Finite Element Analysis of Helical Stair Slab

Ahmadullah Tabani[#], Avinesh Kumar[*]

[#, *] *Department of Civil Engineering Mewar University, Rajasthan, India*

***Abstract*— Staircase is used in buildings for providing access to pedestrian to different floors and roof of a structure. A Stair is a series of steps with or without landings or platforms, which is installed between two or more floors of a building to bridge a large vertical distance. In this work we have analyzed helical stair slabs of different radii by modeling it in ANSYS. Three staircases of different radii ranging from small to relatively large have been modeled and loads have been applied to get an idea of deflection.**

***Keywords*— finite element analysis, helical, stair, slab, ANSYS**

I. INTRODUCTION

Staircase is used in buildings for providing access to pedestrian to different floors and roof of a structure. A Stair is a series of steps with or without landings or platforms, which is installed between two or more floors of a building to bridge a large vertical distance. These are designed as slab supported on the beams or walls or frame structure at edges of landings. The design is generally based on the guidelines by different codes of practices. No special treatment is given for varying support conditions and shape of the stair slab. The behavior of helical stair slab has been very difficult to be understood due to its complex geometry. Individual attempts have been made by researchers to get an idea of approximate behavior of its geometry under different circumstances. The real behavior of the stair slab may be obtained by making a prototype and testing it by applying various loads at different points. In this work we have analyzed helical stair slabs of different radii by modeling it in ANSYS. Three staircases of different radii ranging from small to relatively large have been modeled and loads have been applied to get an idea of deflection produced. Deflection contours have also been obtained. Graphs have been made for deflection and compared for the staircases of smaller and bigger radii.

II. REVIEW OF LITERATURE

Saqib and Ahmad (1982); conducted an experimental work by testing a full scale single flight stair, constructed as per the British Code; found that the stair sustained 133% of the load corresponding to the ultimate strength without any sign of failure. This fact pointed out that even though the British Code of Practice regarding the design of stairs is more liberal than the ACI Code, further saving can be made. Their study suggested that the stair slab does not respond in the same manner as do the simple one way slabs and it further revealed that a typical stair slab of same thickness as designed by British Code requires nearly half the reinforcement required by the conventional American design practice (Winter and Nilson).

A.F.M Saiful Amin and S. Ahmad (1999) analyzed a helical stair using finite element technique. The geometry of the prototype stair used in the model is described in validation section.

The deflection profile along the inner edge, centre line and outer edge of the prototype stair due to the action of uniformly distributed dead load and live load showed a tendency of tilting in the outward direction with a maximum deflection at the mid span. The comparison of the curves of the case study revealed that helical girder solution over estimates vertical moment, lateral moment, lateral shear and radial horizontal shear. The extent of over estimation of the support vertical and lateral moments and mid span vertical is around five times whereas the over estimation of support lateral shear stands over three times.

III. MATHEMATICAL MODELLING

The finite element method (FEM) is a numerical method for solving problems of engineering and mathematical physics. It is also referred to as finite element analysis (FEA). Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. We have used ANSYS to analyze the behavior of helical stair slab of varying geometry. In the modeling structural 3D 4 node 181 shell has been used. Material chosen is structural linear elastic isotropic. Hexagonal mapped type mesh was chosen in meshing the models.

IV. VALIDATION OF ANALYTICAL TEST RESULTS

A.F.M Saiful Amin and S. Ahmad have studied a helical stair slab having the following geometry.

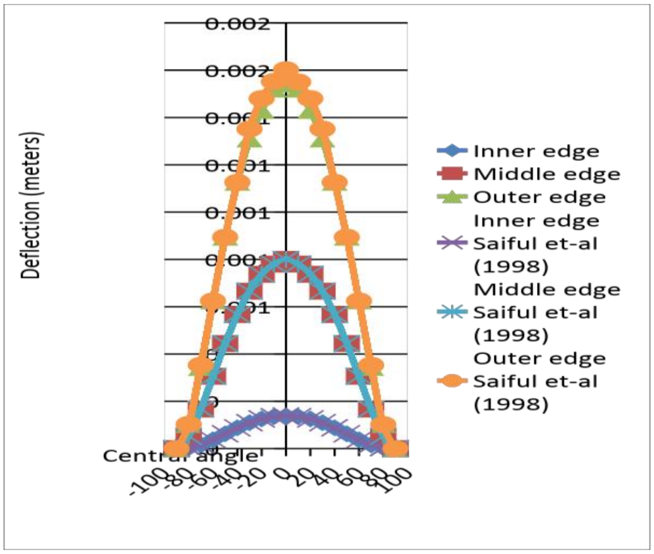
TABLE I

GEOMETRY OF THE STAIR SLAB OF THE MODEL

Inner radius	1.52m
Outer radius	3.80m
Height of the stair case	3.73m
Waist thickness	0.25m
Central angle	180°
Live load (U.D.L)	4790N/m^2

The results were obtained for deflections at each node of the finite elements. To understand the behavior of these slabs the results of deflection has been plotted along suitably chosen sections of the stair slabs. The results were obtained in the form of contours as well as the numerical values at different nodes.

The analytical test result obtained using ANSYS are in close agreement with the results obtained by Saiful et al.



Comparison of stair case deflection obtained using ANSYS with Saiful et al. (1998)

V. PRESENT STUDY

TABLE 2

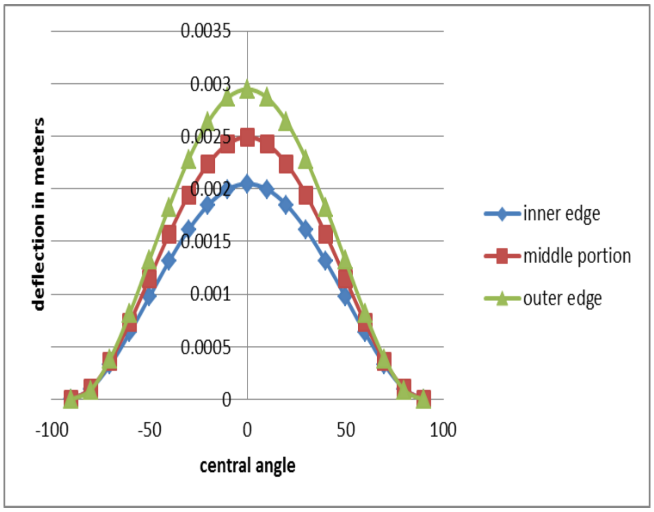
GEOMETRY OF STAIR SLABS TAKEN FOR ANALYSIS.

COMPONENTS	STAIR 1	STAIR 2	STAIR 3
Inner radius	2.8m	3.2m	3.8m
Outer radius	4.0m	4.4m	4.8m
Height of stair	3.6m	3.6m	3.6m
Central angle	180^o	180°	180°
Waist slab thickness	0.30m	0.30m	0.30m
Live load (U.D.L)	5000 N/m^2	5000 N/m^2	5000 N/m^2

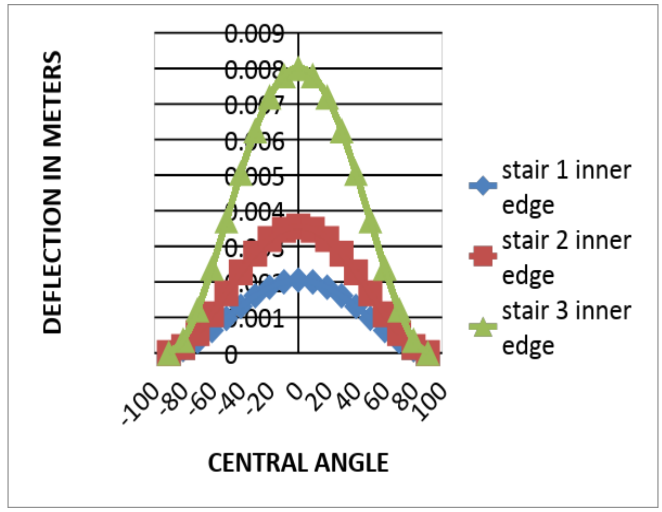
Deflection Obtained in Z Direction and its graphical comparison

TABLE 3
DEFLECTION OBTAINED IN Z DIRECTION FOR ALL STAIR SLABS

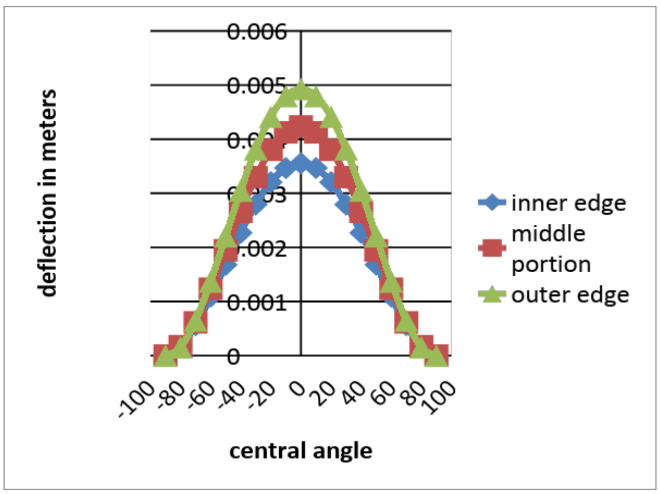
CENTRAL ANGLE	Deflection(m)								
	Stair with outer radius 4 m			Stair with outer radius 4.4m			Stair with outer radius 4.8m		
	Inner Edge	**Middle Portion**	**Outer edge**	**Inner Edge**	**Middle portion**	**Outer edge**	**Inner Edge**	**Middle portion**	**Outer edge**
-90	0	0	0	0	0	0	0	0	0
-80	1.01E-04	1.04E-04	9.02E-05	1.69E-04	1.73E-04	1.53E-04	3.62E-04	3.55E-04	3.16E-04
-70	3.29E-04	3.65E-04	3.87E-04	5.60E-04	6.14E-04	6.46E-04	1.22E-03	1.28E-03	1.32E-03
-60	6.35E-04	7.32E-04	8.20E-04	1.09E-03	1.24E-03	1.37E-03	2.40E-03	2.60E-03	2.80E-03
-50	9.75E-04	1.15E-03	1.32E-03	1.68E-03	1.95E-03	2.21E-03	3.73E-03	4.12E-03	4.52E-03
-40	1.31E-03	1.57E-03	1.83E-03	2.27E-03	2.66E-03	3.05E-03	5.06E-03	5.66E-03	6.26E-03
-30	1.61E-03	1.94E-03	2.28E-03	2.79E-03	3.30E-03	3.81E-03	6.25E-03	7.04E-03	7.84E-03
-20	1.85E-03	2.24E-03	2.64E-03	3.20E-03	3.80E-03	4.41E-03	7.20E-03	8.14E-03	9.09E-03
-10	2.00E-03	2.43E-03	2.87E-03	3.47E-03	4.13E-03	4.80E-03	7.80E-03	8.84E-03	9.89E-03
0	2.05E-03	2.49E-03	2.95E-03	3.56E-03	4.24E-03	4.93E-03	8.01E-03	9.08E-03	1.02E-02
10	2.00E-03	2.43E-03	2.87E-03	3.47E-03	4.13E-03	4.80E-03	7.80E-03	8.84E-03	9.89E-03
20	1.85E-03	2.24E-03	2.64E-03	3.20E-03	3.80E-03	4.41E-03	7.20E-03	8.14E-03	9.09E-03
30	1.61E-03	1.94E-03	2.28E-03	2.79E-03	3.30E-03	3.81E-03	6.25E-03	7.04E-03	7.84E-03
40	1.31E-03	1.57E-03	1.83E-03	2.27E-03	2.66E-03	3.05E-03	5.06E-03	5.66E-03	6.26E-03
50	9.75E-04	1.15E-03	1.32E-03	1.68E-03	1.95E-03	2.21E-03	3.73E-03	4.12E-03	4.52E-03
60	6.35E-04	7.32E-04	8.20E-04	1.09E-03	1.24E-03	1.37E-03	2.40E-03	2.60E-03	2.80E-03
70	3.29E-04	3.65E-04	3.87E-04	5.60E-04	6.14E-04	6.46E-04	1.22E-03	1.28E-03	1.32E-03
80	1.01E-4	1.04E-04	9.02E-05	1.69E-04	1.73E-04	1.53E-04	3.62E-04	3.55E-04	3.16E-04
90	0	0	0	0	0	0	0	0	0



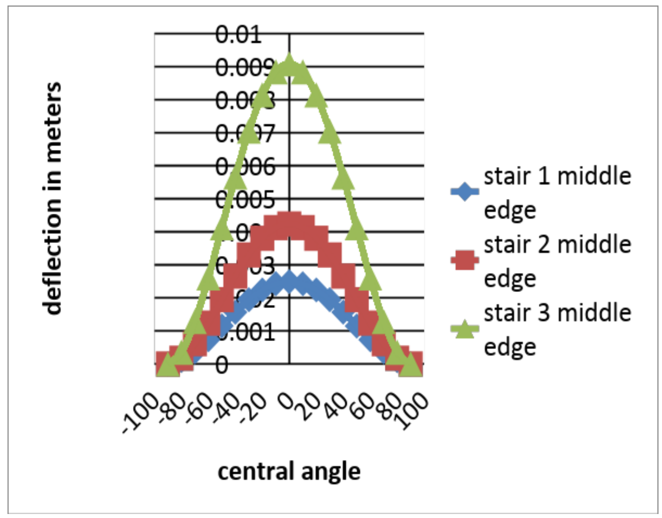
Variation of deflection in Z direction along inner middle and outer edges of stair slab 1



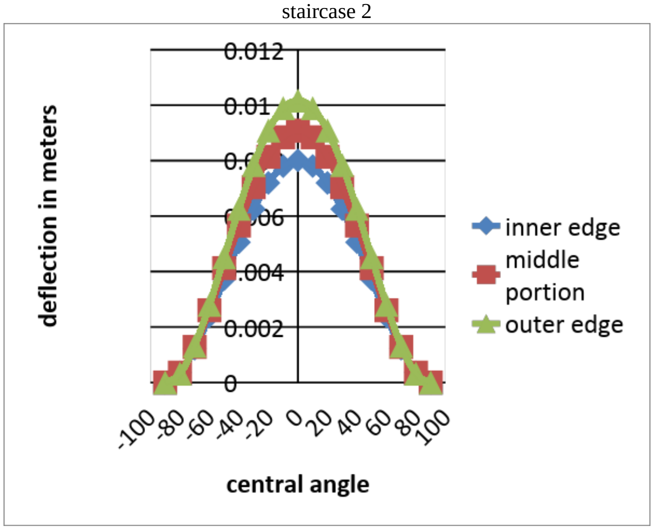
Variation of deflection in Z direction along inner edges of stair slabs 1, 2 & 3.



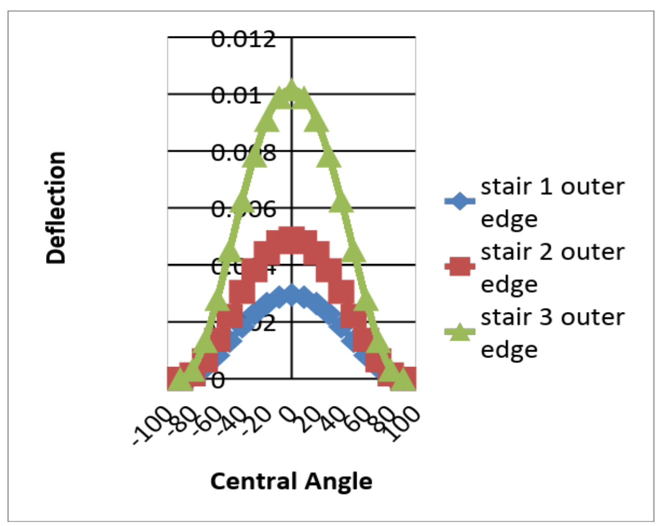
Variation of deflection in Z direction along inner middle and outer edges of staircase 2



Variation of deflection in Z direction along middle portions of stair slabs 1, 2 & 3.

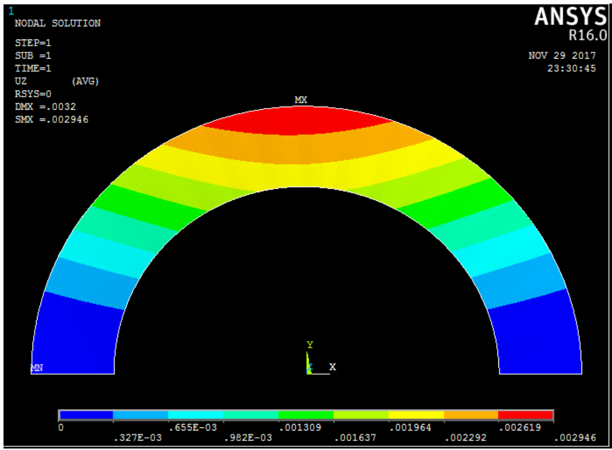


Variation of deflection in Z direction along inner middle and outer edges of staircase 3

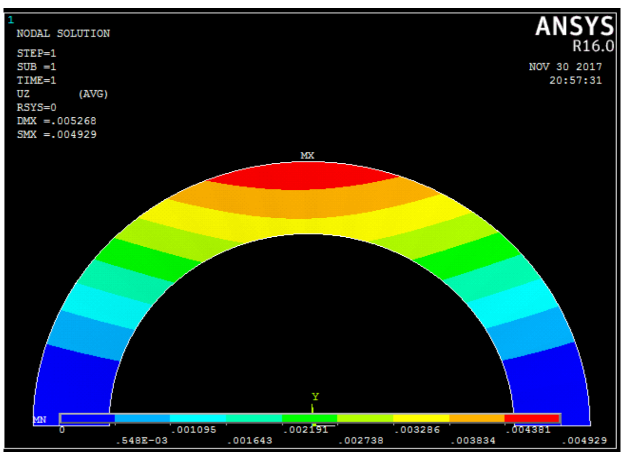


Variation of deflection in Z direction along outer edges of stair slabs 1, 2 & 3.

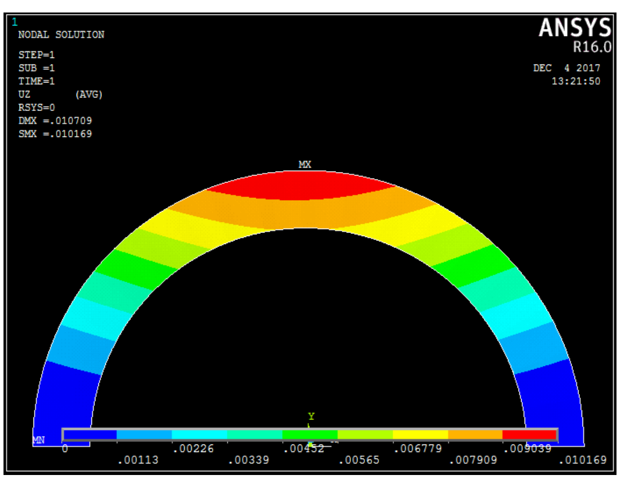
The graphs obtained above show that maximum deflection in the staircase 1 is only 2.05mm where as it is nearly 3.05 mm for staircase 2, and it becomes around 8.01mm for staircase 3 having bigger radii. When the radius is increased the span gets increased which causes the deflection to increase. Similar trend has also been found after graphical comparison of middle and outer edges.



Deflection contours in staircase 1



Deflection contours in staircase 2



Deflection contours of staircase 3

VI. CONCLUSION

The graphs and contours obtained above show that deflection in the all three stair slabs is more in outer edges as compared to middle and inner edges and it reaches maximum at the mid span. The deflection at the starting of the slab is zero. When the radius is increased the span gets increased which causes the deflection to increase. Similar trend has also been found after graphical comparison of middle and outer edges. The deflection is more along the outer edge as compared to intermediate and inner edges. It is also clear from the graph that the deflection is zero at the starting of stair slab where the support is fixed and its value reaches to maximum at mid span.

REFERENCES

[1]. Amin, S. and Ahmad S., ‘An Economic Design Approach for Helicoidal Stair Slabs based on Finite Element Analysis’, Advances in Civil and Structural Engineering Computing for Practice, Editor. B.H.V. Topping, Civil-Comp Press, Edinburgh, pp. 241-246, 1998.

[2]. Amanat, K. M., "A Design Rationale for Free Standing Stair Slabs Based on Finite Element Analysis", M.Sc. Thesis is, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh, 1993.

[3]. Young, Y.E. and Scordelis, A.C., "An Analytical and Experimental Study of Helicoidal Girder", Proceedings, ASCE, Paper No. ST 1756, 1958.

[4]. Scordelis, A.C., "Internal forces in Uniformly Loaded Helicoidal Girder", ACI Journal, Proceedings, 56, pp. 1491- 1502, 1960.

[5]. Morgan, V.A., "Comparison of Analysis of Helical Staircases", Concrete and Constructional Engineering (London), 55, 127-132. 1960.