JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

CONSTRUCTION OF BRIDGES IN SEISMIC AREAS

Mr.Bhushan Kumar Verma[1], Mrs. Gargi Danda De[2]
M.Tech Scholar[1], Head of the Department[2]

Shri Rawatpura Sarkar University Raipur Chhattisgarh

Abstract: The origin of any bridges project arises from a need to unite two realities that are separated by an existing physical barrier. It has a beginning and an end, and the path in the air that unites them can be solved by an infinite number of solutions. In each project, starting with a blank sheet, a journey takes place that goes through a creative process, a continuous back and forth from idea to detail, from the general to the particular, in an exciting game in search of a solution, in search of beauty. This process is subtle, yet has the power to excite and move us, an apparently simple harmony, behind which lies great complexity. Everything has to converge, and the forms and nuances should be balanced in a such a way that everything appears just as it should be nothing missing, yet nothing superfluous, the perfect balance of form and function.

1. INTRODUCTION

Structural conception of bridges is probably more strictly related to function, aesthetics and economics than in any other type of structures. Therefore, bridges give the impression of being simple structures whose seismic response could be easily predicted. Accordingly, seismic design of bridges in India have received relatively little attention in the past, maybe because we have not been exposed to a single very strong event for a long time, or because of our inert behaviour. Seismic calculation of bridge structures in seismic areas is a significant part of the overall calculations with the aim of proving the mechanical resistance and stability. A seismic bridge design is of special importance because its serviceability during and after the earthquake depends on it. In seismic area so an earthquake influence on bridge structure is often relevant for the choice of bridge type structure, computation model, element dimensions, material consumption, detail solutions and for the overall bridge mechanical resistance and stability. basic different codes of practice used for design of bridge -
IRC -5 2015 Section - I General Features of Design (Eighth Revision)
IRC -6 2017 Section: II loads and load combinations (Seventh Revision)
IRC -21 2000 Section: III Cement Concrete (Plain and Reinforced) (Third Revision)
IRC -22 2015 Section: VI Composite Construction (Limit State Design) (Third Revision)
IRC -78 2014 Section: VII Foundation and Substructure (Revised Revision)
IRC-112-2011 Concrete Road bridges
IRC: SP:114-2018 Guidelines for seismic design of road bride

2. LITERATURE REVIEW

Kolay et al.

Conventional seismic design for bridge abutment uses pseudo-static analysis methods based on the approach. However, these methods, originally developed for gravity type retaining walls, do not provide any rational basis for selecting appropriate seismic co-efficient of bridge abutments. Further, it is observed that the displacement at the abutment seat due to combined rigid body sliding and rotation of the abutment depends upon the yield acceleration.

Karantzikis1 et al.

have examined the impacts of soil-abutment interaction on seismic examination and structure of integral bridges. Past experience and late research show that soil-abutment interaction assumes a significant job on seismic reaction of bridge structures. Abutments draw in an enormous bit of seismic forces, especially in the longitudinal heading. In this manner, cooperation of backfill soil at abutments must be thought of. A structure driven philosophy to display the abutment stiffness for either linear or nonlinear investigation, considering the backfill and pier foundation, is introduced. An iterative structure strategy of progressive linear dynamic response examinations that considers the non linear conduct of the abutments brought about by backfill soil yielding is created. Likewise, a non-linear static investigation of bridge soil framework is led. A three-span bridge with monolithic abutments is chosen to exhibit the proposed systems. Parametric examinations show that, if bridge is dissected with the proposed technique rather than a straightforward strategy that disregards backfill stiffness reduction, the moments and determined force at the pier are more noteworthy by 25%-60% and the displacements by 25%-75%, contingent upon soil properties.

Carlo et al.

has examined the impact of soil-structure interaction consequences for the seismic reaction of bridge pier with circular shallow foundation. The pier was displayed as linear beam components, circulated masses and mass corresponding viscous damping. The material nonlinearity was considered in an inflexible plastic hinge with solidifying at the base of pier. The soil was admired as a linear space half space, displayed as lum ped parameter. The examination indicated that the soil structure interaction impact builds the time of vibrating structures, increased the displacements at the pier top and diminishes the base shear values. The diminishing in base shear demonstrates traditionalist plan while increased displacement at the pier top underscores careful design of bearings and connections.

3. PROBLEM IDENTIFICATIONS

Seismic Effects on Bridges

The seismic effects on bridges can be classified as
(i) Seismic displacements
(ii) Pier failure
(iii) Expansion Joint failure
(iv) bearing failure
(v) Abutment slumping and
(vi) foundation failure,
(vii) Partial and complete collapse of bridges due to soil liquefaction.

In horizontally curved superstructure, transverse movement of superstructure translates into longitudinal movement at a joint, which could lead to unseating of deck. In skewed bridges, the centre of mass usually does not coincide with centre of stiffness, which causes rotation of superstructure and large displacements at supports. Also, bridges with large skew angle could rotate and unseat the superstructure under seismic action.

Under earthquake action the bridge decks are subjected to transverse or longitudinal displacement depending on the direction of earthquake. In some situations when sufficient bearing seat width is not provided, the unseating of deck take place. The asynchronous movement of two adjoining spans during earthquake leads to pounding action and cause damage to deck /beam ends, if adequate separation gaps are not provided.

Bridge piers designed without ductile detailing are prone to spalling of cover concrete, buckling of longitudinal reinforcement and crumbling of core concrete. Effect of vertical acceleration, in near field region, often changes the failure mode of bridge pier from flexure to shear. Shear failureof bridge piers may be due to inadequate or no ductile detailing or improper/ premature curtailment of longitudinal reinforcement or design not based on capacity design methods.

Expansion joints are subjected to compression or tension failure during earthquake. When superstructure is subjected to substantial lateral and longitudinal force during earthquake, it can lead to failure of bearing or of connections to substructure.

During earthquake slumping of abutment fill and rotation of abutments occur in case the abutment fill is incompletely consolidated. Abutment back wall may get damaged due to superstructure impact. When bridges are founded on soft or liquefiable soils, amplification of structural vibration response under seismic action had resulted in unseating of bridge deck, especially in simply supported spans.

4. OBJECTIVE OF PRESENT STUDY

- To predict the probable behaviour of solid slab bridge with wall type pier in seismic events.
- To carryout seismic analysis using linear static analysis method.
- To determine the displacement and forces of the structure.

5. Methodology

Following is required for design bride

5.1 ACQUISITION OF DATA

- ➢ Site selection survey
- ➢ Topographical survey
- ➢ Geotechnical Investigation
- ➢ Hydrological Data

Site selection survey

- ➢ A straight reach of river.
- ➢ Steady river flow without whirls and across currents.
- ➢ A narrow channel with firm banks.
- ➢ Sustainable high banks above high flood level on each side.
- ➢ Rock or other hard in-erodible strata close to the river bed level.
- ➢ Proximity to a direct alignment of the road to be connected.
- ➢ Absence of sharp curves in the approaches.
- ➢ Absence of expensive river training works.
- ➢ Avoidance of excessive underwater construction

Topographical survey

- ➢ Topographical survey was carried out for detailed engineering survey of the proposed bridge site. Total station, reflector and measuring tape were usually used for detailed survey.

- After consultation with the technical personnel and the local villagers and as directed by the river morphology; an axis joining line joining left bank and right bank was fixed.
- The bridge site detailing area covers a suitable region along the length of river both upstream and downstream. It also covers left and right banks along the existing approach roads**.**

Geotechnical Investigation

- Geotechnical investigation is one of the major parts of the project work for the design of the proposed bridge. Geotechnical investigation works includes core drilling, test pitting, visual investigation at site. For project this was not quite possible. Thus, the geotechnical data were adopted suitable with locality and as per the similar works done in the region. However, carried out the sieve analysis of the bed soil, finding out its mean size, specific gravity and water content.
- For the high-level bridges, a vertical clearance should be allowed between the H.F.L, and the lowest point of the superstructure. This is required to allow for any possible error in the estimation of the H.F.L., and the design discharge. It also allows floating debris to pass under the bridge without damaging the structure.

Hydrological Data

Geotechnical the Hydrological data was acquired from the secondary sources and the calculation of maximum discharge of the river was calculated using the following method-

A) Rational method :

A rational formula for flood discharge should take into account the intensity, distribution and duration of rainfall as well as the area, shape, slope, permeability and initial wetness of the catchment (drainage basin). The area of the catchment is a major contributing factor for the runoff. The shape of the catchment affects the peak discharge, long and narrow basins yielding less than pear shaped basins. Steep slopes result in shorter time of concentration than flatter slopes. M.any complicated formulae are available in treaties on hydrology.
A typical rational formula is:
Q = AIoλ
Where, Q =maximum flood discharge in m^3 per second
A =catchment area in square kilometers
Io =peak intensity of rainfall in mm per hour
λ = a function depending on the characteristics of the catchment in producing the peak runoff

$$= \frac{\mathbf{0.56\,Pf}}{\mathbf{tc+1}}$$

tc = time of concentration in hours
= (0.87*L3/H)0.385
L = distance from the critical point to the bridge site in kilometers
H = difference in elevation between the critical point and bridge site in kilometers
P = coefficient of run-off for the catchment characteristics.
f = a factor to correct for the variation of intensity of rainfall Io over the area of the catchment.

B) Area velocity method :

The area velocity method based on the hydraulic characteristics of the stream is probably the most reliable among the methods for determining the flood discharge. The velocity obtaining in the stream under the flood conditions is calculated by Manning’s or similar formula: Manning’s formula is used here. The discharge Q is given by equation:

$$\mathbf{Q = A \times v}$$

Where, Q=Discharge in m^3/s

A = Wetted area in m^2
v = Velocity of flow in m/s
$= (1/n)\times R^{2/3}S^{1/2}$
n = manning's coefficient calculated from table
S = slope of the stream
R = Hydraulic mean depth in meters

$$= \frac{\text{Wetted Area}}{\text{Wetted Perimeter}}$$

C) Inglis Formula :

This formula is based on the flood data of catchments the peak flood Q in m^3/s is expressed as

$$\mathbf{Q=\frac{124A}{\sqrt{A+10.4}}}$$

Where, A=catchment area in square km

D) WECS formula :

In Nepalese context, Water and Energy Commission Secretariat (WECS) has developed empirical relationships for analyzing flood of different frequencies. The discharge formula for 100 year of return period is given by:

$$\mathbf{Q = 14.63(A_{3000}+1)^{0.7342}}$$

Where, Q = Maximum discharge in m^3/s
A_{3000} = Basin area below 3000 m elevation in square kilometers

E) Ryves formula (1884) :

According to Ryves, maximum discharge is given by:

$$\mathbf{Q = C_R\times A^{2/3}}$$

Where, Q = maximum discharge in m^3/s
A = Catchment area in sq. km.
C_R = Ryves coefficient

This formula was originally developed for Tamil Nadu region, is in use in Tamil Nadu and parts of Karnataka and Andhra Pradesh. The values of C_R recommended by Ryves for use are

C_R = 6.8 for areas within 80 km from the east coast
= 8.5 for areas which are 80-160 km from the east coast
= 10.2 for limited areas near hills

F) Dickens Formula (1865) :

Dickens formula for discharge calculation is given by:

$$\mathbf{Q = C_D\times A^{3/4}}$$

Where, Q = maximum flood discharge (m^3/s)
A = Catchment Area (km^2)
C_D=Dickens constant with the value of 6 to 30

Following are some guidelines in selecting the value of C_D:

C_D= 6 for North-Indian plains
= 11-14 for North Indian Hilly Regions
= 14-28 for Central India
= 22-28 for Coastal Andhra and Orissa

For actual use, the local experience will aid in the proper selection of C_D. Dickens formula is used in the central and northern parts of the country.

G) Fuller's Formula (1914) :

Fuller's formula is derived for catchments in USA are a typical empirical method which is given by:

$$\mathbf{Q = C_f \times A^{0.8}(1+0.8\log_{10}T)}$$

Where, Q=maximum discharge in m^3/s

C_f = a constant which varies from 0.18 to 1.88

T = Return period in yrs.

A = Catchment Area in sq. km.

For Nepal, the value of C_f is taken as 1.03.

H) Modified Dicken's Formula :

Using Dicken's method, the flood discharge can be calculated by using the formula:

$$\mathbf{Q = C_T \times A^{0.75}}$$

Where, Q= maximum flood discharge in m^3/s

C_T = Modified Dicken's constant proposed by the Irrigation Research Institute, Roorke, India, based on frequency studies on Himalayan rivers which is computed as

$C_T = 2.342\log(0.67T)\log(1185/P) + 4$

$P=100\times (a+6)/(A+a)$

a= perpetual snowfall area in sq. km.

T=Return period in years

Calculation of Linear Waterway, Scour Depth and High Flood Level (HFL)

a) Calculation of linear waterway :

When the water course to be crossed is an artificial channel for irrigation or navigation, or when the banks are well defined for natural streams, the linear waterway should be full width of the channel or the stream.
For large alluvial stream with undefined banks, the required effective linear waterway may be determined using Lacey's formula:

$$\mathbf{P = C\sqrt{Q}}$$

Where, P = the effective linear waterway in meters

Q = the designed maximum discharge in m^3/s

C = a constant usually taken as 4.8 for regime channel, but may vary From 4.5 to 6.3 according to the local conditions

The effective linear waterway is the total width of the waterway of the bridge minus the mean submerged width of the piers and their foundation down to the mean scour level. It is not desirable to reduce the linear waterway below that for regime condition. If a reduction is affected, special attention should be given to the afflux and velocity of water under the bridge. With reduced waterway, velocity would increase and greater scour depths would be involved, requiring deeper foundations. Thus any possible saving from a smaller linear waterway will be offset by the extra expenditure on deeper foundations and protective works. In view of the deficiencies of the assumptions made in the computations for design discharge and for the effective waterway by Lacey's formula, it is often prudent to adopt the full natural width for the linear waterway, taking care not to succumb to the trap of overconfidence in apparently precise methods of calculation

b) Calculation of scour depth :

Scour may be defined as the removal of material from the bed and banks of streams during the passage of flood discharge, when the velocity of the stream exceeds the limiting velocity that can be withstood by the particles of the bed material. If the bridge and its approaches do not constrict the natural flow, the scour will be small. On the contrary, when the designer attempts to reduce the waterway, severe scour usually results during the extraordinary flood conditions.

The scour is aggravated at the nose of the piers and bends. The maximum depth of scour should be measured with reference to existing structures near the proposed bridge site, if this is possible. Such soundings are best done during or immediately after the flood. Due allowance should be made in the observed values for additional scour that may occur due to design discharge being greater than the flood discharge for which the scour was observed, and also due to increased velocity due to obstruction of flow caused by the construction of bridge. When the above practical method is not possible, the mean depth of scour may be computed by the given equation for natural streams in alluvial beds:

$$\mathbf{d_{sm} = 1.34\left(\frac{D_b^2}{K_{sf}}\right)^2}$$

Where, d_{sm} = mean depth of scour below HFL in meters
D_b = discharge in m^3/s per meter width, obtained as the toal design
Discharge divided by the effective linear waterway
K_{sf} = silt factor for a representative sample of the bed material, as in the table below taken as 1.76 times the square root of the particle size in mm (weighted mean diameter of the particle determined as indicated in Appendix 2 of IRC:(5-1998).

In order to provide an adequate margin of safety, the design discharge for the above calculation is increased by 30%, 25 to 20%, 20 to 10% and 10% for catchment areas of below 500 sq. km, between 500 and 5000 sq. km, between 5000 to 25000 sq. km and over 25000 sq. km, respectively. When the effective linear waterway L is less than the regime width W, the value of d_{sm} computed from the above mentioned formula is to be increased by multiplying the same by the factor $(W/L)^{0.67}$.
The maximum depth of scour D below the HFL is to be taken as below:
$d_{smax} = 2.0d_{sm}$ for pier
$= 1.27d_{sm}$ with approach retained or lowest bed level whichever is deeper for abutment
$= 2.0d_{sm}$ for scour all round for abutment
$d_{smax} = 2.0d_{sm}$ in the right-angled bend
$= 1.75\ d_{sm}$ at the severe bend
$= 1.5\ d_{sm}$ at moderate bend
$= 1.27d_{sm}$ in a straight reach
The minimum depth of foundations below HFL is kept at 1.33 D for erodible strata. If the river is of a flashy nature and the bed does not submit readily to the scouring effects of the floods, the maximum depth of scour should be assessed by observations and not by the above calculations.
When a bridge is located close to the mouth of a river joining the sea, the possibility exists for the situation of the high tide opposing the flood discharge, resulting in heading up of the water level in the river. At the end of the high tide, the flood discharge may be relatively sudden, which may cause scour in excess of the values computed by the above equation to calculate the average scour depth. Considerable engineering judgements is required in assessing the required depth of foundation in such cases.**c) Calculation of afflux:**
Afflux is the heading up of water over the flood level caused by constriction of waterway at a bridge site. It is measured by the difference in levels of the water surfaces upstream and downstream of the bridge. Afflux can be computed from the equation as follows:

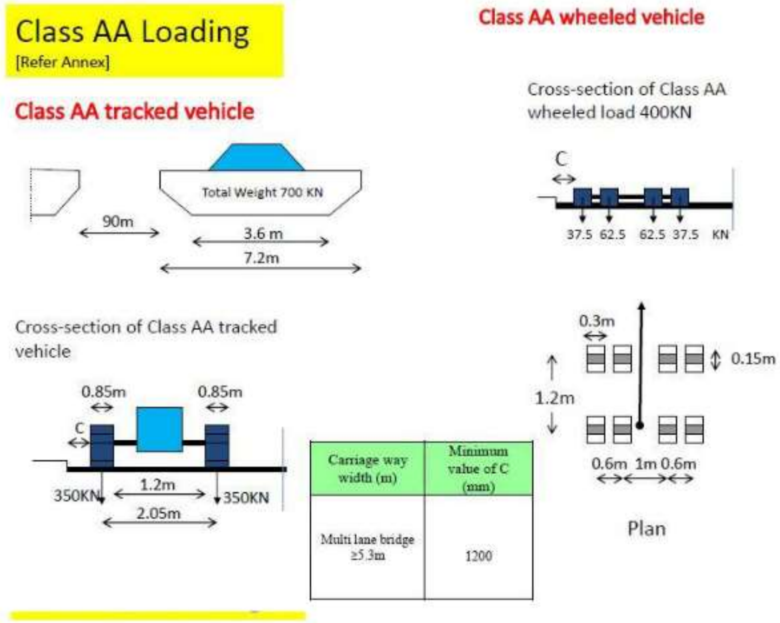
$$x = \frac{v^2}{2g}\left(\frac{L^2}{c^2 L_1^2} - 1\right)$$

Where, x=afflux
v=velocity of normal flow in the stream
g=acceleration due to gravity
L= width of stream at HFL
L_1= linear waterway under the bridge
c = coefficient of discharge through the bridge, taken as 0.7 for sharp
Entry and 0.9 for bell mouthed entry
The afflux should be kept minimum and limited to 1 to 1.5 m. afflux causes increase in velocity on the downstream side, leading to greater scour and requiring deeper foundations. The road formation level and

the top level of guide bunds are dependent on the maximum water level on the upstream side including afflux.
The increased velocity under the bridge should be kept below the allowable safe velocity for the bed material.

c) Calculation of High Flood Level (HFL) :

The HFL of river was determined using Manning’s equation and cross sectional drawing of river at bridge axis through iterative procedure.
Finally, with all the collected and computed data, the design of the bridge was done as per the prevailing Bridge codes .



Carriage way width (m)	Minimum value of C (mm)
Multi lane bridge ≥5.3m	1200

5.2 LOADING IRC LOADS FOR THE BRIDGE

According to IRC: 6-2014, road bridges and culverts are classified on the basis of loadings that they are designed to carry.

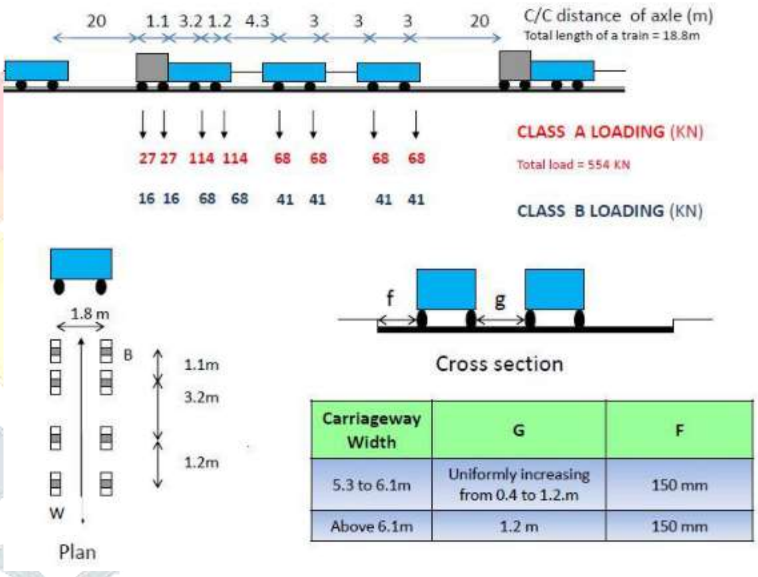
IRC class AA loading

This loading is to be adopted within certain limits, in certain existing or contemplated industrial areas, and along certain specified highways and areas. Bridges designed for class

Loading should be checked for class A loading is considered in each lane.

IRC class A loading

This loading is normally considered on all in which dominant bridges and culverts are constructed. One train of class A loading is considered in each lane



Carriageway Width	G	F
5.3 to 6.1m	Uniformly increasing from 0.4 to 1.2.m	150 mm
Above 6.1m	1.2 m	150 mm

IRC class B loading

This loading is normally considered when the structure is temporary and for bridges in specified area. Structures with timber spans are to be regarded as temporary structures.

5.3 COMPONENTS OF BRIDGE

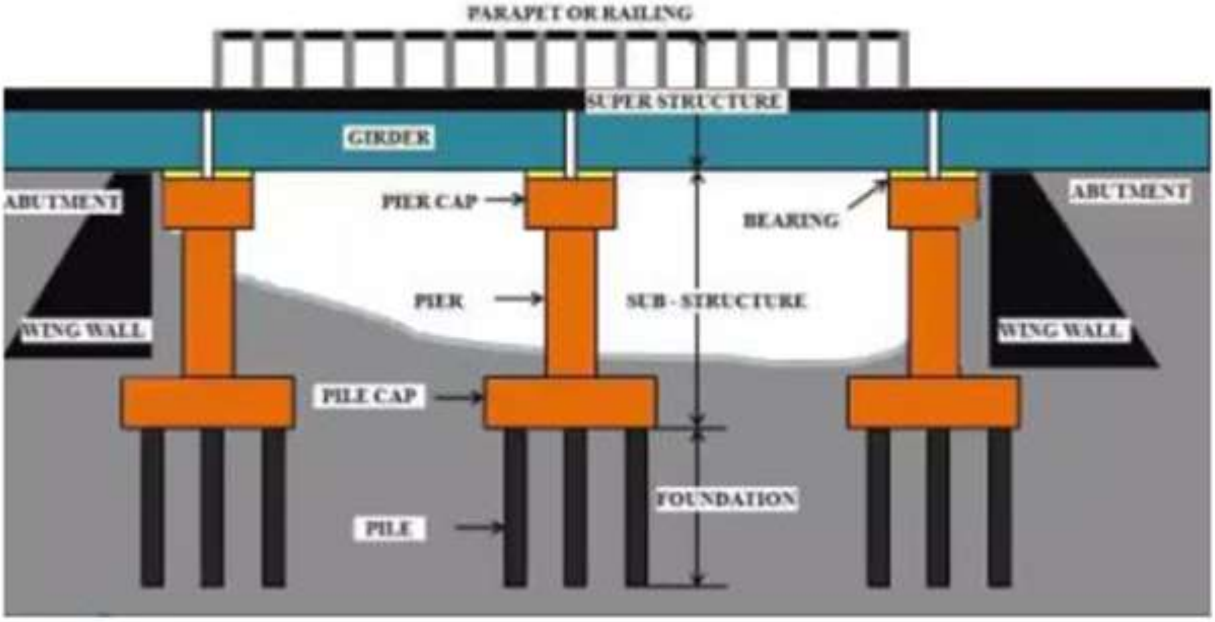


Fig :-5.1 Components Bridge

The major parts of a bridge,

A. Substructure
B. Superstructure
C. Adjoining structure

A. Substructure

The **structure** of the **bridge** below the level of **bearings** is known as the **Substructure.** It **consists** of the following.

The **function** of the **substructure** is to support the **superstructure components** and transmit their **loads safely** to the subsoil,

- **Abutments**

It is a **structure** mostly used for **bridges** and dams as a **substructure** at the ends of a **bridge span** or **dam** and on that **superstructure** is rest.

Bridge with a **single span** has two **abutments** that offer vertical and **lateral support**. It also plays the role of retaining walls to **resist** lateral **movement** of the earthen fill of the **bridge approach**.

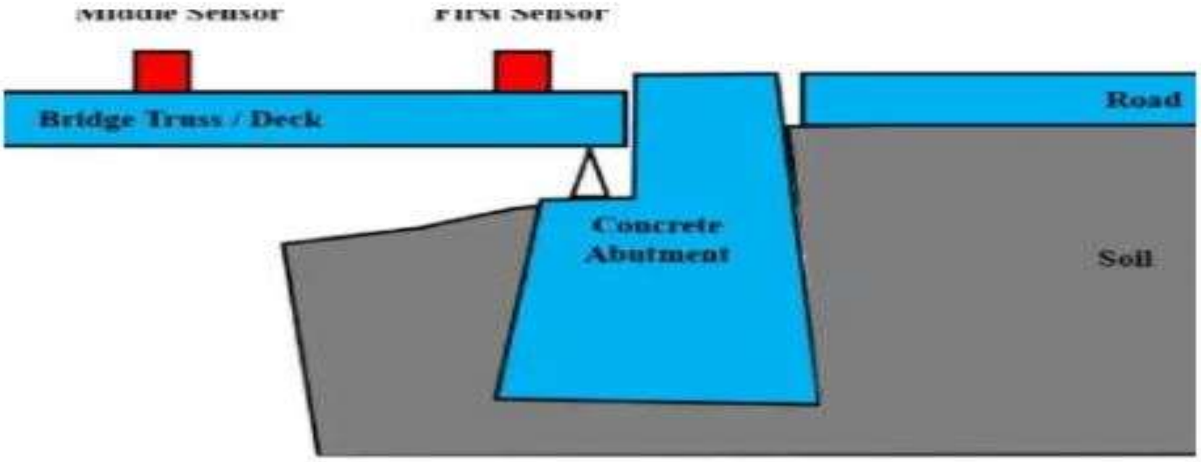


Fig :-5.2 Abutment of Bridge

The **abutment** can also be **defined** by the structure **supporting** one side of an arch, or **masonry** used to resist the **lateral forces**.

- **Piers**

Piers provide **intermediate** support between two **bridge spans**. Bridge piers mainly **support** the bridge superstructure **element** and transfer the load to the **foundation**.

Pier must be **strong** to handle the **horizontal** as well as lateral. **Piers** are **known** as **compression** members of the **bridge**.

- **Wing Walls**

It is one of the earth **retaining structures** in the bridge. They are **located adjacent** to the **abutments** and act as **retaining walls**.

Wing wall **retains soil for abutment, roadway,** and approach **embankment**, which can be at a **right angle** to the abutment or **splayed** at different **angles**.

B. Superstructure

The **components** of the **bridge** above the **bearing** are known as superst**ructures.**
It consists of the following.

- **Beams and girders**

Both have a **similar** function to support the **roadway** and prevent **bending**. Girder is also one type of **beam support**. Where loads are **heavy girders** are used instead of beam **support**.

Beam has a **rectangle** cross-section, whereas girders have composed of **I-shaped cross–sections** with two load-bearing **flanges** and a web for **stabilization**.

- **Bearing**

A **bearing** is provided between the **bridge girder** and the **pier cap**. The main **function** of bearing to allow **free movement** or vibration of the **top superstructure** and reduce effect **stress** to reach the **bridge foundation**.

Fig :-5.3 Bearing in Bridge

- **Parapet Wall and Handrail**

The **parapet** is one of the safety **components** of any bridge which **prevent** the vehicle from falling off where there is a **drop**.

It is also useful for **restricting** views, preventing rubbish from **passing** below, and **acting** as noise **barriers**.

- **Flooring**

Its top **surface** of bridge **roadway** on vehicle travel. It is made of **concrete** or **bituminous** road.

C. Adjoining Structures

It consists of the following:

- **Approaches**

It is **structured** constructed at the starting or **ending** of any **bridge**. Its main function is to provide **smooth** and easy **entry** or **exit** from the bridge.

- **Guard Stones**

They are used to **restrict** traffic on a **particular** lane or **sometimes** as road railing but are generally **positioned** to protect a specific **object**, such as a **corner** of a street or the side of a **gate**.

5.4 IDEALIZATION AND ANALYSIS OF BRIDGE STRUCTURE

The flow chart in Fig. 4 shows the steps adopted to carry out the study.

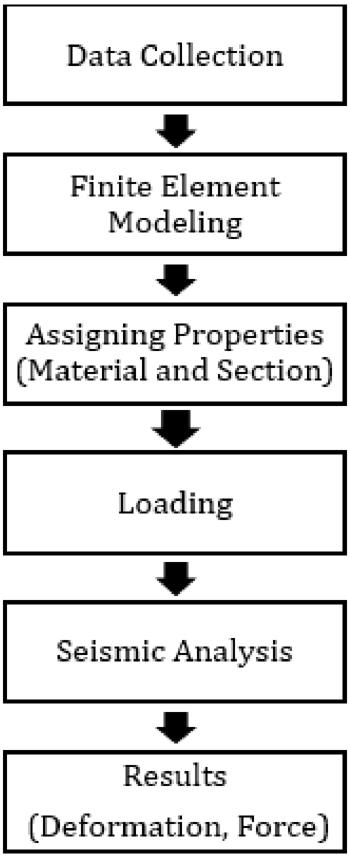


Fig -5.4: Flow Chart

6. BRIDGE INPUT AND ANALYSIS

Model

Modelling of a 120000 mm length bridge using MIDAS Civil software. Three spans are modelled as mentioned above according to the details and dimensions as detailed in Table 6.1 and the model is as shown below in Fig. 6.1,

Table -6.1 : Basic input data

Deck	
Grade of concrete	M30
Grade of steel	Fe500
Deck slab thickness	770 mm
Pier Cap	
Grade of concrete	M30
Grade of steel	Fe500

Depth	300 mm
Width	900 mm
Length	8400 mm
Pier	
Grade of	M25
Grade of steel	Fe500
Depth	4650 mm
Width	Top – 900 mm Bottom – 1130 mm
Length	Top – 8400 mm Bottom – 8630 mm

Fig -6.1: Bridge Model Isometric View

Loading

The loads assigned to the bridge are as per the guidelines provided in IRC: 6 - 2017 as follows,

Dead Load

It includes the self-weight of the structure including the components attached to the structural members such as crash barrier, etc. Wearing coat of 750 mm is input having 22 KN/m^3 unit weight.

Live Load

This is entered in the software in form of moving load. For two numbers of lanes, one lane of Class 70R or two lanes of Class A are applied.

Seismic Force

The bridge site lies in Seismic zone III with a seismic zone factor to be 0.16 and the condition of exposure has been considered as moderate. As the bridge site has rocky strata, the soil type is I. The damping ratio is adopted to be 5%. The importance factor and reduction factor is taken as 1.00.

The load combinations are generated from the software with reference to IRC 6.

Seismic Analysis

Seismic analysis of Deo River Bridge is done by using Ritz Vector Analysis followed by Response Spectrum method of linear dynamic analysis.

This method of analysis is used for the estimation of demands of structure whose response is dominated by more than one node, this method is used to estimate the demand of any structure. Linear dynamic analysis can be categorized further as response spectrum method and elastic time history method. Using response spectrum method, the big values of displacements and member forces in every mode can be identified by using smooth spectra which is common for numerous earthquakes. The response spectrum method allows to contemplate multiple mode shapes from the response of the structure. These mode shapes are combined for evaluation of the total response of the structure. Mode shapes ca be combined by using the methods such as Square Root of the Sum of the Squares (SRSS), Complete Quadratic Combination (CQC), etc. The Table 6.2 shows the response spectrum input generated by software after defining the seismic parameters as mentioned in 4.2.

Table -6.2: Response spectrum analysis input generated by software

Period (sec)	Spectral Data (g)
0	0.08
0.54	0.148
1.02	0.078
1.5	0.053
2.04	0.039
2.52	0.031
3	0.026
3.54	0.022
4	0.02
4.5	0.02
5.04	0.02
5.52	0.02
6	0.02

7. RESULT AND DISCUSSION

Tables 7.1, 7.2, 7.3 and 7.4 indicate the displacements in longitudinal and transverse directions whereas Tables 7.5 and 7.6 indicate the forces.

Table -7.1: Maximum displacements in longitudinal direction

Load case: RS: RS_X	
DX (Displacement component in GCS X)	151.22 mm
DY (Displacement component in GCS Y)	0.00 mm

Table -7.2: Maximum displacements in transverse direction

Load case: RS: RS_Y	
DX (Displacement component in GCS X)	0.00 mm
DY (Displacement component in GCS Y)	151.16 mm

Table -7.3: Displacement at pier top in longitudinal direction

Load case: RS: RS_X	
DX (Displacement component in GCS X)	0.153 mm
DY (Displacement component in GCS Y)	0.00 mm

Table -7.4: Displacement at pier top in transverse direction

Load case: RS: RS_X	
DX (Displacement component in GCS X)	0.153 mm
DY (Displacement component in GCS Y)	0.00 mm

Table -7.5: force in X direction

Load case: RS: RS_X	
FX (Nodal inertia force in GCS)	261.67 KN
FY (Nodal inertia force in GCS)	0.01 KN

Table -7.6: force in X direction

Load case: RS: RS_Y	
FX (Nodal inertia force in GCS X)	0.03 KN
FY (Nodal inertia force in GCS Y)	170.09 KN

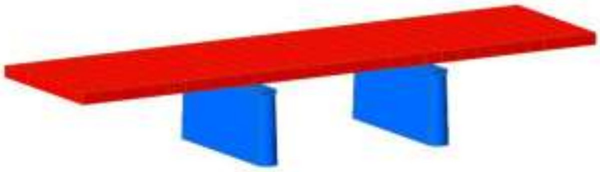


Fig -7.1: DY due to load case RS_X

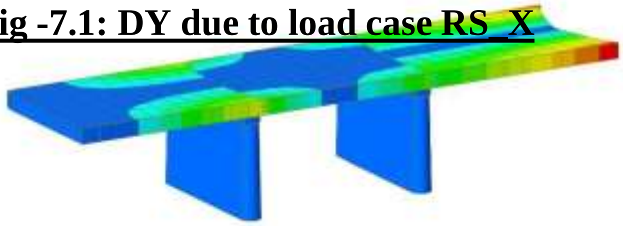


Fig -7.2: DX due to load case RS_Y

8. CONCLUSION

Construction of bridge in seismic areas is quite costlier than normal bridges. In seismic events for solid slab bridge, in both X and Y directions i.e., longitudinal and transverse direction displacement is maximum in superstructure than substructure. So, failure will occur initially at the deck level and thereafter other elements of bridge. Many examples in history gives lesions regarding the design of bridge to analysis of seismic is more important in the areas where seismic effects occur or probable to occur.

REFERENCES

[1] Ponnuswamy, S., Bridge Engineering, Tata McGraw Hill Publishing Co. Ltd., New Delhi,1986,pp.1-544.

[2] IRC 6-2010. "Standard Specifications and Code of Practice for Road Bridges". Section II. Loads and stresses. The Indian Roads Congress. New Delhi, India,

[3]. Michael J Karantzikis1 And Constantine C Spyrakos2; Seismic Analysis Of Bridges Including Soil-Abutment Interaction;2000

[4] G. DE Carlo, M. Dolce, and D. Liberatore, "Influence of soil-structure interaction on the seismic response of bridge piers," in Twelfth World Conference of Earthquake Engineering, 2000, pp. 1–8.

PUBLICATIONS

1] Design Of Bridges By N. Krishna Raju

The book explains the basic principles and techniques involved in the design of the reinforced concrete structures.

[2] Bridge Engineering book by S Ponnuswamy

This book covers the whole extent of bridge engineering-investigation, design, development and upkeep of bridges.