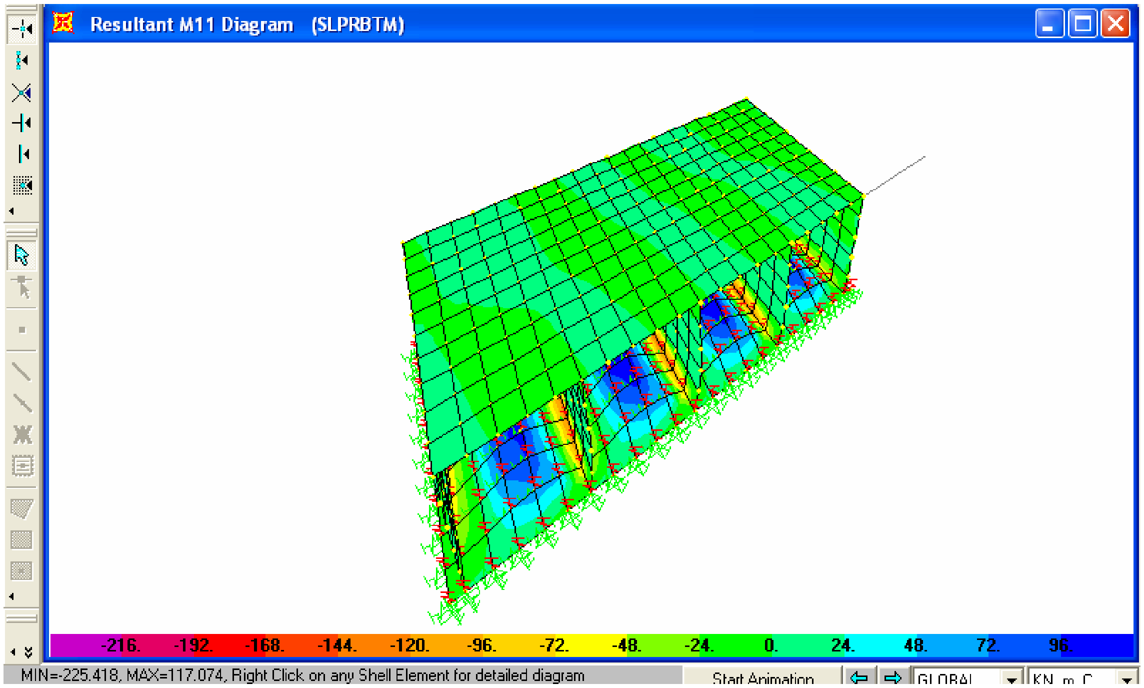



Fig 6.19 Longitudinal moment diagram for top slab and its deflected shape for soil pressure from bottom case

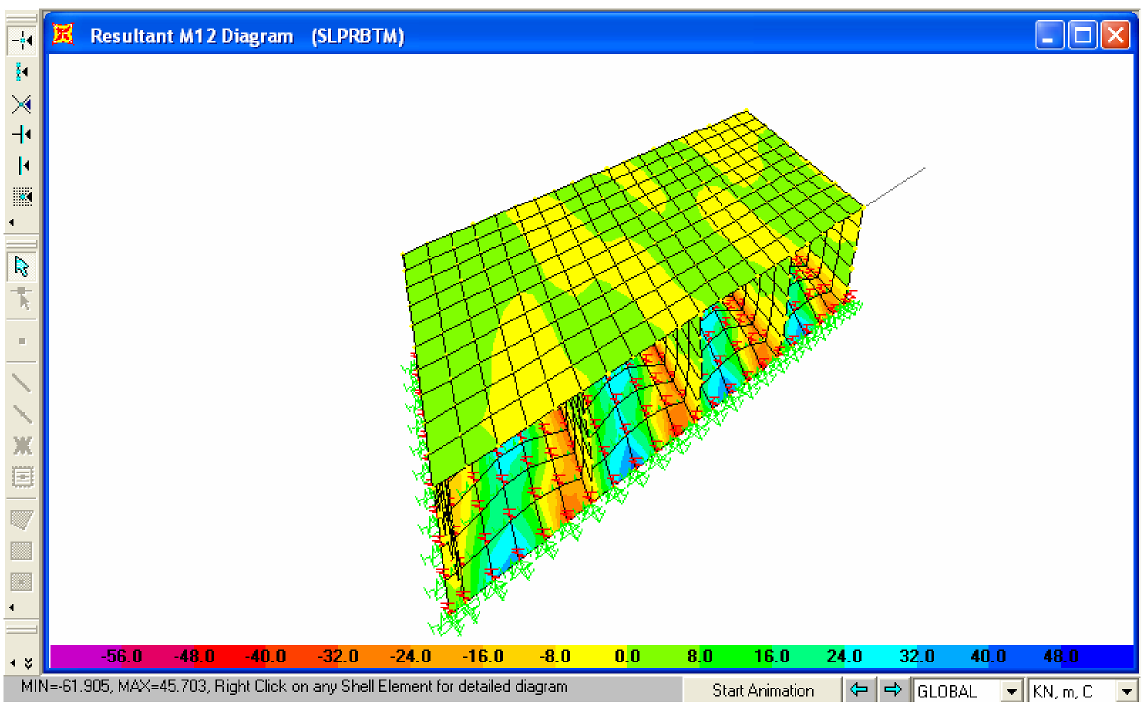



Fig 6.20 Torsional moment diagram for top slab and its deflected shape for soil pressure from bottom case

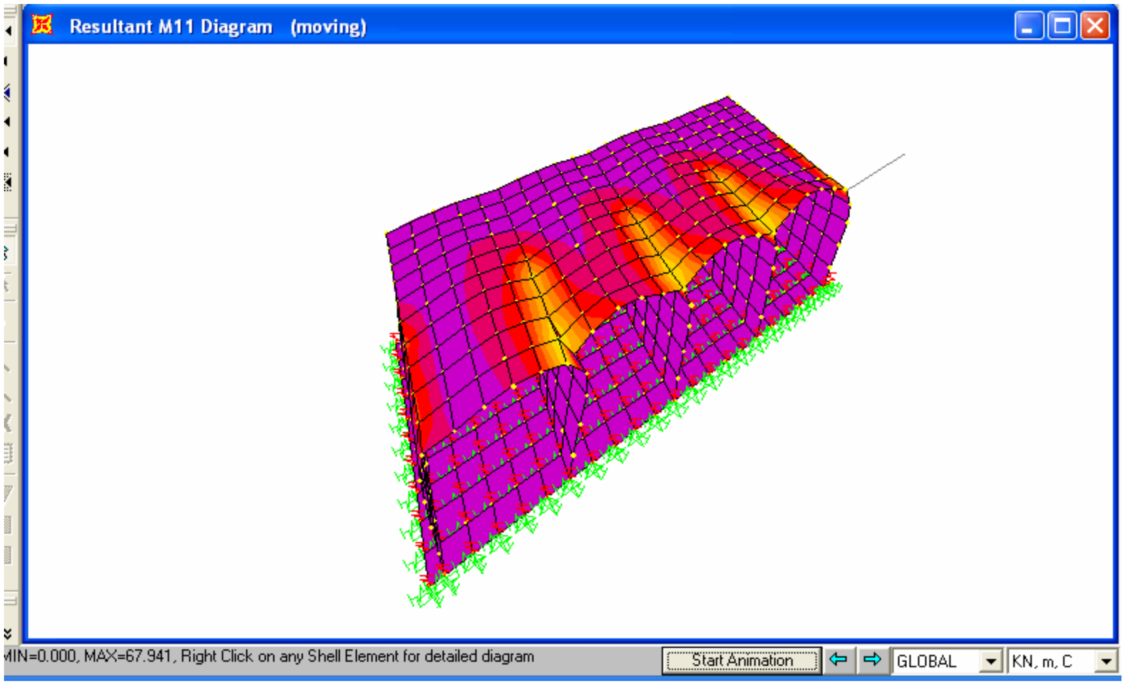



Fig 6.21 Longitudinal moment diagram for top slab and its deflected shape for live load (class AA tracked vehicle) case

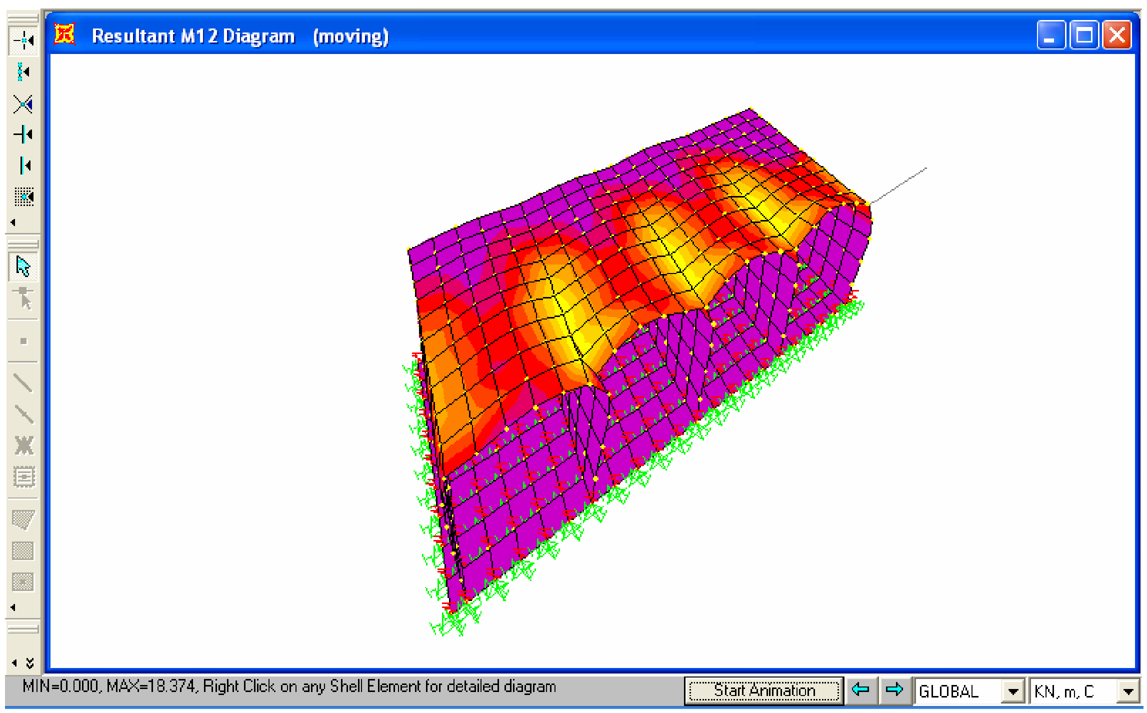



Fig 6.22 Torsional moment diagram for top slab and its deflected shape for live load (Class AA tracked vehicle) case

Table 6.1 Results of axial load, longitudinal and transverse moments for designing of walls

| Walls | Axial load in kN | Longitudinal moment in kNm | Transverse moment in kNm |
|---|---|---|---|
| 1 | 295 | 56 | 15 |
| 2 | 600 | 116 | 29 |
| 3 | 606 | 122 | 32 |
| 4 | 603 | 118 | 33 |
| 5 | 309 | 57 | 17 |

Table 6.2 Results of 25 degree skew slab for designing of components

| Serial No. | Loading cases | Longitudinal Moment in kNm | Transverse Moment in kNm |
|---|---|---|---|
| 1 | Dead load | 29.89 | 10.38 |
| 2 | Super Imposed load | 83.07 | 16.93 |
| 3 | Moving load (Class AA tracked vehicle) | 67.95 | 18.38 |
| 4 | Step live load | 27.22 | 11.58 |
| 5 | Soil pressure from bottom | 117 | 45.70 |

# 7. DESIGNING OF BOX TYPE SKEW CULVERT

## 5.1 GENERAL

In the present chapter, designing of different components of box type skew culvert is given. The design contains top slab, bottom slab and vertical walls. For design of top slab and bottom slab worked out in separate excel work sheet. For designing of vertical walls carried out in excel work sheet.

For top and bottom slab effective depth found out and accordingly steel reinforcement provided. This sheet contains main steel provided on top slab along with transverse reinforcements and same for the bottom slab. For the slab design also shear is checked out.

Vertical wall is designed as a column by moment area transform method.

**Design of outer side wall of box considering as a column**

**Design Data :** **Wall 2**

Length of Pier = 1.000 m

Width of Pier = 0.45 m

Area of Pier @ base = 0.450 $m^2$

Modular Ratio = 10

Axial Thrust P = 60.00 tone

Bending Moment $M_L$ = 11.60 t-m Longitudinal Direction

$M_T$= 2.9 t-m Transverse direction

Permissible stresses in concrete = 84.94 $Kg/cm^2$

Permissible stresses in steel = -2039.28 $Kg/cm^2$

Clear cover = 50 mm

Dia. Of Bar = 25 mm

Effective cover 62.5 mm = 6.25 cm

Area of steel provided in comp. flange = 20.00 $cm^2$ For ML

Area of steel provided in Tension flanges = 35.00 $cm^2$

Area of steel provided in comp. & Tension flan 20.00 $cm^2$ For MT

35.00 $cm^2$

| N - A | Stresses |
|---|---|
| 0.00 | 49.60 |
| 16.42 | -156.97 |

% of steel = 2.44

Assume neutral axis from extreme compression fibre in c 14.845

**Step 1**

Assume 20.000 $cm^2$ of tor steel uniformly distributed along the Tension & comp. flanges.

**Step 2**

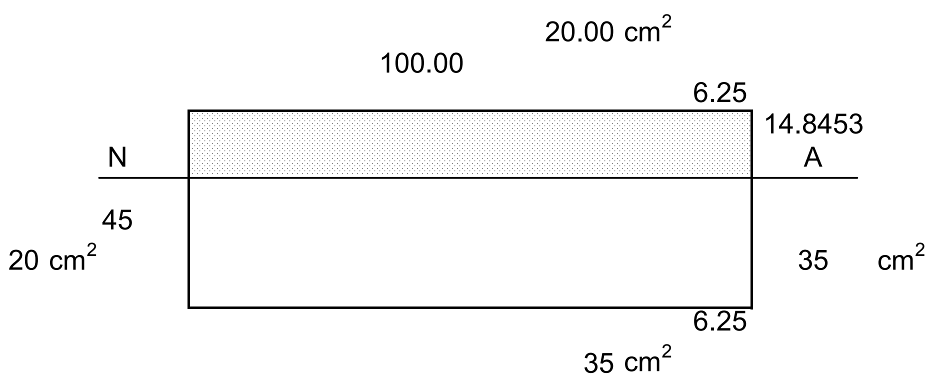
Assume neutral axis 14.8453 cm from extreme compression fibre.

**Step 3** Effective area :

Equivalent length of Pier :

L * 0.45 = 0.450 Where,

L = 1.000 m



| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Concrete Area in comp. | | | | Area of Steel in Comp. | | |
| Aeff = | 100.00 | x | 14.845289 | + | 9 | x | 20 | |
| | | | Area of Steel in Tension | | | | | |
| | + | 10 | x | 35 | 1 | x 10 x | 55 | |
| | **A1** | | **A2** | | **A3** | | | |
| = | 1484.53 | + | 180 | + | 350 | +550.00 | | |

Aeff = 2564.53 $cm^2$

**Step 4**

Distance of Cg eff. From physical centroid of whole section is,

$$e' = \frac{A.X}{Aeff}$$ (By taking moments of effective areas about physical centroid)

where , A1 = 1484.53 $cm^2$ $\quad e1 = \dfrac{45 - 14.85}{2}$

= 15.08 cm

A1 * e1 = 1484.53 x 15.08 = 22382.77 $cm^3$

A2 = 180 $cm^2$ $\quad e2 = \dfrac{45}{2} - 6.25$

= 16.25 cm

A2 * e2 = 180 x 16.25 = 2925 $cm^3$

A3 = 350 $cm^2$ $\quad e3 = \dfrac{45}{2} - 6.25$

= 16.25 cm

A3 * e3 = 350 x 16.25 = 5687.5 $cm^3$

$$e' = \frac{A1 * e1 + A2 * e2 - A3 * e3}{Aeff}$$

$$e' = \frac{22382.77 + 2925 - 5687.5}{2564.5289}$$

e' = 7.65 cm

$$e\text{-}e' = \frac{M}{P} - e' = \frac{1160.00}{60.00} - 7.65$$

e-e' = 19.33 - 7.65 = 11.68 cm

**Step 5**

I eff = I1self + A1.$y1^2$ + A2.$y2^2$ + A3.$y3^2$

$$I1self = 100.00 \times \frac{14.845289^3}{12} = 27264 \ cm^4$$

A1 * $y1^2$ : where , A1 : 1484.53 $cm^2$ $\quad$ y1 = 15.08 - 7.65

= 7.43 cm

A1 *$y1^2$ = 1484.53 x $7.43^2$

= 81880.98 $cm^4$

$A2 * y2^2$ : where , A2 = 180 $cm^2$ y2 = 16.25 - 7.65
= 8.60 cm

$A2 * y1^2$ = 180 x $8.60^2$

= 13310.84 $cm^4$

$A3 * y3^2$ : where , A3 = 350 $cm^2$ y3 = 16.25 + 7.65
= 23.90 cm

$A3 * y3^2$ = 350 x $23.90^2$

= 199934.1 $cm^4$

*Reforcement for Transverse Moment :*

I self = 1 x 200 x $\frac{32.50^2}{12}$ 2

1 x 350 x 32.50
12

= 48411.46 $cm^4$

$A * y^2$ : where , A = 200 $cm^2$ y = 22.5 - 7.65
= 14.85 cm

$A3 * y3^2$ = 200 x $14.85^2$ x 1
350 x $14.85^2$ x 1

= 121277.03 $cm^4$

Ieff = 27264 + 81881.0 + 13310.8 + 199934
+ 48411.5 + 121277.0

Ieff = 492078.1 $cm^4$

**Step 6**

Distance of neutral axis below CG eff.

$$\frac{I\ eff}{A\ eff\ (e-e')} = \frac{492078.1}{2564.53 \times 11.68}$$

= 16.42 cm

Compared to (e' + Assume N. A. from C.G.)

= 7.65 - 7.6547111

= 0.00 cm < 16.42 cm

**Step 7**

(I) Max. compressive stress in concrete

$$= \frac{P}{A\ eff} + \frac{P\ (e-e')\ (D/2 - e')}{I\ eff}$$

$$= \frac{60000}{2565} + \frac{60000 \quad 11.68 \quad 22.5 \quad 7.65}{492078}$$

= 23.396 + 21.15

= 44.549 $Kg/cm^2$ < 84.94 $Kg/cm^2$ **o.k.**

(ii) Max. tensile stress :

$$= m\ \left\{\frac{P}{A\ eff} - \frac{P\ (e-e')\ (d - D/2 + e')}{I\ eff}\right\}$$

where , m = 10     P / Aeff = 23.396 $Kg/cm^2$

| | | | | | |
|---|---|---|---|---|---|
| P (e-e') (d - D/2 + e') | 60000 | 11.68 | 38.75 | 22.5 | 7.65 |
| I eff | | | 492078 | | |

= 34.05 $Kg/cm^2$

= 10 x 23.396 - 34.05

= -106.5 $Kg/cm^2$ > -2039.3 $Kg/cm^2$ **o.k.**

**Stresses from Transverse Direction :**

Transverse Moment = 2.90 t-m

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $I_T$ = | 14.845289 | x | $\frac{100.00^3}{12}$ | | | | | |
| + | 35 | x | $\frac{100.00^2}{12}$ | x | 10 | x | 2 | |
| + | 20 | x | $43.75^2$ | x | 10 | x | 1 | |
| + | 35 | x | $43.75^2$ | x | 10 | x | 1 | |
| $I_T$ = | 1237107.4 | + | 583333.33 | + | 382813 | + | 669922 | |

= 2873175.1 $cm^4$

(I) Compressive stress in concrete

$$fc = \frac{290000 \times 100.00}{2873175.1 \times 2}$$

= 5.047 $Kg/cm^2$

(ii) Tensile stress :

ft = m * fc = 10 x 5.047

= -50.467 $Kg/cm^2$

Net stresses in Pier :

fc = 44.549 + 5.047

= 49.596 $Kg/cm^2$ < 84.94 $Kg/cm^2$ **o.k.**

ft= -106.502 + -50.467

= -156.969 $Kg/cm^2$ > -2039.28 $Kg/cm^2$ **o.k.**

**Reinforcement calculation :**

***Vertical steel***

Vertical steel required on comp. side = 20 $cm^2$

Vertical steel required on tension. side = 35 $cm^2$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Provide , | 20 mm Φ | bars @ | 150 mm c/c | on comp fa | $Ast_{provided}$= | 21 | $cm^2$ |
| Provide , | 25 mm Φ | bars @ | 125 mm c/c | on tension | $Ast_{provided}$= | 39 | $cm^2$ |

# 8. PARAMETRIC STUDY

## 8.1 GENERAL

Parametric study done for the box type multibarrel skew culvert.

## 8.2 PARAMETRIC STUDY FOR DIFFERENT SOIL BEARING CAPACITY

From the analysis of problem formulation chapter, parametric study for different soil bearing capacity is considered. As base slab is supported on elastic foundation so that soil stiffness provides more flexibility to the structure. Considering different soil bearing capacity of 100 kN/$m^2$ , 150 kN/$m^2$, 200 kN/$m^2$, 250 kN/$m^2$, 300 kN/$m^2$. It is shown in Fig 8.1

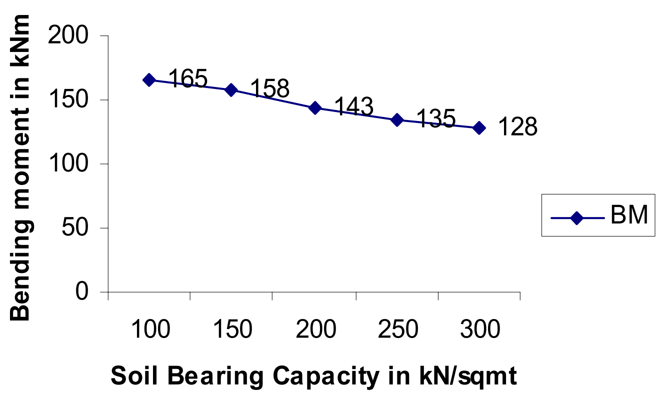



Fig 8.1 Parametric study for various soil bearing capacity

In the base slab considering area springs and providing different soil stiffness to the structure in kN/$m^3$. As we have seen from the result that as we increase the SBC, the bending moment decreases. As we move from the SBC of 100 kN/$m^2$ to 300 kN/$m^2$ bending moment decreased up to 23 percentage. So on actual case if we are incorporating soil structure interaction with considering actual bearing capacities on field data, the value of bending moment will decreases. So ultimately thickness of raft slab is decreased and provided steel also decreased so that project becomes economical.

## 8.3 PARAMETRIC STUDY CONSIDERING BASE SLAB RIGIDITY

Normally base slab support condition, outer wall is considered as fixed and internal wall considered in hinged condition. So considering base slab as parameter two different support conditions will be considered. One support condition in which external wall having fixed support and internal walls having hinged condition while on the other hand whole base slab is resting on elastic foundation (Providing spring support) in which soil stiffness will be incorporated. It can be seen in Fig 8.2 Various load cases denotes on x axis. 1 denotes dead load, 2 denote super imposed dead load, 3 denotes soil pressure form bottom, 4 denotes live load, 5 denotes multi step live load.

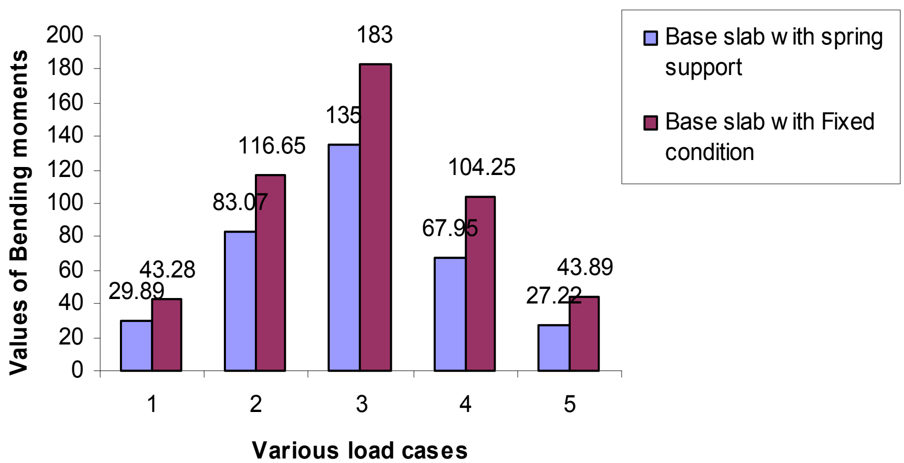



Fig 8.2 Parametric study considering base rigidity for bending moment

While comparing base slab resting on hinged & fixed condition with spring support we can seen from the result that bending moment reduce tremendously. Value of bending moment on hinged and fixed support condition is 183 kNm while on spring support condition 135 kNm. So bending moment reduced up to 28 percentages. So if we considered slabs on elastic foundation and incorporating soil structure interaction with soil stiffness bending moment reduces tremendously which reduces bending moment and decreases base slab thickness. Thus we can save concrete and steel cost by considering this soil stiffness and project becomes economical.

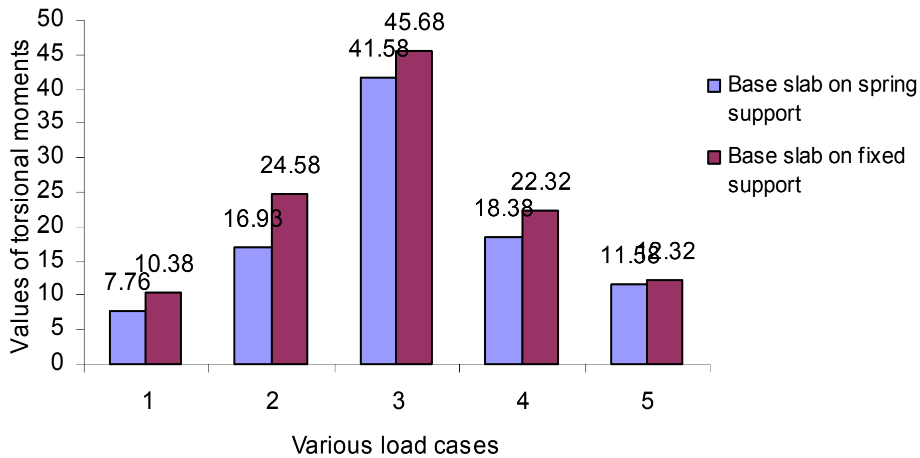



Fig 8.3 Parametric study considering base rigidity for torsional moment

Above graph shows the comparison of base slab considering on spring support and hinged & fixed condition supports. The value of graph shows that if we are considering soil stiffness then torsional moment also decreases 9 percentages which will be reduce torsional moment at the corners and so that less steel provided and project becomes economical.

## 8.2 PARAMETRIC STUDY DIFFERENT SKEW ANGLES:

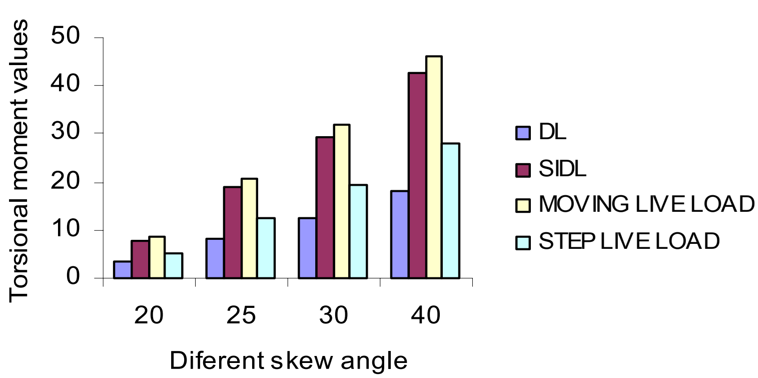



Fig 8.4 Parametric study of various skew angles for twisting moment

As we are considering 25 degree of skewness on problem formulation. Fig 8.4 denotes as keeping all the dimensions same i.e. height, width and span keeping constant only various the different skew angles, variation on twisting moment can be seen. All four load cases considered dead load, super imposed dead load, live load of class AA tracked vehicle and multi step live load.

Fig 8.4 shows as skew angles increased the value of torsional moment is also increased from 20 degree to 25 degree the value of twisting moment will increased up to 48 percent, from 25 degree to 30 degree the value of torsional moment will increased up to 35 percentage same way from skew angle of 30 degree to 40 degree the value of twisting moment will be increased up to 32 percentage.

# 9. CONCLUSION

## 9.1 CONCLUSION

Based on above study following conclusions are drawn:

- Analysis was carried out by two different methods. By performing the conventional approach of design where for the base slab, outer wall is supported on fixed condition and internal walls are supported on hinged condition (rigid condition), and for whole base slab resting on spring support (Flexible condition), designing moment at base will be reduce on the flexible condition.
- For the flexible condition where slabs resting on elastic foundation and incorporating soil structure interaction with soil stiffness, bending moment reduces tremendously. This reduces the thickness of base slab and so that less concrete and less steel will be provided and project becomes economical.
- Twisting moment for the skew slab at the corners is influenced by the skew angle. As the skew angle increases twisting moment at the corners are increased.
- In the base slab considering flexible condition and providing different soil stiffness to the structure, result shows that as by increasing the SBC, the bending moment will decrease. So on actual case by incorporating soil structure interaction with considering actual bearing capacities on field data, the value of bending moment will decreases.

## 9.2 FURTHER SCOPE OF WORK :

- Perform dynamic analysis of skew type box culvert
- Angle of skew can be increased up to 60 degree
- Meshing size can be changed for the further analysis.
- Dimension of box can be changed by changing the height of the box.
- Dimension of box (length and width of box) can vary.
- Perform analysis for more than four barrels and compare bending moment and twisting moment.
- Prepare a computer programme for the multibarrel box culvert.

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