Design, Analysis & Cost Comparison of Box Culvert By Using GFRP & HYSD Bar Using Software (As Per IRC: 137-2022 Guidelines)

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***Abstract*—This study presents a comprehensive comparison between Glass Fiber Reinforced Polymer (GFRP) and High Yield Strength Deformed (HYSD) bars in the design, analysis, and cost evaluation of box culverts. The objective is to investigate the structural performance and cost-effectiveness of these two materials in culvert construction using staad pro software.**

***Index Terms*—Design Analysis, Cost Comparison, Box Culvert**.

I. INTRODUCTION

This study aims to explore and compare the design, analysis, and cost implications of box culverts constructed using GFRP and HYSD Bar, adhering to the IRC: 137-2022 Guidelines. By leveraging software tools tailored for structural engineering analysis, a comprehensive assessment will be conducted to evaluate the performance of each material in different scenarios.

The Indian Road Congress (IRC) provides comprehensive guidelines and standards for the design, construction, and maintenance of roads and bridges in India. The IRC: 137-2022 Guidelines specifically address the design aspects of box culverts, encompassing various parameters such as loading conditions, structural analysis methods, and material specifications.

The outcomes of this research will contribute to the body of knowledge regarding the application of advanced materials in civil infrastructure projects, particularly in the context of box culverts. Additionally, the cost analysis conducted in this study will aid decision-makers in making informed choices regarding material selection, considering both technical and economic factors.

A. Objectives

- To conduct a comprehensive cost comparison between box culverts constructed with GFRP bars and those with HYSD bars, considering both initial construction costs and long-term maintenance expenses.
- To ensure all designs meet or exceed safety standards required by IRC: 137-2022 and other relevant regulations.

B. Scope of work

- To compare the design, structural performance, and cost-effectiveness of box culverts constructed with Glass Fiber Reinforced Polymer (GFRP) bars versus High Yield Strength Deformed (HYSD) bars.
- Select appropriate engineering software tools capable of modelling and analyzing box culverts using both GFRP and HYSD bars (e.g., STAAD Pro.)

II. LITERATURE REVIEW

A. Analysis And Design of Single Cell Rcc Box Type Vup by Staad-pro. Hardeep pilania 2Rajeev Singh Parihar 3Abhay Kumar Jha, 4Barun Kumar, 5Rajesh Misra (ISSN: 2320-2882)

- The design of the RCC box is comprehensively addressed through the consideration of three distinct load cases. The calculated values for design moments and other parameters closely align with those obtained through manual calculations for these load cases. The highest shear forces are observed at the corners of the top and bottom slabs when the RCC box is fully loaded, with the top slab bearing both the dead and live loads.

B. Rcc Box Culvert - Methodology and Designs Including Computer Method (B.N. Sinha & R.P. Sharma).

- Box culverts used for cross drainage under high embankments offer several advantages over slab culverts, by extending the projection of the base slab, the load is effectively distributed, ensuring that the base pressure remains within the safe bearing capacity of the soil.
- As a result, the box culvert does not require complex foundations and can be easily installed on soft ground by increasing its base slab projection.

C. To Study of a Box Culvert for Semi-Arid Zone for Improvement of Life Span and it's Cost Analysis, Talha Rahim, Volume-1, Issue-12, December-2018.

- The main objective of this study is to determine the most stable and load resisting structure. To determine the costing of RCC& PCC cutoff and curtain wall.
- To compare PCC and RCC Cutoff and Curtain wall in terms of Life span Stability and costing, Seepage pressure is less in box culvert with RCC cutoff & curtain walls.

D. Analysis and Design of Box Culvert: Roshan patel & sagar jamle. Dept. of civil Engineering, Volume-5, Issue-01, April-2019.

- Box culverts are available in a variety of materials, sizes, and shapes, with concrete hollow box culverts standing out as the most durable and cost-effective option.
- Designing and analyzing these structures not only saves time and money but also enhances road planning and management while minimizing risks, especially when selections are made based on weather conditions.

III. METHODOLOGY

We carried out the following steps to achieve our objectives:

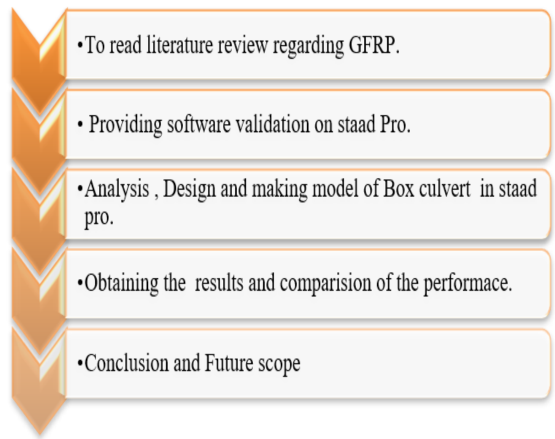

Fig. 1. Process of Work

- To read literature review of different journals & authors from website and try to study deep in detail of GFRP rebar and their properties.
- Analysis Model preparation in Staad. Pro. And trying to get results of shear force and bending moment etc.
- In this research we will try to conclude a G.F.R.P. material to considered for making it composite design. This material contains glass as the supporting segment for the polymer network. It has high thickness and medium weight, additionally more affordable as contrast with other material.

IV. EXPERIMENTAL PROGRAMEE

A. Analyse and design of a box culvert for size 2 x 3.0 x 3.50 size

Table: 1 Given Data & Assumptions Size: 2.0 X3.0x3.50

No. of Cell	2	
Width of Slab	12.5	m
Clear Length	3	m
Clear Height	3.5	m
Width of Crash Barrier/ Kerb	0.5	m
Top Slab Thickness	0.45	m
Bottom Slab Thickness	0.45	m
External Wall Thickness	0.42	m
Inner Wall Thickness	0.35	m

Wearing coat thickness on Top Slab	0.075	m
Filling Height (Cushion)	0	m
Main diameter of steel	16	mm
Clear Cover Top Slab	50	mm
Clear Cover	75	mm
Grade of Concrete	25	
Density of Concrete	2.4	t/m3
Density of Wearing Coat	2.2	t/m3
Density of Filling Material	2	t/m3
Grade of Steel	500	
Effective depth of Slab	0.392	m
Effective Length	3.385	m
(a) Clear Span + Width of Wall	3.385	m
(b) Clear Span + effective Depth	3.392	m
Total Width of Box (C/C)	6.77	m
Effective Height of Box	3.95	m
Bottom Slab Projection	0.3	m
Total Width of Box at bottom	7.79	m
Angle of Skew	0	°
Box in Straight	Straight	
SBC of Soil	15	T/m2

- One of the key codes used in the design of box culverts in India is IRC: 106-2017, titled "Guidelines for the Design of Small Bridges and Culverts." This code covers various aspects of bridge and culvert design, including structural design, and construction specifications. It provides detailed guidelines for the design of box culverts based on factors such as traffic loads, soil conditions and material specifications.
- One of the key documents that might be relevant to box culvert design is IRC: 112-2011, titled "Code of Practice for Concrete Road Bridges." While this code primarily focuses on concrete road bridges, it may contain provisions or guidelines that are applicable to box culverts, especially those made of concrete.

B. Modelling of Box culvert in STAAD Pro.

- To model a box culvert in STAAD.Pro and obtain the output of the shear force (SF) and bending moment (BM) diagrams.
- As per the above data geometry of the box culvert including its Dimension and loading condition output of staad model have been mention below.

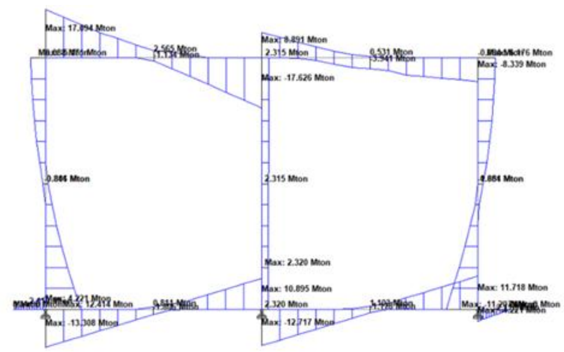

Fig. 2. Model Of Two Cell showing S.F. Diagram

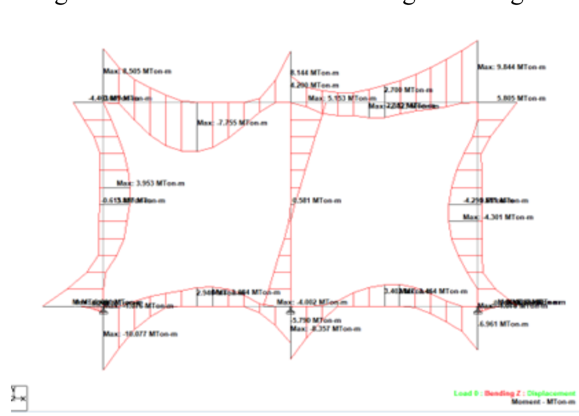

Fig. 3. Model Of Two Cell showing U.L.S. Diagram

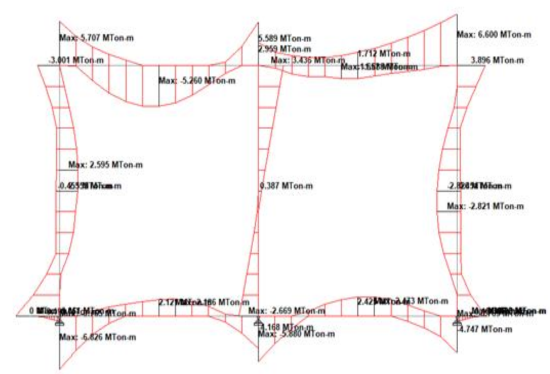

Fig. 4. Model Of Two Cell showing RARE Diagram

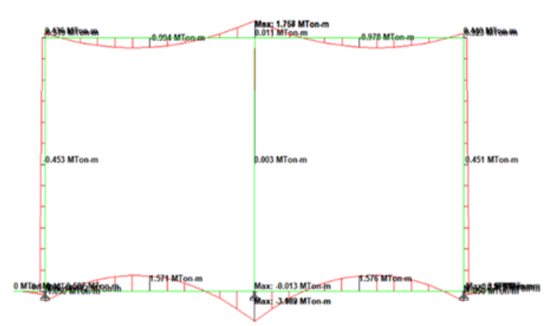

Fig. 5. Model Of Two Cell showing QUASI.Diagram.

Table: 2 Results of Sf. And Bm. From Staad Pro

Member	Section	Design Moments (Mt)			Design Shear
		Ultimate Limit State	Rare Combination	Quasi Combination	Ultimate Limit State
		T.m	T.m	T.m	T
Top Slab	MID (+ve)	7.76	5.26	0.99	17.626
	Support (-ve)	9.84	6.60	4.78	
Bottom Slab	MID (+ve)	3.40	2.43	1.58	13.308
	Support (-ve)	10.08	6.83	4.44	
Vertical Wall(outer)	MID (+ve)	4.30	2.82	2.73	12.414
	Support (-ve)	9.00	6.06	3.96	
Vertical Wall (Inner)	MID (+ve)	0.58	0.39	0.00	2.320
	Support (-ve)	5.15	3.44	0.01	

C. Reinforcement area provided as per HYSD and GDRP bar.

Table: 3 Area Provided as Per Hysd Bar

COMPONENT		Bar Dia	Spacing	Bar No	Area Req.	Area Pro.	Check
Top Slab	+ve	16.00	160.00	9.00	571.00	1256.64	Hence OK
		0.00	160.00	NA			
	-ve	16.00	160.00	10.00	570.75	1256.64	Hence OK
		0.00	160.00	11.00			
Shear Check							Hence No Shear
Distribution Steel		8.00	160.00	14.00	114.15	314.16	Hence OK
Bottom Slab	+ve	16.00	160.00	4.00	535.00	1256.64	Hence OK
		0.00	160.00	NA			
	-ve	12.00	160.00	1.00	588.16	1197.73	Hence OK
		10.00	160.00	2.00			
Shear Check							Hence No Shear
Distribution Steel		8.00	160.00	17.00	117.63	314.16	Hence OK
External Wall	-ve	16.00	160.00	3, 5	568.00	2513.28	Hence OK
Distribution Steel		8.00	160.00	15, 26	113.60	314.16	Hence OK
Shear Check							Hence No Shear
Internal Wall	-ve	10.00	160.00	6.00	451.00	981.74	Hence OK
Distribution Steel		8.00	160.00	16.00	90.20	314.16	Hence OK
Shear Check							Hence No Shear

Table: 4 Area Provided as Per Gfrp Bar

COMPONENT		Bar Dia	Spacing	Bar No	Area Req.	Area Pro.	Check
Top Slab	+ve	12.70	240.00	9.00	512.00	527.82	Hence OK
		0.00	240.00	NA			
	-ve	12.70	240.00	10.00	511.75	527.82	Hence OK
		0.00	240.00	11.00			
Shear Check							Hence No Shear
Distribution Steel		6.30	300.00	14.00	102.35	103.91	Hence OK
Bottom Slab	+ve	9.50	210.00	4.00	326.00	337.53	Hence OK
		0.00	210.00	NA			
	-ve	9.50	500.00	1.00	481.33	479.30	Hence OK
		9.50	210.00	2.00			
Shear Check							Hence No Shear
Distribution Steel		6.30	405.00	17.00	76.87	76.97	Hence OK
External Wall	-ve	9.50	405.00	3, 5	375.00	350.04	Increase Steel

Distribution Steel		6.30	405.00	15, 26	75.00	76.97	Hence OK
Shear Check							Hence No Shear
Internal Wall	-ve	6.30	405.00	6.00	269.00	153.94	Hence OK
Distribution Steel		6.30	405.00	16.00	53.80	76.97	Hence OK
Shear Check							Hence No Shear

D. Cost comparison for HYSD & GFRP Bar.

Type	Steel (Mt)	Rate (Mt)	Total Cost (Rs)
Hysd	10.88	78015.14	848804.76
Gfrp	3.91	191600.8	749159.13
Total Diff. Of Cost			99645.63

V. CONCLUSION

- Based on the provided data, the comparison between GFRP and HYSD steel bars reveals a significant cost difference. GFRP, with a lower quantity of 3.91 MT but a higher rate of ₹191600.80 per MT, resulted in a total cost of ₹749159.13. On the other hand, HYSD, with a higher quantity of 10.88 MT and a lower rate of ₹78015.14 per MT, led to a total cost of ₹848804.76. The difference in total cost between the two types of steel bars amounts to ₹99645.63.
- HYSD bars typically provide more area for reinforcement compared to GFRP bars due to their larger diameter and higher density. GFRP bars, being less dense and having smaller diameters, offer less area for reinforcement compared to HYSD bars.

VI. FUTURE SCOPE

- To investigate alternative approach to use GFRP as shear reinforcements other than stirrups.
- To investigate and compare the performance of GFRP with different percentage of reinforcement.
- To find ways to improve fracture performance of Concrete reinforced with GFRP rebars.
- To compare the performance of specimen reinforced with GFRP and Steel under harsh environmental conditions.

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