DESIGN AND ANALYSIS OF BRIDGE DESIGN USING SAP 2000

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Abstract

The response of bridges under a moving vehicle is complex due to the interaction between bridge and the vehicle. As the bridge deck surface deteriorates over time, the road surface roughness profile will vary accordingly. The varying surface roughness profiles over time will generate increased dynamic loads on the bridge decks through dynamic interaction between surface roughness, vehicles of heavy traffic and bridge structures. The present study aims to characterize the effects of the time-varying dynamic loads from heavy traffic and bridge performance.

The paper presents the results of dynamic analysis of both the concrete girder bridge and infers which type will be dynamically stable. Both bridges contain AASHTO type girders and were designed to carry two lanes of HS20 loading. The vehicular load was HS-20 truckloads, designed to deliver the ultimate live load specified by the AASHTO Code. The dynamic load were performed with the vehicle traveling at 23 m/s, 46 m/s, and 92 m/s speed.

Keywords – Sap 2000, Concrete Girder Bridge, Dynamic Analysis, moving loads

INTRODUCTION

A bridge is a structure built to span physical obstacles such as a body of water, valley, or road, for the purpose of providing passage over the obstacle. There are many different designs that all serve unique purposes and apply to different situations. Designs of bridges vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed and anchored, the material used to make it, and funds available to build it.

The first bridges were made by nature itself as simple as a log fallen across a stream or stones in the river. The first bridges made by humans were probably spans of cut wooden logs or planks and eventually stones, using a simple support and crossbeam arrangement. Some early Americans used trees or bamboo poles to cross small caverns or wells to get from one place to another. A common form of lashing sticks, logs, and deciduous branches together involved the use of long reeds or other harvested fibers woven together to form a connective rope capable of binding and holding together the materials used in early bridges.

The Arkadiko Bridge is one of four Mycenaean corbel arch bridges part of a former network of roads, designed to accommodate chariots, between Tiryns and Epidauros in the Peloponnese, in Greece. Dating to the Greek Bronze Age (13th century BC), it is one of the oldest arch bridges still in existence and use. Several intact arched stone bridges from the Hellenistic era can be found in the Peloponnese in southern Greece.

The greatest bridge builders of antiquity were the ancient Romans. The Romans built arch bridges and aqueducts that could stand in conditions that would damage or destroy earlier designs. Some stand today. An example is the Alcntara Bridge, built over the river Tagus, in Spain. The Romans also used cement, which reduced the variation of strength found in natural stone. One type of cement, called pozzolana, consisted of water, lime, sand, and volcanic rock. Brick and mortar bridges were built after the Roman era, as the technology for cement was lost then later rediscovered.The Arthashastra of Kautilya mentions the construction of dams and bridges. A Mauryan bridge near Girnar was surveyed by James Princep. The bridge was swept away during a flood, and later repaired by Puspagupta, the chief architect of Emperor Chandragupta I. The bridge also fell under the care of the Yavana Tushaspa, and the Satrap Rudra Daman. The use of stronger bridges using plaited bamboo and iron chain was visible in India by about the 4th century. A number of bridges, both for military and commercial purposes, were constructed by the Mughal administration in India.

Although large Chinese bridges of wooden construction existed at the time of the Warring States, the oldest surviving stone bridge in China is the Zhaozhou Bridge, built from 595 to 605 AD during the Sui Dynasty. This bridge is also historically significant as it is the world's oldest openspandrel stone segmental arch bridge. European segmental arch bridges date back to at least the Alcontar Bridge (approximately 2nd century AD), while the enormous Roman era Trajan's Bridge (105 AD) featured open-spandrel segmental arches in wooden construction. Rope bridges, a simple type of suspension bridge, were used by the Inca civilization in the Andes mountains of South America, just prior to European colonization in the 16th century. During the 18th century there were many innovations in the design of timber bridges by Hans Ulrich, Johannes Grubenmann, and others. The first book on bridge engineering was written by Hubert Gautier in 1716. A major breakthrough in bridge technology came with the erection of the Iron Bridge in Coalbrookdale, England in 1779. It used cast iron for the first time as arches to cross the river Severn.

Fig 1: The Arkadiko Bridge in Greece (13th century BC), one of the oldest arch bridges in existence

With the Industrial Revolution in the 19th century, truss systems of wrought iron were developed for larger bridges, but iron did not have the tensile strength to support large loads. With the advent of steel, which has a high tensile strength, much larger bridges were built, many using the ideas of Gustave Eiffel.In 1927 welding pioneer Stefan Brya designed the first welded road bridge in the world, the Maurzyce Bridge which was later built across the river Sudwia at Maurzyce near owicz, Poland in 1929. In 1995, the American Welding Society presented the Historic Welded Structure Award for the bridge to Poland.

The objectives are:-

• To analyze a proposed bridge structure as concrete girder bridge and a suspension cable bridge subjected to moving vehicles.

• To compare the dynamic response of the concrete girder bridge with suspension cable bridge and infer which type will be dynamically stable for proposed structure.

DESCRIPTION OF DESIGN

Every bridge must be designed individually before it is built. The designer must take into account number of factors, including the local topography, water currents, river ice formation possibilities, wind patterns, earthquake potential, soil conditions, forecasted traffic volumes, esthetics, and cost limitations.

Before the design, it is necessary to take the topographic and geodesic measurements and estimate natural terrain conditions, since every building should be constructed considering the needs of traffic and transport situation on roads. Collecting data for visual alignment of the bridge center line on the area shall be provided after assessment of costs and construction conditions.

This is the most laborious and time-consuming stage of the work: it is necessary to find out the soil type, depth level of groundwater, slope stability, river floodplains structure, riverbed stability, level of water rise in flood conditions. All these data cannot be obtained from maps; alot shall be surveyed before the design is started.

For this purpose a group of workers equipped with necessary devices (theodolite, tacheometer, level, inclinometer, bore auger) visit the relevant place aiming to make all the measurements, whereas local residents shall be questioned concerning the character of the river flow.

The bridge design shall be executed in two stages – the project with summary estimate and the specification documents. It shall contain the construction organization plan (COP). COP shall determine the construction periods, best period for construction and assembly equipment, transport, material sourcing. All this data is obtained considering preliminary survey based on technology of pillar and bridge superstructure construction, as well as on existing communications.

Methods of implementation, types of structures and auxiliary facilities, vehicles and machinery are chosen based on comparison of technical and economic options and project decisions.

Therefore prior to the detailed design of the bridge, it is necessary to choose one of the few variants satisfying several requirements – the construction cost, labour input, construction time. All these should be overall considered.

After the certain variant of the bridge is chosen, it is necessary to estimate the load-carrying capacity of the structure, its deformation, vibration, etc. As during the construction period something may change, the estimates are made at various scenarios of design and construction.

LITERATURE REVIEW

D.R. Panchal & Dr. S.C. Patodi evaluated the seismic performance of multistoried building for which they have considered Steel-Concrete Composite and R.C.C. For their analysis the methods that they used were Equivalent static method and Linear Dynamic Response Spectrum Analysis. The results thus obtained were analyzed and compared with each other .

Jingbo Liu, Yangbing Liu, Heng Liu proposed a performance based fragility analysis based method in which the uncertainty due to variability in ground motion and structures are considered. By the proposed method of fragility analysis they performed analysis of a 15 storeyed building having composite beam and concrete filled square steel tube column.

G.E. Thermou, A.S. Elnashai, A. Plumier, C. Doneux have discussed clauses and deficiencies of the Eurocode which earlier used to cause problem for the designers. For obtaining the response of the frames, methods of pushover analysis were also employed. Their main purpose was to study and investigate if the designed structure could behave in an elastically dissipative way.

Shashikala. Koppad, Dr. S.V.Itti considered steel-concrete composite with RCC options for analyzing a B+G+15 building which is situated in earthquake zone III and earthquake loading is as per the guidelines of IS1893(part-I): 2002. The parameters like bending moment and maximum shear force were coming more for RCC structure than the composite structure. Their work suggested that composite framed structures have many benefits over the traditional RC structures for high rise buildings.

D.R. Panchal and P.M. Marathe used a comparative method of study for RCC, Composite and steel options in a G+30 storey commercial building situated in earthquake Zone IV. For this they used Equivalent static method and used the software ETABS. The comparative study

included size, deflections, material consumption of members in RCC and steel sections as compared to Composite sections was also studied closely and based on this study a cost comparison analysis was also performed.

Traffic study

The traffic in terms of the cumulative number of Standard axles (8160 Kg) to be carried by the pavement during the design life. The following information is needed:

i) Initial traffic after construction in terms of number of commercial vehicles per day (CVPD)

ii) Traffic growth rate during the design life in percentage

iii) Design life in number of years

iv) Vehicle damage factor (VDF)

v) Distribution of Commercial traffic over the carriageway.

- Initial Traffic: Estimate of initial daily average traffic flow for any road should normally be based on atleast 7 days, 24 hour classified traffic counts. In case of new roads, traffic estimates can be made on the basis of potential land use and traffic on existing routes in the area.
- Traffic growth rate: Traffic growth rates should be estimated by study. If adequate data is not available, average annual growth rate of 7.5% may be

adopted. The factor is reduced to 6% for roads desiged adopting IRC:SP 20-2002

- Design life: The Design life is defined in terms of cumulative number of Standard axles that can be carried before strengthening of the pavement. Normally the pavement for NH & SH is the designed for life of 15 years, Expressways and Urban roads for 20 years and other roads for 10 to 15 years. When it is not possible to provide the full thickness of pavement at the time of initial construction, stage construction technique should be resorted to. Roads in Rural areas should be designed for a design life of 10 years.
- Vehicle damage factor (VDF): VDF is arrived at from axle load surveys. The indicative value of VDF factor is given below:

Distribution of Commercial traffic over the carriage way:

i) Single lane : Design should be based on total number of commercial vehicle in both directions multiplied by two

ii) Two lane (single Carriageway) : 75% of the total number of commercial vehicle in both the direction.

iii) Four lane (single Carriage way) : 40% of the –do iv) Dual Carriageway: 75% of the number of commercial vehicle in each direction. For dual 3 lane and dual 4 lane carriageway, the distribution factor will be 60% and 45% respectively.

Computation of design traffic under IRC 37: 2002

The design traffic is considered in terms of Cumulative number of standard axles to be carried during the design life of the road. Computed by the equation

N= 365x [(1+r)n-1] x A x D x Fr

Initial traffic in terms of commercial vehicle per day	Terrain (Rolling/Plain Hilly)
0-150	1.5 0.5
150-1500	3.5 1.5
More than 1500	4.5 2.5

Where

- N: The cumulative number of standard axles to be catered for in the design in terms of MSA
- A: Initial traffic in the year of completion of construction in terms of number of commercial vehicles per day
- D: Lane distribution factor
- F: VDF
- n: Design life in years

- r : Annual growth rate of commercial vehicles (for 7.5% annual growth rate r=0.075)

The traffic in the year of completion is estimated using the following formula:

A= P (1+r) x

Where

P = Number of Commercial vehicle as per last count

x = Number of years between the last count and the year of completion of construction

Computation of design traffic under SP 20:2002

The traffic for design life is computed as –

Number of commercial vehicles per day for design A = P(1+r)n+x

Where

r= Annual growth rate of commercial vehicle (i.e 6%)

P, x & n = as above

Bridge:

Bridge is a structure having a total length of above between the inner faces of the dirt walls for carrying traffic on road or railway. The bridges shall be classified as minor bridge and major bridge.

Minor bridge – Bridge having a total length up to 60 meters. Clause 101.1 of IRC 5:1998

Major bridge – Bridge having a total length above 60 meters.

The bridges are designed and constructed adopting the following IRC specifications.

•IRC 5:1998 Standard specification and code of practice for road bridges- Section I general features of design

•IRC 6:1966 Standard specification and code of practice for road bridges – Section II load and stress

•IRC 21:1987 Standard specification and code of practice for road bridges- Section III cement concrete

•IRC 40 : 1995 Standard specification and code of practice for road bridges- Section IV (bricks, stones and masonry)

•IRC 22:1986 Standard specification and code of practice for road bridges- Section VI composite construction

•IRC 78:1983 Standard specification and code of practice for road bridges- Section VII formation and sub structure

•IRC 83:1987 Standard specification and code of practice for road bridges- Section IX bearings

•IRC SP:20 2002 Rural Road Manual

•IRC SP 13:2001 Guideline for the design of small bridges and culvert

Component of Bridge

The component of the bridge is broadly grouped into

i) Foundation

ii) Substructure

iii) Superstructure

The foundations are different type viz., open foundation, well foundation, raft foundation and pile foundation. The substructure is the portion of the bridge structure such as pier and abutments above the foundation unit and supporting the superstructure. It shall also include returns and wing walls but exclude bearings. Superstructure is the portion of bridge structure above the substructure level viz., deck slab/beam, hand rail, foot path etc.

IMAGE OF BRIDGE SHOWING VARIOUS COMPONENTS OF BRIDGE:

1. Deck

2. Girder

3. Bearing units

4. Pedestals

5. Pile cap

6. Pile

7. Live load

Terminology:

Clearance: Is the shortest distance between the boundaries at a specified Position of a bridge.

Free Board: Free board at any point is the difference between the highest flood level after allowing for afflux if any, and the formation level of road embankment on the approaches or top level of guide bunds at that point. Free Board for high-level bridge shall in no case be less than 600 mm

Linear Water way: is the width of waterway between the extreme edge of water surface at the highest flood level measured at right angles to the abutment faces.

Effective Linear Water way: is the total width of the waterway of the bridge at HFL minus the effective width of obstruction.

Afflux: The rise in flood level of the river immediately on the up steam of the bridge as a result of obstruction to the natural flow caused by the construction of bridge and its approaches.

Scour Depth: In natural stream, the scouring action of the current is not uniform all along the bed width particularly at the bends and also round obstructions to the flow eg. The piers of bridges there is deeper scour than normal. The assessment of the scour depth is relevant for the design of bridge foundations and protective works. Whenever possible such assessment should be based on data made available from actual Sounding taken at the proposed bridge site or in its vicinity. Such soundings are being taken during immediately after a flood before the scour holes have had time to silt up appreciably. Necessary allowance shall be made in the observed scour depth for increased depth for various reasons.

Vertical clearance: Adequate vertical clearance shall be provided in case of all high level bridges which is usually the height from the designed HFL with afflux to the lowest point of the bridge superstructure. Such clearance shall be allowed as follows

Discharge in cu.meters	Minimum vertical clearance in mm
Upto 0.3	150
Above 0.3 and upto 3	450
Above 3 and upto 30	600
Above 30 and upto300	900
Above 300 and upto 3000	1200
Above 3000	1500

DESIGN ANALYSIS OF BRIDGE

FINITE ELEMENT ANALYSIS

SAP2000 is a general purpose finite element program which performs the static or dynamic, linear or nonlinear analysis of structural systems. It is also a powerful design tool to design structures following AASHTO specifications, ACI and AISC building codes. These features and many more make SAP2000 the state-of-the-art in structural analysis program.

BRIDGE DESCRIPTION AND GEOMETRY

It is proposed to construct bridge analasis design SAP 2000, flyover concrete grader bridge design in location of construction bridge in Vijayawada, constructed by soma construction pvt ltd company

A Finite Element model for the bridge was developed in order to obtain the bridge deck response under dynamic loads. SAP2000 software was employed to establish the finite element model (FEM). The dimensions and material properties which were used in this model follow the above bridge

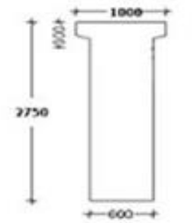
Slab

Thickness of slab = 250 mm

Main girder

The girder dimensions are as follows:

1.T Girder



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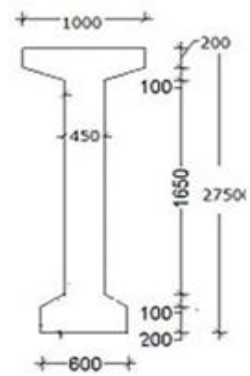
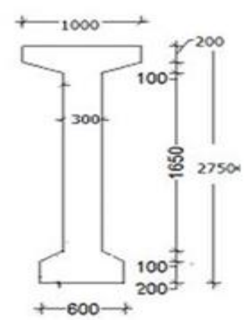
2.Average I Girder



3.I Girder



Modal Analysis

In structural engineering, modal analysis uses the overall mass and stiffness of a structure to find the various periods at which it will naturally resonate. These periods of vibration are very important to note in earthquake engineering, as it is imperative that a building's natural frequency does not match the frequency of expected earthquakes in the region in which the building is to be constructed. If a structure's natural frequency matches an earthquake's frequency, the structure may continue to resonate and experience structural damage Although modal analysis is usually carried out by computers, it is possible to hand-calculate the period of vibration of any high-rise building through idealization as a fixed-ended cantilever with lumped masses.

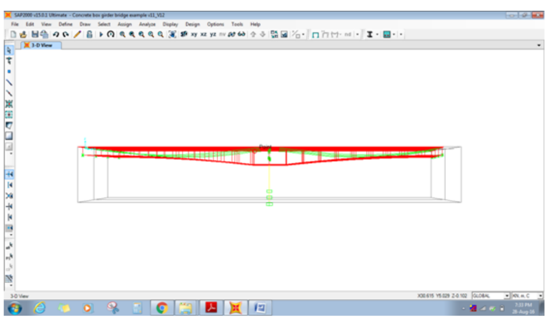


Fig: frount view

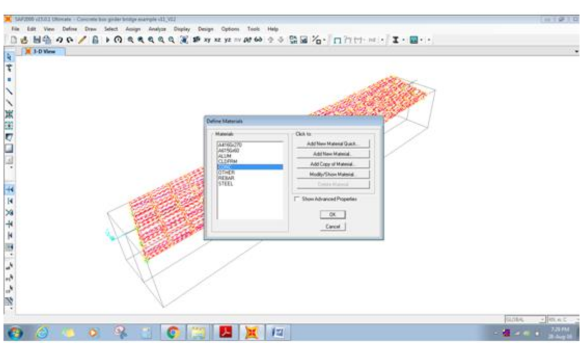


Fig: concrete material

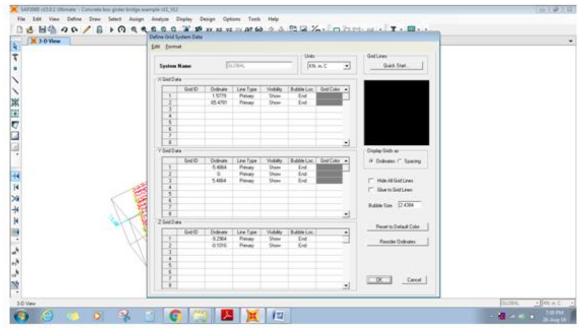


Fig: bridge co-ordinator

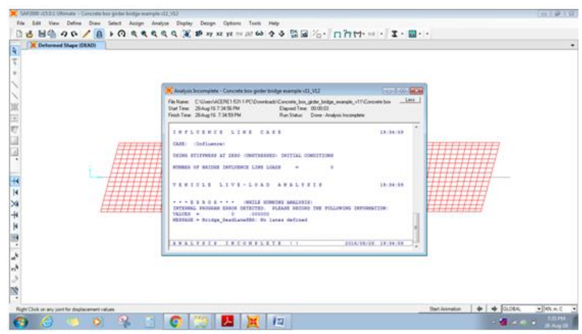


Fig: Run analysis

RESULTS AND DISCUSSIONS

Finite element analysis using SAP 2000 was conducted to investigate the structural response of concrete girder bridge subjected to moving vehicles. The results obtained are as shown below:-

Dynamic Vehicle Loading Analysis

The deformation diagram of both the bridges obtained is given below:-

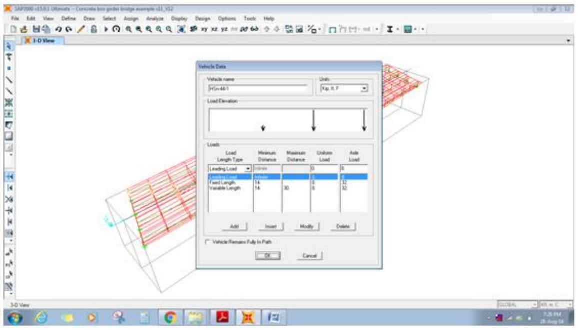


Fig: Deformation Diagram of concrete girder bridge due to Moving Vehicle

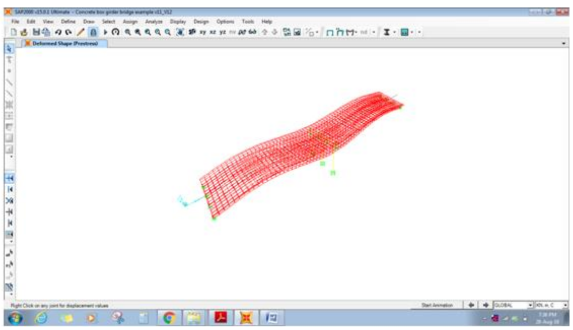


Fig: bridge stress

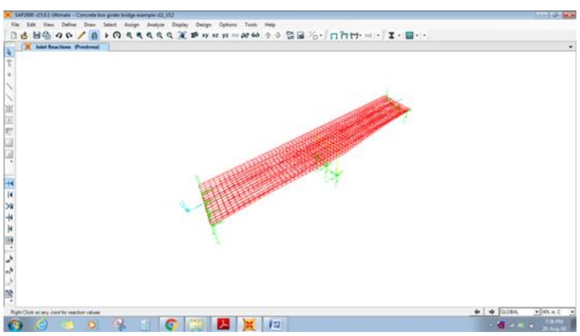
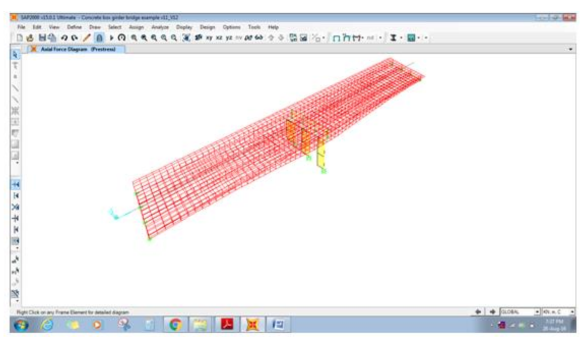


Fig: force

TABLE: Joint Displacements

Joint	OutputCase	CaseType	U1	U2	U3	R1	R2	R3
Text	Text	Text	ft	ft	ft	Radians	Radians	Radians
265	DEAD	LinStatic	0.000041	-0.000232	- 0.000945	0.000015	-7.677E-08	- 0.000001994
265	Prestress	LinStatic	0.000465	-0.000086	0.000026	-3.272E-08	0.000047	0.000026
265	DCON1	Combination	0.000057	-0.000325	- 0.001323	0.000022	-1.075E-07	- 0.000002792
266	DEAD	LinStatic	0.000044	-0.000232	- 0.000922	0.000015	-7.677E-08	- 0.000001994
266	Prestress	LinStatic	0.000426	-0.000086	0.000026	-3.272E-08	0.000047	0.000026
266	DCON1	Combination	0.000061	-0.000325	-0.00129	0.000022	-1.075E-07	- 0.000002792
267	DEAD	LinStatic	0.000037	-0.00023	- 0.000976	0.000015	-7.677E-08	- 0.000001994
267	Prestress	LinStatic	0.00051	-0.000086	0.000027	-3.272E-08	0.000047	0.000026
267	DCON1	Combination	0.000051	-0.000322	- 0.001366	0.000022	-1.075E-07	- 0.000002792
268	DEAD	LinStatic	0.000032	-0.00023	- 0.001014	0.000015	-7.677E-08	- 0.000001994
268	Prestress	LinStatic	0.000576	-0.000086	0.000027	-3.272E-08	0.000047	0.000026
268	DCON1	Combination	0.000044	-0.000322	-0.00142	0.000022	-1.075E-07	- 0.000002792
269	DEAD	LinStatic	0.000022	-0.00023	- 0.001086	0.000015	-7.677E-08	- 0.000001994
269	Prestress	LinStatic	0.000699	-0.000086	0.000027	-3.272E-08	0.000047	0.000026
269	DCON1	Combination	0.000031	-0.000322	- 0.001521	0.000022	-1.075E-07	- 0.000002792
270	DEAD	LinStatic	0.000017	-0.00023	- 0.001125	0.000015	-7.677E-08	- 0.000001994
270	Prestress	LinStatic	0.000764	-0.000086	0.000027	-3.272E-08	0.000047	0.000026
270	DCON1	Combination	0.000024	-0.000322	- 0.001575	0.000022	-1.075E-07	- 0.000002792
271	DEAD	LinStatic	0.000012	-0.00023	- 0.001164	0.000015	-7.677E-08	- 0.000001994
271	Prestress	LinStatic	0.00083	-0.000086	0.000027	-3.272E-08	0.000047	0.000026
271	DCON1	Combination	0.000017	-0.000322	- 0.001629	0.000022	-1.075E-07	- 0.000002792
272	DEAD	LinStatic	0.000003137	-0.00023	- 0.001236	0.000015	-7.677E-08	- 0.000001994

Table: Displacement



fig; axial force

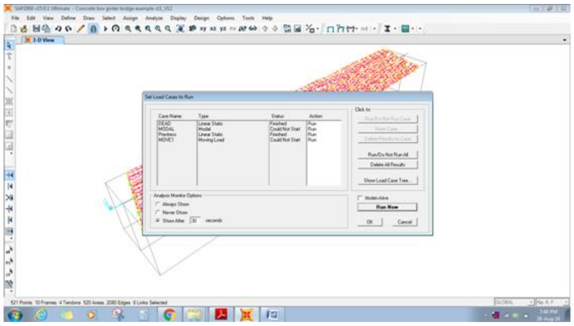


Fig:Bridge analysis

TABLE: Base Reactions

OutputCase	CaseType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ
Text	Text	Kip	Kip	Kip	Kip-ft	Kip-ft	Kip-ft
DEAD	LinStatic	-1.824	-6.806	2465.437	-172.8831	-271195.127	-9114.9404
Prestress	LinStatic	1.949	7.275	-374.076	14.1232	37589.6654	2065.133
DCON1	Combination	-2.553	-9.528	3451.612	-242.0363	-379673.18	-12760.9165

Table: base reaction

SUMMARY AND CONCLUSIONS

In this paper, a comparison of dynamic response of concrete girder bridge and suspension cable brige was studied. For that the proposed bridge structure was modeled and analyzed as concrete girder Bridge using software SAP 2000.

From the bending moment values and deflections obtained, the suspension cable brige provides lesser moments and high deflections as compared to that of concrete girder bridge for the same vehicle loading condition.

The values of the frequencies of concrete bridges are generally larger than those of continuous concrete girder bridges.

Finally, it is inferred that continuous concrete girder bridge has the advantage of good stability for heavy vehicles and economical in comparison with the concrete bridge.

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VI composite construction

•IRC 78:1983 Standard specification and code of practice for road bridges- Section

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