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Finite Element Analysis of a RCC Stair Using STAAD-Pro

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***Abstract*—In the present paper, the effects of staircase on the dead load and live load performance of the RCC frame buildings of different heights and different plans have been studied. The FEM analysis method of analyzing stairs fail to predict the distribution of any stress resultant and the actual three dimensional behavior of the stair slab system. A more rationale but simple and accurate method of analysis based on finite element method is presented. Stair analysis is used to evaluate unknown displacements at each node of a rectangular plate element. The identification of the weakest elements of the stair structure, the failure type considering the presence of the stairs, and their contribution in the nonlinear performance of RC frame buildings are some of the areas on which the present study has presented. For analysis and design, STAAD-PRO V8i has been used. The results obtained for stresses and deflections are used to describe the behavior of such stair slabs with the variations of slab thickness, including locations of critical moments and deflections.**

***Index Terms*—Stair, Finite Element Analysis, Reinforced Concrete, STAAD Pro**

I. Introduction

Stairs is a set of steps which give access from floor to floor. Stair is an important functional element of a building. Presently, Stairs are gaining popularity because of their attractive appearance. However, design of the stair and its analysis is very difficult Due to the complex geometric configuration of this structure, the present methods of analysis are based on various idealizations and assumptions. Under this background, finite element approach has been applied to study the validity of the current methods in use. The study has been extended further to determine the stress resultants of the stair slab including an intermediate landing for the development of a simplified design process. Stairs are essential features of all residential and commercial buildings. A staircase is constructed with steps rising without a break from floor to floor or with steps rising to a landing between floors, with a series of steps rising further from the landing to the floor above. Although many types of stairs can be planned and designed in concrete, steel or timber. It must be designed to carry certain loads, which are similar to those used for design of the floors. The design is generally based on the guidelines provided in different codes of practices, considering no special treatment for varying support conditions and shape of the stair slab. Specially, the behavior of helical stair slab has not been well understood due to its inherent geometry. Individual attempts made by few researchers claim drastic change in the behavior due to varying support conditions and the specifications provided by codes of practices are insufficient for the designers to help in rational design of stair slabs of different types. The real behaviour of the stair slab may be established by comprehensive theoretical analysis with different support arrangements and experimental tests conducted on full scale or prototype staircases.

II. RCC Frame Structures

An RCC framed structure is essentially an assembly of slabs, beams, columns and foundation inter -related to every different as a unit. The load switch, in such a shape takes place starting the slabs to the beams, from the beams to the columns then to the lower columns and at ultimate to the foundation that successively conveys it to the soil. The ground area of a R.C.C framed structure is 10 to 12 % higher than of a load carrying capacity walled building. Heavy creation is viable with R.C.C framed structures and that they will withstand vibrations, wind load and shocks additional efficiently than load bearing walled buildings.

III. Stair Case

Staircase is an important component of a building providing access to different floors and roof of the building. It consists of a flight of steps (stairs) and one or more intermediate landing slabs between the floor levels. Different types of staircases can be made by arranging stairs and landing slabs. Staircase, thus, is a structure enclosing a stair. The design of the main components of a staircase-stair, landing slabs and supporting beams or wall – are already covered in earlier lessons. The design of staircase, therefore, is the application of the designs of the different elements of the staircase.

IV. STAAD-PRO

STAAD or (STAAD-Pro V8i) is a structural analysis and design computer program originally developed by Research Engineers International in Yorba Linda, CA. In late 2005, Research Engineers International was bought by Bentley Systems. It is the World's Structural Analysis and Design

Software. The analysis is done in a numerical way by the STAND.PRO program, a finite element package, which enables us to solve the linear and the nonlinear

PDE"s and thus the modulus of elasticity of the beam material are obtained. STAAD-Pro is a comprehensive and integrated finite element analysis and design offering, including a state-of-the-art user interface, visualization tools, and international design codes. It is capable of analyzing any structure exposed to static loading, a dynamic response, soil-structure interaction, wind, earthquake, and moving loads. STAAD-Pro V8i is the premier FEM analysis and design tool for any type of project including towers, culverts, plants, bridges, stadiums, and marine structures. Advanced Analysis and Design. With an array of advanced analysis capabilities including linear static, response spectra, time history, cable, and pushover and non-linear analyses, STAAD-Pro V8i.

Provides your engineering team with a scalable solution that will meet the demands of your project every time. STAAD-Pro V8i will eliminate the countless man-hours required to properly load on structure by automating the forces caused by wind, earthquakes, snow, or vehicles.

V. MODELLING OF STAIRS USING STAAD-PRO

Model of staircase design by using STAAD-Pro is developed, analyzed. Following specifications are given to the Staircase:

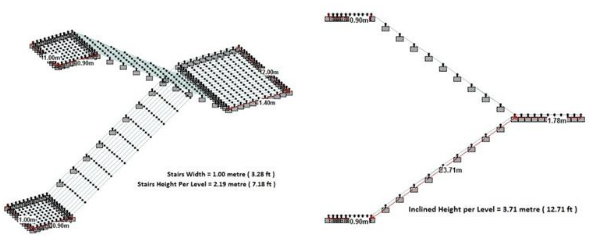

Fig. 1. Design of stair case

TABLE I
DIMENSIONS OF STAIR CASE

Stair elements	Dimensions (meter)
Width of stair	1
Vertical Height per Level	2.19
Inclined Height per level	3.71

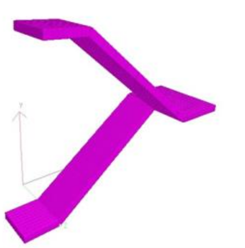

Fig. 2. 3D render view of staircase

These values are provided as an input to the STAAD-Pro software for drawing, analysis and designing purposes.

- Supports: The base supports of the structure are assigned as fixed. Figure 3 shows the Staircase structure.
- Loading: The loadings were optimized partially manually and remaining was analysed using STAAD-Pro load generator. The loading cases were considered as:
  Load case 1: Dead load
  Load case 2: Live load
- Pressure on Slab: pressure of 3 KN/m^2 applied on the slab.

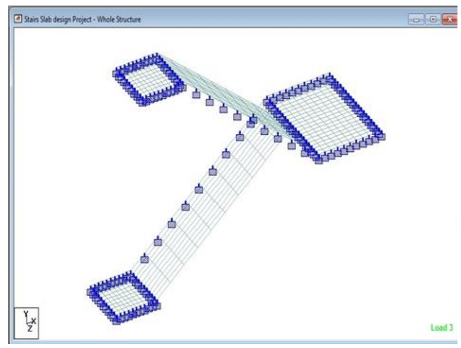

Fig. 3. Fixed support applied

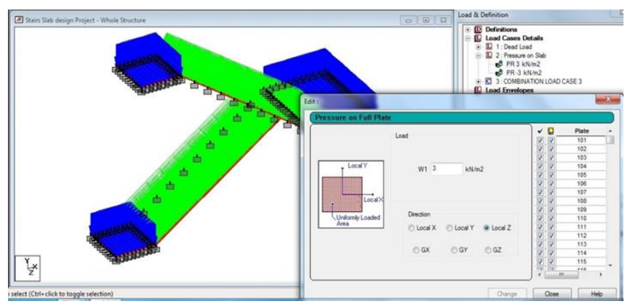

Fig. 4. Pressure applied on slab

VI. RESULTS AND DISCUSSION

TABLE II
DEFLECTIONS ON VARIOUS NODES

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	22	3 COMBINATI	0.050	-0.072	-0.000	0.087	0.000	0.000	-0.000
Min X	354	3 COMBINATI	-0.050	-0.072	0.000	0.087	-0.000	0.000	0.000
Max Y	3	1 Dead Load	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Min Y	354	3 COMBINATI	-0.050	-0.072	0.000	0.087	-0.000	0.000	0.000
Max Z	86	3 COMBINATI	0.002	-0.004	0.000	0.005	0.000	0.000	0.000
Min Z	77	1 Dead Load	0.001	-0.002	-0.000	0.002	0.000	0.000	-0.000
Max rX	22	3 COMBINATI	0.050	-0.072	-0.000	0.087	0.000	0.000	-0.000
Min rX	354	3 COMBINATI	-0.050	-0.072	0.000	0.087	-0.000	0.000	0.000
Max rY	354	3 COMBINATI	-0.050	-0.072	0.000	0.087	-0.000	0.000	0.000
Min rY	3	1 Dead Load	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rZ	346	3 COMBINATI	-0.009	-0.014	-0.000	0.016	-0.000	0.000	0.000
Min rZ	362	3 COMBINATI	-0.009	-0.014	0.000	0.016	-0.000	0.000	-0.000
Max Rs	354	3 COMBINATI	-0.050	-0.072	0.000	0.087	-0.000	0.000	0.000

Stair case designed in STAAD-Pro with the variations in slab thickness of 0.15m, 0.18m and 0.2m. After analysis the model of stair case find out deflections for all slab thickness that designed to optimized the behavior of slab thickness variations. Table 2 shows deflections values on nodes in staircase model using STAAD Pro. The reason for this is design personnel is generally believed that stair member to the structure stress influence is not big, through the structural measures can ensure safety, structure design software did not provide stair to participate in global analysis function, so the author through the discussion stair design problem, analysis the importance of stair design.

TABLE III
DEFLECTION IN MM DUE TO DEAD LOAD

Slab Thickness (m)	Max. Stress (MPa)	Min. Stress (MPa)	Deflection (mm)
0.15	0.259	0.007	0.043
0.18	0.217	0.006	0.03
0.2	0.196	0.006	0.025

TABLE IV
DEFLECTION IN MM DUE TO DEAD LOAD AND LIVE LOAD

Slab Thickness (m)	Max. Stress (MPa)	Min. Stress (MPa)	Deflection (mm)
0.15	0.526	0.01	0.087
0.18	0.403	0.01	0.057
0.2	0.347	0.012	0.044

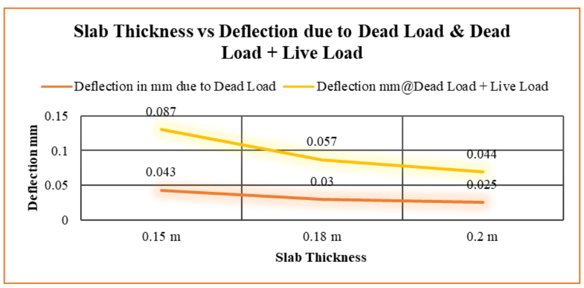

Fig. 5. Slab Thickness vs. Deflection due to Dead Load & Live load

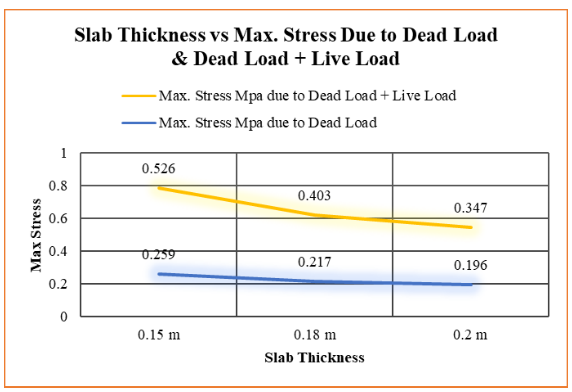

Fig. 6. Slab Thickness vs. Maximum Stress due to Dead Load & Live load

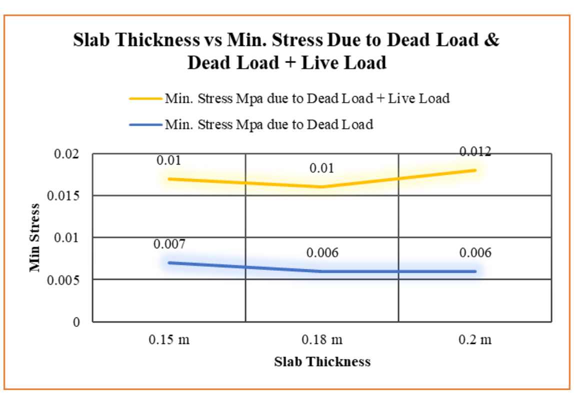

Fig. 7. Slab Thickness vs. Minimum Stress due to Dead Load & Live load

VII. CONCLUSION

The method used is limit state analysis, the factor of safety for concrete is 1.5 and steel is 1.1 it means 50% more concrete and 10% more steel is considering. Where as in working state method which is widely followed in our country has factor of safety of 3 for concrete and 1.7 for steel it means 200% more concrete and 70% more steel. As amount of more concrete and steel, bigger areas can be seen in working stress method. As we can reduce out area by following limit state method and hence also proved as economical. The design follow analysis with STAAD pro and found out the structure is safe in deflections, stresses, loads and moments. The aspects and prospects are made according to NBC of India, which gives various advantages over random arrangements. Following conclusions are described below:

- As per increasing slab thickness deformation of stair slab decreases slightly and we found minimum deformation on 0.2m slab thickness. Maximum deformations found 0.087 mm of 0.15m slab thickness due to dead load and live load.
- If we consider 0.18 m slab thickness, then deflection due to dead load and live load found 0.03mm which is nearest to the 0.25mm deflection of 0.2m slab thickness. So we can say that 0.18m slab thickness found satisfactory results.
- Maximum stress found 0.526 MPa due to dead load and live load combination of staircase and 0.259 MPa stress found due to only dead load.
- In condition of minimum stresses, we found minimum stress of 0.01 MPa on 0.18m slab thickness which is comparatively lower than stress generated in 0.2m slab thickness which is 0.012 MPa due to combination of dead load and live load.
- Due dead load conditions on staircase we found same stresses in 0.18m and 0.2m slab thickness that is 0.006 MPa.
- So as per above study we found satisfactory results on 0.18m slab thickness hence our dead design for 0.18m slab thickness is best for above given conditions.

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