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DYNAMIC ANALYSIS OF CABLE-STAYED BRIDGES - STAAD PRO

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Abstract:

Being that it takes a long time to traverse gaps in the ground, bridges are built. Bridges are structures that offer access across a lake, river, valley, road, or other obstacle. Bridges supported by cables have become the most common long-span structural solution in the last 20 years. Strong materials and cutting-edge procedures could be used to build a long-span bridge. Tension wires firmly attached to the tower balance the structure's dead weight (the bridge deck's own weight) and the bridge's carrying capacity. The bridge itself transfers the live weight to the bridge deck. The bridge's tower carries the whole operational weight. Creative efforts have been made to minimize the depth. This is the final span. A computer is needed to solve this kind of structure, with the exception of a very straightforward bridge supported by cable scenarios. It is necessary to use computer programmers to create impact schemes for forces exerted by cables, beam rigidity, bending instances, and scissors, tower, and pier responses. A fairly efficient design should consider the need for programmers to quickly respond to a variety of parametric efforts and loads. The most important issues are probably cable size and layout, as well as the determination of the stiffness section's ideal section.

Keywords: Cable-stayed Bridge, STAAD.Pro, Structure, Cables, Span, Loads, Dead loads.

I.Introduction:

1.1 General:

Cable-stayed bridges are a type of bridge that uses one or more towers to support cables that run directly to the bridge deck, arranged either in a fan pattern or parallel lines. This is different from suspension bridges, which suspend the deck vertically from the main cable anchored at both ends of the bridge running between the towers. Cable-stayed bridges are most suitable for spans that are longer than cantilever bridges but shorter than suspension bridges. Cable-stayed bridges were first used in the early16th century and widely used in the 19th century. They consist of three primary subsystems: The stiffening girder, Tower or Pylons & inclined cables. The towers are placed in the center of the bridge, and the girder segments are connected to the pylons using connected to one or two towers. The weight of the girder is supported by a series of cables that run directly to one or more towers. Advancements in the construction industry have made cable-stayed bridges more popular again in recent times. These advancements include improvements in materials, with improved internal structures and the use of post-tensioning technology on the bridge cables. There have also been updates in engineering analysis, design and construction methodology.

Cable-stayed bridges provide design flexibility in terms of the shape of pylons, girder shape and cable arrangements. This allows for the application of various structural systems to create cable-stayed bridges that are suitable for different geographic environments. They are highly cost-effective structures, particularly for long-span bridges, and also offer aesthetically pleasing design solutions.Cable-stayed bridges are also known for their durability, with many structures lasting for decades without requiring major maintenance or repairs.

They are also more resistant to strong winds and earthquakes compared to other bridge types. Additionally, Cable-stayed bridges are often used as iconic landmarks in cities, providing a distinctive appearance and attracting tourists. One of the most notable cable-stayed bridges in the world is the Russky Bridge in Russia, which has the longest cable-stayed span in the world at 1,104 meters. Another famous cable-stayed bridge in the Millau Viaduct in France, which has the highest road bridge tower in the world at 343 meters. Cable-stayed bridges are also popular in Asia, with many notable structures such as the Sutong Tangtze River Bridge in China, the Penang Bridge in Malaysia, and the Bosphorus Bridge in Turkey.

While cable-stayed bridges offer many advantages, they also have some limitations. for instance, their construction can be challenging due to the complex geometry of the cables and towers. Additionally, the cables require inspections and maintenance to ensure their structural integrity, which can be costly and time-consuming. Despite these challenges, cable-stayed bridges remain a popular choice for many bridge projects due to their numerous benefits.

II. Design Components Of Cable Stayed Bridge:

Cable-stayed bridges are modern engineering marvels that rely on tensioned cables to support the weight of the bridge deck. These types of Bridges consist of several crucial parts that work together to create stable and durable structures. The main components ofa Cable-stayed bridge include the Pylon, the Deck, the Cable, and the Anchorage systems. Each of these components plays a critical role in the overall stability and longevity of the bridge.

1) **The Pylon** - It’s a tall tower-like structure that supports the weight of the cables and the bridge deck. They are typically made of steel, concrete, or a combination of both. The choice of material depends on various factors like the height of the pylon, the location of the bridge, and the environmental conditions.

2) **The Deck** – It’s the horizontal roadway surface that connects the two ends of the bridge. The deck is supported by the cables, which are anchored to the pylon and the deck. The deck can be made of many materials such as concrete, steel or composite materials. The choice of material depends on various factors such as the weight of the traffic, the expected lifespan of the bridge,and the aesthetic design of the bridge.

3) **The Cables** – They are responsible for supporting the weight of the deck and transmitting the load to the pylon and the anchorage systems. The cables are made of high-strength steel wires that are bundled together to form a cable. The no. of wires and the diameter of the cable depend on various factors, such as the length of the span, the weight of the traffic, and the environmental conditions.

4) **The Anchorage Systems** – It’s a component that connects the pylon to the deck. These are designed to transmit the load from thecables to the pylon and the deck without causing and damage to the structure. The anchorage systems are typically made of steel, or concrete and are designed to withstand the tensile forces generated by the cables.

Above are the critical components of a cable-stayed bridge, and each of these parts must be carefully selected and designed to ensure the bridge’s durability and safety.

III. Modelling of The Cable-Stayed Bridge:

3.1 Overview: A three-dimensional (3D) model of the structural system is required to capture the response of the entire bridge system and individual components under specific seismic demand characteristics. The interaction between the response in the orthogonal bridge directions and the variation of axial loads in column bents throughout the analysis are captured more accurately in a 3D model. This enables correct evaluation of the capacity and ductility of the system under seismic loads or displacements applied along any given direction, not necessarily aligned with the principal axis of the bridge.

In this study, Cable-stayed Bridge modeling and analysis is done in STAAD PRO software. STAAD.PRO is the Structural Analysis and Design Software established by Bentley System Inc. founded by Mr. Keith A. Bentley in conjunction with his brother Mr. Barry J. Bentley in 1984. The present version of STAAD-pro is STAAD-pro V8i is one of the most awaited structural analysis and design software. It has provisions for steel works, and concrete design codes. It is used to analyze various structural forms from the traditional static analysis, p-delta analysis and geometrical non-linear analysis.

3.2 Considerations For Modelling Of Bridge:

Considerations for modeling cable-stayed bridge in Staad Pro are as follows:

i. Defining Material
ii. Sectional properties.
iii. Tower modeling.
iv. Boundary condition input- End support at both ends is simply supported whereas the base of the pylon is fixed.
v. Loading condition input based on type of analysis.
vi. Finding initial pretension force in cables.
vii. Defining Construction stages

A. Loads considered:

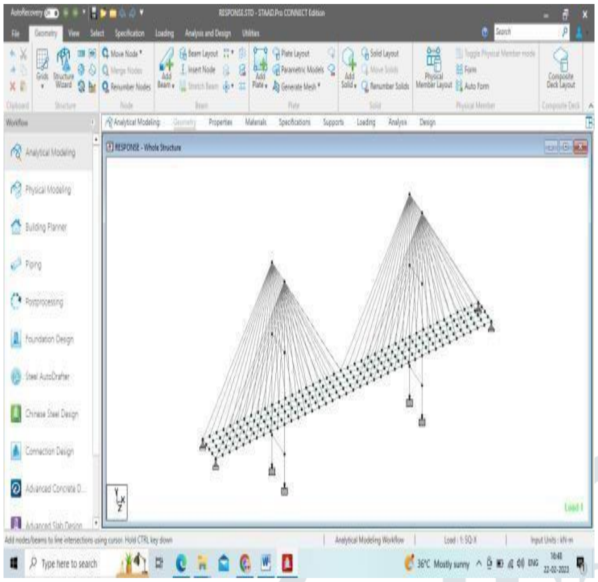
i. Dead load.
ii. Live load.
iii. Seismic load (zone 4)

B. Details of the model:

i. Bridge's overall length with cable stays = 400cm
ii. Bridge width = 850cm
iii. Deck slab height = 200mm
iv. Wearing coat taken = 70mm
v. Carriageway width = 7.5m
vi. Pylon's height above the deck slab = 30m.
vii. Pylon height is below the deck slab level =12.5m
viii. Spacing between cables = 5m
ix. Number of cables = 80

C. The Size Of The Components:

i. Pylon’s diameter = 1500cm
ii. Girder's longitudinal cross-section =500×80
iii. Cross Section of an overhead girder =400 × 800
iv. Slab thickness for the deck = 20cm
v. Cable diameter = 40cm



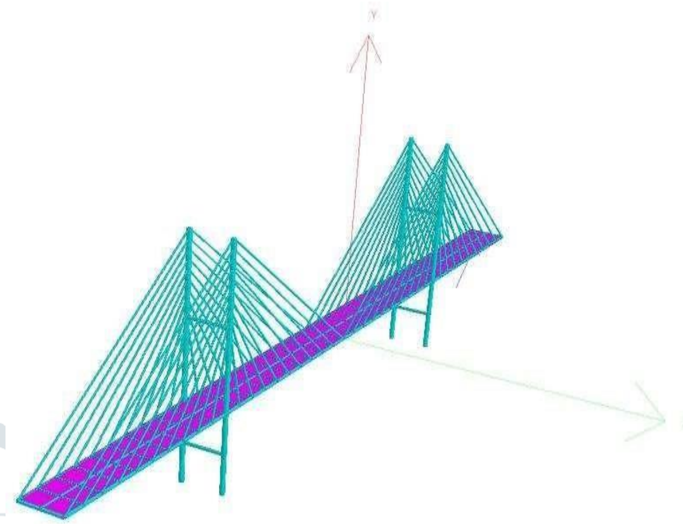


Figure 1: 3D- Modeling Of Cable StayedBridge. **Figure 2:** Cable- bridge in 3D rendered.

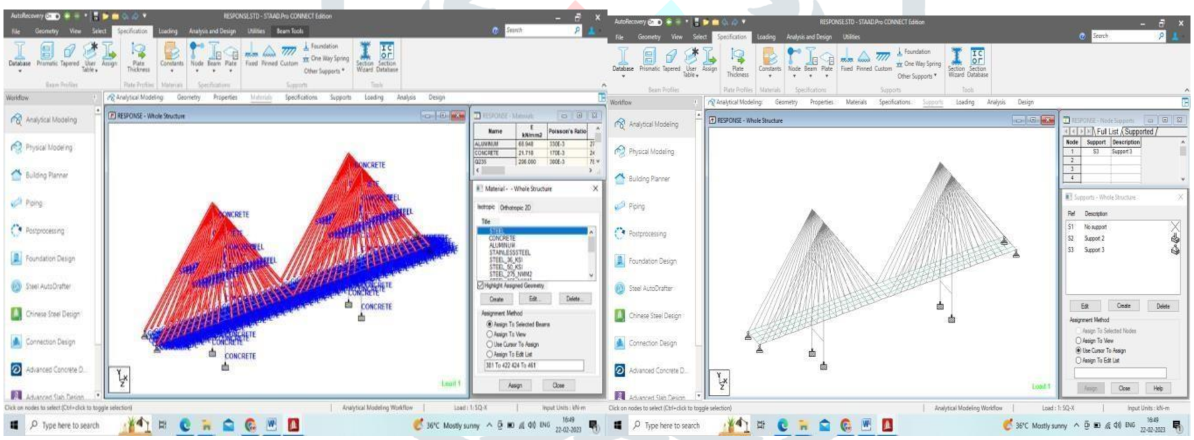
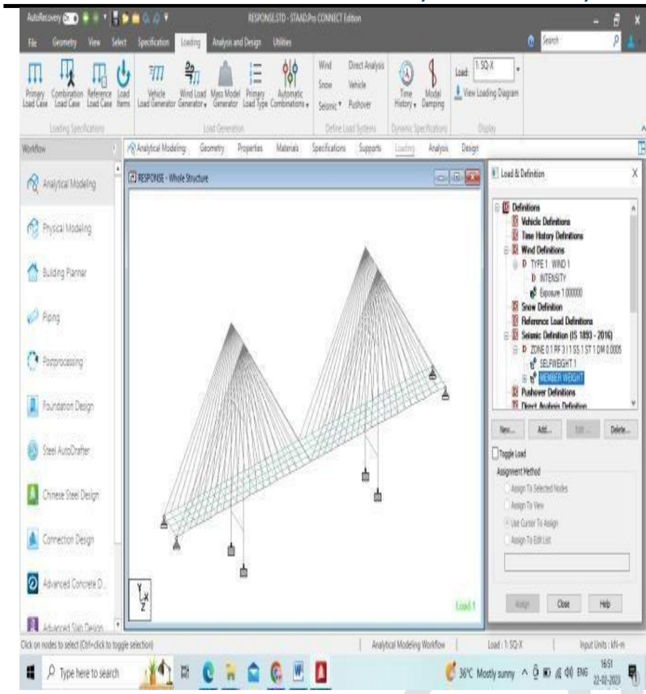


Figure 3. Assigning Properties and Supports of Bridge with CableStays.



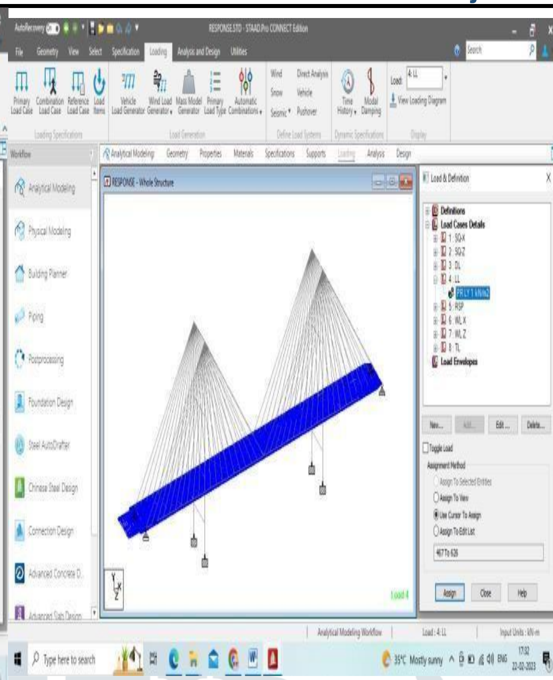
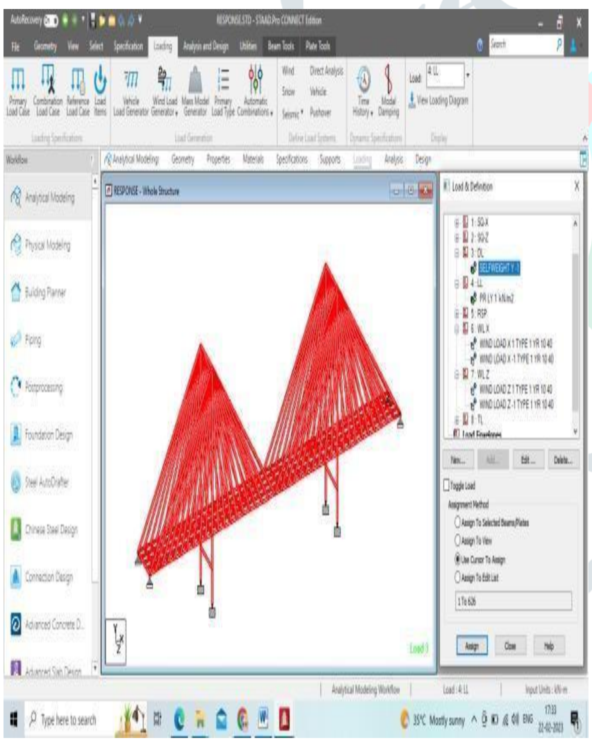


Figure 4. Load Assigning and Cable BridgeDefinitions

Figure 5. Bridge with cable stays under live load



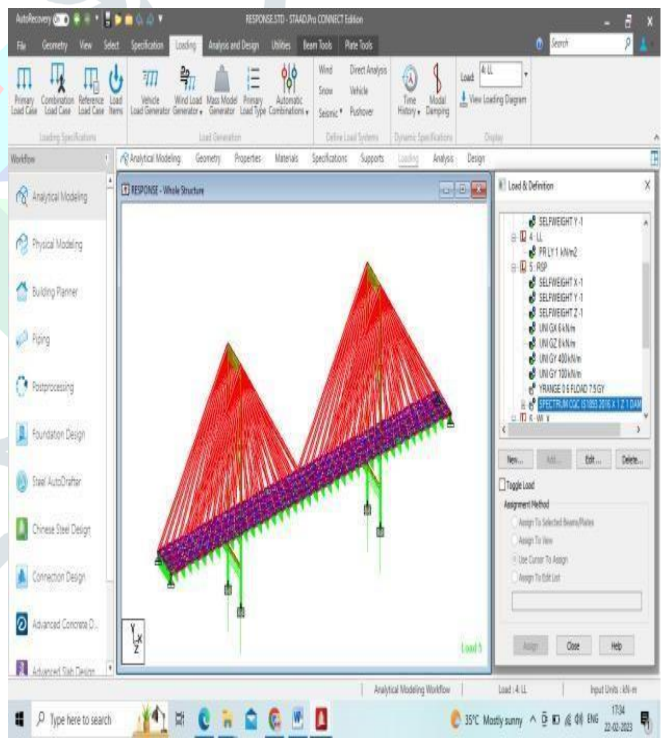
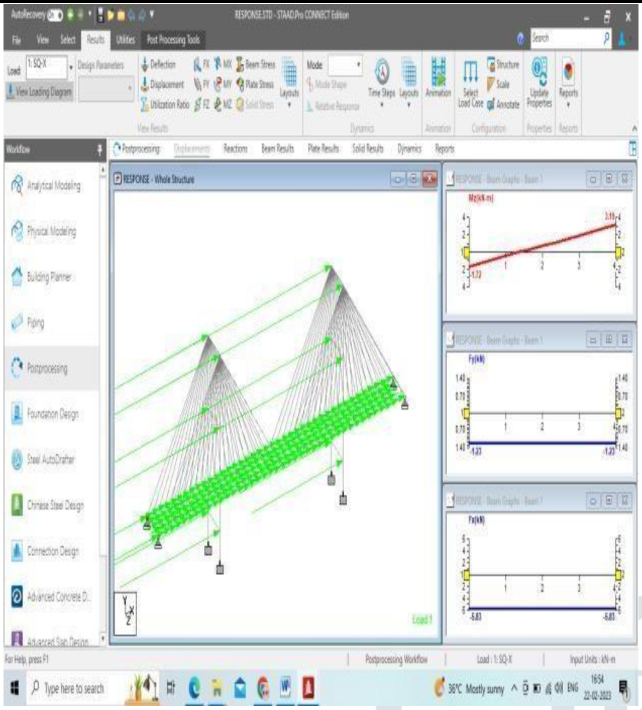


Figure 6. bridge with cable stays under dead load.

Figure 7. Bridge with Cable Stays: Response spectrum



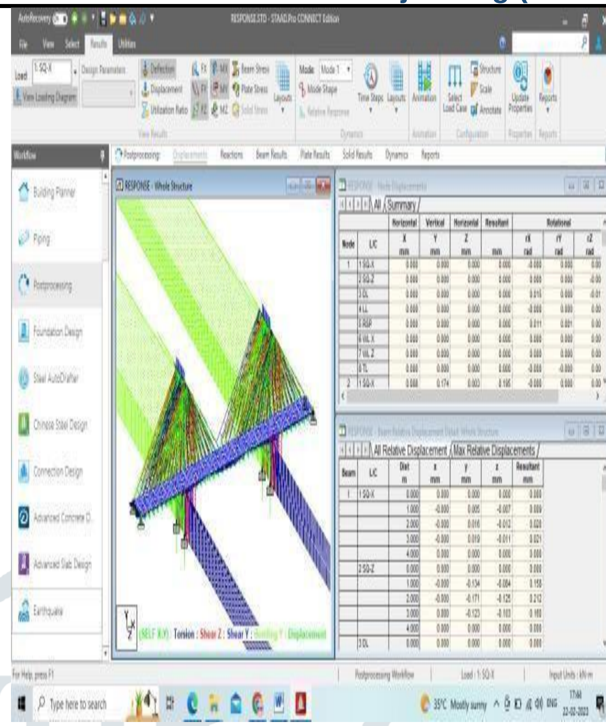


Figure 8. Bridge with cable stays under seismicstrain.

Figure 9. Bridge with Cable Stays: Dynamic Analysis

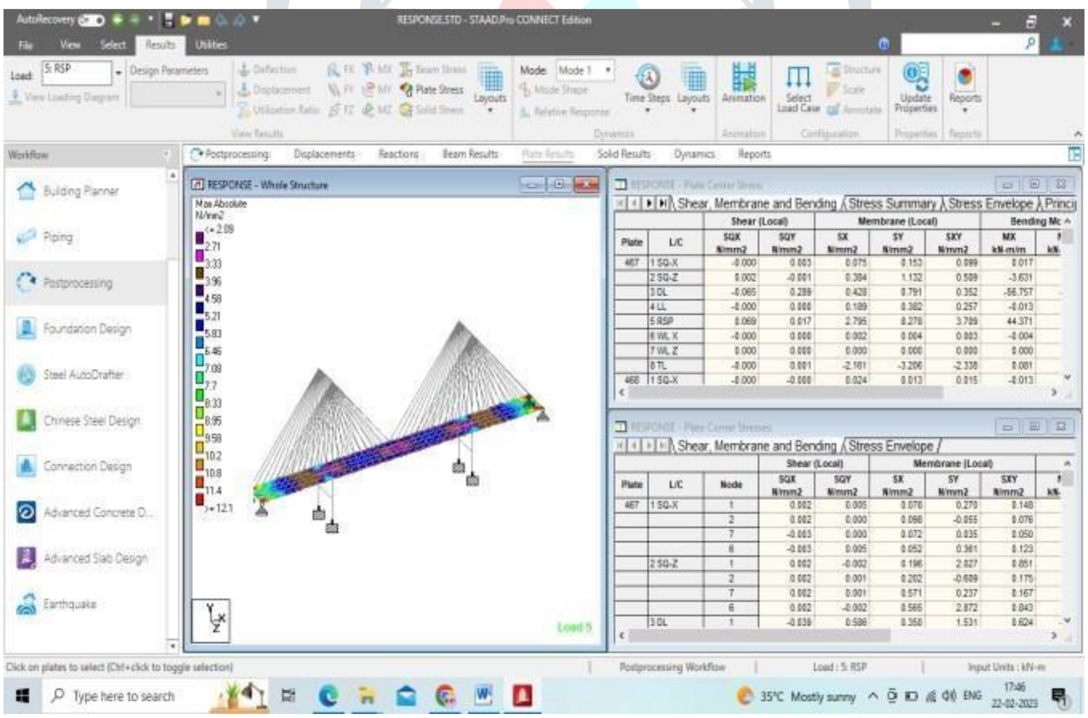


Figure 10. Bridge with Cable Stays: Plate Stresses.

IV. Design Output and Discussion:

A Study on the cable-stayed bridge has been completed and various inspections of allowable and maximum deflections have been completed. Shear force, bending moment, shear stress, reactions, and shear stress are applied and determined to be satisfactory, and bridge analysis is performed using computer software. The results obtained as a result of computer calculations confirm the design.

Table 1. Ultimate Bending Moment.

Beam	L/C		Distance (m)	Moment (z)	Distance (m)	Moment (y)
3	1 SQ-X	Maximum +ve	0.000	0.613	0.000	0.904
		Maximum -ve	4.000	- 0.085	N/A	N/A
	2 SQ-Z	Maximum +ve	4.000	24.75 5	4.000	2.790
		Maximum -ve	N/A	N/A	0.000	- 5.956
	3 DL	Maximum +ve	N/A	N/A	4.000	3.579
		Maximum -ve	0.000	- 530.2 83	N/A	N/A
	4 LL	Maximum +ve	0.000	0.025	0.000	2.462
		Maximum -ve	4.000	- 0.074	N/A	N/A
	5 RSP	Maximum +ve	4.000	253.2 35	0.000	55.14 3
		Maximum -ve	N/A	N/A	N/A	N/A
	6 W LX	Maximum +ve	N/A	N/A	0.000	0.027
		Maximum -ve	4.000	- 0.028	N/A	N/A
	7 W LZ	Maximum +ve	0.000	0.000	0.000	0.000
		Maximum -ve	0.000	0.000	0.000	0.000
	8 TL	Maximum +ve	0.000	0.625	4.000	4.425
		Maximum -ve	N/A	N/A	0.000	- 16.48 1

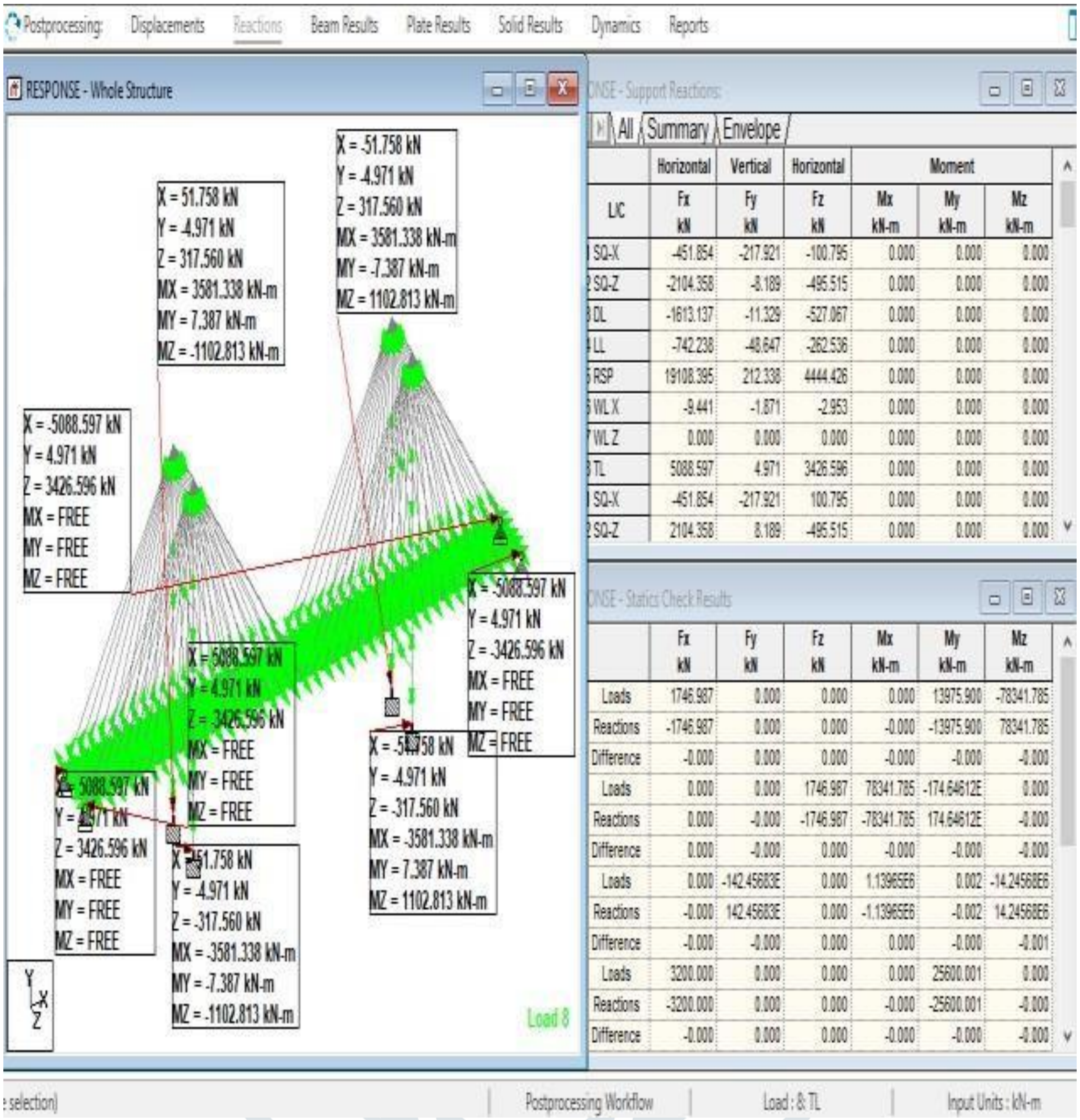


Figure 10. Bridge Stabilized by Seismic Load onCable

V. Conclusion:

i. In this paper modelling design and Analysis of a Cable-stayed Bridge on STAAD.PRO software.

ii. The cable-stayed bridge is a bridge type that is a common application today with larger applicable scope of span, and good-looking appearance. After half a century, the technology of cable-stayed bridge got unprecedented development.

iii. In the analysis of Cable Bridge on STAAD PRO software cable forces of 5m span is -332.625KN is minimum and 3818.091KN is maximum.

iv. The Cable Bridge has been modeled and analyzed with moving loads of IRC class AA+A loading.

v. The response of the Cable Bridge under various combinational moving and seismic loads is studied.

vi. Mode shapes were identified to be similar in both cases.

vii. It was observed that the natural frequency due to combinational seismic and moving loads is higher than combinational seismic and static vehicle loads.

viii. By conducting modal analysis it was found that the predominant mode shape was observed at the fifth mode in both combinational cases.

From all the above observations on we can conclude that **H-shaped pylons** show satisfactory performance by the parametric observations on displacement, period frequency and acceleration with respect to Single pylon bridges except the deviated deck displacement and acceleration parametersto be considered for analysis and design.

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