Analysis of suspension bridge with different types of anchoring considering vehicular loading using SAP2000

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ABSTRACT:

Cable-supported bridges are classified into cable-stayed and suspension bridges. Suspension bridges are one of the main types of long-span bridges and possess significant benefits in terms of material properties and height-span ratio of the stiffening girders. Suspension bridges are comprised of main beams, tower piers, cables, and anchorages, with the anchorages playing the major role in anchoring the suspension bridge's main cables. Based on the main cable anchoring method, suspension bridges are classified into self-anchored or earth-anchored.

In a self-anchored bridge type, the main cable is directly attached to the stiffening girder, whereas in the earth-anchored type, the main cable is directly attached to the bridge via anchorages at the beginning and end locations.

Anchorages are vital parts of earth-anchored suspension bridges, and support the tension of the main cables . Anchorages for earth-anchored suspension bridges can be classified into gravity and tunnel types.

In this study proposing, the pull-out behaviour of a tunnel-type anchorage considering both geometric and rock joint characteristics.

Keywords: bridge, concrete, anchorage, analysis, force, stress.

INTRODUCTION:

A suspension bridge is referred to a type bridge supported by cables. This type of bridge has been with mankind since ancient times. Today's large and magnificent suspension bridges were made possible through the establishment of structural analysis methods, material developments, construction methods, and computer technology developments. Suspension bridges are one of the most beautiful special bridges, and are considered one of the types of bridges many structural engineers dream to design.

Anchorages are important structures that transmit the horizontal and vertical forces of the main cable to the foundations. The types of anchorages are classified into gravity-type anchorages, tunnel-type anchorages, and rock anchorages. Gravity-type anchorage consists of a method of resisting the loads from the cables with the self-weight of the foundation and anchor frame. Many suspension bridges use gravity-type anchorages. Tunnel-type anchorage is a method of resisting the loads of the cables by using the shear forces of the outer circumference of the steel frame and the pressure of the plug body. Rock anchorage is a method of resisting the loads of the cable by using the weight, adhesion, and frictional resistance of rock wedges. This method is used in areas with good rock formations.

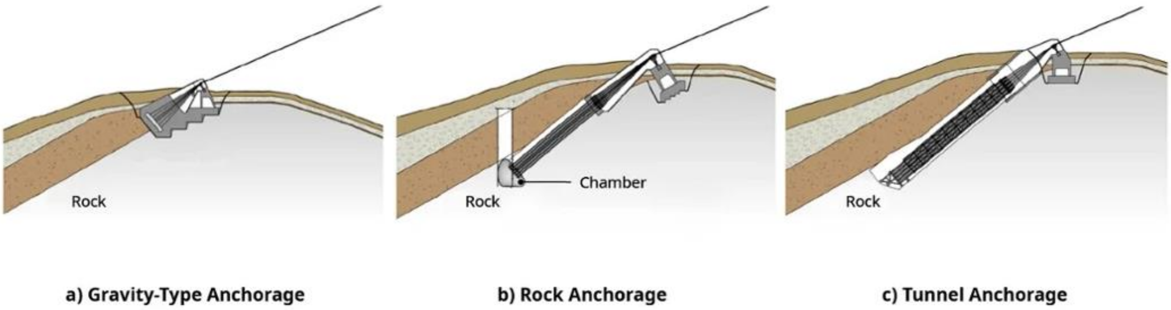


Fig 1 Anchorage types

LITERATURE REVIEW:

Xiangong Zhou et.al (2022) the research and analysis method of structural fragility of three-tower self-anchored suspension bridge was presented in detail based on practical engineering cases.

Under the action of seismic waves along the bridge, the damage exceedance probability of the damped connection system is lower than that of the fully floating structure system. At the same time, the difference in damage exceedance probability of the two systems under the same damage level continues to expand. It shows that the addition of a damper device can significantly improve the seismic performance of the structure, and the reduction effect of a damper device for a high-intensity earthquake is more obvious than that for a low-intensity earthquake. The probability of slight and moderate damage to the piers and bearings of the floating system of the threetower self-anchored suspension bridge is high, while the probability of damage to the bridge tower is relatively small. This design is in line with the design idea of taking the easily repaired components as secondary components in the seismic design.

Zhijin Shen et.al (2022) research paper conducted a field-scale experiment to study the north side tunnel of Wujiagang Bridge in Yichang, China. According to the similarity principle, the

1:12 tunnel anchor scale model was established. The tunnel anchor scale model was selected in the area adjacent to the actual project site to ensure the similarity of stratigraphic conditions. Through the use of a displacement meter, inclinometer hole, strain gauge, micrometers, and other comprehensive monitoring methods, the design load test, overload test, overload rheological test, and ultimate bearing capacity failure test were carried out. Through the structural deformation observation and stress observation of the anchorage body and surrounding rock, the stress deformation characteristics and rheological characteristics of the anchorage body and surrounding rock in the field-scale experiment were analyzed. The deformation failure mechanism, deformation failure process, potential failure mode, and overload capacity of solid tunnel anchor were investigated.

Based on the limit equilibrium analysis results of the model, the safety and rationality of the tunnel anchorage structure design of the actual suspension bridge were evaluated. According to the model experiment results, under the design load of 1P, the deformation of the rock mass at the top of the anchor tunnel is the largest, which is 0.005 mm followed by the deformation of the rock mass at the front anchor surface, and the deformation of the rock mass at the rear anchor surface is the smallest, which is 0.001 mm. According to the similarity principle, it is speculated that the maximum deformation of the front anchor surface of the solid anchor is about 1.2 mm under 1P load. Rheological test results show that the long-term rheological characteristics of tunnel anchorage are not obvious under the action of design load and step-by-step overload load, and the anchorage can be in a long-term stable state under rheological load. The scheme of tunnel anchorage on the north side of Wujiagang Yangtze River Bridge in Yichang can meet the engineering requirements.

OBJECTIVES OF THE RESEARCH

The primary goals of the current examination are as per the following:-

1. To determine the pull out behaviour of the tunnel type anchorage and gravity type based on rock joint.
2. To investigation the load bearing capacity of the anchorage bridge with two different condition.
3. To determine finite element analysis of anchorage based bridge using analysis tool SAP2000.

4 To determine the most suitable type of anchorage in comparison.

METHODOLOGY:

Steps of the Analysis

Step 1 First step is to study different research papers from authors all across the globe to understand the research done in the same field and this gave our study base and scope for further research.

Step 2 this step includes defining the unit to design the model initialization where the units is measured as Metric SI. Steel code and concrete design code is locked as IS 800:2007 and IS 456:2000.

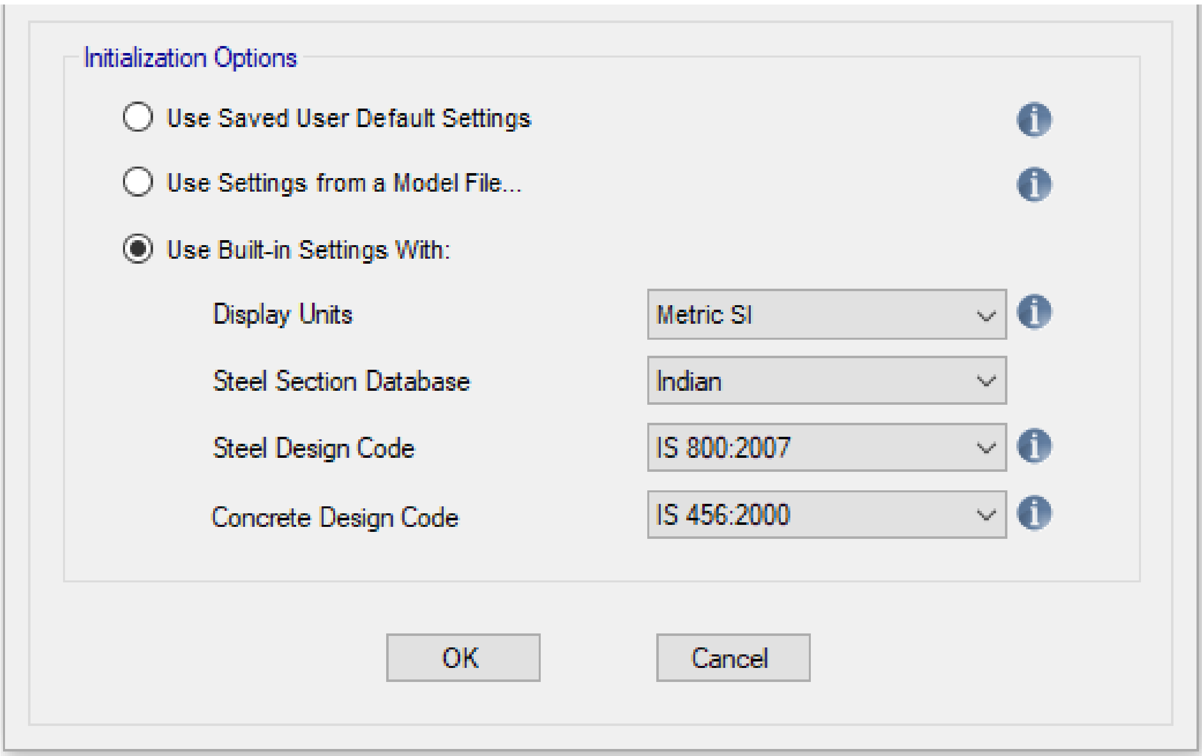


Fig 2 Initialization of Model

Step 3: Modelling of the section a working drawing

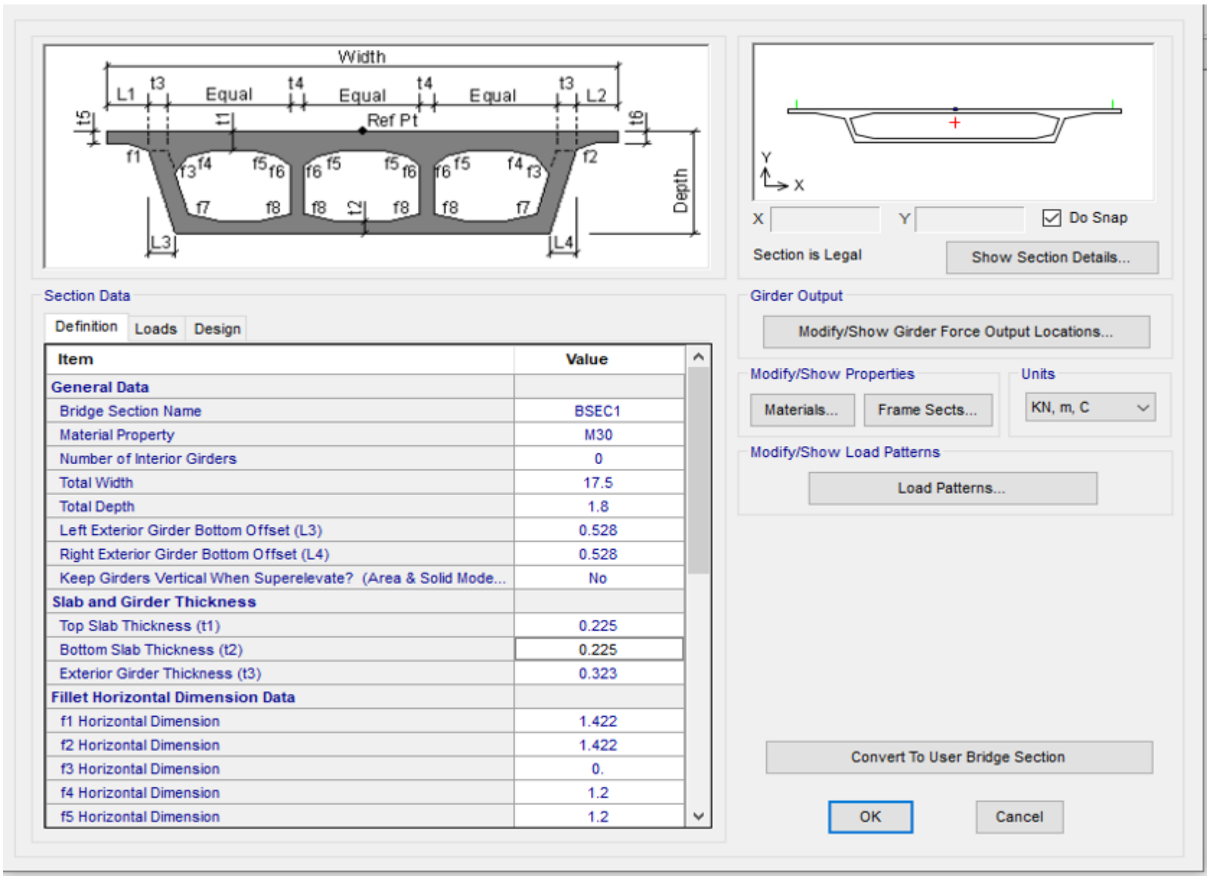


Fig 3 Modeling of Sectional Drawing

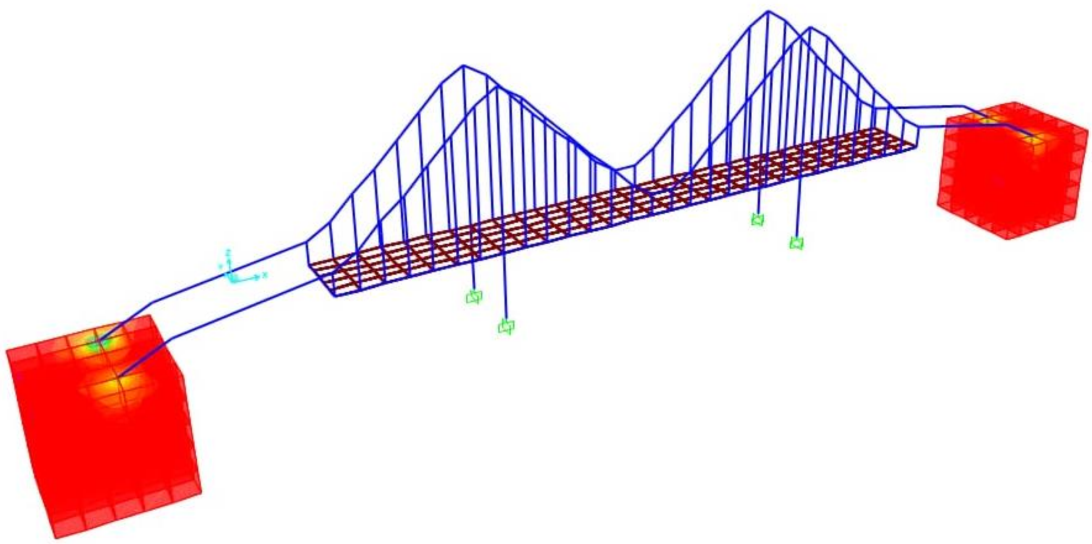


Fig 4 Model Structure

Step 4: Defining materials as per Indian Standards and assigning to the structural members

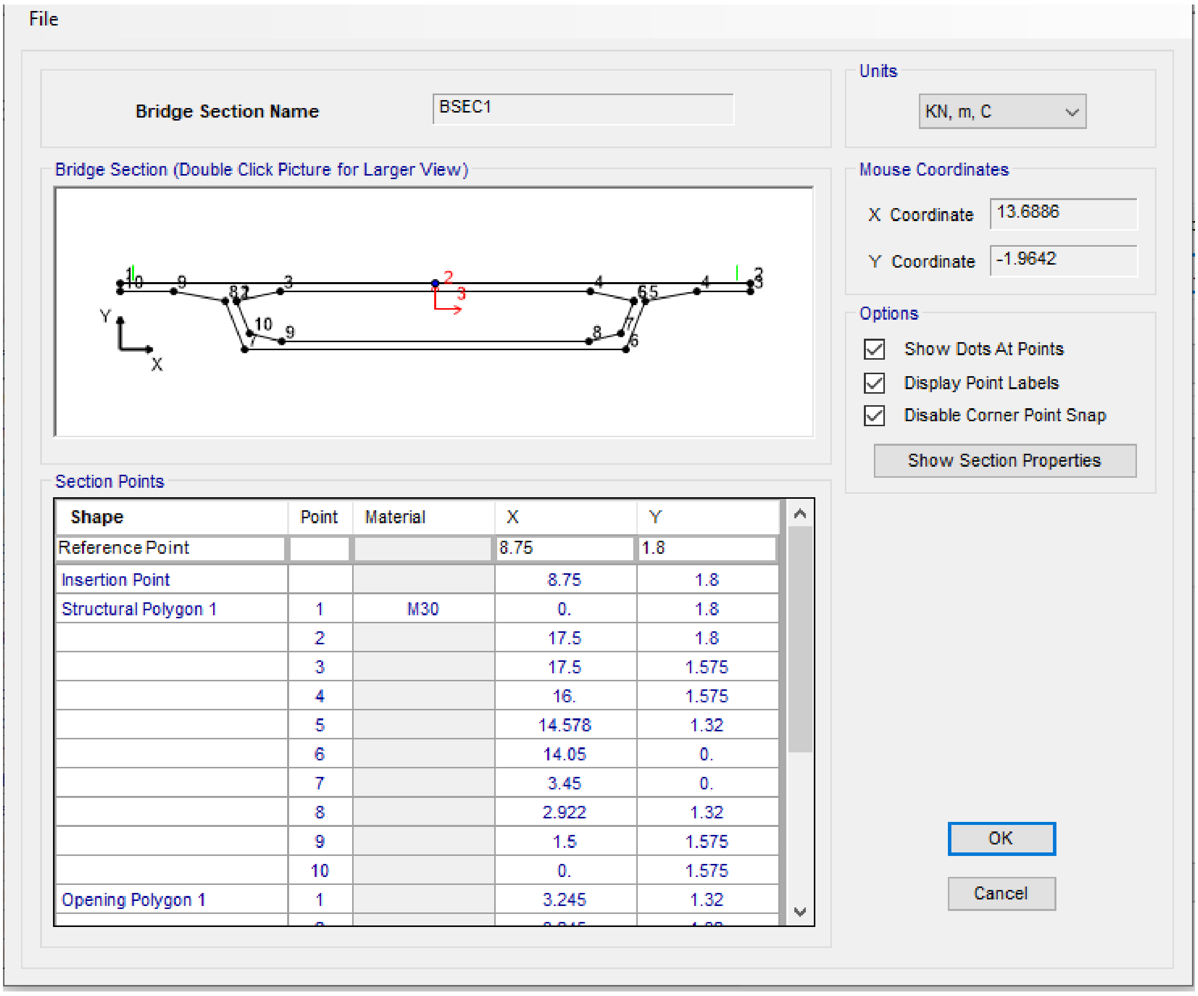


Fig 5 Defining Bridge Section

Step 5: Defining Properties of Material

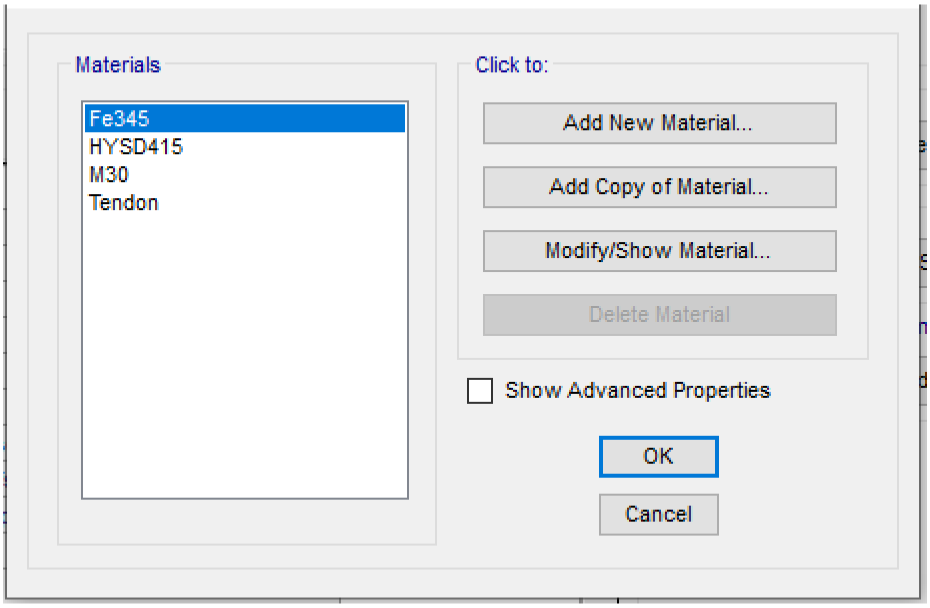
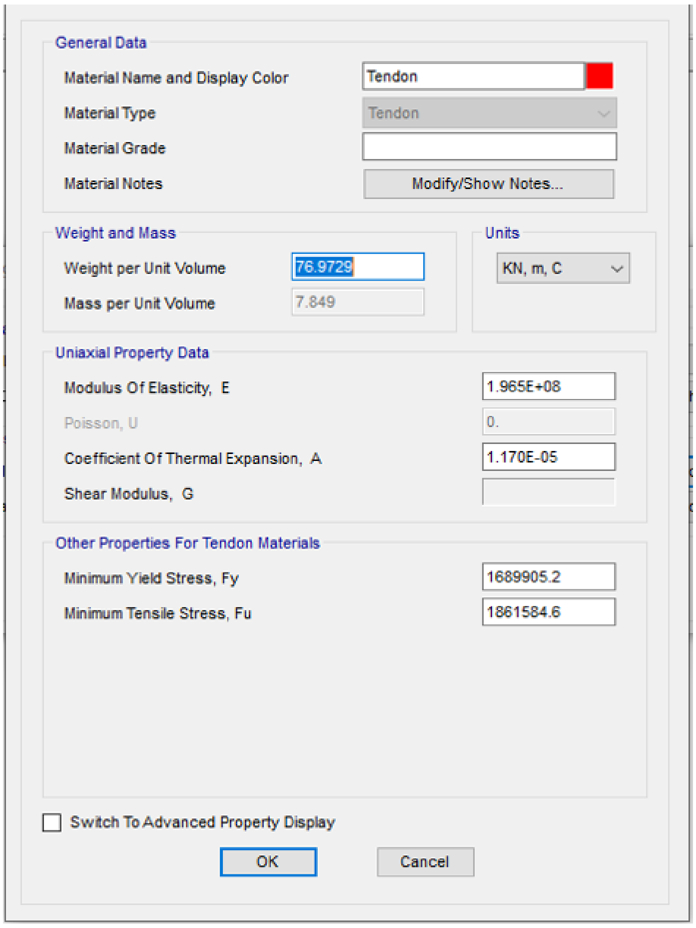


Fig 6 Defining Properties of Material

Step 6: Assigning tendons to precast segmental beam.



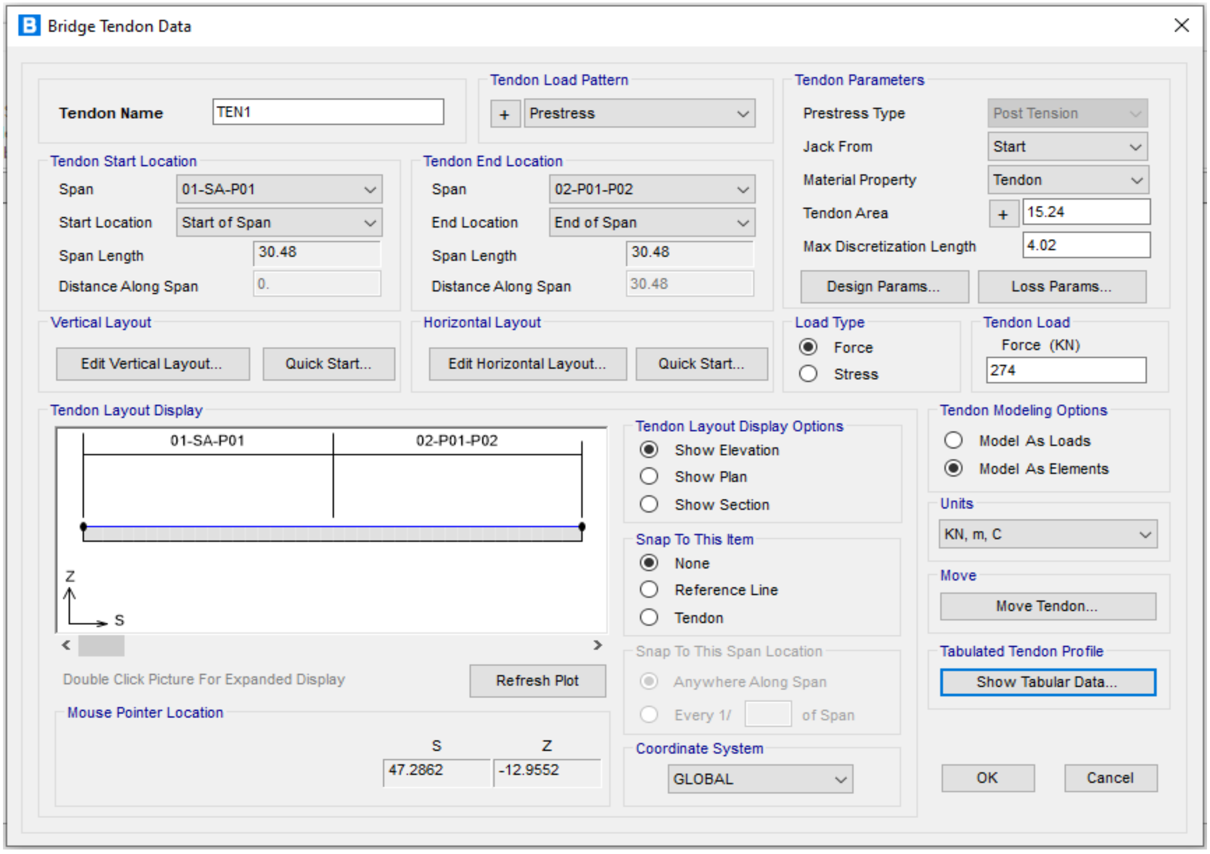


Fig 7 Defining and Assigning Bridge Tendons

Step 7: Assigning Loading conditions to the model Precast Segmental beam with tendons.

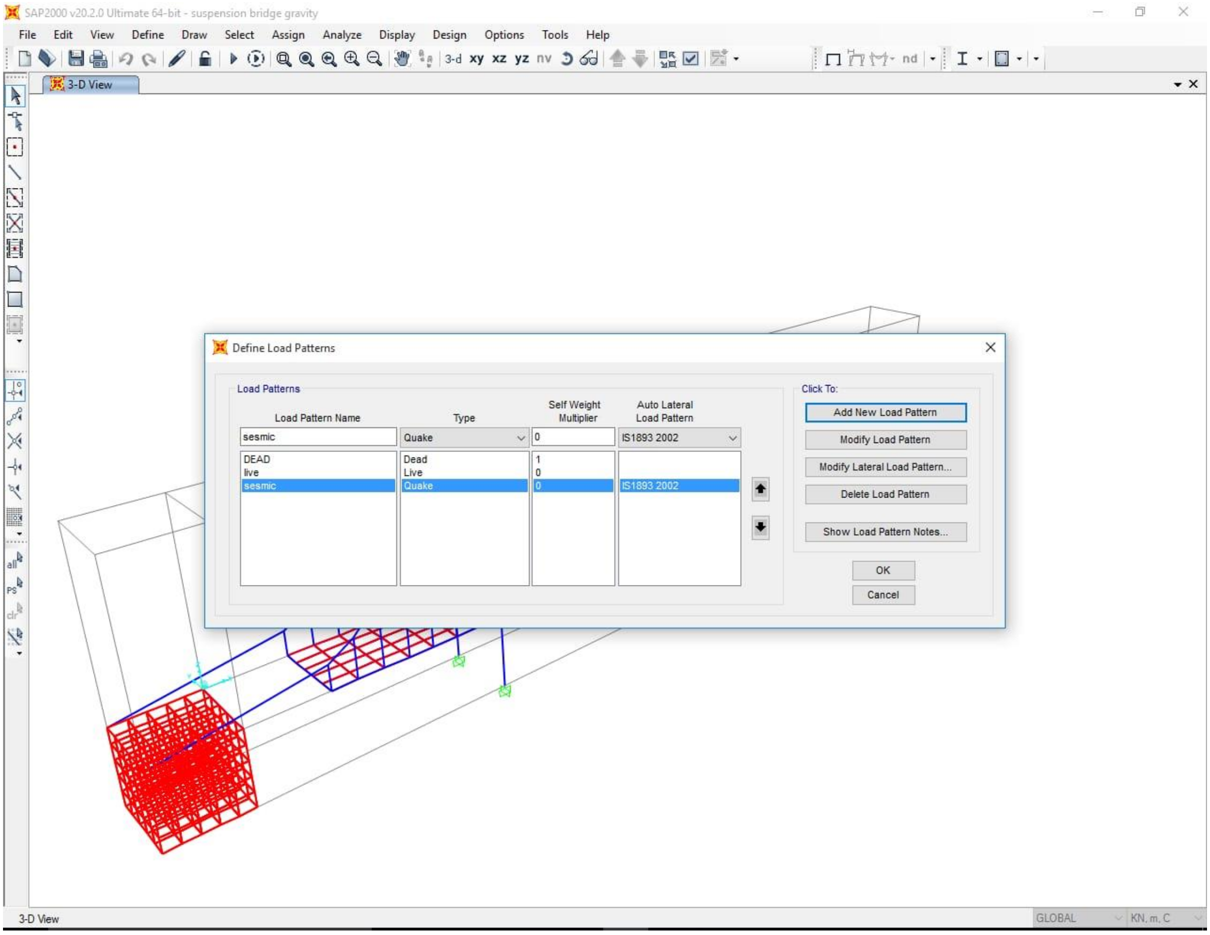


Fig 8 Defining Load Pattern

Step 8: Defining Vehicular Loading

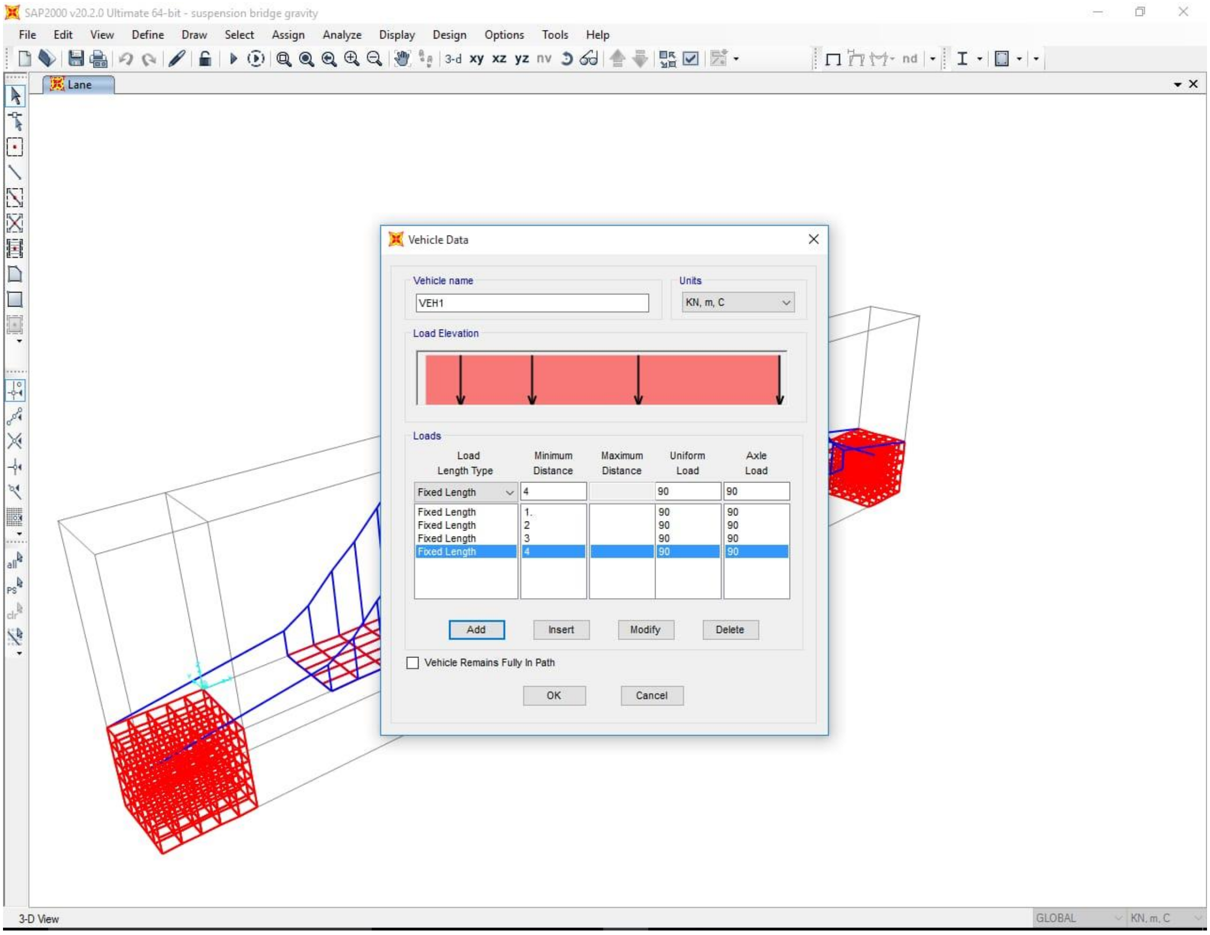


Fig 9 Vehicular Loading

Step 9: Defining Seismic loading as per IS 1893:2016 Part I

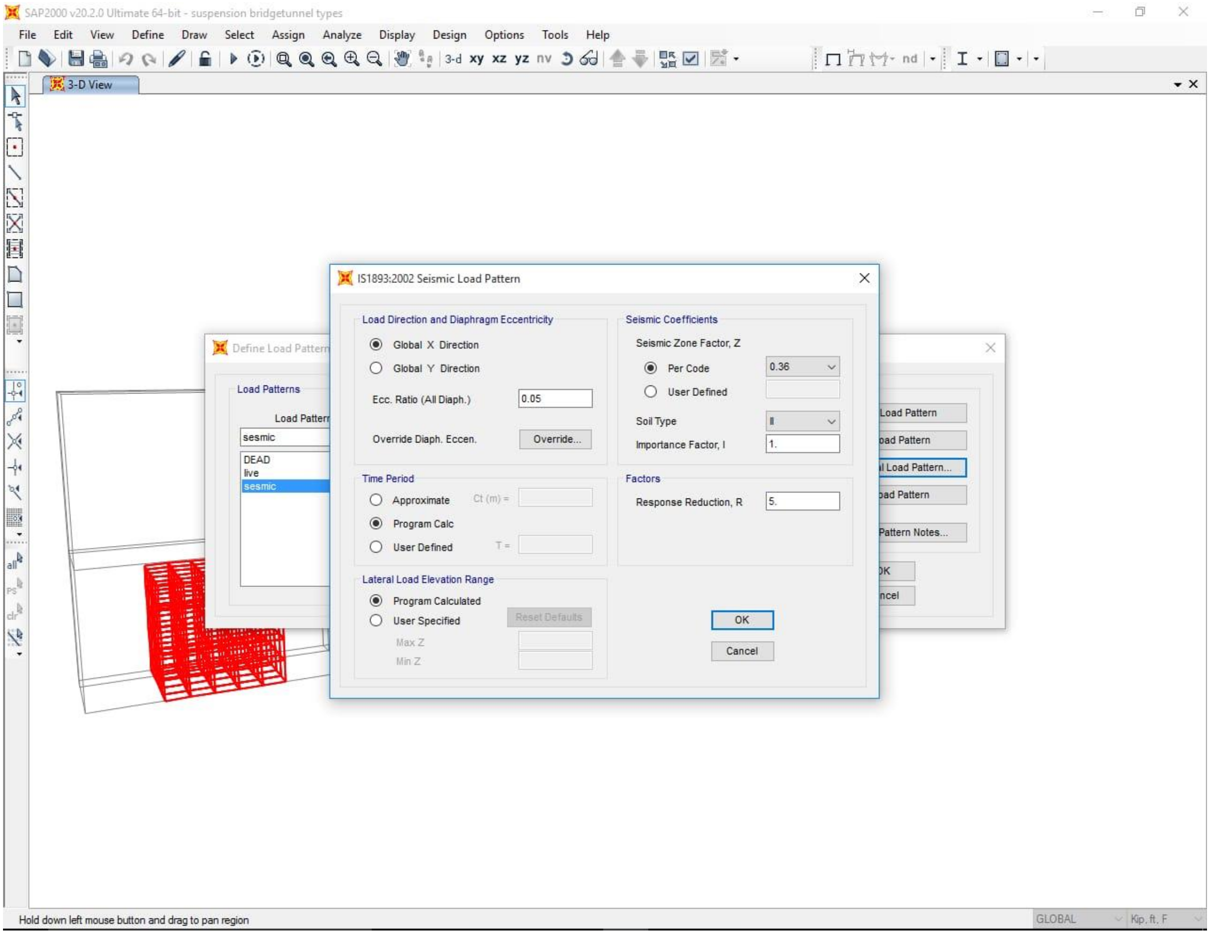


Fig 10 Defining Seismic Loading

Step 10: Analyzing the stress on the structure

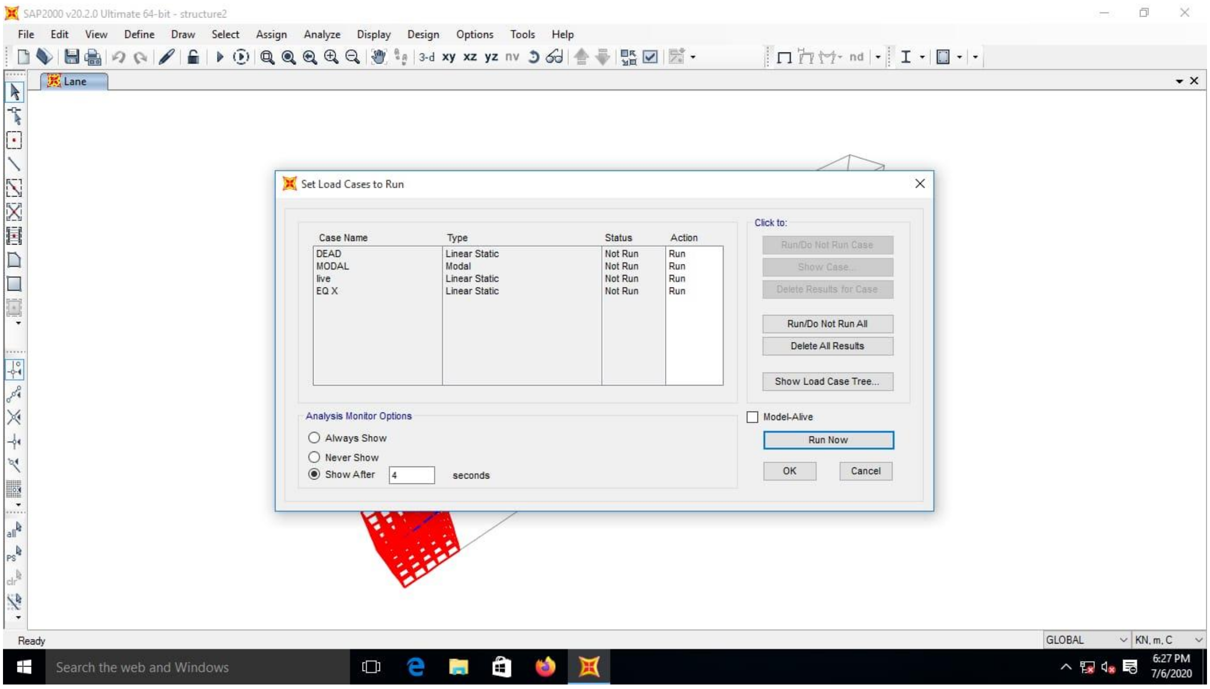


Fig 11 Running Load Cases

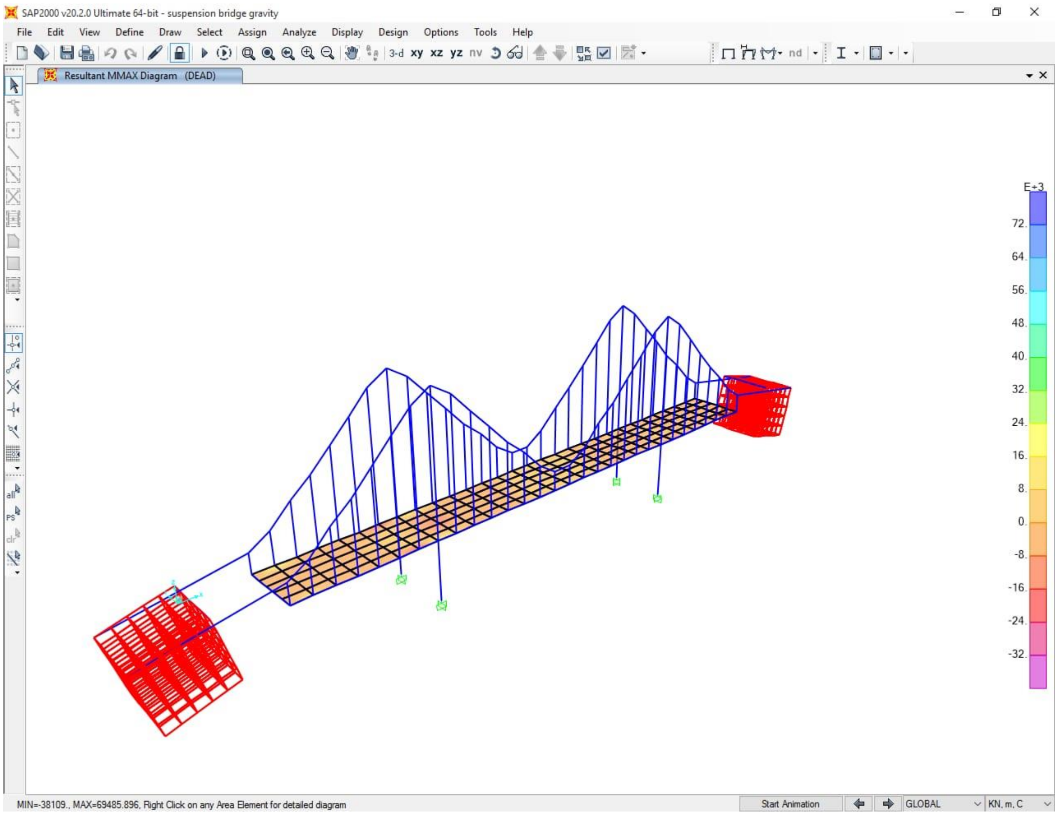


Fig 12 Stress Analysis

Flow Chart of the Study

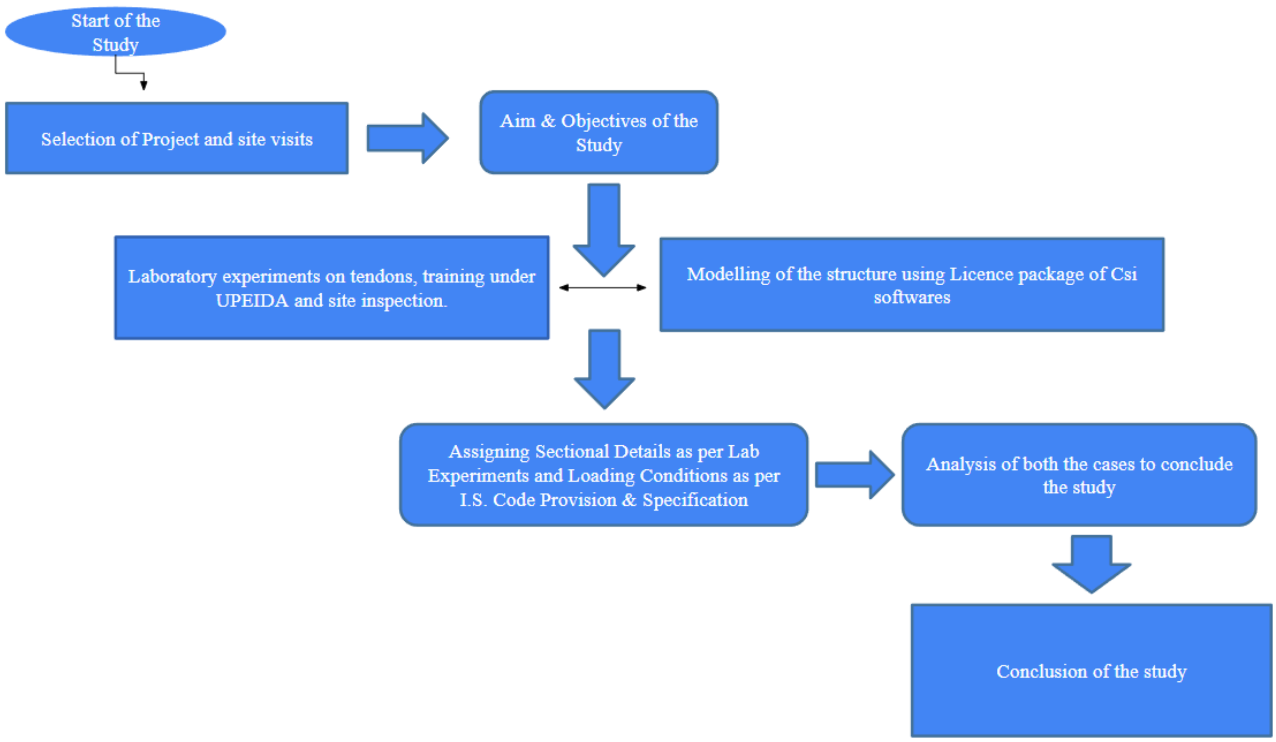


Fig 13 Flow Chart of the Study

Table 1 Geometrical Description

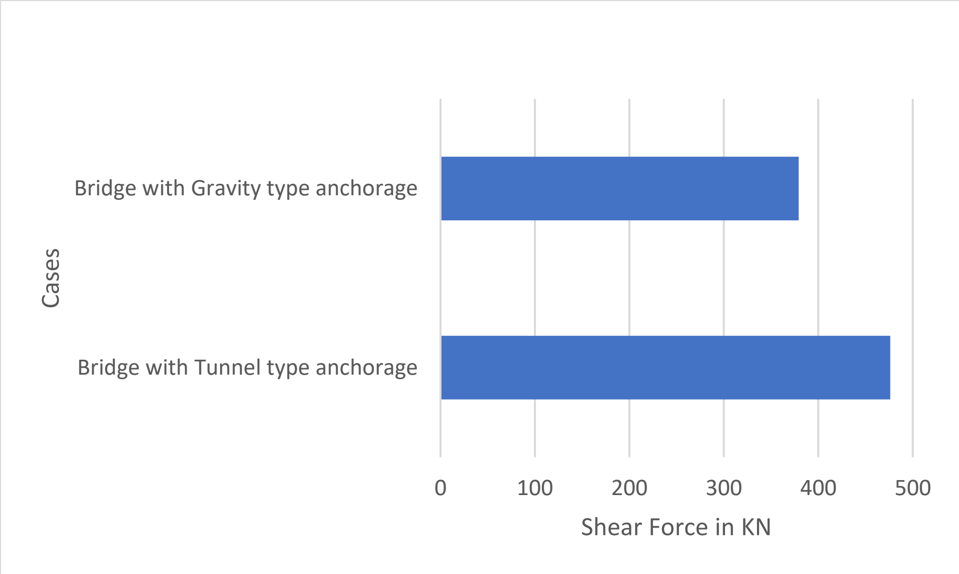
Dimension of the model	
Length	17500 mm
Height	3400 mm
Web thickness	300 mm
Construction joint for crash barrier portion	3000 mm
Opening	800 x 900 mm
Anchorage	Tunnel and Gravity
Haunch	100 x 100 mm

ANALYSIS RESULT

Shear Force in kN

Table 2 Shear Force in kN

Shear force in kN	
Bridge with Tunnel type anchorage	476.098
Bridge with Gravity type anchorage	379.207

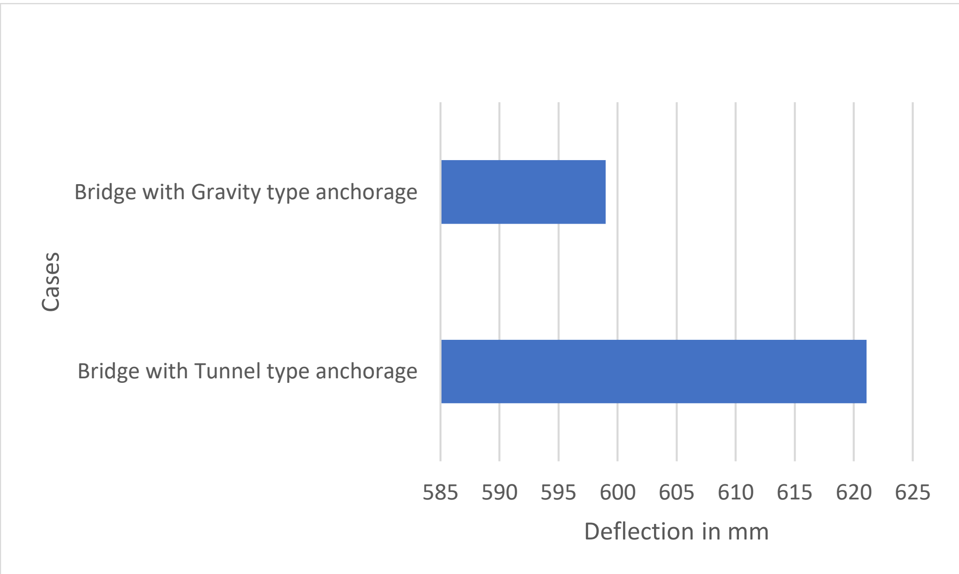


Discussion: As the above graph stated shear force was least found in bridge with gravity type anchorage as shear force for bridges with Gravity type anchorage was 379.207 kN whereas shear force for bridge with Tunnel type anchorage was 476.098 kN.

Maximum Deflection in mm

Table 3 Maximum Deflection in mm

Maximum Deflection in mm	
Bridge with Tunnel type anchorage	621.098
Bridge with Gravity type anchorage	598.992

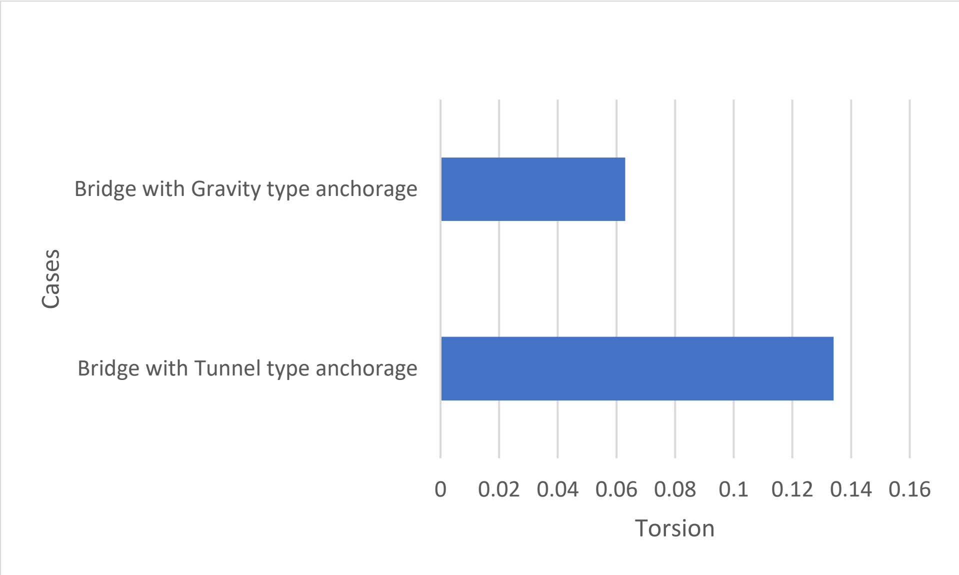


Discussion: The structure was fragmental in segments to evaluate maximum deflection as minor gap was seen in both the cases as of 9% difference.

Torsional Values in kN-m

Table 4 Torsional Values in kN-m

Torsional Values in KNm	
Bridge with Tunnel type anchorage	0.134
Bridge with Gravity type anchorage	0.063



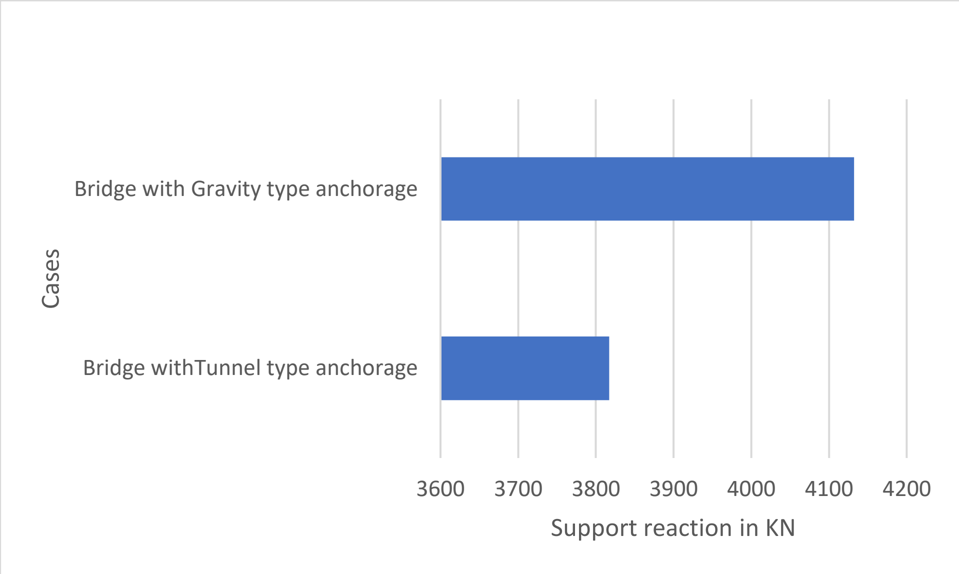
Discussion: Torsion is the state of strain in a material that has been twisted by an applied torque. Something happens when a structural member is subjected to a twisting force. Torsion is the state of strain that has deformed the rectangles, and it is made up entirely of pure shear. The torsion values for bridge with tunnel anchorage was 0.134 kn-m and bridge with gravity anchorage was 0.063 kN-m.

Support Reaction in kN

Table 5 Support Reaction in kN

Support Reaction in kN	
Bridge withTunnel type anchorage	3817.098

Bridge with Gravity type anchorage	4132.276

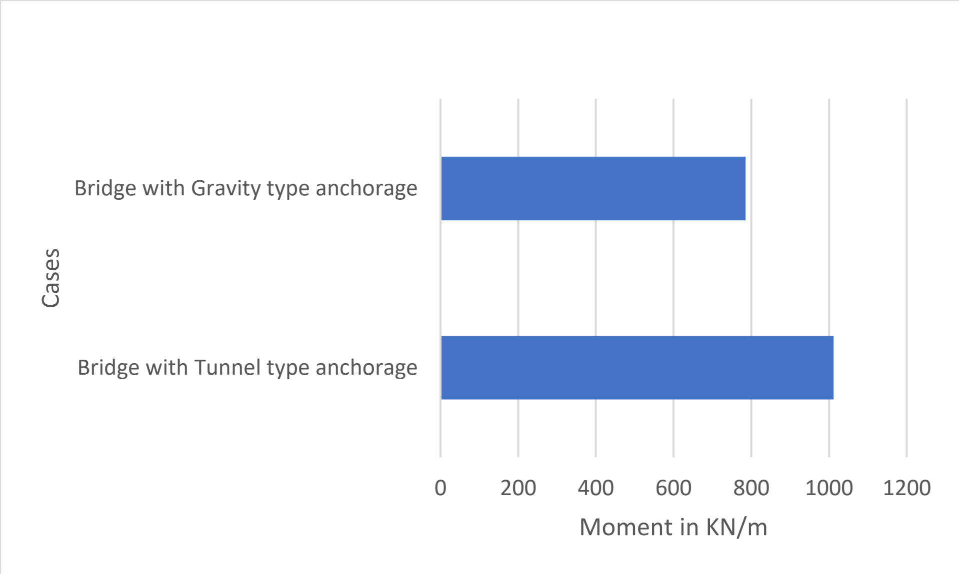


Discussion: A support reaction is a force that is applied to a support or a resultant restraining end moment that occurs as a result of the inability to move. Support responses in structural systems are in balance with external forces operating on the structure. Here the support reaction was maximum with a bridge with gravity anchorage in comparison to a bridge with tunnel anchorage.

Maximum Moment in kN-m

Table 6 Maximum Moment in kN-m

Maximum Moment in kN-m	
Bridge with Tunnel type anchorage	1011.88
Bridge with Gravity type anchorage	785.007



Discussion: The maximum bending moment in a girder occurs when the shear force at that section is zero or changes sign because the bending moment is zero at the point of contra flexure. A sagging bending moment, also known as a positive bending moment, is one such bending moment. Here the bending moment was 785.007 kN-m for bridge with gravity anchorage whereas 1011.88 kN-m for bridge with tunnel anchorage.

CONCLUSION

Shear Force in kN

Shear force was least found in bridges with Gravity anchorage as shear force for bridges was 379.207 kN whereas shear force for bridges with tunnel anchorage was 476.098 kN.

Maximum Deflection

The structure was fragmental in segments to evaluate maximum displacement as a minor gap was seen in both the cases of 9% difference.

Torsional Values

The state of strain in a material that has been twisted by an applied torque is known as torsion. When a structural element is subjected to a twisting force, something happens. Torsion is the state of strain that has deformed the rectangles, and it is made up entirely of pure shear. The torsion values for bridge with tunnel anchorage was 0.134 kn-m and bridge with gravity anchorage was 0.063 kn-m.

Support Reaction

A support reaction is a force that is applied to a support or a resultant restraining end moment that occurs as a result of the inability to move. Support responses in structural systems are in balance with external forces operating on the structure. Here the support reaction was maximum with a bridge with gravity anchorage in comparison to a bridge with tunnel anchorage.

Maximum Moment

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Summary: As per our comparative results stated above it can be said that Gravity type anchorage is comparatively more suitable in comparison to tunnel type thus it can be said that gravity type anchorage can result in more reliable type of anchorages.

REFERENCES

1. Chang-ke Jiao, Xin Dong, Ai-qun Li, Guang-dong Zhou, and Xiao-ping Wu, [Seismic Response of Long-Span Triple-Tower Suspension Bridge under Random Ground Motion], Hindawi Mathematical Problems in Engineering Volume 2017, Article ID 3457452, 16 pages.

2. Xiangong Zhou, Lei Cao, Heng Han, Xiaobo Zheng , Hanhao Zhang and Zhiqing Zhang, [Seismic Fragility Analysis of Self-Anchored Suspension Bridge Considering Damping Effect], Hindawi Advances in Civil Engineering Volume 2022, Article ID 6980221, 12 pages.

3. Nana Li, Yongqiang Zhou, Yanqiang Zhao and Guiju Li, [Analysis of suspension bridge tunnel-type anchorage construction on the stability of surrounding rock], E3S Web of Conferences, 2020.

4. Wen Lina, Cheng Qiangong, Cheng Qiang and Guo Xifeng, [Stabilitation Research of the Tunnel Anchorage of Dadu River Bridge in Luding in Yaan to Kangding Expressway], American Journal of Civil Engineering 2017; 5(4): 196-204.

5. Serap Altın, Kubilay Kaptan and Semih S. Tezcan, [Dynamic Analysis of Suspension Bridges and Full Scale Testing], Open Journal of Civil Engineering, 2012, 2, 58-67.

6. Farhan Farid Reshi, Priyanka Singh, Shivangi, Ravinder Kumar Tomar and S K Singh, [Analysis and Design of Cable Stayed and Suspension Bridge Subjected to Wind Loading], IOP Conf. Series: Earth and Environmental Science 889 (2021) 012059.

7. Hyunsung Lim, Seunghwan Seo, Sungjune Lee and Moonkyung Chung, [Analysis of the passive earth pressure on a gravity-type anchorage for a suspension bridge], Lim et al. Geo-Engineering, 2020.

8. Feifei Shao, Zhijun Chen and Hanbin Ge, [Parametric analysis of the dynamic characteristics of a long-span three-tower self-anchored suspension bridge with a composite girder], Advances in Bridge Engineering (2020) 1:10.

9. Wen-Liang Qiu, Chang-Huan Kou, Chin-Sheng Kao, Shih-Wei Ma, and Jiun Yang, [STUDY ON THE SEISMIC BEHAVIOR OF SELF-ANCHORED SUSPENSION BRIDGES], Journal of Marine Science and Technology, Vol. 20, No. 4, pp. 384-391 (2012).

10. Zhijin Shen, Jianhong Jia, Nan Jiang, Bin Zhu and Wenchang Sun, [Field-Scale Experiment on Deformation Characteristics and Bearing Capacity of Tunnel-Type Anchorage of Suspension Bridge], Energies 2022, 15, 4772.

11. T.Subramani, J.Karthick rajan, V.R.Perumal, A.Palani and P.Kesavan, [Design and Analysis of Suspension Bridge], International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 8, Issue 3, March 2019, ISSN 2319 - 4847.

12. G. M. Savaliya, A. K. Desai and S. A. Vasanwala, [THE INFLUENCE OF CABLE SAG ON THE DYNAMIC BEHAVIOUR OF CABLE-STAYED SUSPENSION BRIDGE WITH VARIABLE SUSPENSION TO MAIN SPAN RATIO], International Journal of Research in Engineering and Technology eISSN: 2319-1163, Volume: 04 Issue: 11 | Nov-2015.

13. Abhishek Pandey and Nitesh Kushwah, [Seismic Analysis and Design of Cable Stayed Bridge with Different Cable Arrangements], International Research Journal of Engineering and Technology (IRJET), Volume: 07 Issue: 12 | Dec 2020.

14. Luca Martinellia, Marco Domaneschia and Chunxia Shib, [Submerged Floating Tunnels under Seismic Motion: Vibration Mitigation and Seaquake effects], Procedia Engineering 166 (2016) 229 – 246.

15. Neel Shah, Prashant Kanzariya and Bimal Shah, [PARAMETRIC STUDY OF CABLE STAYED BRIDGE USING DIFFERENT PYLON CONFIGUARTION], International Journal of Engineering Applied Sciences and Technology, 2021 Vol. 5, Issue 10, ISSN No. 2455-2143, Pages 342-348.