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Analysis of RC Bridge Decks for National and International Standard Loadings Using Graphical user interfaces method

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Abstract: **This article provides the graphical user interface (GUI) for analysis and design of R.C simple span bridges. The GUI (Graphical User Interface) is developed by using MAT LAB programming. The GUI provides the analysis and design of an R.C solid deck slab and R.C T-beam deck slab bridges. The bridges are analyzed for subjecting loads as a one dimensional structure by using finite element method and design is carried out according to I.S specifications. The analysis is carried out for dead loads, IRC live loads, earth pressure, water pressure and seismic force. The GUI contains specified inputs required for analysis and design of the selected bridge structure. The output contains analysis results such as moments, axial forces, shear forces, deformations and design results such as reinforcement detailing of bridge structure. From the research it can concluded that the analysis can be done for any span of bridge, grade of concrete and grade of rebar. Hence, this article may help the structural engineer to analyze and design R.C simple span bridges.**

Keywords: **GUI, Simple Span Bridges, Solid Deck Slab Bridge, T-Beam Deck Slab Bridge, Finite element method.**

I. INTRODUCTION

A bridge is a structure having a total length above 6m between the inner face of the dirt walls to carry the traffic loads above the natural obstruction (streams, rivers etc.) or artificial obstructions. The superstructure of the bridge comprises of the deck slab and supports. On the simple span bridge, the deck slab lay specifically on bearings through which forces and moments are transferred to the sub-structure. The deck slab bridge comprises superstructure as deck slab and supports as abutments. Fig. 1.1 shows the typical sections of the solid deck Slab Bridge which contains components such as deck slab wearing coat, abutment and footing. The solid deck slab casting is up-front with simple, and the concrete moulds are extremely easy to build. Solid volumes might be expanded. The T-beam deck Slab Bridge include deck slab sections supported by longitudinal girders are supported by abutments. The girders give the stiffness and strength essential for the length, and empower the section to be moderately thin and inexpensive to build. The details are required for the design of the abutment and substructure is span of bridge.

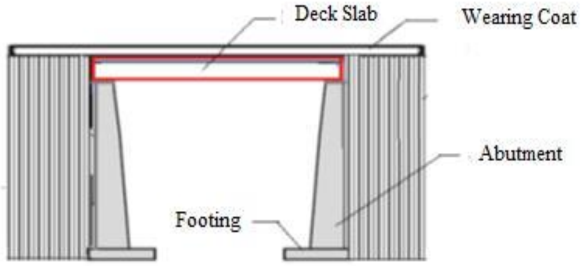

Fig 1.1: Longitudinal section of Solid Deck Slab

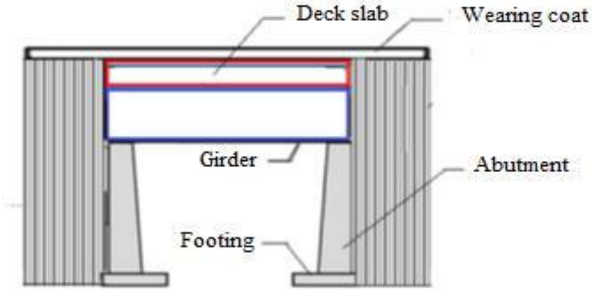

Fig 1.2: Longitudinal section of Solid Deck Slab Bridge

Fig-1.2 shows the typical sections of the T-beam deck slab bridge, which contains components such as, deck, slab, three longitudinal girder, wearing coat, abutment and footing. The required number of girders used is needy upon a few aspects, for example, the depth of the slab deck and the slenderness of the girder. Moulds for cast in-situ girder and section of slab deck are more convoluted than that essential for solid concrete slab decks. The requirements for the analysis and design of the superstructure and substructure are span, carriageway width and reduced levels etc.

2. OBJECTIVES

The primary objective of the present Research is,

“To develop software to analyse and design an RCC solid slab and T-beam culvert/bridge”.

To achieve the above primary objective following steps are followed:

- Generation of graphical user interface (GUI) in MATLAB for input of geometric and material property data on bridge/culvert under study.
- Coding in MATLAB for analyses of bridge “slab/culverts” structural components using finite element method for the data given in GUI.
- Coding in MATLAB for the design of “slab/culverts” structural components using Indian standard specifications for the data given in GUI.
- Extracting the analysis result obtained from MATLAB coding pictorially in the form of figures and tables.
- Extracting the design result obtained from MATLAB coding pictorially in the form of figures and tables.

3. LITERATURE REVIEW

B.N. Sinha et al. [1] conducted a work on the culverts, which are built under an earth mound for passage of a watercourse, like the watercourses through the ridge as road banks cannot be allowed to block the waterway. The structural design of the box culvert is carried out. The structural design includes the concern of load cases (box with empty, full, surcharge loads, etc.). The components of the structure are required to be designed to resist the extreme bending moment and shear force and specified a full conversation on the requirements in the Codes, considerations and validation of all the above aspects of design. *C.V. Alkunte et al.* [2] presented the project on the piers, exposed to different loads in along directed and horizontal direction, like wind load, topical water power, seismic force, etc. I.R.C code regulations were used for the assessment and the effect of different forces on the bridge pier. A parametric study is explained for the effectiveness by IRC living load for different heights of the pier and spans of the bridge for the different shape of the pier. In the end, effect of IRC the living load is studied for different heights of the pier and spans of the bridge for the different shape of the pier. *S.V.Dinesh et al.* [2013] presented the comparison of the effect of different standard loadings on a set of reinforced concrete bridge decks using the finite-element method was attempted. The parameters investigated include the feature ratio (span/width) and IRC vehicle loading. The outcomes show that two IRC standard loading were 5 to 15% maximum difference in deflection and longitudinal bending moment. The maximum vehicle axle-load of IRC standards found to be 0.45 times lower than that of Euro standards. Hence, 0.58 to 0.55 times decreases the numerical value of response parameters of the structure.

4. LOADS ON BRIDGE

As per IRC 6-2000, the loads are provided for analysis of the bridge structure, such as dead loads, IRC live loads, earth pressure and seismic force. In this research, IRC class AA tracked vehicle live load is considered. The Fig 1.3 shows that the nose to tail length for two successive vehicles shall not exceed 90 m and the spacing between two transient or passage vehicles, a maximum load of vehicle for single wheel. All dimensions are in meters and loads are in tonnes.

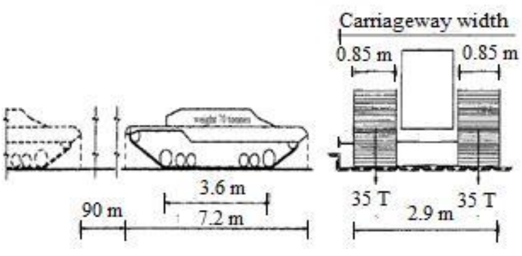

Fig 1.3: IRC Class AA tracked vehicle.

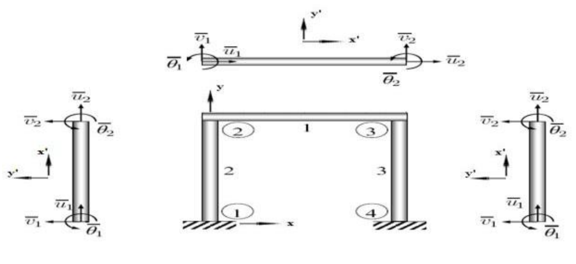

Fig 1.4: 2D Solid Deck Slab Bridge in the form of Frame element.

5. ANALYSIS OF SIMPLE SPAN BRIDGE BY FINITE ELEMENT METHOD

The RCC Solid Deck Slab Bridge is modelled as 2-dimensional with frame element as shown in above Fig 1.4. The frame element has 3 degrees of freedom per node such as vertical deformation, axial deformations and rotations. The Fig. 1.4 shows, the frame element can carry axial force, transverse shear force and bending moment in the global co-ordinate system. Where, Where, u = Horizontal displacement, V = Vertical displacement, θ = Slope. From Fig 1.1, the various bridge components are discussed with respect to its sectional and material properties. The bridge structure is analysed using 2-dimensional frame element. Hence, the length of the structure is assumed as 1 m. The dimensions of cross section of the deck slab and girders are initially assumed as per IS specifications or from experience and to ensure safety factor checks are done in the design processes as per IS specifications.

6. DESIGN OF BRIDGE STRUCTURE

By using analysed results, the components of slab culvert are designed manually according to Indian Standard specifications. The designed components are as deck slab, abutment and footing. The working stress method is used for designing the deck slab as per IRC 21-2000. The deck slab is flexural member; hence it is designed for maximum bending moment to get required reinforcement details. The shear resistance checked and designed for shear reinforcement if required. The grade of concrete is M_{35} and Fe-500 is considered for design. According to the given grade of concrete and rebar, from Table-9 and Table-10, IRC 21-2000, permissible stress in concrete is 11.67 N/mm^2 and the permissible stress in rebar is 200 N/mm^2.

Graphical user interfaces (GUI) provide point-and-click control of software applications, eliminating the need to learn a language or type commands in order to run the application. MATLAB apps are self-contained MATLAB programs with GUI front ends that automate a task or calculation. The GUI typically contains controls such as menus, toolbars, buttons, and sliders. Many MATLAB products, such as Curve Fitting Toolbox, Signal Processing Toolbox, and the Control System Toolbox, include apps with custom user interfaces. The Graphical representation of any algorithm is defined as a flow chart as shown in Fig 1.5.

7. VALIDATIONS BY STAAD PRO TOOL

The importance of this research is to validate the results of numerical analysis with respect to that of in STAAD Pro and GUI. The Solid Deck Slab Bridge already numerically analysed for the IRC Class AA Tracked live load placed as near to support. Hence, to validate the numerical analysis results, the same structure subjected to the IRC Class AA Tracked live load placed as near to support is modelled and analysed in STAAD Pro and then validated results of both the numerical and analysis by the STAAD Pro. The analysis results indicated that the numerical analysis and STAAD Pro software are found to be almost similar. Therefore the above numerical analysis is observed to be correct for the assumed given slab culvert.

8. RESULTS AND DISCUSSION

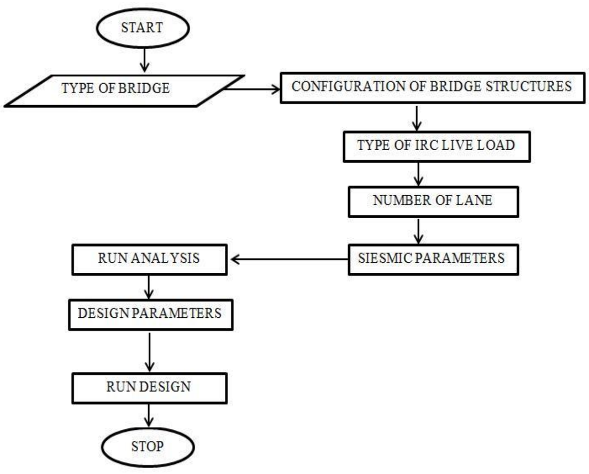

Fig 1.5: Flow chart of the designed algorithm.

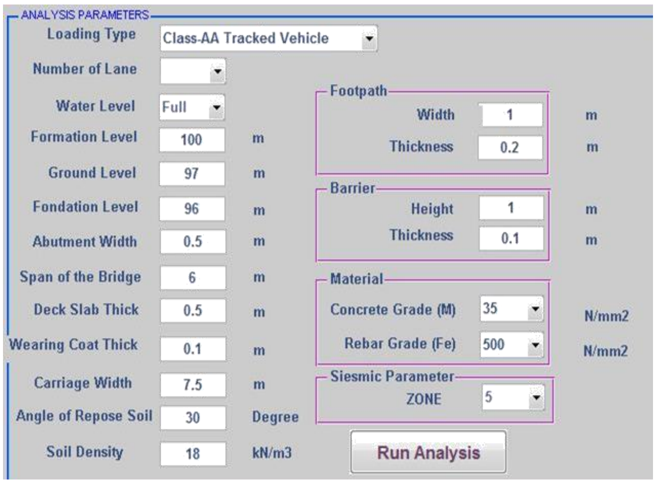

Fig 1.6: Input page for analysis of Solid Deck Slab Bridge

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8.1 Modules of GUI:

The GUI helps the user to select the type of simple span bridge require for construction. The Fig 1.6 shows the GUI, that gives moments, shear force, axial force, length and interconnected nodes of each discrete beam element of part-1 analysis for Solid Deck Slab Bridge. Fig 1.7 shows part-1 analysis on the GUI. The part-1 analysis gives the details of various loads acting on the structure, such as dead loads, earth pressure, water pressure and seismic force and gives the length of the each finite beam elements, which are connected between successive six nodes. The Fig 1.8 shows the GUI, that gives moments, shear force, axial force, length and interconnected nodes of each discrete beam element of part-1 analysis for "Solid Deck Slab Bridge". The Fig 1.9 shows the GUI, that gives moments, shear force, axial force, length and interconnected nodes of each discrete beam element of part-2 analysis. Fig. 1.10 shows the GUI, which contains various input data essential for the design of "Solid Deck Slab Bridge" components, such as deck slab, abutments and footings. Fig 1.11 shows the GUI that contains reinforcement detailing, section properties, length of "Solid Deck Slab Bridge" components, reduced levels of bridge, span of the bridge, and height of the bridge.

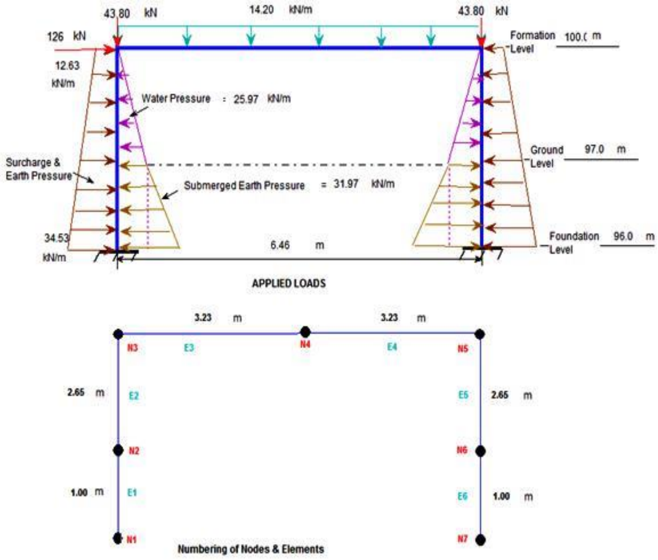

Fig 1.7: Part-1 analysis in GUI for Solid Deck Slab Bridge

	Length m	Nodes	HSF kN	VSF kN	BM kNm
E1	1	1	62	57	132
		2	-63	-56	-77
E2	2.6500	2	62	55	76
		3	-63	-36	49
E3	3.2300	3	91	18	-50
		4	-92	27	34
E4	3.2300	4	91	-28	-35
		5	-92	73	-129
E5	2.6500	5	117	91	128
		6	-118	-72	80
E6	1	6	117	71	-81
		7	-118	-69	150

BENDING MOMENT (kNm) & SHEAR FORCES (KN)

Nodes	Horizontal Deflection	Vertical Deflection	Slope
1	0	0	0
2	1.8414e-04	-4.2015e-06	-3.3777e-04
3	0.0014	-1.5335e-05	-4.1487e-04
4	0.0014	-3.9603e-04	1.5323e-04
5	0.0014	-2.8921e-05	-2.1066e-04
6	2.0742e-04	-7.9236e-06	-3.7701e-04
7	0	0	0

DEFORMATIONS

Fig 1.8: The Results of part-1 analysis for Solid Deck

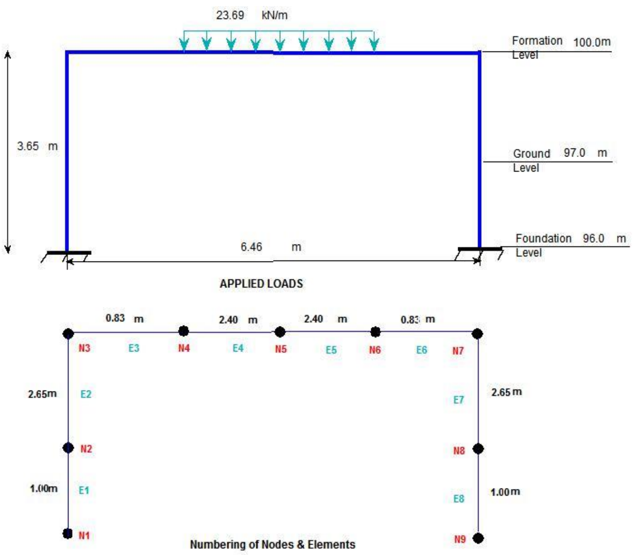

Fig 1.9: Part-2 analysis in GUI for "Solid Deck Slab Bridge".

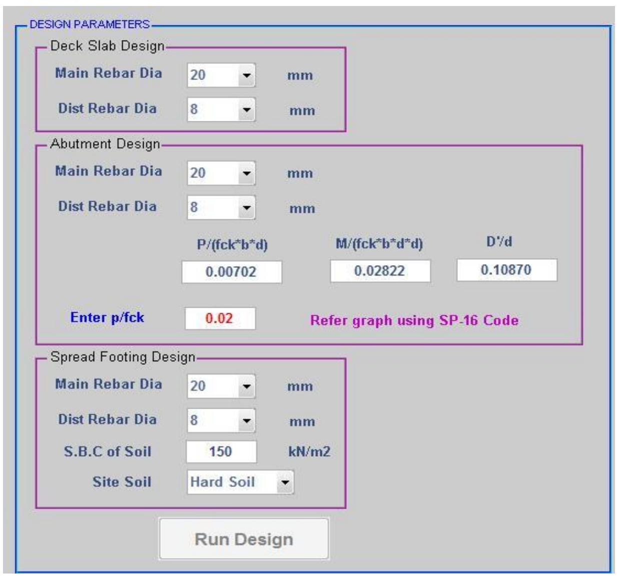

Fig 1.10: GUI for design of RC Solid Deck Slab Bridge".

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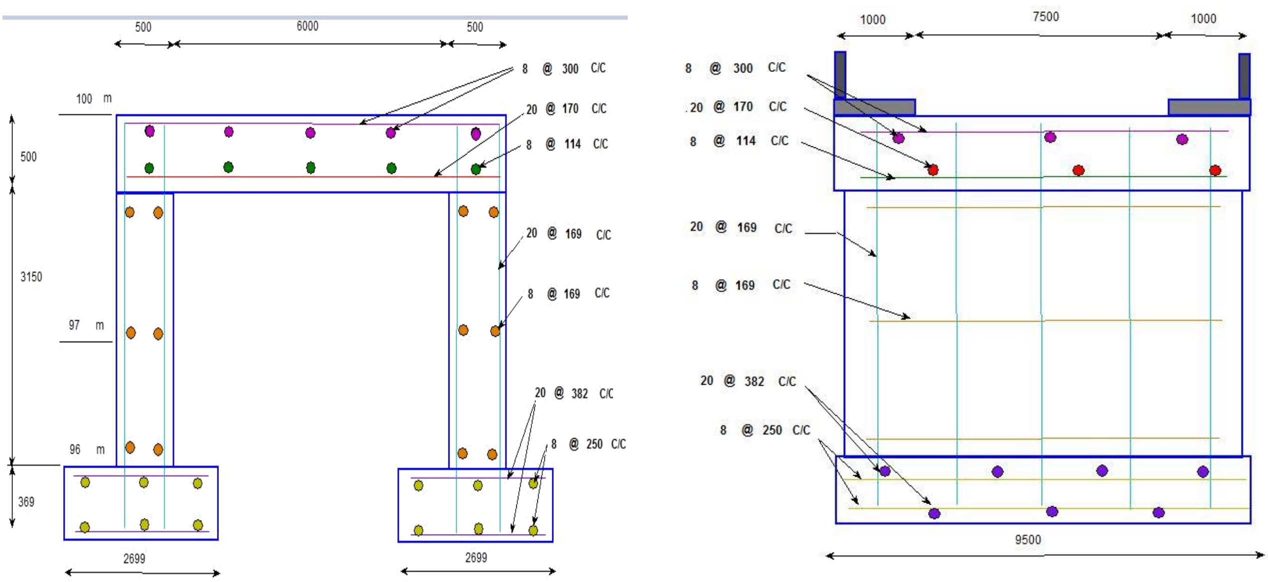

Fig 1.11: Design details in longitudinal and cross section of Solid Deck Slab Bridge [All dimensions are in mm]

Table 1: The Maximum Bending Moment and Shear Force for all applied loads by Numerical Methods

Description	Max. DL. B.M (kNm)	Max. LL. B.M (kNm)	Total B.M (kNm)	Max. DL. S.F (kN)	Max. DL. S.F (kN.)	Total S.F (kN)
Deck slab	129	58	187	73	72	115
Abutments	150	59	209	97	22	113
Footing	150	28	178			

Table 2: Shows, Analyzed Results in STAAD Pro.

Structure123 - Beam End Forces:

All / Summary / Envelope

Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
3	1 LOAD CAS	3	21.448	72.045	0.000	0.000	0.000	55.04
		4	-21.448	-15.213	0.000	0.000	0.000	49.66
4	1 LOAD CAS	4	21.448	15.213	0.000	0.000	0.000	-49.66
		5	-21.448	41.619	0.000	0.000	0.000	17.97
5	1 LOAD CAS	5	21.448	-41.619	0.000	0.000	0.000	-17.97
		6	-21.448	41.619	0.000	0.000	0.000	-51.11
6	1 LOAD CAS	6	41.619	21.448	0.000	0.000	0.000	51.11
		7	-41.619	-21.448	0.000	0.000	0.000	5.72
7	1 LOAD CAS	7	41.619	21.448	0.000	0.000	0.000	-5.72
		8	-41.619	-21.448	0.000	0.000	0.000	27.17

9. CONCLUSION

- The developed GUI (Graphical User Interface) led to the user quick and accurate analysis and design of simple span RC solid slab bridge using finite element method and Indian Standard Specifications respectively subjected to dead loads, IRC live loads, earth pressure and seismic force.
- The developed GUI (Graphical User Interface) led to the user quick and accurate analysis and design of simple span RC "T-Beam Deck Slab Bridge" using finite element method and Indian Standard Specifications respectively subjected to dead loads, IRC live loads, earth pressure and seismic force.
- The developed GUI (Graphical User Interface) gives the reinforcement detailing of a component of both RC "Solid Deck Slab Bridge"
- Validation of analysis done using STAAD Pro software gave results closer to manual results.

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