Analysis in the Effects of Model Design of R. C. C Foot Bridge Construction Considering Cushion Arrangements

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Abstract: ***A Footbridge is a structure that allows water to flow under a road, railroad, trail, or similar obstruction from one side to the other side. Typically embedded so as to be surrounded by soil, a Footbridge may be made from a pipe, reinforced concrete or other material. Foot Bridge is generally used as cross-drains for ditch relief and for passing water under a road at natural drainage to stream crossings. A Foot bridge may be a bridge-like structure designed to allow vehicle or pedestrian traffic to cross over the waterway while allowing adequate passage for theater. The Footbridges are also made to balance the flood water on the both sides of the earth embankment to reduce the flood level on the other side of the road which reduces the water head on corresponding side, thus reducing water menace.***

Keywords: Aspect ratio, Bending Moments, IRC, Cushion, Earth pressure, Surcharge loading

1. Introduction

Footbridges come in many sizes and shapes including round, elliptical, flat-bottomed, pear-shaped, and box-like constructions. The Footbridge type and shape selection is based on a number of factors including: requirements for hydraulic performance, limitation on upstream water surface elevation, and road way embankment height viz arch, slab and of box types. Several agencies had recently developed environmentally sensitive design guidelines which combine modern hydraulic criteria and economic construction and maintenance costs, with help of natural stream channel integrity, flood prevention, and habitat issues.

In general, the Footbridge crossing is located on the stream where it will have the least short-and long-term impacts to the stream valley and its habitat. Whenever possible the Footbridge crossing must be located in a section of the stream where the bank full storm event channel geometry can be maintained. The scope of this dissertation work has been restricted to the design of Foot bridge. The design of Footbridge includes consideration of case load and factors i.e. super load, effective wide, dispersal of load through fill, braking forces of braking, coefficient of earth pressure etc. The relevant codes are required to be referred. The structural parts are designed to withstand the maximum bending and shear force. The work provides full discussion on the provisions given in the code and all the aspects of design.

As the Footbridge passes through the earthen embankment, they are subjected to various loads mainly traffic loads. Thus, there is a need to design Foot bridges for such loads. This project mainly deals with design of R.C.C. Foot bridges having cushion and no-cushion. Different parameters such as size, invert level, layout etc. are decided by hydraulic considerations and location conditions. The cushion load depends upon the road profile at the Footbridge location.

2. Brief History of Past Work Done

1] B. N. Sinha and R. P. Sharma, (2009)
This paper deals with Footbridges made of RCC, with and without cushion The size, invert level, layout etc. are decided by hydraulic consideration & site conditions. The cushion depends on road profile at the Foot bridge location. The scope of this paper has been restricted to the structural design of the box. The structural design involves consideration of load cases (box empty, box full, surcharge loads etc.) & factors like live load, effective width, braking force, impact factor, coefficient of earth pressure etc. in reference to Relevant IRC codes. The inferences drawn from the paper were that box for cross drainage works across high embankments has many advantages as compared to a slab Footbridge. The design of box was covered by three load cases in the paper using STAADPro V8i.Braking force is to be considered particularly in case of box without cushion for smaller span Footbridge. When effect of braking force is considered same effective width is applicable for vertical application of live load otherwise the design shall be unsafe.

2] Jerin Jose, Kiran S Chirayath, M. A Muhammed Riswan, Megha Shankar, Rose Mariya George, (2012) This paper deals with the design of Footbridge made of RCC, without cushion using limit state method. The design of RCC

Footbridge presented in this paper is as per relevant IRC codes. STADDPro is used of analysis for the design of shear force and bending moment. The structural elements are required to be designed to withstand maximum bending moment and shear force. The paper provides full discussions on the provisions in the codes, considerations and detailing of the Footbridge.

3] D. J. kadbhane and C. D. Modhera (2019)
This paper is to compare the over burden effect (up to 6m) on the structure by using two dimensional analysis in STAAD_Pro_V8i and excel spreadsheet. Study of the effect of an overburden on the axial and shear force, safe bearing capacity sagging and moments and steel requirement.

4] A. D. Patil, A. A. Galatage (2019)
This report devotes to the Footbridges constructed in reinforced concrete having different aspect ratios. The Foot bridges are analyzed for varying cushion and no cushion loading. The main highlight is given to the behaviour of the structure under the types of loading as per IRC codes and their combinations top produce worst effect of loading for safe structure. Collation and conclusion are made on the basis of maximum bending moments shown for different loading cases.

5] Molly Mathew, Snehal Mali (2014)
This paper deals with study of some of the design parameters of Foot bridges like angle of dispersion or effective width of live load, effect of earth pressure and depth of cushion provided on top slab of Foot bridges. Depth of cushion is important item for live loads on box without cushion and with cushion for structural deformations.

6] Indian Road Congress- Standard Specifications and Code of Practice Road Bridge IRC:6-2016, Section: II “Loads and Stresses”
This code provides the different loads acts on Bridges such as Dead Load, Super imposed Load, Live Load, Longitudinal Force, Earth pressure, Earthquake Force, Wind Load, Snow Load, etc. The load combinations for both Working Stress Method and Limit State Method are given in this code.

IRC: 112-2011,“Code of practice for concrete road bridges”

This code consists of parameters required for design of plain and reinforced concrete bridges. For Limit State Design IRC: 112-2011 shall be adopted.

IRC: 78-2000, “standard specification and code of practice for road bridges” section VII foundation and substructure.

Structural Details

Particulars	span2x3		span3x3		span4x3		span5x3	
	Without cushion (mm)	With cushion (mm)	Without cushion (mm)	With cushion (mm)	Without cushion (mm)	With cushion (mm)	Without cushion (mm)	With cushion (mm)
Top Slab	300	350	400	400	450	500	500	520
Side wall	300	350	350	400	400	450	450	500
Bottom slab	300	350	400	400	450	500	500	550

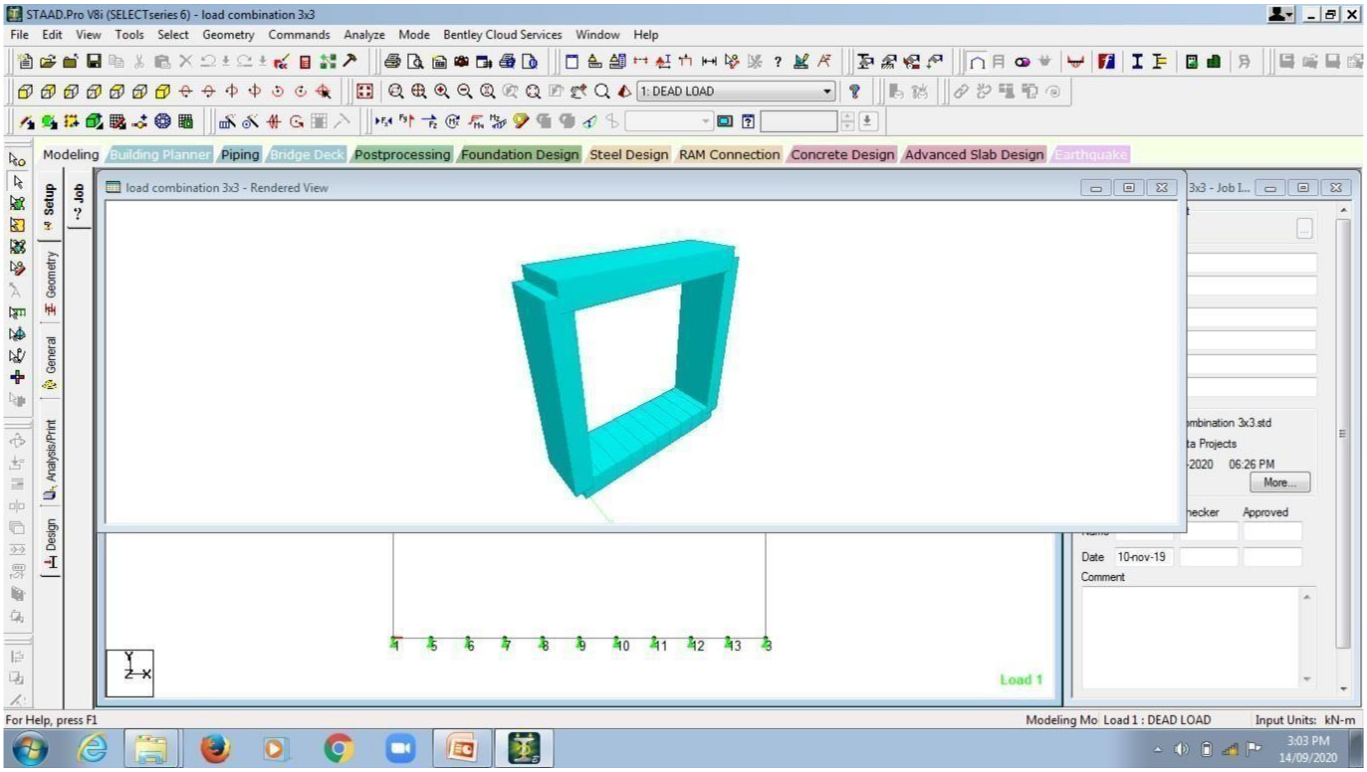
Material Density and Safe Bearing Capacity of Soil
Unit weight of concrete= 25kN/m3Unit weight of earth=20kN/m3
Unit weight of wearing coat = 25 kN/m3Safe bearing capacity of soil = 150 kN/m2

Grade of Materials: Concrete grade =M30
Steel grade=Fe500

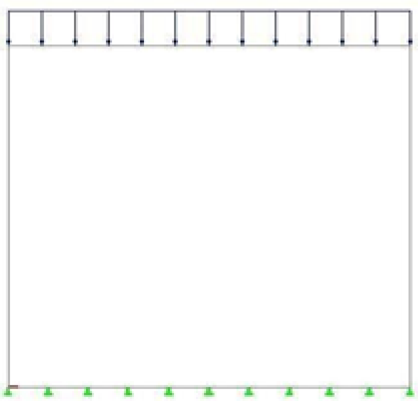
3. Methodology

Foot bridge is modeled as line diagram and analysed in STAAD Pro software and 1 m strip of the box is considered for modeling. Bottom slab is divided into equal parts and Spring support is provide database of slab and soil spring stiffness.
Ks=40xSFxqo

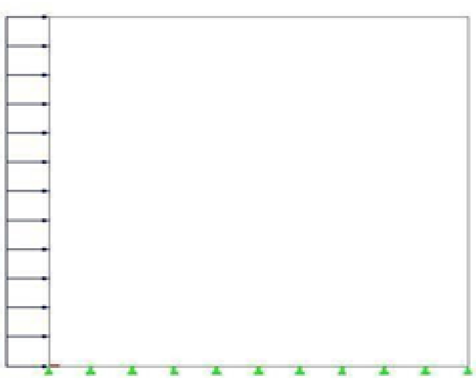
STAAD Model



Load calculations (IRC:6 -2016)



Dead Load & SIDL.



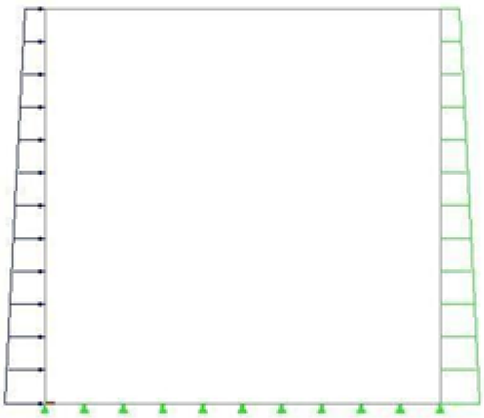
Live Load Surcharge one side

Live Load Surcharge both side

Earth Pressure

Equivalent Height of earth due to live load surcharge=1.2m Coefficient of Earth Pressure at Rest, K0= 0.5 Intensity of live load surcharge K0x ϒsxh.

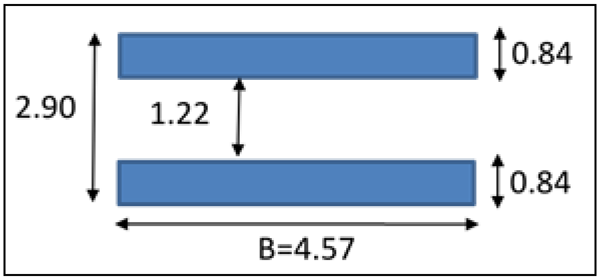
Live Load (IRC:6-2016,cl.204)



For analysis of structure 1 m strip of box is consider in modeling. As for 1 m strip axle load with total width of vehicles more than 1 m are not possible to be placed on 1 m strip, therefore wheels loads are taken for analysis. Maximum bending moments occurring from vehicle loads without impact (STAAD Output)

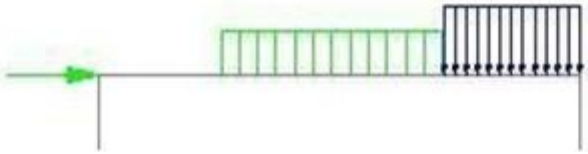
Live Load with Impact

Class 70R track
Length of dispersion of load=B+2(D+ t)
Where, B = Tyre contact length D = Top slab thickness t=Fill over slab including wearing coat

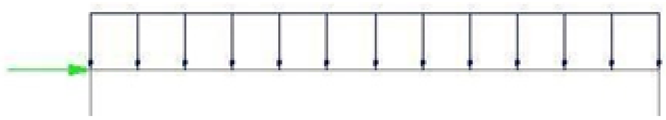


Load Combination

Max, Bending moment and Shear force
- ULS (Basic combination)
- SLS (Rare combination)
- SLS (Quasi Permanent combination)



IRCCLASS70R- Bogie Load (40T)



IRCCLASS70R-Track Load (70T)

4. Results with Summary of Analysis

Summary of results from Staad pro. (span 2mx3m)

Particulars		ULS combination (kN.m)		Rare combination (kN.m)		Quasi combination (kN.m)		Shear force (kN)	
		Without Cushion	With Cushion	Without Cushion	With Cushion	Without Cushion	With Cushion	Without Cushion	With Cushion
Top Slab	Mid	76.92	86.57	52.35	61.90	2.82	17.06	317.48	357.37
	Support	119.43	156.61	79.88	105.88	11.66	40.34		
Side Wall	Mid	13.92	24.70	9.80	14.73	9.37	23.84	124.10	204.23
	Support	125.26	171.63	84.30	116.46	18.79	48.46		
Bottom Slab	Mid	101.79	109.34	68.89	77.32	7.21	22.52	227.95	280.86
	Support	106.41	111.23	72.24	78.21	7.66	23.76		

Summary of results from Staad pro. (span 3mx3m)

Particulars		ULS combination (kN.m)		Rare combination (kN.m)		Quasi combination (kN.m)		Shear force (kN)	
		Without Cushion	With Cushion	Without Cushion	With Cushion	Without Cushion	With Cushion	Without Cushion	With Cushion
Top Slab	Mid	133.06	168.30	91.19	120.29	16.63	59.66	376.27	402.71
	Support	145.90	208.28	97.93	142.66	17.39	62.30		
Side Wall	Mid	33.53	32.95	23.44	26.19	4.09	4.98	103.89	207.70
	Support	147.033	220.13	99.54	151.45	27.96	72.41		
Bottom Slab	Mid	157.82	175.97	108.23	126.00	24.98	65.77	278.63	347.70
	Support	160.83	181.81	109.93	129.57	25.90	68.05		

Summary of results from Staad pro. (span 4mx3m)

Particulars		ULS combination (kN.m)		Rare combination (kN.m)		Quasi combination (kN.m)		Shear force (kN)	
		Without Cushion	With Cushion	Without Cushion	With Cushion	Without Cushion	With Cushion	Without Cushion	With Cushion
Top Slab	Mid	286.54	377.63	195.18	266.20	34.65	121.67	387.37	460.31
	Support	267.20	351.66	179.70	240.96	26.65	93.09		
Side Wall	Mid	111.84	122.57	76.77	88.74	5.04	22.66	132.66	216.54
	Support	272.72	356.93	184.71	245.58	41.44	105.35		
Bottom Slab	Mid	291.25	378.24	199.09	267.23	46.51	128.99	301.43	416.61
	Support	300.65	384.60	205.61	270.93	48.02	132.80		

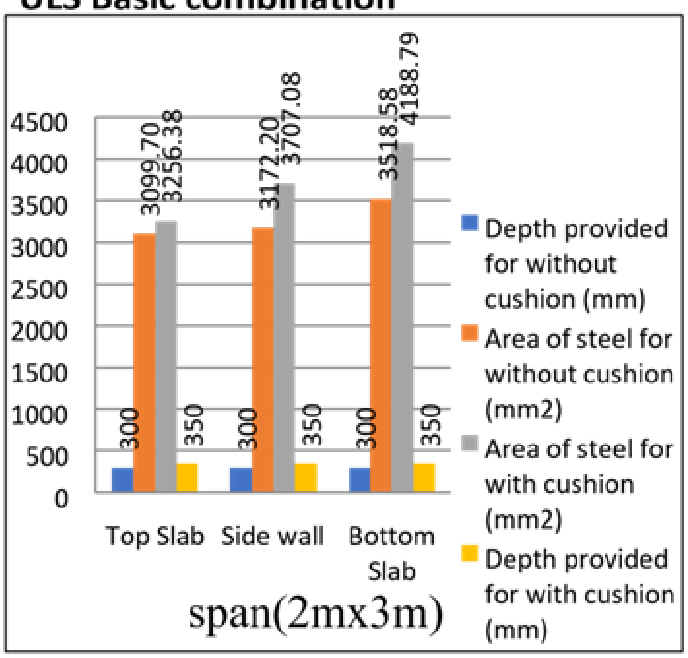
Summary of results from Staad pro. (span 5mx3m)

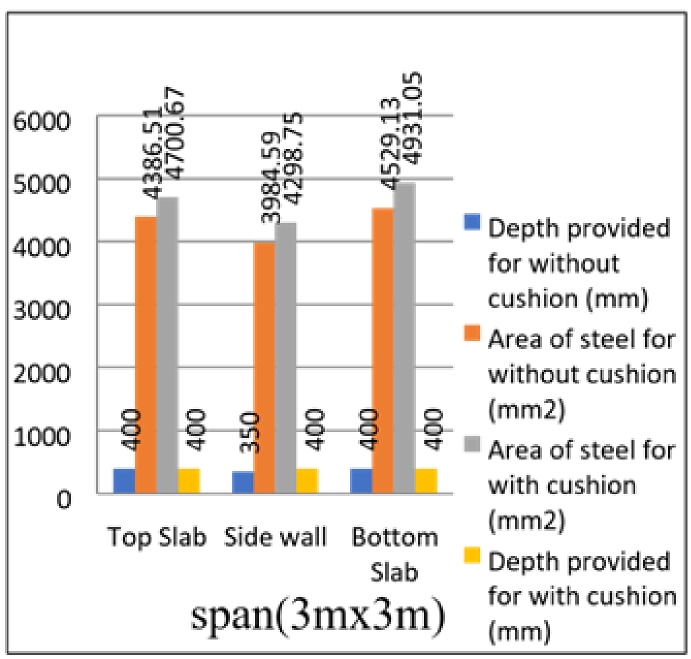
Particulars		ULS combination (kN.m)		Rare combination (kN.m)		Quasi combination (kN.m)		Shear force (kN)	
		Without Cushion	With Cushion	Without Cushion	With Cushion	Without Cushion	With Cushion	Without Cushion	With Cushion
Top Slab	Mid	358.080	482.319	244.950	341.316	57.440	180.593	448.082	658.93
	Support	354.570	478.602	226.020	331.481	41.530	149.408		
Side Wall	Mid	173.370	227.661	119.420	164.078	20.460	72.061	154.57	230.06
	Support	336.460	478.602	229.100	331.481	60.630	152.220		
Bottom Slab	Mid	354.940	498.604	244.210	353.641	71.350	195.576	416.76	583.05
	Support	362.220	500.320	248.800	354.260	73.540	201.056		

Particulars		2x3				2x3			
		Stress in steel 6_{sc} (N/ mm^2)	Check	Stress in concrete 6_{sc} (N/ mm^2)	Check	Stress in steel 6_{sc} (N/ mm^2)	Check	Stress in concrete 6_{sc} (N/ mm^2)	Check
		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2	
Top Slab	Mid	290.52	Safe	9.72	Safe	238.00	Safe	8.30	Safe
	Support	288.95	Safe	12.35	Safe	244.42	Safe	11.44	Safe
Side Wall	Mid	56.68	Safe	1.94	Safe	56.61	Safe	1.97	Safe
	Support	249.27	Safe	14.31	Safe	238.07	Safe	13.44	Safe
Bottom Slab	Mid	257.98	Safe	12.99	Safe	188.36	Safe	9.57	Safe
	Support	270.49	Safe	13.62	Safe	190.53	Safe	9.68	Safe

Summary of design results

ULS Basic combination





As per CL. 12.2.1, IRC: 112-2011, the maximum compressive stress in concrete under rare combinations of loads shall be limited to 0.48 fck

Check for Serviceability

As per CL.12.2.2, IRC: 112-2011, the maximum tensile stress in concrete under rare combinations of loads shall be limited to 0.80 fy

Particulars		2x3 without cushion				2x3 with cushion			
		Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check	Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check
		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)	
		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2	
Top Slab	Mid	290.52	Safe	9.72	Safe	238.00	Safe	8.30	Safe
	Support	288.95	Safe	12.35	Safe	244.42	Safe	11.44	Safe
Side Wall	Mid	56.68	Safe	1.94	Safe	56.61	Safe	1.97	Safe
	Support	249.27	Safe	14.31	Safe	238.07	Safe	13.44	Safe
Bottom Slab	Mid	257.98	Safe	12.99	Safe	188.36	Safe	9.57	Safe
	Support	270.49	Safe	13.62	Safe	190.53	Safe	9.68	Safe

Check for Serviceability

Particulars		3x3 without cushion				3x3 with cushion			
		Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check	Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check
		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)	
		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2	
Top Slab	Mid	242.65	Safe	8.44	Safe	259.93	Safe	10.53	Safe
	Support	179.11	Safe	7.79	Safe	268.80	Safe	11.88	Safe
Side Wall	Mid	75.50	Safe	2.91	Safe	71.77	Safe	2.54	Safe
	Support	242.49	Safe	12.32	Safe	261.65	Safe	13.30	Safe
Bottom Slab	Mid	220.62	Safe	10.18	Safe	256.84	Safe	11.85	Safe
	Support	224.08	Safe	10.34	Safe	264.12	Safe	12.18	Safe

As per CL.12.2.1, IRC: 112-2011, the maximum compressive stress in concrete under Quasi combinations of loads shall be limited to 0.36 fck

Particulars		4x3 without cushion				4x3 with cushion			
		Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check	Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check
		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)	
		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2	
Top Slab	Mid	252.05	Safe	11.42	Safe	271.60	Safe	12.73	Safe
	Support	286.56	Safe	11.56	Safe	284.16	Safe	12.24	Safe
Side Wall	Mid	210.37	Safe	7.44	Safe	252.51	Safe	7.51	Safe
	Support	229.42	Safe	14.23	Safe	235.05	Safe	14.29	Safe
Bottom Slab	Mid	226.97	Safe	12.41	Safe	266.73	Safe	13.56	Safe
	Support	251.84	Safe	13.19	Safe	290.62	Safe	14.15	Safe

Particulars		5x3 without cushion				5x3 with cushion			
		Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check	Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check
		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)	
		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2		6sc<400 N/ mm^2		6c< 14.40 N/ mm^2	
Top Slab	Mid	257.75	Safe	11.49	Safe	290.65	Safe	14.38	Safe
	Support	207.52	Safe	10.07	Safe	297.47	Safe	14.27	Safe
Side Wall	Mid	284.56	Safe	9.35	Safe	198.86	Safe	8.43	Safe
	Support	259.71	Safe	14.16	Safe	216.75	Safe	14.32	Safe
Bottom Slab	Mid	243.76	Safe	12.39	Safe	273.95	Safe	14.15	Safe
	Support	248.34	Safe	12.63	Safe	266.29	Safe	14.00	Safe

As per CL.12.2.2, IRC: 112-2011, the maximum tensile stress in concrete under Quasi combinations of loads shall be limited to 0.80 fy

Particulars		2x3 without cushion				2x3 with cushion			
		Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check	Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check
		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)	
		6sc<400 N/ mm^2		6c< 10.80 N/ mm^2		6sc<400 N/ mm^2		6c< 10.80 N/ mm^2	
Top Slab	Mid	16.98	Safe	0.21	Safe	71.40	Safe	0.94	Safe
	Support	46.71	Safe	0.75	Safe	103.97	Safe	1.84	Safe
Side Wall	Mid	58.94	Safe	0.76	Safe	99.75	Safe	1.31	Safe
	Support	63.41	Safe	1.37	Safe	112.81	Safe	2.40	Safe
Bottom Slab	Mid	30.39	Safe	0.57	Safe	61.76	Safe	1.18	Safe
	Support	32.28	Safe	0.61	Safe	65.14	Safe	1.25	Safe

Particulars		3x3 without cushion				3x3 with cushion			
		Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check	Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check
		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)	
		6sc<400 N/ mm^2		6c< 10.80 N/ mm^2		6sc<400 N/ mm^2		6c< 10.80 N/ mm^2	
Top Slab	Mid	48.14	Safe	0.63	Safe	142.02	Safe	2.18	Safe
	Support	35.26	Safe	0.58	Safe	130.33	Safe	2.18	Safe
Side Wall	Mid	17.61	Safe	0.26	Safe	12.22	Safe	0.16	Safe
	Support	76.67	Safe	1..47	Safe	140.79	Safe	2.71	Safe
Bottom Slab	Mid	56.75	Safe	0.99	Safe	149.44	Safe	2.61	Safe
	Support	58.84	Safe	1.03	Safe	154.61	Safe	2.70	Safe

Particulars		4x3 without cushion				4x3 with cushion			
		Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check	Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check
		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)	
		6sc<400 N/ mm^2		6c< 10.80 N/ mm^2		6sc<400 N/ mm^2		6c< 10.80 N/ mm^2	
Top Slab	Mid	50.20	Safe	0.87	Safe	138.50	Safe	2.48	Safe
	Support	46.78	Safe	0.72	Safe	121.52	Safe	2.00	Safe
Side Wall	Mid	15.03	Safe	0.20	Safe	69.34	Safe	0.78	Safe
	Support	59.23	Safe	1.39	Safe	115.70	Safe	2.68	Safe
Bottom Slab	Mid	60.11	Safe	1.25	Safe	144.81	Safe	2.81	Safe
	Support	66.37	Safe	1.32	Safe	159.52	Safe	2.97	Safe

Particulars		5x3 without cushion				5x3 with cushion			
		Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check	Stress in steel 6_{sc}	Check	Stress in concrete 6_{sc}	Check
		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)		(N/ mm^2)	
		6sc<400 N/ mm^2		6c< 10.80 N/ mm^2		6sc<400 N/ mm^2		6c< 10.80 N/ mm^2	
Top Slab	Mid	67.11	Safe	1.14	Safe	172.48	Safe	3.26	Safe
	Support	42.69	Safe	0.79	Safe	149.92	Safe	2.75	Safe
Side Wall	Mid	52.81	Safe	0.66	Safe	96.54	Safe	1.56	Safe
	Support	77.89	Safe	1.62	Safe	115.31	Safe	2.91	Safe
Bottom Slab	Mid	80.10	Safe	1.56	Safe	170.64	Safe	3.37	Safe
	Support	82.56	Safe	1.60	Safe	170.55	Safe	3.43	Safe

Check for Crack Width

Particulars		2x3 without cushion		2x3 with cushion	
		Crack Width (w_k) <0.3mm	Check	Crack Width (w_k) <0.3mm	Check
		(mm)		(mm)	
Top Slab	Mid	0.02	Safe	0.07	Safe
	Support	0.03	Safe	0.07	Safe
Side Wall	Mid	0.07	Safe	0.11	Safe
	Support	0.06	Safe	0.11	Safe
Bottom Slab	Mid	0.03	Safe	0.07	Safe
	Support	0.04	Safe	0.07	Safe

Particulars		3x3 without cushion		3x3 with cushion	
		Crack Width (w_k) <0.3mm	Check	Crack Width (w_k) <0.3mm	Check
		(mm)		(mm)	
Top Slab	Mid	0.04	Safe	0.12	Safe
	Support	0.03	Safe	0.12	Safe
Side Wall	Mid	0.02	Safe	0.01	Safe
	Support	0.08	Safe	0.15	Safe
Bottom Slab	Mid	0.07	Safe	0.17	Safe
	Support	0.07	Safe	0.18	Safe

Particulars		4x3 without cushion		4x3 with cushion	
		Crack Width (w_k) <0.3mm	Check	Crack Width (w_k) <0.3mm	Check
		(mm)		(mm)	
Top Slab	Mid	0.03	Safe	0.11	Safe
	Support	0.04	Safe	0.11	Safe
Side Wall	Mid	0.02	Safe	0.09	Safe
	Support	0.05	Safe	0.10	Safe
Bottom Slab	Mid	0.06	Safe	0.15	Safe
	Support	0.07	Safe	0.17	Safe

Particulars		5x3 without cushion		5x3 with cushion	
		Crack Width (w_k) <0.3mm	Check	Crack Width (w_k) <0.3mm	Check
		(mm)		(mm)	
Top Slab	Mid	0.04	Safe	0.14	Safe
	Support	0.03	Safe	0.12	Safe
Side Wall	Mid	0.06	Safe	0.09	Safe
	Support	0.08	Safe	0.10	Safe
Bottom Slab	Mid	0.08	Safe	0.18	Safe
	Support	0.08	Safe	0.17	Safe

5. Conclusion

In this study it is observed that the bending moment and shear force is greater when cushion considered over the box as compared to box without cushion. Their corresponding results like maximum bending moment, shear force with impact for ULS combination and SLS combination are obtained according to provision given in codes. Area of steel indices is studied for both conditions which are shown by graph in result analysis. The required area of steel is greater for overburden structure so the depth adopted for sections Foot Bridge without cushion is not suitable for box with cushion. Structure can be failed or unsafe to carry the stress in concrete while designing. So the adopted depth of section for overburden Footbridge is more than no cushion condition for safety purpose. All structures are safe within considered safe bearing capacity. The design carried out with safe in moment of resistance, shear resistance, stresses in short term effect, stresses in long term effect. It is also designed to safe in crack width.

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