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Analysis of a Substructure Part of Metro Structure as Per Live Data Using Analysis Tool

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ABSTRACT

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A metro system is a railway transport system in an urban area with a high capacity, frequency and the grade separation from other traffic. The Metro System is used in cities, agglomerations, and metropolitan areas to transport large numbers of people. An elevated metro system is a more preferred type of metro system due to ease of construction and also it makes urban areas more accessible without any construction difficulty. An elevated metro system has two major elements: a pier and box girder. The present study focuses on two major elements, pier and box girder, of an elevated metro structural system.

The parametric study on behaviour of box girder bridges showed that, as curvature decreases, responses such as longitudinal stresses at the top and bottom, shear, torsion, moment and deflection decreases for three types of box girder bridges and it shows not much variation for fundamental frequency of three types of box girder bridges due to the constant span length. It is observed that as the span length increases, longitudinal stresses at the top and bottom, shear, torsion, moment and deflection increases for three types of box girder bridges. As the span length increases, fundamental frequency decreases for three types of box girder bridges. Also, it is noted that as the span length to the radius of curvature ratio increases responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are increased for three types of box girder bridges. As the span length to the radius of curvature ratio increases, fundamental frequency decreases for three types of box girder bridges.

Keywords : Elevated Metro Structure, Bridge Pier, Box Girder Bridge, Direct Displacement Based Seismic Design, Performance Based Design, Force Based Design.

I. INTRODUCTION

Metro Product is utilized in metropolitan areas, agglomerations, and urban centers to move large figures of individuals at high frequency. The grade separation enables the metro to maneuver freely, with fewer interruptions and also at greater overall speeds. Metro systems are usually situated in subterranean tunnels, elevated viaducts above street level or grade separated at walkouts. A heightened metro structural product is a more preferred one because of easy construction and it makes cities readily available with no construction difficulty. A heightened metro structural system has the advantage that it's more economic than a subterranean metro system and also the construction time is a lot shorter. A heightened metro system has two major components: a pier and box girder. Viaduct or box girder of the metro bridge requires a pier to aid the each length of the bridge and station structures. Piers are built in a variety of mix sectional shapes like round, elliptical, square, and rectangular along with other forms. The piers considered for that present study have been in a rectangular mix section which is located under station structure. Box girders are utilized extensively in the making of a heightened metro rail bridge and using horizontally curved in plan box girder bridges in modern metro rail systems is very appropriate in fighting off tensional and warping effects caused by curvatures. The tensional and warping rigidity of the box girder is a result of the closed portion of the box girder. This area section also offers high bending stiffness and there's a competent utilization of the complete mix section.

Fig 1 Girder Bridge

II. Objectives of the Study

- Analysis of girder bridge using analytical application staad pro.
- Analysis of Bhopal metro line considering their dpr for phase II.
- Structural analysis considering vehicular loads.
- Effect of transverse prestressing in the analysis and design of PSC box girder.
- Structural performance includes comparison of shear force, bending moment, deflection, torsional moment, bearing reactions, quantity of reinforcement required, no of tendons required etc.

III. Summary of Literature

Nadavala Mahesh and G Tamilanban (2016) research paper concentrated on two major elements, pier and box girder, of the elevated metro structural system. Throughout a seismic loading, the conduct of merely one pier elevated bridge relies totally on the ductility and also the displacement capacity. The style of the pier was completed by both the pressure-based seismic design method and the direct displacement-based seismic design method in the study. Within the second part, parametric study conduct of box girder bridges is transported out by utilizing finite element methods. These parameters are utilized to assess the responses of box girder bridges, namely, longitudinal stresses at the very top and bottom, shear, torsion, moment, deflection and fundamental frequency of three kinds of box girder bridges. The moving load analysis is conducted for a live load of two lanes IRC 6 Class A (Tracked Vehicle) loading for the cases considered by utilizing SAP 2000. The longitudinal stress at the very top and bottom, shear, torsion, moment, deflection and the fundamental frequency is calculated and in contrast to Single Cell Box Girder (SCBG), Double Cell Box Girder (DCBG) and Triple Cell Box Girder (TCBG) bridge cases for a number of parameters viz., the radius of curvature, span length, and span length towards the radius of curvature ratio. The modelling of Box Girder Bridge was transported out using Bridge Module in SAP 2000.

In the case of the Direct Displacement Based Design Method, the selected pier achieved the conduct factors greater than the targeted Values. It's observed that because the span length increases longitudinal stresses at the very top and bottom, shear, torsion, moment and deflection increases for 3 kinds of box girder bridges. Because the span length increases, the fundamental frequency decreases for 3 kinds of box girder bridges. Also, it's noted that because the span length towards the radius of curvature ratio increases responses parameter longitudinal stresses at the very top and bottom, shear, torsion, moment and deflection are increases for 3 kinds of box girder bridges. Because the span length towards the radius of curvature ratio increases fundamental frequency decreases for 3 kinds of box girder bridges.

Vivek Gajera et.al (2019) the research paper depicted the study of seismic analysis of reinforced concrete bridge piers as per provisions of Indian Road Congress (IRC) guidelines. Seismic analysis of Reinforced Cement Concrete (RCC) bridge pier was carried out as per provisions of prevailing guideline IRC:6-2017. The base shear value of IRC:6-2017 was compared with IRC SP:114-2018 which now supersedes seismic provisions of IRC:6-2017. For analysis, different span lengths of 25 m, 30 m and 36 m were used. To assess the impact of the height of piers in earthquake analysis, various pier heights such as 10 m, 20 m and 30 m are assumed. The analysis was carried out as per Elastic Seismic Acceleration Method with consideration of different zones and importance of the bridge as per IRC guidelines. The effect of vertical ground motion was further considered in the analysis.

The results stated that in the case of the bridge crossing more than two railway lines, change in importance was clearly visible as base shear values were increased to 25% for 10 m and 20 m height of pier. The base shear value for 30 m height in IRC SP:114-2018 is 97.84 % higher than IRC:6- 2017 in the longitudinal direction and 102 % in the transverse direction. As per new provisions IRC SP:114-2018, the vertical component is independent of the horizontal component and now the vertical component depends on the time period of the superstructure. Hence, results summarized base shear and vertical forces have increased remarkably as per IRC SP:114-2018 compared to IRC:6-2017.

Step-1 Modeling of the structure using analytical applications Staad pro v8 i.

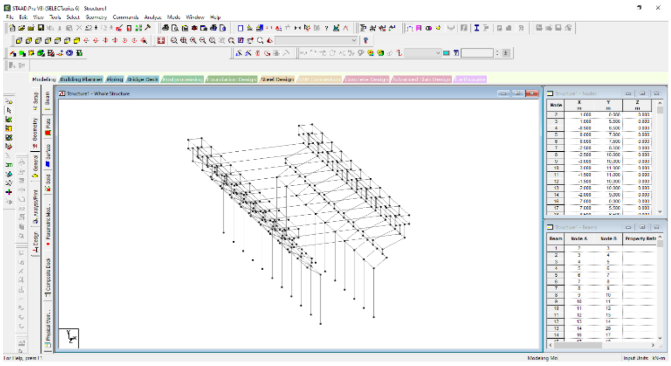


Fig 2 Modeling of structure

Step 2 Defining section property of the structure

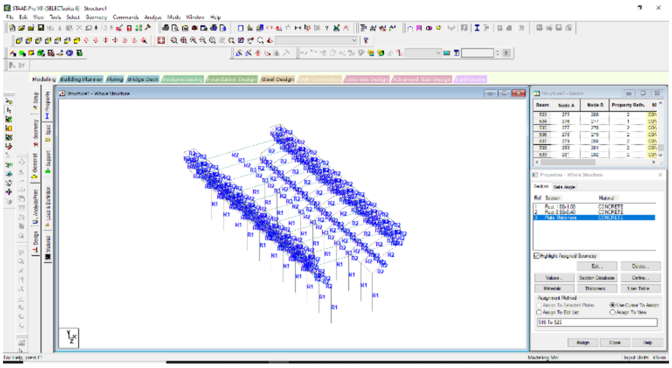
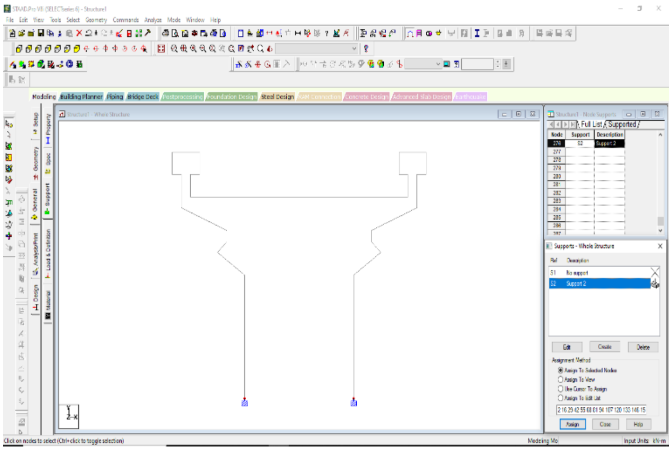


Fig 3 Defining section properties

Step 3 - Assigning fixed support at bottom of the structure



Step 4 - Defining of loads

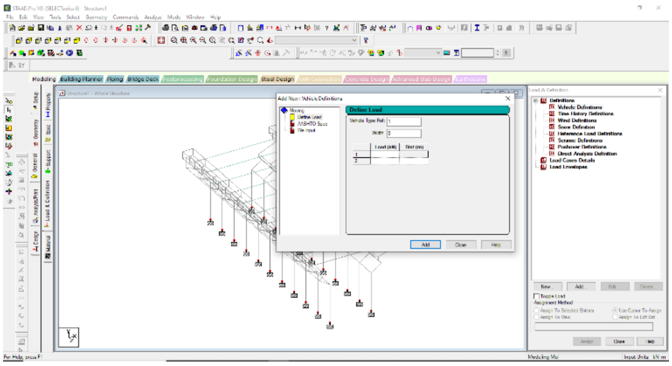
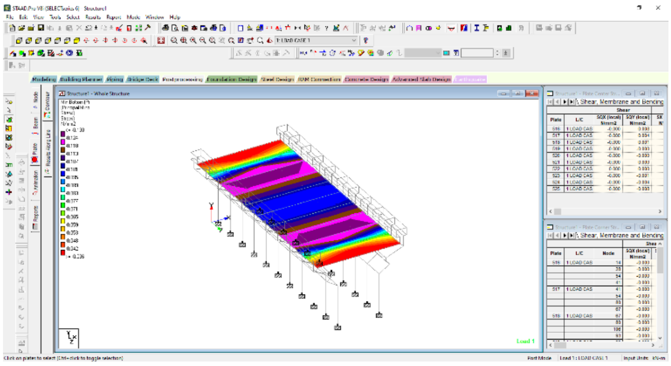


Fig 4 Defining different load combination to the model

Step 5- Stress analysis of the structure in the post processing

Part 1-



Part 2-

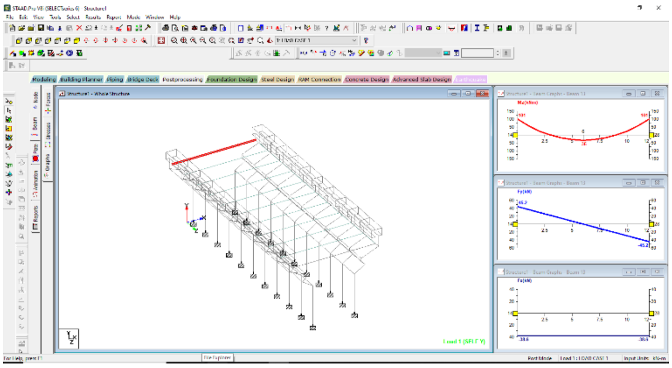
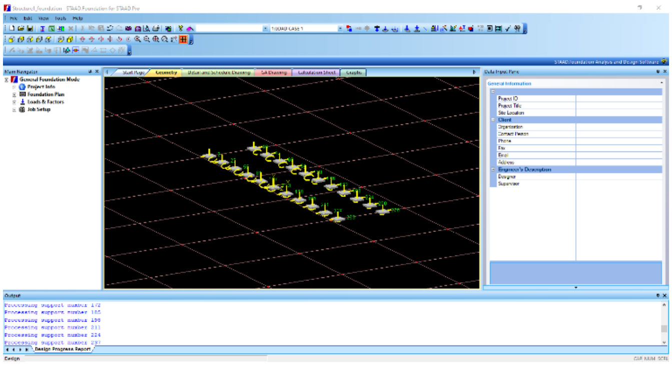


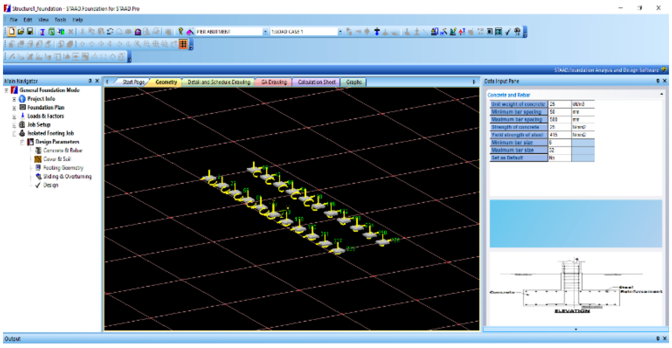
Fig 5 Stress Analysis

Step 6: Quantity analysis and foundation parameters of the model

Part -1



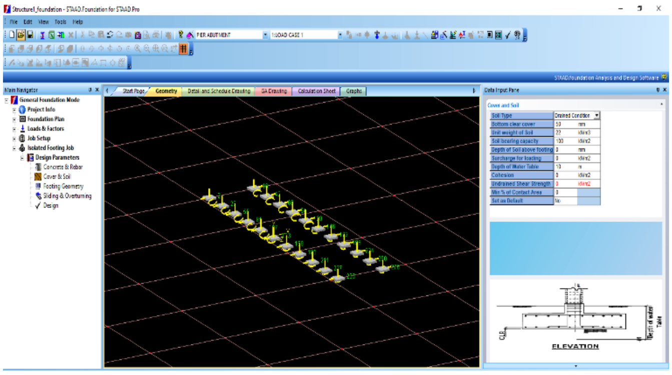
Part 2- Defining concrete and Rebar



Concrete and Rebar

Unit weight of concrete	25	kN/m3
Minimum bar spacing	50	mm
Maximum bar spacing	500	mm
Strength of concrete	25	N/mm2
Yield strength of steel	415	N/mm2
Minimum bar size	6	
Maximum bar size	32	
Set as Default	No	

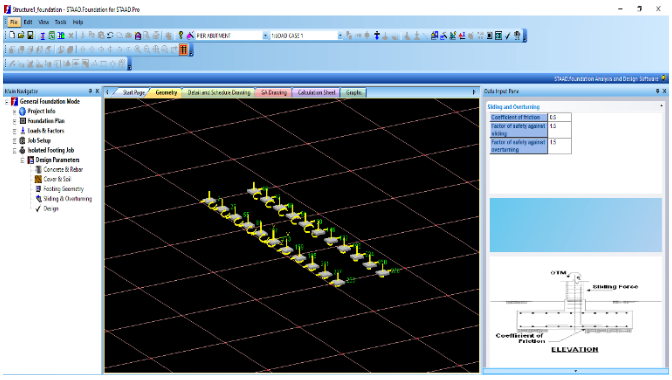
Part 3- defining cover and soil



Cover and Soil

Soil Type	Drained Condition	
Bottom clear cover	50	mm
Unit weight of Soil	22	kN/m3
Soil bearing capacity	100	kN/m2
Depth of Soil above footing	0	mm
Surcharge for loading	0	kN/m2
Depth of Water Table	10	m
Cohesion	0	kN/m2
Undrained Shear Strength	0	kN/m2
Min % of Contact Area	0	
Set as Default	No	

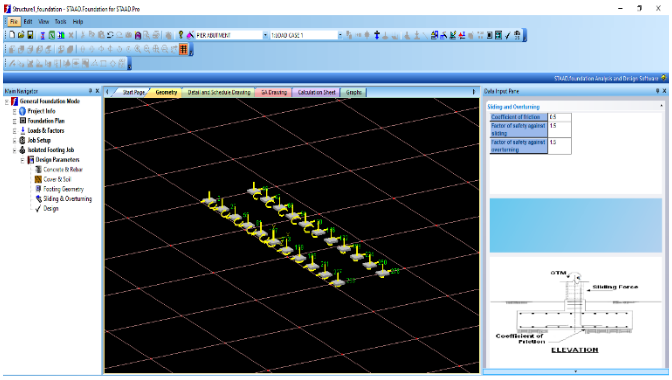
Part 4- Defining footing type and design type



Sliding and Overturning

Coefficient of friction	0.5
Factor of safety against sliding	1.5
Factor of safety against overturning	1.5

Part 5- Sliding and Overturning



Sliding and Overturning

Coefficient of friction	0.5
Factor of safety against sliding	1.5
Factor of safety against overturning	1.5

Fig 7 Foundation Designing

IV. RESULTS AND DISCUSSION

Speed Acceleration

Speed km/h	
10	0.02655
20	0.02925
30	0.03822
40	0.037985
50	0.04186
60	0.04245
61.3	0.04426
67.08	0.04143
70	0.03881

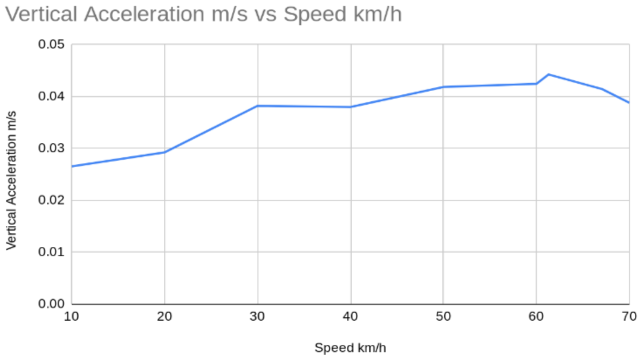


Fig 8 Vertical Acceleration m/s Speed km/h

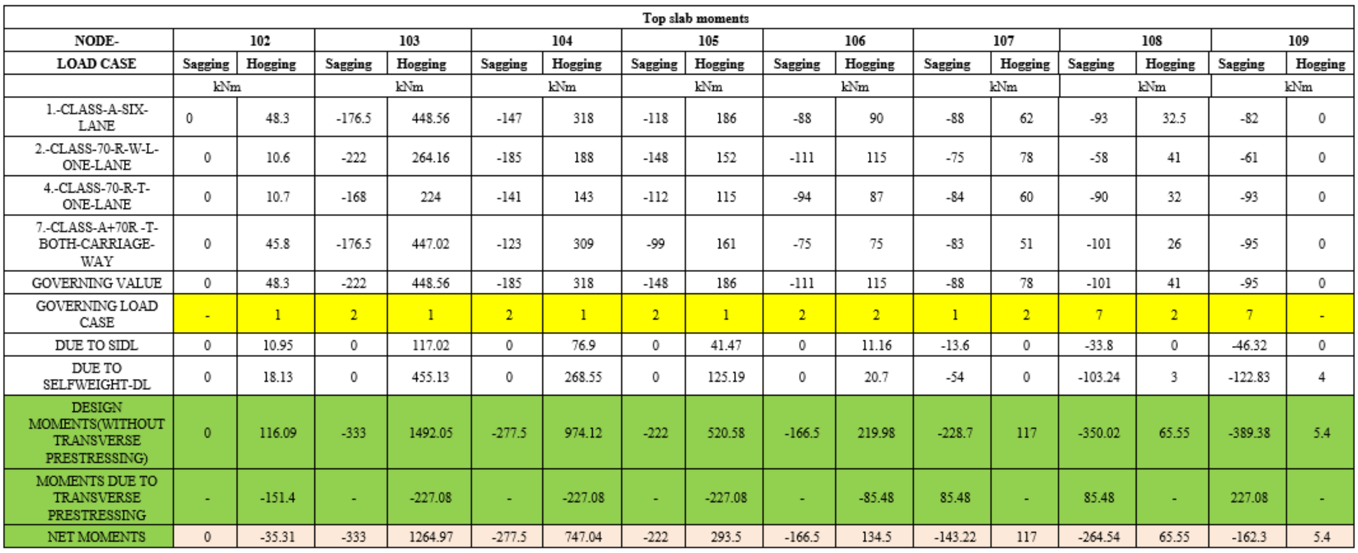
Table 1. Effective width calculation for the load case having class A one lane

Calculation of wheel load using effective width concept for one lane loaded class															
		C = Cantilever													
Inc =	0.315625	S = Simply Supported/Continuous					Load 1								Load 2
	Distance	Load Distance from nearest support	Case	Calculated beff	Modified, beff	Load with IF-Impact Factor	Peq=Load/ beff	Wheel Distance	Distance	Load Distance from nearest support	Case	Calculated beff	Modified, beff	Load with IF-Impact Factor	Peq, =Load/ beff
	in m	in m		in m	in m	in mton	in mton/m	in m	in m	in m		in m	in m	in mton	in mton/m
1	0.4	3.4	C	4.49	2.845	8.32	2.92	1.8	2.2	1.6	C	2.33	1.765	8.32	4.71
2	0.716	3.084	C	4.111	2.656	8.32	3.13	1.8	2.516	1.284	C	1.951	1.576	8.32	5.28
3	1.031	2.769	C	3.733	2.466	8.32	3.37	1.8	2.831	0.969	C	1.573	1.386	8.32	6
4	1.347	2.453	C	3.354	2.277	8.32	3.65	1.8	3.147	0.653	C	1.194	3.354	8.32	2.48
5	1.663	2.138	C	2.975	2.088	8.32	3.98	1.8	3.463	0.337	C	0.815	2.975	8.32	2.8
6	1.978	1.822	C	2.596	1.898	8.32	4.38	1.8	3.778	0.022	C	0.436	2.596	8.32	3.2
7	2.294	1.506	C	2.218	1.709	8.32	4.87	1.8	4.094	0.294	S	1.163	2.218	8.32	3.75
8	2.609	1.191	C	1.839	1.519	8.32	5.47	1.8	4.409	0.609	S	1.946	1.573	8.32	5.29
9	2.925	0.875	C	1.46	1.33	8.32	6.25	1.8	4.725	0.925	S	2.704	1.952	8.32	4.26
10	3.241	0.559	C	1.081	1.081	8.32	7.69	1.8	5.041	1.241	S	3.436	2.318	8.32	3.59
11	3.556	0.244	C	0.703	0.703	8.32	11.84	1.8	5.356	1.556	S	4.141	2.671	8.32	3.11
12	3.872	0.072	S	0.596	0.596	8.32	13.95	1.8	5.672	1.872	S	4.821	3.011	8.32	2.76
13	4.188	0.387	S	1.398	1.299	8.32	6.4	1.8	5.988	2.188	S	5.475	3.338	8.32	2.49
14	4.503	0.703	S	2.174	1.687	8.32	4.93	1.8	6.303	2.503	S	6.104	3.652	8.32	2.28
15	4.819	1.019	S	2.924	2.062	8.32	4.03	1.8	6.619	2.819	S	6.706	3.953	8.32	2.1
16	5.134	1.334	S	3.648	2.424	8.32	3.43	1.8	6.934	3.134	S	7.282	4.241	8.32	1.96
17	5.45	1.65	S	4.346	2.773	8.32	3	1.8	7.25	3.45	S	7.833	4.516	8.32	1.84
18	5.766	1.966	S	5.018	3.109	8.32	2.68	1.8	7.566	3.766	S	8.357	4.779	8.32	1.74

19	6.081	2.281	S	5.665	3.432	8.32	2.42	1.8	7.881	4.081	S	8.856	5.028	8.32	1.65
20	6.397	2.597	S	6.285	3.743	8.32	2.22	1.8	8.197	4.397	S	9.329	5.264	8.32	1.58
21	6.713	2.913	S	6.88	4.04	8.32	2.06	1.8	8.513	4.713	S	9.776	5.488	8.32	1.52
22	7.028	3.228	S	7.448	4.324	8.32	1.92	1.8	8.828	5.028	S	10.196	5.698	8.32	1.46
23	7.344	3.544	S	7.991	4.596	8.32	1.81	1.8	9.144	5.344	S	10.592	5.896	8.32	1.41
24	7.659	3.859	S	8.508	4.854	8.32	1.71	1.8	9.459	5.659	S	10.961	6.08	8.32	1.37
25	7.975	4.175	S	8.999	5.1	8.32	1.63	1.8	9.775	5.975	S	11.304	6.252	8.32	1.33
26	8.291	4.491	S	9.464	5.332	8.32	1.56	1.8	10.091	6.291	S	11.621	6.411	8.32	1.3
27	8.606	4.806	S	9.903	5.552	8.32	1.5	1.8	10.406	6.606	S	11.913	6.556	8.32	1.27
28	8.922	5.122	S	10.317	5.758	8.32	1.44	1.8	10.722	6.922	S	12.178	6.689	8.32	1.24
29	9.238	5.438	S	10.704	5.952	8.32	1.4	1.8	11.038	7.238	S	12.418	6.809	8.32	1.22
30	9.553	5.753	S	11.065	6.133	8.32	1.36	1.8	11.353	7.553	S	12.632	6.916	8.32	1.2
31	9.869	6.069	S	11.401	6.3	8.32	1.32	1.8	11.669	7.869	S	12.82	7.01	8.32	1
32	10.184	6.384	S	11.711	6.455	8.32	1.29	1.8	11.984	8.184	S	12.981	7.091	8.32	1.17
33	10.5	6.7	S	11.994	6.597	8.32	1.26	1.8	12.3	8.5	S	13.118	7.159	8.32	1.16
34	10.816	7.016	S	12.252	6.726	8.32	1.24	1.8	12.616	8.816	S	13.228	7.214	8.32	1.15
35	11.131	7.331	S	12.484	6.842	8.32	1.22	1.8	12.931	9.131	S	13.312	7.256	8.32	1.15
36	11.447	7.647	S	12.69	6.945	8.32	1.2	1.8	13.247	9.447	S	13.37	7.285	8.32	1.14
37	11.763	7.963	S	12.87	7.035	8.32	1.18	1.8	13.563	9.763	S	13.403	7.301	8.32	1.14
38	12.078	8.278	S	13.025	7.112	8.32	1.17	1.8	13.878	9.922	S	13.409	7.305	8.32	1.14
39	12.394	8.594	S	13.153	7.176	8.32	1.16	1.8	14.194	9.606	S	13.39	7.295	8.32	1.14
40	12.709	8.909	S	13.255	7.228	8.32	1.15	1.8	14.509	9.291	S	13.345	7.272	8.32	1.14
41	13.025	9.225	S	13.332	7.266	8.32	1.14	1.8	14.825	8.975	S	13.273	7.237	8.32	1.15
42	13.341	9.541	S	13.383	7.291	8.32	1.14	1.8	15.141	8.659	S	13.176	7.188	8.32	1.16
43	13.656	9.856	S	13.407	7.304	8.32	1.14	1.8	15.456	8.344	S	13.053	7.127	8.32	1.17
44	13.972	9.828	S	13.406	7.303	8.32	1.14	1.8	15.772	8.028	S	12.905	7.052	8.32	1.18
45	14.288	9.512	S	13.379	7.29	8.32	1.14	1.8	16.088	7.712	S	12.73	6.965	8.32	1.19
46	14.603	9.197	S	13.326	7.263	8.32	1.15	1.8	16.403	7.397	S	12.529	6.865	8.32	1.21
47	14.919	8.881	S	13.247	7.224	8.32	1.15	1.8	16.719	7.081	S	12.303	6.751	8.32	1.23
48	15.234	8.566	S	13.143	7.171	8.32	1.16	1.8	17.034	6.766	S	12.05	6.625	8.32	1.26
49	15.55	8.25	S	13.012	7.106	8.32	1.17	1.8	17.35	6.45	S	11.772	6.486	8.32	1.28
50	15.866	7.934	S	12.855	7.028	8.32	1.18	1.8	17.666	6.134	S	11.467	6.334	8.32	1.31
51	16.181	7.619	S	12.673	6.936	8.32	1.2	1.8	17.981	5.819	S	11.137	6.169	8.32	1.35
52	16.497	7.303	S	12.464	6.832	8.32	1.22	1.8	18.297	5.503	S	10.781	5.991	8.32	1.39

53	16.813	6.987	S	12.23	6.715	8.32	1.24	1.8	18.613	5.187	S	10.399	5.8	8.32	1.43
54	17.128	6.672	S	11.97	6.585	8.32	1.26	1.8	18.928	4.872	S	9.991	5.596	8.32	1.49
55	17.444	6.356	S	11.684	6.442	8.32	1.29	1.8	19.244	4.556	S	9.558	5.379	8.32	1.55
56	17.759	6.041	S	11.372	6.286	8.32	1.32	1.8	19.559	4.241	S	9.098	5.149	8.32	1.62
57	18.075	5.725	S	11.034	6.117	8.32	1.36	1.8	19.875	3.925	S	8.612	4.906	8.32	1.7
58	18.391	5.409	S	10.67	5.935	8.32	1.4	1.8	20.191	3.609	S	8.101	4.65	8.32	1.79
59	18.706	5.094	S	10.281	5.74	8.32	1.45	1.8	20.506	3.294	S	7.563	4.382	8.32	1.9
60	19.022	4.778	S	9.865	5.533	8.32	1.5	1.8	20.822	2.978	S	7	4.1	8.32	2.03
61	19.338	4.462	S	9.424	5.312	8.32	1.57	1.8	21.138	2.662	S	6.411	3.805	8.32	2.19
62	19.653	4.147	S	8.956	5.078	8.32	1.64	1.8	21.453	2.347	S	5.796	3.498	8.32	2.38
63	19.969	3.831	S	8.463	4.832	8.32	1.72	1.8	21.769	2.031	S	5.155	3.177	8.32	2.62
64	20.284	3.516	S	7.944	4.572	8.32	1.82	1.8	22.084	1.716	S	4.488	2.844	8.32	2.92
65	20.6	3.2	S	7.399	4.299	8.32	1.93	1.8	22.4	1.4	S	3.795	2.498	8.32	3.33
66	20.916	2.884	S	6.828	4.014	8.32	2.07	1.8	22.716	1.084	S	3.077	2.138	8.32	3.89
67	21.231	2.569	S	6.231	3.715	8.32	2.24	1.8	23.031	0.769	S	2.332	1.766	8.32	4.71
68	21.547	2.253	S	5.608	3.404	8.32	2.44	1.8	23.347	0.453	S	1.561	1.381	8.32	6.02
69	21.863	1.937	S	4.959	3.08	8.32	2.7	1.8	23.663	0.137	S	0.765	4.959	8.32	1.68
70	22.178	1.622	S	4.285	2.742	8.32	3.03	1.8	23.978	0.178	C	0.624	4.285	8.32	1.94
71	22.494	1.306	S	3.584	2.392	8.32	3.48	1.8	24.294	0.494	C	1.003	3.584	8.32	2.32
72	22.809	0.991	S	2.858	2.029	8.32	4.1	1.8	24.609	0.809	C	1.381	1.291	8.32	6.44
73	23.125	0.675	S	2.106	1.653	8.32	5.03	1.8	24.925	1.125	C	1.76	1.48	8.32	5.62
74	23.441	0.359	S	1.328	1.264	8.32	6.58	1.8	25.241	1.441	C	2.139	1.669	8.32	4.98
75	23.756	0.044	S	0.524	0.524	8.32	15.89	1.8	25.556	1.756	C	2.518	1.859	8.32	4.47
76	24.072	0.272	C	0.736	0.736	8.32	11.3	1.8	25.872	2.072	C	2.896	2.048	8.32	4.06
77	24.388	0.588	C	1.115	1.115	8.32	7.46	1.8	26.188	2.388	C	3.275	2.238	8.32	3.72
78	24.703	0.903	C	1.494	1.347	8.32	6.18	1.8	26.503	2.703	C	3.654	2.427	8.32	3.43
79	25.019	1.219	C	1.873	1.536	8.32	5.41	1.8	26.819	3.019	C	4.033	2.616	8.32	3.18
80	25.334	1.534	C	2.251	1.726	8.32	4.82	1.8	27.134	3.334	C	4.411	2.806	8.32	2.96
81	25.65	1.85	C	2.63	1.915	8.32	4.34	1.8	27.45	3.65	C	4.79	2.995	8.32	2.78

Table 2 Summary of Top Slab Moments in S_3.8_IS



Top slab moments																
NODE-	102		103		104		105		106		107		108		109	
LOAD CASE	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
	kNm		kNm		kNm		kNm		kNm		kNm		kNm		kNm	
1.-CLASS-A-SIX-LANE	0	48.3	-176.5	448.56	-147	318	-118	186	-88	90	-88	62	-93	32.5	-82	0
2.-CLASS-70-R-W-L-ONE-LANE	0	10.6	-222	264.16	-185	188	-148	152	-111	115	-75	78	-58	41	-61	0
4.-CLASS-70-R-T-ONE-LANE	0	10.7	-168	224	-141	143	-112	115	-94	87	-84	60	-90	32	-93	0
7.-CLASS-A+70R -T-BOTH-CARRIAGE-WAY	0	45.8	-176.5	447.02	-123	309	-99	161	-75	75	-83	51	-101	26	-95	0
GOVERNING VALUE	0	48.3	-222	448.56	-185	318	-148	186	-111	115	-88	78	-101	41	-95	0
GOVERNING LOAD CASE	-	1	2	1	2	1	2	1	2	2	1	2	7	2	7	-
DUE TO SIDL	0	10.95	0	117.02	0	76.9	0	41.47	0	11.16	-13.6	0	-33.8	0	-46.32	0
DUE TO SELFWEIGHT-DL	0	18.13	0	455.13	0	268.55	0	125.19	0	20.7	-54	0	-103.24	3	-122.83	4
DESIGN MOMENTS(WITHOUT TRANSVERSE PRESTRESSING)	0	116.09	-333	1492.05	-277.5	974.12	-222	520.58	-166.5	219.98	-228.7	117	-350.02	65.55	-389.38	5.4
MOMENTS DUE TO TRANSVERSE PRESTRESSING	-	-151.4	-	-227.08	-	-227.08	-	-227.08	-	-85.48	85.48	-	85.48	-	227.08	-
NET MOMENTS	0	-35.31	-333	1264.97	-277.5	747.04	-222	293.5	-166.5	134.5	-143.22	117	-264.54	65.55	-162.3	5.4

Table 3 Summary of Design SF and BM

SUMMARY OF BM							SUMMARY OF SF			Moment due to torsion,M TORSION
Element No	Location of BM	MDL	MSIDL	MLL			VDL	VLL	VSIDL	
				With Impact-1.088	With Congestion factor-1.45	With Reduction factor-0.8				
No	m	kN*m	kN*m	kN*m	kN*m	kN*m	kN	kN	kN	kN*m
1	0	0	0	0	0	0	-13762	-4730.7	-2334.1	20299.9
	0.5	6811.01	1153.72	2294.4	3326.88	2661.5	-13484	-4588.8	-2284.1	20112.3
2	1.5	20020.3	3391.24	6707.46	9725.82	7780.65	-12934	-4471.6	-2190.9	19390.5
3	2.5	32679.1	5535.53	10800.7	15661.1	12528.9	-12384	-4248.6	-2097.7	18365.1
4	3.5	44787.6	7586.59	14888.8	21588.7	17271	-11833	-4104.9	-2004.4	18238.7
5	4.5	56345.7	9544.42	18689.1	27099.2	21679.3	-11283	-3976.8	-1911.2	17484.4
6	5.5	67353.4	11409	22219.9	32218.9	25775.1	-10733	-3763.8	-1818	16983.7
7	6.5	77810.7	13180.4	25735.4	37316.4	29853.1	-10182	-3670.7	-1724.8	16585.1
8	7.5	87717.6	14858.5	28826.7	41798.6	33438.9	-9631.7	-3506.6	-1631.5	16052.1
9	8.5	97074.2	16443.4	31802.1	46113	36890.4	-9081.4	-3314.3	-1538.3	15828.1
10	9.5	105880	17935.1	34541.1	50084.6	40067.7	-8531	-3244.9	-1445.1	15239.7
11	10.5	114136	19333.6	37088	53777.6	43022.1	-7980.6	-3089.9	-1351.8	14831.1
12	11.5	121842	20638.8	39407.1	57140.3	45712.2	-7430.2	-2945.8	-1258.6	14677.3
13	12.5	128997	21850.8	41646.5	60387.4	48309.9	-6879.8	-2858.4	-1165.4	14041.4
14	13.5	135601	22969.5	43669.5	63320.8	50656.6	-6329.4	-2718.6	-1072.1	13465.5
15	14.5	141655	23995.1	45456.7	65912.2	52729.7	-5779	-2545	-978.91	13637.5
16	15.5	147159	24927.4	47067	68247.1	54597.7	-5228.7	-2513	-885.68	13318.8

17	16.5	152113	25766.4	48593.3	70460.3	56368.3	-4678.3	-2352.7	-792.45	12631.4
18	17.5	156516	26512.3	49884.2	72332.1	57865.7	-4127.9	-2202.2	-699.22	12959.9
19	18.5	160368	27164.9	50937.5	73859.4	59087.5	-3577.5	-2177.2	-605.99	12591.2
20	19.5	163671	27724.3	51909.5	75268.8	60215	-3027.1	-2018.2	-512.76	11902.6
21	20.5	166423	28190.4	52646.3	76337.1	61069.7	-2476.7	-1850.9	-419.53	12349.5
22	21.5	168624	28563.3	53153.4	77072.5	61658	-1926.4	-1845	-326.3	11990.3
23	22.5	170275	28843	53566.8	77671.8	62137.5	-1376	-1689.5	-233.07	11321.5
24	23.5	171376	29029.5	53774.2	77972.6	62378	-825.58	-1534	-139.84	11794.6
25	24.5	171927	29112.7	53675.4	77829.3	62263.5	-275.19	-1528	-46.61	11512.4
	25	172029	29122.7	53775.4	77974.3	62379.5	0	1528	0	11213.2
	25.5	171927	29112.7	53675.4	77829.3	62263.5	275.19	1528.04	46.62	10920.6
27	26.5	276183	29029.5	53776.2	77975.5	62380.4	825.58	1533.95	139.85	11536.2
28	27.5	274409	28843	53566.8	77671.8	62137.5	1375.96	1689.48	233.08	11224.6
29	28.5	271748	28563.3	53153.4	77072.5	61658	1926.35	1844.98	326.31	11321.5
30	29.5	268200	28190.4	52646.3	76337.1	61069.7	2476.73	1850.89	419.54	12014.1
31	30.5	263765	27724.3	51909.5	75268.8	60215	3027.12	2018.17	512.77	11634.5
32	31.5	258443	27164.9	50937.5	73859.4	59087.5	3577.5	2177.18	606	11899.6
33	32.5	252234	26512.3	49884.2	72332.1	57865.7	4127.89	2202.19	699.23	12615
34	33.5	245138	25766.4	48593.3	70460.3	56368.3	4678.27	2352.74	792.46	12351.8
35	34.5	237156	24927.4	47067	68247.1	54597.7	5228.66	2513.01	885.69	12521.4
36	35.5	228286	23995.1	45456.7	65912.2	52729.7	5779.04	2544.97	978.92	13342.6
37	36.5	218529	22969.5	43669.5	63320.8	50656.6	6329.43	2718.61	1072.15	13097.7
38	37.5	207885	21850.8	41646.5	60387.4	48309.9	6879.81	2858.41	1165.38	13453.7
39	38.5	196355	20638.8	39407.1	57140.3	45712.2	7430.2	2945.79	1258.61	14241.1
40	39.5	183937	19333.6	37088	53777.6	43022.1	7980.58	3089.9	1351.84	14266.3
41	40.5	170632	17935.1	34541.1	50084.6	40067.7	8530.97	3244.93	1445.07	14831.1
42	41.5	156441	16443.4	31802.1	46113	36890.4	9081.35	3314.31	1538.3	15394.6
43	42.5	141362	14858.5	28826.7	41798.6	33438.9	9631.74	3506.6	1631.53	15398.9
44	43.5	125396	13180.4	25735.4	37316.4	29853.1	10182.1	3670.65	1724.76	16052.1
45	44.5	108544	11409	22219.9	32218.9	25775.1	10732.5	3763.79	1817.99	16749.3
46	45.5	90804.3	9544.42	18689.1	27099.2	21679.3	11282.9	3976.81	1911.22	16717.1
47	46.5	72177.8	7586.59	14888.8	21588.7	17271	11833.3	4104.94	2004.45	17489.2
48	47.5	52664.3	5535.53	10800.7	15661.1	12528.9	12383.7	4248.6	2097.68	18315.4
49	48.5	32263.8	3391.24	6707.46	9725.82	7780.65	12934.1	4471.64	2190.91	18365.1
50	49.5	10976.4	1153.72	2294.4	3326.88	2661.5	13484.4	4588.81	2284.14	19390.5
	50	0	0	0	0	0	13762	4730.72	2334.13	20299.9
Shear force due to torsion at support,V TORSION									665.53	kN

Transverse analysis results

The following graph gives the comparison of reinforcement steel required per cubic meter of box section. It shows that the least steel required in S_3.8_TP case as transverse prestressing of deck slab reduces design moment and hence steel requirement comes to less compare to other configurations.

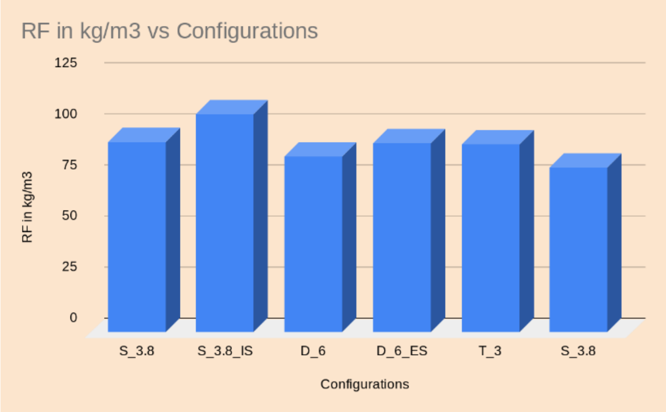


Fig. 9 Comparison of Reinforcement Quantity due to Transverse Bending

The graph gives the downward deflection at central node which is being compared with the allowable deflection. By observation we can say that the S_3.78_TP has good performance in terms of deflection and S_3.8_IS shows worst structural performance when only vehicular load is on it. Another point we can say is that the all configurations pass the deflection criteria given in IRC 112:2011. The graph no 7.3 gives the downward deflection at cantilever node which is being compared with the allowable deflection. By observation we can say that the S_3.78_TP has good performance in terms of deflection and D_6 shows the worst structural performance in terms of deflection. Another point we can say is that the all configurations pass the deflection criteria given in IRC 112:2011.

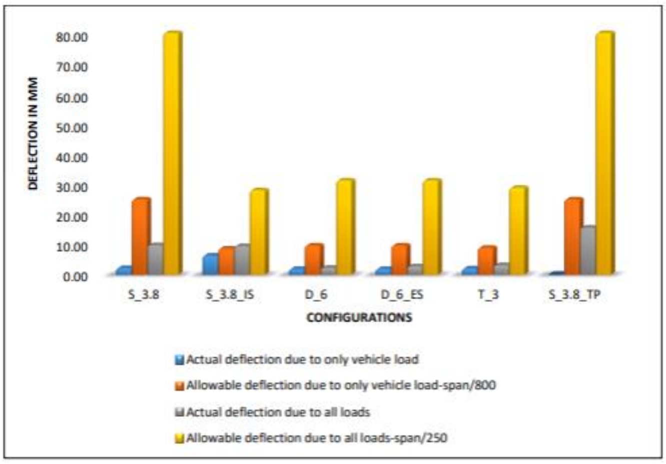


Fig. 10 Comparison of Downward Deflection at Central Node

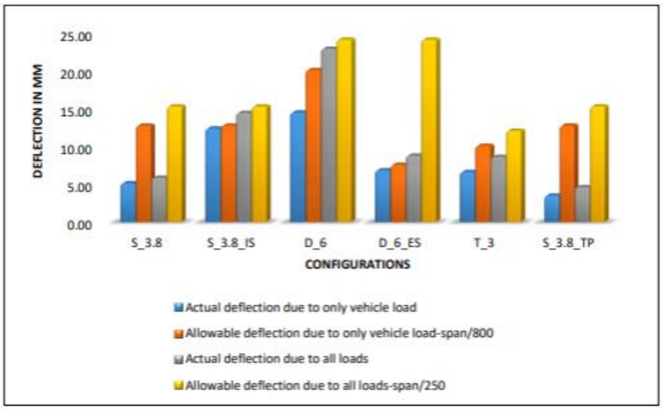


Fig. 11 Comparison of Downward Deflection at Cantilever End

V. CONCLUSION AND FUTURE SCOPE

Conclusion

The design of the pier is done by both force based design method and direct displacement based design method. Displacement Based Design Method, selected pier achieved the behaviour factors more than targeted Values. These conclusions concede to the selected pier only and to get further knowledge about direct displacement approach a large number of case studies is to be carried out. These conclusions can be considered only for the selected pier. For General conclusions large numbers of case studies are required and it is treated as a scope of future work. The parametric study on behaviour of box girder bridges showed that, As the radius of curvature increases, responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are decreases for three types of box girder bridges and it shows not much variation for fundamental As the span length to the radius of curvature ratio increases responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are increases for three types of box girder bridges and as span length to the radius of curvature ratio increases fundamental frequency decreases for three types of box girder bridges.

By performing transverse analysis using effective width concept given in IRC 112:2011,it is noticed that same concept cannot be used in configurations with Internal Struts and External struts as they are not continuous members in the longitudinal direction. .To know true dispersion of load in transverse direction, 3D Finite Analysis should be performed in configurations having internal or external strut. .S_3.8 is not advisable configuration for this 6-lane cross section. Instead of using Single cell one should use single cell with internal strut. D_6 is the worst configuration amongst all. To minimize deflection at cantilever end, external strut should be provided. In the case where strut is provided, detailing and construction must be taken care properly as true behavior of compression member should be achieved. One can use steel strut as a substitute of concrete strut. There is no guidelines available in IRC: 112-2011 for design of steel for the transverse tension in strut case. L/D = 18 for simply supported/continuous slab and L/D = 8 for cantilever slab holds good for RCC slab design in box girder as it satisfies deflection criteria. By doing transverse prestressing in deck slab, the ratio of L/D for simply supported/continuous slab can be go in the range of 35 to 40. Friction loss analysis plays vital role in the case of transverse prestressing case as geometry changes at each and every point based on moment envelope. (I.e. for provided cable profile). Potential cracking due to transverse prestressing should be taken care while construction. Deck slab should be locally thick to get better advantage of transverse prestressing. Special Vehicle load and its combinations are critical in longitudinal analysis. One should not ignore it as given in latest Amendments of IRC-006. By means of constructionability, T_3 is the best suitable configuration. Self-weight can be more minimized if transverse prestressing would have been done in T_3 configuration. It is advisable not to give more than 3 m clear cantilever in the configuration where external strut is not provided. By looking at the results it is observed that the T_3 is the best suitable configuration amongst all other configurations as its structural performance is reasonably superior and looks economical amongst all.

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