Analysis And Design of Substructure Using Midas Civil Software

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Abstract- *A bridge is a structure built to pass a physical obstacle which is usually something otherwise difficult or impossible to pass. Its construction today has achieved a worldwide level of importance and with its origin in its different types like RCC,PSC, Balanced Cantilever, Extradosed, Cable Stayed Bridges etc., it has become even more safer and aesthetic to construct in lesser period of time. In present time, Prestressed Concrete Bridge has gained a high level of popularity among the bridge construction section due to its better stability, best aesthetic versatility, strength, quality, shortened construction time, structural efficiency and serviceability. As in any structure, substructure section plays an important part to consider, hence this present paper deals with the analysis and design of substructure for PSC-I type of Bridge style. A Finite Element Analysis Software by name Midas Civil is being used for the analysis part and excel sheet for the design calculations. In addition to Midas civil and excel, Smath Studio Software is used for designing the plate elements like Well Cap, Dirt wall, Return wall.*

Keywords- RCC, PSC, Balanced Cantilever, Extradosed, Cable Stayed Bridges, Midas civil, Smath Studio Software, Well Cap, Dirt wall, Finite Element Analysis, Return wall.

I. INTRODUCTION

Substructure is that part of the bridge which supports the superstructure and distributes all bridge loads to below ground bridge footing. Here we will come across two types of substructure sections namely Abutment Type and Pier type which are selected on the basis of different criteria like retaining the soil, depth of foundation etc.

1.1 Primary notion of Substructure

Mostly taking into account of the traffic conditions & hydraulic data, configuration of the structure being finalized and the same is designed & analyzed with proper loading of different class of vehicles. Different types of pressure are laid on the structure like Earth pressure, Wind Pressure, water current, Hydrodynamic pressure, braking force and most importantly a base pressure is performed to check whether the existing soil strata can withstand the load of the bridges or not.

1.2 Type of Substructure Sections

In this present case, as we have considered a structure of dimension 5x48 (5 Span with 48m length each), hence in this case we come across two types of substructure sections which will be analyzed and designed: -

1. Abutment Type Substructure
2. Pier Type Substructure

Abutment Type is used at the start and end location of the bridge which functions of retaining the earth work around the corner, whereas the Pier type is used in the intermediate portion where it encounters water current pressure. Both are consolidated with M35 grade of concrete. As shown in the figure-1, *A1 & A2* are the abutment type and *P1 to P4* are of pier type.

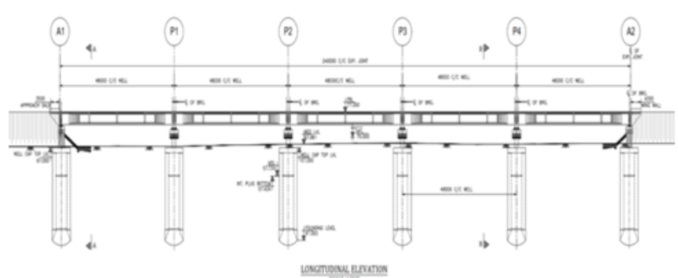


Figure 1: Bridge (5x48)- 240m

1.3 Configurations Details

In this present case, we have considered a Pre-Stressed Concrete -I Bridge of total length 240 meters dividing it in 5 spans of 48m each (5x48).

Table 1: Configuration Details

Sr. No.	Description	Details
1	Total Length of Bridge	240 m
2	Total Width of Bridge	17.8 m
3	No. of Span	5
4	Type of Abutment	Fix
5	Type of Well	Circular
6	Diameter of Well	7.5 m
7	Highway Lane	3 lanes

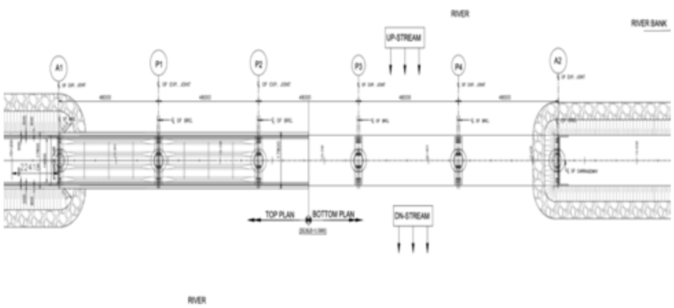


Figure 2: BridgeSection across River

II. METHODOLOGY

The substructure is configured as per the required span & width of bridge and designed for different loadings coming from the superstructure section which in turn is designed for IRC loading with live load at different positions of the structure. Once the loading is laid on the substructure parts like Well, Well Cap, Abutment, Pier, Return Wall etc. in the Midas software, the same is given with boundary conditions at the well cap.

The Model is checked for any errors and analysis process is initiated. After this each substructure part 's final stresses, principles, deflection., etc. are tabulated for further design part in excel sheet and Smath Sheet.

Flowchart of Methodology

- Load values from Superstructure are noted
- Substructure is Modelled to considered configuration
- Loads are applied consisting live load, dead load, earth pressure etc.
- Analyzing is initiated and structure is analyzed
- Results are obtained in form of deflection, reaction, bending moments, shear force and stresses etc.,
- Obtained results are taken for design part
- Total reinforcement required for the structure is tabulated.

2.1 Considered Details from Superstructure

The details noted from the superstructure model are presented as below

Table 2: Loads from Superstructure

Sr. No.	Description	Details	
		Abutment Type	Pier Type
1	Dead Load of Superstructure	852.38 t	1704.77 t
2	Dead Load of Crash Barrier	16.62 t	16.62 t
3	Dead Load of Wearing Coat	15.07 t	15.07 t

Load	Abutment Type (At Corners) (tonne)			
	R1	R2	R3	R4
Class A	40.49	7.53	1.64	-4.36
2L-Class A	54.41	33.63	6.19	-3.64
3L-Class A	57.35	47.32	28.87	2.35
4L-Class A	55.93	48.91	49.22	27.14
Class 70R	54.71	30.35	2.84	-4.39
2L-Class 70R	63.52	66.77	34.17	2.57
1L-ClassA+Class 70R	53.89	42.51	31.30	-2.05
2L- Class A+Class 70R	53.23	41.63	52.83	22.45
Special Vehicle	42.33	100.18	85.22	34.22
LL for Max R	**55.93**	**48.91**	**49.22**	**27.14**
LL for Max MT	**54.71**	**30.35**	**2.84**	**-4.39**

Load	Pier Type (In the Middle) (tonne)							
	R1	R2	R3	R4	R5	R6	R7	R8
Class A	28.89	-1.44	0.58	-0.37	19.76	4.26	0.73	-2.28
2L-Class A	33.26	22.59	-0.39	-0.12	27.03	16.42	3.49	-1.99
3L-Class A	32.37	31.81	19.80	-0.98	28.63	23.26	14.19	1.32
4L-Class A	32.72	29.19	35.75	13.01	27.80	24.44	23.89	13.75
Class 70R	59.76	33.98	-1.28	-2.24	0.00	0.00	0.00	0.00
2L-Class 70R	63.04	80.49	36.91	-0.01	0.00	0.00	0.00	0.00
1L-ClassA+Class 70R	21.05	22.20	19.83	3.07	43.20	28.70	5.06	0.15
2L- Class A+Class 70R	20.43	21.18	27.78	20.19	42.58	29.42	20.65	10.10
Special Vehicle	15.33	78.96	64.58	11.60	18.22	71.39	59.75	13.93
LL for Max R	32.72	29.19	35.75	13.01	27.80	24.44	23.89	13.75
LL for Max MT	59.76	33.98	-1.28	-2.24	0.00	0.00	0.00	0.00

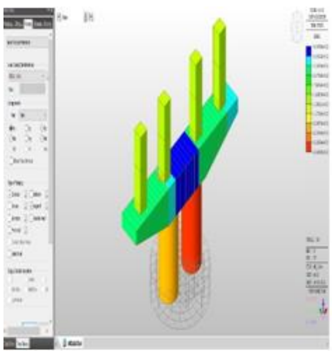
III. PROCEDURE FOR DESIGN AND ANALYSIS

- Existing structure if available is checked for its strength and present data is collected.
- Hydraulic Data is tabulated
- Type of Bridge structure is opted as per the site conditions.
- Geotechnical Investigation is done at Pier and Abutment Location.
- Superstructure is designed for required width of deck
- All loads coming from Superstructure and different kinds of pressure are noted
- All details are tabulated in the excel sheet and substructure configuration if fixed

- Substructure is modelled in Midas Civil
- Loads are applied on each part of the structure
- Model is initiated for Analyzing and results are tabulated
- Results like stresses, bending moment, shear force etc. are noted
- Excel sheet records all the results and further does the work of designing
- After designing, different checks are performed for safer stability
- Reinforcement details are received once it'sdone.

3.1 Analysis of the Substructure: -

The Substructure is modelled in the Midas Civil and the same is being analyzed by applying the loads. The behavior of the structure is shown as follows:



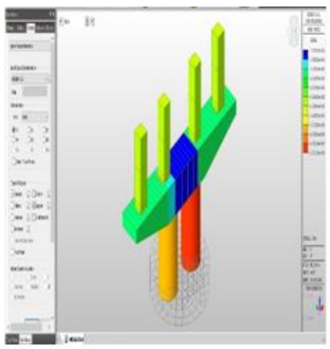
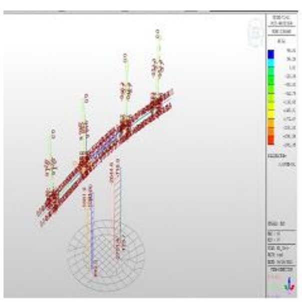


Fig 3: Ultimate Limit State Mode Fig 4: Serviceability Limit State Mode



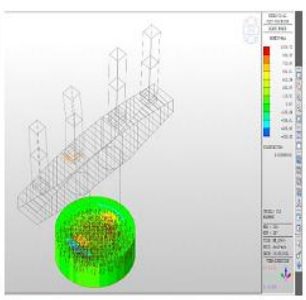


Fig 5: Deformed Pressure Diagram Fig 6: Well Cap Plate Element Diagram

Analyzed results in form of maximum bending moment, shear force etc. is tabulated as below: -

Table 3: Bending Moment for Dirt Wall from Midas Civil

	Bottom Face of Dirt Wall (+ve moment)		Top Face of Dirt Wall (-ve moment)		Shear Force
	X Direction	Y Direction	X Direction	Y Direction	
ULS	121.169	46.887	-14.731	-17.739	78.73
SLS	80.598	31.793	-10.119	-12.404	
Quasi	55.716	31.793	-10.119	-12.404	

Table 4: Vertical Forces on Abutment from Midas Civil

	Load Combination		Pz (kN)	My (kN)	Mz (kN)
SLS	Max Fx	SLS (all)	7816.4	3.23	868.92
	MaxMx	SLS (all)	6156	20842.58	307.34
	Max My	SLS (all)	5640.5	5673.47	6762.83
ULS	Max Fx	ULS (all)	10552	4.36	1173.04
	MaxMx	ULS (all)	8556.8	31338.19	367.68
	Max My	ULS (all)	7801.3	8532.3	9417.51
Quasi Permanent	Max Fx	Quasi(all)	4861.2	5.54	5252.92
	Max My	Quasi(all)	4858.9	5.54	5257.34

In the same manner results of all substructure elements are tabulated and used during the design part.

3.2 Design of Substructure:

As the required results are tabulated from the Midas Civil, now the design part is initiated as per each element of the substructure namely Abutment, Dirt Wall etc., and various checks are performed like:

1. Check for Flexure
2. Check for Shear as per IS 112:2010
3. Check for Ultimate Limit State (Stress Limitations) as per IS 112-2010

Table 6: illustrative Design Parameters considered for Well Design

Grade of Concrete		F_{ck}	=	30	MPa
Grade of Reinforcement		F_{yk}	=	500D	MPa
Grade of Steel Stirrups		F_{ywk}	=	500D	MPa
Tensile strength of concrete Table 6.5 of IRC 112		F_{ctm}	=	2.5	MPa
Partial safety factor for concrete for Basic & Seismic comb.		gm	=	1.5	MPa
Partial safety factor for reinforcement		gs	=	1.15	MPa
Design compressive strength of concrete		F_{cd}	=	$\frac{\alpha * fck}{\gamma m}$	
Factor *Cl 6.4.2.8 of IRC 112-2011*		a	=	0.67	
		f_{cd}	=	13.4	MPa
Design tensile strength of reinforcement		f_{yd}	=	434.783	MPa
Design tensile strength of reinforcement stirrups		f_{ywd}	=	434.783	MPa
Secant modulus elasticity of Concrete (Table 6.5 of IRC 112)		E_{cm}	=	31000	MPa
Elastic modulus of Steel		E_s	=	200000	MPa
Ultimate compressive strain in concrete (Table 6.5 of IRC 112)		εcu3	=	0.0035	MPa
Ultimate tensile strain in steel		εst	=	0.00217	MPa
Limiting neutral Axis to depth ratio		$\frac{\chi u,max}{d}$	=	$\frac{\varepsilon cu3}{\varepsilon cu3+\ \varepsilon st}$	
Limiting neutral Axis to depth ratio			=	0.617	

IV. CONCLUSION

- As a substructure of PSC-I Girder Bridge is analyzed and designed for total length 240m, hence in all cases, deflection and stresses are within the permissible limit
- We Can clearly make out the effectiveness of using the PSC type bridge as it gives us most of the design parameters within permissible limits of serviceability, deflection and shear compared to ordinary structure type.
- Midas Civil is the best in use software available in the market which is handy and very accurate with its results in less time
- As we get the appropriate shear force and bending moment details, the design part is made easy by this software.

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