Parametric Study On Underpass RCC Bridge With Soil Structure Interaction

Vinayak Demane [1]and Prof. Swapnil Cholekar [2]
1-Post Graduate Student, Department of Civil Engineering, KLEMSSCET, Belgaum,
Karnataka, India, 590008
2- Professor, Department of Civil Engineering, KLEMSSCET, Belgaum*,*
Karnataka, India, 590008

Abstract

The bridges are structure, which provides means of communication over a gap. Bridges provided passage for vehicular or other type of traffic. The Underpass RCC Bridge is very rarely adopted in bridge construction but recently the Underpass RCC Bridge is being used for traffic movement. Hence constructing Underpass Bridge is a better option where there is a constraint of space or land.

The model is analyzed for bending moment, shear force and axial thrust for different loading combinations as per IRC: 6-2010 standards. As the box structure directly rests on soil and also soil pressure acts at the side walls. It is important to study the soil structure interaction of such structure. To study the response of structure with rigid supports, with soil structure interaction applied to base only and with soil structure interaction applied to base and side walls of the structure and comparing the results.

1. Introduction

The Underpass RCC Bridge is adopted in bridge construction and used for traffic movement and control. Since the availability of land in the city is less, such type of bridge utilizes less space for its construction. Hence constructing Underpass Bridge is a better option where there is a constraint of space or land. The RCC Bridge consists of two horizontal and two vertical slabs. These are economical due to their rigidity and monolithic action. Separate foundations are not required, since the bottom slab resting directly on the soil, serves as raft slab. The barrel of the underpass should be of sufficient length to accommodate the carriageway and kerbs.

For a Underpass bridge, the top slab is required to withstand dead loads, live loads from moving traffic, earth pressure on sidewalls and pressure on the bottom slab besides self weight of the slab.

2. Details of the Structure

A. Modelling and Analysis

For the present study Two-dimensional cross sectional model is considered for the analysis. The analysis is carried out in STAAD.Pro V8i software. For the cross section model two-dimensional cross section of unit width is taken center-to-center distance between vertical members is taken as effective span for the horizontal members. For this model three types of foundation conditions are taken for the study:

Case A: Rigid frame with manually calculated upward pressure

Case B: Bottom slab resting on uniformly spaced springs with stiffness equal to modulus of subgrade reaction of soil.

Case C: Bottom slab and Sidewalls resting on uniformly spaced springs with stiffness equal to modulus of subgrade reaction of soil.

B. Assumptions

In the proposed study, the single cell box structure of span 5.6m and length 24.3m subjected to vehicle loading, dead load, lateral earth pressure and pedestrian load was taken for the proposed study.

C. Geometric Properties

. Overall width of bridge = 24.30m
. Thickness of the top slab = 0.500m
. Thickness of the bottom slab = 0.500m
. Thickness of the vertical wall = 0.500m
. Thickness of wearing coat = 0.081m
. Effective horizontal span for Bridge =5.1+ 0.5 = 5.6m
. Effective vertical span =2.9+0.5 = 3.4m

Live load is calculated manually and it is found that class AA wheel load is maximum compared to other class loading as per IRC: 21-2000.

D. Idealization of the Structure

CASE A: - For this case the structure is idealized as shown in the figure 1. In this case the following types of

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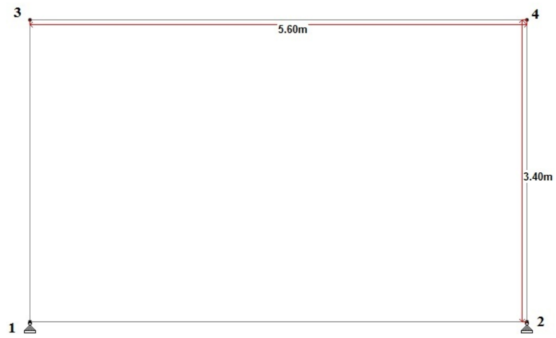
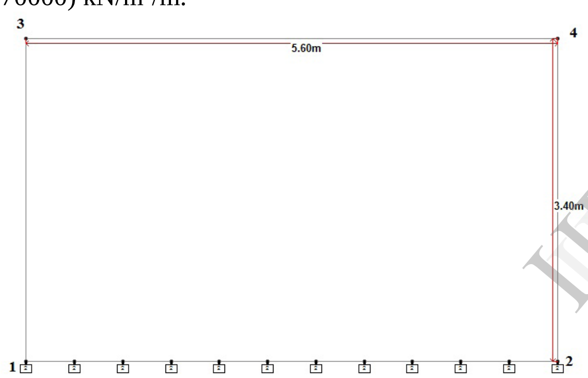
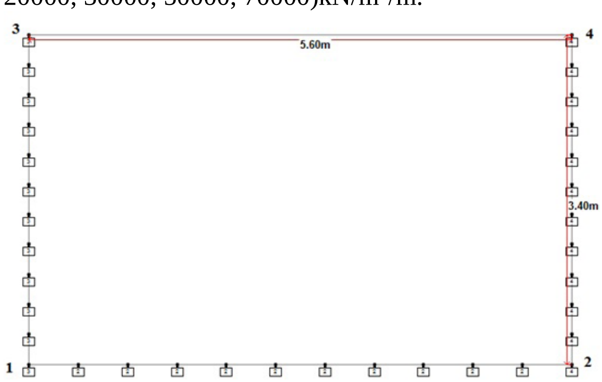
supports are provided below the vertical members. At the nodes 1, 2 supports are pinned.



CASE B: - In this case the nodes are at equal spacing i.e. 0.56m in the bottom slab and spring supports having modulus of sub-grade reaction as stiffness are given at each node. The parametric study is carried out for different values of sub-grade modulus in the practical range named Ks = (5000, 10000, 20000, 30000, 50000, 70000) kN/m^2/m.



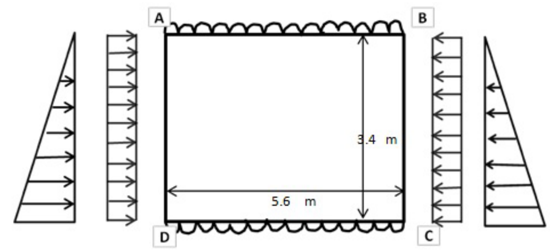
CASE C: - In this case the nodes are at equal spacing i.e. of 0.56m in the bottom slab and side walls and spring supports having modulus of sub-grade reaction as stiffness are given at each node. The parametric study is carried out for different values of sub-grade
modulus in the practical range named Ks = (5000, 10000, 20000, 30000, 50000, 70000)kN/m^2/m.



3. Parametric Study

The Underpass Bridge has been analyzed for its self-weight superimposed dead load (due to wearing coat), live load (IRC Class AA Wheeled Vehicle) and earth pressure on sidewalls. The following loads to be considered for the analysis:

1. Dead Load
2. Live Load
3. Concentrated loads
4. Uniform distributed load
5. Weight of side walls
6. Earth pressure on vertical side walls
7. Uniform lateral load on side walls



The following load combinations are considered for the analysis:

1. Dead Load + Live Load + Earth Pressure (Dry Condition) + Pedestrian Load + Base Pressure + Surcharge.
2. Dead Load + Live Load + Earth Pressure (Dry Condition) + Base Pressure + Surcharge.
3. Dead Load + Earth Pressure (Dry Condition) + Base Pressure + Surcharge.
4. Dead Load + Live Load + Earth Pressure (Submerged) + Base Pressure + Surcharge.
5. Dead Load + Live Load + Earth Pressure (Submerged) + Pedestrian Load + Base Pressure + Surcharge.
6. Dead Load + Earth Pressure (Submerged) + Base Pressure + Surcharge.

The above analysis is carried out for following support cases:

Case 1: Rigid supports with uniform soil pressure beneath the bottom slab.

Case 2: Spring supports at base with different sub-grade modulus

Case 3: Springs supports at Base as well as side walls for different sub-grade modular
i.e.

a. Ks = 5000 kN/m^2/m.
b. Ks = 10000 kN/m^2/m.
c. Ks = 30000 kN/m^2/m.
d. Ks = 50000 kN/m^2/m.
e. Ks = 70000 kN/m^2/m.

4. Results and Discussions

From the soil structure interaction studies, it is seen that structure analyzed with rigid supports give erroneous results as compared to soil structure interaction at base and at base and side walls. Therefore neglecting soil structure interaction is not feasible. It has been seen that shear force and bending moments values lower With Soil Structure Interaction Base and side wall.

Table 4.1 Results for Load case 1 at Base Spring only

MEMBER	RESULTS		BASE SPRINGS					
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	239.266	239.266	239.266	239.266	239.266	239.266	239.266
	BM Mid Span	-188.55	-180.32	-179.86	-179.01	-178.23	-176.84	-175.65
	BM Corner	146.421	154.651	155.106	155.959	156.741	158.127	159.317
Bottom Slab	Max SF	336.924	232.726	230.229	225.544	221.228	213.533	206.864
	BM Mid Span	248.805	183.092	178.237	169.17	160.869	146.21	133.681
	BM Corner	-222.88	-162.90	-159.58	-153.36	-147.66	-137.56	-128.88
Side Wall	Max SF	111.718	91.654	90.543	88.465	86.558	83.179	81.784
	BM Mid Span	115.779	89.9	88.467	85.786	83.326	78.962	75.225
	BM Corner	222.889	162.902	159.58	153.365	147.664	137.562	128.885

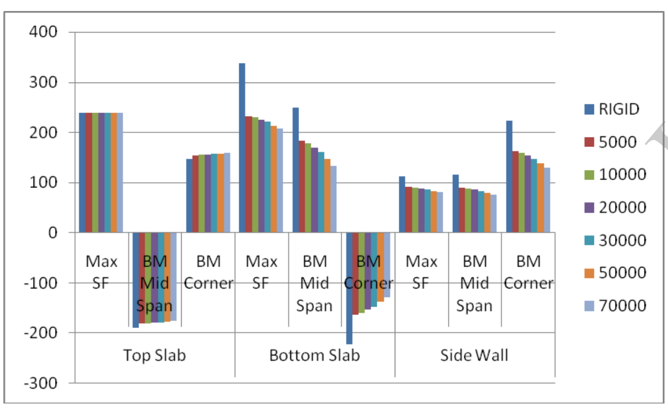


Fig. 4.1 Variation of Load case 1 at Base Spring only

Table 4.2 Results for Load case 1 at Base and Side Wall Springs only

MEMBER	RESULTS		BASE + SIDE WALL SPRINGS					
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	239.266	239.266	239.266	239.26	239.266	239.266	239.266
	BM Mid Span	-188.55	-158.78	-158.66	- 158.41	-158.15	-157.64	-157.15
	BM Corner	146.421	176.188	176.31	176.56	176.819	176.328	177.815
Bottom Slab	Max SF	336.924	34.116	33.407	32.064	30.895	28.922	27.277
	BM Mid Span	248.805	-15.037	-14.43	-13.38	-12.506	-11.088	-9.968
	BM Corner	-222.889	32.365	31.517	29.981	28.612	26.236	24.21
Side Wall	Max SF	111.718	118.742	119.476	120.94	122.395	125.203	127.857
	BM Mid Span	115.779	32.946	32.544	31.722	30.893	29.27	27.729
	BM Corner	222.889	176.188	176.31	176.56	176.819	177.328	177.815

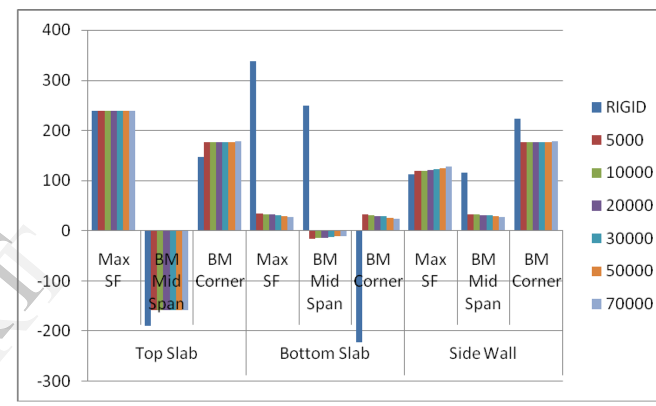


Fig. 4.2 Variation of Load case 1 at Base and Side Wall Spring only

Table 4.3 Results for Load case 2 at Base Springs only

MEMBER	RESULTS		BASE SPRINGS					
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	239.266	239.266	239.266	239.266	239.266	239.266	239.266
	BM Mid Span	-187.25	-180.32	-179.86	-179.01	-178.23	-176.84	-175.65
	BM Corner	147.714	154.651	155.106	155.959	156.741	158.127	159.317
Bottom Slab	Max SF	322.924	226.362	230.229	225.544	221.228	213.533	206.864
	BM Mid Span	238.628	183.092	178.237	169.17	160.869	146.21	133.681
	BM Corner	-213.46	-162.90	-159.58	-153.36	-147.66	-137.56	-128.88
Side Wall	Max SF	108.56	91.654	90.543	88.465	86.558	83.179	81.784
	BM Mid Span	111.714	89.9	88.467	85.786	83.326	78.968	75.225
	BM Corner	213.466	162.902	159.58	155.959	147.664	158.127	159.317

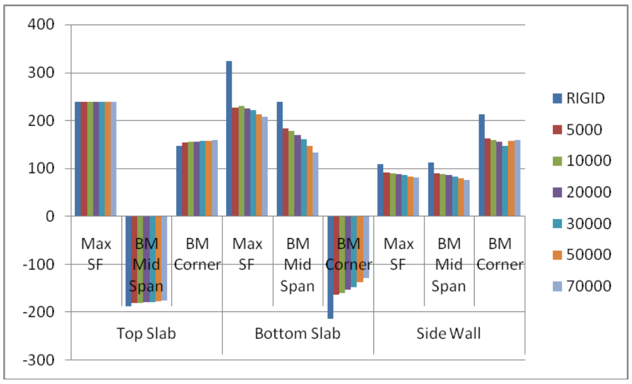


Fig. 4.3 Variation of Load case 2 at Base Spring only

Table 4.4 Results for Load case 2 at Base and Side Wall Springs only

MEMBER	RESULTS		BASE + SIDE WALL SPRINGS					
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	239.266	239.266	239.266	239.26	239.266	239.266	239.266
	BM Mid Span	-187.25	-158.78	-158.66	-158.41	-158.15	-157.64	-157.15
	BM Corner	147.714	176.188	176.31	176.56	176.819	177.328	177.815
Bottom Slab	Max SF	322.924	34.166	33.407	32.064	30.896	28.922	27.277
	BM Mid Span	238.628	-15.037	-14.43	-13.38	-12.506	-11.088	-9.968
	BM Corner	-213.466	32.365	31.517	29.981	28.612	26.236	24.21
Side Wall	Max SF	108.56	118.742	119.476	120.94	122.395	125.203	127.857
	BM Mid Span	111.714	32.946	32.544	31.722	30.893	29.27	27.729
	BM Corner	213.466	176.188	176.13	176.56	176.819	177.328	177.815

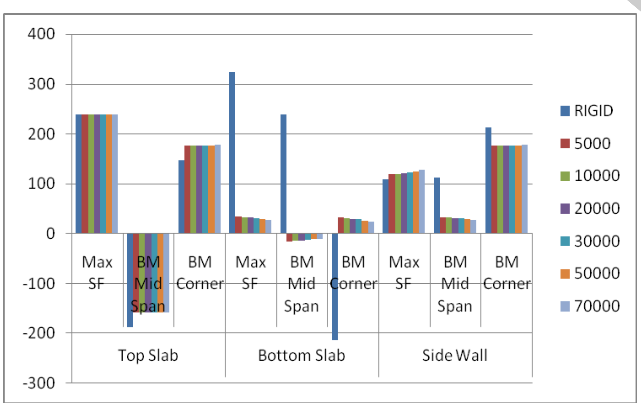


Fig. 4.4 Variation of Load case 2 at Base and Side Wall Spring only

Table 4.5 Results for Load case 3 at Base Springs only

MEMBER	RESULTS		BASE SPRINGS					
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	39.99	39.99	39.99	39.99	39.99	39.99	39.99
	BM Mid Span	-35.51	-30.6	-30.483	-30.263	-30.061	-29.704	-29.397
	BM Corner	20.475	25.385	25.503	25.723	25.924	26.282	26.589
Bottom Slab	Max SF	123.648	68.605	67.968	66.773	65.963	63.716	62.024
	BM Mid Span	87.433	48.836	47.577	45.226	43.072	39.269	36.016
	BM Corner	-85.674	-49.884	-49.027	-47.423	-45.953	-43.348	-41.111
Side Wall	Max SF	53.34	41.37	41.083	40.547	40.055	39.184	38.436
	BM Mid Span	31.002	15.562	15.192	14.501	13.866	12.742	11.777
	BM Corner	85.674	49.884	49.027	47.423	45.953	43.348	41.111

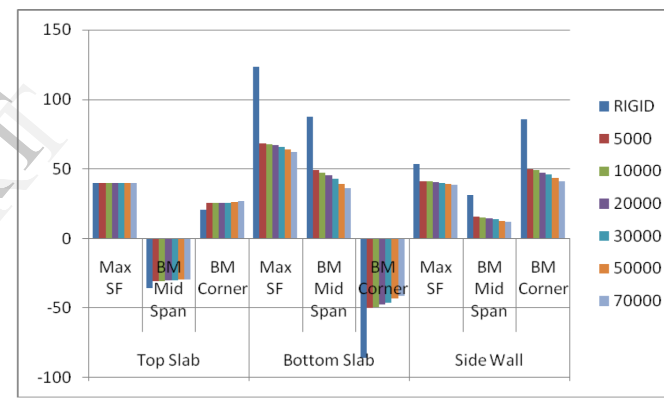


Fig. 4.5 Variation of Load case 3 at Base Spring only

Table 4.6 Results for Load case 3 at Base and Side Wall Springs only

MEMBER	RESULTS		BASE + SIDE WALL SPRINGS					
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	39.99	39.99	39.99	39.99	39.99	39.99	39.99
	BM Mid Span	-35.51	-25.734	-25.874	-26.084	-26.229	-26.399	-26.478
	BM Corner	20.475	30.251	30.112	29.902	29.757	29.586	29.508
Bottom Slab	Max SF	123.648	33.461	32.128	29.93	28.182	25.552	23.642
	BM Mid Span	87.433	-20.495	-19.144	-16.933	-15.197	-12.634	-10.82
	BM Corner	-85.674	25.608	24.453	22.529	20.981	18.61	18.61
Side Wall	Max SF	53.34	17.88	17.597	17.216	17.007	16.898	16.85
	BM Mid Span	31.002	3.664	4.049	4.621	5.008	5.443	5.618
	BM Corner	85.674	30.251	30.112	29.902	29.757	29.586	29.508

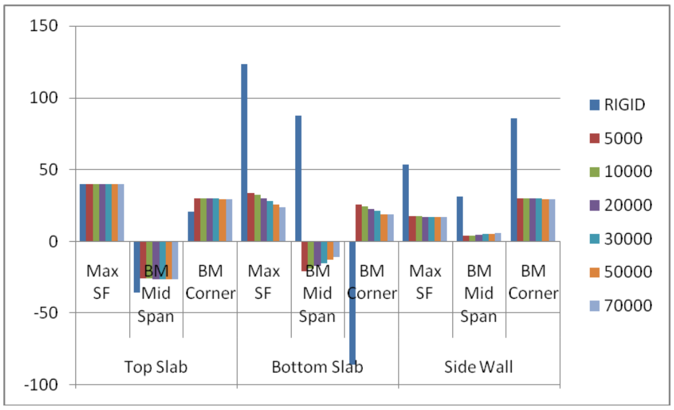


Fig. 4.6 Variation of Load case 3 at Base and Side Wall Spring only

Table 4.7 Results for Load case 4 at Base Springs only

MEMBER	RESULTS	BASE SPRINGS						
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	239.266	239.266	239.266	239.266	239.266	239.266	239.266
	BM Mid Span	-184.798	-177.87	-177.42	-176.59	-175.82	-174.47	-173.31
	BM Corner	150.174	157.1	157.545	158.379	159.143	160.498	161.661
Bottom Slab	Max SF	322.924	232.79	230.356	225.789	221.583	214.086	207.592
	BM Mid Span	235.564	180.137	175.387	166.515	158.392	144.048	131.785
	BM Corner	-216.53	-166.04	-162.79	-156.72	-151.15	-141.27	-132.80
Side Wall	Max SF	125.948	109.062	107.976	105.945	104.081	100.779	97.943
	BM Mid Span	103.508	81.729	80.328	77.708	75.304	71.045	67.387
	BM Corner	216.53	166.044	162.798	158.379	159.143	160.498	161.661

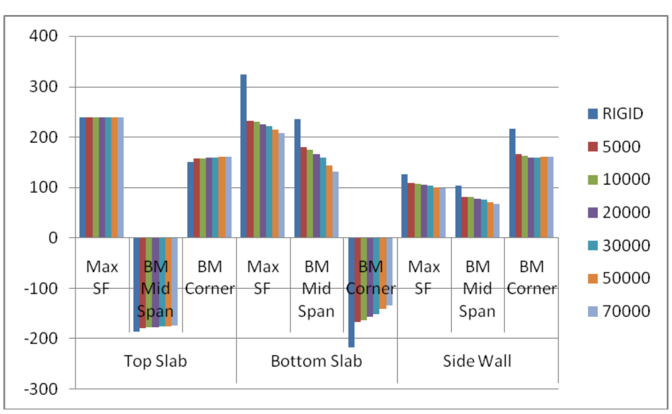


Fig. 4.7 Variation of Load case 4 at Base Spring only

Table 4.8 Results for Load case 4 at Base and Side Wall Springs only

MEMBER	RESULTS	BASE + SIDE WALL SPRINGS						
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	239.266	239.266	239.266	239.26	239.266	239.266	239.266
	BM Mid Span	-184.798	- 158.784	- 158.662	- 158.41	- 158.153	- 157.644	- 157.156
	BM Corner	150.174	176.188	176.31	176.56	176.819	177.328	177.815
Bottom Slab	Max SF	322.924	34.166	33.407	32.064	30.896	28.922	27.277
	BM Mid Span	235.564	-15.037	-14.43	-14.43	-12.506	-11.088	-9.968
	BM Corner	-216.53	32.365	31.517	29.981	28.612	26.236	24.21
Side Wall	Max SF	125.948	118.742	119.476	120.94	122.395	125.203	127.857
	BM Mid Span	103.508	32.946	32.544	31.722	30.893	29.27	27.729
	BM Corner	216.53	176.188	176.31	176.56	176.819	177.328	177.815

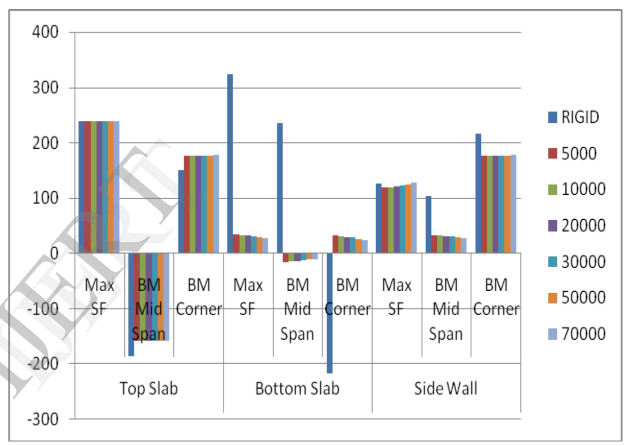


Fig. 4.8 Variation of Load case 4 at Base and Side Wall Springs only

Table 4.9 Results for Load case 5 at Base Springs only

MEMBER	RESULTS	BASE SPRINGS						
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	239.266	239.266	239.266	239.266	239.266	239.266	239.266
	BM Mid Span	-186.019	-177.87	-177.42	-176.59	-175.82	-174.47	-173.31
	BM Corner	148.881	157.1	157.545	158.379	159.143	160.498	161.661
Bottom Slab	Max SF	336.924	232.79	230.356	225.789	221.583	214.086	207.592
	BM Mid Span	245.741	180.137	175.387	166.515	158.392	144.048	131.785
	BM Corner	-225.95	-166.04	-162.79	-156.72	-151.15	-141.27	-132.80
Side Wall	Max SF	129.1	109.062	107.976	105.945	104.081	100.779	97.943
	BM Mid Span	107.574	81.729	80.328	77.708	75.304	71.045	67.387
	BM Corner	225.953	166.044	162.798	158.379	159.143	159.143	161.661

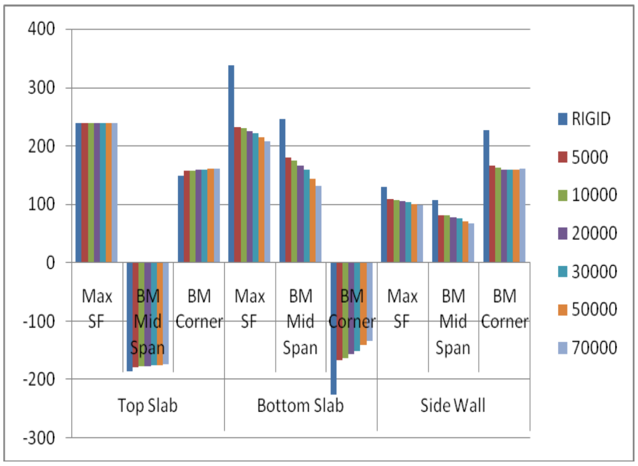


Fig. 4.9 Variation of Load case 5 at Base Spring only

Table 4.11 Results for Load case 6 at Base Springs only

MEMBER	RESULTS	BASE SPRINGS						
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	39.99	39.99	39.99	39.99	39.99	39.99	39.99
	BM Mid Span	-21.539	-16.682	-16.616	-16.491	-16.377	-16.175	-16.003
	BM Corner	34.446	39.303	39.37	39.414	39.609	39.81	39.983
Bottom Slab	Max SF	123.648	68.925	68.595	67.982	67.424	66.446	65.619
	BM Mid Span	72.305	34.25	33.507	32.119	30.846	28.592	26.656
	BM Corner	-100.802	-65.4	-64.914	-64.005	-63.137	-61.703	-60.445
Side Wall	Max SF	125.948	114.107	113.944	113.64	113.362	112.87	112.45
	BM Mid Span	-12.219	27.492	27.702	28.094	28.453	29.087	29.629
	BM Corner	100.802	65.4	64.914	64.005	63.173	61.703	60.445

Table 4.10 Results for Load case 5 at Base and Side Wall Springs only

MEMBER	RESULTS	BASE + SIDE WALL SPRINGS						
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	239.266	239.266	239.266	239.26	239.266	239.266	239.266
	BM Mid Span	-186.019	-158.78	-158.66	-158.41	-158.15	-157.64	-157.15
	BM Corner	148.881	176.188	176.31	176.56	176.819	177.328	177.815
Bottom Slab	Max SF	336.924	34.166	33.407	32.064	30.896	28.922	27.277
	BM Mid Span	245.741	-15.037	-14.43	-13.383	-12.506	-11.088	-9.968
	BM Corner	-225.953	32.365	31.517	29.981	28.612	26.236	24.21
Side Wall	Max SF	129.1	118.742	119.476	120.94	122.395	125.203	127.857
	BM Mid Span	107.574	32.946	32.544	31.722	30.893	29.27	27.729
	BM Corner	225.953	176.188	176.31	176.56	176.819	177.328	177.815

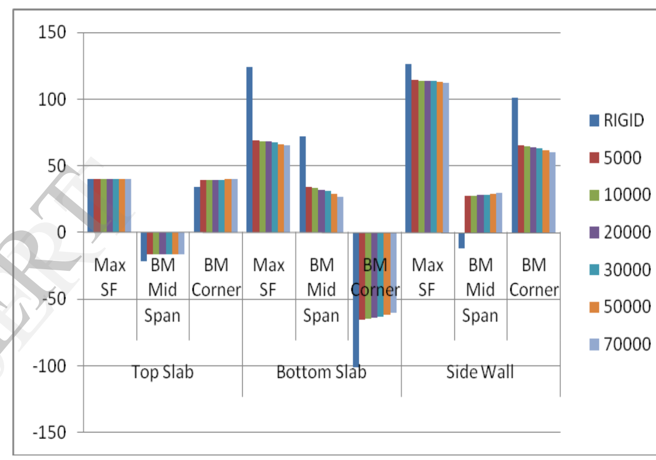


Fig. 4.11 Variation of Load case 6 at Base Spring only

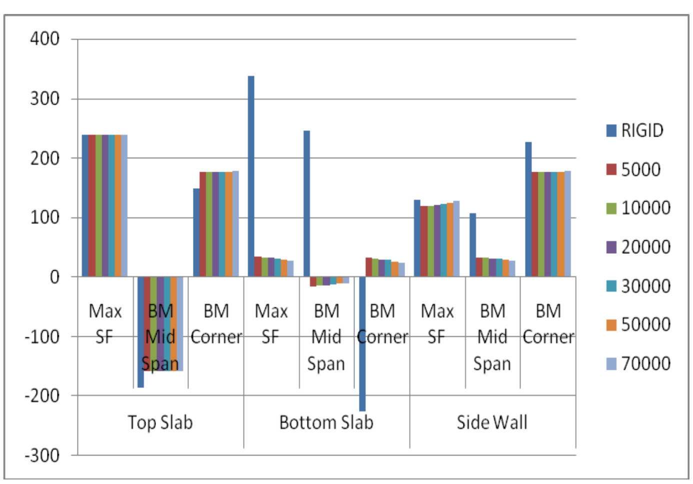


Fig. 4.10 Variation of Load case 5 at Base and Side Wall Springs only

Table 4.12 Results for Load case 6 at Base and Side Wall Springs only

MEMBER	RESULTS	BASE + SIDE WALL SPRINGS						
		RIGID	5000	10000	20000	30000	50000	70000
Top Slab	Max SF	39.99	39.99	39.99	39.99	39.99	39.99	39.99
	BM Mid Span	-21.53	-14.54	-15.01	-15.79	-16.41	-17.36	-18.06
	BM Corner	34.446	41.442	40.971	40.191	39.567	38.62	37.925
Bottom Slab	Max SF	123.648	33.461	32.128	29.93	28.182	25.552	23.642
	BM Mid Span	72.305	-30.954	-28.29	-23.995	-20.69	-15.958	-12.754
	BM Corner	-100.802	12.659	10.747	7.704	5.407	2.215	0.152
Side Wall	Max SF	125.948	71.587	70.199	67.877	65.999	63.105	60.941
	BM Mid Span	-12.219	36.582	34.808	31.868	29.569	26.096	23.588
	BM Corner	100.802	41.442	40.971	40.191	39.567	38.62	37.925

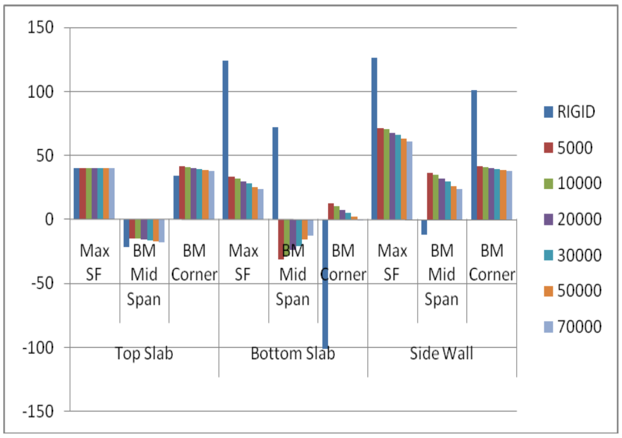


Fig. 4.12 Variation of Load case 6 at Base and Side Wall Springs only

5. Conclusions

1.The bottom slab shear force, corner bending moment and mid span bending moment values decreases about 50%, 60%, 40% from rigid support condition to soil structure interaction respectively at base only.

2. The top slab shear force is similar in both cases and corner bending moment is increases and mid span bending moment values decreases about 5% to 10% from Rigid support condition to soil structure interaction at base only.

3. The side wall shear force, corner bending moment and mid span bending moment values decreases about 30%, 40%, 50% from rigid support condition to soil structure interaction respectively at base only.

4. The bottom slab shear force, corner bending moment and mid span bending moment values decreases with increase in stiffness of soil for all the load conditions at base and side walls.

5. The top slab shear force is similar in both cases and corner bending moment is increases and mid span bending moment values decreases about 20% to 30% from rigid support condition to soil structure interaction at base and side walls.

6. The side wall shear force is increase about 10% to 15% and corner bending moment and mid span bending moment values decreases with increase in stiffness of soil at base and side walls.

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