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Effect of Certain Parameters on Load Enhancement of Simply Supported Rectangular HSSCC Slabs

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Abstract - *The ultimate loads of reinforced concrete tested slabs are found to be higher than the computed yield line load. This enhancement beyond yield line load is due to change of geometry, boundary restraints and consequent development of in plane forces. These effects are considered in the membrane analysis and some methods of analysis of the same are available in the literature which are based on rigid plastic theory. In the studies at M.S.R.I.T., Bangalore. Some modifications to the earlier methods were introduced and the load-deflection behavior was satisfactorily predicted for simply supported rectangular HSSCC (high strength self compacting concrete)slabs subjected to uniformly distributed loading. In the present study, the above analysis has been used to study the effect of certain parameters viz., the coefficient of orthotropy, aspect ratio, span/depth ratio, concrete cube strength, percentage of reinforcement. Numerical results have been obtained for a typical data taken from the experimental work and the variations are presented here.*

***Key Words*: HSSCC Slabs, Membrane action, Yield line load, In plane forces, Load-deflection, parametric study**

1. INTRODUCTION

In simply supported reinforced concrete slabs, the experimental ultimate loads are higher than the computed yield line load. This is due to the development of in plane membrane forces. At large central deflection of the slab, the central region of the slab tends to move inwards but is restrained from doing so by adjacent outer regions. This causes the tensile membrane stresses to develop at the centre of the slab together with a ring of compression near the edges. The compressive forces have a beneficial effect on the yield criterion, resulting in an increase in the load carrying capacity of the slab. Taylor suggested that the ultimate loads could be determined by a redistribution of concrete compressive zone. Kemp presented a rigid plastic solution to determine the ultimate load of a square slab by considering the geometrical conditions, in plane equilibrium and the yield criterion. Sawzuck gave an equilibrium method in which the membrane and bending effects were considered separately for isotropic reinforcement only. Hayes extended Sawzuck's method to orthotropically reinforced rectangular slabs. Morley presented a method which takes into account the effect of membrane action. These earlier investigations were based on rigid plastic approach and their theoretical load-deflection plots do not correspond to the experimental load-deflection behavior of the slab. Desayi and Kulkarni introduce the effect of the deflections that occur prior to the yield line load and generalized the method for rectangular simply supported slabs. Their method predicted satisfactorily the experimental load-deflection behavior and the ultimate loads of rectangular simply supported slabs subjected to distributed loading . subsequently Desayi and Prabhakara extended the above analytical method to simple supported skew slabs. In the present study, these analyses have been used to obtain the load enhancement beyond yield line load and its variations with respect to certain parameters viz., coefficient of orthotropy, aspect ratio, span-depth ratio, concrete cube strength, skew angle and percentage of reinforcement. Certain ranges of above parameters have been assumed and the numerical results obtained for such slabs are presented. Results of a similar study conducted on the influence of certain physical parameters on the ultimate load and the deflection of restrained reinforced concrete rectangular, skew and circular slabs have been reported elsewhere.

1.1 Rectangular Simply Supported Slabs

The method of analysis has been developed in two stages by Desayi and kulkarni . In the first stage, the load-deflection behavior up to yield line load has been established. The effect of cracking and the reduction in the modulus of elasticity of concrete has been taken into account by modifying the flexural rigidity of the slab section. In the second stage, the load-deflection behavior beyond yield line load is predicted by taking tensile membrane action into account. In this method of analysis, load enhancement of simply supported rectangular reinforced concrete slabs has been determined with respect to the following parameters; coefficient of orthotropy, aspect ratio, and span-depth ratio. The following material and sectional properties of the slab section from tests conducted have been used for the purpose of this study.

2. PARAMETRIC STUDY ON HSSCC RECTANGULAR SLABS.

In this section the proposed analysis is used to study the effect of variation of several parameters which affect the load-deflection behavior of High strength Self compacting concrete (HSSCC) slabs. The parameters considered are

1. Coefficient of orthotropy.
2. Concrete strength.
3. Aspect ratio.
4. Span/depth ratio.

5. Percentage of reinforcement.

The following strength and sectional properties of HSSCC slab specimen from the experimental investigation has been used for the purpose of study.
2Lx = span in x direction
2Ly= span in y direction
Sx = spacing of bars in x direction
Sy = spacing of bars in y direction
Dx = effective depth in y direction
fy = yield stress of steel
Lx = 900 mm, Ly = 1400mm, Sx = 150 mm
Sy = 150 mm, dx = 35 mm, dy= 40 mm, f y = 550 N/mm^2
Percentage of steel= 0.33.

2.1 Effect of Coefficient of Orthotropy.

The coefficient orthotropy K is varied from 1.0 to 2.75. With an increment of 0.25. The results are obtained using computer Program , the results are shown in table 1. Chart 1 show the effect of coefficient of orthotropy on the load enhancement. It is noted that with the increase in coefficient of orthotropy, the load enhancement decreases for all the respective slabs.

Table -1: Results of load enhancement V/S coefficient of orthotropy.

f_{ck} (Mpa) \ C.O	1	1.25	1.5	1.75	2	2.25	2.5	2.75
15	62.36	61.26	59.73	57.96	56.02	53.96	51.81	49.56
20	64.77	63.6	62.03	60.24	58.31	56.28	54.18	52.01
30	67.07	65.82	64.2	62.38	60.45	58.44	56.37	54.25
40	69.28	67.95	66.27	64.41	62.46	60.46	58.41	56.32
50	71.4	69.99	68.25	66.35	64.38	62.36	60.33	58.26
70	73.46	71.96	70.15	68.21	66.21	64.18	62.14	60.09

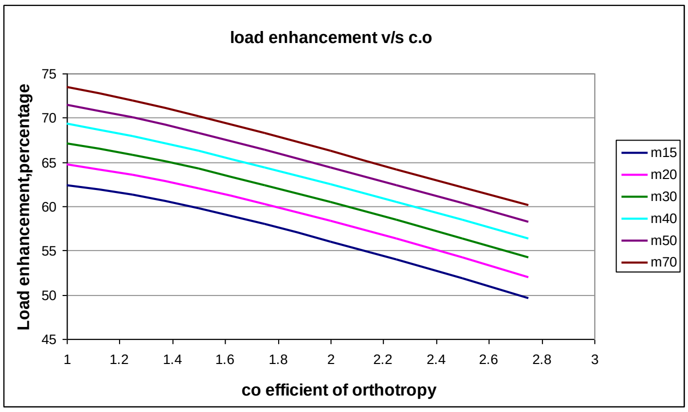

Chart-1: Effect of coefficient of orthotropy on the load enhancement of HSTVC slabs.

2.2 Effect of Concrete Strength.

The cube strength of concrete is varied from 50 N/mm^2 to 70 N/mm^2 with an increment of 5 N/mm^2. The coefficient of orthotropy is fixed at 1.5. Chart 2 shows the effect of concrete cube strength on the load enhancement. It is observed that with increase in cube strength, the load enhancement increases.

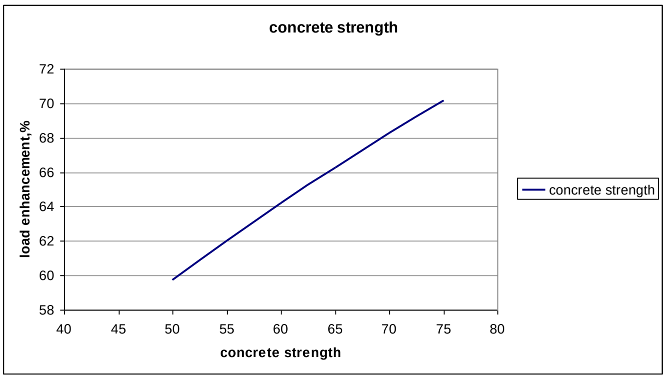

Chart-2: Effect of concrete strength on the load enhancement of slabs.

2.3 Effect of Aspect Ratio.

The aspect ratio is varied from 1.0 to 2.25 with an increment of 0.25. It is noted that the load enhancement increases up to a certain value and then decreases. The results are obtained using a computer program. The results are shown in table 2. It is observed from chart 3, that for a given aspect ratio, the load enhancement increases with increase in grade of concrete.

Table -2: Results of load enhancement V/S Aspect Ratio.

f_{ck} (Mpa) \ A.R	1	1.25	1.5	1.75	2	2.25
15	60.17	59.61	57.87	55.93	54.09	52.47
20	63.97	63.34	61.4	59.21	57.11	55.23
25	67.46	66.77	64.66	62.26	59.94	57.84
30	70.7	69.97	67.71	65.12	62.6	60.31
40	73.75	72.97	70.58	67.82	65.13	62.66
50	76.63	75.82	73.31	70.4	67.55	64.92
55	79.382	78.53	75.91	72.86	69.87	67.09
60	82.01	81.14	78.41	75.24	72.1	69.198
70	84.54	83.64	80.82	77.52	74.26	71.22
75	86.99	86.07	83.15	79.74	76.36	73.2

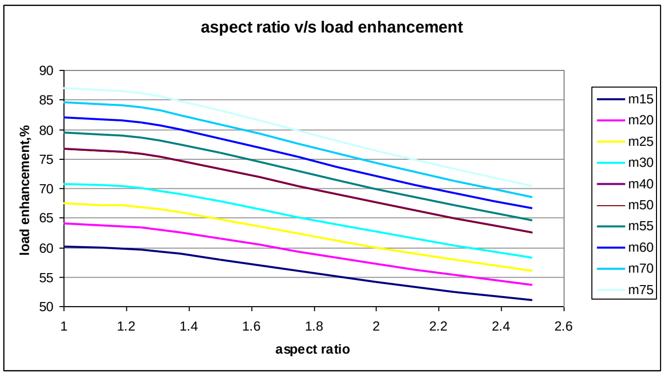

Chart-3: Effect of aspect ratio on the load enhancement of slabs.

2.4 Effect of Span Depth Ratio.

The span depth ratio was varied from 15 to 35 with an increment of 5. The results are obtained using a computer program, and are are shown in table 3. Chart 4 shows the effect of the span-depth ratio on the load enhancement. It is noticed that from Chart 4, the load enhancement in generally increases with the span-depth ratio.

Table -3: Results of load enhancement V/S span-depth ratio.

f_{ck} (Mpa) \ S.D	15	20	25	30	35
15	66.69	85.33	112.02	154.39	225.98
20	69.06	87.47	113.77	155.31	225.045
30	71.34	89.54	115.49	156.34	224.53
40	73.52	91.54	117.19	157.43	224.32
50	75.621	93.48	118.87	158.58	224.35
70	77.66	95.37	120.52	159.77	224.56

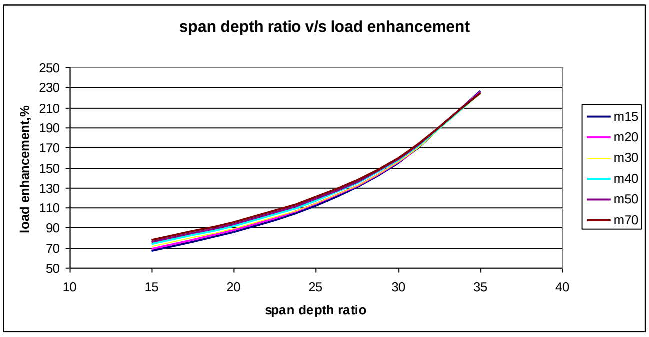

Chart-4: Effect of span-depth ratio on the load enhancement of slabs.

2.5 Effect of Percentage of Reinforcement.

The percentage of reinforcement was varied from 0.2 to 0.8 percent. The results were obtained using a computer program Program and are shown in table 4. Chart 5 shows the effect of percentage of reinforcement on the ultimate load. The load enhancement decreases with increase in percentage of reinforcement. It is also noted that with an increase in angle, the load enhancement also increases. The ultimate load is computed at a deflection of 0.8 times the thickness of the slab.

Table-4: Results of load enhancement V/S Percentage of Reinforcement.

f_{ck} (Mpa) \ P.R	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
15	62.59	60.6	57.54	53.77	49.77	45.48	40.93	36.09
20	65.03	62.92	59.72	56.1	52.21	48.1	43.78	39.23
30	67.36	65.12	61.86	58.25	54.44	50.47	46.33	42.02
40	69.6	67.21	63.89	60.27	56.51	52.64	48.65	44.52
50	71.76	69.23	65.82	62.18	58.54	54.66	50.78	46.8
70	73.86	71.16	67.67	63.99	60.28	56.54	52.75	48.89

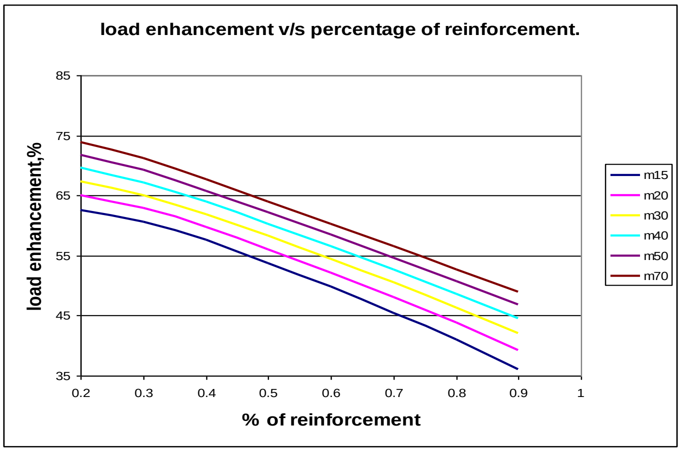

Chart-5: Effect of percentage of reinforcement on the load enhancement of slabs.

3. CONCLUSIONS

The following are the conclusions drawn from the parametric study on HSSCC simply supported rectangular slabs:

- With an increase in the coefficient of orthotropy, the load enhancement decreased for all grades of concrete but increased for higher grades of concrete.
- The load enhancement increased with increase in the grade of concrete.
- For a given aspect ratio, the load enhancement increased with an increase in the grade of concrete. And decreases with increase in aspect ratio.
- The load enhancement in general, increased with the span-depth ratio.
- The load enhancement decreased with an increase in the percentage of reinforcement.

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