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COMPARATIVE PERFORMANCE EVALUATION OF SHORT SPAN RC BRIDGES SUBJECTED TO VARIOUS SOIL STRUCTURE INTERACTION USING SAP 2000 AS A TOOL

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ABSTRACT:

The modeling and seismic analysis of bridge structures have been a major evolution over recent decades linked directly to the rapid development of digital computing. In past, elastic analysis procedures used for bridge structural assessment which is not sufficient for the inelastic performance evaluation of structure when subjected to hazardous seismic forces. Nonlinear dynamic analysis become essential for bridges structural assessment however, it's costly consuming. For that, nonlinear static analysis (pushover) becomes preferable inelastic seismic behavior tool in structural evaluation of bridges because of its low costs and time consuming. A three-dimensional finite element of nonlinear pushover analysis for short span Reinforced Concrete (RC) bridge with circular piers cross section is modeling to present effects of soil structural interaction (SSI) using SAP 2000 as a finite element tool. Structural element models are including linear foundation springs modeling, and nonlinear RC piers modeling. In this study the SSI effects of nonlinear pushover analysis of short span RC bridges to determine the significant effects on seismic characteristics, displacement capacity and performance of short span RC bridges. In this comparative analysis considering nonlinear static pushover Analysis for different SSI of Hard soils, Medium soil, Loose soils according to I.S. 1893-2016.

Keywords: Soil Structure Interaction, Pushover Analysis, lateral displacement, longitudinal displacement, Stability, RC Bridge, Soil types.

I. INTRODUCTION

Every architecture represents the current state of mortal knowledge on material applications. An efficient link between two corridors that are separated by swash or other ground impediments requires the presence of a bridge. By splitting the bottleneck in the bridge lane and ground Position thruway, it connects two corridors across a body of water or those in a megacity. As time went on, bridge design became less complex because engineers wanted to combine usefulness for truly great distances with aesthetic appeal. Every building is significantly vulnerable to unforeseeable natural calamities. Therefore, it is crucial to protect the beautiful edifice from any natural disaster to guarantee the safety of people and the nation's economy. To improve the construction and increase its resilience to earthquake and wind effects, several studies are conducted.

In contrast to structures, the collapse of the entire bridge structure is more likely to result from the failure of one structural component or link between the components inside the bridge. Due to recent earthquake-related structural damage and bridge failure, it is now known that retrofit procedures need be taken to analyse and modify the bridges' structural susceptibility. The weight will climb significantly as the span rises. In order to reduce the load, unneeded material that isn't fully utilised is eliminated from the section; depending on whether shear deformations are frequently ignored or not, this results in the shape of girder or cellular constructions. A bridge is referred to be a beam bridge if the majority of its beams are made up of rectangle-shaped girders. Typically, prestressed concrete, steel, or a combination of reinforced concrete and steel make up the beam. In motorway and bridge systems, girders are widely used because of their structural effectiveness, improved stability, serviceability, cost-effectiveness during construction, and attractive aesthetics. opposing directions. The road bridges in our nation are constructed in accordance with the specifications and recommendations set forth by the Indian Road Congress (IRC).

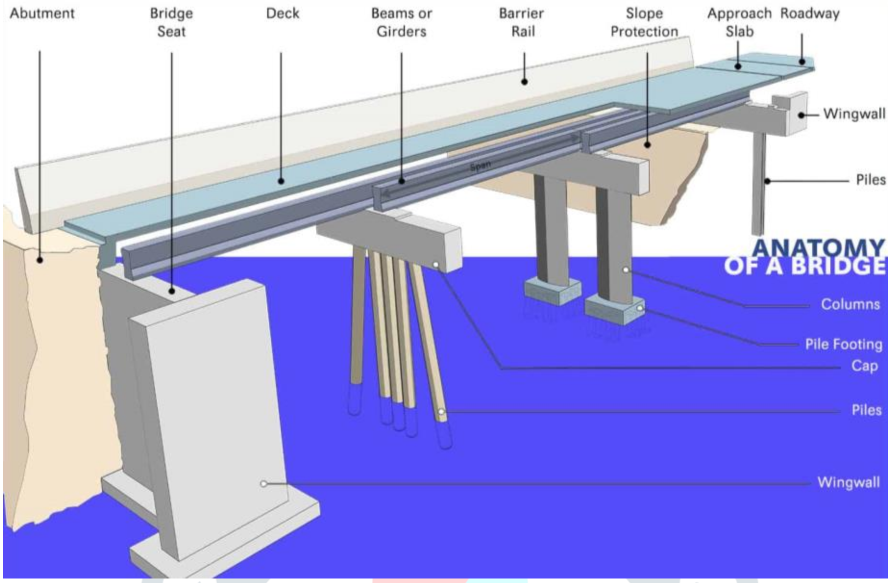

Fig. 1 Anatomy of a Bridge

II. LITERATURE REVIEW

Galuta and Cheung (1995) In order to examine box-girder bridges, a hybrid analytical approach that incorporates the boundary element technique with the finite-element method was created. The bridge's webs and bottom flange were modeled using the finite-element method, while the deck was modeled using the boundary-element method. Comparing the results with the finite element solution, it was discovered that the bending moments and vertical deflection were in good agreement.

Zasiah Tafheem and Khan Mahmud Amanat (2011) the findings of this search that's been carried out using a 3 concrete deck girder bridge as it was being subjected to seismic pressure. To explore the deck girder bridge, a finite element model was made using the finite element application ANSYS. The response spectrum approach should be used for the seismic load analysis of the bridge, according to the overall findings, in order to get a more dependable and secure design. Bridges were an essential part of every type of contemporary transportation system. The technical understanding of earthquake engineering has significantly improved during the last half-decade. Results from the bridge were crucial both before and during an earthquake. Therefore, it must continue to operate long after the earthquake event has passed in order to serve both security and relief purposes.

Godse P.A. (2013),Ghosh et al. (2014), examined how composite tectonic and live loads adversely affected the estimation of the highway bridges' seismic dependability. The researcher initially created the probabilistic seismic demand model from statistical analysis of the non-linear time history response of the bridge in order to discover the connection between the median of the peak seismic response of the bridge component and, consequently, the intensity of the seismic excitation. Second, the bridge fragility curve was designed with the assumption that the bridge is a collection of interconnected systems, suggesting that the failure of a single component will cause the structure to collapse. The model and analysis used the assumption that there is only one vehicle present in the deck at any one moment under free-flowing traffic. The study's findings demonstrated that bridges were more susceptible to failure when subjected to seismic stress.

Thomas Wilson, worked on "Seismic performance o reinforced concrete bridges in mountainous states". The damages observed in Chile in 2010 were maximum in case of bridges. Hence the author tested the bridge geometrical properties in mountainous west region with concrete installed bridges. 8 bridge models were modeled with a box girder as support. Nonlinear time-history analysis was carried out on each bridge configuration using detailed CSi models. The results obtained were tabulated and compared with other bridge combination. columns induced a planar rotation thus resulting in transverse moment and longitudinal shear. Even the curvature installed a larger moment at the principal axis and hence lowering the capacity of structure.

Jong-Su Jeon et.al did research on "Geometric parameters affecting seismic fragilities of multi-frame concrete box-girder bridges with integral abutments". In this the author studied the variation of the behavior of the box girder bridge when certain geometric parameters such as horizontal radius of curvature column skewness and height of column when the bridge is subjected to earthquake loading. The author has considered the California region for the study. In this three dimensional inelastic models were created with integral abutments. The box girders with different height were examined and tested whether height influences the results of seismic resistance. The results indicated that increase in the horizontal curvature decreased the fragility curves. Abutment skewness showed little impact on the fragility of structure whereas the column height and fragility of column were inversely proportional hence increasing the structures vulnerability.

Mohammed (2016) tried to quantify the effect of duration on collapse capacity and to recommend whether this effect should be included in seismic design provisions. His study showed that spectral accelerations at collapse for columns subjected to long-duration motions were lower by 21% to 29% than the column subjected to short duration motion. The geometric mean of the displacement capacities of the long-duration specimens was 32% lower than the maximum displacement capacity of the short-duration specimen**.**

Lehman et al., (2004) to evaluate the seismic performance of wellconfined circular RC bridge columns at some damage state range. The deciding variables were axial load ratio, longitudinal reinforcement ratio, aspect ratio, spiral reinforcement ratio, and well-confined region length next to the plastic hinging zone. Using cumulative probability curves they concluded that the key damage states of residual cracking, core crushing and cover spalling were related to concrete compressive strain and longitudinal reinforcement tensile strain

III. METHODOLOGY

There are several ways to do seismic analysis on a concrete girder bridge with a span length of 100 meters; Sap2000 software was employed. The deformed shape, relative acceleration, relative velocity, base shear, base reaction, shear forces, stresses, base moment, torsion, and relative displacement are all included while analyzing the seismic response of a girder bridge. The equivalent static seismic force technique, time history analysis method, response spectrum method, and non-linear static pushover analysis are some of the approaches used to quantify the seismic reaction of a bridge structure. In this study, the seismic response of the structure is examined using the response spectrum approach and the pushover analysis method. Therefore, rather than only considering a structure's strength, its components and maximum allowable inelastic displacements are considered. The structure is only tested for strength at the global and component levels when it satisfies the specified performance requirements. The development of powerful processing power and the accessibility of advanced analytical tools have made it much simpler to introduce and advance this strategy.

3.1. DATA ANALYSIS

The structural response of the Bhuj earthquake was employed in this study to assess seismic analyses. An earthquake with a magnitude of 7.7 was recorded by the IMD strong motion seismograph, and the intensity in the affected area was as high as X (Extreme) on the MSK (Medvedev-Sponheuer-Karnik) scale of intensity. In 2001, an earthquake that lasted 22 seconds had its epicenter 16 kilometers under the Kutch area of Gujarat, India. Despite scientists' ability to forecast and forewarn earthquakes in advance and engineers' ability to create buildings that are earthquake-safe, hundreds of thousands of people have been murdered by earthquakes. Due to the development of earthquake analysis and design concepts the effects of the earthquake and structural damage. These are the several categories of earthquake analysis techniques.

When an earthquake is strong, the linear static analysis or seismic coefficient approach, a traditional elastic design method, does not provide accurate results. To accurately depict how structures react to mild to strong earthquakes, non-linear analysis is required.

Site-specific ground motion investigations are necessary for nonlinear dynamic analysis (Time history analysis). The assessment of dynamic earthquake parameters is necessary yet computationally challenging, time-consuming, and impractical for the majority of actual applications.

Many important aspects that have a substantial impact on a building's seismic performance are believed to be impossible to account for using the traditional elastic design analysis technique. The structural behavior of a structure during seismic ground vibrations is determined by its ability to withstand inelastic deformations. As a result, while exploring a system, it's indeed crucial to consider the inelastic deformation that seismic stress needs. The nonlinear static method known as pushover analysis is increasingly used by structural engineers to evaluate seismic requirements for buildings. It is a routine method that yields respectable outcomes.

3.2. RESPONSE SPECTRUM ANALYSIS

In accordance with IS-1893:2002, the total sum of the modal masses of all modes taken into consideration for the analysis should be at least 90% of the overall seismic mass.

For structures without any horizontal plan irregularities, ASCE 7-05, a Guide for the Planning of Diaphragms, allows diaphragms of concrete slabs or concrete stuffed metal decks with a span-to-depth ratio of 3:1 to be idealised as rigid; otherwise, the structural evaluation shall expressly embody believed of the stiffness of the diaphragm without elaborating. Nasser et al. (1993), Mansur et al. (1999), and Abdalla and Kennedy (1988) provided information on how an opening in rectangular RC and prestressed beams impacts stress distributions and a concrete beam's capacity in the field of concrete beams having net openings. Sadly, there was little evidence that the theory was developed to include other configurations; it was just marked against readily available experimental findings.

3.3. PUSHOVER ANALYSIS:

Buildings sustain crucial inelastic deformation under a powerful earthquake and dynamic characteristics of the structure evolve over time, so analyzing the implementation of a structure needs inelastic science methods depicting these dynamics. Inelastic analytical techniques grasp the people knows of structures by identifying letdown modes as well as the possibility for dynamic breakdown. Inelastic analysis techniques essentially combine inelastic analysis of time history as well as inelastic data observed that would otherwise be called pushover analysis.

The elastic - plastic time history study is the most precise method to predict the force and displacement demands at various components of the construction. In any event, the employment of inelastic time history analysis has been limited in due to the fact that dynamic response is exceedingly sensitive to showing and ground movement qualities. Additionally, it needs accessibility of an array of deputy seismic ground records that tracks for disturbances and differences in severity, regularity and length of time characteristics.

In a sense, the modeling approach in anticipating earthquake requests should be explored for low, intermediate and high rise constructions by distinguishing certain concerns, for instance, demonstrating non - linear part conduct, algorithmic fully intend of a method, varieties in the prognostications of different horizontal responsibility designs used during customary pushover analysis, aptitude of conserved parallel burden designs in talking to wave propagation impacts and precise assessment of target upending during which seismic interest assumption of pushover technique is conducted.

3.4. OBJECTIVES OF STUDY

A thorough literature study is carried outside to describe the goals of the thesis. The literature survey is reviewed and quickly outlined as follows:

1. To decide the capacity of bridge structure soil interaction to different soil types.

2. Dynamic investigation of the bridge structures considering response spectrum examination.
3. Utilization of Advanced diagnostic applications of software like Sap2000 for response plot examination of load opposing structure.
4. To decide the capacity and dynamic investigation in the terms of displacement, base reactions and object forces of the bridge structure subjecting to IS load combinations.
5. To set up a reference study for the construction of bridge structures for different soil types according code standards.

IV. BUILDING MODELLING AND ANALYSIS

For a analysis in Sap 2000 firstly select the Bridge tab and define the elements and material property in define then add the required material which we use in analysis of bride structure. By choosing bridge option bridge object in this case, we had first specified the material property. By providing the necessary information in the defining tab, we introduced different soil types. Then, by choosing the response spectrum function in desired zone and soil type shown below, we defined elements and added the necessary sections for girders, piers etc.

Total span length	30 m
Number of spans	3
Length of each span	10 m
Length after abutment	10 m on both sides
Bridge width	15.54 m
Bridge height	10 m
Asphalt Thickness	75 mm
Soil type	Type I, Type II & Type III
Design criteria	Modal analysis using Response spectrum method and for performance Push-over analysis is to be performed
Zone considering	V
Importance Factor, I	1.2
Response Reduction Factor, R	5 (RC girder Bridge with seismic isolation factor)
Support condition of columns	Fixed

Table 1: Geometrical properties & location factors

Pier size	As per IRC-112
Girder size	As per IRC-112
Grade of concrete	M-50
Grade of steel	Fe-550

Table 2: Section & material properties

Live load	IRC Class A
Regulation	IRC-5, IRC6, IRC-18, IRC-112 & IRC-SP-114
Seismic loading	IS: 1893-2016, IS :1893 (Part 3)
Serviceability conditions	IS 1984 & IS 2007
Wind loading	IS 875 Part III
Vehicle loading	IRC-6
Geometry	IRC-112
Permissible stress	IRC-18

Table 3: Loading details

Bridge Type: Precast RC I Girder Bridge
Four Lane Bridge
Each lane = 3600 mm

Concrete Strength = 50 MPa
Steel Strength = 420 MPa 60 grade
Steel for Stirrups = 40 grade 300 MPa
Asphalt Thickness = 75 mm
Overhang = 1000 mm
Barrier/Central Median = 380 mm
The Total width of Bridge = 3600 x 4 + 380 + 2 x380 = 15540 mm

The Length of Bridge = 30 m
Two bents each at 10 m interval
The effective span = 10000 mm
As per Code, $h_{min} = \frac{1.0(s+300)}{30}$ = 450 mm (where‘s’ is the spacing between the girders)
Modulus of Elasticity = $5000\sqrt{f_{ck}}$
$= 5000\sqrt{50}$ = 35355.339 N/mm^2

U = 1.25DC+1.5DW+1.75(LL+IM)
15540 = 1000+1000-6xS
S = 2250 mm Girder spacing (from the Total width of bridge we will get 7 girders)
6x2250+2xoverhang =15540 mm
Overhang = 1020 mm
$h_{min} = \frac{1.0(s+300)}{30}$ = 450 mm
Depth of Girder h_{min} = 85 mm

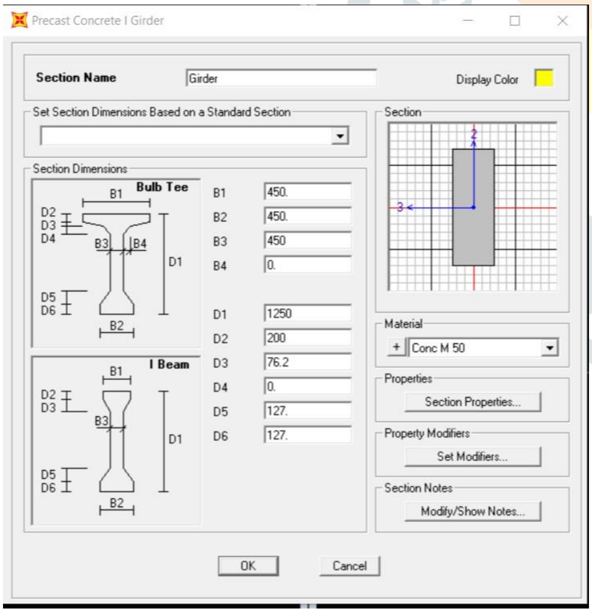

Fig 1. Section details of precast concrete Girder

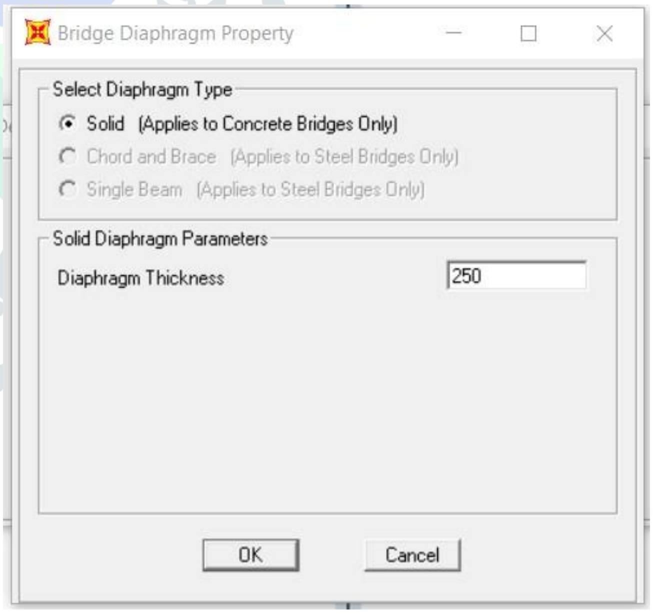

Fig 2. Bridge Diaphragm properties

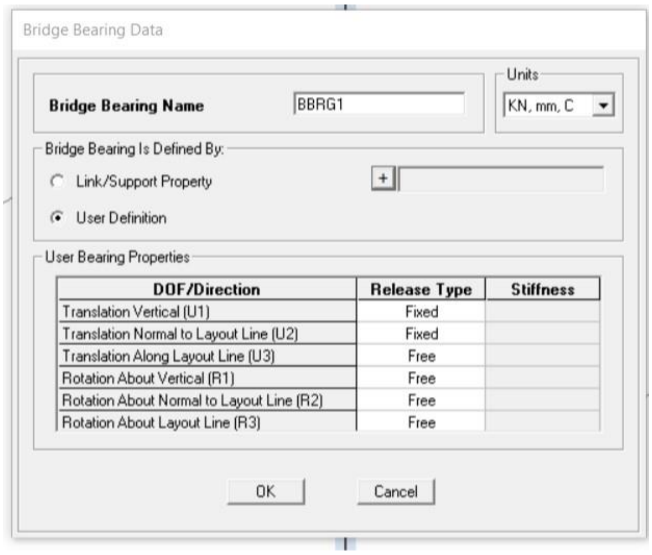

Fig 3. **Bridge Bearing Data**

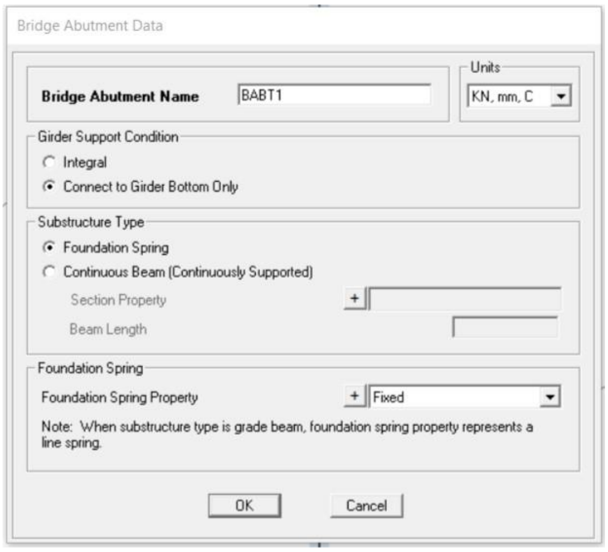

Fig 4. Bridge Abutment Data

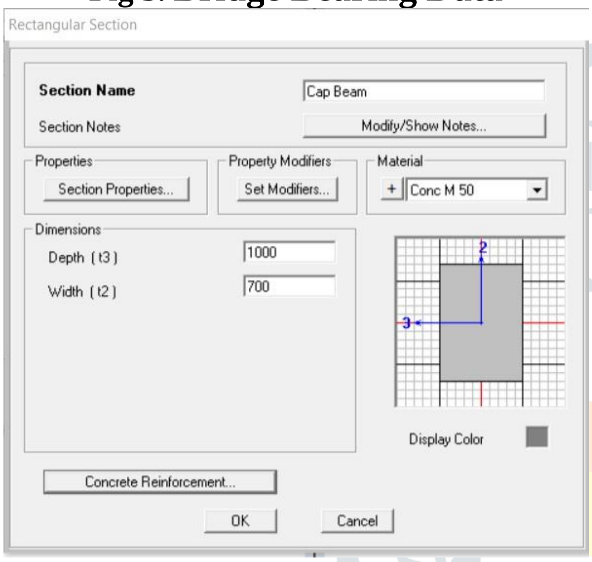

Fig 5. Bridge Cap Beam Data

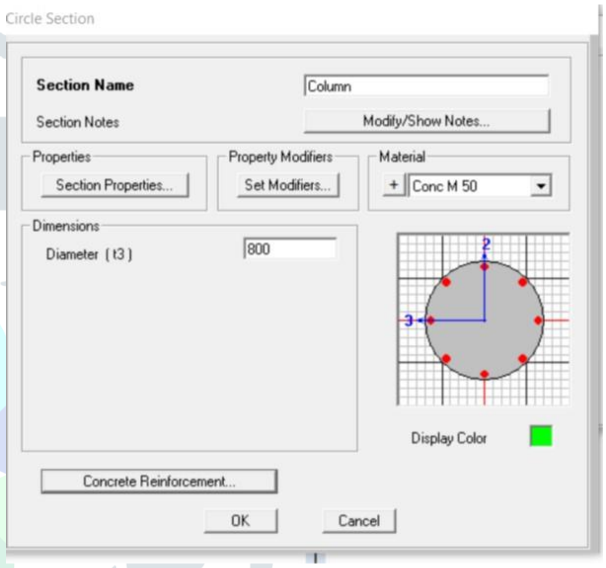

Fig 6. Bridge Pier Data

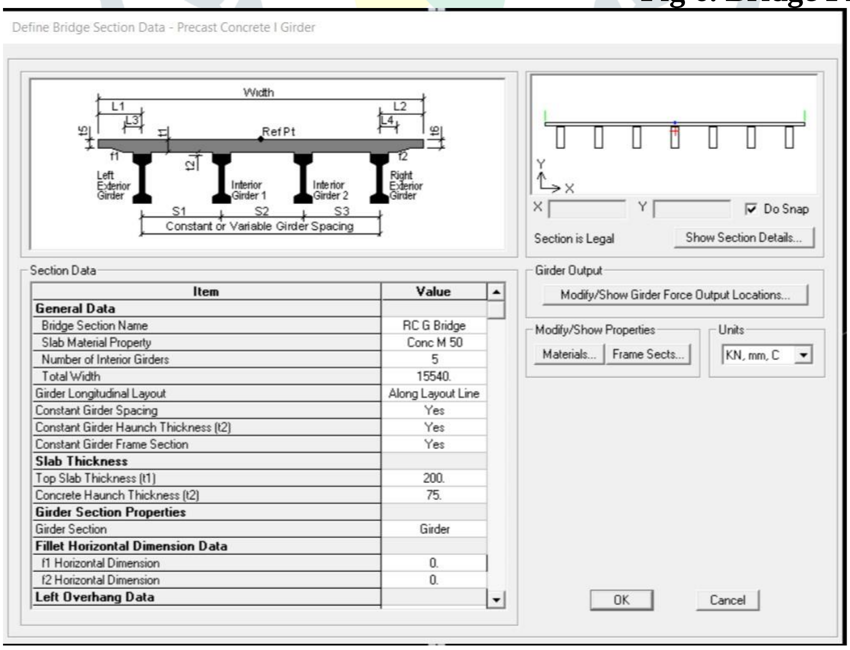

Fig 7. Bridge Section Data

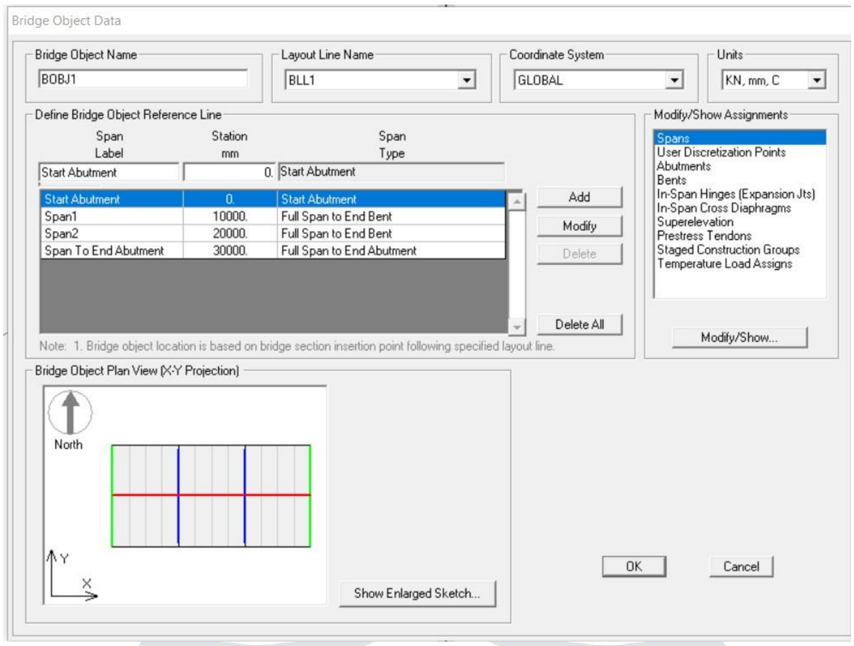

Fig 8. Bridge Bent Data

Considering all the above properties the bridge model is developed.

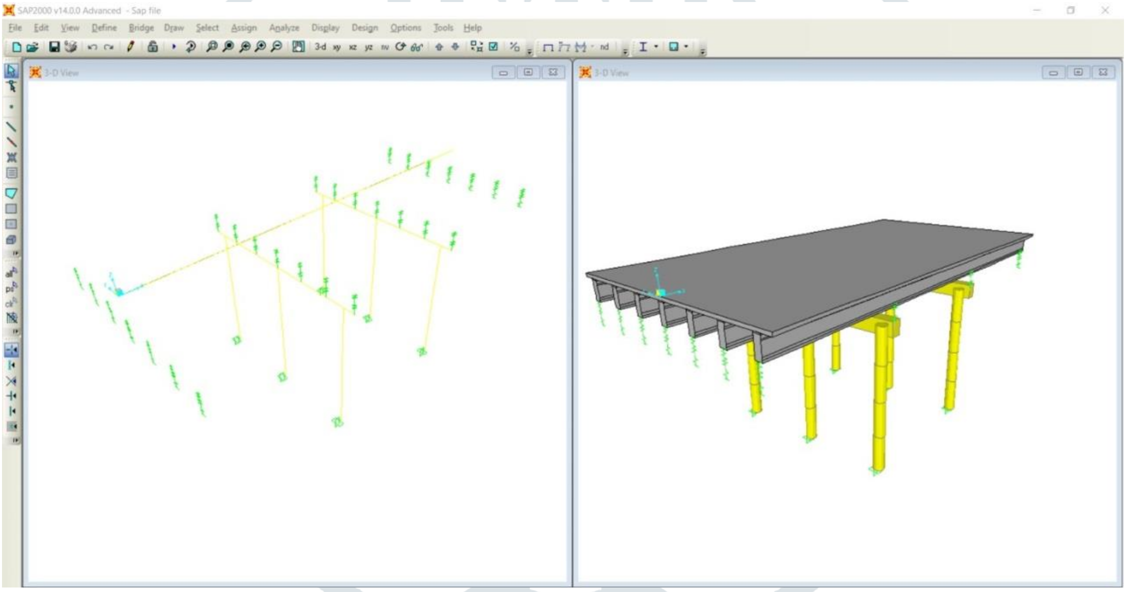

Fig 9. Bridge Model of 3 spans each 10 m

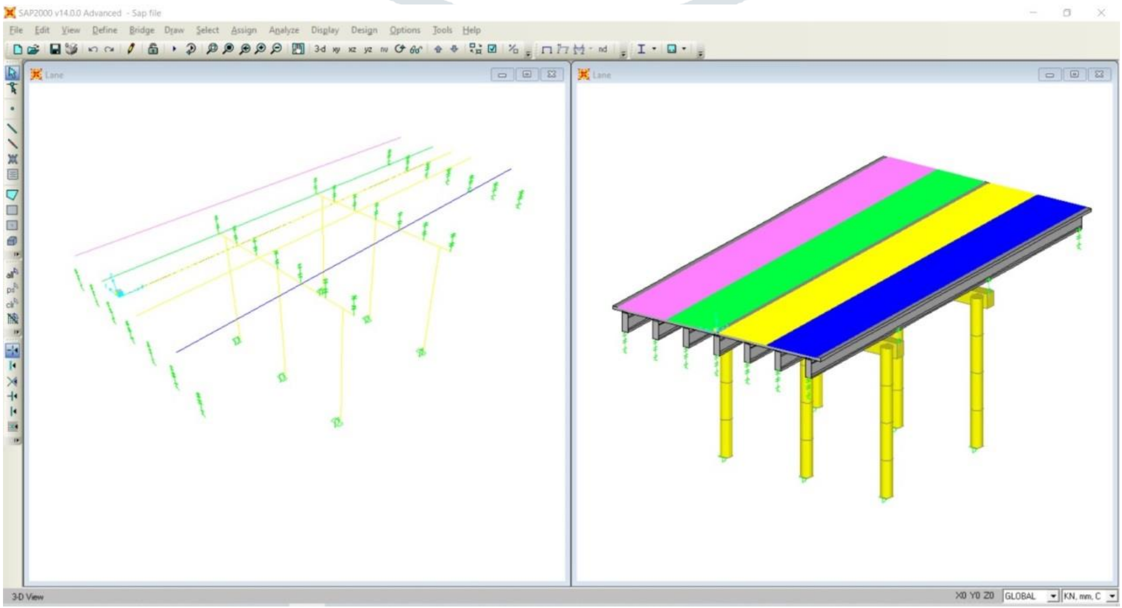

Fig 10. Defining of lanes of each 3.6 m

The total width of Bridge model is divided in to 4 parts i.e., 4 lanes in which two for the through traffic and the two for opposite traffic which are separated by a barrier at the center.

V. RESULTS AND DISSCUSIONS

The chosen bridge model is reviewed through response spectrum analysis and load combination prescribed by the IS standards. The following are the terms in which the response spectrum results are presented in form of story response plots. The terms in which these results are compared are defined below.

Shear force and Bending moment Diagram: Shear force and bending moment diagrams are analytical tools used in conjunction with structural analysis to help perform structural design by determining the value of shear forces and bending moments at a given point of a structural element such as a beam.

Object forces: Two major forces act on a bridge at any given time: compression and tension. Compression, or compressive force, is a force that acts to compress or shorten the thing it is acting on. Tension, or tensile force, is a force that acts to expand or lengthen the thing it is acting on.

Joint Displacements: Bridge expansion joints are designed to allow for continuous traffic between structures while accommodating movement, shrinkage, and temperature variations on reinforced and pre-stressed concrete, composite, and steel structures.

5.1. RESULTS FROM RESPONSE SPECTRUM ANALYSIS

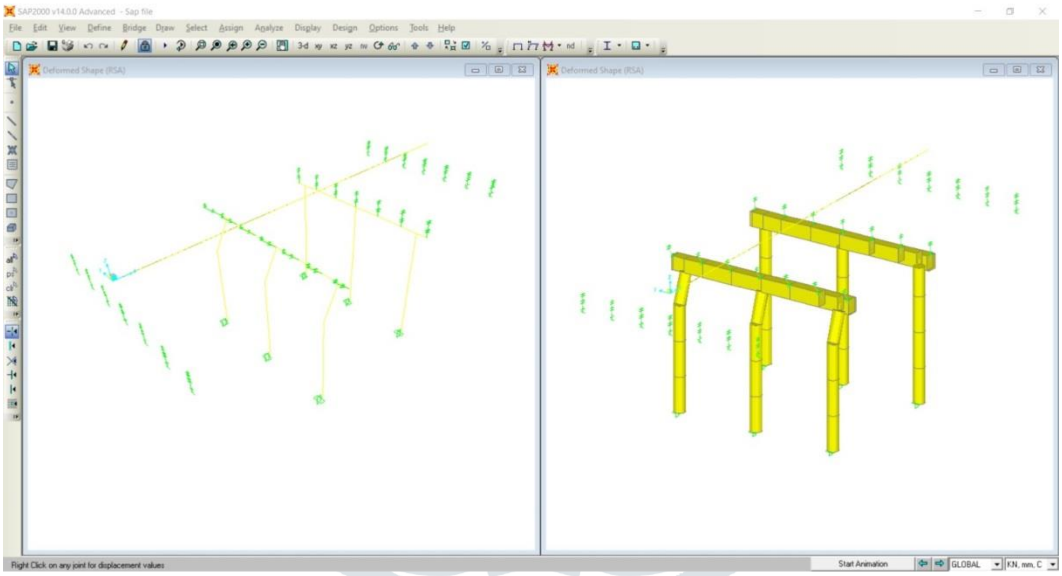

Fig 11. Deformed Shape of Bridge Model (RSA)

From the figure we can see that how the bridge model is deformed when it effected to static and dynamic loads.

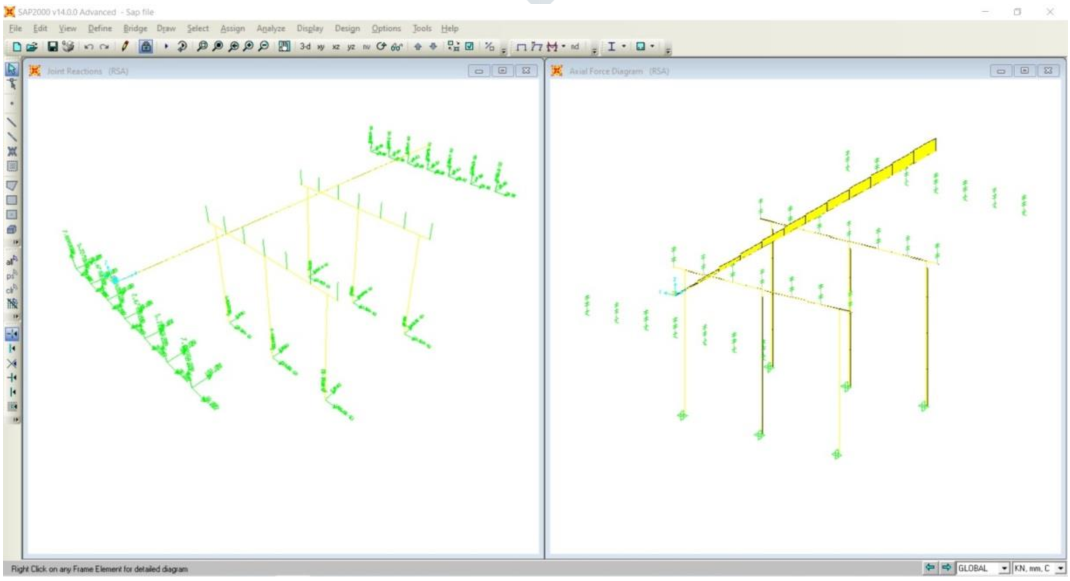

Fig 12. Joint Reactions and Axial Force Diagram (RSA)

From the figure we can see the Joint Reactions and Axial force Diagram.

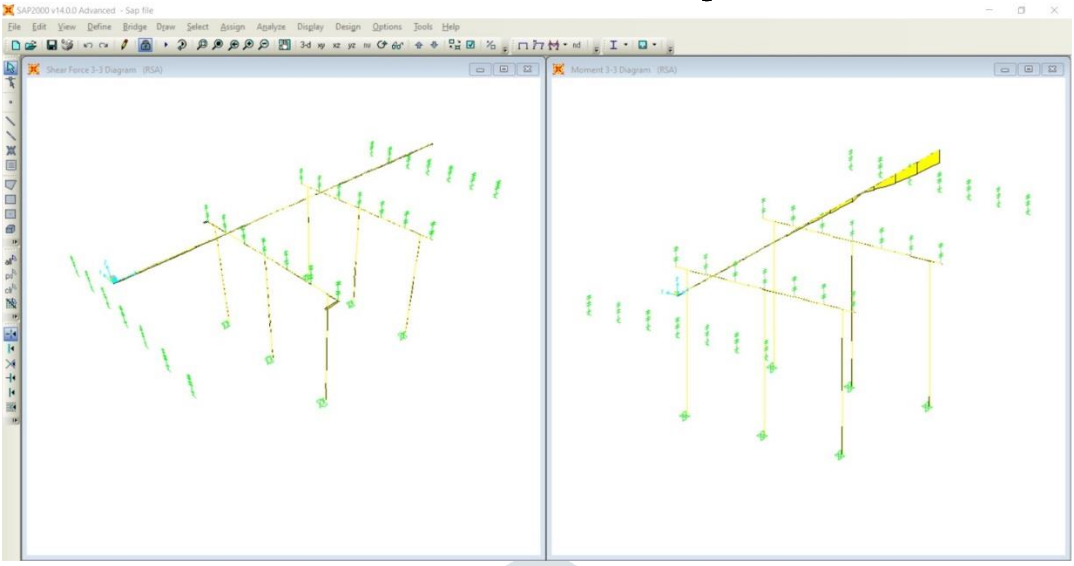

Fig 13. Shear force and Moment Diagrams (RSA)

From the figure we can see the Shear force and Moment Diagrams.

MAXIMUM JOINT DISPLACEMENTS:

Type of Soil	U1 (mm)	U2 (mm)	U3 (mm)
Type I	40.527	60.375	10.905
Type II	52.436	73.543	21.725
Type III	61.509	82.257	34.735

Table 4: Maximum Joint Displacements

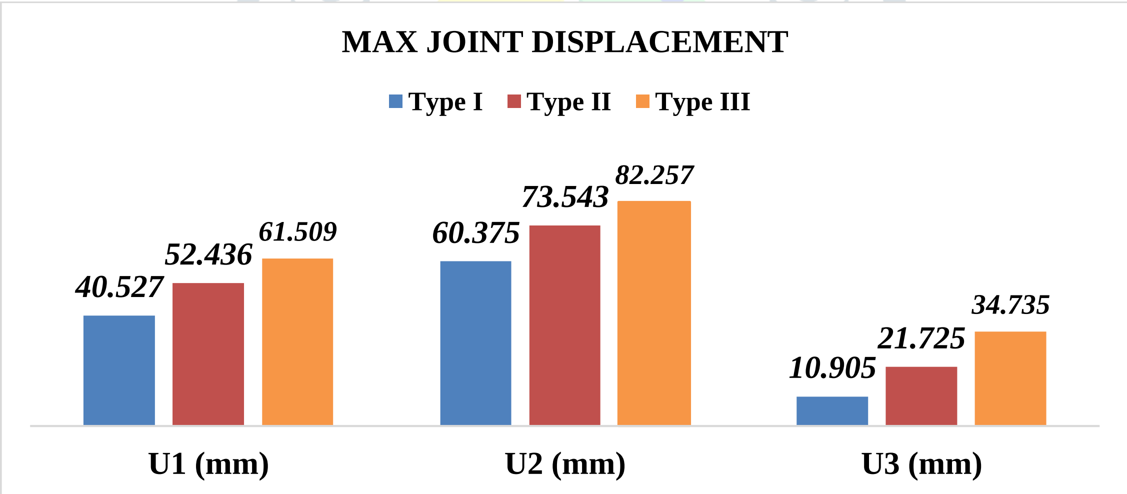

Fig 14. Maximum Joint Displacements (RSA)

MAXIMUM BASE REACTIONS:

Type of Soil	Global X (kN)	Global Y (kN)	Global Z (kN)
Type I	471152.522	8463911.639	8538089.036
Type II	404672.435	7657492.573	7538089.509
Type III	358934.936	6995476.364	6838089.357

Table 5: Maximum Base Reactions

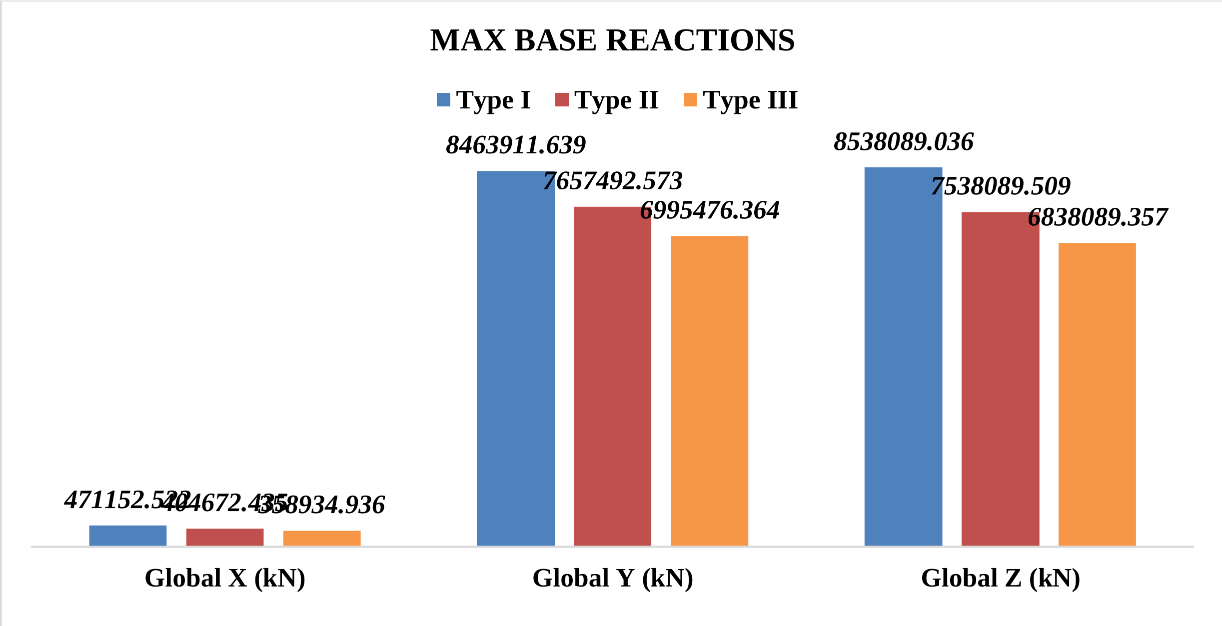

Fig 15. Maximum Base Reactions (RSA)

MAXIMUM OBJECT FORCES:

Type of Soil	P (kN)	V2 (kN)	V3 (kN)
Type I	451328.742	3081850.804	3557432.512
Type II	383625.396	2463872.063	2963737.252
Type III	329734.735	1963374.534	2593998.247

Table 6: Maximum Object Forces

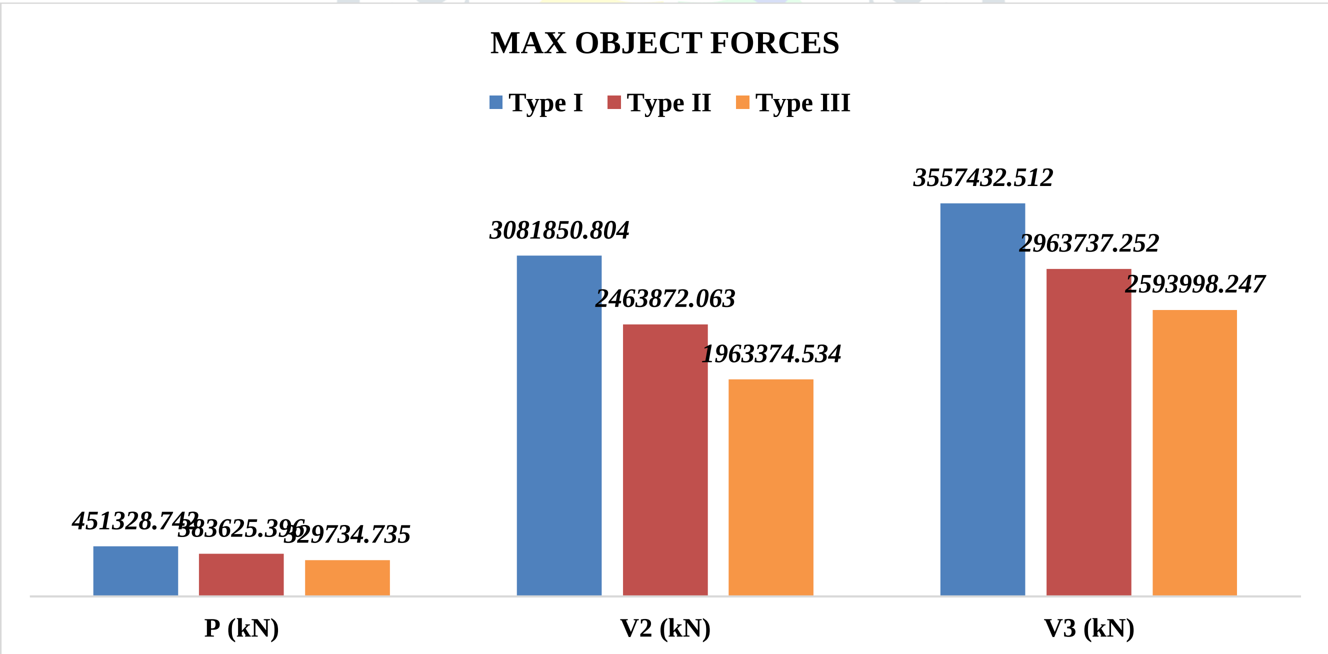

Fig 16. Maximum Object Forces (RSA)

From the above results it can be noted that Type I of soils has the greater impact in the seismic resistance when compared to Type II and Type III.

Now performing the Non-linear static Pushover analysis in the displacement control manner we got the results in terms of Hinges and Hinge M3..

5.2. RESULTS FROM PUSHOVER ANALYSIS –

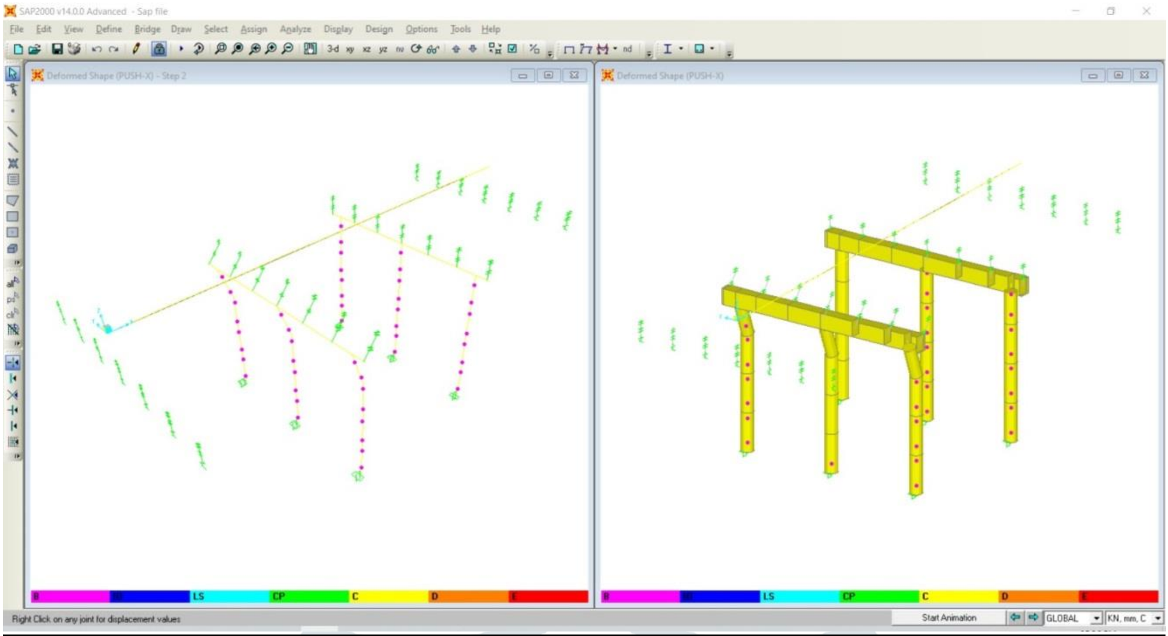

Fig 17. Hinges after performing Push-over analysis

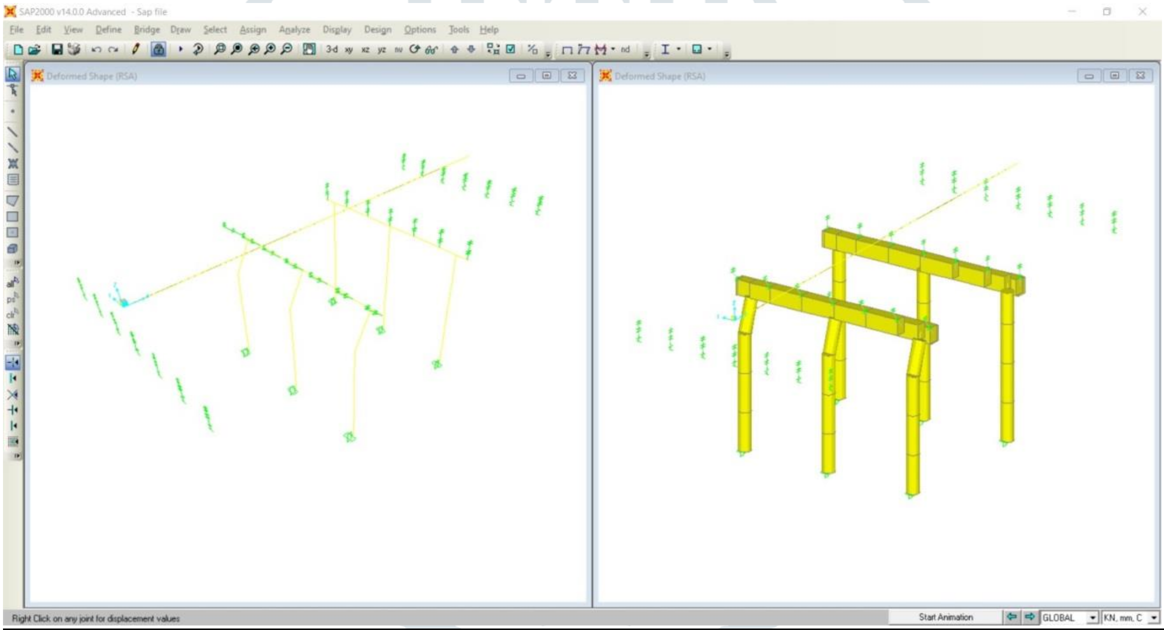

Fig 18. Deformed Shape

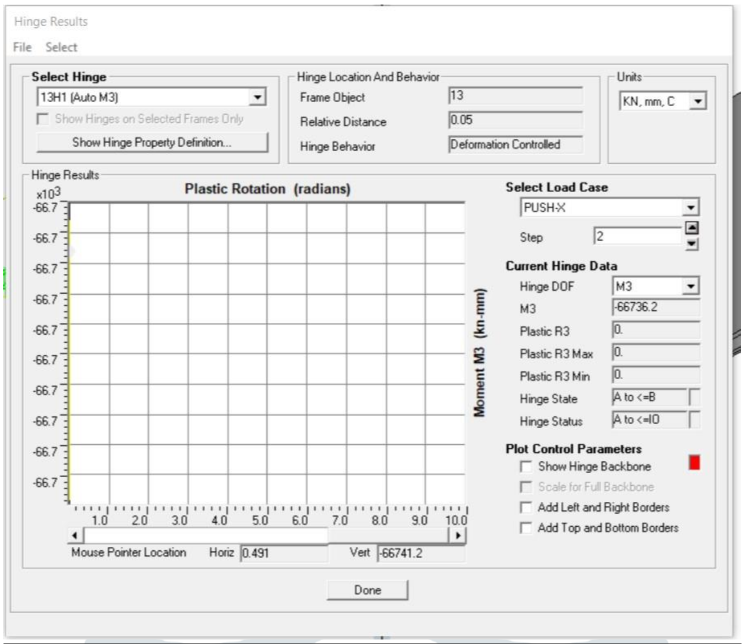

Fig 19. Hinge Results for Beam Hinge

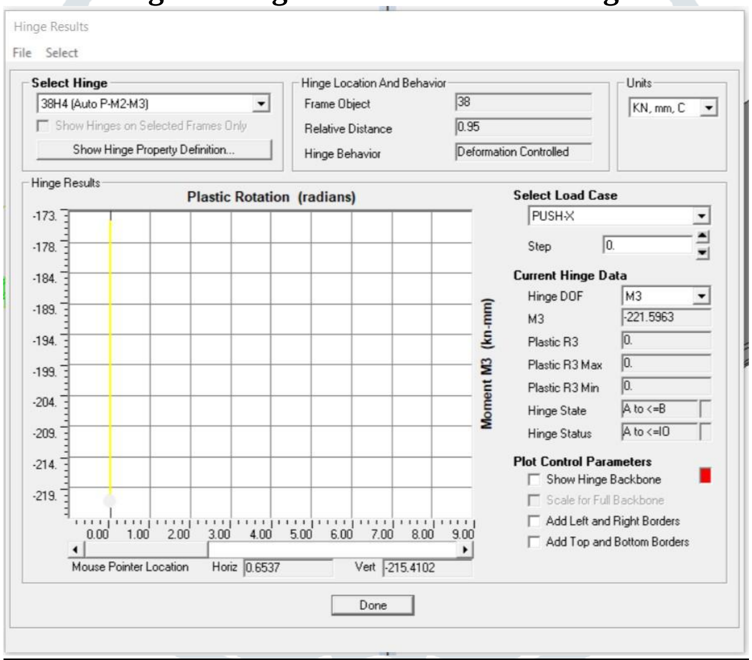

Fig 20. Hinge Results for Column Hinge

Performing the push-over analysis for soil types as soil structure interaction we will get the following hinge results.

MAXIMUM HINGE RESULTS

Type of Soil	Beam Hinge M3	Column Hinge M3
Type I	66742.40	221.5963
Type II	72956.45	283.3645
Type III	80635.36	359.5287

Table 7: Maximum Hinge Results

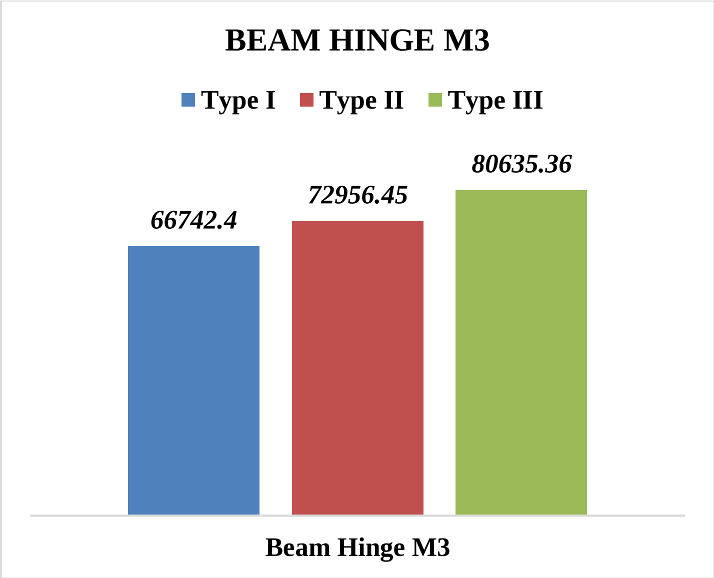

Fig 21. Maximum Hinge Results (Beam)

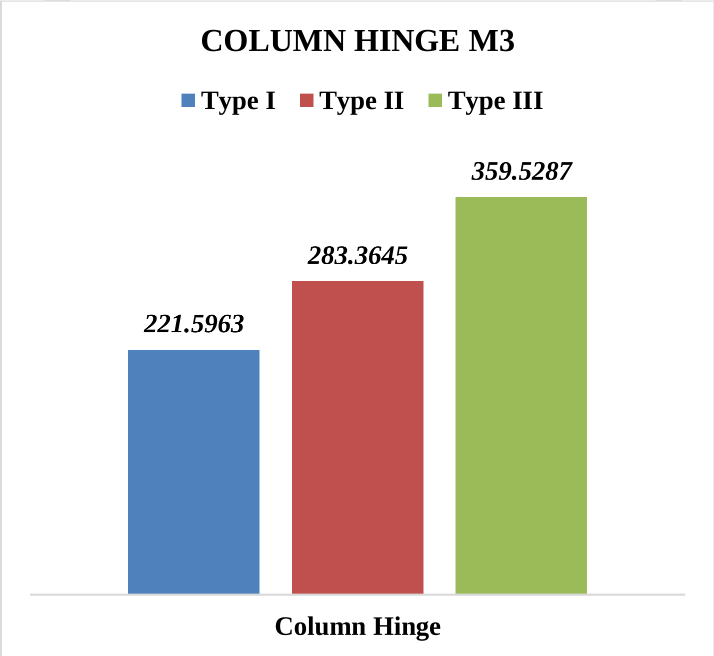

Fig 22. Maximum Hinge Results (Column)

Due to the seismic effects in the Zone V the maximum hinge results occurs in Type III soil of the structure, maximumjoint displacement occurred at the to first bent which is at 10 m from the origin, and the maximum object forces of the structure is found out.

All the models' push over curves practically coincides in the Y direction. Pushover Curves from this study's findings demonstrate that the bridge's reaction towards the seismic effect on structure differs significantly for soil types. Soil Type I has the lower displacement results than the Type II & Type III.

From the above figures Soil Type III have the compatibly more Hinges displacement results when performing nonlinearstatic pushover analysis.

VI. CONCLUSIONS

1. The bridge is more resistant to seismic acceleration when it constructed on soil type I. When a structure is modelled, the results of the modal analysis reveal certain peculiar modes. However, it is discovered that such forms get very little mass engagement. As a result, these modes won't materially alter the building's reaction.
2. More caution needs to be used while constructing bridges in soil type III.

3. Soil type II, which is likewise good for construction, produces better outcomes when bridges are built than type III.
4. When compared to soil type III, soil type II and soil type III's joint displacements, base reactions, and object forces have all better results.

This study thus concludes that the bridge is more secure when it has constructed in soil type I and type II and suggests that more research is required with various problems.

VII. REFERENCES

[1]. Francesco lo month (2017) Seismic Vulnerability Assessment and Retrofitting Design of a Multi-span Highway Bridge: Case Study, J bridge Eng. 23(2): 65017016.

[2]. Yang (2014) research on seismic response and isolation effect of the continuous box Girder Bridge with HRD ASCE.

[3]. Qiang Han (2017) Nonlinear Seismic Response of Skewed Highway Bridges Subjected to Bidirectional Near-Fault Ground Motions DOI:10.1061/(ASCE) BE.1943- 5592.0001052. © 2017.

[4]. Abdel-Salam (1988) seismic response of the curved steel box Girder Bridge, J struck Eng. 114:2790-2800.

[5]. N Krishna Raju, (2008), Design of bridge, OXFORD & IBH-PUBS COMPANY- NEW DELHI.

[6]. D. Johnson victor, (2007), "Essentials of BRIDGE ENGINEERING" 6th edition OXFORD & IBH PUBS COMPANY- NEW DELHI.

[7]. IRC: 5-(2015), "Standard specifications and code of practice for road bridges", section-I, "General features of design" 8th revision IRC NEW DELHI.

[8]. IRC: 6-(2016), "Standard specifications and code of practice for road bridges", section- II, "LOAD AND STRESSES" 8th revision, IRC NEW DELHI.

[9]. IRC: 112 (2011) "Standard specifications and code of practice for road bridges", code of practice for the concrete bridge, IRC NEW DELHI.

[10]. IS 1893-2016 (Part 4): Criteria for earthquake resistant design of the structure, Part 4.

[11]. IS 875 (Part 2): code of practice for design loads (other than earthquake) for building and structure, Part 2 imposed load (2nd revision).

[12]. IRC (Indian Road Congress) (2017). Standard Specifications and Code of Practice for Road Bridges, Section:II, Loads and Load Combinations 7th Revesion. IRC-7. New Delhi, India: Indian Road Congress.

[13]. ACI (American Concrete Institute) (2014). Building Code Requirements for Structural Concrete. ACI 318. Michigan, United States of America: American Concrete Institute.

[14]. IITK-RDSO (Indian Institute of Technology KanpurResearch Designs and Standards Organisation), (2010). Guidelines on Seismic Design of Railway Bridges. NICEE (National Information Centre of Earthquake Engineering), Indian Institute of Technology Kanpur, India: Indian Institute of Technology Kanpur.

[15]. AASHTHO-LRFD (American Association of State Highway and Transportation Officials - Load and Resistance Factor Design) (5th), (2010). Bridge Design Specifications. New York, United States of America: American Association of State Highway and Transportation Officials. How to cite this article: Tarafder, N. and Prasad.

[16]. Chaudhary, M.T.A. (2016) Effect of Soil-Foundation-Structure Interaction and Pier Column Non-Linearity on Seismic Response of Bridges Supported on Shallow Foundations. Australian Journal of Structural Engineering , 17, 67-86. https://doi.org/10.1080/13287982.2015.1116178

[17]. Dutta, S.C., Bhattacharya, K. and Roy, R. (2004) Responses of Low-Rise Building under Seismic Excitation Incorporating Soil Structure-Interaction. Soil Dynamics and Earthquake Engineering , 24, 893-914. https://doi.org/10.1016/j.soildyn.2004.07.001

[18]. Spyrakos, C.C. (1990) Assessment of SSI on the Longitudinal Seismic Response of Short Span Bridges. Engineering Structures , 12, 60-66. https://doi.org/10.1016/0141-0296(90)90038-T

[19]. SeismoSoft, *SeismoStruct V.7 – A Computer Program for Static and Dynamic Nonlinear Analysis of Framed Structures, available from URL:* http://www.seismosoft.com.

[20]. V. Papanikolaou, and A. Elnashai, "Evaluation of conventional and adaptive pushover analysis I: Methodology", *J. Earthquake Eng.*, vol. 9, no. 6, pp. 923-941, 2005.

[21]. ATC 4 (Applied Technology Council) "Seismic Evaluation and Retrofit of Concrete Buildings" Volume 1, Nov-1996.

[22]. FEMA 273 (Federal Emergency Management Agency) "Guidelines for the Seismic Rehabilitation ofBuildings" Oct-1997.

[23]. FEMA 356 "Pre-standard and Commentary for the Seismic Rehabilitation of Buildings" Nov-2000.

[24]. FEMA 440 "Improvement of Nonlinear Static Seismic Analysis Procedures" June-2005.

[25]. IS 1893: 2002 "Criteria for Earthquake Resistant Design of Structures (Part I)".