"SEISMIC ANALYSIS OF RCC BOX GIRDER BRIDGE WITH VARIOUS SUPPORT CONDITIONS"

A

THESIS

Submitted in partial fulfilment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY
IN
CIVIL ENGINEERING

With specialization in

STRUCTURAL ENGINEERING

Under the specialization
of

Dr. Tanmay Gupta
(Assistant professor)

By

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

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HIMACHAL PRADESH, INDIA

MAY-2022

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report **"Seismic response analysis of Rcc box girder bridge with various support conditions"** submitted for partial fulfilment of the requirements for the degree of Master of technology, in Civil Engineering at **Jaypee University of Information Technology Waknaghat** is an authentic record of my work carried out under the guidance of **Dr. Tanmay Gupta,** Assistant Professor. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully for the contents of my project report.

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SUPERVISOR'S CERTIFICATE

This is to certify that the work entitled, **"Seismic Response analysis of Rcc Box girder Bridge with various support conditions''** submitted by **"Aanchal Choudhary"** in partial fulfilment for the award of degree of Master of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** has been carried out under my supervision. The work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Date: 25/05/22

Signature of Supervisor	Signature of HOD	Signature of External
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PREFACE AND ACKNOWLEDGEMENT

I student of **"JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY (JUIT), SOLAN"**, sincerely thankful to all those people who have been giving us any kind of assistance in the making of this project.

I express my gratitude to "**Dr. Tanmay Gupta**", Assistant Professor Department of Civil Engineering, Jaypee University of Information Technology, Solan, who has through his vast experience and knowledgewhich helps me towards the project.

I would hereby, make most of the opportunity by expressing our interest. Our sincerest thanks to all our faculties whose teaching gave us conceptual understanding and clarity of comprehension, which ultimately made our job easier. Credit also goes to all my friends whose encouragement kept me in good stead. Their continuous support has given me the strength and confidence to complete the current objective for the project without any difficulties.

Last, but not least, I would like to thank the authors of various research articles and books that were referred to.

Aanchal Choudhary

(202652)

ABSTRACT

Bridge plays an important role in connecting people, good and transports but these days Box Girder bridges catches the attention as such type of bridges are beneficial where long span, curvature and difficult terrain are major concern area. For this study a bridge data has taken from the project named of C/O 24mtr. SPAN BRIDGE OVER SALATI KHAD ON RAJPURA DARSHAL MANTALNI ROAD RD 4/105. This study covers literature review of box girder bridges and also describes about the seismic responses using Midas CIVIL as per Indian code. Midas Civil software has been used to model the bridge structure as it is widely used because it has few features and few design tools which will save time and seismic analysis has been performed with various methods of seismic analysis depending upon static, dynamic, linearity and non- linearity requirement.

In this study 4 different RCC Box Girder bridges with different radii of curvature while other parameters are assumed to be identical such as length of the bridge, number of spans etc. are modelled using Midas CIVIL Software and for the purpose of seismic analysis of curved bridges "time history analysis method" has been adopted because for the scenario of an earthquake event it provides a better check to the safety of the structure. Also it describe seismic response of four curved bridge models having different curvature for each created support conditions with different orientation angle which helps to get the clear picture about the best orientation of bearing among those created conditions to each models gives better restriction to earthquake. This study of curved Box Girder Bridge is necessary to be analyzed for seismic action to get the maximum utilization for using such bridges without compromising its seismic demand to fulfill its design period. The results also show the effect of increase in curvature angle or decrease in radius of girder on girder's lateral displacement.

Keyword: Box Girder Bridge, Curvature, Midas CIVIL, Bearings, Seismic Analysis, Time History Analysis, Support Orientation

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CHAPTER 1: INTRODUCTION

1.1. General

Now a days the “box girder bridge” is a “popularly used bridge system” across the world. As when it comes to different types of bridges, Box Girder bridges catches the attention because it is “commonly used for the long span” for ignoring the “heavy weight” in comparison to the other bridge system. This Bridge is better stable, serviceable and economical. Box Girder Bridges have shown better distribution of load in transverse direction due to its extreme rigidity behavior and also it’s very complex because it is the three-dimensional and transverse direction. Different types of bridge failure comes in picture during earthquake excitation at the parts of deck and pier which sometimes buckled or even collapsed in worse condition. Hence, “Seismic vulnerability of highway bridges remains an important problem and has received increased attention as a consequence of unprecedented damage observed during several major earthquakes”. May there is numerous numbers of existing structures, which might not successfully withstand the presently seismic must-have demand, may suffer damage within large-scale or even fall down completely if severe ground excitation is generated due to earthquake loading.

1.2. Scope

The main objective of this project is to analyze the bridge model by MIDAS CIVIL, to study the seismic behavior of “Box Girder Bridge” and the study of different methods of seismic analysis with the help of the software and also to analyze the seismic response of the box girder bridge with various support condition because it’s a way to better estimate the possible damage of a civil structure caused by an earthquake is to improve the accuracy of a seismic response analysis using a 3D structural model.

To get the required objective, have studied about the bridges which includes their importance, components of the bridges, their classification and about the loads on bridges. Have also gone through **the “IRC: 112 (code of practice for concrete road bridges)” and “IRC: SP 114(guidelines for seismic design of concrete road bridges)”.** The software that used for modelling and designing is **Midas Civil** so modeling of bridges is done by the software and also the detailed process for seismic analysis has been discussed in this study. For the study the real-life project **i.e., C/O 24mtr. Span Bridge over NogliKhad on Rajpura Darshal Mantalni road RD 4/10** has been taken and, modeled this bridge using **Midas Civil.** In order to get the results of seismic response by linear and Non- linear analysis method so, "free vibration analysis" (Eigen Value Analysis), "Response spectrum analysis" and "nonlinear time history analysis" are performed.

The seismic response under various created support conditions are obtained for four different curved bridges with 0° to 60° curvature angle of girder with an interval of 15° and also examine all the corresponding results of them in details for better understanding the effect of different support conditions on seismic behavior of the structure.

1.3. Bridges

"A bridge is a structure built to span a physical obstacle without closing the way underneath such as a body of water, valley, or road, for the purpose of providing passage over the obstacles". Bridges play an important part in urban, social, cultural and economic development of a region and they also have major military significance. Hence, they are considered as lifelines of the infrastructural system of a country.

Figure 1.1: Dhola-Sadiya Bridge (Beam Bridge) and Chenab Bridge (Rail Bridge)

1.4. Importance of bridges

- Connects difficult terrains like Royal Gorge Bridge which is surrounded by breathtaking view of rugged rocky mountain wilderness & hanging nearly 1000ft above the Arkansas River and Lake Ponchartrain which is a causeway bridge & the world's longest bridge over a body of water with span nearly 24 miles.

Figure 1.2: Royal Gorge Bridge (Suspension Bridge), USA and Lake Ponchartrain causeway Bridge, USA

- **Military use-** Bridge also have major military significances like Bailey Bridge which is a type of portable prefabricated truss bridge which was developed for military use and Pantoon Bridge which is used by army to transport military vehicle over eater obstacles and mushy ground.

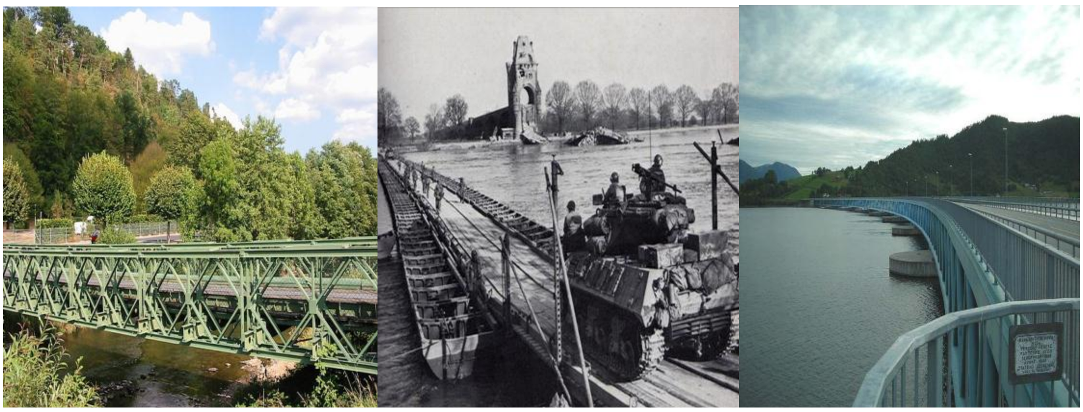


Figure 1.3: Bailey Bridge and Pantoon Bridge

- Some other advantages a bridge can provide are Easy trade and transport of goods, reduce travelling time, Political and economic importance, and Less emission due to displacement – Brooklyn Bridge and Pamban Bridge are the best example which explain how bridge can play an important role in the those mentioned things. Brooklyn Bridge was famous because it became the first roadway to connect Manhattan and Brooklyn which were the separate cities and Pamban Bridge which is a railway bridge over sea which connects the town of Mandapan with Pamban Island so these bridges provide a route where it seems impossible at that time but now it can be imagine how it brings an easiness and an opportunity in person's life in many aspects.

Figure 1.4: Brooklyn Bridge, USA and Pamban Bridge, India

1.5. Components of Bridges

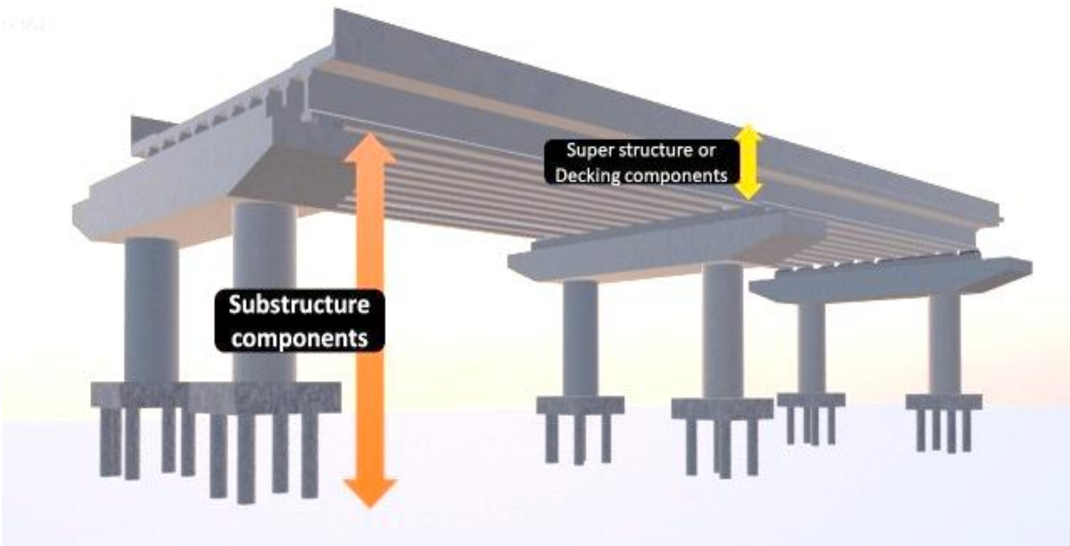


Figure 1.5: Typical section of a bridge structure

Superstructural Components of Bridges- Superstructure is the position of the bridge that represent generally the components above the bearings which is provided to resist the load directly exerted on it and then transfer these loads to the substructure components.

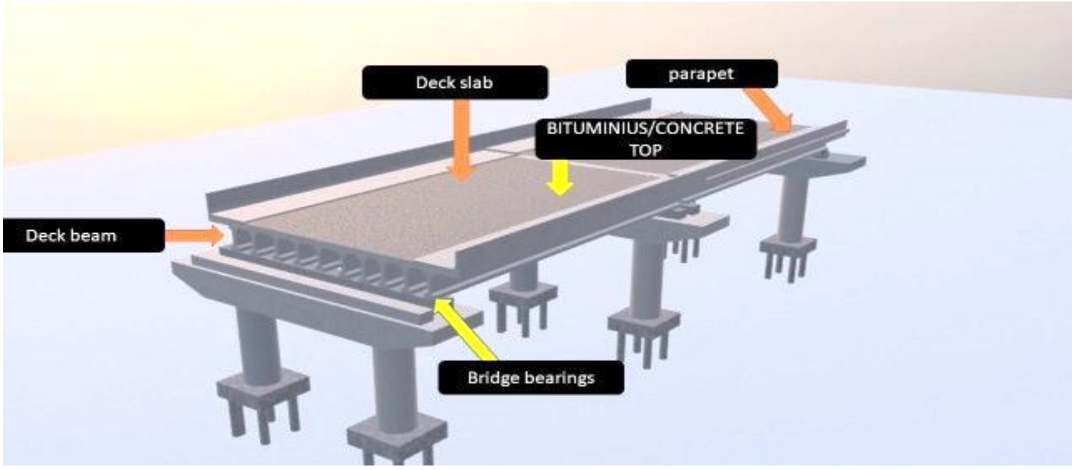


Figure 1.6: Components of Superstructure

Bearings: It lie in between the super and substructure components of the bridges to make the flow of the load possible which is coming from the components of superstructure to substructure in order to attain the surety for the uniform distribution of the loads and it also make the structure stable and allow the movements in translational and rotational direction of it.

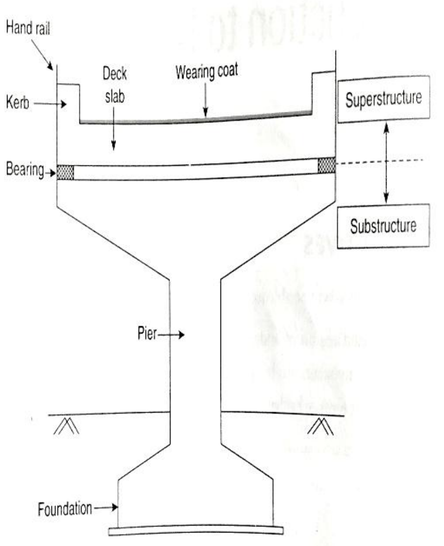


Figure 1.7: Bearing location between the superstructure and substructure

Substructural Components of bridges- Substructure is the position of the bridge that represent generally the components that lie below the bearings which is provided to make the flow of the load possible from the superstructure to the underlying soil layer.

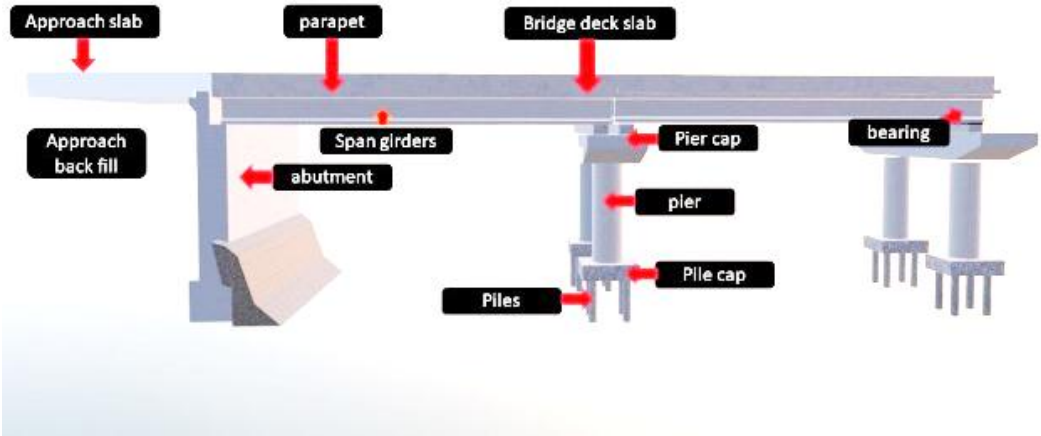


Figure 1.8: Components of Substructure

1.6. Classification to Bridges

- Based on **Construction Material**- on the basis of materials used for constructing the bridges are classified as “Timber Bridge”, “Masonry Bridges”, “Reinforced Concrete Bridges”, “Steel Bridges”, “Prestressed Bridges”, “Composite Bridges”, etc.

Figure 1.9: Bridge classification on the basis of construction material

- Based on **Usage/Traffic/Functionality**- on the basis of function or purpose for which the bridge is designed are classified as Pedestrian Bridges, Highway Bridges, Railway Bridges, Aqueduct, Equipment Bridges, Pipeline Bridges.

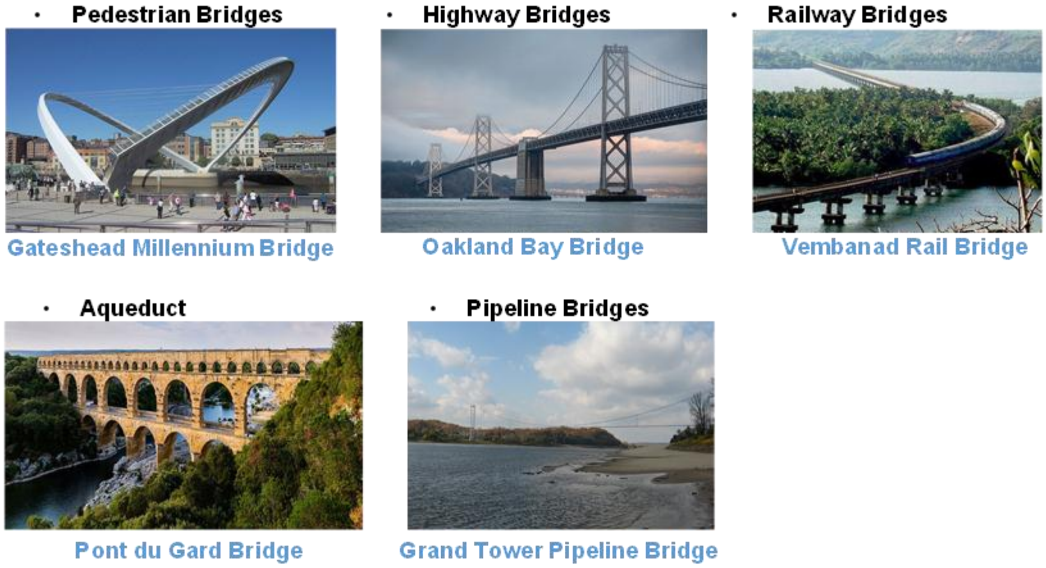


Figure 1.10: Bridge classification on the basis of functionality

- Based on **Span**- on the basis of span or length, the bridge structure can be categorized as culverts and bridges.
- Culverts- If the length of the bridge structure is ≤ 6m
- Bridges- A bridge is a structure having a length more than 6m.Bridge of length up to 60m are known as minor or short span bridges. For length more than 60m, the bridge are called major bridge. If the length is ≥ 150m, then the bridges are called long span bridges.
- Based on **life span**- on the basis of the duration of use, the bridges are classified as Permanent, Temporary and Semi- permanent Bridges.
- Based on **horizontal Arrangement**- on the basis of alignment of bridge in horizontal direction, the bridges are classified as Straight Bridge, Skewed Bridge and Curved Bridges.

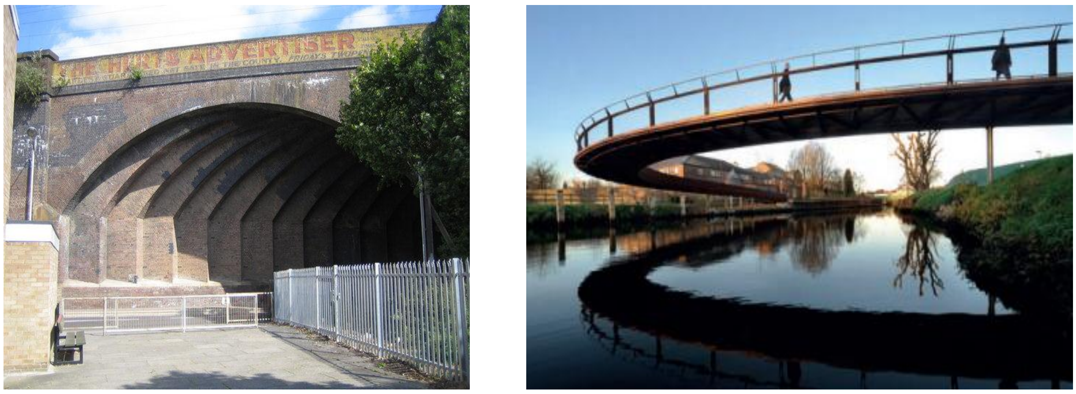


Figure 1.11: Southdown Road Skew Bridge and Jarrold Bridge

- Based on **Vertical Arrangement**- on the basis of alignment of bridges in vertical direction, the bridges are classified as Horizontal/Flat/Normal Bridges and Inclined Bridges.

Figure 1.12: Eshima Ohashi Bridge

- Based on **Movements**- on the basis of movements of bridge, the bridges are classified as Movable bridges and Fixed Bridges.

Figure 1.13: London Tower Bridge

- Based on **Structural Forms**- on the basis of form and type of superstructure, the bridges are classified as "Slab Bridges, Girder Bridges, Truss Bridges, Arch Bridges, Suspension Bridges, Cable-stayed bridges, etc."

Figure 1.14: Bridge Classification on the basis of structural forms

1.7. Bridge Design Principles

- **Capacity-** Bridge has the authority over the capacity of the transportation system

  "If the width of a bridge is insufficient to carry the number of lanes required to handle the traffic volume, then there will be a restriction to the traffic flow".

  "If the strength of a bridge is deficient and unable to carry heavy trucks then load limits will be posted and truck traffic will be rerouted".

The design should therefore be able to accommodate the traffic expected throughout the design Life of the bridge

- **Cost-**

Bridges are "expensive structure" as the "cost per meter of a bridge is high" in comparison to the road.

"This can be controlled by right choice of the location, materials, structural form etc".

The design should therefore optimize all options in order to minimize costs as much as possible.

- **Safety-**

If the bridge fails, the transportation system will not be in a position to give function.

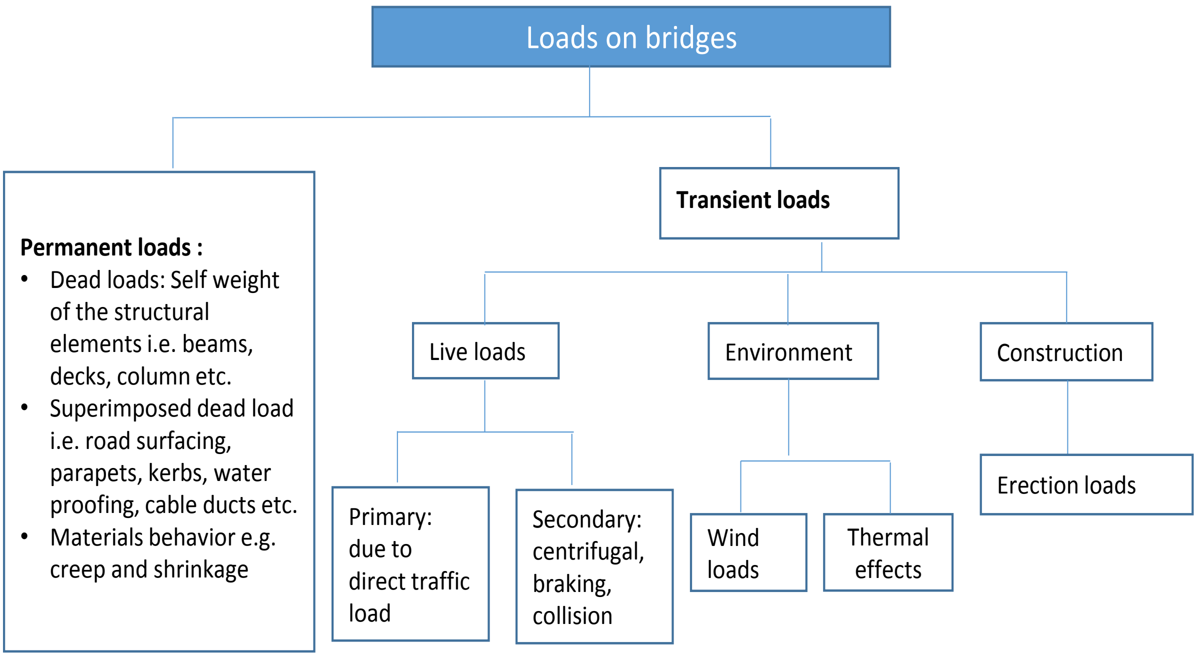
Like – "traffic may be deviated over routes which isn't designed to manage the growth in volume".

"Forced the users to undergo discomfort due to fuel expenses and more travelling period"

"Until the bridge isn't repaired or replaced normality will not go back to its usual state"

The design should therefore analyze all the factors that might affect the structural integrity of the bridge.

1.8. Loads on bridge



1.9. Load, Forces and Stresses

- **Dead Load-**Include the "self-weight of the structure" and the "superimposed dead loads"**.** These loads are permanent as it presents along the service life of the bridge. Dead loads and superimposed dead loads are in general transferred to the substructure using safety factors. The dead loads are also critical for seismic analysis, which is converted into masses.

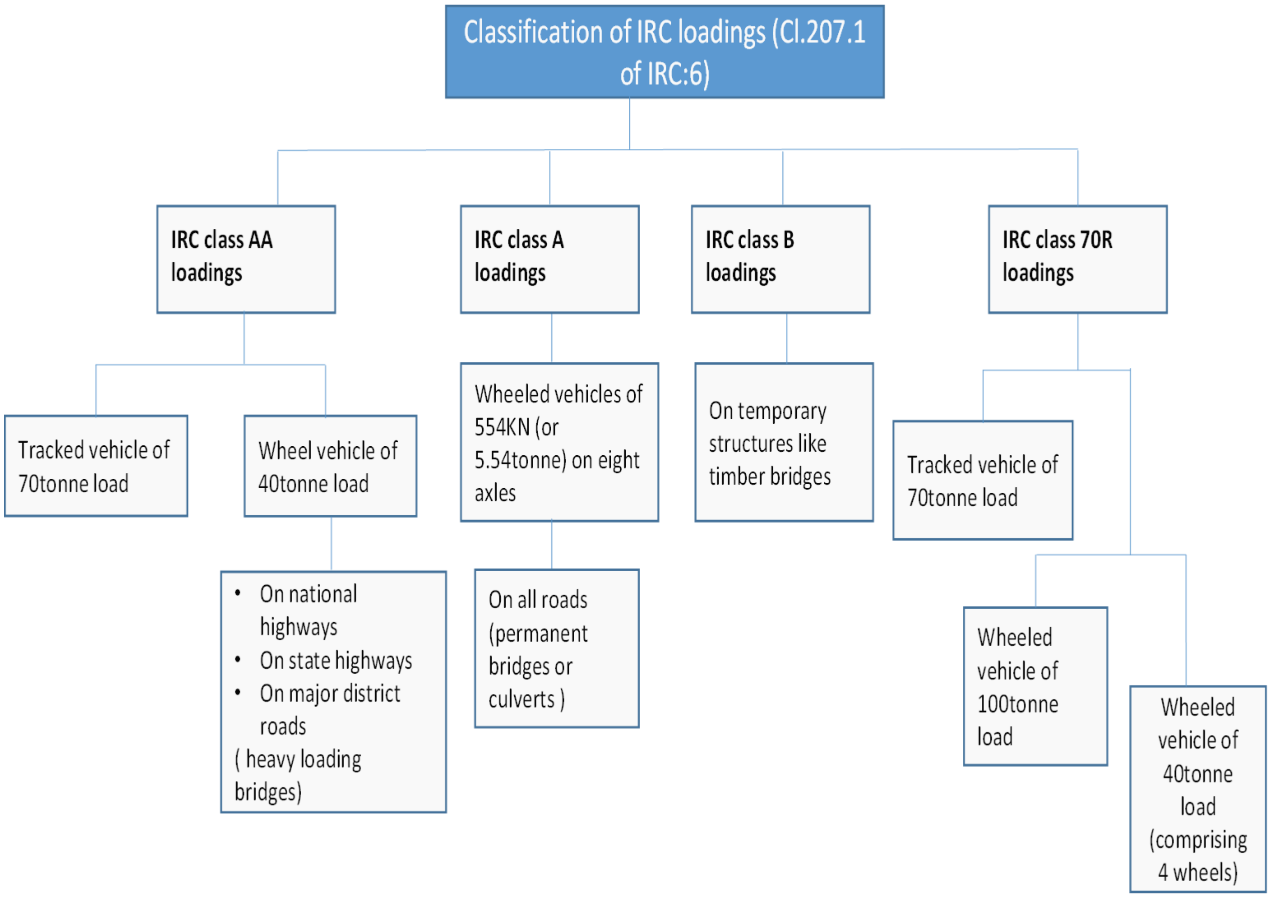
- **Live Load-**The live load includes moving load which acts all over the length of bridge**.** i.e., vehicles, pedestrians etc. Some recommendation in IRC has been made for imaginary vehicles as live loads because selection of vehicles for the safe design is not that easy which can display permissible outcome against the moving vehicle on the bridge no matter what type of vehicle it is in real.

The classifications of vehicular loading are done as follows –

"IRC class AA loading"

"IRC class A loading"

"IRC class B loading"



- **Impact Load** -The impact load on bridge is due to the loads acted within a short period resulted from the moments of vehicles on the bridge meaning "When the wheel is not in static position, the live load will change continuously with time from one wheel to another due to which the Impact load on bridge generated".

- **Wind Load** -Wind load also an important factor in the bridge design. Such loads has no effects for bridges with shorter span but if the span is in medium range, it should be consider for substructure design. Wind load is also taken in consideration in design of superstructure if the span of bridges is long.

- **Longitudinal forces**-The longitudinal forces are the results of forces exert due to sudden brake or accelerate action of vehicle occur on the bridge. If the vehicle comes to a static state instantly, it bring out such forces on the structure of bridge mostly on the part which is below the bearing.so, IRC suggested that "live load must be taken in account as 20% for longitudinal force on the bridges".

- **Centrifugal forces**-If bridge is to build with some curvature on plane projection, then the movement along such surface with curvature will lead to arise of centrifugal force on the superstructure. Hence, for such cases centrifugal force must be kept in mind while designing the bridge.

  Centrifugal force represented as -

  "C (KN/m) = WV^2/ 12.7R"

  Where,

  "W" = "live load" (KN)

  "V" = "Design load" (Kmph)

  "R" = "Radius of curve" (m)

- **Buoyancy effect**-Buoyancy effect is taken in account for substructures if the bridge is large and submerged too deep down in water bodies which can't be avoided.

- **Forces by water current**-When the bridge has to be built where it came in contact with water bodies and also its some parts of the substructure covered or swamp under water then"the water current induces forces on submerged portion in horizontal direction". The "forces caused by water currents" are "maximum at top of water level and zero at the bottom of water level or at the bed level".

  Water current exerted "pressure" can be computed as,

  "(p) =KW (v^2/2g)"

  Where, "p" = "Pressure" (KN/m)

"K" = "Constant"

"W" = "unit weight of water"

"V" = "water current velocity" (m/s)

"g" = "acceleration due to gravity" (m/s^2)

- **Thermal stresses**-Thermal stresses are generally related with the degree of climate condition meaning "when its degree shows ignorable variance which exerts stresses in the bridge elements especially at bearings and deck joints".

- **Seismic load**-When the bridge is lie under seismic zone or earthquake prone area, it became the demand of the situation to observe earthquake loads which can act in vertical and horizontal direction at the event of an earthquake. The "magnitude of forces" exerted is totally "depends on the self- weight of the structure" i.e., "larger the weight of the structure, larger the induced forces will be acted".

- **Deformation and Horizontal Effects**-Deformation stress are corresponding to the variation in material properties which increase the risk of creep, shrinkage effect due to concrete material. Horizontal forces caused due to variation in climate degree, breaking of vehicles, earthquake etc.

- **Erection stresses**-Erection stress are coming in picture when the equipment for construction during construction process fulfill their role by performing their action but its effect might be minimized by just providing suitable supports for the members

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction to Box Girder Bridges

“Girders are the large section beams above which the slab (deck) rests. They are generally adopted for the bridges”. The Box Girder are “hollow channel-shaped beams” containing two (or more) side webs and two flanges.

Figure 2.1: Concrete Box Bridge (Canada), San Francisco-Oakland Bay bridge (Steel Box Girder Bridge), and Cognac Bridge, France (Composite Box Girder Bridge)

The “box shape” can be either “trapezoidal” or “rectangular”. In such girder, “one of the flanges remains in compression and the other in tension”. The Bridges having such kind of a girders are called “Box girder bridges”.

The literature was studied in relation to the objectives of the present study. There are various studies done by researchers on box girder bridges like “Study on the Behavior of Box Girder bridge” by “Raghava Sudhir V” & “Vickranth V” which covers the detailed study about the box girders bridge for a general case of an eccentric load has been studied and also summarized some general specifications with reference to IRC:18 have been discussed. “Analysis of Box Girder under IRC Loading” by “Harish MK”, “Chethan VR”, & “Ashwini BT” in which analysis of single and multi-cell box girder bridges has been discussed under IRC loading using CSI Bridge software “Response of Box Girder Bridge Spans Influence Based Moving Load Analysis” by “G. Venkata Siva Reddy”, “Chandan Kumar” which deals with the response of Reinforced concrete and Prestressed concrete bridges when subjected to standard moving vehicular loads and analysis is carried out using Midas software for which Influence lines and Influence surfaces are generated to analyze the response of bridge structure subjected to live loading within designated lanes. “Analysis of Prestressed Box Girder Bridge under Different Standard Codes: Comparative Study” by “Shubham S. Hande”, “Sharda P. Siddh”, & “Prashant D. Hiwase” in which study was done about Prestressed concrete bridge under two different loading standards and specifications i.e. IRC: 6 2000 and AASTHO- LRFD standards. Modelling and analysis of bridge was done using Midas civil. Also, the study conclude that prestressed box girder bridge analysis and design can be done effectively using IRC standards and specifications. “Parametric Study on Behavior of Box-Girder Bridges using Finite Element Method” by “PK Gupta”, “K.K. Singh” & “A. Mishra” in which detailed study of different cross section of box girder bridge i.e., Rectangular, Trapezoidal and Circular has been discussed by performing the linear analysis using SAP-2000 for dead load and live load of IRC 70R Loading and result shows that rectangular section is the most superior one among them.

Other research papers regarding the seismic response of a structure have also studied in order to achieve the objective are “Seismic Analysis of Box Girder Bridge” by “Shoeb Alam”, “Misbah Danish Sabri” which covers the study to evaluate and examine multi-span seismic output with up to five spans of 100-meter-long Girder Bridge frame. “Seismic Performance of Box Girder Bridge with Non-linear Static Pushover Analysis” by “Nilanjan Tarafdar” & “Prasad Mlv” in which material used in Box Girder Bridge is replaced with DCC to examine the performance during an earthquake using pushover analysis and the results shows that performance of the bridge is enhanced in both the directions due to new proposed material. “Effect of Isolation Systems on a Steel Box Girder Bridge in Tabiz” by “M Jamali Golzar” & “M. Azharian” and “M. A Jamali Golzar” in which how the seismic performance of a structure can be improving by using a isolators on the base of structures. Basically, this study is based on lead rubber bearing for a non-linear time history analytical study and the comparison has been done with Elastomeric systems. “Seismic Response Analysis of Multispan Bridge using FEM” by “Zhan CHEN” and “XIedong ZHANG” in which modelling is done by Midas Civil for different bridges with different span length, number of span and pier height shows the effect on seismic behavior of the bridges due to change in span length, height of pier etc. “Response Structure Analysis of Prestressed Box Girder Concrete Bridge due to Earthquake Loads” by “M Miranda” , “R Suryanita” and “E Yuniarto” in which study of seismic response of Prestressed box girder Concrete bridge has been carried out with three soil conditions by performing response spectrum analysis using Midas Civil software. “Impact of Support Bearing Orientation upon

Skewed Concrete Box Girder Bridges" by "Tanmay Gupta" & "Manoj Kumar" in which impact of support bearing orientation upon structural response of skew box- girder bridges have been discussed thoroughly.

Also some papers on curved bridges are studied thoroughly to achieve the goal of this study like "The Deformation Analysis of the Curved Box Girder bridges under Different Radius" by "Liu Fangping" & "Zhou Jianting" in this paper influence of radius on the deformation of curved box girder bridges has been discussed for five different curved bridges which are modelled underweight and prestressing "Parametric Seismic Analysis of Curved Steel Box – Girder Bridges with Two Continuous Spans" by "Haiyong Wu" & "Walid S. Najjar" which deals in which study results of design with highest potential recommendation are highlighted and also seismic criteria by local and national specifications are discussed. "Stability Against Overturning of Curved Continuous Box Girder Bridges with Single Column Piers" by "Guohua Song, Delu Che" & "Minghui Li" in which factor of stability against overturning came in picture and also its influence over curvature radius and bearing eccentricity has been discussed in detail and " The effect of curvature angle of curved RC box girder continuous bridge on their transient response and vertical pounding subjected to near-source earthquakes" by "S.Tamaddon", "M. Hosseini", "A.Vasseghi" which covers theoretical approach using the relationships of structural dynamics to evaluate the effect of central curvature angle on the seismic response of curved bridge. "The effect of Superstructure Curvature on the Seismic performance of Box- Girder Bridges with In-span Hinges" by "F. Soleimani", "Chuang- Sheng walter Yang" & "Reginald Desroches" in which common potential damages concern areas like damage to bearings and expansion joints has been discussed and the seismic response of bridge has obtained by performing non-linear time history analysis in opensees.

2.2. Advantages Associated with Box Girders

- Appearance of such box-shaped girder are very art-conscious which gives the structure smooth or sleek modernist look.
- Location of box chamber is under the deck of bridge which brings the advantage of utilization of those spaces among the chambers in handling of electrical wires, sanitary pipelines, etc. with ease without any obstruction in deck of bridge.

- In comparison to I-section torsional stiffness of box girder of the bridge is nearly greater hundred to thousand times therefore, when occurrence of effect of torsion have high chances of generation, it showed big advantages for such areas like high speed moving rails, curved section of the bridge.
- They can possible the easiness in safe design even the structure and slabs of bridge's deck are so huge.
- Using such girder in bridges shows huge stability in dealing with the forces generated from the motion of air or other gaseous fluids.

2.3. Disadvantages

- Numerous numbers of bridges has been build up across the world using Box girder bridge technology, it is still very far from being popular among research scholars so there is not much testified theory about such bridges which created so many hardship and roughness in work over design, section statement, procedure of construction, and manner of installment.
- Construction methods are very much cost effective.
- Very difficult and risky for maintenances.
- Availability of cables bracing with box girder increase the risk of corrosion from inside which correspondingly increase the necessity of high maintenance as those cables located in inmost closed in space.
- For deck construction everlasting formworks must utilized but there might be possibility for the use of temporary false works and formworks which lead to complication, uneasiness, and threat to the workers.

2.4. Applications

A "box girder bridge" is a "special type of bridge where the key structural element is one or multiple closed cells that are acting in bending". Such girders are used for "footbridges", "railway bridges" and "highway bridges".

- Footbridges — Box girders are used for footbridges over 30m span. Box girder footbridges use an all-steel configuration as the entire cross section including the parapets can be fabricated.

- Railway bridges — The only option to accommodate the railway bridges where the construction depth is tightly constrained is box girders.
- Highway bridges — These comprise composite box girders, curved bridges, cable-supported box girders and steel box girders.

2.5. Specifications

It could cover a scope of reach from “25 m up to the biggest non-suspended decks worked; of the request of three hundred meter”. “One cell box girders” may also consider “decks up to 30 m wide”. For the extra prolonged “traverse pillars”, past round 50 m, they may be generally the primary viable desk region. Beneath “30m precast shafts” or “voided piece decks” are greatly suitable at the time as over 50m one cell box path of action is normally more monetary.

“One cell box-girder” forged in-site are applied for “traverses shape 40m to 270m”.The “box plan” is achieved so that desired look can obtained “where the web of box will pass approximately as a fine appearance whilst joined with a thin parapet profile”. This form of deck is constructed “traverse by-traverse”, making use of complete-“tallness platform” or “trusses”, or calibrated “cantilever utilizing structure explorers”. This could be specifically crucial for “medium length spans” along the variety in the “vicinity of 40m and 55m”. Such traverses are “too ache” for “dual rib type decks”, and “too short” for “cast-in-situ adjusted cantilever development of box girders”, “while an aggregate length of box area deck of not exactly around 1,000 m does no longer legitimize putting in a precast segmental office”.

2.6. Behavior of Box Girder Bridge

- Common loading on a box girder applied in such a way as shown in “fig 2.1 (i)” for box with one chamber due to which in the cross-section effect of bending, twisting, and warping arise.
- Girders having these closed thin wall section have high rigidness and stability in torsion even the components responsible for torsional effect have a very minor effect on bridges with such girders.

- If the component of loading responsible for torsional effect is acted as a shear, the segment phase might get twisted without any kind of a distortion.
- The ensuing stresses due to warping in longitudinal direction are very less and no stresses are generated due to flexural distortion in transverse direction. But, if the torsional loading acted in a way as in "fig 2.1 (ii)", the segment of girder will deform due to the forces exerted on the plate elements fig 2.1 (iii)
- The actions of the "plate elements of the cross-section" purpose "distortion stresses in the transverse course" and "warping stresses within the longitudinal path".

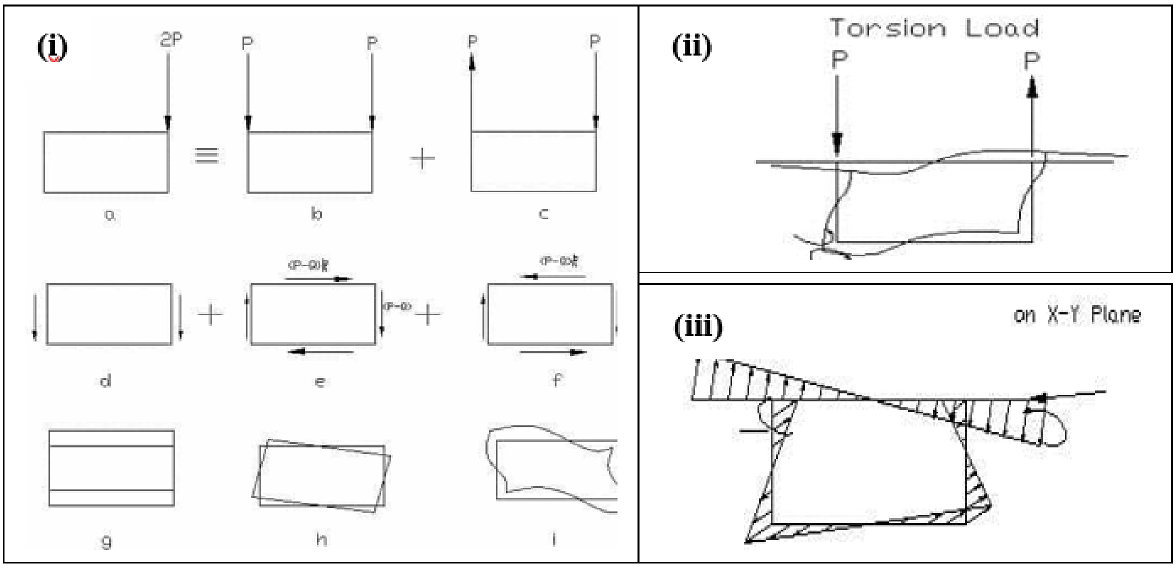


Figure 2.2 (i) General Loading on Box Girder, (ii) Distortion Stress from Transverse Flexure and (iii) Warping Stress Pattern

2.6.1. Flexure

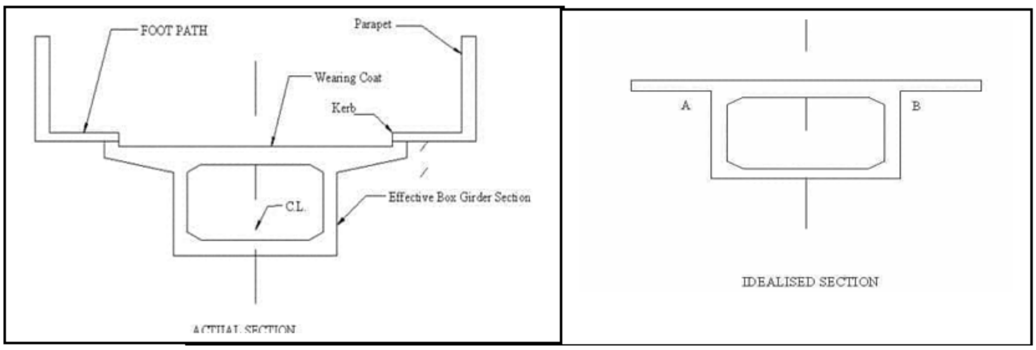


Figure 2.3: Load Transferred by Flexure to Web of Box Girder

- A vehicle load is transmitted by deck's flexure portion to the web of box girder in transverse direction.
- First of all, take into account that deflection in the webs portion of box girder are restricted as the structure bear a resemblance to a portal frame for know-how the numerous stresses generated.
- The flexure of the deck result in generation of "bending stresses in the webs as well as in the bottom flanges of the girder". Any vehicle load can as consequences get replaced by a way of the forces on the intersections of deck and web as shown in "fig 2.2"

2.6.2. Torsion

- The excessive strength of the box segment in terms of torsion responsible for it being highly appropriate for bridges with greater span length.
- The box girders when "experienced torsion", go through "deformation or distortion of the section", giving upward push to "transverse" in addition to "longitudinal stresses".
- For a girder with one chamber, shear flow is responsible for the torque to be restricted which exerts all over the wall of the box which is represented by "**q=T/2A",** Where "T is the torque" and "A is the closed in box area".
- The pure torsion responsible for the generation of warping effect of segment due to the section of thin wall.
- Consider "four panels of a rectangular box subjected to pure torsion".
- Consider, Width of box=B,

  Depth=D,

  Flange thickness=t_f,

  Web thickness=t_w.

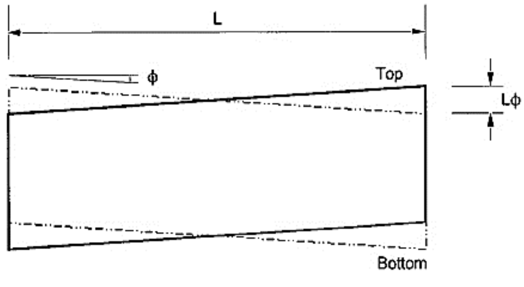


Figure 2.4: Shear Displacement of Top and Bottom Flanges (ends kept plane)

- The shear flow for the torque T is represented as "**$q=T/2BD$".**
- The shear stresses in the flanges is "**$T_f=q/t_f=T/2BDt_f$".**
- Being observed from top view each flange is sheared forming the shape of a parallelogram with an angle of shear "**$\Phi = t_f/G$".**
- "If the end sections were to remain plane", "the relative horizontal displacement between top and bottom corners would be ΦL at each end".
- There would be a "twist" between the "two ends" of "**$2\Phi L/D=2t_fL/DG=TL/BD^2Gt_f$".**

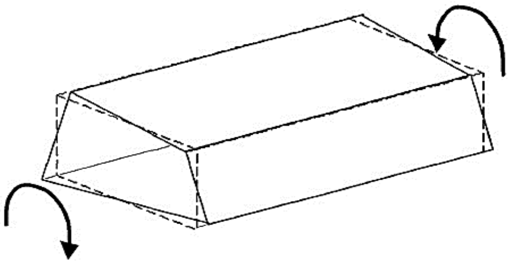


Figure 2.5: Warping of a Rectangular Box Subject to Pure Tension

- Being observed from side of the box in terms of displacements of the webs and if still end sections would stay in the same position of plane, then the section twist represented by "**TL/B^2DGt_w".**
- The end sections maintain the same position as plane if "**$TL/BD^2Gt_f=TL/B^2DGt_w$"** or "**$Dt_f=Btwt_w$**
- If this situation not met "the end sections cannot remain plane, there might be a moderate counter-rotation in their planes of the two flanges and of the two webs, and a consequent warping of the section".

2.6.3. Distortion

- When "torsion is applied directly around the perimeter of a box segment", with the aid of a pressure exactly identical to the flow of shear at all the four sides of the box, this will not have the enough capacity to mold its form of the segment.

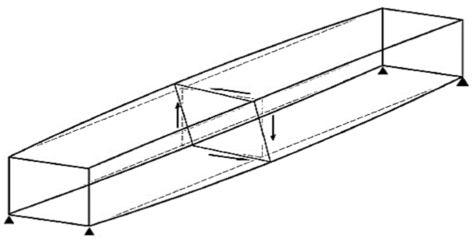


Figure 2.6: Distortion of Unstiffened Box (pinned corners)

- The “distortional forces” are tending to “increase the length of one diagonal” and “shorten the other”.
- Elaboration about how distortion is going to be act and bring out between powerful restraints, box with simply supported boundary conditions is taken in account with “diaphragms only at the supports” that is put through under point load at mid-span over its one web.

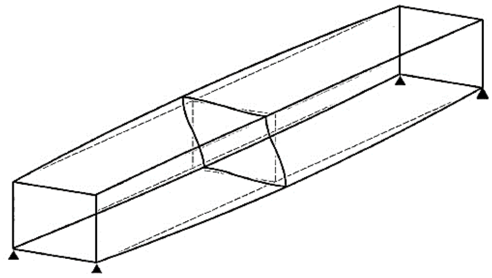


Figure 2.7: Distortion of Box with Stiff corners or Cross- frames

- When there may be no continuity in moment of transverse direction on the corners (a pinned boundary condition between web and flange), distortion might be in a way shown in “fig 2.6” for the segment.
- The in-plan bending of every aspects responsible for the generation of stresses and strains in longitudinal direction but being applied on the opposite faces of the cross-section of box in different direction to each other produces warping effect.
- The longitudinal stresses consequently referred to as distortional warping stresses and similarly shear stresses referred as distortional shear stresses.

2.6.4. Warping Of Cross Section

- Warping of cross-section acted as an out of plane, bobbing up due to the loading caused by torsion.
- When beams without any diaphragms of such boxes of concrete undergo loading due to torsional have go through warping displacements which is created because of its two components i.e. torsional and distortional warping displacements.
- Each these provide upward push to normal stresses in longitudinal direction for every occasion warping is restrained.
- Box girder of concrete have stresses due to warping which is primarily cause by distortion

of cross section , while distortion is particularly hold out with aid of bending strength of transverse direction of the partitions and no longer by way of diaphragms.

2.6.5. Shear Lag

- A very high shear flow of a box girder is generally travelled from webs to flanges, reasons in deformation due to shear in plane of "flange plates", the result of that's that the displacements of flange plate in central portion of longitudinal direction lag in the back of the ones behind those close to the web, while the bending idea predicts "equal displacements" which consequently produces "out of plane warping" of an first of all "planar cross section" resulting in the "SHEAR LAG".

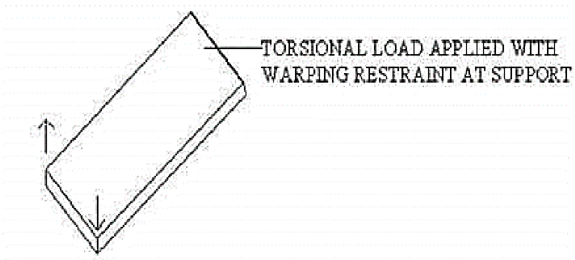
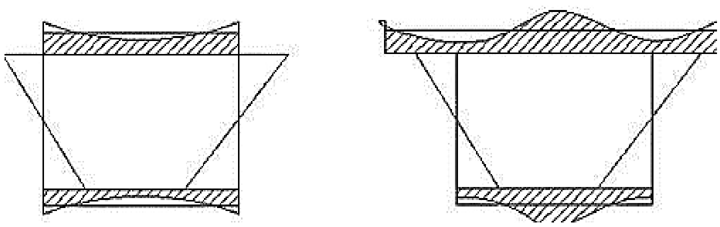


Figure 2.8: Shear Lag due to Torsional Load Applied with Warping Restraint at Support

- Positive shear lag is that which responsible for the growth of bending stresses of girder generated close to the web which has a flange of wide range
- Negative shear lag is that which responsible for the decrease of bending stresses of girder generated close to the web which will grow by moving away from flange.



(i) (ii)

Figure 2.9: (i) Bending Stress Distribution Modified by Positive Shear Lag (ii) Bending Stress Distribution Modified by Negative Shear Lag

- Shear lag of both positive or negative nature can be produced when an uniform load is exerted over the box girder of cantilever type

2.7. Construction

- Box girder bridges may be built in one-of-a-kind methods in steps with their sorts. The general techniques are forged on the site, assembly and creation, precast, and association of units of lesser scale.
- Box Girder Bridge made with concrete is typically forged on the site and performed with the aid of supports, false works, and frameworks. These kinds of a bridges are built up with construction joint into unique section.
- But it could additionally be casted before the construction actually started and placed on the site via cranes after which in a while joint are filled up with concrete.
- When steel box girder is considered then its various components and sections are manufactured and created inside the workshop but bolting or welding process must be done for making joints to complete the whole setup.
- When composite steel and concrete bridges are considered then it’s far regularly casted on the site with the temporary works and framework having the support of girder of steel bracings which are generally manufactured and setup together before the placement.
- A new technique of creation of those kinds of bridges meaning the approach is generally the step-wise launching method for the construction of bridges which is popularly adopted these days.
- When considering this type of technique then modern form of machinery and gantry cranes, supports which have the capability of providing the stability to the structure and maintain loads for a brief period are adopted. With the help of a crane’s new segments of the bridges which are already manufactured are transported to the site
- Once the setting is done then again, the gantry crane will used for the placement of other segments of the bridge over the already placed segments
- Bridges are constructed from one side of bridge and persisted till the other side of it connect. Hence, until it coincides with the other side it will behave as a cantilever as it is in the hanging position from that side. There additionally the available facility of “holes for the prestress concreting in order to connect all the segments of the bridges”.

CHAPTER 3: SEISMIC ANALYSIS

3.1. Introduction

"Seismic analysis is a subset of structural analysis and is the calculation of the response of a building/bridge (non-building) structure to earthquake". It is part of the process of "structural design", "earthquake engineering" or "structural assessment" and "retrofit" in regions where earthquake is prevalent.

3.2. Importance of Seismic Analysis

"Seismic analysis" makes us familiar with the responses of bridges at the event of an earthquake, which might be shown in the form of additional forces or deformations as a result due to earthquake loading.

Thus, once the correct evaluation of results obtained from seismic analysis is done, safe design of the structure can be possible which can withstand a particular level ground excitation.

3.3. Methods of Seismic Analysis

Certain methods are developed to estimate the earthquake forces

Structure/Action	Elastic	Non- Linear
Static	"Equivalent Force analysis"	"Pushover analysis"
Dynamics	"Response spectrum analysis"	"Non-linear time history analysis"

Table 3.1: Classification of Elastic and Non-Linear analysis method on the basis of structural forces

3.4. Pros and Cons of Elastic Analysis

- **Static Seismic Analysis**

  Pros

  - Relatively simple to understand and apply
  - Does not need rigorous calculation and hence quick

  Cons

  - Does not take into account the “dynamic response of the structure”
  - The non-linearity of the material is ignored
  - Does not lead to detailed response in earthquake

- **Response Spectrum Analysis**

  Pros

  - Applies the dynamic equation of motion for force determination
  - Different modes of excitation are considered for obtaining the earthquake effect
  - Damping is considered while obtaining results

  Cons

  - The non-linearity of the material is ignored
  - Does not lead to detailed response in earthquake
  - Various combination methods and results depends on them

3.5. Pros and Cons of Non-Linear Analysis

- **Pushover Analysis**

  Pros

  - Simple to understand and application
  - Non- linear behavior of concrete and steel considered
  - Consideration of second order effects (P delta)

  Cons

  - Dynamic equation of motion is not considered
  - Structure is supposed to excite only in one direction or mode
  - Various methods of distribution of forces, hence no specified scheme

- **Non-Linear Time History Analysis**

  Pros

  - Consideration of dynamic equation of motion
  - Non-linear behavior of concrete and steel considered
  - Gives the displacement, velocity or acceleration of the structure with time in earthquake
  - Considering damping

Cons

  - Very difficult to understand and application
  - Requires computer software
  - Requires various additional parameters to do

CHAPTER 4: MODELING OF BRIDGE

4.1. General Description

PROJECT: C/O 24mtr. SPAN BRIDGE OVER SALATI KHAD ON RAJPURA DARSHAL MANTALNI ROAD RD 4/105

Type of bridge - RCC Box Girder Bridge
Bridge span - 24m
Bridge width - 5.2m
Number of lanes - Single Lane
Thickness of wearing Coat - 75mm
Depth of deck - 2m
Live load - IRC CLASS A
Grade of Concrete - M30 for both superstructure and substructure

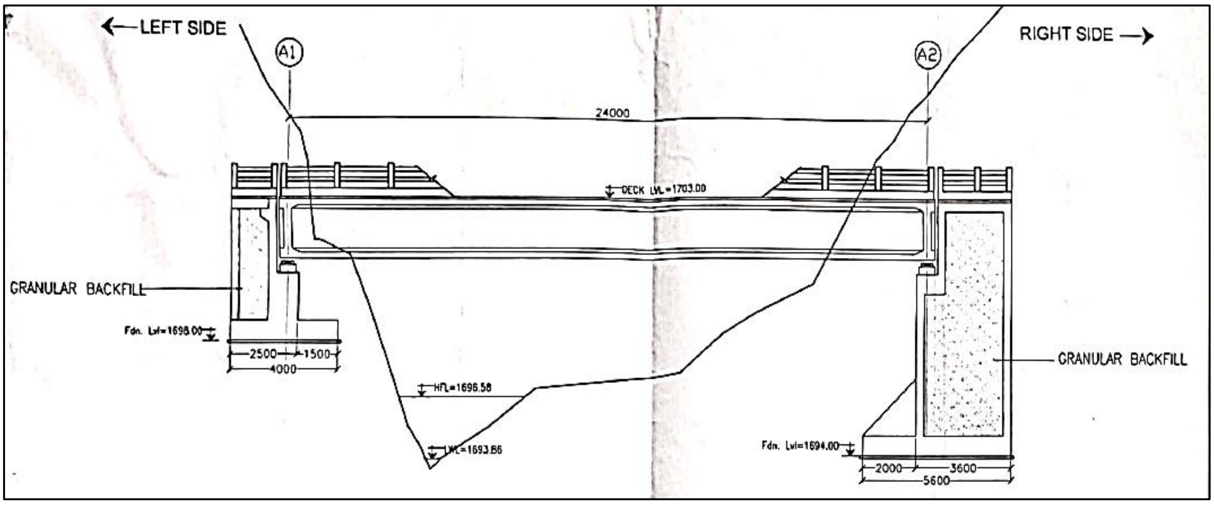
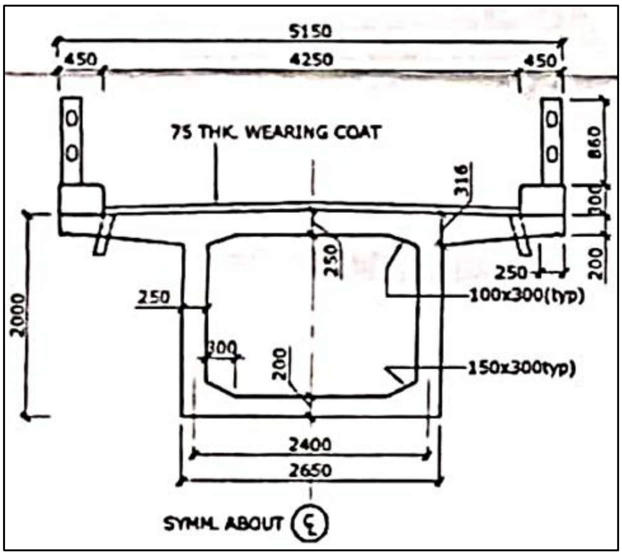
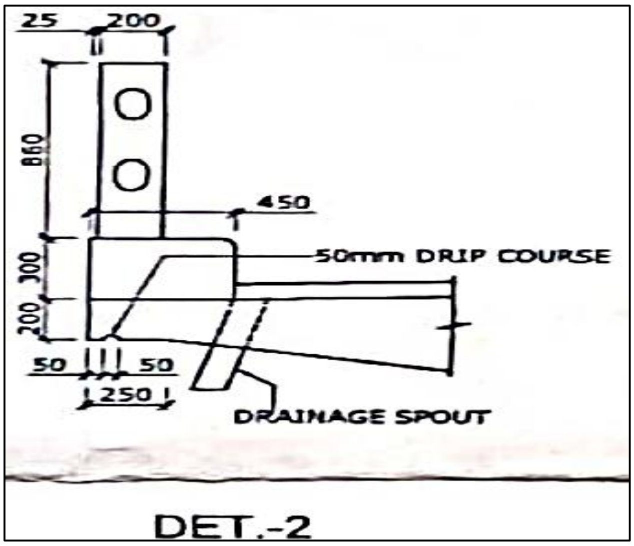


Figure 4.1: Longitudinal Section

4.1.1. Cross section of Box Girder





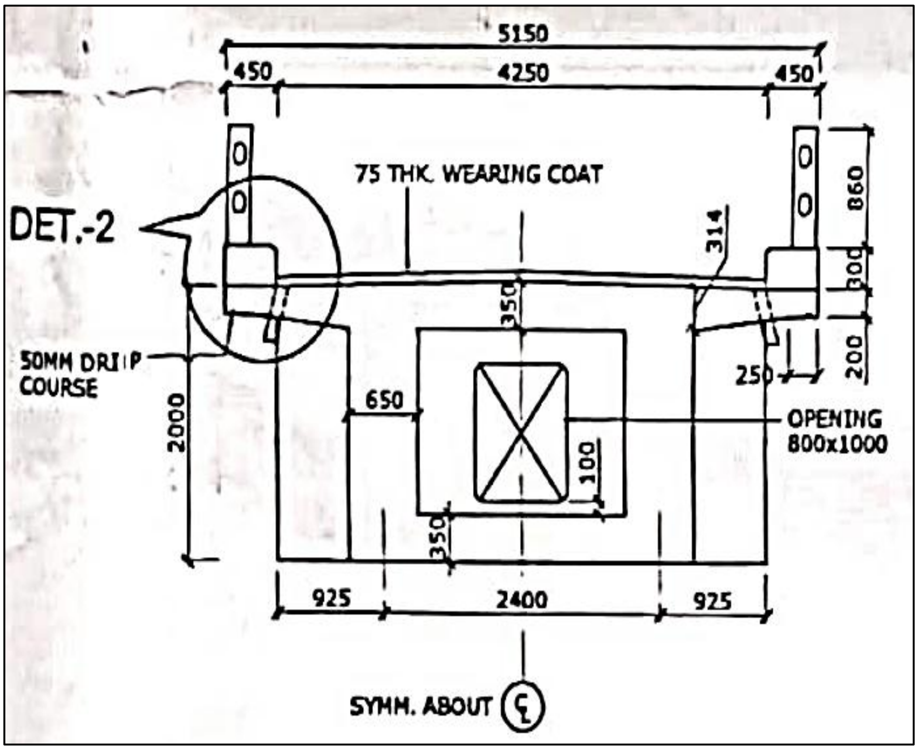


Figure 4.2: Drawing detail for cross-section of box girder

4.1.2. Drawing for Left Bank Side Abutment

- **Abutment Left Bank Side**

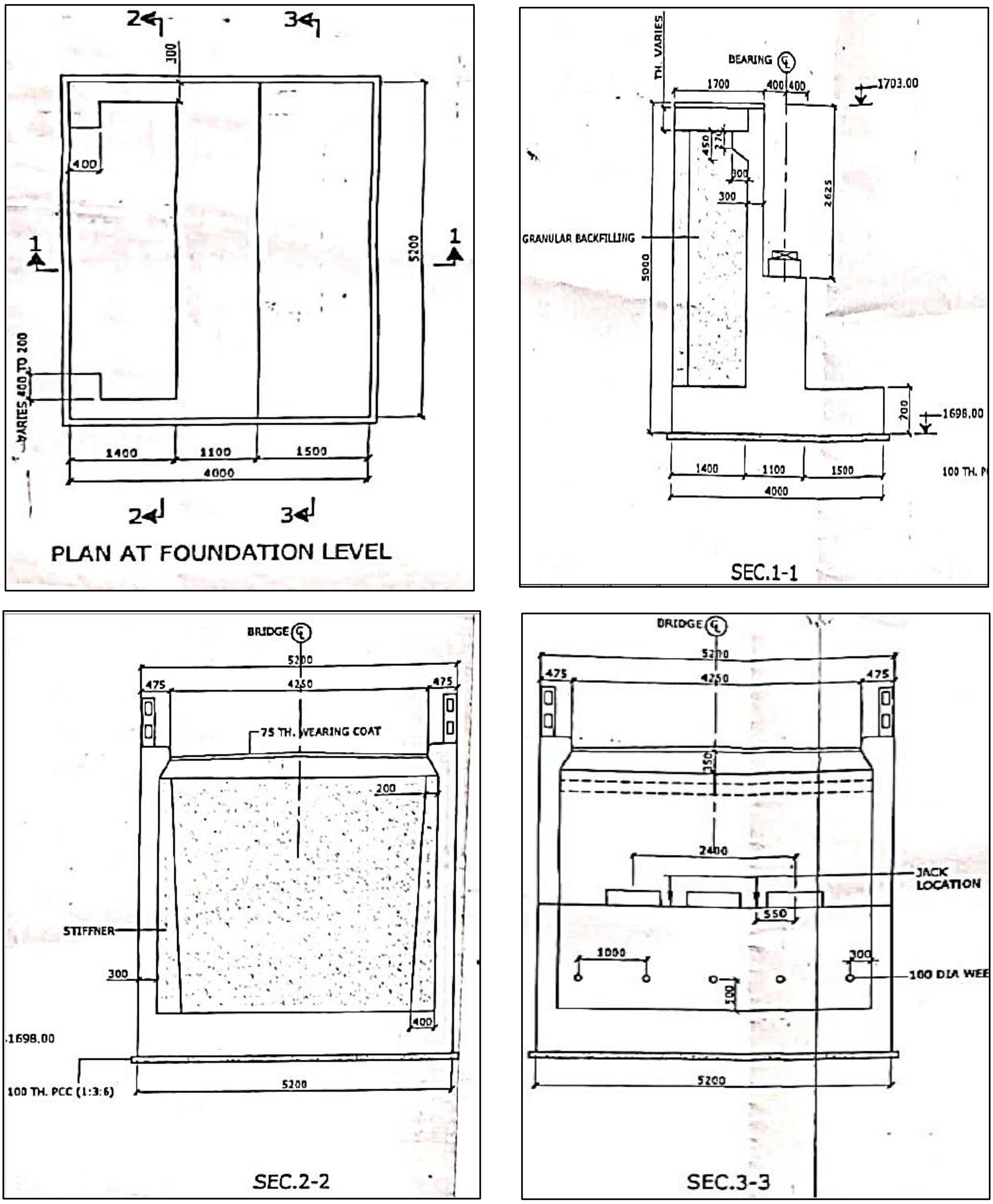


Figure 4.3: Cross section of Left Bank Abutment

4.1.3. Drawing for Right Bank Side Abutment

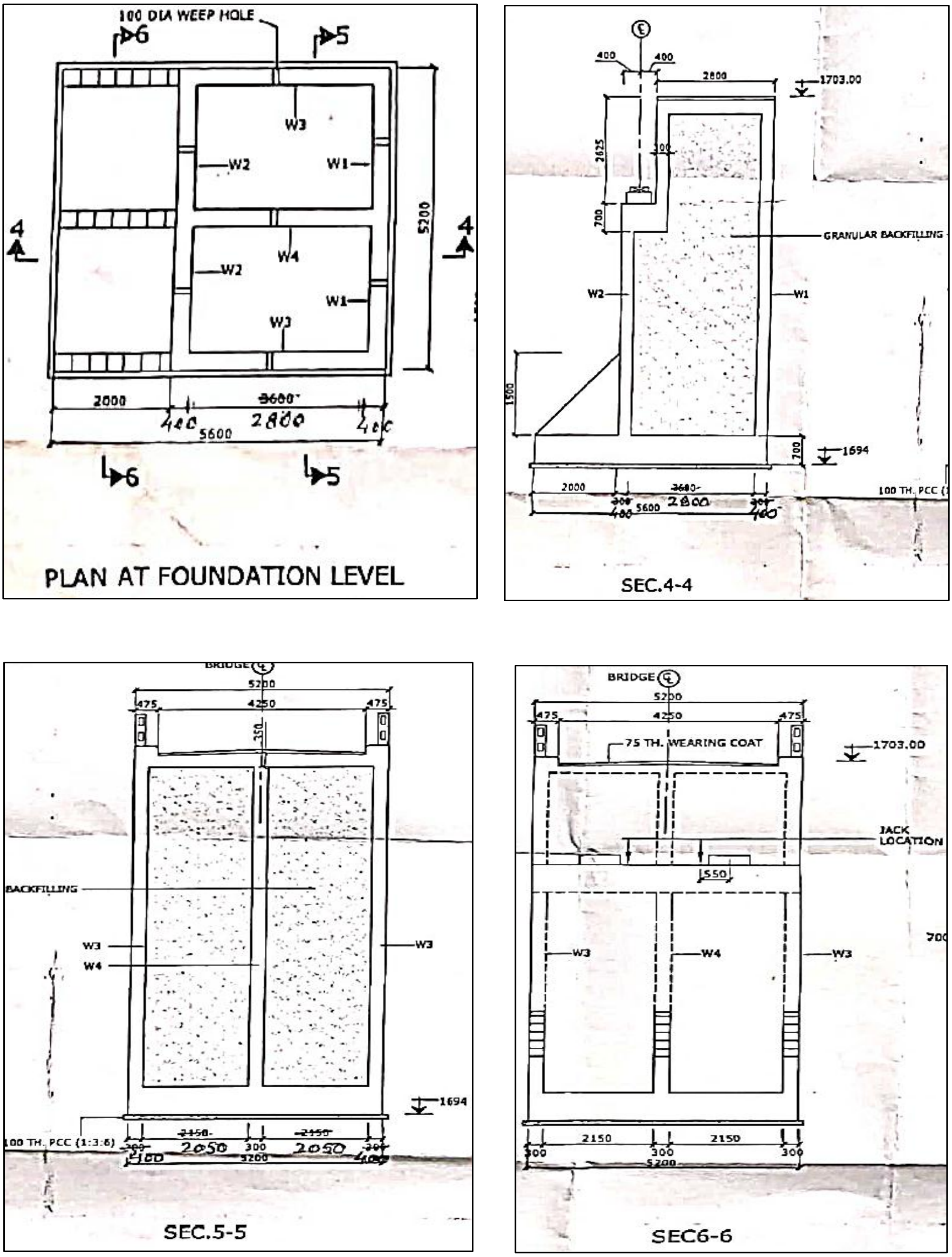
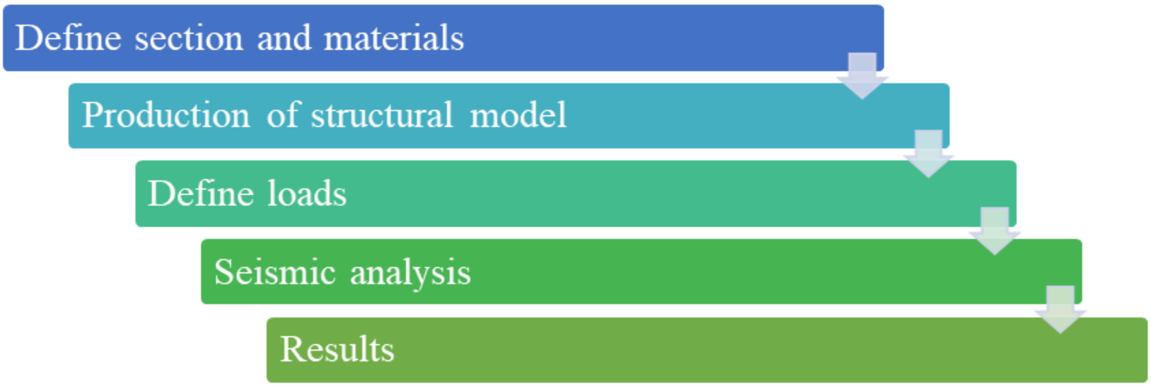


Figure 4.4: Cross section of Right Bank Abutment

4.2. Modeling of Bridge using Midas Civil

Steps for Modelling a Bridge



4.2.1. Create Material Properties

M30 Grade of Concrete is created for material properties

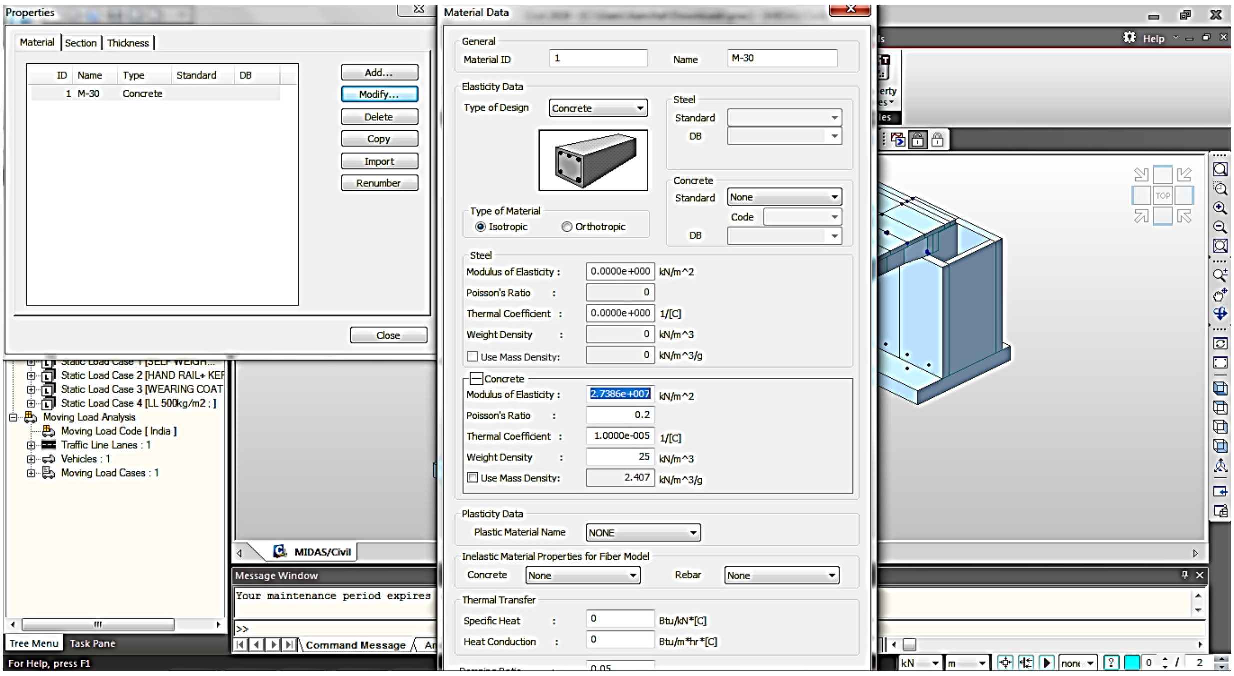
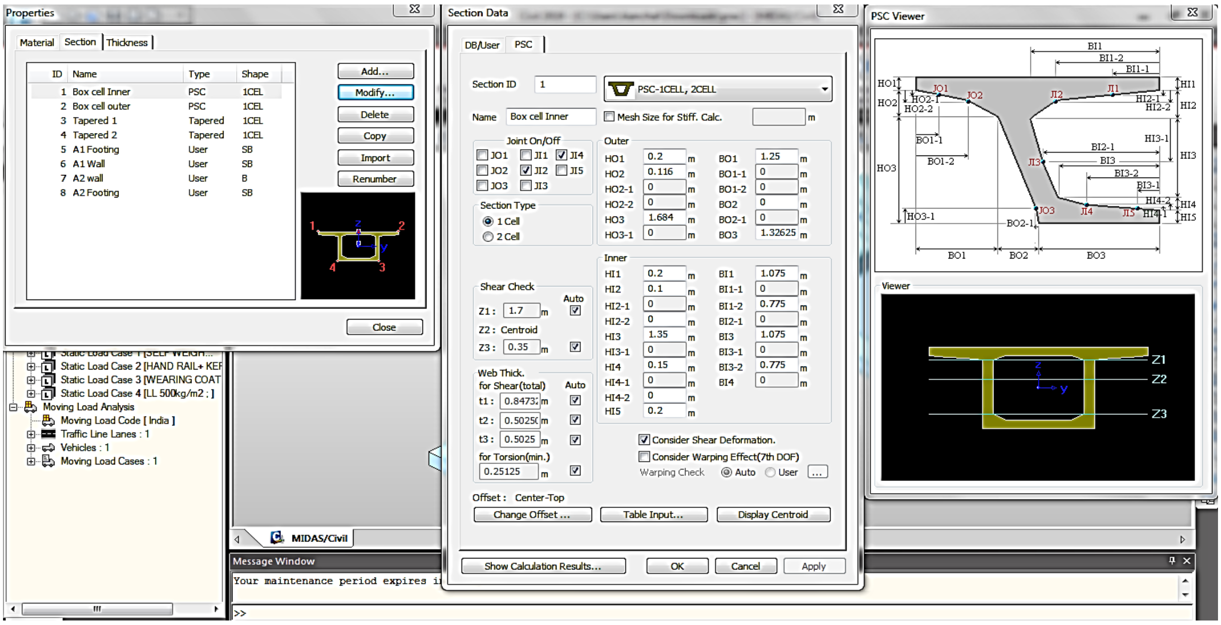


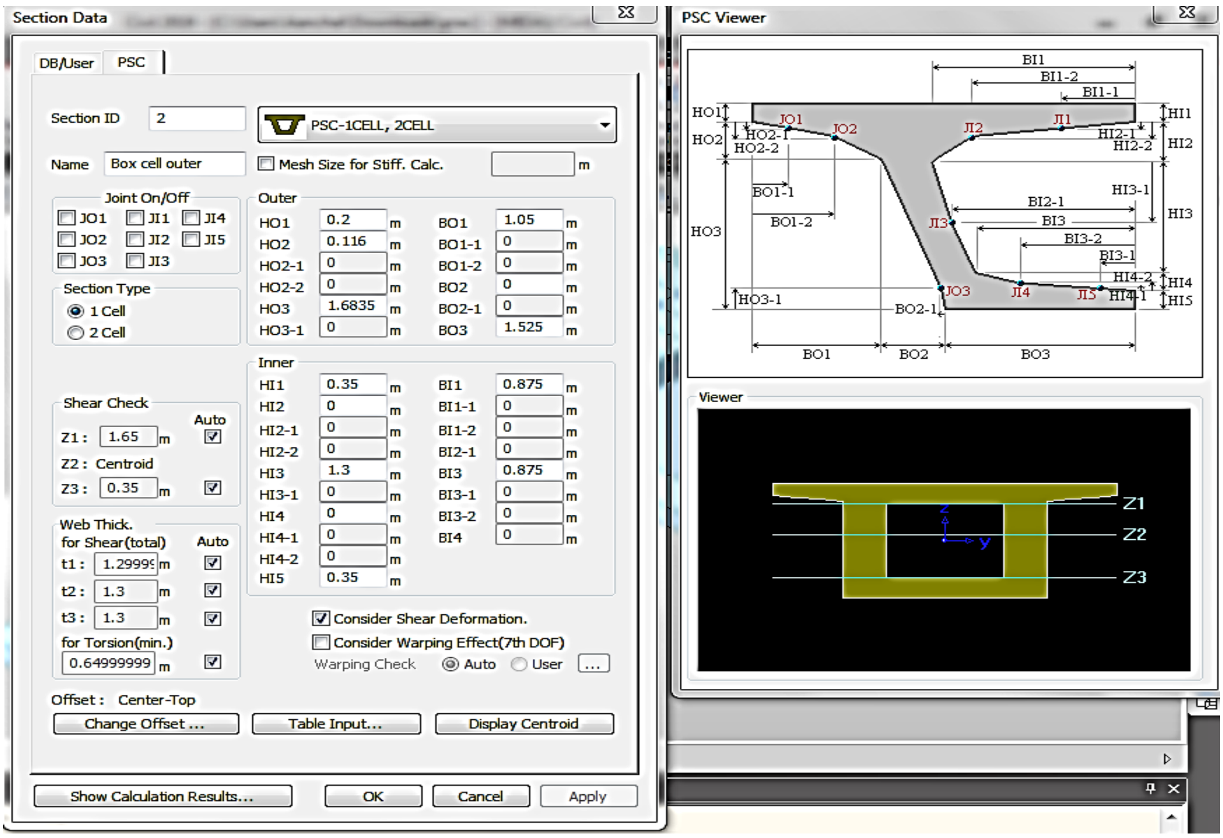
Figure 4.5: Create Material Properties

4.2.2. Create Section Properties

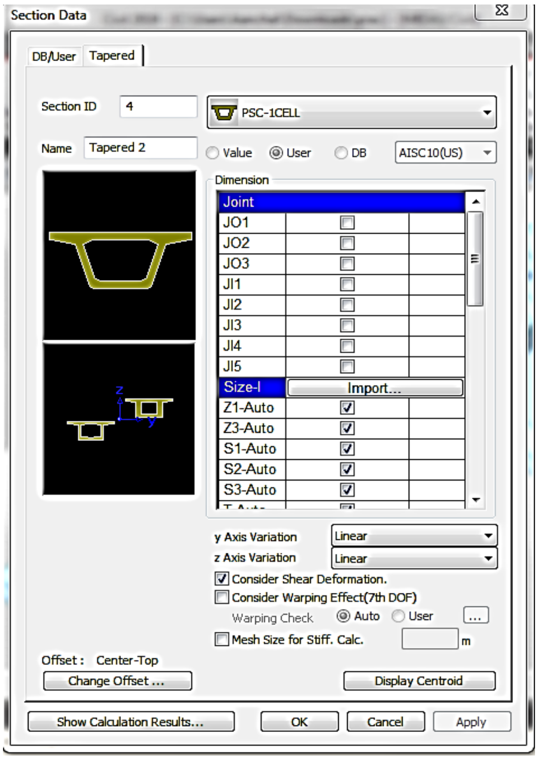
As per the drawing Inner and Outer Box Cell are created and to make the continuity between them two tapered sections also created i.e., one for support to mid-section and other is for mid to support section. For the abutments footings and walls are created as per drawings for abutment 1 and 2.



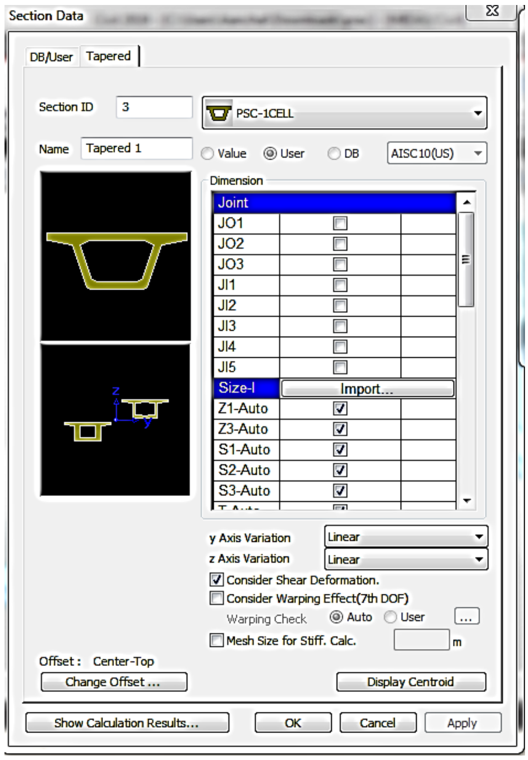
(a)



(b)


Section Data
DB/User
Tapered
Section ID
4
PSC-1CELL
Name
Tapered 2
Value
User
DB
AISC10(US)
Dimension
Joint
JO1
JO2
JO3
JI1
JI2
JI3
JI4
JI5
Size-I
Import...
Z1-Auto
Z3-Auto
S1-Auto
S2-Auto
S3-Auto
y Axis Variation
Linear
z Axis Variation
Linear
Consider Shear Deformation.
Consider Warping Effect(7th DOF)
Warping Check
Auto
User
Mesh Size for Stiff. Calc.
m
Offset : Center-Top
Change Offset ...
Display Centroid
Show Calculation Results...
OK
Cancel
Apply

(c)


Section Data
DB/User
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3
PSC-1CELL
Name
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Value
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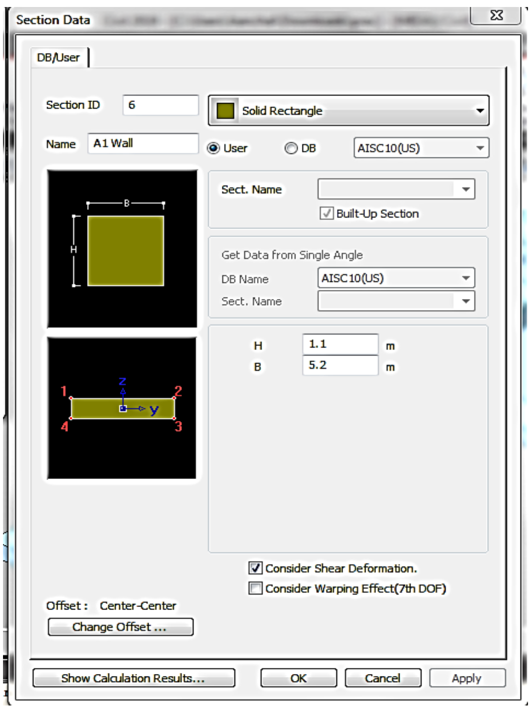
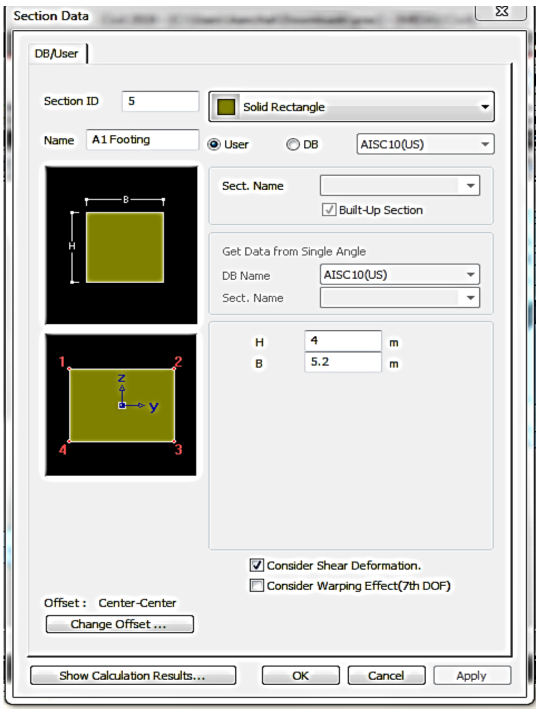
DB
AISC10(US)
Dimension
Joint
JO1
JO2
JO3
JI1
JI2
JI3
JI4
JI5
Size-I
Import...
Z1-Auto
Z3-Auto
S1-Auto
S2-Auto
S3-Auto
y Axis Variation
Linear
z Axis Variation
Linear
Consider Shear Deformation.
Consider Warping Effect(7th DOF)
Warping Check
Auto
User
Mesh Size for Stiff. Calc.
m
Offset : Center-Top
Change Offset ...
Display Centroid
Show Calculation Results...
OK
Cancel
Apply

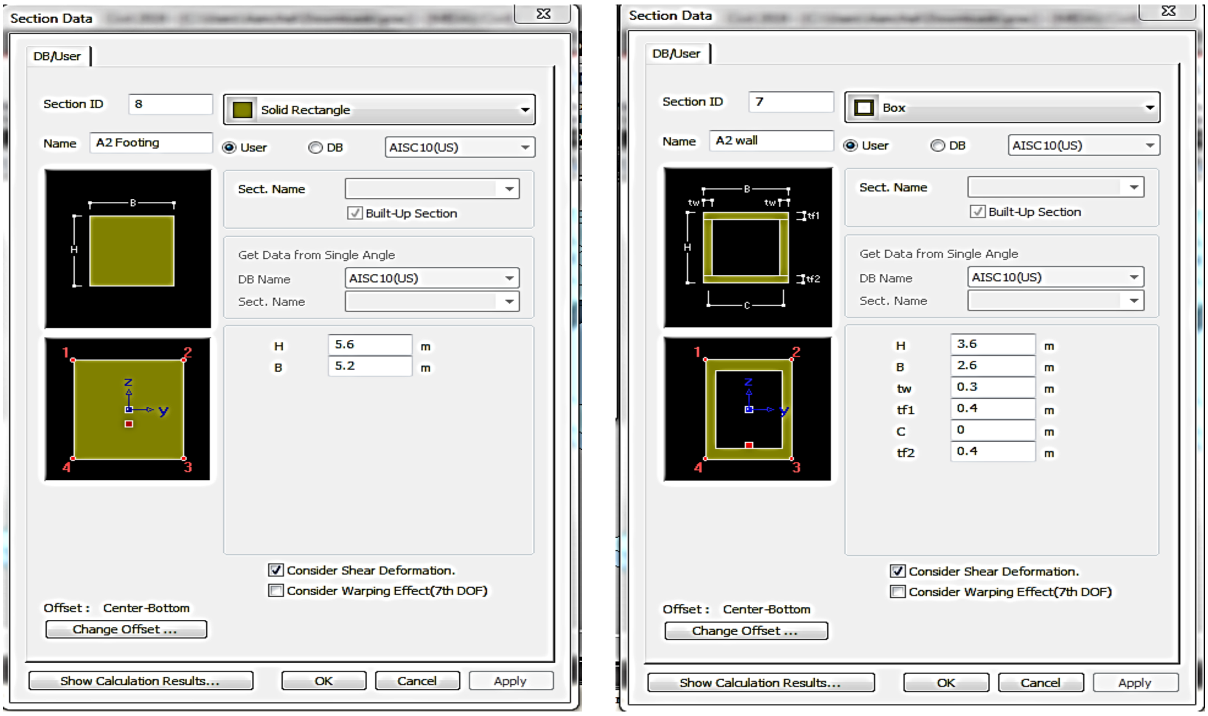
(d)


Section Data
DB/User
Section ID
6
Solid Rectangle
Name
A1 Wall
User
DB
AISC10(US)
Sect. Name
Built-Up Section
Get Data from Single Angle
DB Name
AISC10(US)
Sect. Name
H
1.1
m
B
5.2
m
Consider Shear Deformation.
Consider Warping Effect(7th DOF)
Offset : Center-Center
Change Offset ...
Show Calculation Results...
OK
Cancel
Apply

(e)


Section Data
DB/User
Section ID
5
Solid Rectangle
Name
A1 Footing
User
DB
AISC10(US)
Sect. Name
Built-Up Section
Get Data from Single Angle
DB Name
AISC10(US)
Sect. Name
H
4
m
B
5.2
m
Consider Shear Deformation.
Consider Warping Effect(7th DOF)
Offset : Center-Center
Change Offset ...
Show Calculation Results...
OK
Cancel
Apply

(f)



(g) **(h)**

Figure 4.6: Create Section Properties as (a),(b),(c),(d),(e),(f),(g)and (h)

4.2.3. Section Assignment

Assign Box Cell with extrude command in 2@ 0.325, 1@1.2, 20@1.0475, 2@0.325, 1@1.2 line segments and assign other section properties as per requirement.

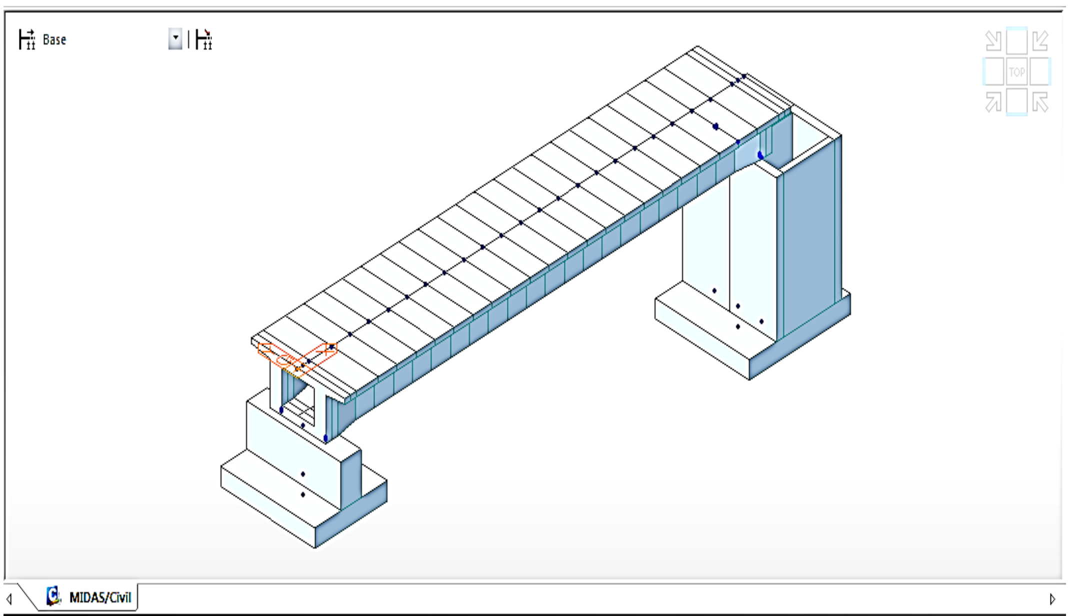


Figure 4.7: Section Assignment

4.2.4. Assigning of supports

Assign supports at the bottom node of the footing which is corresponding to the bearing node.

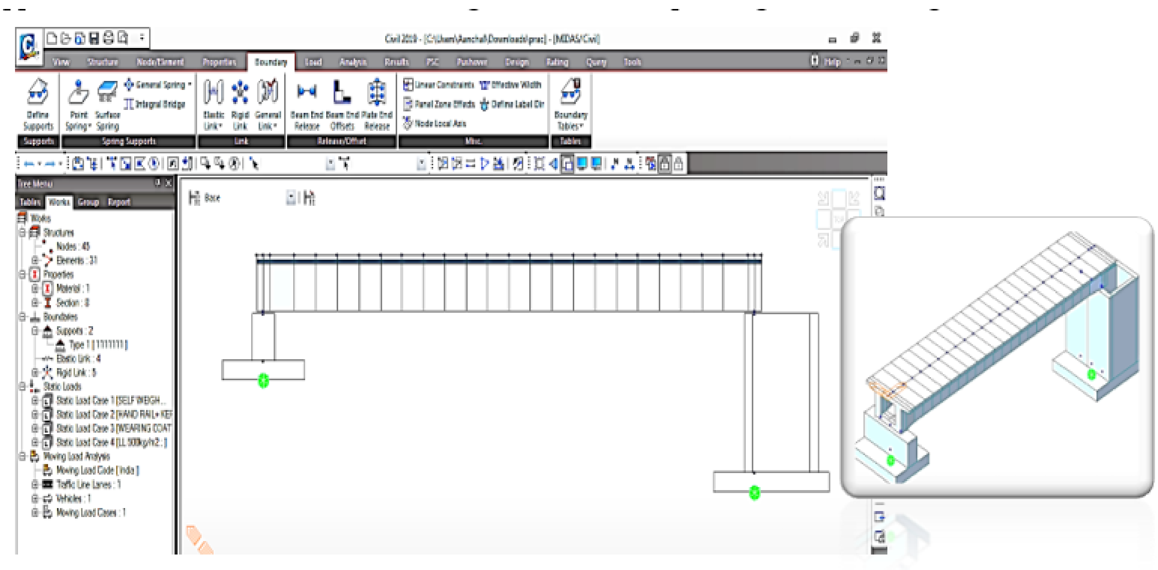


Figure 4.8: Assigning of the Supports

4.2.5. Assigning of Elastic Links

Assign elastic link at all the 4 bearing nodes

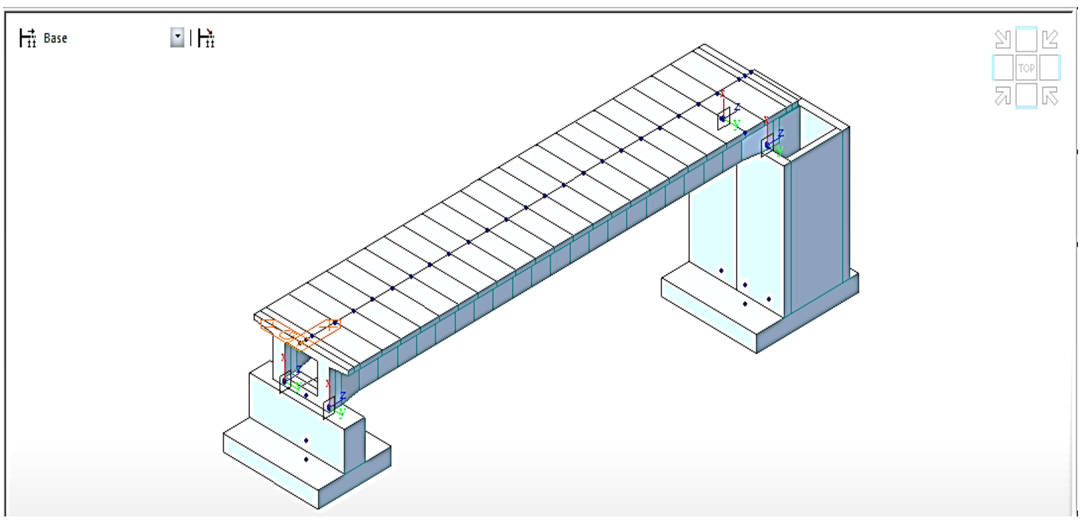
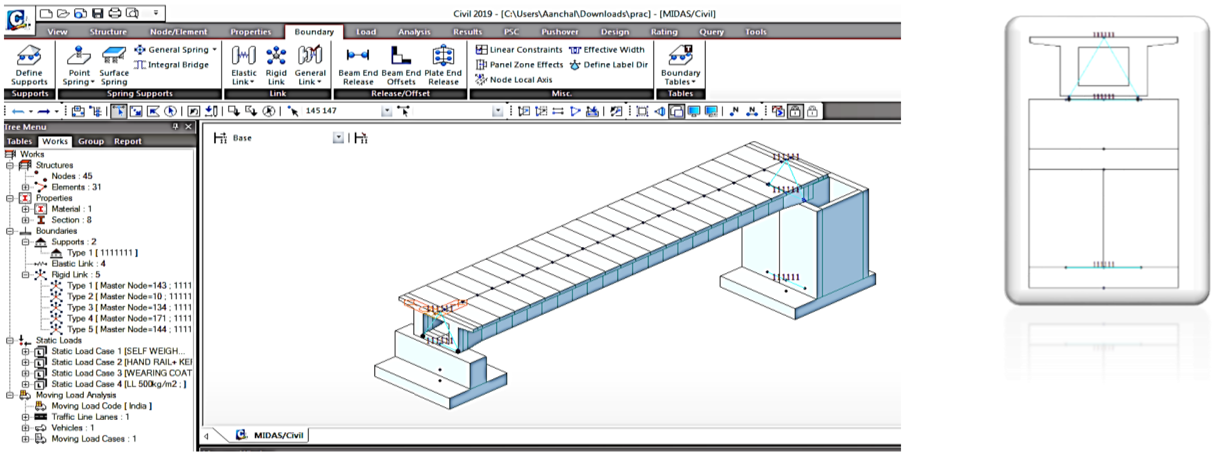


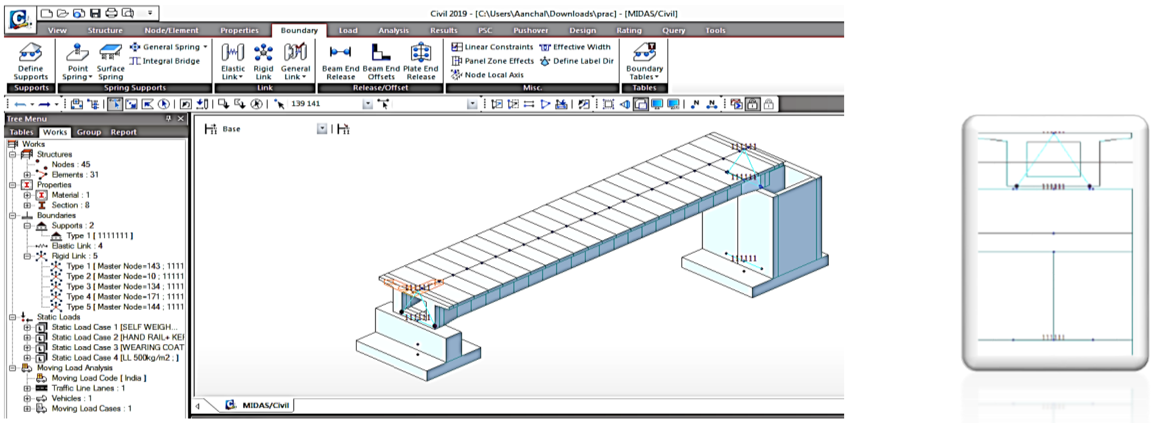
Figure 4.9: Assigning of Elastic Links

4.2.6. Assigning Rigid Link

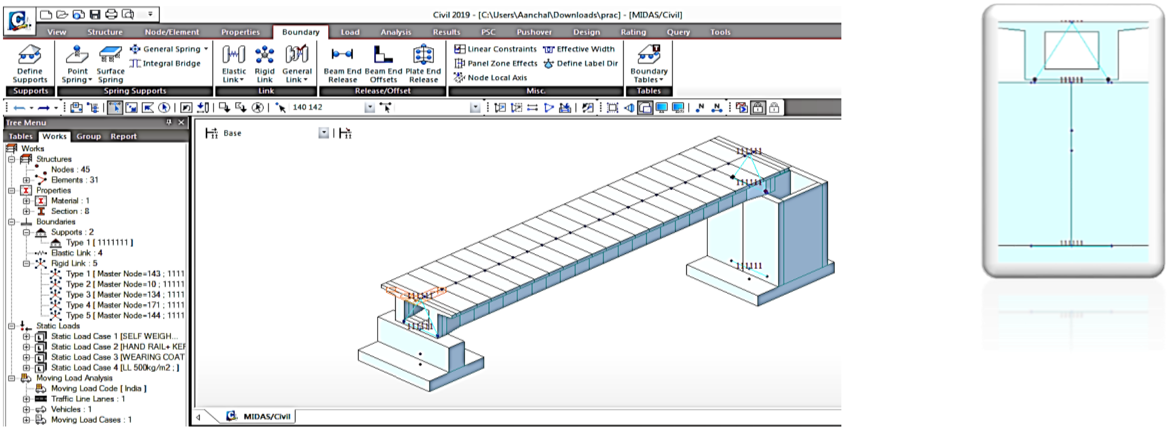
Here 5 rigid links are created i.e., one is at right side corner of the girder and other is on left side and one is at the top of wall of abutment 1 and other is on abutment 2 and one is created to make the two hollow block of abutment 2allign or rigid.



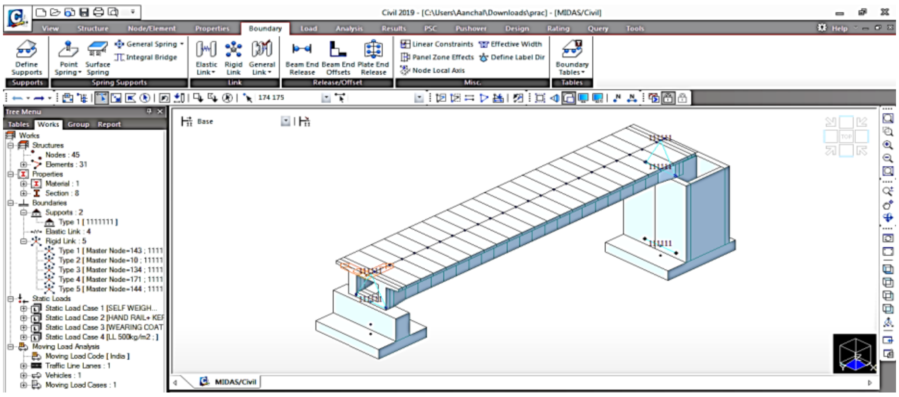
(a)



(b)



(c)



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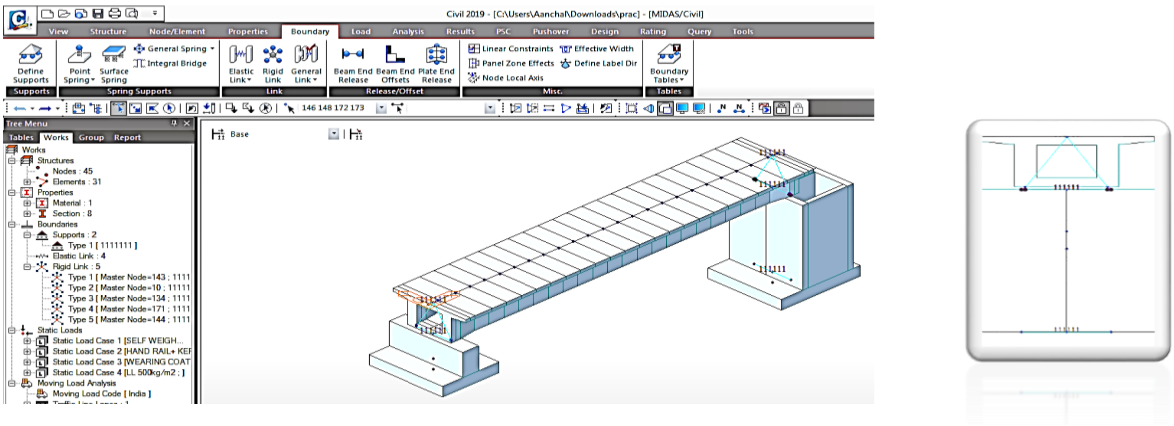


(e)

Figure 4.10: Assigning of Rigid Links as (a),(b),(c),(d)and(e)

4.2.7. Define Static Load Cases

For this project four static load cases are created i.e. Self-weight, hand rail, wearing coat and LL 500kg/m.

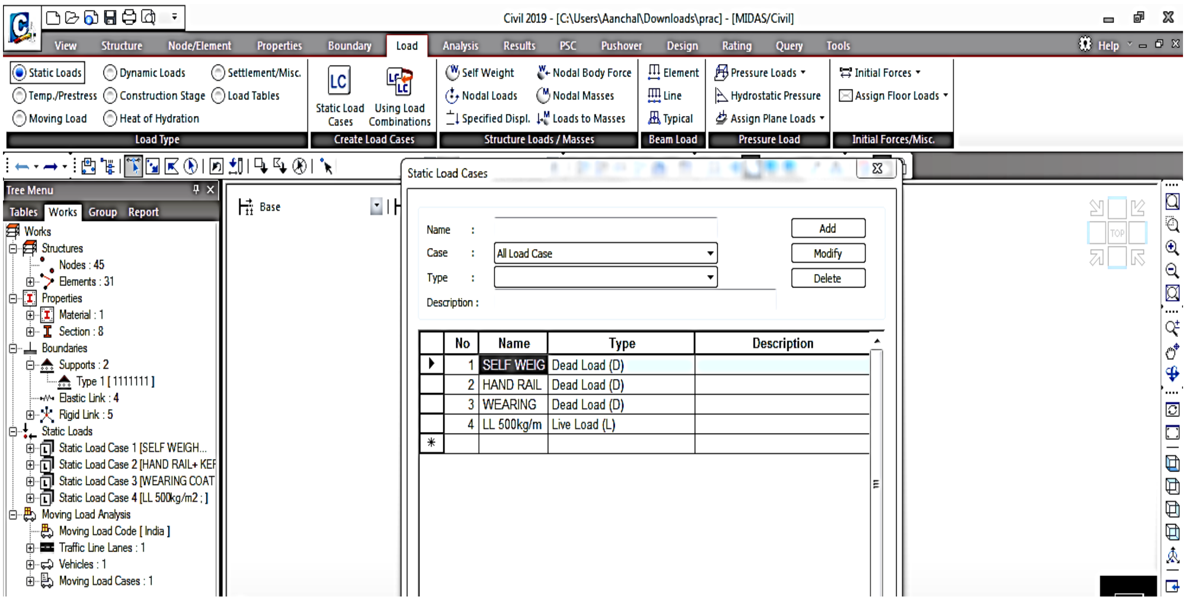
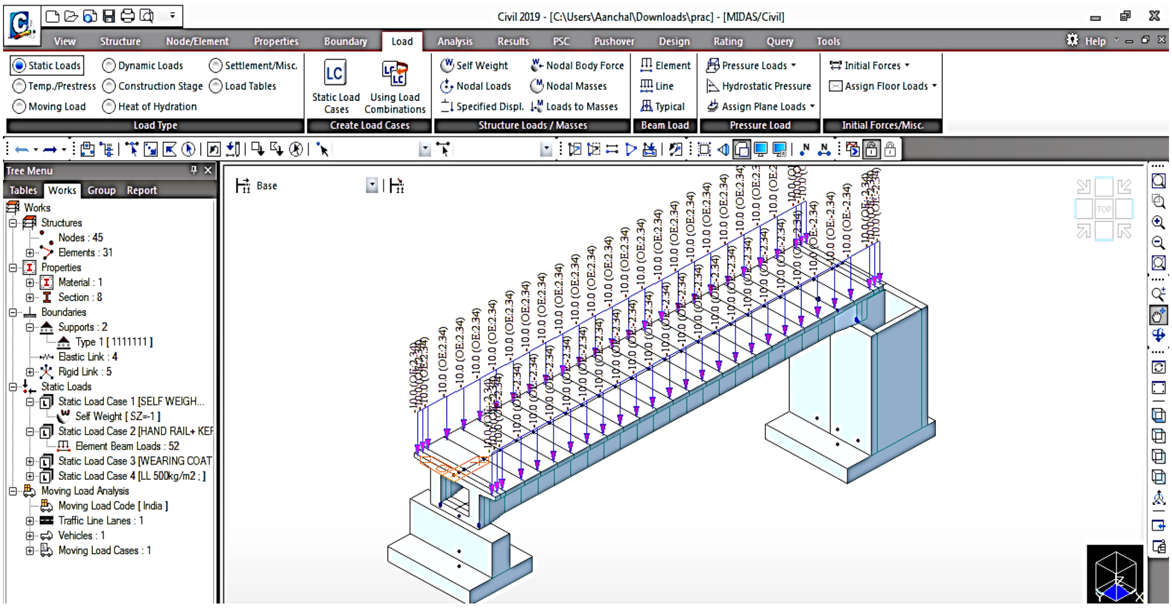


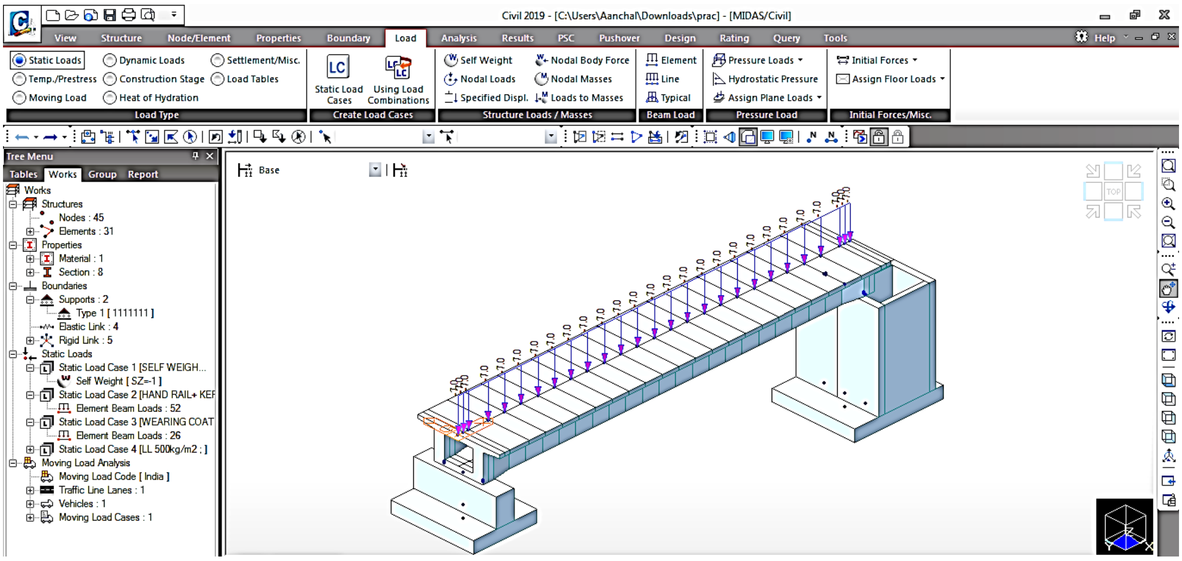
Figure 4.11: Define Static Load Cases

4.2.8. Assigning of Static Loads

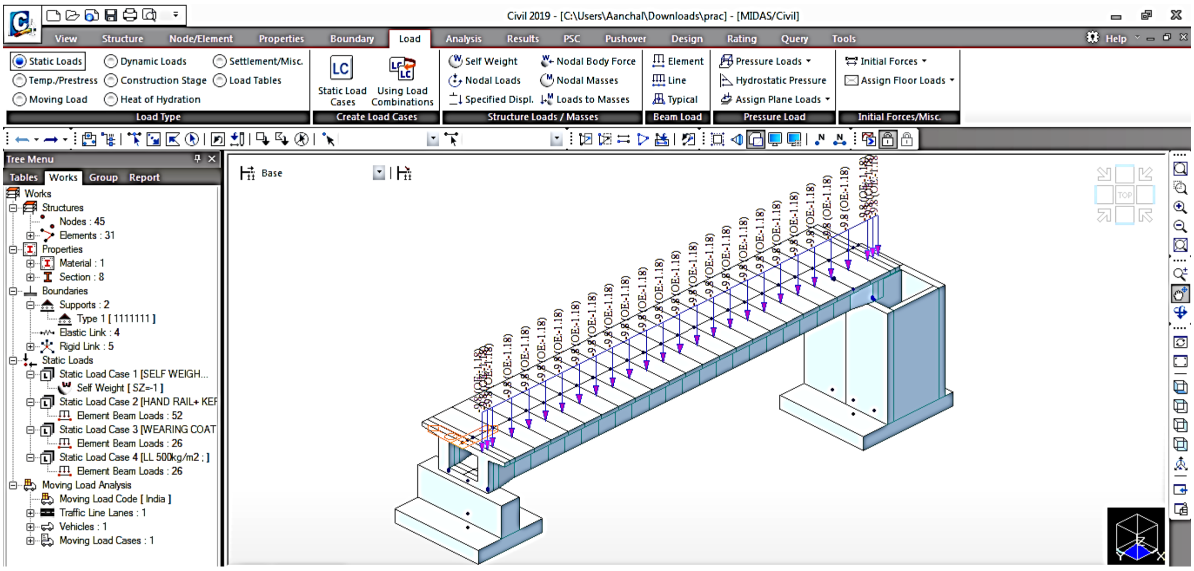
Add -1 factor in Z-direction for self-weight, other static loads in the form of UDL over the over the bridge are assigned as per requirement



(a)



(b)



(c)

Figure 4.12: Assigning of Static Loads(a),(b)and(c)

4.2.9. Define and Assign Moving Load

First select Indian code then create a lane and add standard vehicular load (here class A load is considered) and then define moving load cases as per requirement.

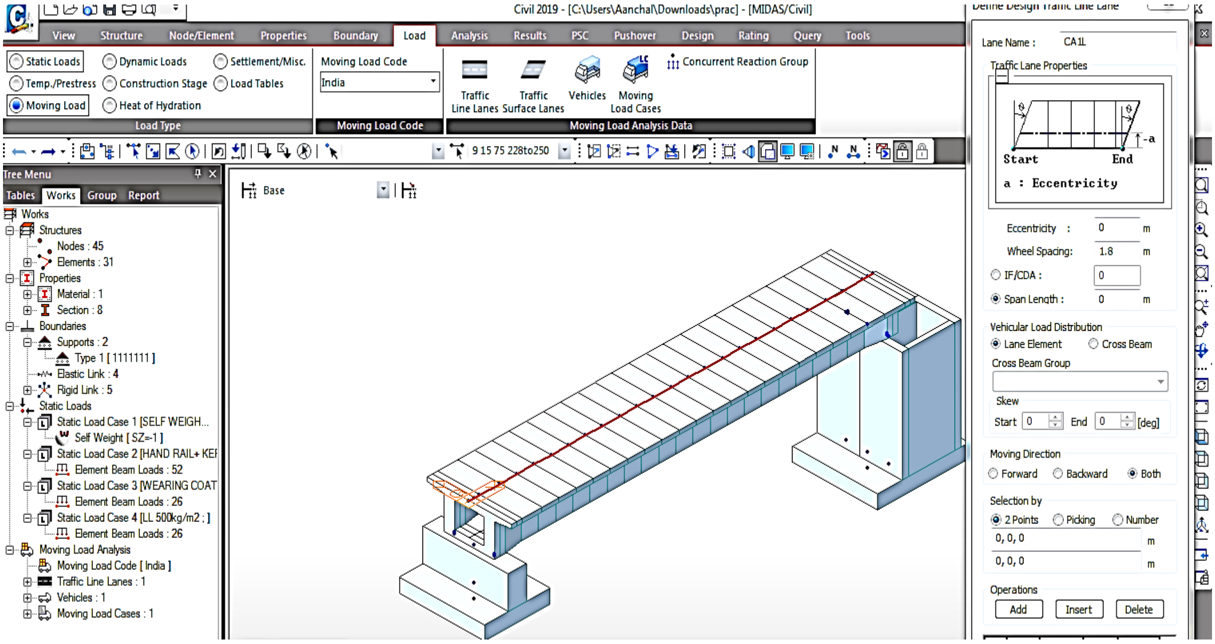


Figure 4.13: Moving Load- Create Lanes

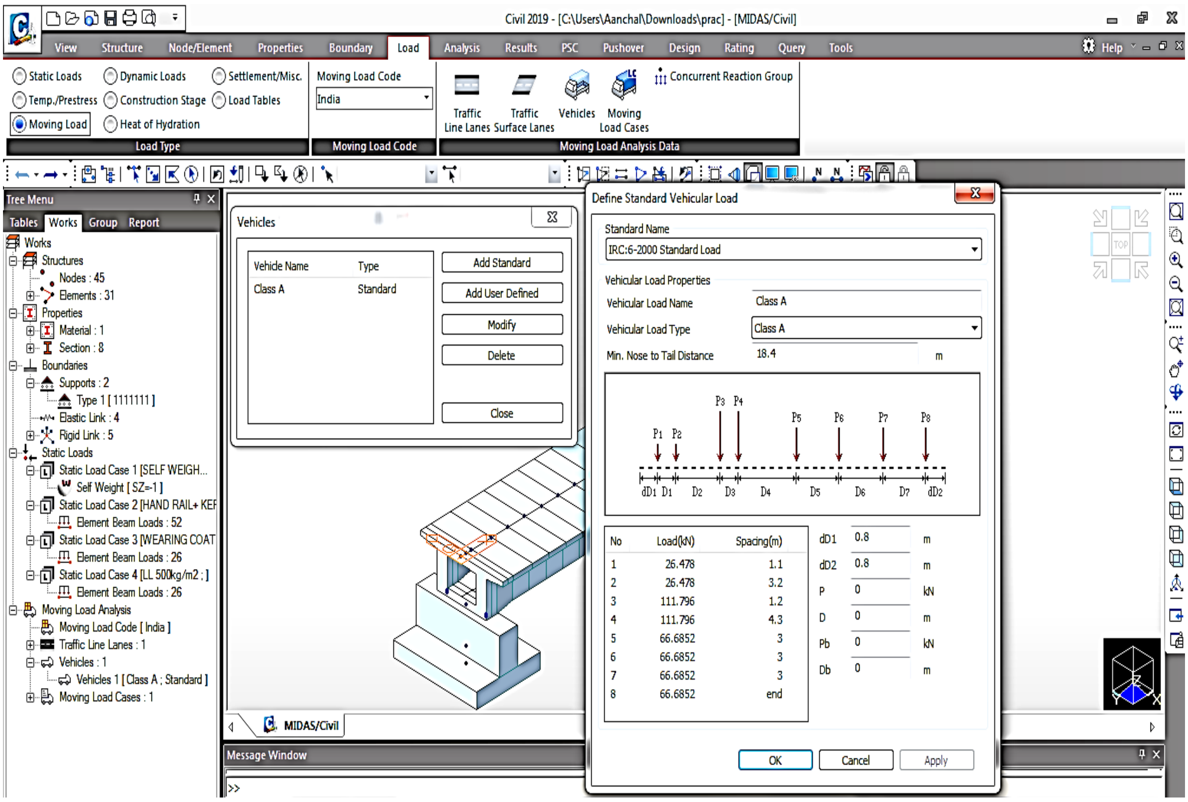


Figure 4.14: Moving Load- Add Standards

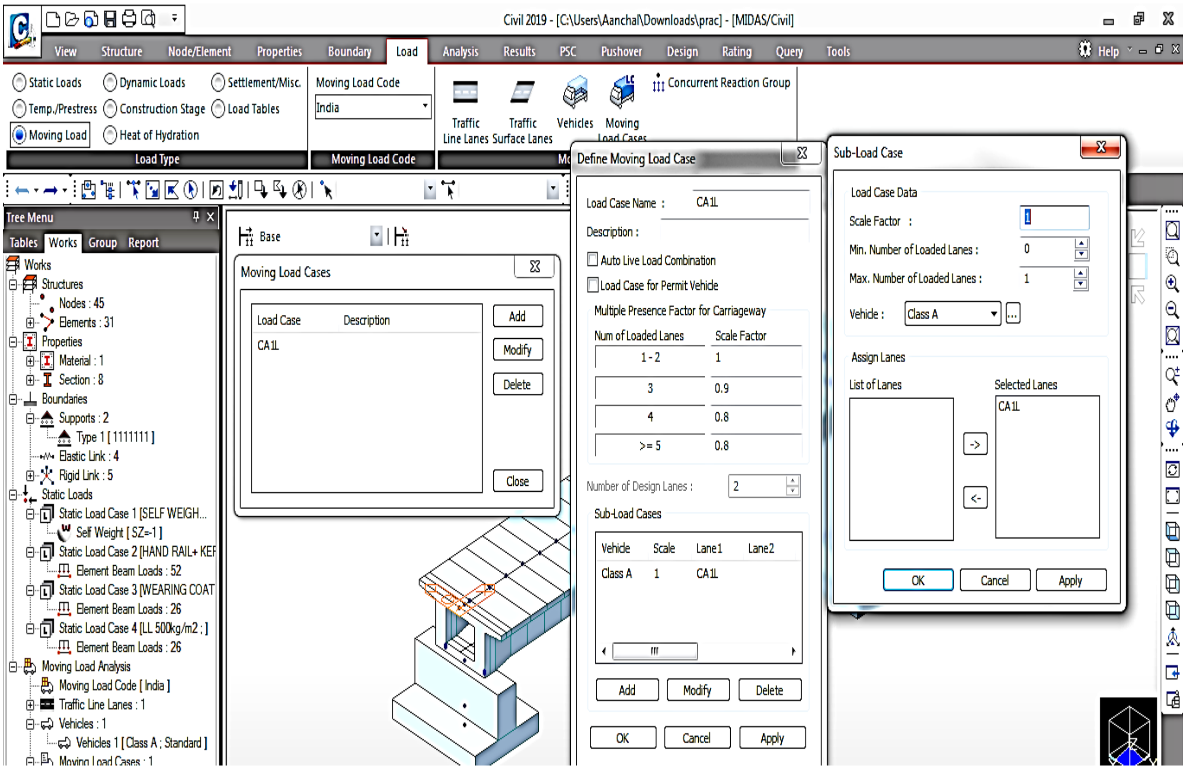


Figure 4.15: Moving Load- Define Moving Load Case

4.3. Results for Static and Moving Load Analysis

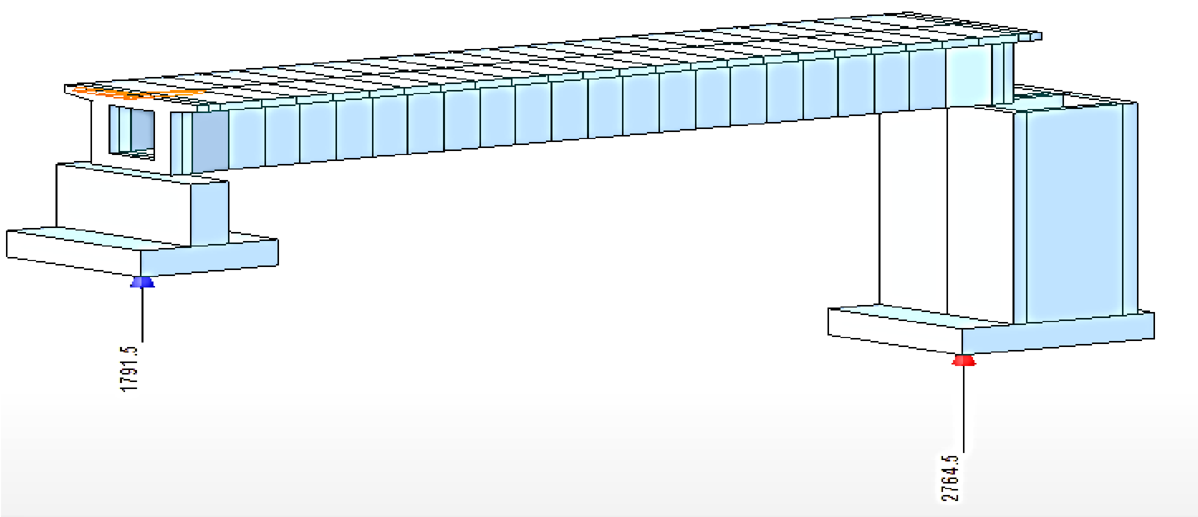


Figure 4.16: Results- Reactions due to DL + LL

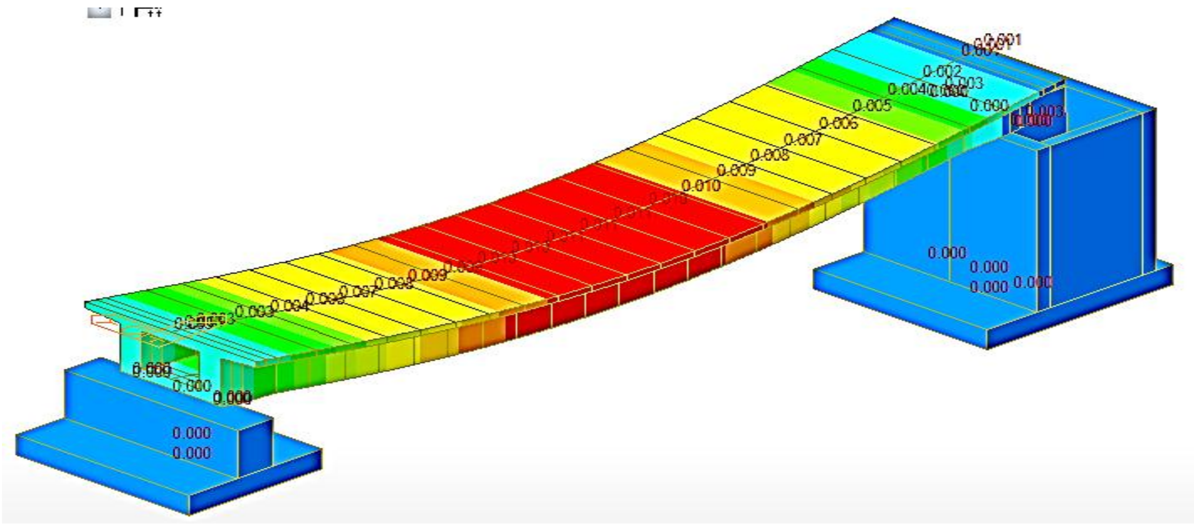


Figure 4.17: Result-Deformation due to DL+LL

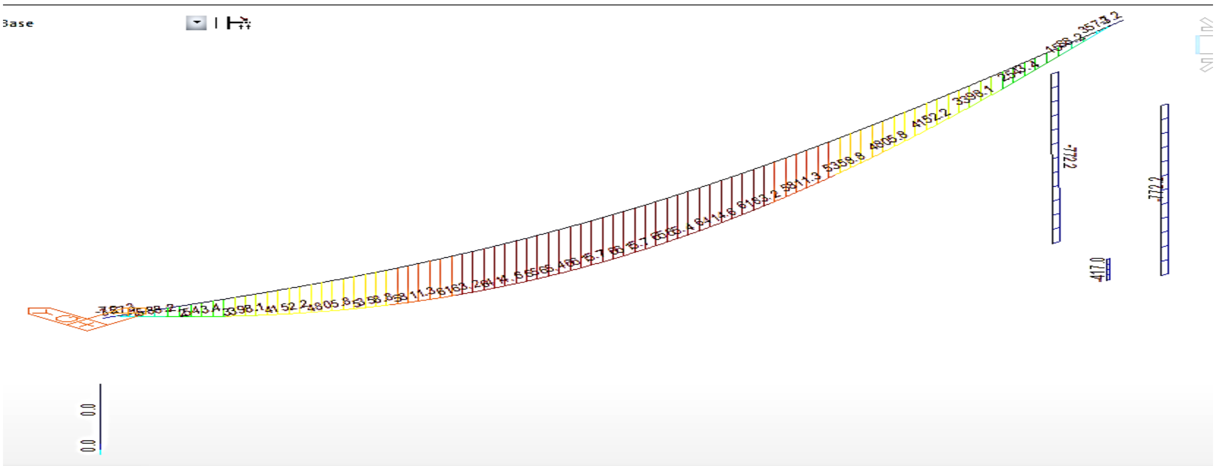


Figure 4.18: Result- Beam Diagram

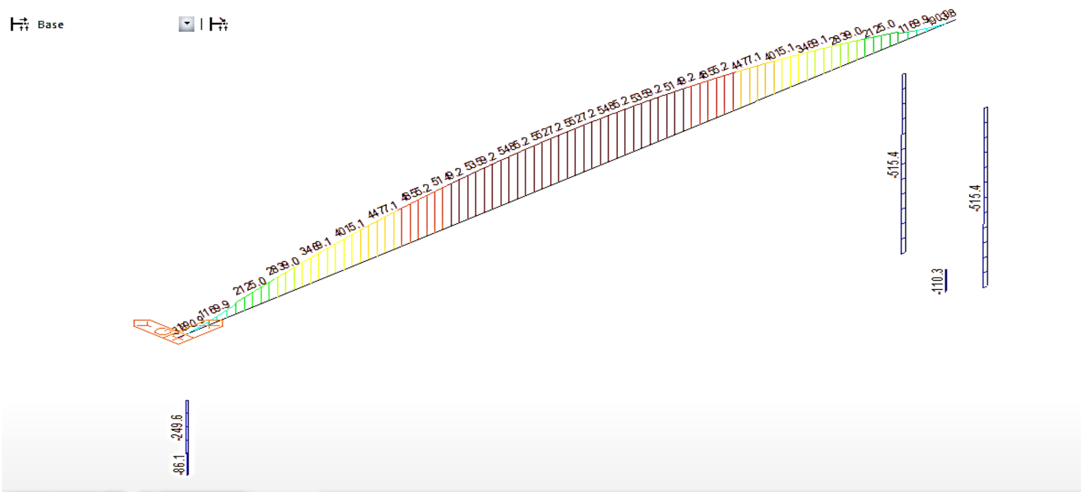


Figure 4.19: Result- Beam Stress Diagram

CHAPTER 5: SEISMIC ANALYSIS OF BRIDGE WITH DIFFERENT METHODS

5.1. Linear Static Analysis

Generally dynamic analysis isn't done for most of the structures, but an equivalent static seismic lateral load is applied instead. This static equivalent load is derived based on the zone factor, importance factor, response reduction factor, and code-based spectral acceleration. This method is simple, does not need rigorous calculation, and is relatively fast.

In Midas Civil, we calculate the equivalent static load manually and then apply it using the Element Beam Load option.

5.1.1. Eigen value Analysis

Eigenvalue analysis is the process of determining the dynamic characteristics of the structure of an undamped free vibration. We determine the "natural vibration modes", "natural frequencies" of the given structure. When the applied load frequency matches with the natural frequency of the structure, then the amplitude of structural vibrations will tremendously increase which is called resonance, hence modal analysis is a crucial tool to "determine the natural dynamic characteristics of the structure".

"Mode shapes and natural periods of an undamped free vibration are obtained from the characteristic equation below":

$$“[K]\{\emptyset_n\} = w_n^2[M]\{\emptyset_n\}”$$

where,

$[K]$:Stiffness matrix

$[M]$:Mass matrix

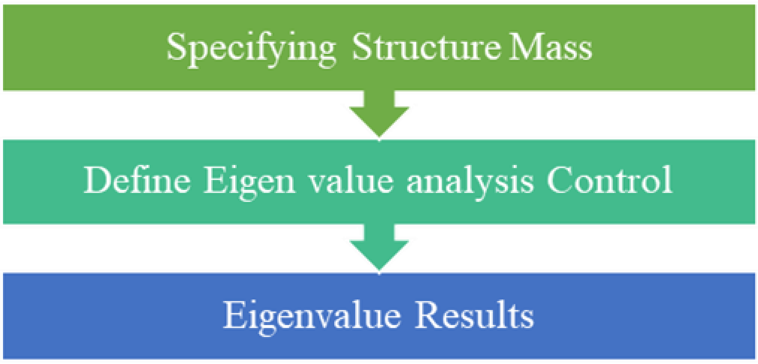
w_n^2 :n-th mode eigenvalue

$\{\emptyset_n\}$:n-th mode eigenvector (mode shape)

Eigenvalue analysis method can also by signify as "free vibration analysis" and this method plays important role for the estimation of dynamic properties of structures.

5.1.1.1. Procedure for Eigen value Analysis

Steps for Eigen Value Analysis



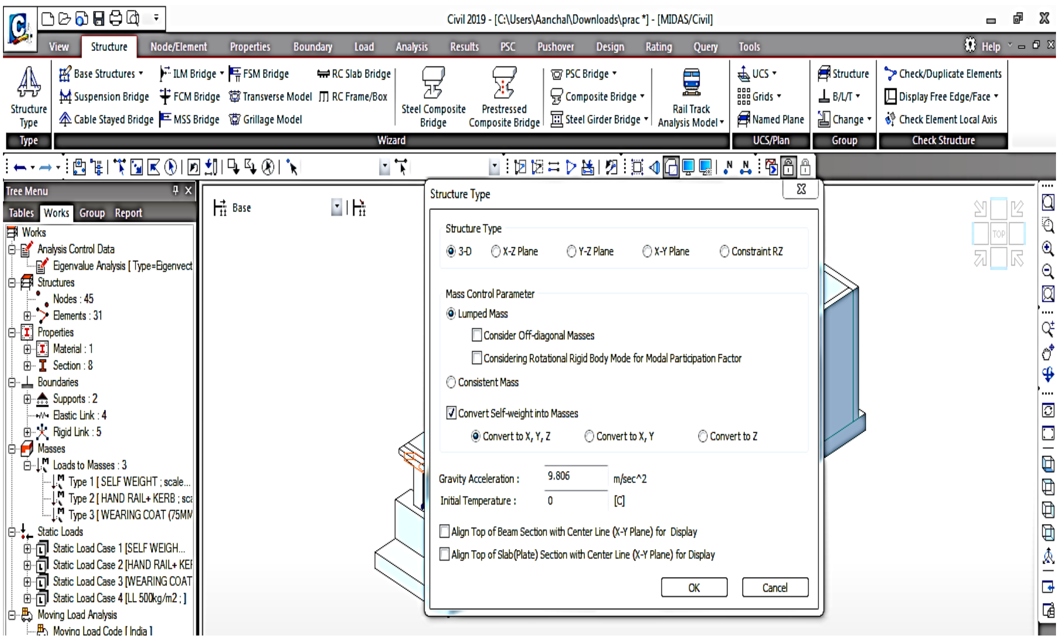


Figure 5.1: Convert Self-Weight into Masses

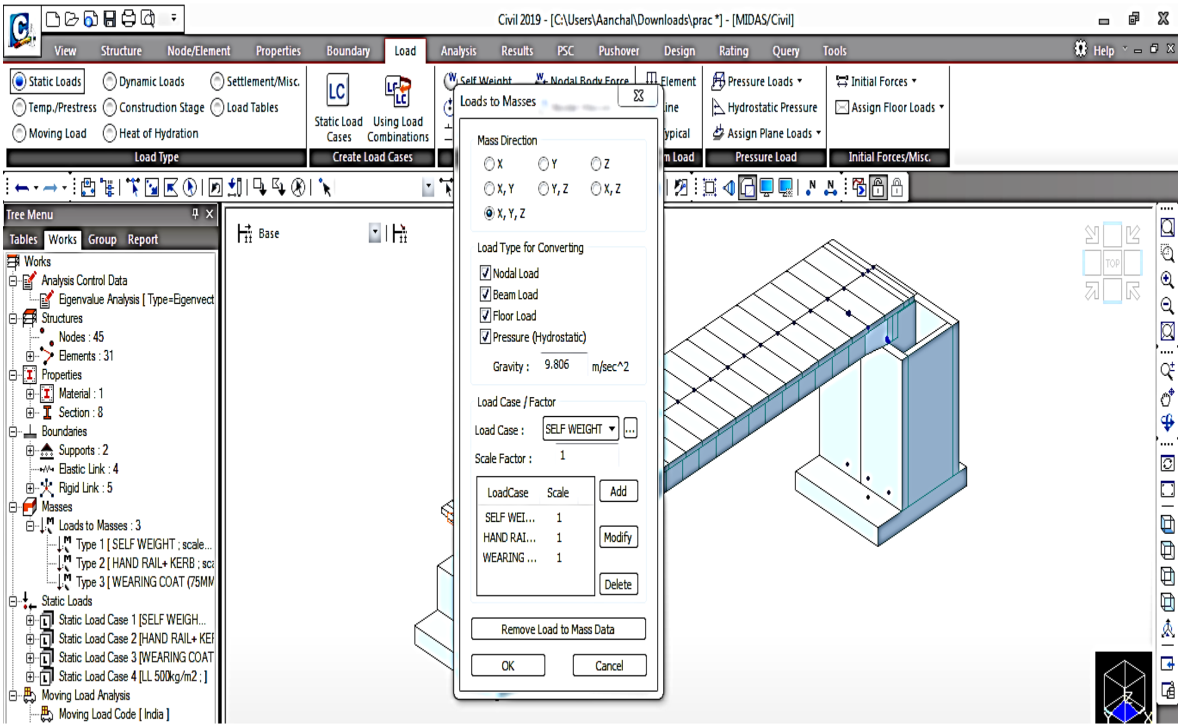


Figure 5.2: Convert other Dead Load into Masses

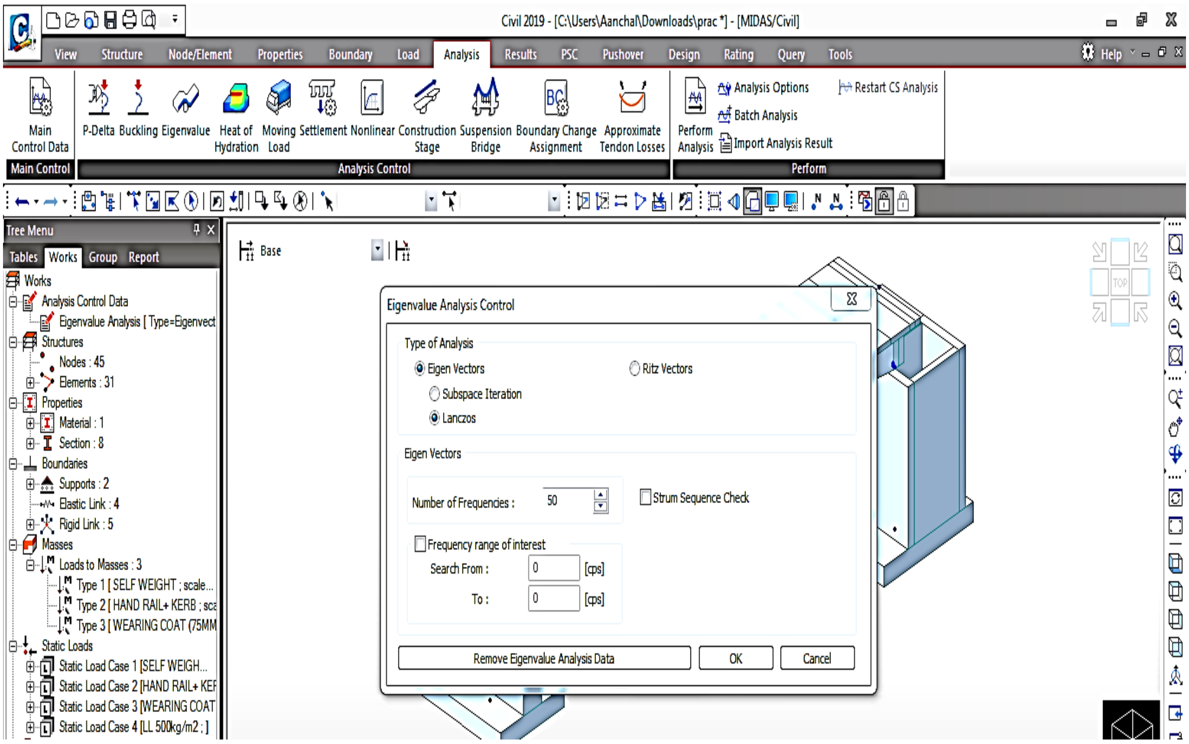


Figure 5.3: Define Eigen Value analysis

5.1.1.2. Results for Eigen Value Analysis

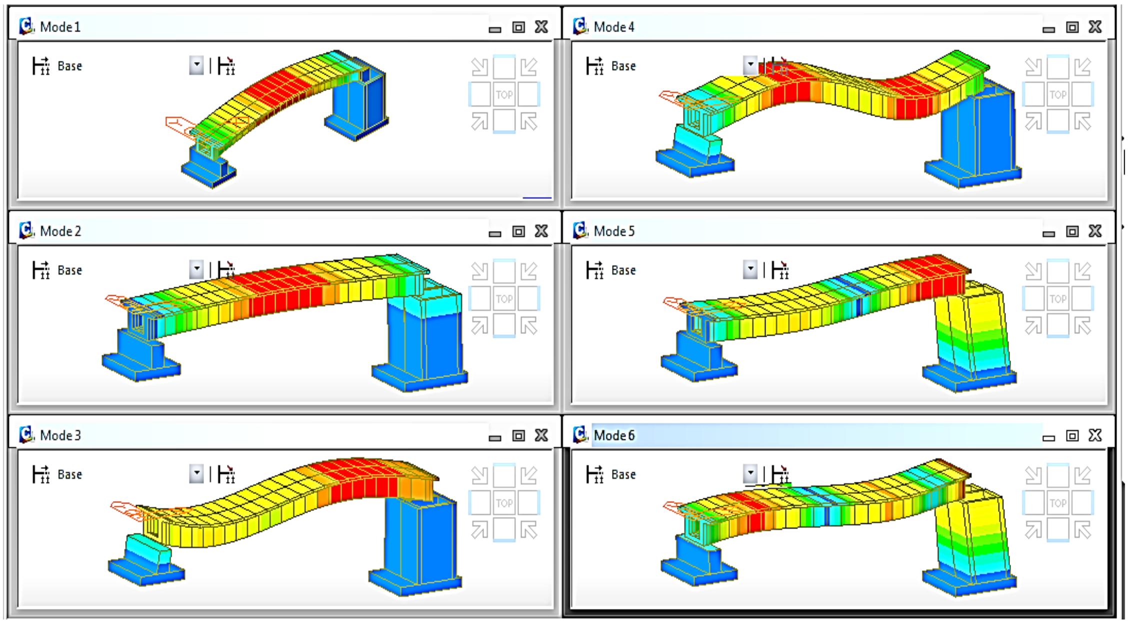


Figure 5.4: Result- Mode shape

EIGENVALUE ANALYSIS				
Mode No	Frequency		Period	Tolerance
	(rad/sec)	(cycle/sec)	(sec)	
1	33.133942	5.273431	0.189630	0.0000e+000
2	61.074580	9.720321	0.102877	0.0000e+000
3	97.435074	15.507274	0.064486	0.0000e+000
4	138.535487	22.048608	0.045354	0.0000e+000
5	149.261866	23.755764	0.042095	0.0000e+000

MODAL PARTICIPATION MASSES PRINTOUT												
Mode No	TRAN-X		TRAN-Y		TRAN-Z		ROTN-X		ROTN-Y		ROTN-Z	
	MASS(%)	SUM(%)	MASS(%)	SUM(%)	MASS(%)	SUM(%)	MASS(%)	SUM(%)	MASS(%)	SUM(%)	MASS(%)	SUM(%)
1	3.12	3.12	0.00	0.00	40.88	40.88	0.00	0.00	1.82	1.82	0.00	0.00
2	0.00	3.12	49.51	49.51	0.00	40.88	21.49	21.49	0.00	1.82	1.21	1.21
3	40.54	43.66	0.00	49.51	1.27	42.15	0.00	21.49	0.32	2.13	0.00	1.21
4	13.31	56.97	0.00	49.51	0.07	42.22	0.00	21.49	18.79	20.93	0.00	1.21
5	0.00	56.97	4.51	54.02	0.00	42.22	0.11	21.59	0.00	20.93	37.81	39.02
46	0.00	74.56	0.00	74.54	0.31	72.80	0.00	29.96	0.77	56.14	0.00	63.68
47	0.00	74.56	0.00	74.54	0.48	73.28	0.00	29.96	1.01	57.15	0.00	63.68
48	0.00	74.56	0.01	74.54	0.00	73.28	0.00	29.97	0.00	57.15	0.07	63.75
49	0.00	74.56	0.00	74.54	0.60	73.88	0.00	29.97	1.39	58.54	0.00	63.75
50	0.00	74.57	0.00	74.54	0.61	74.48	0.00	29.97	1.33	59.86	0.00	63.75

Figure 5.5: Result- Natural Frequencies and proportional Masses

5.1.2. Response Spectrum Analysis

“Response spectrum analysis” is a “linear dynamic analysis method” which measures the structural response to seismic events and it considers the behavior of a system having more than two co-ordinates to describe the system. A “response spectrum” is a “plot of the peak or steady state response to natural frequency of vibrations of varying oscillators” that are modeled through a numerical integration process for which that are “forced into motion by the same base vibration or shock”. The core of a spectrum is proposed in the form of displacement, velocity and acceleration as by keeping them with in the allowable limit helps in designing a sustainable structure for the possible event of an earthquake.

The “dynamic equilibrium equation for a structure” used in a “response spectrum analysis” under the influence of a ground excitation are:

$$“[M]\ddot{u}(t)+[C]\dot{u}(t)+[K]u(t)= -[M]w_g(t)”$$

Where,

“[M]”: “Mass matrix”

“[C]”: “Damping matrix”

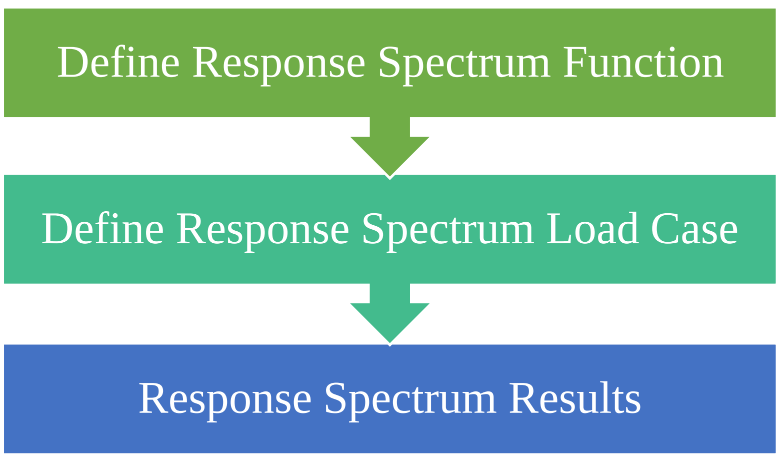
“[K]”: “Stiffness matrix “

“w_g(t)”: “Ground acceleration”

And “u(t)”, “$\dot{u}$(t)”, and “$\ddot{u}$(t)” are “relative displacement”, “velocity” and “acceleration respectively”.

5.1.2.1. Procedure for Response Spectrum Analysis

Steps for Response Spectrum Analysis



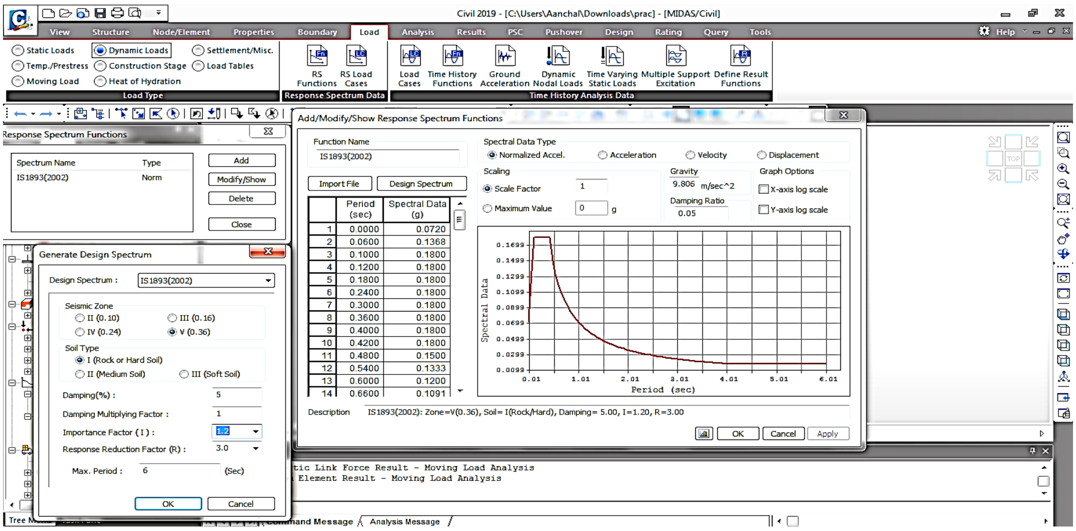


Figure 5.6: Define Response Spectrum Analysis

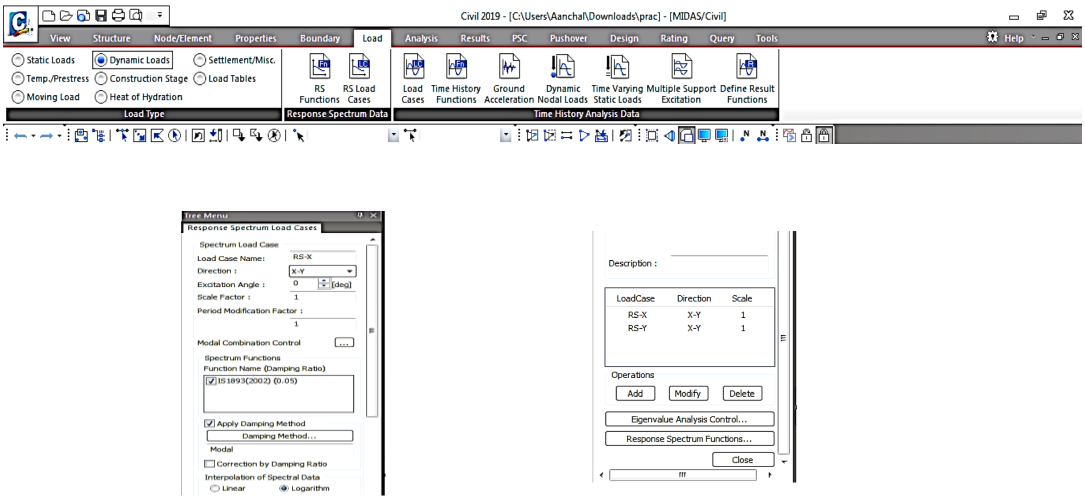
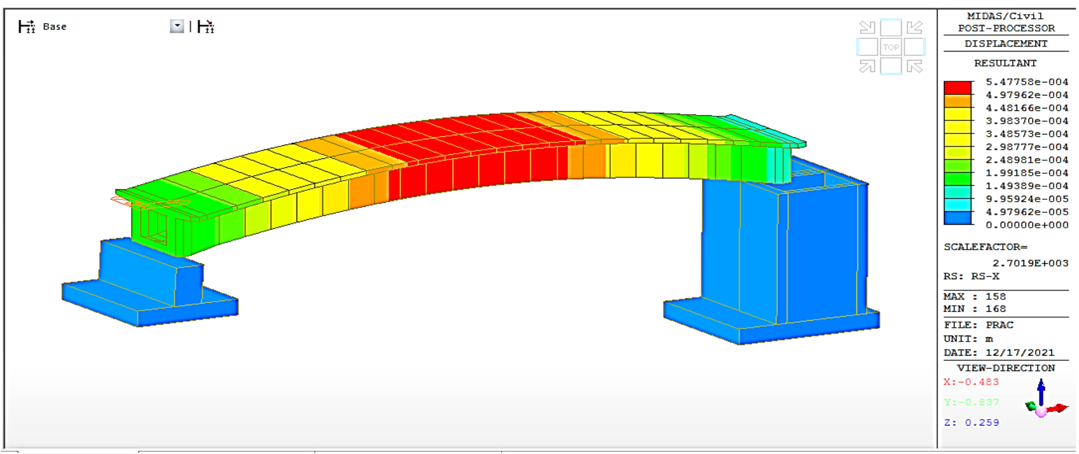
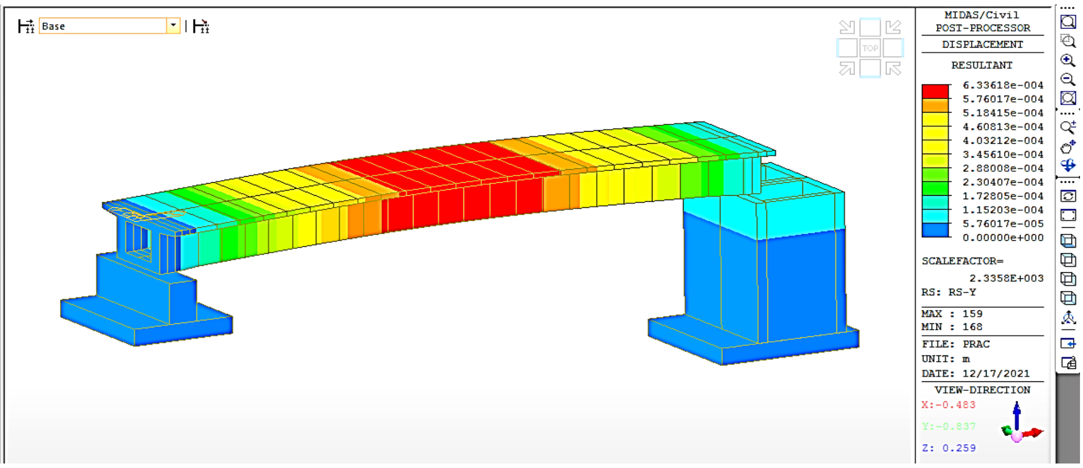


Figure 5.7: Define Response Spectrum Load Case

5.1.2.2. Results for Response Spectrum Analysis



(a)



(b)

Figure 5.8: Result-Deformation due to RS(x) and RS(y) as (a)and(b)

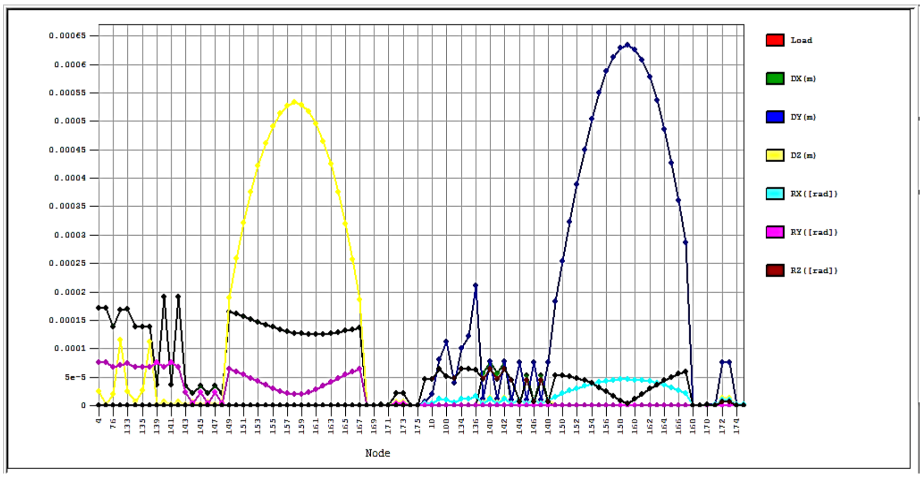


Figure 5.9: Result- Graphical Representation of Deformation at Each Nodes of the structure

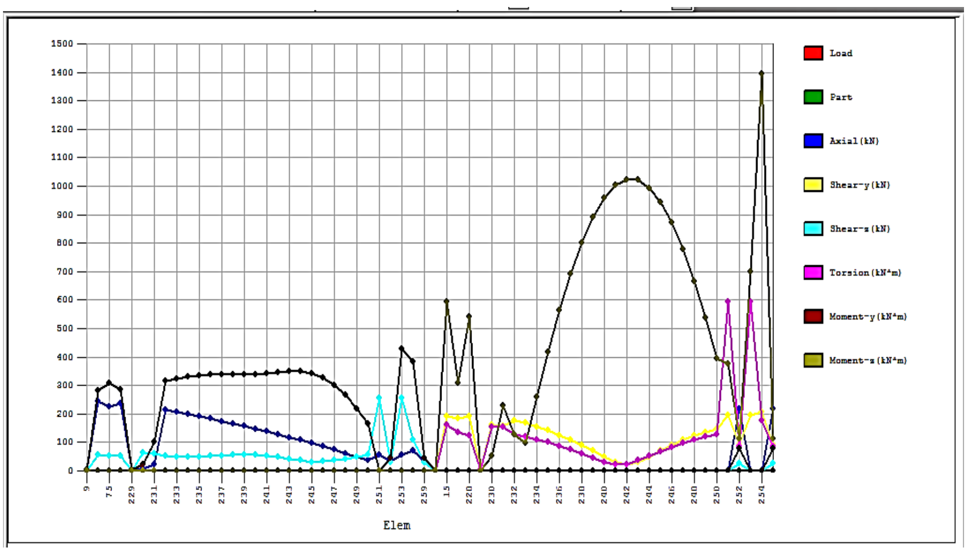


Figure 5.10: Result- Graphical Representation of Beam force/moment at each Elements of the structure

5.2. Non-Linear Time History Analysis

"Time history analysis" seeks out a solution for the "dynamic equilibrium equation when a structure is subjected to dynamic loads". It estimated a series of "structural responses" like "displacements", "member forces", etc. within a given period of time "based on the dynamic characteristics of the structure" under the applied loads. "Midas Civil uses the Modal Superposition Method for time history analysis".

Types of Time History Analysis:

- Boundary Nonlinear Time History Analysis
- Inelastic Time History Analysis.

The "equation of motion for a structure", which contains "General links elements of force type", is as follows:

$$\text{“}M\ddot{u}(t) + C\dot{u}(t) + (K_s + K_N)u(t) = B_p p(t) + B_N(f_L(t) - f_N(t))\text{”}$$

where,

"M": "Mass matrix"

"C": "Damping matrix"

"K_s": "Elastic stiffness without General Link elements of Force Type"

"K_N: "Effective stiffness of General Link elements of Force Type"

"B_p","B_N": "Transformation matrices »

"u (t)", "$\dot{u}$(t)", "$\ddot{u}$ (t)": "Nodal displacement, velocity & acceleration"

"p (t)" : "Dynamic load"

"f_L(t)": "Internal forces due to the effective stiffness of nonlinear components contained in General Link elements of Force Type"

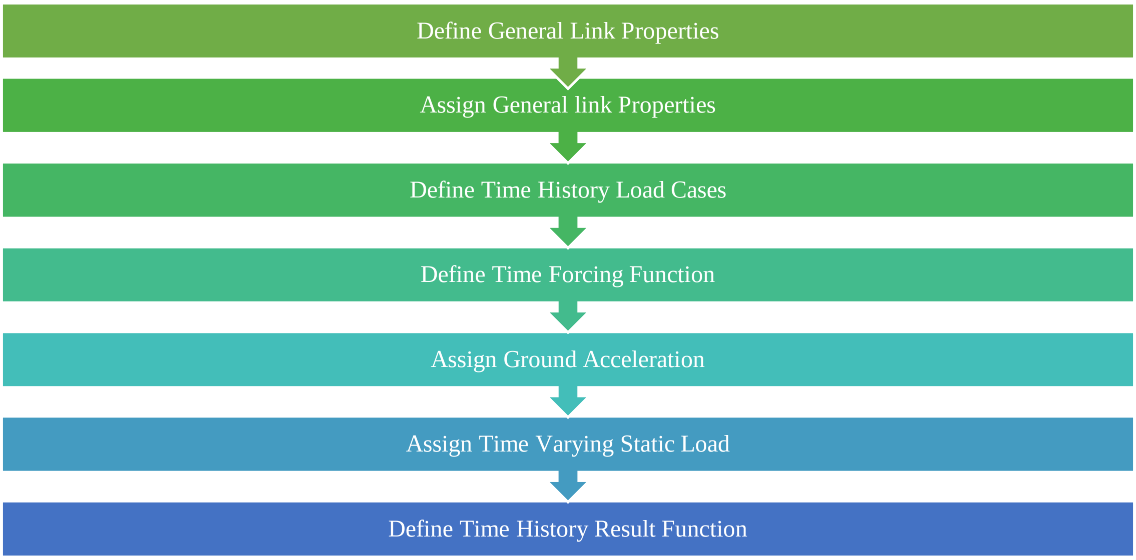
"f_N(t)": "True internal forces of nonlinear components contained in General Link elements of Force Type"

5.2.1. Boundary nonlinear time history analysis

This analysis beneficial for those structure which has the limitation in behavior of non-linearity from among of the various method of nonlinear time history analyses. Modelling of structure having behavior of nonlinearity could be done through “General Link of Force Type” while the rest of the structure must be modelled on the basis of linear elastic behavior. This method works by examine the structure on the basis of “conversion of member forces of the nonlinear system into loads exerted in the linear system”.

5.2.1.1. Procedure for Time History Analysis (Boundary Nonlinear)

Steps for Non-Linear Time History Analysis



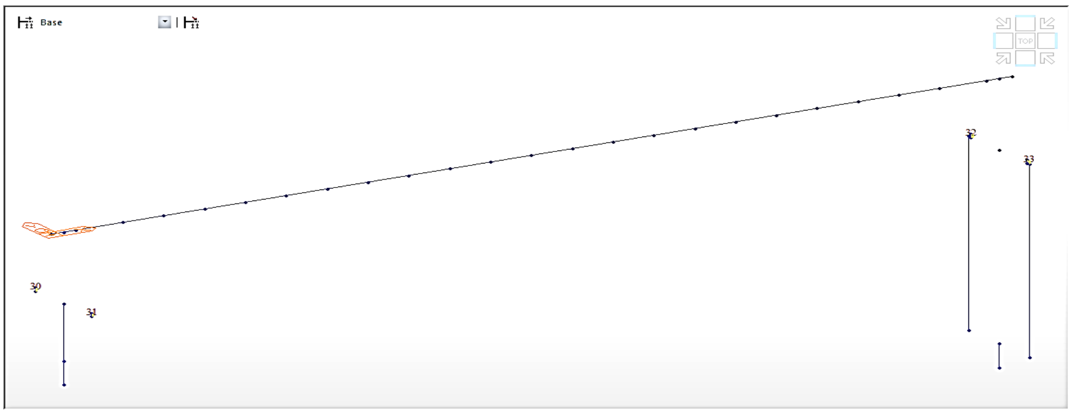


Figure 5.11: Location of General Link

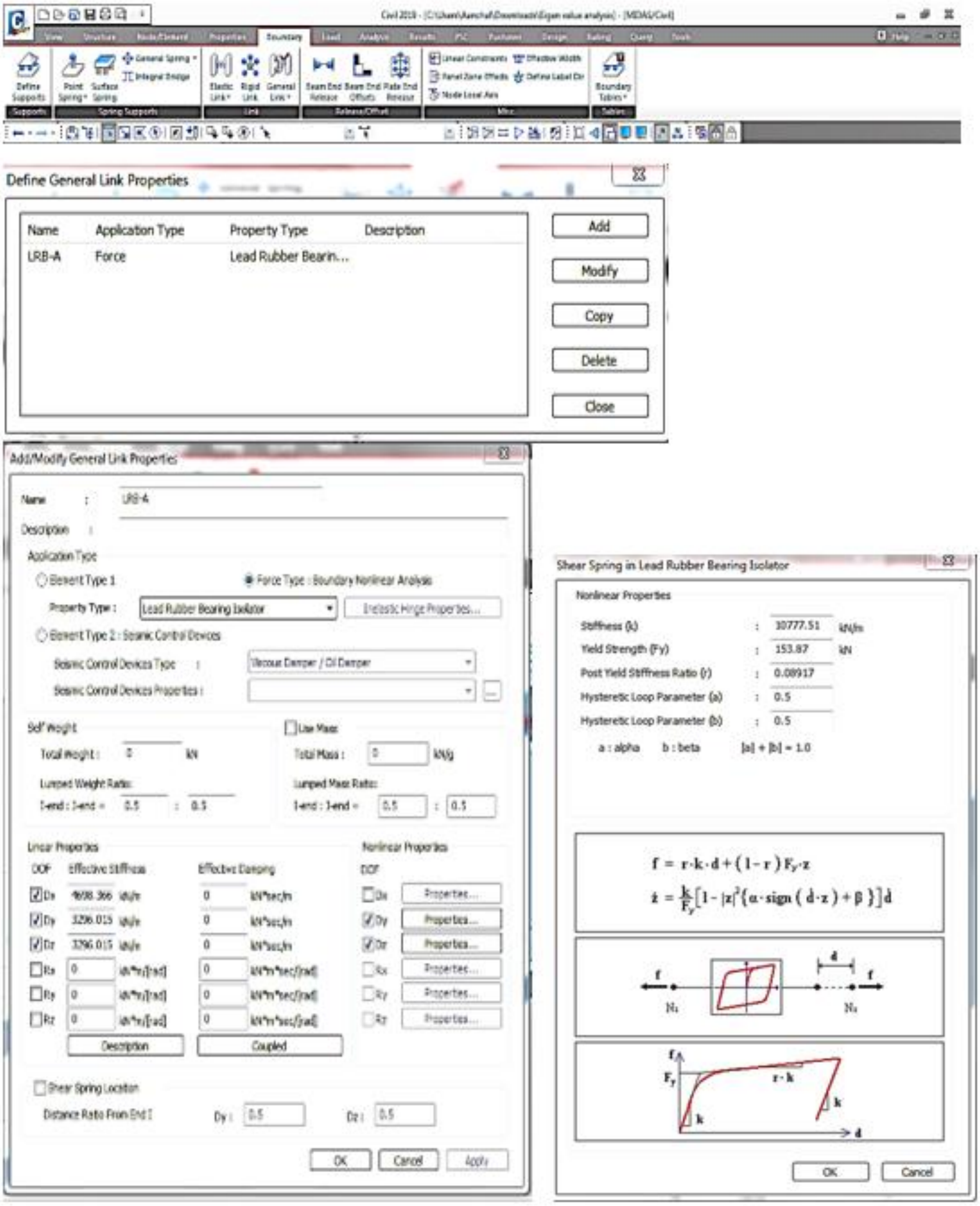


Figure 5.12: Define and Assign General Link Properties

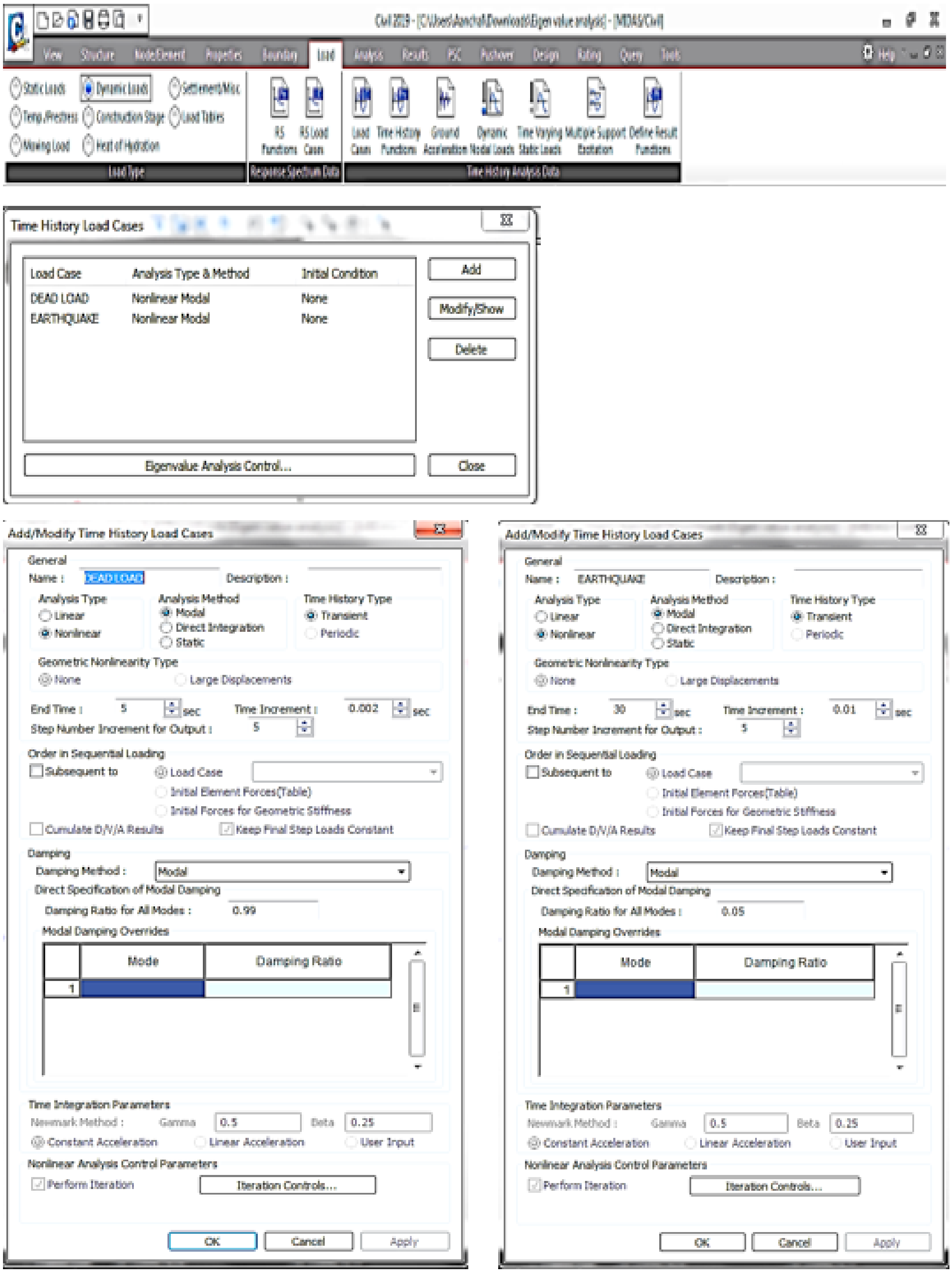


Figure 5.13: Define Time History Load Cases

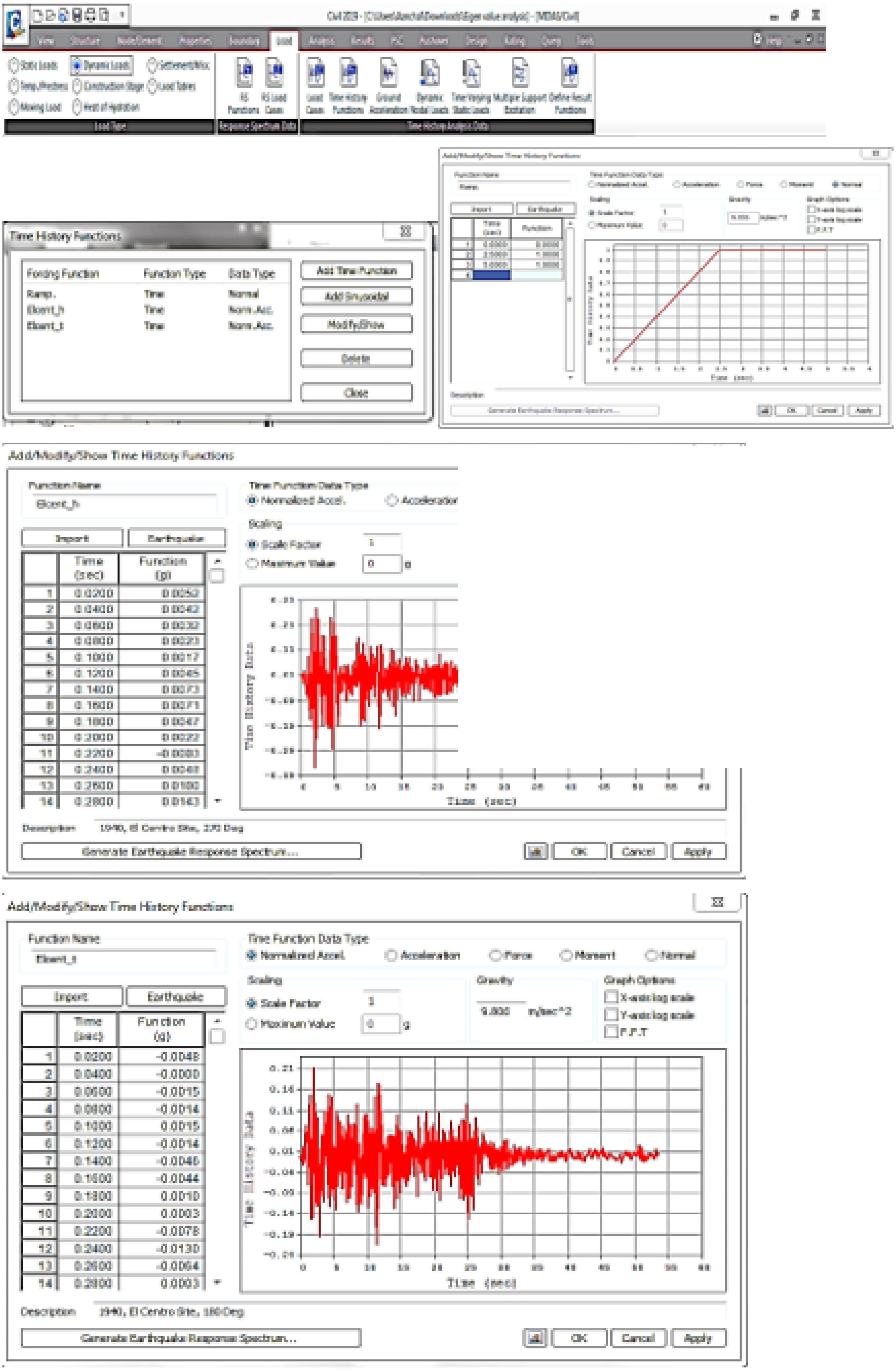


Figure 5.14: Define Time Forcing Function

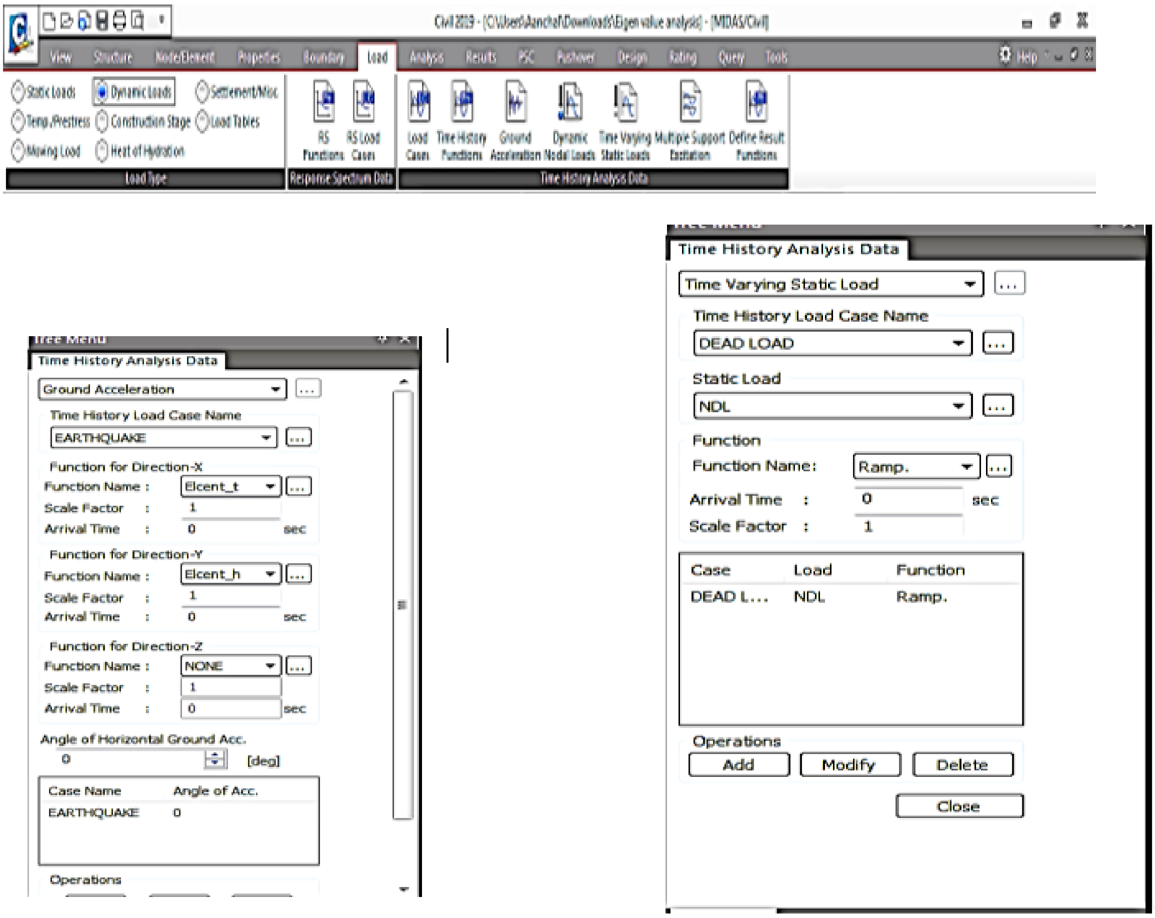


Figure 5.15: Define Ground Acceleration and Time Varying Static Load

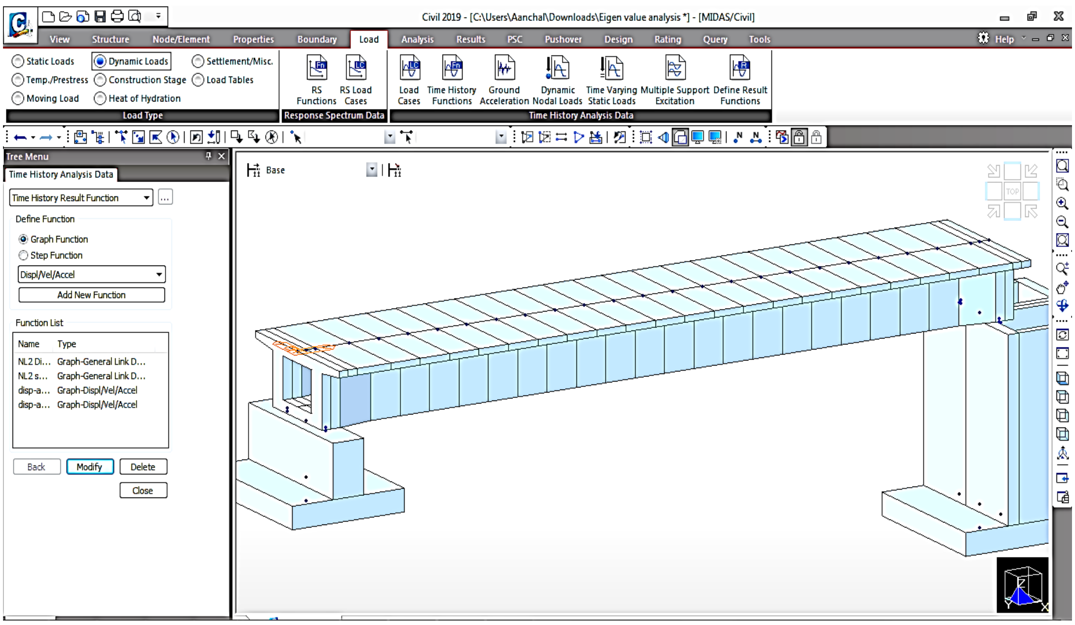


Figure 5.16: Define Time History Result Function

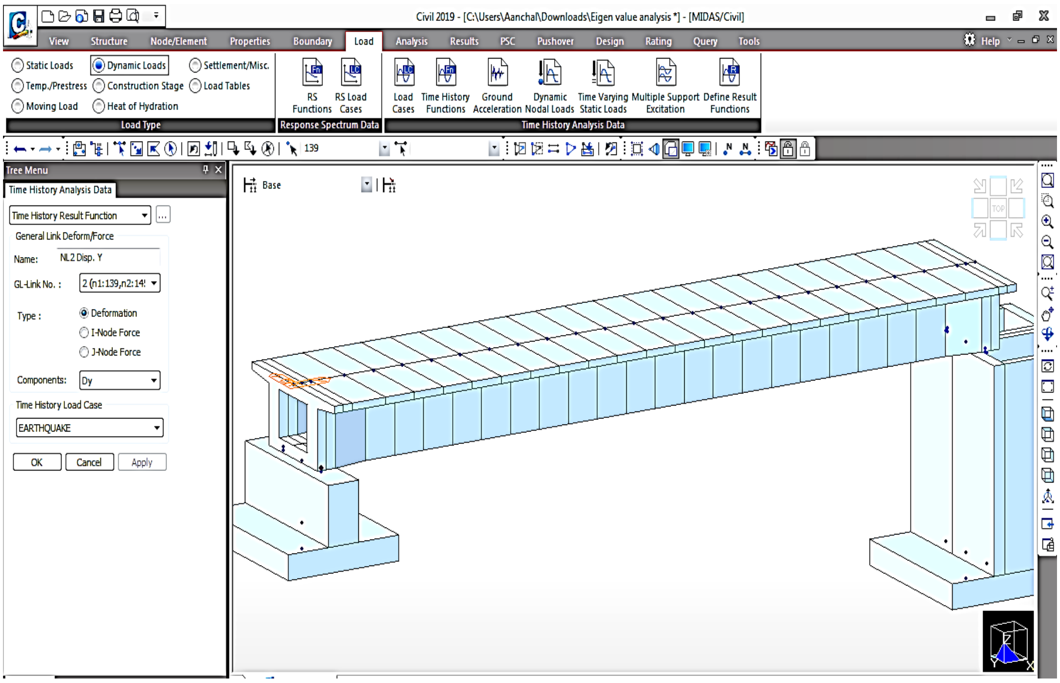


Figure 5.17: Result Function 1 –For displacement in Y direction at node 139

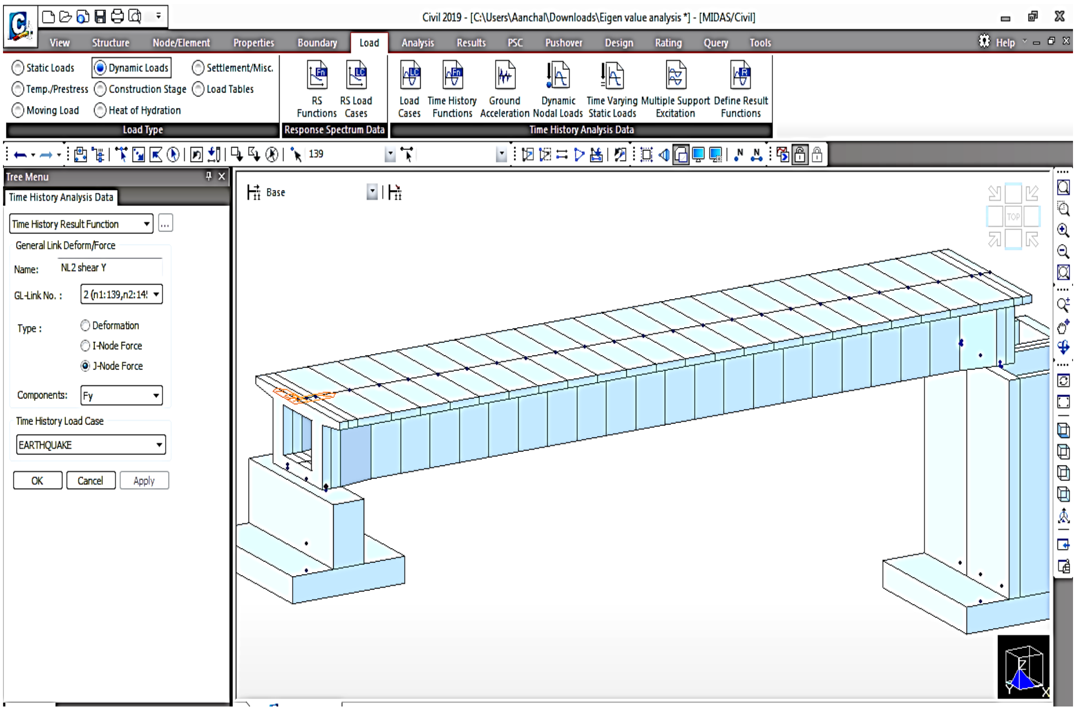


Figure 5.18: Result Function 2 –For shear at the bottom of bearing in Y direction at node 139

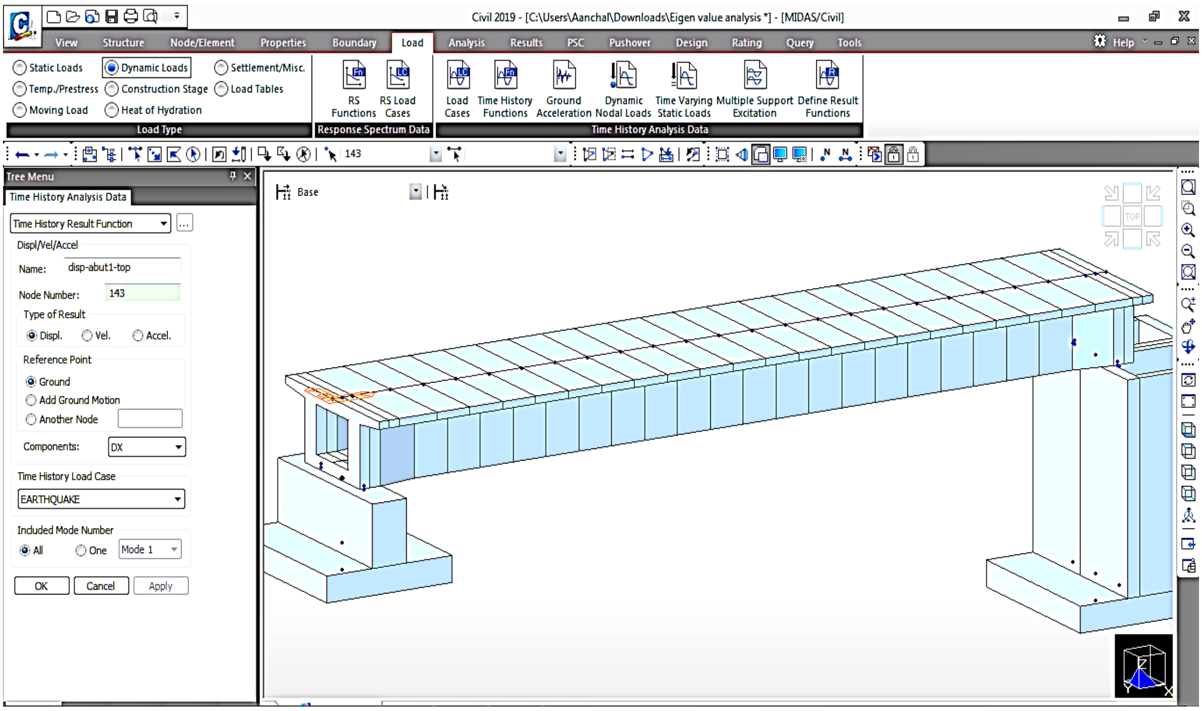


Figure 5.19: Result Function 3 –For displacement at the top of left abutment

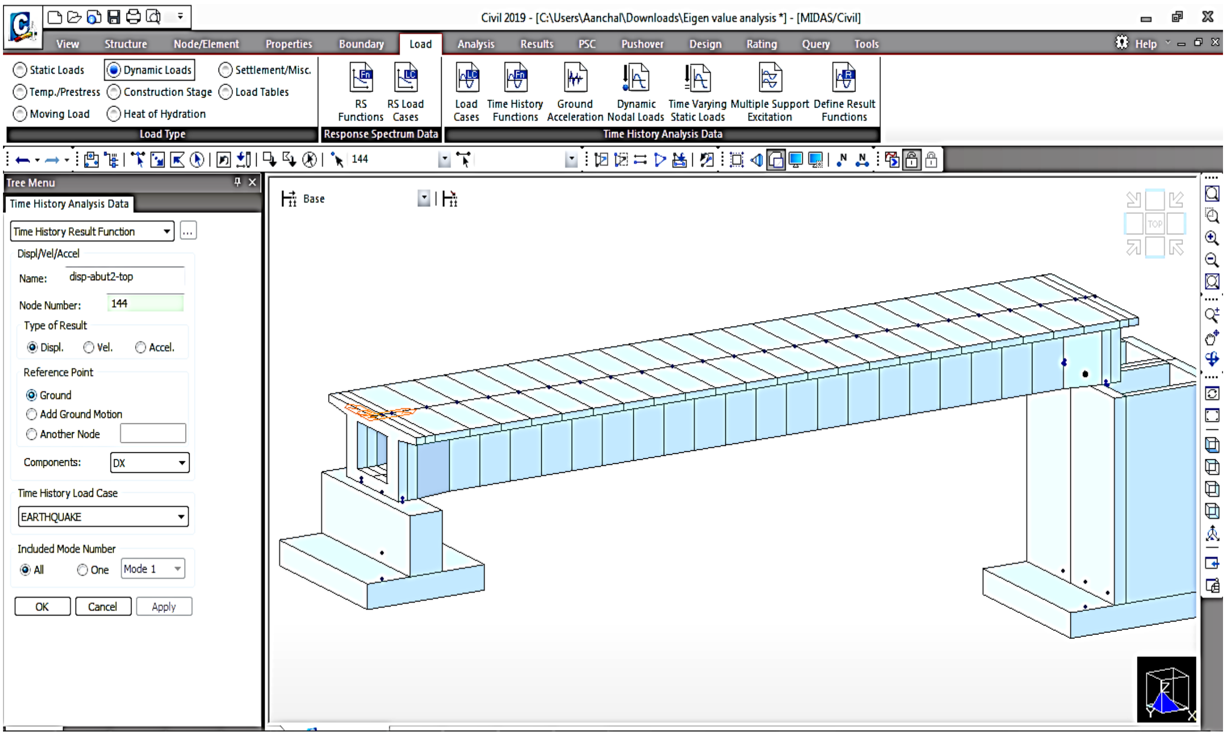


Figure 5.20: Result Function 4 –For displacement at the top of right abutment

5.2.1.2. Results for Non-Linear Time history Analysis

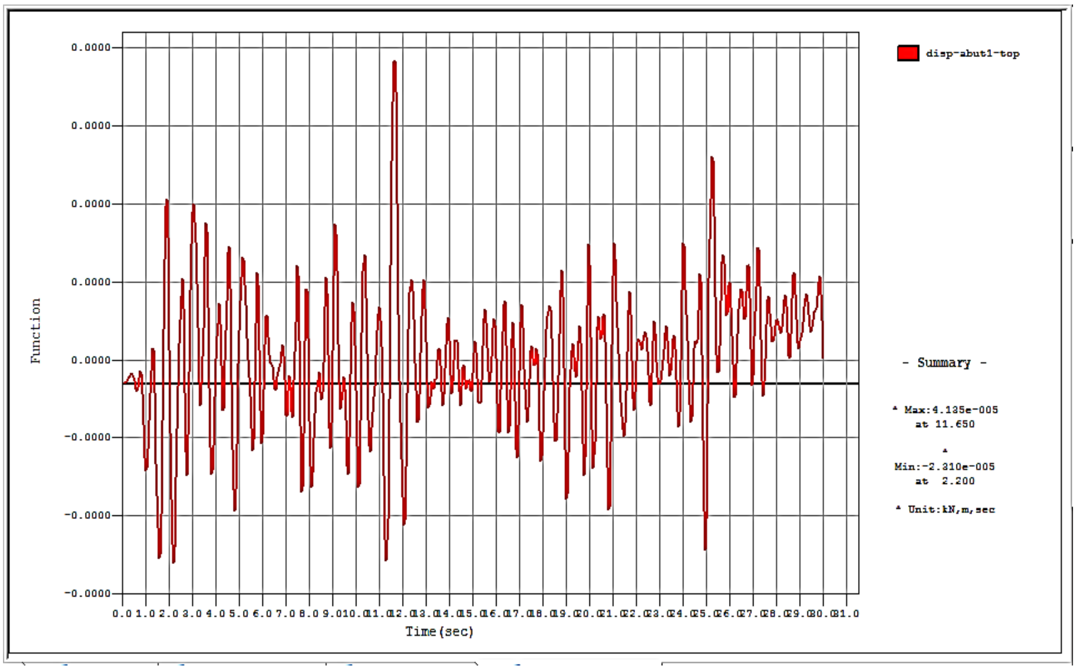


Figure 5.21: Result-Displacement with time Graph for the top node of left abutment

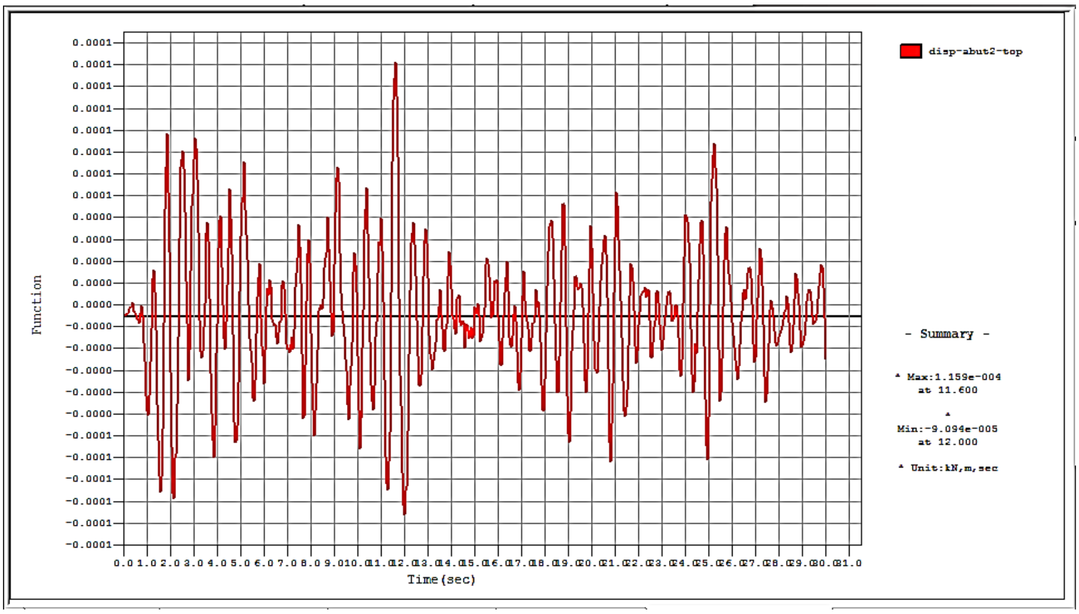


Figure 5.22: Result-Displacement with time Graph for the top node of Right abutment

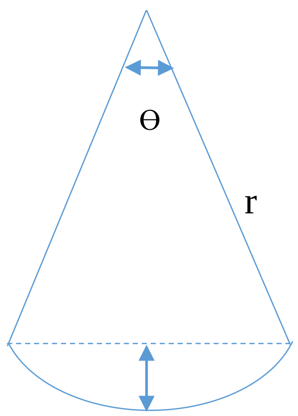
CHAPTER 6: IMPACT OF SUPPORT CONDITIONS ON STRAIGHT AND CURVED BOX GIRDER BRIDGES

6.1. General Description

In this chapter the four finite element model of RCC box girder curved bridges with same length of 24m and same geometry of abutments and also with same loading condition except changing its curvature angle of girder with an interval of 15° from 0° to 60° curvature angle are modeled in Midas CIVIL to carry out its seismic responses. Bridge geometry has been shown in **"fig 4.1"** and four finite element model of curved bridge have been shown in "**fig:6.1"** In this study also IRC:6 is used for vehicular loading and IRC:112 for geometry purpose and IS:1893-2016 for seismic loading consideration and also from IRC:18 permissible stress have been taken. Non-linear time history analysis method has been adopted to obtain a seismic behavior of curved bridges with different support conditions.

6.2. Geometrical Characteristics of Curved Bridges Model

Curvature angle is assumed in 15° of interval from 0° to 60° and radius of curvature can be obtained from length of arc formulae i.e. $length\ of\ arc = 2\pi r\ ({}^{\theta}/_{360})$ and also Height of a circle with radius r relative to a chord (also called sagitta) i.e. $S = r\left[1 - cos\left(\frac{\theta}{2}\right)\right]$ is necessary to estimate for each four curved model in order to obtained the co-ordinates for the section assignment of curved bridge model.



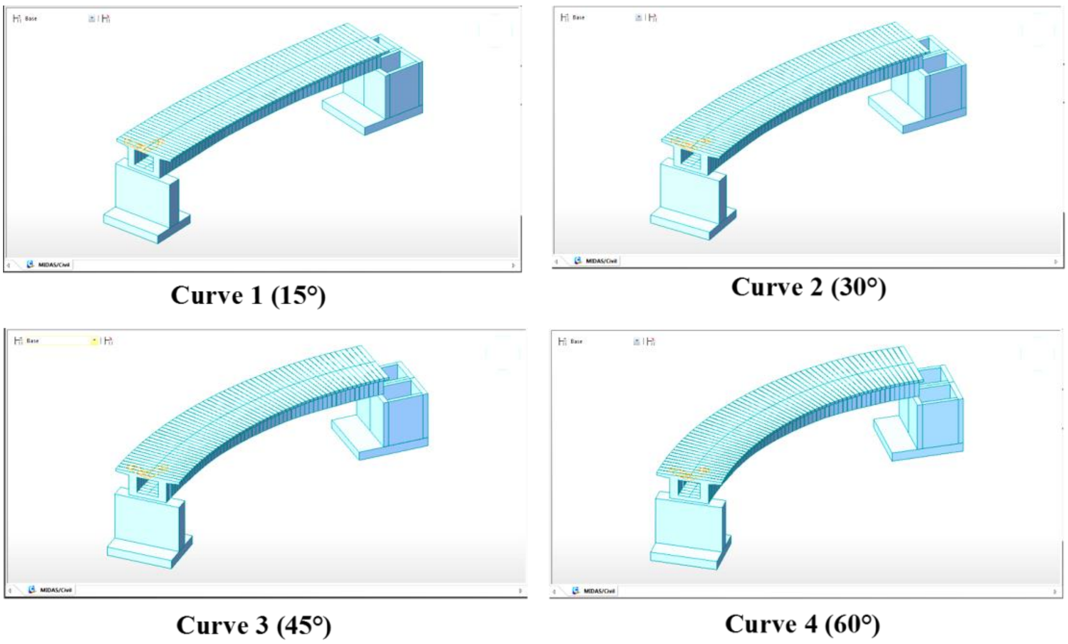
Where, r – Radius of curvature

Θ – Curvature angle

S – Sagitta (perpendicular distance from the Chord of a circle)

Model Name	Curvature Angle (in degrees)	Radius of Curvature (in meter)	Sagitta (in meter)
Curve 1	15°	91.67325	0.7843
Curve 2	30°	45.83662	1.5618
Curve 3	45°	30.55775	2.3261
Curve 4	60°	22.9183	3.0705

Table 6.1: Detail for curved bridges model



Curve 1 (15°)

Curve 2 (30°)

Curve 3 (45°)

Curve 4 (60°)

Figure 6.1: FEM model for curved bridges with different curvature angle

6.3. Results for Non- linear Time History Analysis

Time history graph shows displacement of the top node of both the abutment with time due to earthquake load and also displacement and shear of a particular node of general link with time due to earthquake load in any required direction.

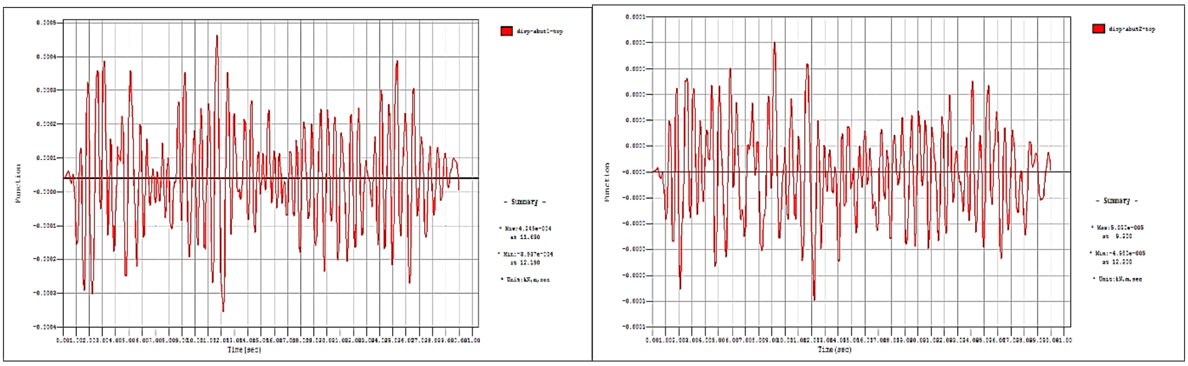


Figure 6.2: Result-Displacement with time Graph for the top node of left abutment and Result-Displacement with time Graph for the top node of Right abutment for curve 1 (curvature angle-15°)

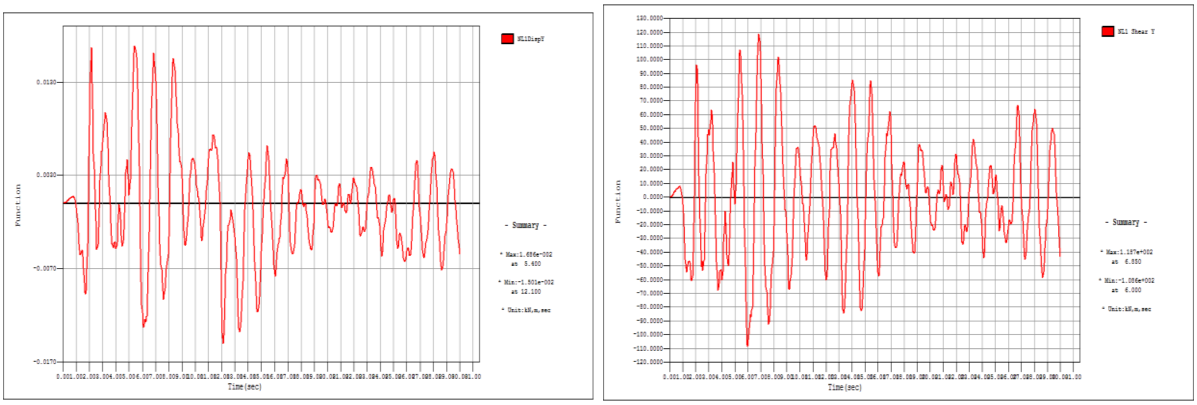


Figure 6.3: Result-Displacement with time Graph in Y direction of node 63 at the bottom of the General Link and Result-Shear with time Graph in Y direction of node 63 at the bottom of the General Link for curve 1 (curvature angle-15°)

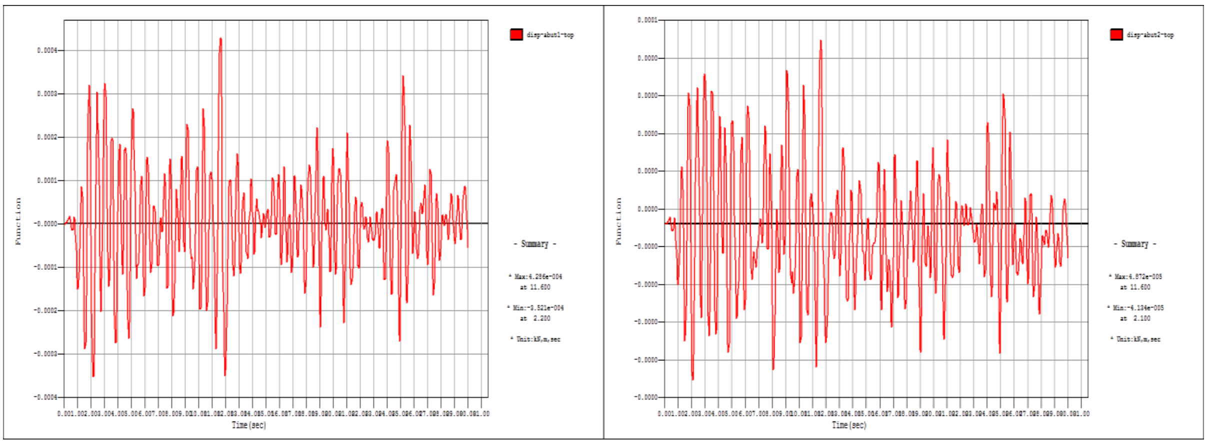


Figure 6.4: Result-Displacement with time Graph for the top node of left abutment and Result-Shear with time Graph for the top node of right abutment for curve 2 (curvature angle-30°)

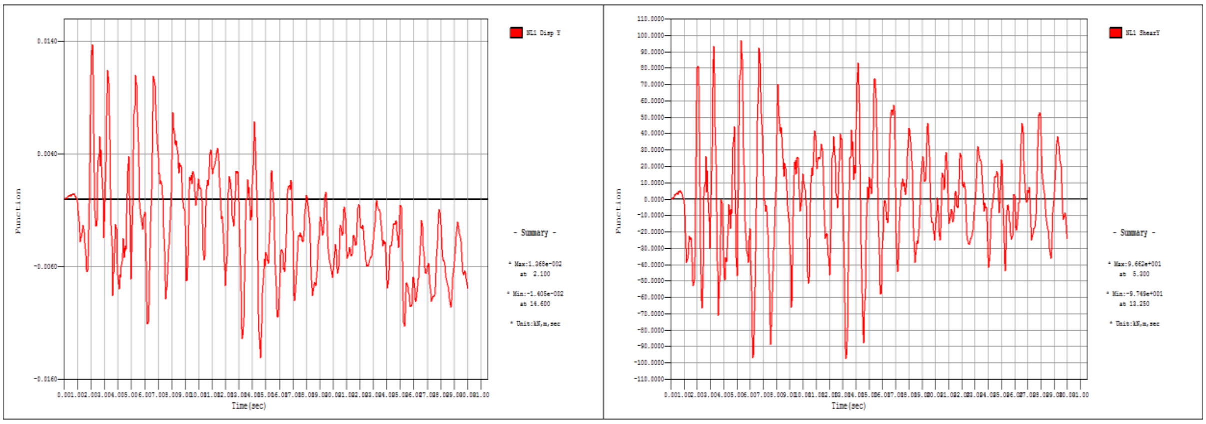


Figure 6.5: Result-Displacement with time Graph in Y direction of node 63 at the bottom of the General Link and Result-Shear with time Graph in Y direction of node 63 at the bottom of the General Link for curve 2 (curvature angle-30°)

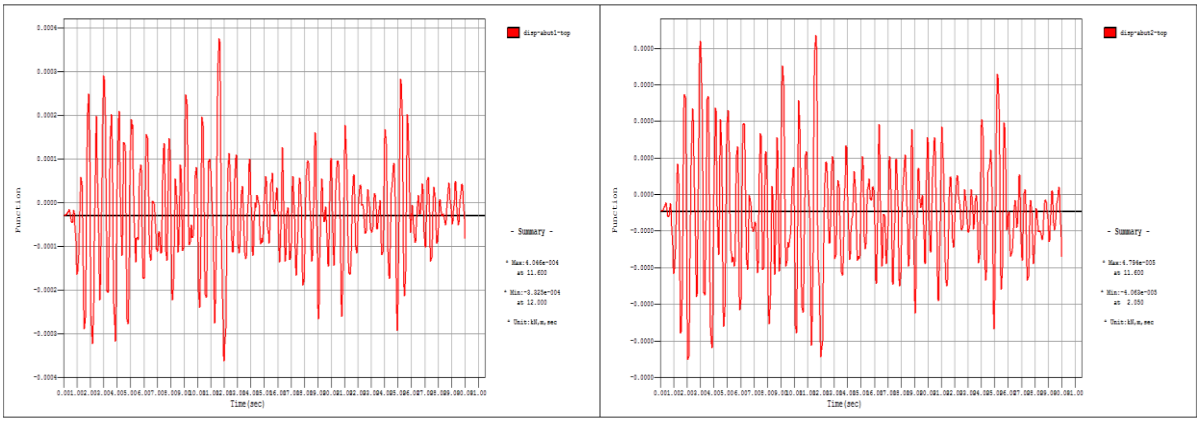


Figure 6.6: Result-Displacement with time Graph for the top node of left abutment and Result-Shear with time Graph for the top node of right abutment for curve 3 (curvature angle-45°)

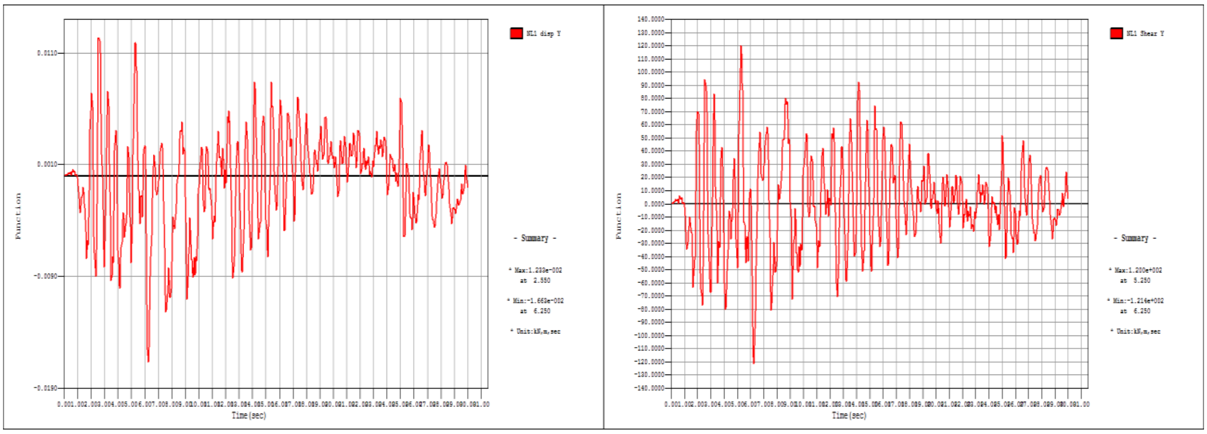


Figure 6.7: Result-Displacement with time Graph in Y direction of node 63 at the bottom of the General Link and Result-Shear with time Graph in Y direction of node 63 at the bottom of the General Link for curve 3 (curvature angle-45°)

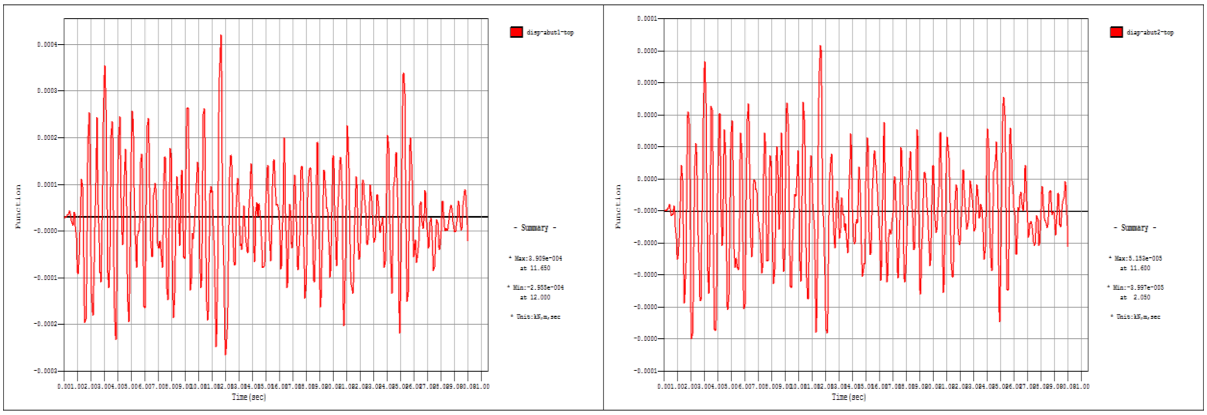


Figure 6.8: Result-Displacement with time Graph for the top node of left abutment and Result-Shear with time Graph for the top node of right abutment for curve 4 (curvature angle-60°)

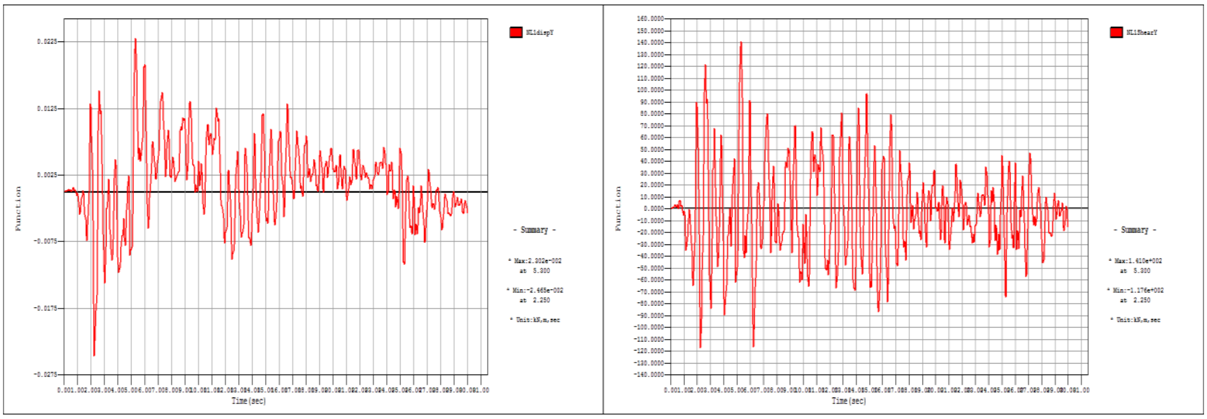


Figure 6.9: Result-Displacement with time Graph in Y direction of node 63 at the bottom of the General Link and Result-Shear with time Graph in Y direction of node 63 at the bottom of the General Link for curve 4 (curvature angle-60°)

6.4. Seismic Response of curved bridges with different support conditions

To obtain the seismic behavior of all four modelled curved bridges ten different support conditions has been formed so that "non-linear time history analysis" can be performed to obtain the "seismic response of curved bridges" with all the created support conditions. Here each created support conditions has been applied with different orientation angle from 0° to 60° with an 15° interval by rotating the Y-Z plan of bearing and keeping the local X direction of it same for all the conditions hence for each condition there will be 20 model results (i.e. for each condition there will be 5 different orientation of bearing location on each curve model)

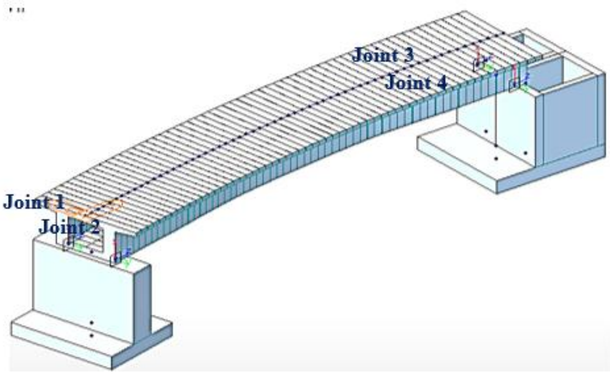


Figure 6.10: bearing's Joint Location

Table 6.2: Combination of Different Support Conditions

S.No	Notation	Joint 1	Joint 2	Joint 3	Joint 4
1	**RRRR**	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X direction of bearing"
2	**PPPP**	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X and Z direction of bearing"
3	**PRRR**	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X direction of bearing"
4	**PRPR**	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X direction of bearing"
5	**PPRR**	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X direction of bearing"

S.No	Notation	Joint 1	Joint 2	Joint 3	Joint 4
6	**PRRP**	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X and Z direction of bearing"
7	**FFFF**	"High elastic stiffness in X, Y and Z direction of bearing"	"High elastic stiffness in X, Y and Z direction of bearing"	"High elastic stiffness in X, Y and Z direction of bearing"	"High elastic stiffness in X, Y and Z direction of bearing"
8	**RPFF**	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X, Y and Z direction of bearing"	"High elastic stiffness in X, Y and Z direction of bearing"
9	**RPFL**	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X, Y and Z direction of bearing"	"High elastic stiffness in X and Y direction of bearing"
10	**PRLF**	"High elastic stiffness in X and Z direction of bearing"	"High elastic stiffness in X direction of bearing"	"High elastic stiffness in X and Y direction of bearing"	"High elastic stiffness in X, Y and Z direction of bearing"

Here R- free bearing,

P- Transversely free bearing,

F- Fixed bearing,

L- Longitudinally free bearing

CHAPTER 7: CONCLUSION

7.1. Introduction

Bridges being an important part for the development in transportation areas but as in this study among various type of bridges, Box girder bridges catches the eye so the whole study is carried out on the box girder bridges and the seismic behavior of bridges are obtained by performing various seismic analysis method i.e. “Eigen value analysis”, “Response spectrum analysis” and “Non- linear time history analysis” but for curved bridges seismic responses are estimated from “Non-linear time history analysis”.

7.2. Analytical Investigation for Straight Box Girder Bridge

7.2.1. Linear Analysis

From this study, linear analysis results has been obtained by performing the free vibration analysis (Eigenvalue analysis) which gives result in the form of natural frequencies and modal deformation and Response spectrum analysis which gives results in the form of deformation and forces. Hence, the following conclusion can be drawn:

- The mode shapes tell us how the structure deforms at specific natural frequencies to prevent the weld area as it can affect the fatigue life of the structure if it has become an area of high stress.
- Mode with the highest mass participation is the most critical mode shape so here mode 1 will be the critical mode for transitional Z direction and mode 2 will be the critical mode for transitional Y direction means that mode will likely to be excited by forces in that direction
- Demand of the structure in the event of an earthquake has been obtained from response spectrum analysis which is necessary in order to ensuring the design of the structure must have the capacity greater than that demand.

7.2.2. Non-linear Time History Analysis

From this study, "Non-linear time history analysis" results has been obtained by performing the time history analysis with nonlinear analysis type, modal analysis method and transient time history type. Hence, the following conclusion can be drawn:

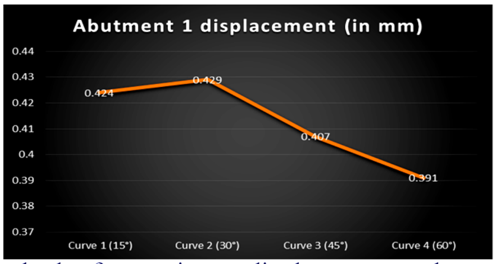
This analysis method gives more realistic results for seismic response of a structure than other methods but the reliability of non-linear time history analysis is sensitive to assumptions and parameters made during modelling of a bridge. Detailed information of deformation and shear forces can be obtained for any node in any direction due to earthquake loading. Here 1940, El centro site earthquake data has been applied with incident angle of 270 degree (i.e. Elcent_h) in global Y direction and 180 degree (i.e. Elcent_t) in global x direction means Elcent _h shows behavior of a bridge if such type of a ground motion is generated in global X direction and Elcent_t shows behavior of a bridge if such type of a ground motion is generated in global negative X direction.

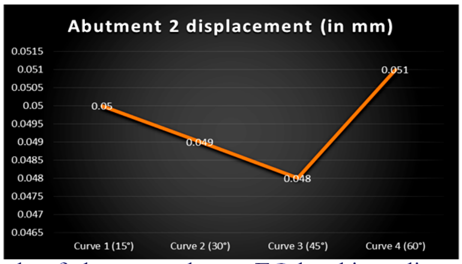
Non-linear time history results provide detailed information about the damages which might get occurred in the structure due to the applied ground motion which is generally related to the deformation and shear forces due earthquake in any required direction. Here we got the "maximum deformation" and "max shear force" in y direction at one of the general link and also the "maximum displacement" at the top of the both the abutments in x direction due to earthquake load with time variation so we can made the changes in the design accordingly by observing the structure deformation with time due to the given ground motion which helps in get the better design in terms of making the structure seismic proof.

7.3. Analytical Investigation for Curved Box Girder Bridge

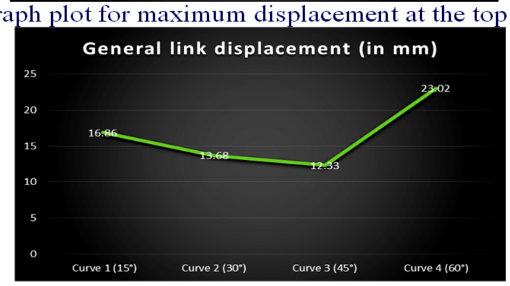
7.3.1. Non – linear Time History Analysis

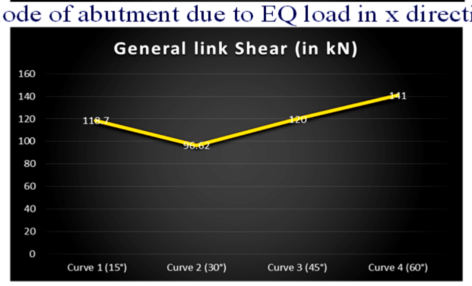
From this study, Non-linear time history analysis results has been obtained for four curved model with different curvature angle from 0° to 60° with an interval of 15° by performing the time history analysis with nonlinear analysis type, modal analysis method and transient time history type. Hence, the following conclusion can be drawn:





Graph plot for maximum displacement at the top node of abutment due to EQ load in x direction





Graph plot for maximum displacement and shear at the bottom of the GL due to EQ load in y direction

Figure 7.1: Observation for maximum displacement of both the abutments and for General Link from the results of time history graph

7.3.2. Result Interpretation

With the help of a results of time history graph it can be concluded that with increase in curvature angle, displacement at top node of both the abutments and displacement and shear at the bottom node of general link shows some variation but the curve with 45° curvature angle shows better restriction towards the seismic event hence we can get the maximum utilization of box girder's bridge property for such 24m length of bridge at 45 ° for normal as well as in seismic condition.

7.4. Analytical Investigation for Curved Box Girder Bridge with different support conditions

"Non- linear time history analysis" has been adopted to obtain the "seismic response of a curved bridges" with each ten created support conditions in order to find the best orientation angle of bearing which is also rotate with a 15° interval from 0° to 60° by just rotating the local Y-Z plane of bearing and keeping the local X direction fixed for all the conditions. Hence, the following conclusion can be drawn by observing the maximum displacement at the top node of both the abutments for each condition with different bearing angle for each curved bridge model due to earthquake loading in global x direction

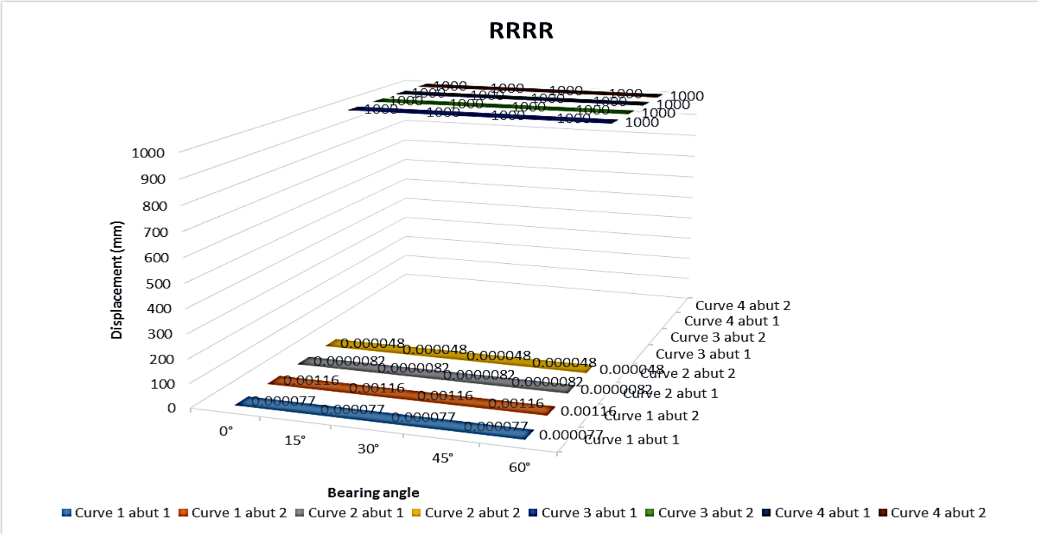


Figure 7.2: Observation – RRRR

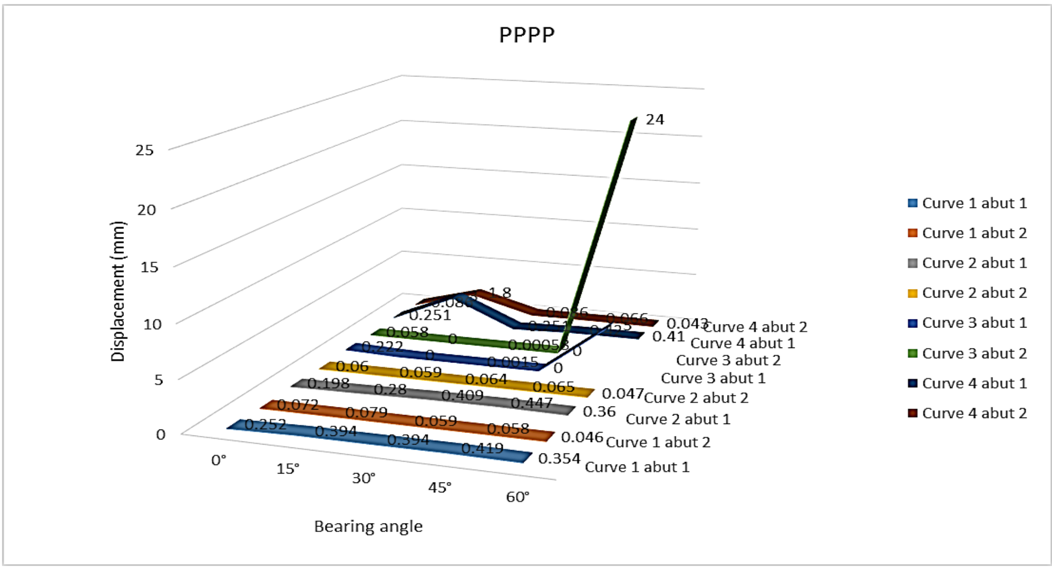


Figure 7.3: Observation - PPPP

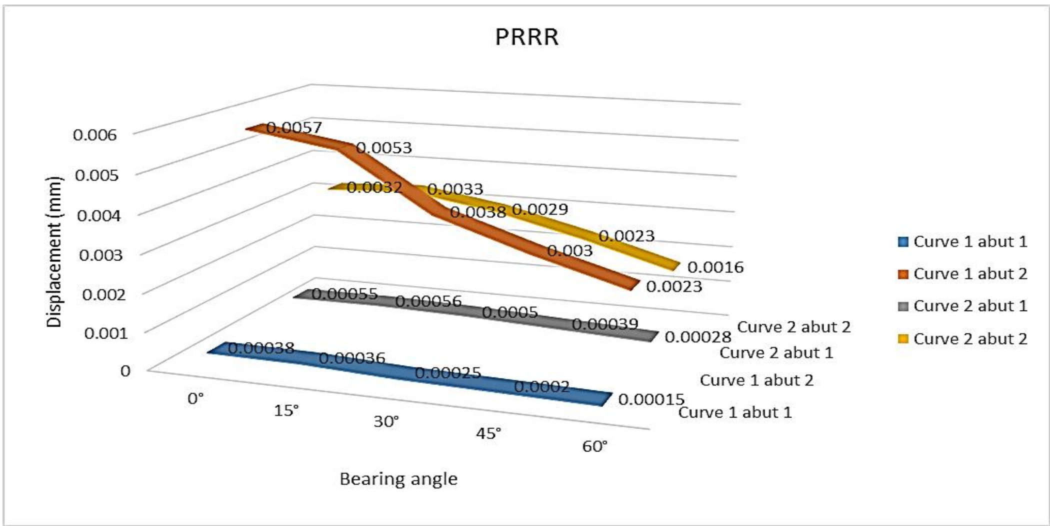


Figure 7.4: Observation - PRRR

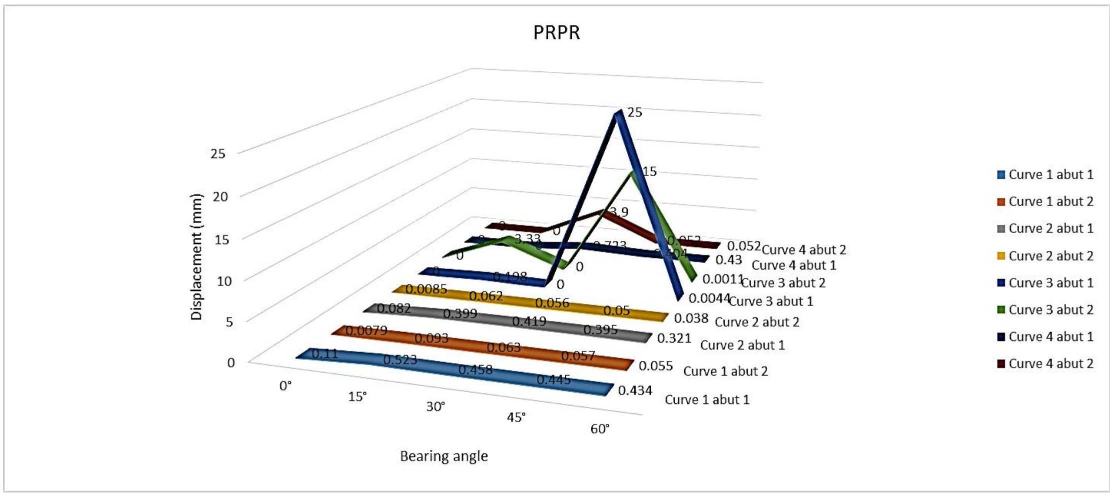


Figure 7.5: Observation - PRPR

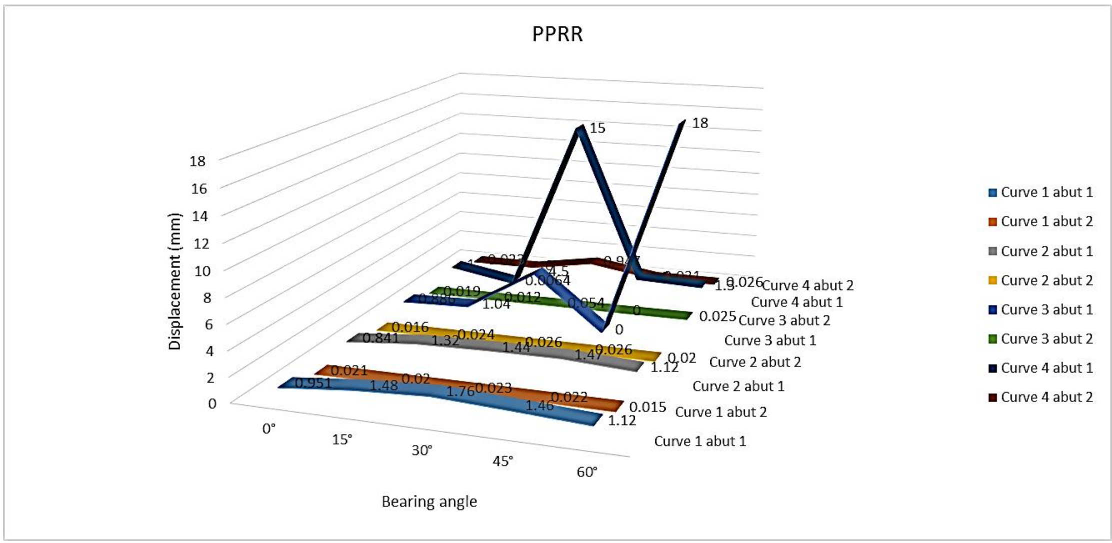


Figure 7.6: Observation - PPRR

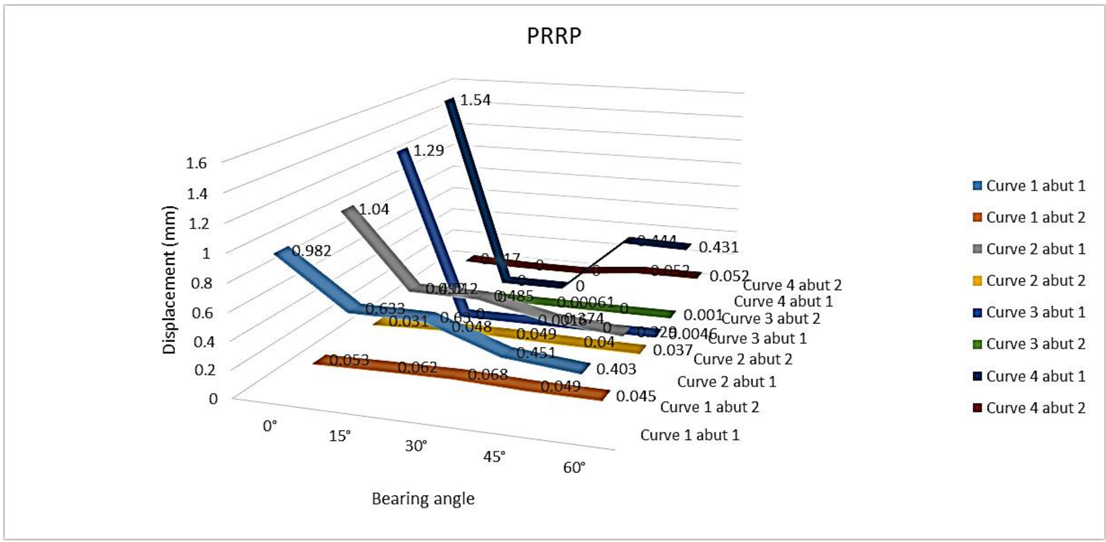


Figure 7.7: Observation - PRRP

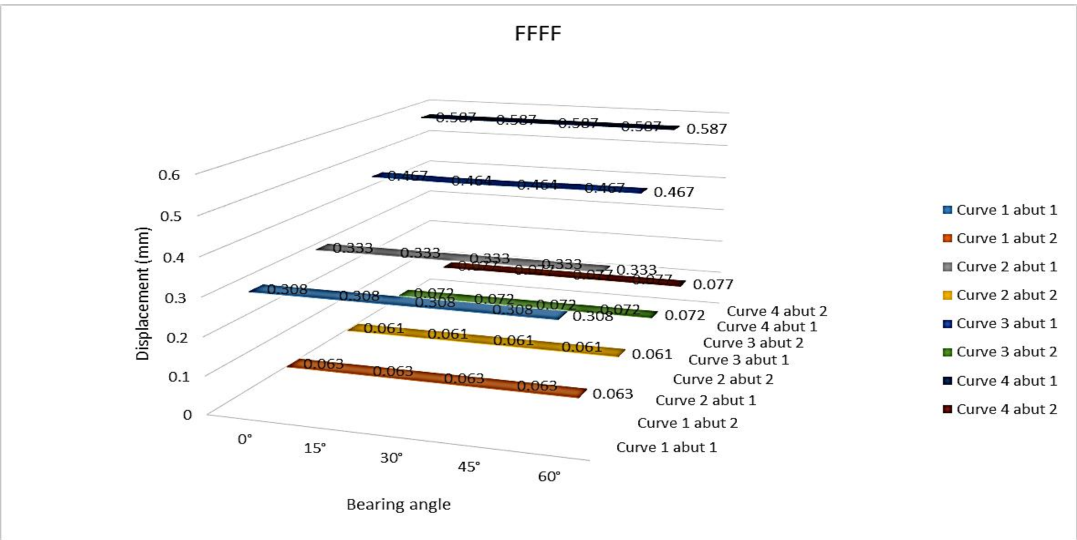


Figure 7.8: Observation - FFFF

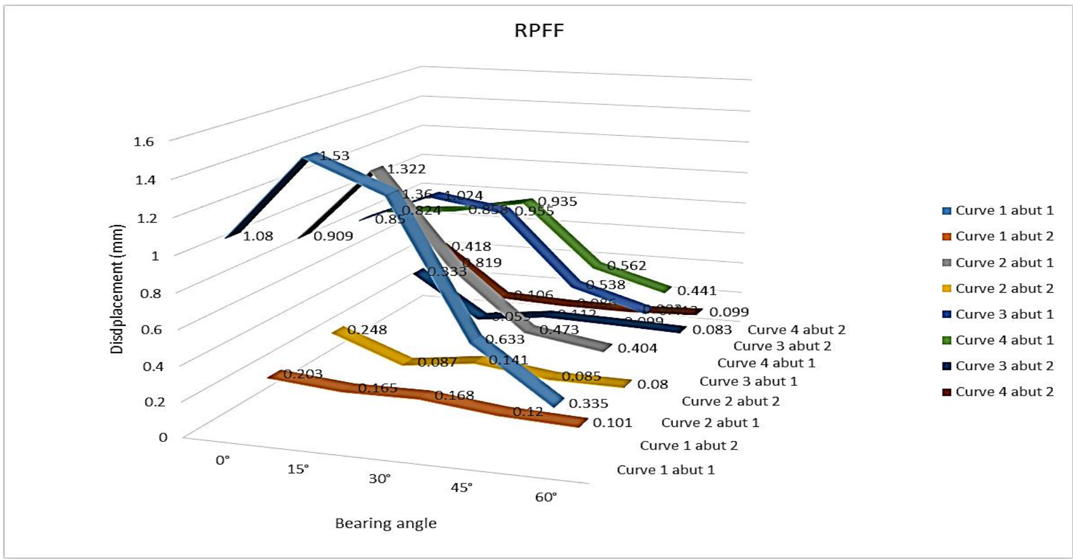


Figure 7.9: Observation - RPFF

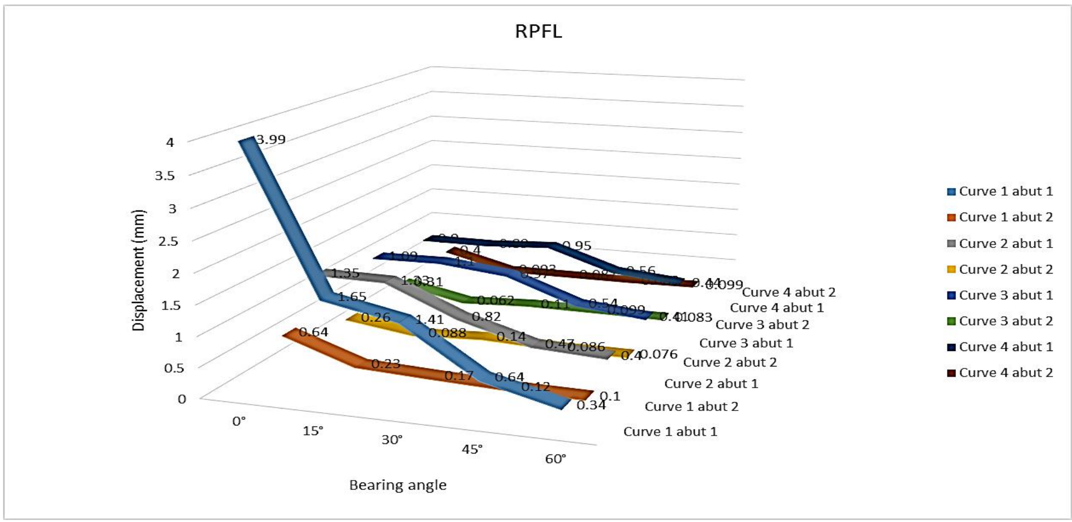


Figure 7.10: Observation - RPFL

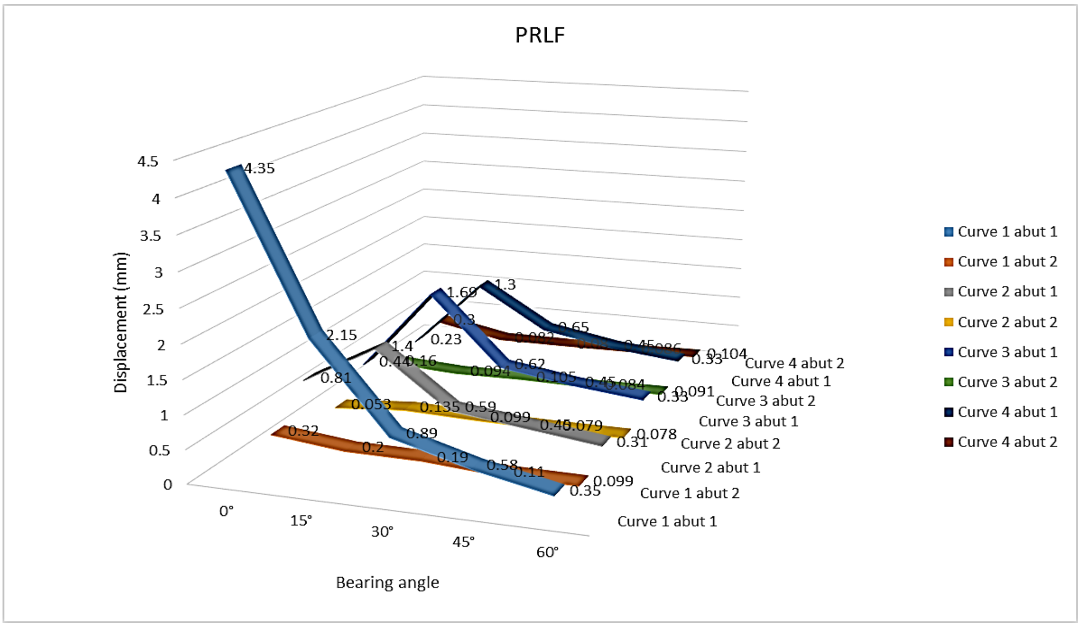


Figure 7.11: Observation - PRLF

7.4.1. Result Interpretation

Four curved model with different curvature angle from 0° to 60° with an interval of 15° has been analyzed for each created ten different support conditions having different orientation which is applied by just rotating the Y-Z plane from 0° to 60° with an interval of 15° of bearing and keeping the X- direction same for all the conditions by "performing the non-linear time history analysis" then with the help of a results of time history graph for each created conditions for support bearings which shows maximum deformation for the top node of both abutment 1 and abutment 2 due to earthquake load in X-direction by considering the ground excitation of 1940,El centro earthquake can be concluded that curved model in the order of stability would be in such a way i.e. curve 2 > curve1 > curve3 > curve4 means curve 2 model shows better stability among all four model which has the curvature angle of 30° with the stable bearing angle are in the order of 60° > 45° > 30° > 0° > 15°. Hence, bearing with 60° is the best orientation for the bridge model which has 30° curvature angle on which we get the maximum utilization of box girder's bridge property for such 24m length of bridge under seismic condition.

7.5. Scope for Future Work

Bridge being an important area in the concern with the scope of development but as Box Girder Bridge gaining worldwide fame because of having the outshine quality in comparison with the other type of bridges as it shows outstanding performance in terms for longer span bridges and also bridges experiences torsional effect like curved bridges. This study currently is limited to the composite bridges which are catching attention of most of the designers. For the future research there is a wide range domain for the scope which is mentioned below:

- Analyzing and estimation of results should also not only limited to forced based analysis method but can also be done on the basis of displacement based analysis which is more realistic.
- This study for the curved bridges is limited to only on displacement based analysis but for creating the better understanding the behavior of a bridge should also be examined on the basis of other parameters like shear forces, twisting moment or many more.
- Number of analysis can be performed for optimizing the best orientation of bearing on the created conditions.

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