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Comparative Analysis of Box Culvert with Cushion and Without Cushion Usign Staad-Pro

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ABSTRACT

Bridges are essential for the efficient movement of trains and locomotives, as well as for crossing water courses such as streams across embankments as roads are not allowed to obstruct the natural flow of water. Culverts provide balance to the water flow on both sides of the road, as well as protecting and balancing the embankment in order to reduce flooding. Different types of bridges exist, such as arch, slab, and box. Masonry (brick, stone, etc.) or reinforced cement concrete can be used to build them. The bridges pass through the embankment and are therefore subject to the same traffic loads that the road carries, so they must be designed accordingly. Depending on where the bridge is located, the cushion will vary. Structures must be designed to take into account the loads (empty, full, surcharge, etc.) along with factors such as live loads, width, force of braking, load dispersion within the fill, impact factor, and earth pressure. Referrals are required for relevant IRCs. It is necessary to design structural elements that can withstand maximum bending moment and shear force. The culvert crosses over the earthen embankment, so it is subject to the same traffic load as the roads; as a result, it has to be designed for such loads acting on the culvert surface.

KEYWORDS: *STAAD Pro, Box Culvert, Bending Moments, IRC Loading, Single Cell, Cushion*

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The present study focuses on reinforced concrete box culverts with different aspect ratios. The box culverts are analysed for varying cushion and no cushion loading. A large emphasis is placed on determining how well a structure will behave under various types of loading as recommended by IRC codes, and the combinations that will cause the most harmful effects on the structure. Comparative analysis and conclusions are based on maximum bending moments for different loading conditions.

part 1 The study deals with the planning and analysis of Box Culvert using Staad-Pro software. In this study Box Culvert clear span is 5m and clear height is 3m and the slab is fixed supported. The drafting and detailing work was completed using AutoCAD software and thereafter the entire analysis work was completed using “Staad-Pro v8i ss6.

Part 2 Comparison of Box Culvert with cushion or without cushion also the analysis results in term of shear, bending moment, axial force and deflection were checked by STAAD-Pro which is passes through many different load combinations. The maximum design moments resulting from the combinations of various loading cases.

1. INTRODUCTION

Culverts are structures built below roads and railroads for the purpose of allowing natural drainage to cross underneath. Sometimes they are built to provide access to the animals across the road as well. The culvert opening should be determined according to the maximum amount of water it will have to handle during the design flood, and the culvert section should be thick the structures must be capable of carrying those loads. The purpose of culverts and bridges is often the same, although the size of each differs. The type of material, how they carry weight, and how closely a culvert is bound to the soil surrounding them determine whether culverts are flexible, semi-rigid, or rigid. When it comes to carrying imposed loads, culverts depend on many factors, including the type of material they are made of, the age of the material, and the surrounding materials. In a box culvert, more than one cell can be present and the top slab may be situated so that it almost touches the road and there is no cushion. After repetitive loading of heavy trucks, material aging and degradation has a tendency to decrease capacity gradually. The report discusses reinforced concrete box culverts with varying aspect ratios. In addition to culverts placed within embankments, slab-top culverts can also be installed along roadway embankments. This type of box is a cushion. The box culverts are analysed for different cushion loadings and no cushion loadings. According to IRC codes, this paper explores how variations of loads can negatively impact structures and what combinations can trigger significant impacts. Structures must be loaded safely.

Specifically, this paper focuses on the behaviour of structures under different types of loads, as defined by IRC codes, and possible combinations that will cause the most detrimental effects. of loading for safe structures. A comparison is made between the maximum bending moments for each loading case. It depends on the country you live in whether you want to cast your culvert in situ, since some prefer cost-effective and fast workmanship. There are different types of culverts; they differ in shape and they are also used as bridges. In this case, the sewer box culvert is 0m-6m in span (clear span). The culvert has four sides that monolithically connect, so it can safely handle all the water coming from the canal and river, as well as the storm and flood water. Cushioning is very important in every culvert, as well as bearing capacity of the soil on the site. Across highways and railways, Culverts provide drainage for the natural flow of water. They are part of infrastructure that is very important to maintain A box culvert's opening is governed by hydraulic design. Water runs through a 6m wide culvert (IRC 5-1998). A culvert and a bridge often perform the same function, but their sizes differ. A box culvert does not need to be designed to withstand seismic forces, so no considerations are made for earthquake forces in the IRC: 6-2016. Considering the presence of overburden, the design of the culverts is based on five-metre width arrangements with three-metre heights. According to the loads applied on the culvert section, the culvert section's thickness is determined. Hydraulic designs determine the box size and invert level. The cushion height is determined by the road profile at the location of the culvert. Occasionally, the road alignment crosses a stream at an angle other than right angle. In such situations, a skew culvert might be necessary.

During operation, a box culvert's top slab needs to withstand dead weight, live loads from moving traffic, earth pressure, water pressure, and pressure on the bottom slab, in addition to self-weight. On the basis of the relative stiffness of the slab and vertical walls, a rigid frame is built using an element of one meter and a moment distribution method to obtain final distributed moments. It doesn't require any explanation of how the method works. Moments at free ends are recalculated after adjusting for moments at supported ends, resulting in the mid span moments. Various combinations of loads are obtained at the center and on the supports of slabs and walls, and the members are designed based on the maximum moments they may be subjected to. Design also considers the shear force produced by the wall at a distance of effective depth from the face of the wall, and the stresses it produces in the section. Generally, a rigid frame is considered a box and a unit length of this box is taken as a basis for design (usually 1 m).

2. OBJECTIVES –

1. Checking structure safety
2. Analyzing R.C.C box culvert using STAD pro software.
3. To design for cost-effectiveness.
4. Conceptualization of entire Project.
5. To Design all structural elements of box culvert.
6. To investigate how box culverts, respond to different aspect ratios with various cushion
7. Loads.
8. To determine which load combination will have the worst effect on the structural design.

3. LITERATURE REVIEW –

1. **Kalyanshetti and Gosavi (2014)** provided an overview of Cost optimization of the box culvert based on different cell aspect ratios. In order to divide a channel length of 12 m into single, double, and triple cells, a height variation of 2 to 6 meters is used. The load is a tracked live load of class AA according to IRC. Stiffness matrices are used for analysis, and a computer program in C language is developed for cost evaluation. Various aspect ratios are studied with regard to their effect on bending moment variation. The costs for each ratio are then compared. Based on optimum thicknesses, single, double, and triple cell cost reduction percentages are presented. In order to design an economical box culvert, the optimal thickness presented here is used. We evaluate optimum widths for a single cell, double cell, and triple cell based on these optimum thicknesses. The results of the study show that when optimum thicknesses are considered for box culverts, the cost reduces.

2. **Chandrakant and Malgonda (2014)** discussed on the finite element analysis of box culverts. A program is developed to analyse the structural elements to determine the maximum bending moment and shear force, and the results are compared to the results of a software program. For this reason, we analyse box culverts for different conditions and suggest structural designs for critical cases. An analysis of skew box culverts is carried out under a variety of conditions considering various angles.
3. **Kolate et al. (2014)** an analysis and design discussion on RCC box culverts was presented. The team determined that Box culverts are easy to expand should the road widen, and they are structurally strong, rigid, & safe. By extending the base slab to retain pressure within the safe bearing capacity of the ground soil, the box does not require elaborate foundations and can be placed over soft substrates.
4. **Patil and Galatage (2016)** worked on Analysis of box culverts under cushion loading. In this report, reinforced concrete box culverts with different aspect ratios are discussed. This paper analyses the variation in cushion strains and load without cushion in box culverts. An emphasis is placed on how the structure behaves under the types of loading per IRC codes and how they combine to produce the worst effect of loading. In the analysis, the maximum bending moments of the different loading cases are compared and concluded.
5. **Sharif (2016)** a comparison was made between STAAD and MDM results for railway box bridges. Throughout the paper, the provisions of the Codes are discussed, considerations and justified. Therefore, the effectiveness of the results obtained by both methods of analysing all of these aspects should be examined. You can analyse the box bridge using either software or computation.
6. **Saurav and Pandey (2017)** worked on Economic design of rcc box culvert through comparative study of conventional and finite element method, they examined the economics of RC box culverts. Box culverts are complex to design and analyse. In the present era, structures can be analysed using finite element software that uses 3D models of the structures. Using ANSYS software, we show the comparative study of conventional and FEM methods.
7. **Kazmi et al. (2017)** they worked on the analysis and design of a minor railway bridge of the box type. A manual approach and a computational approach are used to analyse and design a RCC box type minor bridge. A comparative study of the results obtained from the two approaches has been conducted to validate the accuracy of the results. The structural elements were designed to withstand the Ultimate Load criteria based on various loads and serviceability criteria, the analysis was observed to become quite tedious and cumbersome when carried out manually, and it became quite difficult when handling complex structures, so using a computational method seemed to be the obvious choice. Based on the results of the MDM, the results obtained using computational methods are in good agreement.
8. **Ghumde and Gaikwad (2017)** a study of deck bridge culvert design and analysis using STAAD Pro for comparing various designs and spans. Various authors have been compared and the findings of their research are shown in this study. The results of culvert analysis with software approach and comparison with manual approach are also included. Using IRC loadings, the paper investigates the effects of cushioning and uncushioned conditions on culverts. Both cushioned and no cushioned loading cases are checked for pressure. Structures are designed to withstand maximum bending moments and shear forces. A full explanation of the provisions of the codes, considerations, and justification of all these aspects of design is provided in the present study.
9. **Kakade and Dubal (2017)** as part of this research, RCC box culverts were tested for behaviour under static and dynamic loads according to the IRC.This analysis has been carried out with ANSYS using design parameters related to earth pressure and the depth of the cushion in box culverts. Numerical models can be compared to ANSYS's finite element model as a strain problem. Additionally, box culverts with and without cushions are compared for different cases.
10. **Shende and Chudare (2018)** analysed a RCC culvert using computer software. Using software for culvert analysis by using different L/H ratios with an angle of friction is discussed in this paper. During floods, culverts are provided to balance water levels on both sides of embankment so water flows according to its natural course, and they are also used as road passes. Such culverts are referred to as balancers. A reinforced concrete box culvert is designed by analysing the rigid frame for moments, shear forces, and thrusts

resulting from a variety of types of loading conditions.

11. **Krishna and Rajasekhar (2018)** Analysing and designing box culverts has been his focus. STAAD PRO software will be used to analyse and model the box culvert in this project. A powerful and user-friendly tool for the generation, analysis, and multi-material design of three-dimensional models. Comparing the results obtained from STAAD PRO with those obtained manually using MATLAB. Constructed from concrete or reinforced concrete, box culverts can resist the maximum amount of bend and crush forces. In almost all cases, the results obtained from STAAD are the same as those obtained from manual calculations.
12. **Raza and Khedikar (2019)** Researched and designed a variety of slab culverts for different mix designs and spans. This paper compares culvert designs that are designed with different mix designs and spans.
13. **Patel and Jamle (2019)** developed a manual approach for the analysis and design of box culverts. In this paper, we study complete box culvert design manually and analyse parameters such as earth pressure effect, the depth of cushions above the culvert, braking force, load impact, live load, load dispersal from tracked and wheeled vehicles, and effective width. Study of culverts with and without cushions was carried out for different IRC loading classes and conclusions drawn based on bending moments and shear forces under different cushioning situations. As part of the discussion of Indian Standards, their justifications and considerations are taken into account for design purposes.
14. **Bangari et al. (2019)** researched the parametric behaviour of rcc box culverts under dynamic loading. As a main source of human life, bridges allow human beings to travel from place to place. This research examines the analysis and design of bridges. Bridges are modelled and analysed with the help of the software Staad-pro. A box culvert bridge is the design we came up with. According to IRC 6, design loads are taken into account. Staad-pro is used to design the box culvert and the results are compared manually.
15. **Hussien (2020)** He studied the effect of the haunch on the stresses in box culverts. The paper analyses the effects of the haunch on the stresses in box culverts by studying the thickness of the haunch, the coefficient of earth pressure, the thickness of the box culvert, and the fill depth on the top slab. Comparing different widths of culverts in terms of stress and cost was examined by the researchers. The cost of culverts is reduced by a specific percentage when a haunch is present.
16. **Bhujade and Gaikwad (2020)** worked on Design of RCC box culvert with cushion and without cushion. Box culverts are structures that are built beneath highways and railways to allow natural drainage to pass through, with the opening determined based on the waterway needed to pass a design flood. Box culvert is suitable CD structure where hydraulic head is limited. This paper deals with study of box culvert constructed in reinforced concrete without cushion and with cushion as per limit state method. According to IRC, the thickness of the culvert section should be calculated based on the vehicular loading in order to create the strongest load for a safe structure. Using STAAD Pro, structural engineers must analyze bending moments and shear forces to determine how the steel should be designed to withstand maximum bending moments and shear forces.
17. **Chaithra et al. (2021)** worked on Parametric Study on Single Cell Box Culvert Design Considerations-A Review. The use of box culverts in transportation networks is vital since they are a cost-effective alternative to bridges that require substantial amounts of funding. Basically, a culvert is a structure that provides a way for vehicles and pedestrians to cross over a waterway while allowing water to pass through. The natural stream passes through channels since they are normally cheaper than bridges. A culvert can be constructed from a pipe, reinforced concrete or another material. It is common to use culverts both for drainage under roads and to pass water under channels at natural drainage and river crossings. A stiffness matrix method is used to analyze box culverts. Suppose that the boundary conditions of a box culvert are discrete and externally determined. A single cell box consists of a top slab, a bottom slab, and two vertical walls, forming a rigid frame enclosed in a rigid box. It is assumed that the structure is externally determined. A review of various authors, including their views on the design and analysis of box culverts with software approach, has been done in this study, and a comparison between manual and software approaches has been made. IS standards are used in the structural designs of concrete box culverts (IRC-6-2000, IS 21-2000) in design manuals for roads and bridges. A full

discussion is provided of the provisions in the Codes, as well as the considerations and justifications for all the things listed above.

4. METHODOLOGY –

A. Examine historic and contemporary documents related box culvert bridge structures.

B. Modeling and analysis of culvert by STAAD pro.

C. It is important to choose the geometrical box and the size of the elements so as to ensure the highest degree of accuracy.

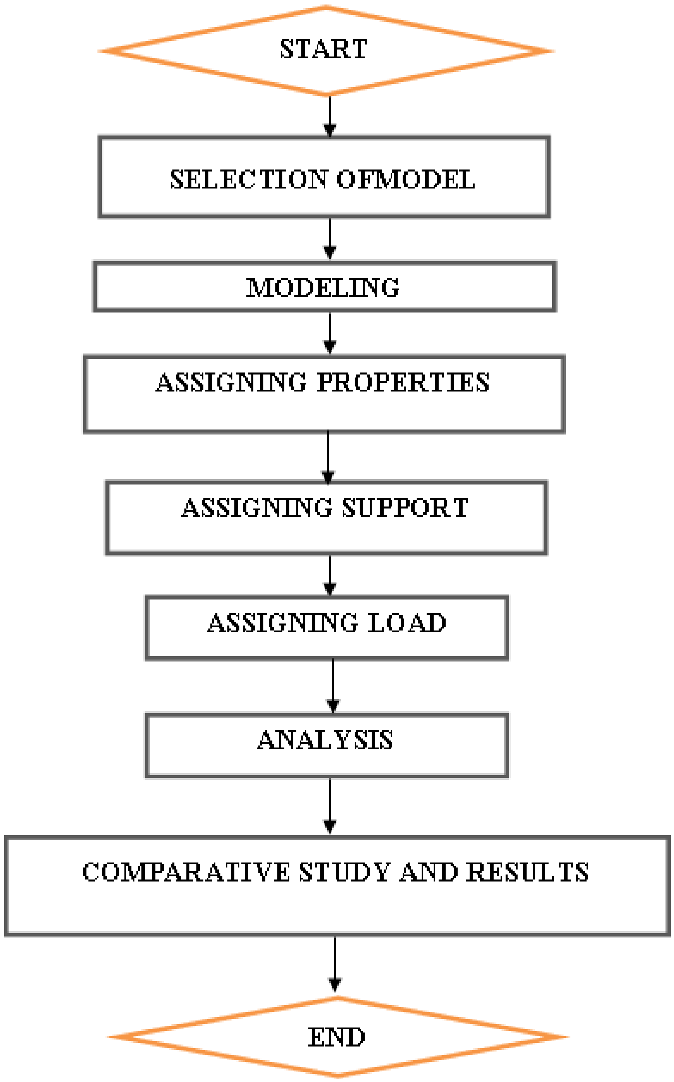
D. Specifying the thickness (top slab, side walls, bottom slab) and material properties.

E. Now installed spring support under the bottom slab.

F. Various load cases for the structural design of RCC culverts, such as effective live loads, effective width, and coefficient of earth pressure should be considered

G. Axial forces on the Deck slab, Axial forces on the Side Walls, Shear forces on the Deck slab, Shear forces on the Side Walls, Deck slab bending moments are all considered as part of the Ultimate Bearing Capacity.

H. Calculations are output for the Maximum bending moment, Maximum shear force, and Maximum axial force.



Flowchart of Analysis in STAAD Pro

Dimensions of structure

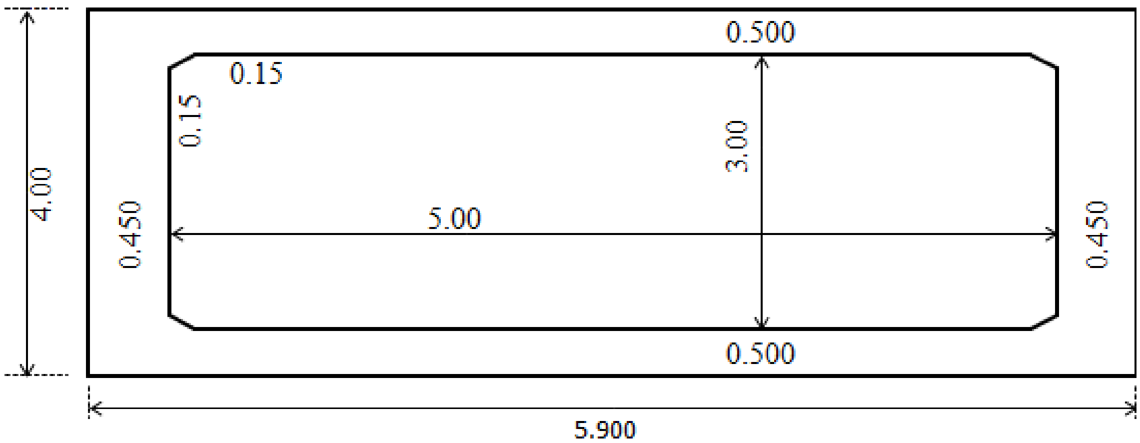
S. no	Type of Member	Dimensions or nos.
1.	Top Slab	6000 mm x 16000 mm x 500 mm
2.	Bottom Slab	6000 mm x 16000 mm x 500 mm
3.	Outer Wall	450 mm x 16000 mm x 3000 mm

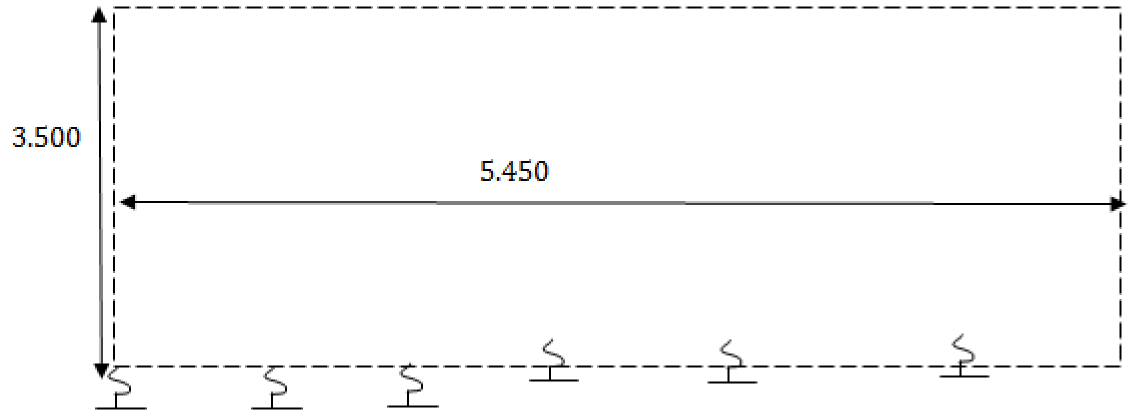
4.1. Materials properties

Material properties

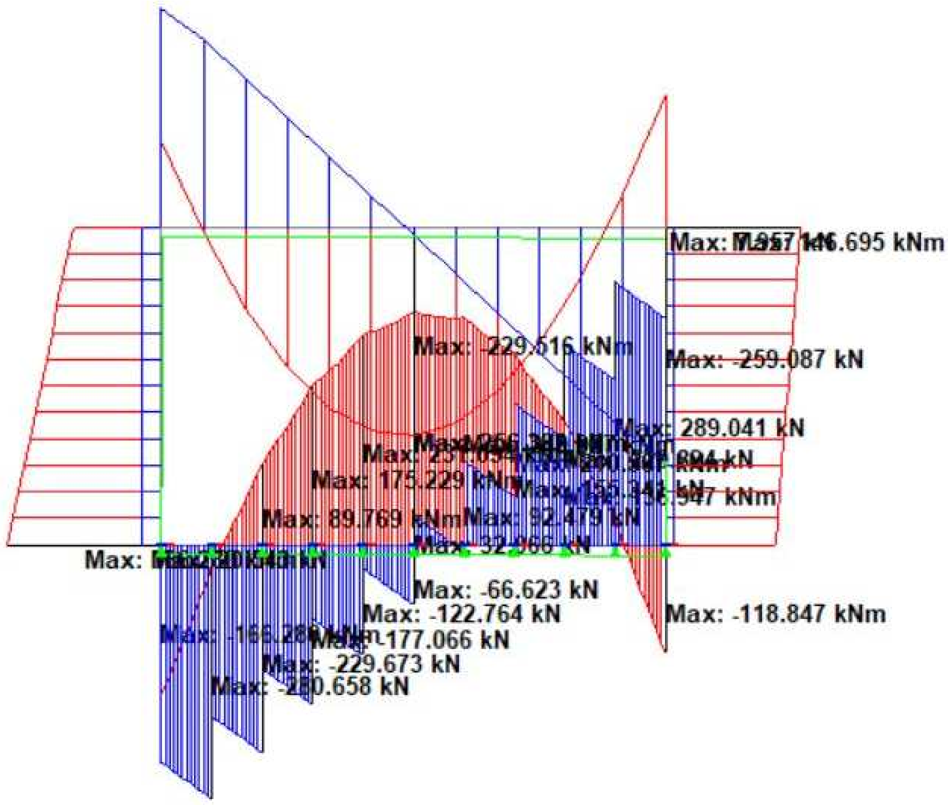
Material	Grade	Density (kg/m^3)	Modulus E kN/mm^2	Posion ratio (v)
Conrete	M-25	2500	30	0.20
Steel	Fe-500	7850	200	0.30

5. RESULT –

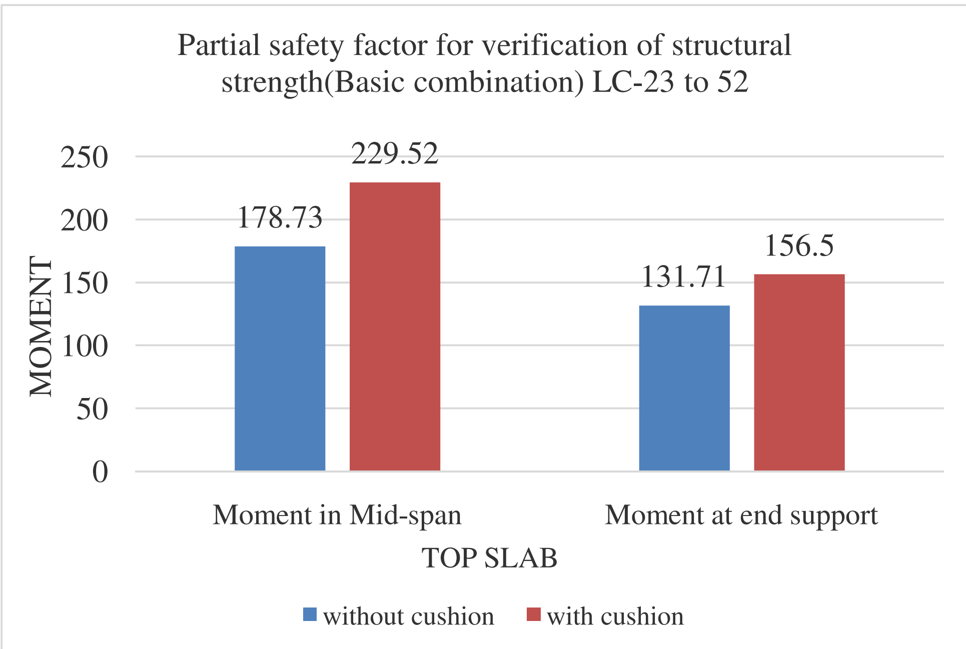




Idealised Structure for Staad analysis



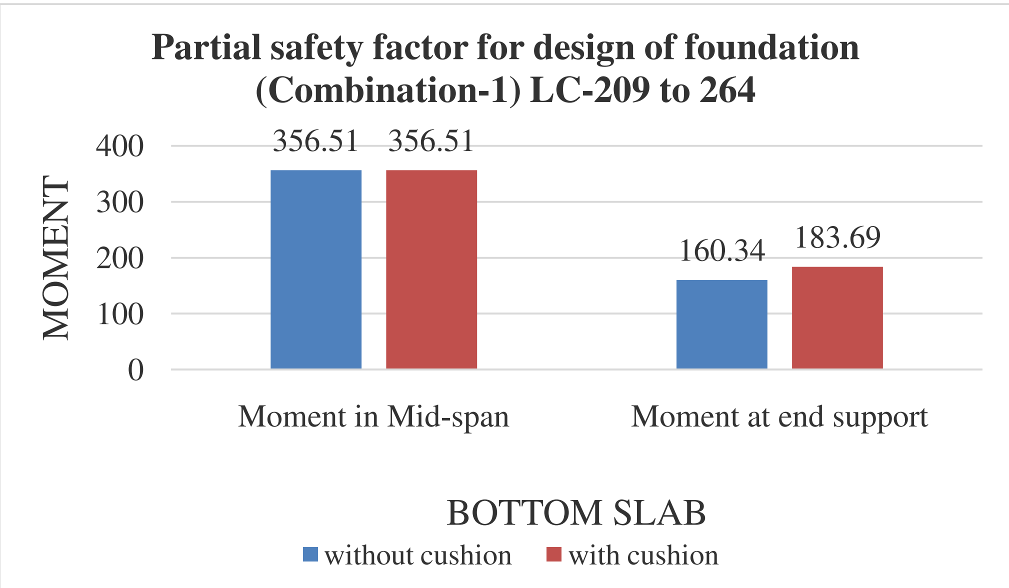
Maximum Shear Force and Bending Moment from Staad Pro



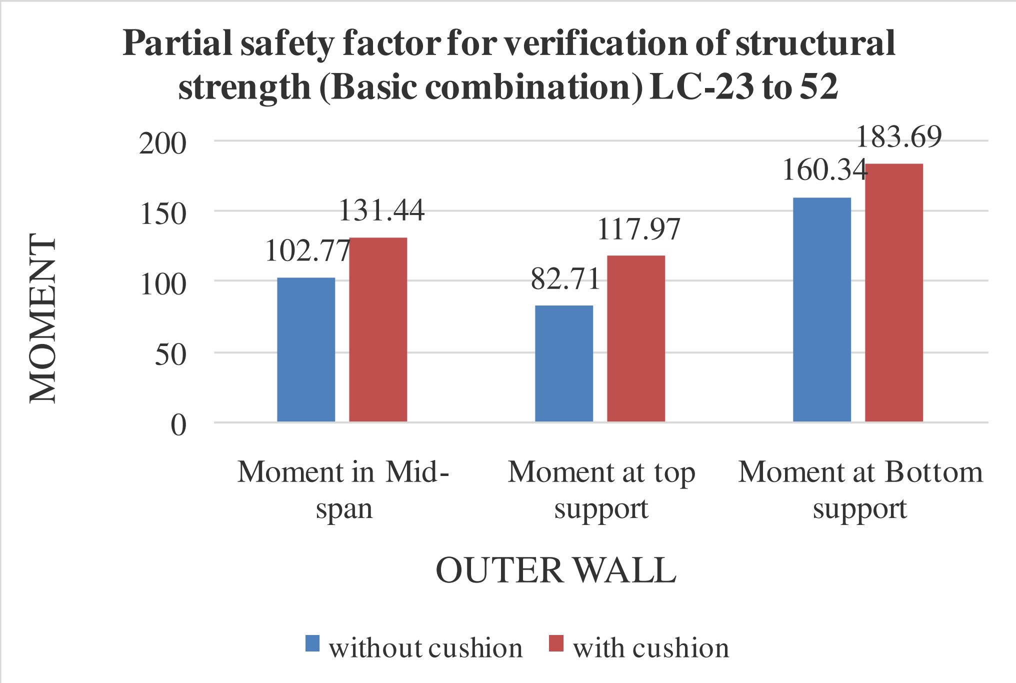
Max. Bending Moment for Top Slab (Basic combination)

Summary of Design moments with cushion

Dimension of Cell	TOP SLAB		BOTTOM SLAB		OUTER SLAB		
Load Case	Moment in Mid-span	Moment at end support	Moment in Mid-span	Moment at end support	Moment in Mid-span	Moment at top support	Moment at Bottom support
	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m	kN-m
Partial safety factor for verification of structural strength (Basic combination) LC-23 to 52	229.52	156.50	-	-	131.44	117.97	183.69
Partial safety factor for verification of structural strength (Accidental combination) LC-53 to 84	148.49	97.16	-	-	85.94	77.98	119.62
Partial safety factor for verification of Serviceability limit state (Rare combination) LC-85 to 144	162.66	111.30	272.47	132.46	93.40	85.73	132.46
Partial safety factor for verification of Serviceability limit state (Frequent combination) LC-145 to 204	148.49	96.55	249.61	118.98	85.94	77.37	118.98
Partial safety factor for verification of Serviceability limit state (Quasi-permanent) LC-205 to 208	105.98	59.61	143.84	86.14	48.83	73.72	86.14
Partial safety factor for design of foundation (Combination-1) LC-209 to 264	-	-	356.51	183.69	-	-	-
Partial safety factor for design of foundation (Combination-2) LC-265 to 320	-	-	365.99	144.62	-	-	-



Max. Bending Moment for Bottom Slab (Combination-1)



Variation of Max. Bending Moment for outer wall (Basic combination)

6. CONCLUSION –

1. Staad Pro will show the entire study and behavior of bridge structure under different IRC loading conditions.
2. A bridge structure can be constructed economically with the help of the software.
3. The basic combination of loading vehicles is the most critical instance of maximum BM, since this is the loading that results in maximum BM
4. Load positions along a longitudinal edge affect shear stress at a reference point.
5. As the distance between edge and 2.7 m from RHS is varied, the absolute maximum total deformation (moment) first increases, and then decreases while the distance from RHS to edge is changed.
6. As the size of the box structure is reduced, the total deformation, and the shear stress at a reference point decreases.
7. Bending moment reaches its highest value at the center, and shear force reaches its highest value at the support.
8. With a cushion, the Bending Moment and Shear Force are higher than without.

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