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Analysis of Rubberized Concrete Deck Slab for different Bridge Structures as Per IRC Loadings

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ABSTRACT

Bridge is an important structure required for the transportation network. Now a day with the fast innovation in technology the conventional bridges have been replaced by the cost effective structured system. For analysis and design of these bridges the most efficient methods are available. Different methods which can be used for analysis and design are AASHTO, Finite element method, Grillage and Finite strip method. In this research work the finite element method is used for the analysis of three different type of bridges i.e. cable stayed, cable suspension and deck slab bridge of constant width and length is considered. In this study analyze different bridge sections for same loading conditions and sections. The loading class considered is CLASS 70R from IRC 006-2014. A Finite Element model is formulated for this study using Staad beava software package. This model is then analyzed, for parameters like deflection, stress under the influence of moving vehicle load also to discuss the cost effectiveness of each type of bridge. The basis aim for this study is to give the best output for implementation of these results in future working conditions. In this study it is concluded that cable suspension bridge is comparatively more stable whereas cable stayed bridge is economical of all the types of bridge considered and deck slab bridge shows worst results overall.

Keywords : Staad Beava, Irc, Vehicle, Bridge, Stresses, Deflection, Rubberized Concrete.

I. INTRODUCTION

A bridge is a structure, by which a road, railway or other service is carried over an obstacle such as a river, valley, other road or railway line. The superstructure of a bridge is the part directly responsible for carrying the road or other service. Its layout is determined largely by the disposition of the service to be carried. Supports at convenient locations. A typical configuration of a truss bridge is a 'through truss' configuration. There is a pair of truss girders connected at bottom chord level by a deck that also carries the traffic, spanning between the two trusses.

Rubberised Concrete:

Rubber from discarded tyres use in, floor mats, belts, gaskets, shoe soles, dock bumpers, seal, muffler hangers, shims and washers. 3% to 5% Rubber crumbs and upto 10% reclaimed rubber is particularly used in automobile tyres. Tyre pieces are used as fuel in cement and brick kiln. However, various local authorities are now banning the tyre burning due to atmosphere pollution. Whole tyres also used as highway crash barriers, furniture, boat bumpers on marine docks, etc. Land filling or burning tyres for energy have limited prospects as environmental authorities are acknowledging the need for its greener alternatives. Rubberized concrete have necessitated the need for the experimental investigations on rubberized concrete. Therefore, in this study an attempt has been made to identify the various properties necessary for the design of concrete mix with the coarse tyre rubber chips as aggregate in a systematic manner.

Figure 1: Rubberized Concrete

NAOH Treated Rubberized Concrete:

It was found that the duration of 24 h for treatment of crumb rubber was the most promised duration, which resulted in favourable fresh and hardened concrete characteristics. Compared to rubberised concrete prepared with untreated rubber, rubberised concrete prepared with the 24-h NaOH treated method had 25% improvement in compressive and flexural strength, respectively. It is experimentally indicated that using this treatment method resulted in notable improvement for the compressive strength, and moderate enhancement in the flexural strength.

II. LITERATURE REVIEW

Daniel N. Farhey (2018) [25] This paper demonstrates a comprehensive national network-level analysis to determine the relative deteriorations and operational structural performances of the various types of bridge structural design and/or construction. The study analyzes the entire database of the U.S.National Bridge Inventory for the year 2013 and considers bridge counts along with bridge deck areas that provide more significant results. Analysis of the proportional distribution of structural deficiency reveals issues of deterioration. Considering the structural deficiency, service life cycle and deterioration trends of bridge types over time, the multi-criteria equivalent structural performances incorporate the condition, durability, longevity, rate and pattern performances. The results provide support for more sustainable engineering and management decisions. Stringer/multi beam or girder (type 02) bridges are the most common bridge type, 40.75% by counts and 61.88% by areas. The structural performance of type 02 bridges seems comparable to the average of all bridges, yet they have lower durability and longevity performances, revealing a relative service life cycle vulnerability. The lowest structural performances are orthotropic (type 08) and segmental box girder (type 21) bridges; while their condition performances are rather high, their durability, longevity, rate and pattern performances are essentially low. The slight improvement of structural performance from 2006 to 2013 for most bridge types is not significant over seven years. Also, certain bridge types worsened.

Guohui Cao et. al. (2018) [1] A long-term load test of 420 days was performed on three prestressed steel–concrete composite continuous box beams (non-prestressed, partly prestressed, and fully prestressed) to investigate the combined effects of sustained load, shrinkage, creep, and prestressing. Several time-varying parameters, such as deflection, concrete strain, prestressing force, support reaction, and relative slippage between the concrete slab and the steel box beam, were monitored in the test. The long-term performance of the prestressed beams that was developed using a special law increased and decreased the support reactions at the middle and end piers over time, respectively, due to the distinct configuration of prestressed strands (i.e., installation was only at the negative moment area). The growth rate of the deflection of the prestressed beams was slightly greater than that of the deflection of the non-prestressed beam. Moreover, cracking at the negative moment region significantly accelerated the development of the relative slippage of the non-prestressed beam. A calculation model of long-term deflection based on classical theories was proposed to theoretically analyze the measured data and provide valuable insights for future research.

Neeladharan et. al. (April 2017) [2] Structural design requires a full understanding and knowledge of all the components comprising the structure. A suspension bridge is a type of bridge in which the deck (the load-bearing portion) is hung below suspension cables on vertical suspenders. The design of modern suspension bridges allows them to cover longer distances than other types of bridges. The main element of a cable suspended bridge is the cable system. Bridges are normally designed for dead load, live load and other occasional loads. All loading and unloading conditions in analysis and design are provided as per IRC codal specifications. The whole modeling of the suspension parts of the bridge was done by using SAP2000. Suspension cable bridge having 1km span with single lane road, the intensity of road is given has 20 numbers of vehicles each loaded with 350KN (heavy loading class A-A track load) is analysed by SAP2000. The output of the software presents results including moments, axial loads, shear force and displacements. Moreover, moments and axial load at each node and at any point within the element can be easily obtained from the software output. This thesis examines issues analysis and design calculation in over a structure will safe under all conditions.

Alaa Hussain et. al. (2017) [4] Studied that In this project, the structural analysis of suspension bridge is conducted using the computer program named as (CSi Bridge). The analysis is based on adopting AASHTO and Iraqi specifications standard for loading in bridges. The 14th – July suspension bridge built in Baghdad in 1963 was taken as a case study. The actual data (Bridge geometry in material properties) was input to the program with standard loading mentioned above. The results indicate that the max tensile stress in the main cable was 0.36 Fu. The maximum compressive stress in the tower was 0.51 Fy, while the maximum normal and shear stresses in the plate of the main girder were 0.8 Fy and 0.33 Fu respectively. It is a type of bridges in which a continuous deck (the load-bearing portion) is hung below the suspension cables on vertical suspenders that connect the deck with the main cable. The cables are connected to towers at either end of the bridge, and are balanced by anchors. The suspension bridge must be anchored at each end of the bridge, since any load applied to the bridge is transformed into tension in the main cables in which they transform that load to the main towers.

Luke J. et. al. (2017) [3] The Sunniberg Bridge in Switzerland, designed by Christian Menn, is a tall cable-stayed bridge with low pylons. It is a an excellent example of the way that structural members, shaped in response to engineering considerations can be both functional and have high aesthetically qualities. This paper examines the close link between the aesthetics and the form of the structural elements; compares the loading used for the design with loading from the British Standards; uses simplified structural elements to analyse the stresses in the bridge; and examines the construction process. The Sunniberg Bridge is a harp arrangement cablestayed bridge with 3 main spans (the longest measures 140m) and 2 side spans. The reinforced concrete deck is 526m long and follows a tight of curve of radius 503m at an inclination of 3.2%. The deck is 12.37m wide in total, 9m wide curb to curb, and it carries 2 lanes. The piers/pylons are also constructed from reinforced concrete, the tallest of which rises a total of 75m above the valley floor, 62m up to the roadway and 15m above it.

Objectives:

The main objectives of the present study are as follows:-

- To determine finite element analysis on different types (Deck, Suspension and Cable stayed) of bridges.
- To determine most effective and stable bridge type.
- To determine the most economical type of bridge In cost comparison.
- To find out the implementation of STAAD. Beava for IRC specification.
- To study the effect of rubberized and NaOH treated rubberized concrete in different types of bridges.

III. METHODS AND MATERIAL

Step 1: Selection the geometry of superstructure by using coordinate system in STAAD Pro or plot over the AUTO CAD, which can be import in Staad-Pro as per dimension of girder, c/c distance of bearing, expansion to expansion distance and no.of diaphragm etc. Schematic sketch of the superstructure are shown in below figures.

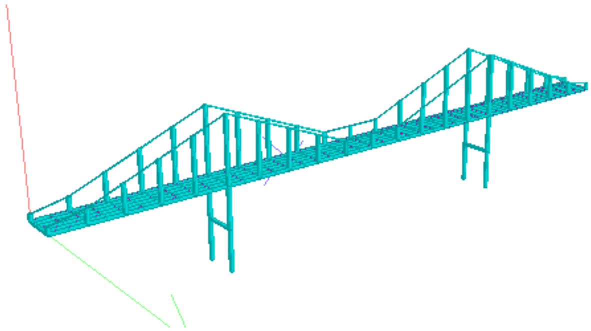


Figure 2. R.C.C Bridge Type

Step 2: Different type of bridge material and models are prepared of same dimension and same loadings as per Indian standards. finite element modeling of the model considering the above parameters. It is considered that R.C.C. bridge of different types such as Deck Slab, Cable Stayed and Cable Suspension bridge types of superstructure define the dimensions like 200 length, 10 meter wide, which include in the girder property and steel material property of the structure as per Indian sections.

Different types of bridge sections considered are as follows:

A. Deck Slab Bridge :

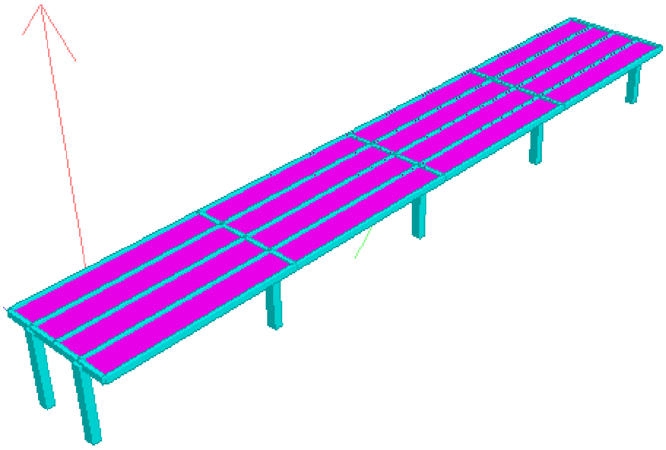


Figure 3. Deck Bridge

A Deck Bridge (fig 3) is the surface of a bridge, and is one structural element of the superstructure of a bridge. It is not to be confused with any deck of a ship. The deck may be constructed of concrete, steel, open grating, or wood. Sometimes the deck is covered with asphalt concrete or other pavement

A. Cable Stayed Bridge:

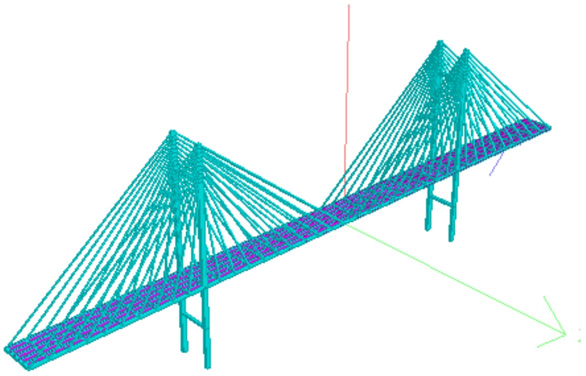


Figure 4. Cable Stayed Bridge

A Cable Stayed Bridge (fig 4) has one or more towers, from which cables support the bridge deck. A distinctive feature are the cables which run directly from the tower to the deck, normally forming a fan-like pattern or a series of parallel lines

B. Cable Suspension Bridge:

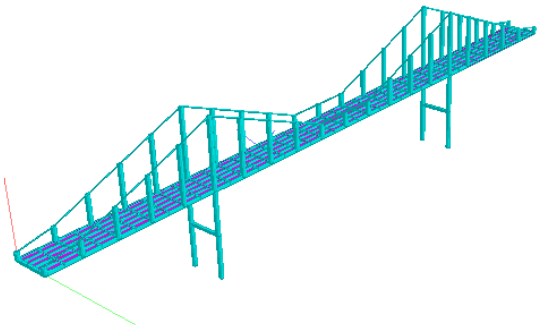


Figure 5. Cable Suspension Bridge

Cable Suspension Bridge (fig 5) is a type of bridge in which the deck (the load-bearing portion) is hung below suspension cables on vertical suspenders. The first modern examples of this type of bridge were built in the early 19th century Simple suspension bridges, which lack vertical suspenders, have a long history in many mountainous parts of the world

Step 3: Apply the material property as shown in above figures, after that support condition has been considered at the bearing locations of the superstructure which is pinned / hinged as shown in below figure.

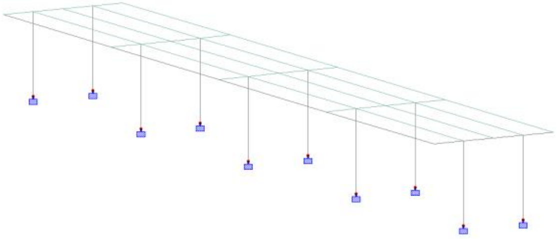


Figure 6. Support Condition

Step 4: After apply the support condition, now the next step to be considered for the Deal Load of the superstructure i.e. “selfweight”.

Step 5: After apply the Dead Load, now the next step to be considered for the **Equivalent Uniformly Distributed Loads (EUDL)** load

For Bending Moment, L is equal to the effective span in metres. For Shear Force, L is the loaded length in metres to give the maximum Shear Force in the member under consideration. The Equivalent Uniformly Distributed Load (EUDL) for Bending Moment (BM), for spans upto 10m, is that uniformly distributed load which produces the BM at the centre of the span equal to the absolute maximum BM developed under the standard loads. For spans above 10m, the EUDL for BM is that uniformly distributed load which produces the BM at one-sixth of the span equal to the BM developed at that section under the standard loads. EUDL for Shear Force (SF) is that uniformly distributed load which produces SF at the end of the span equal to the maximum SF developed under the standard loads at that section.

Step 6: After apply the EUDL Load, now the next step to be considered for the Moving Live Load (LL) in which include the Breaking Load and Vehicle Load are as follow

1) DFC (*Dedicated Freight Corridor*) LOADING FOR BENDING MOMENT [Eccentric & Concentric]
2) DFC LOADING FOR SHEAR FORCE [Eccentric & Concentric]
3) Coefficient of Dynamic Augment (CDA) *Coefficient of Dynamic Augment* FOR PROVIDED DECK LENGTH.

Step 7: After applied all the boundary condition and forces, now the model has to be "Analyze" for getting the results i.e. Axial force, shear force, deflection and support reactions etc.

Step 8: after analysis results designing is followed as per Indian Standard 456:2000 R.C.C. design and optimization of each case is done to provide its economical section for same loading and geometry in all the cases.

Step 9: After optimization process comparative results are drawn in all cases to determine the best one with the help of graph using M.S. Excel.

Table 1 : Geometric Details

S.NO	Description	Value
1	Length of Bridge	200 m.
2	Number of bays in X direction	40
3	Number of bays in Z direction	5
4	Height of Bridge structure	4 m
5	Width of the bridge section	10 m
6	Bay width in Z direction	2 m
7	Support type	Pinned support

Table 2 : Material Description

S.NO	Description	Value
1	Sections	Standard
2	Young's modulus of steel, Es	2.17x10^4 N/mm^2
3	Poisson ratio	0.17
4	Tensile Strength, Ultimate Steel	505 MPa
5	Tensile Strength, Yeild Steel	215 MPa
6	Elongation at Break Steel	70 %
7	Modulus of Elasticity Steel	193-200 GPa
8	Concrete	M60

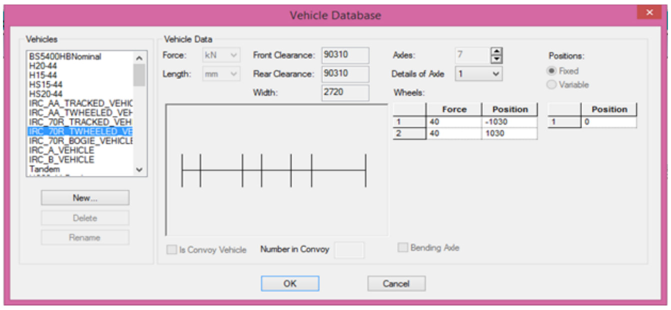
Step for loading condition.

The load condition has to be defined as per requirement of the analysis.

As we know the model is R.C.C. structure of the bridge in which vehicle load has to be apply in different patterns. There are the different type of load has to be calculate and apply with the help of software and load are as under -

(i) Dead Load: Dead load is the self weight of the sections, as we defined the density of sections accordingly the load has to be generated by the software. The view of the "Selfweight".

Vehicle Live Load: This is the important load in which the moving vehicle load gives the critical values in term of bending moment & shear force etc. All these The design of bridges shall be in accordance with the Indian I.R.C. Code of Practice for the Design of R.C.C. or Composite Bridges carrying Road or Pedestrian Traffic (Bridge Code).



Force: kN
Length: mm
Front Clearance: 90310
Rear Clearance: 90310
Width: 2720
Axles: 7
Details of Axle 1
Positions: ● Fixed ○ Variable

Wheels:

	Force	Position
1	40	-1030
2	40	1030

	Position
1	0

Figure 7. Assigning lanes and vehicular load

IV. RESULTS AND DISCUSSION

Analysis Results :

Shear Force:

Deck Bridge

Table 2 : Shear force in Deck Bridge

Shear Force kN	
Deck Bridge (Rubberized)	Deck Bridge (NaOH treated rubberized)
705.87	654.87

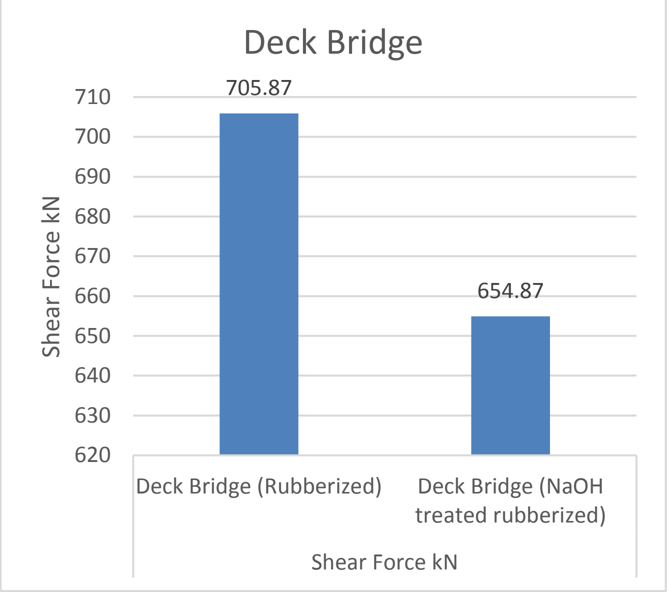


Figure 8. Shear Force in Deck Bridge

Cable Stayed Bridge

Table 4. Shear force in Cable Stayed Bridge

Shear Force kN	
Cable Stayed Bridge (Rubberized)	Cable Stayed Bridge (NaOH treated rubberized)
590.97	540.045

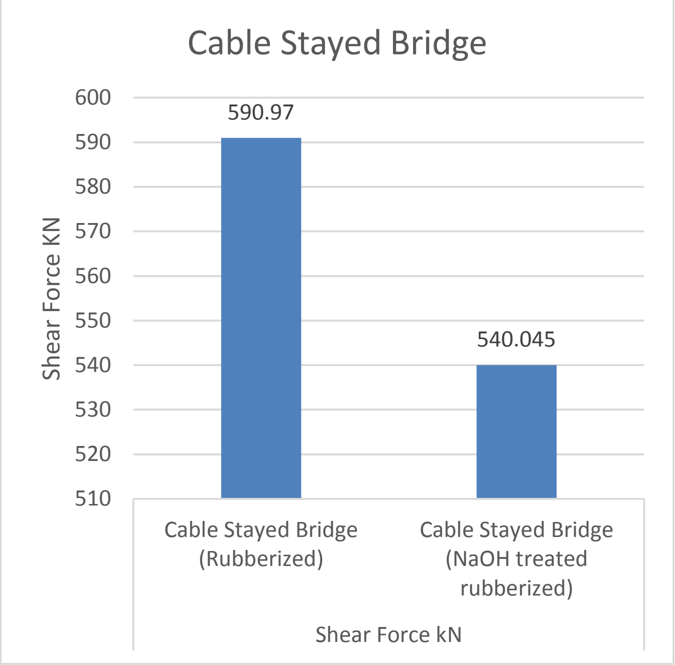


Figure 9. Shear Force in Cable Stayed Bridge

Suspension Bridge

Table 5. Shear force in Suspension Bridge

Shear Force kN	
Suspension Bridge (Rubberized)	Suspension Bridge (NaOH treated rubberized)
678.09	600.05

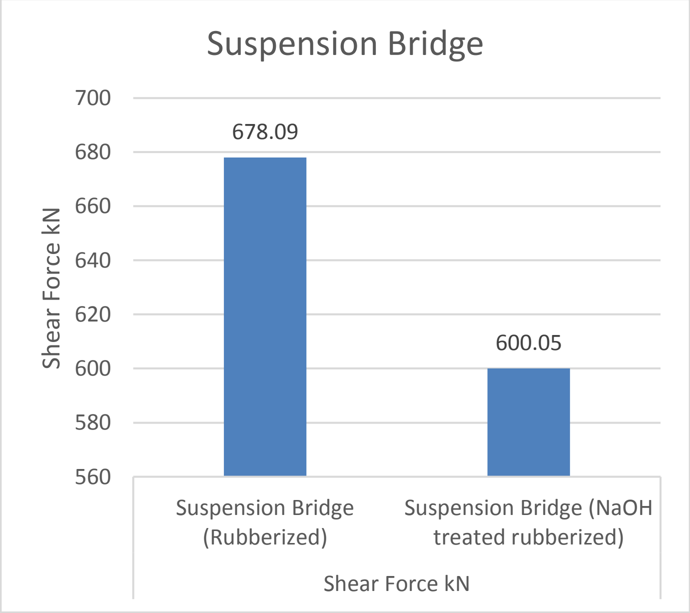


Figure 10. Shear Force in Suspension Bridge

Axial Force:

Deck Bridge

Table 6. Axial force in Deck Bridge

Axial Force kN	
Deck Bridge (Rubberized)	Deck Bridge (NaOH treated rubberized)
2008.09	1980.55

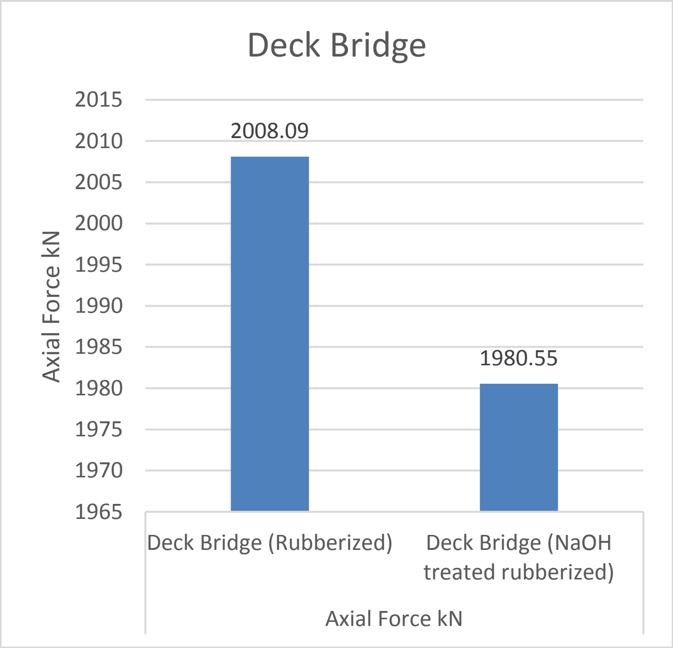


Figure 11. Axial Force in Deck Bridge

Cable Stayed Bridge

Table 7. Axial force in Cable Stayed Bridge

Axial Force kN	
Cable Stayed Bridge (Rubberized)	Cable Stayed Bridge (NaOH treated rubberized)
1800.65	1785.98

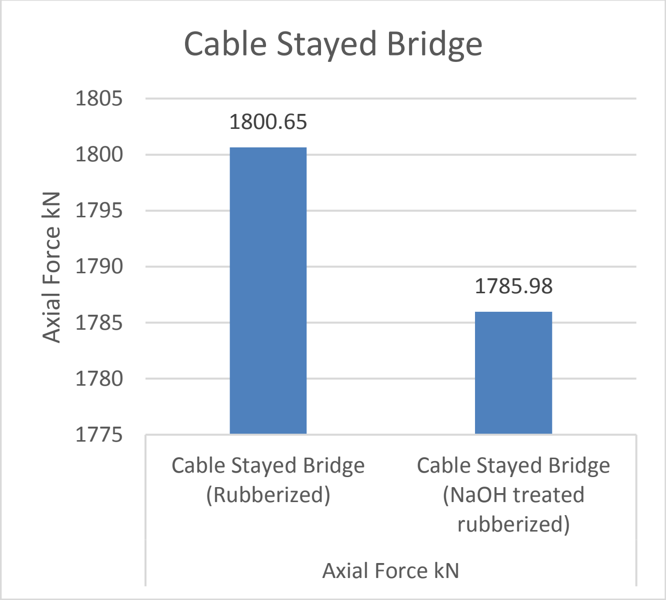


Figure 12. Axial Force in Cable Stayed Bridge

Suspension Bridge

Table 8. Axial force in Suspension Bridge

Axial Force kN	
Suspension Bridge (Rubberized)	Suspension Bridge (NaOH treated rubberized)
1966.05	1920.55

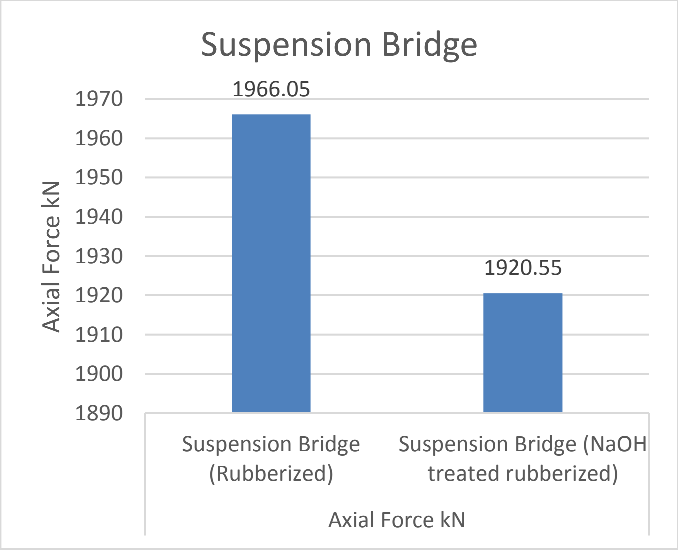


Figure 13. Axial Force in Suspension Bridge

Bending Moment

Deck Bridge

Table 9. Bending moment in Deck Bridge

Bending moment kN-m	
Deck Bridge (Rubberized)	Deck Bridge (NaOH treated rubberized)
507.76	448.21

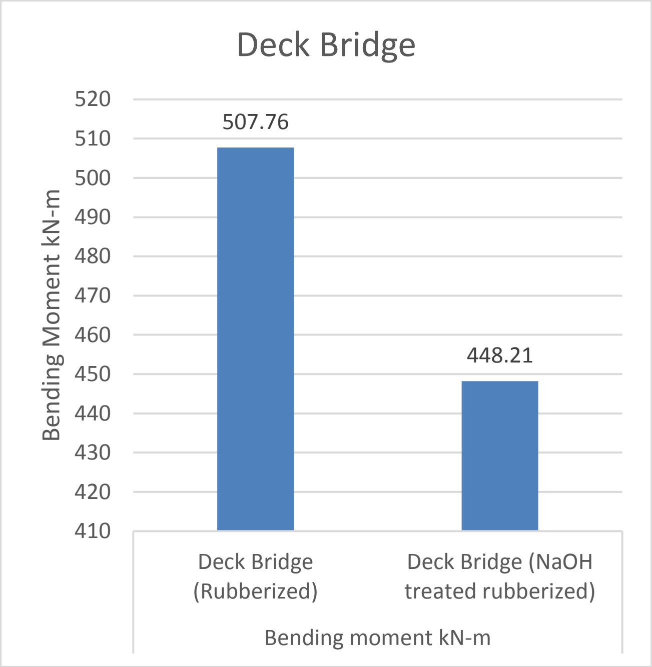


Figure 14. Bending moment in Deck Bridge

Cable Stayed Bridge

Table 10. Bending moment in Cable Stayed Bridge

Bending moment kN-m	
Cable Stayed Bridge (Rubberized)	Cable Stayed Bridge (NaOH treated rubberized)
426.34	400.06

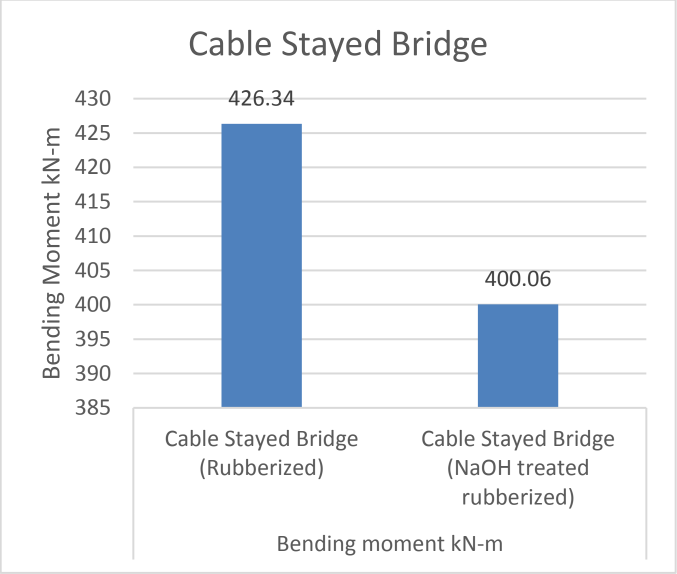


Figure 15. Bending moment in Cable stayed Bridge

Cable Suspension Bridge

Table 11. Bending moment in Suspension Bridge

Bending moment kN-m	
Suspension Bridge (Rubberized)	Suspension Bridge (NaOH treated rubberized)
498.04	421.55

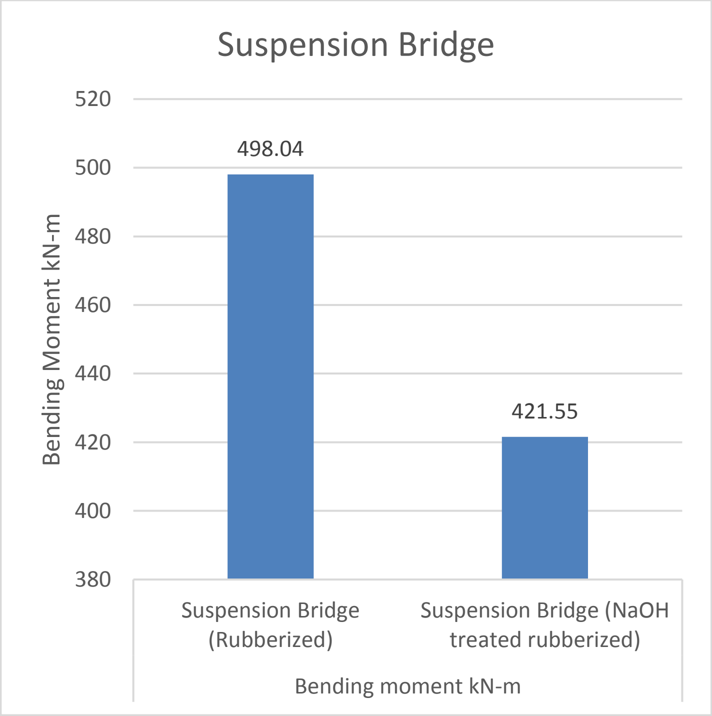


Figure 16. Bending moment in Suspension Bridge

Deflection:

Deck Bridge

Table 12. Deflection in Deck Bridge

Deflection mm	
Deck Bridge (Rubberized)	Deck Bridge (NaOH treated rubberized)
59.76	52.04

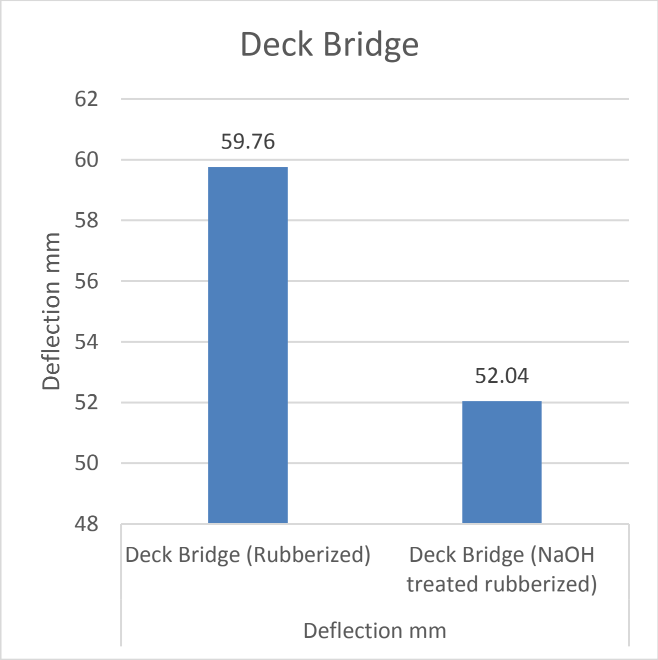


Figure 14. Deflection in Deck Bridge

Cable Stayed Bridge

Table 13. Deflection in Cable Stayed Bridge

Deflection mm	
Cable Stayed Bridge (Rubberized)	Cable Stayed Bridge (NaOH treated rubberized)
42.56	37.45

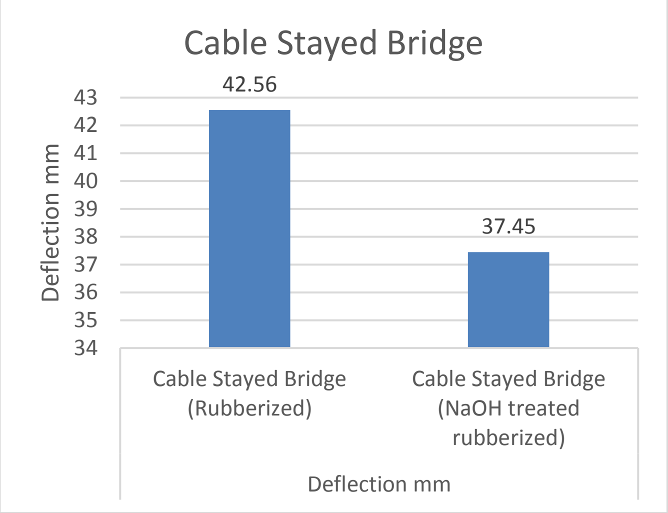


Figure 18. Deflection in Cable Stayed Bridge

Suspension Bridge

Table 14. Deflection in Suspesion Bridge

Deflection mm	
Suspension Bridge (Rubberized)	Suspension Bridge (NaOH treated rubberized)
45.98	40.87

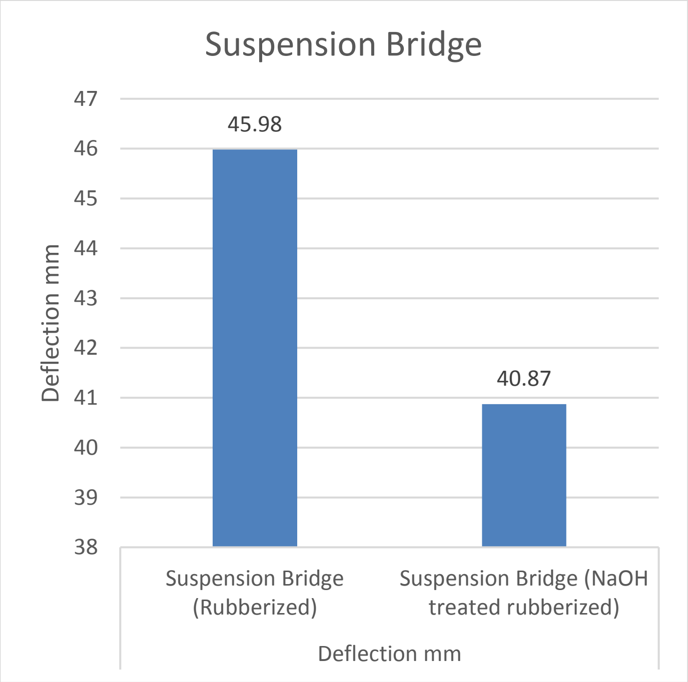


Figure 19. Deflection in Suspension Bridge

Support Reaction:

The magnitude of maximum reaction at supports of various form of bridge has been plotted in shows maximum value of support reaction is on Deck bridge which means it transmit forces more effectively. Cable suspension bridge shows less reaction which means this structure is not stable.

Table 15. Support Reaction

Support reaction (Y) direction		
Deck Slab	Cable Stayed	Cable Suspension
1538.305	1538.252	1538.25

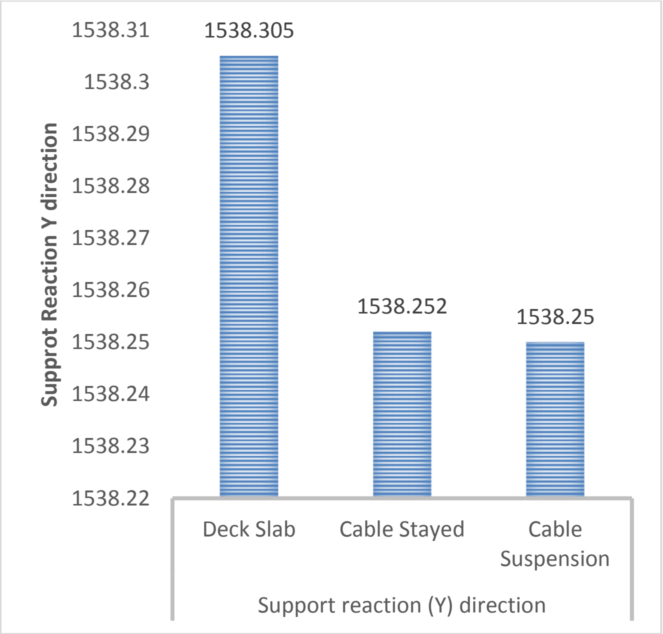


Figure 20. Support Reaction

V. CONCLUSION

Conclusion

As discussed in the last chapters, we have considered Class A+ 70R vehicle load cases along with dead load for the Rubberized and NaOH treated Rubberized concrete bridges for analysis by using Staad-Pro software. Following are the salient conclusions of this study-

Deflection

In case of deflection we observed in above chapter that maximum deflection is obtained in rubberized concrete in all cases when comparing with NaOH treated concrete.

Support Reaction

For the case of reaction analysis, we have analysis number of cases for critical the values and observed that out of the three cases Deck slab bridge gives maximum values i.e. 1538.305 kN (Y).

Bending Moment

In terms of bending moment it is observed that minimum bending is in NaOH treated rubberised concrete, which is resulting in comparatively most economical in comparison as bending moment is directly proportional to reinforcement requirement.

Shear Force

Shear force in known as the unbalance force observed due to transmission of load from beam to column, in our study it is observed that with NaOH treated rubberized concrete it can be minimized in all the cases considered for study.

Axial Force

Axial force is known as the vertical force observe in piers, this force is meant to distribute load from pier to earth. It is observed in the results that with NaOH treated rubberized concrete Distribution of vertical forces can be processed easily.

VI. SUMMARY

Here in our study out of all cases cable stayed bridge shows least values with NaOH treated rubberized concrete which mean for the same loading it will take less weight of construction material which makes it more economical than others.

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