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Analytical Study on Curved Slab: An Alternative for Conventional Slab

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Abstract - *Slab is one of the basic components of a structural system. It has gone through many revelations yet continue to be traditional in relative terms. In this paper, a curved slab with high load bearing capacity and less volume of concrete is proposed, in comparison with a conventional slab. A conventional slab is designed according to the provisions of IS 456: 2000 and the same slab is given a curved profile. Both the slabs are modeled in ANSYS WORKBENCH 16.1 and underwent 3-point flexural testing. From the result, there is a 20% increase in load bearing capacity and 9% increase in the ductility of curved slab in comparison to flat slab. So, in order to get a curved slab of comparable load resistance and deformation the thickness of the curved slab is reduced. By a trial and error method a curved slab with reduced thickness of 10 % of conventional slab showed almost similar result. This showed that to provide the same strength a curved slab needed less thickness than conventional slab. The self-weight of the slab can be reduced by 4 %. The floor made of such slab will have an undulated surface. In order to make the surface flat any waste material slurry can be used as filling. The use of such waste material provides an environmental benefit, which is also brought by the reduction of concrete use and can also bring economy to the construction.*

Key Words: Curved Slab, Corrugated Slab, Flexural Test, 3-point test, ANSYS.

1. INTRODUCTION

One of the most common structural element of building, consisting of flat, horizontal surface made of cast concrete is a slab. Floors and ceilings are constructed of steel-reinforced slabs, typically between 100 and 500 mm thick, whereas thinner mud slabs are built for exterior paving.

In most buildings, the ground floor is constructed on either a thick concrete slab supported on foundations or directly on the subsoil. Slabs are generally classified as ground-bearing or suspended. A slab, if it rests directly on the foundation it is ground-bearing, otherwise the slab is suspended.

2. DESIGN OF SLAB

Codal provisions for design of Concrete Slab has been given in IS 456: 2000. Accordingly, safe and efficient slabs can be designed for the purpose of construction.

Yield Strength of Steel, $f_y = 415\ N/mm^2$

Characteristic Strength of Concrete, $f_{ck} = 25\ N/mm^2$

Length, l = 3000 mm

Effective Depth, d = 80 mm

Overall Depth, D = 105 mm

Main Reinforcement: 10 mm diameter bars at 115 mm center to center spacing.

Distribution Steel: 6 mm diameter bars at 224 mm center to center spacing.

3. MATERIAL PROPERTIES

Table -1: Material Properties

PROPERTIES	REBAR	CONCRETE
Grade	Fe415	M25
Poisson's Ratio	0.3	0.15
Strength	415MPa (Y)	25MPa (C)
Density	7860 kg/m^3	2400 kg/m^3
Young's modulus	20000 MPa	25000 MPa

*Y – Yield, C – Compressive

4. DIMENSIONS OF THE CURVED SLAB

Dimensions of the curved slab is identical to the conventional slab designed above. Curved slab of varying thickness of 105 mm, 95 mm, 90 mm are modeled and analyzed. The rise of the curved slab was varied of the order 10 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm, 40 mm, 45 mm, 50 mm.

5. MODELLING OF CURVED SLAB

The conventional slab is modelled according to design in specifications mentioned above. The material properties are fed into the software and applied to appropriate materials. A slab of concrete is modelled primarily modelled using the tools in drawing and extrusion. The reinforcements are embedded into the concrete and they are bonded efficiently.

Supports and loading beam is modelled of the rebar material. The supports are given simply supported condition with one end hinged and the other rotational. The loading beam is placed at the center of the slab along the length of 1000 mm, width 75 mm and depth 25 mm. This is same in the case of supports as well.

Curved slab is modelled by providing a curve in the width wise direction, instead of a line, and generated so that a curved slab is formed.

6. ANALYSIS OF CURVED SLAB

The ANSYS 16.1 software was used to model all the specimens for analysis. The modelled slabs where given required meshing size and after ensuring proper connection and contact they were set for testing. The results were set to be given on parameters like Total Deformation, Equivalent Plastic Strain, Maximum Principal Strain, Force Reaction and Moment Reaction.

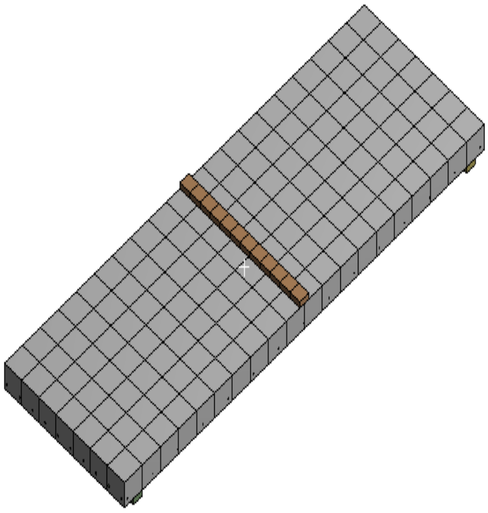

Fig -1: Meshing of a Conventional Slab

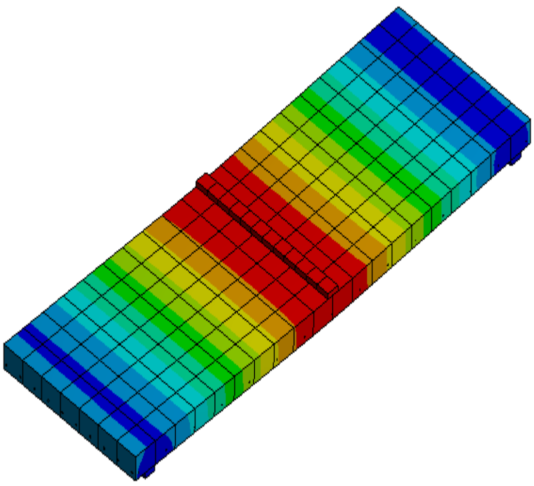

Fig -2: Total Deformation of a Conventional Slab

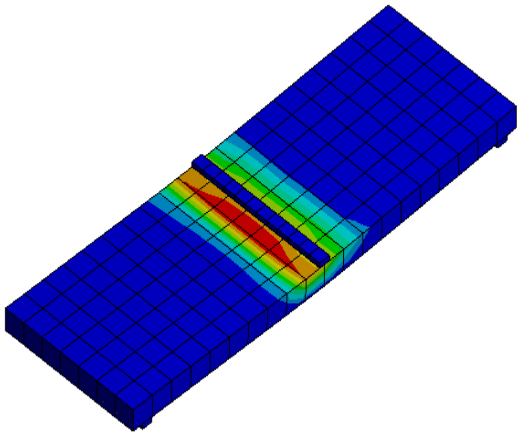

Fig -3: Equivalent Plastic Strain of Conventional Slab

7. RESULTS AND DISCUSSIONS

Total 12 slabs were modeled and tested. 3 slabs were modeled for thickness study of curved slab, 8 slabs were modeled for rise study of curved slab and 1 conventional slab.

7.1 Thickness Study

All specimens have a 10 mm rise. This analytical study shows that, a curved slab of the same thickness as of the conventional slab has a 20 % increase in load carrying capacity. The load carrying capacity of slabs with reduced thickness is also studied to get a specimen of comparable strength as conventional slab. Load deformation curve is shown in the Chart -1.

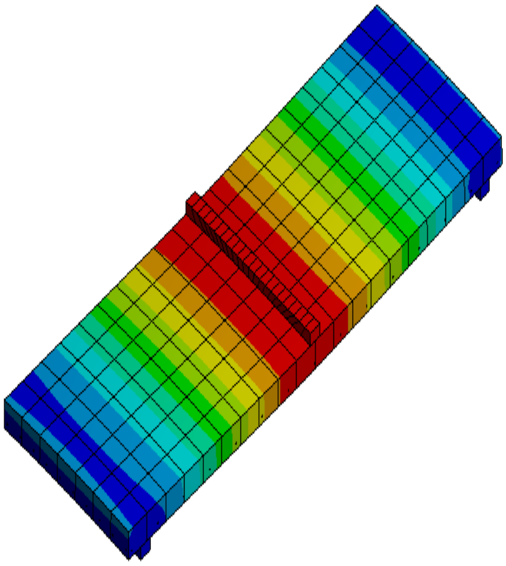

Fig -4: Total Deformation of 105 mm Thick Curved Slab

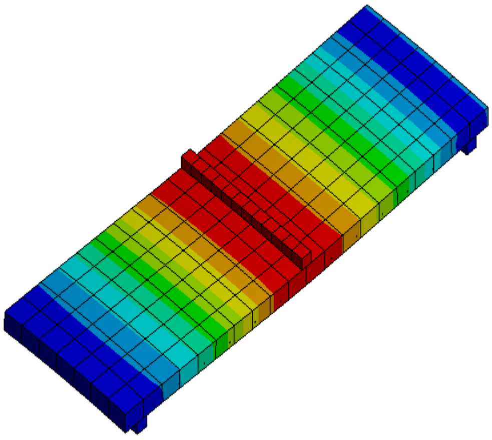

Fig -5: Total Deformation of 90 mm Thick Curved Slab

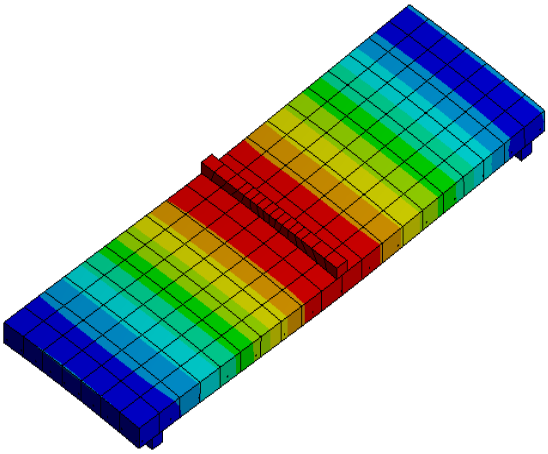

Fig -6: Total Deformation of 95 mm Thick Curved Slab

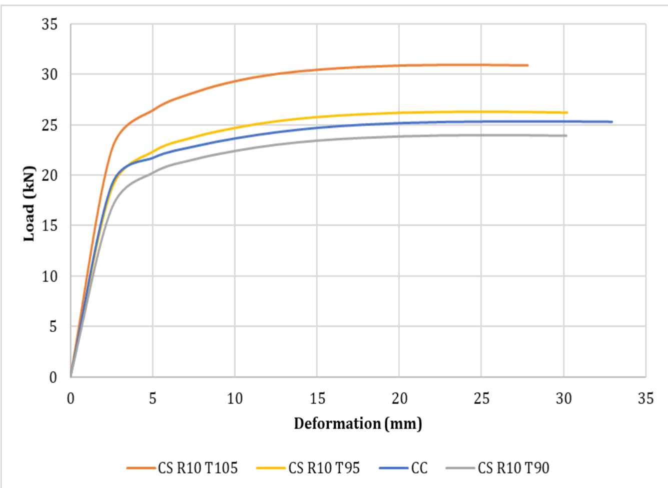

Chart -1: Load Deformation Curve of Thickness Study

7.2 Rise Study

95 mm was chosen as the optimum thickness for the specimens from the thickness study. Rise analytical study shows that, as the rise is increased the load carrying capacity increase. Load deformation curve is shown in the Chart -2.

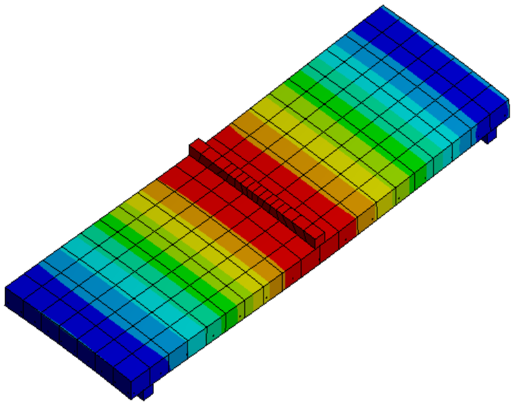

Fig -7: Total Deformation of 95 mm Thick 10 mm Rise Curved Slab

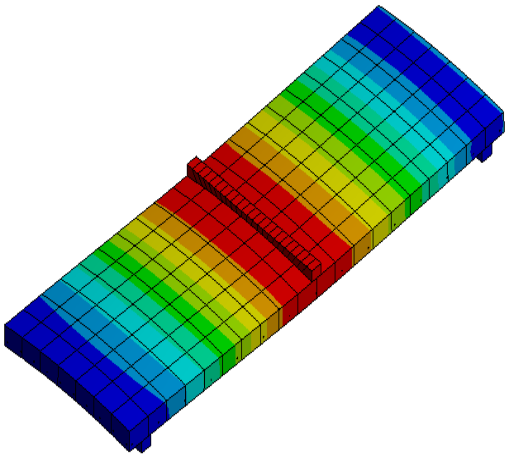

Fig -8: Total Deformation of 95 mm Thick 25 mm Rise Curved Slab

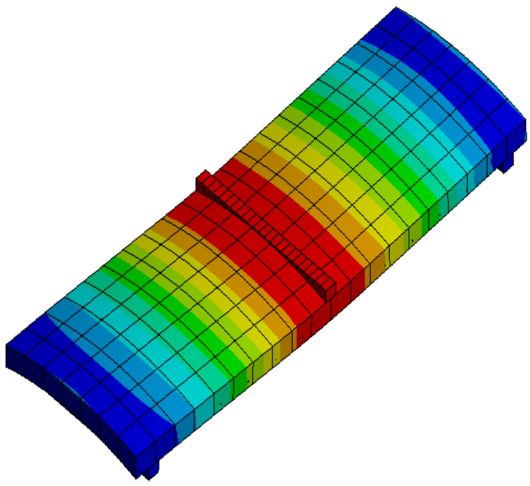

Fig -9: Total Deformation of 95 mm Thick 50 mm Rise Curved Slab

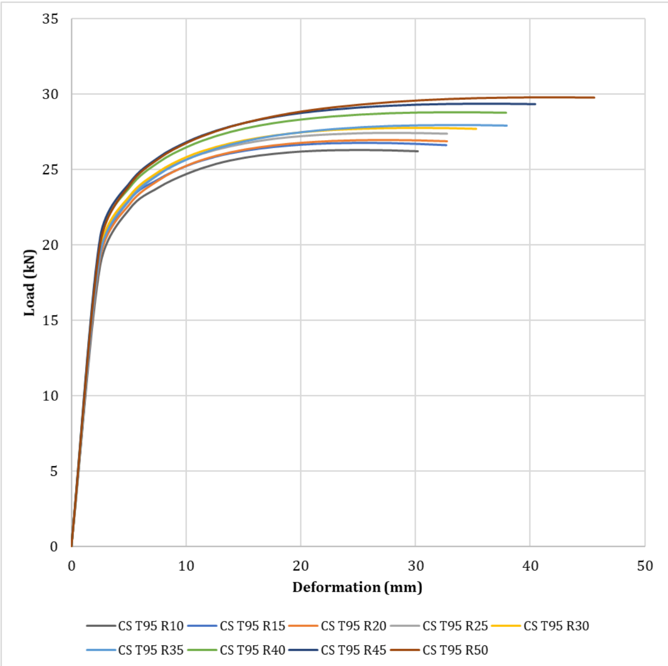

Chart -2: Load Deformation Curve of Rise Study

8. ANALYTICAL RESULTS

Comparison of specimens studied are shown in Table 2 and Table 3.
PIS - Percentage Increase in Strength (%),
UL – Ultimate Load (kN), UD – Ultimate Deformation (mm),
YL - Yield Load (kN), YD - Yield Deformation (mm)
CC - Conventional Slab
CS R10 T105 - Curved Slab with Rise 10 mm and Thickness 105 mm
CS R10 T95 - Curved Slab with Rise 10 mm and Thickness 95 mm
CS R10 T90 - Curved Slab with Rise 10 mm and Thickness 90 mm

Table -2: Thickness Study

SPECIMEN	UD	UL	PIS	YD	YL	DUCTILITY
CC	27.87	25.37	1	2.511	19.05	11.101
CS R10 T105	22.76	30.92	21.88	2.513	22.51	9.057
CS R10 T95	25.16	26.29	3.64	2.508	18.63	10.032
CS R10 T90	25.143	23.986	-5.47	2.5074	16.706	10.027

CS T95 R15 - Curved Slab with Thickness 95 mm and Rise 15 mm
CS T95 R20 - Curved Slab with Thickness 95 mm and Rise 20 mm
CS T95 R25 - Curved Slab with Thickness 95 mm and Rise 25 mm
CS T95 R30 - Curved Slab with Thickness 95 mm and Rise 30 mm
CS T95 R35 - Curved Slab with Thickness 95 mm and Rise 35 mm
CS T95 R40 - Curved Slab with Thickness 95 mm and Rise 40 mm
CS T95 R45 - Curved Slab with Thickness 95 mm and Rise 45 mm
CS T95 R50 - Curved Slab with Thickness 95 mm and Rise 50 mm

Table -3: Rise Study

SPECIMEN	UD	UL	PIS	YD	YL	DUCTILITY
CC	27.87	25.37	1	2.51	19.05	11.10
CS T95 R10	25.16	26.29	3.64	2.508	18.63	10.03
CS T95 R15	27.66	26.73	5.34	2.507	19.16	11.03
CS T95 R20	27.73	26.93	5.78	2.509	19.13	11.05
CS T95 R25	27.70	27.42	7.47	2.508	19.58	11.04
CS T95 R30	30.25	27.76	8.60	2.508	19.71	12.06
CS T95 R35	32.89	27.96	9.25	2.509	19.43	13.10
CS T95 R40	32.81	28.79	11.87	2.509	20.28	13.07
CS T95 R45	35.34	29.37	13.62	2.510	20.52	14.08
CS T95 R50	40.50	29.79	14.83	2.511	20.09	16.12

9. CONCLUSIONS

•From analysis of curved slab, it is evident that even the slightest change in profile curvature an bring a positive flexural behavior of slabs
•For a curved slab with the same thickness as the conventional slab the ultimate load increased by 21.883%

•By reducing the thickness of the curved slab to get a specimen of comparable strength as the conventional slab, the thickness can be reduced by 10%
•The self-weight of the slab decreased by 4%
•As rise or crest increases the strength keeps on increasing from 3.645 for a 10 mm crest to 14.83% for a 50 mm rise
•As the rise of the curvature is increased the load carrying capacity increases by 3% for each 10 mm rise
•For up to 25 mm rise for curved slab there is not much change in ductility from conventional slab, but from 30 mm to 50 mm rise there is steady increase by a factor of 1

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