Analysis of Dog-Legged Stair Case

Mohd Khubaib Altamush[1], Imran Alam[2], Abdul Baqi[3], M. R. Sadique[4]
[1, 2] Integral University, Lucknow, India
[3, 4] Aligarh Muslim University, Aligarh, India

Abstract- *Staircase is quite essential part of a building yet it is not given appreciable attention in term of design and analysis, as far as its actual behavior is concerned, in various leading codes of practice. In this study, the behavior of staircase has been investigated using Finite Element method. A multi flight stair slab with landings and simply supported at extreme edges of landings have been analyzed. The results obtained for Mises stresses and deflections are used to describe the behavior of such stair slabs. A three dimensional numerical investigation in ABAQUS/CAE of dog-legged stair case for a multi-storey building has been carried out using finite element method with landing slab simply supported at the extreme edges has been developed. The critical location of deflection in the dog-legged stair case has been identified. Also, the critical location of stresses have been predicted. The behavior of stair slab has been shown in terms of the deflection along longitudinal direction and the values of Mises stresses have been represented graphically. The effect of continuity of the material at landing level is clearly seen as the critical value of deflection and stresses are obtained near mid span as well as near the kinks both at uprising and downward slope of landings; which otherwise may not be so clearly defined by the conventional method as recommended by the standard code of practice.*

Keywords- Dog-legged Stair Slab, 3D Analysis, ABAQUS/CAE, Deflection, Stresses

I. INTRODUCTION

In order to make the pedestrian reach different floors and roof of a structure, stairs are provided. These are in the form of slabs supported on beams or walls or frame structure at edges of the landings. The design of stairs is generally based on the guidelines by different codes of practices, considering no special treatment for varying support conditions and shape of the stairs.

II. BACKGROUND

Dog-legged stair slabs, commonly used for easy movements, are supported at landing levels on walls or beams provided along and/or at right angles to the direction of flight. These supports provide significant rigidity in the stair slab and hence a redistribution of moments is possible along the span of the flight. This phenomenon is normally ignored when designers consider the stair slab as simple beam supported at the ends and the span of the stair slab is taken as the distance between the end supports. The traditional methods of analysis of such stair were based on various idealizations and assumptions. Even the American code of practice [4] does not provide any recommendation regarding the restraining effect in the slab due to inherent support conditions. British code [3], however, considers the above fact and a reduction in the effective span of the stair slab are suggested which results in some saving in the design as compared to the conventional design. For stair slabs with landings supported parallel to the direction of flight, Indian code of practice for plain and reinforced concrete [7] suggests a reduced span of the stair slabs i.e. equal to the going of the stairs (the horizontal projection of the inclined portion) plus at each end either half the width of landing or 1m, whichever is smaller. An experimental study conducted in Bangladesh [5] also claimed a considerably high ultimate load (about 133%) achieved in the stair slab designed as per specifications of the British Code [3]. A similar study by Ahmad et. al. [6] proved that the landings supporting the stair slab derive considerable restraining effect both at inner and outer edges of the flight. Consequently, a reduction in span of 30% and 20% of the going respectively in dog-legged and open-well stair slabs of selected size was suggested. Aslam [1], based his analytical study on the behavior of dog-legged stair slab, reported that the maximum sagging moment obtained as per provisions of Indian code [7] are on conservative side. Further, the study revealed that considerable hogging and twisting moments are developed at different locations in stair slab and the landings for which no care had been suggested by Indian code. A similar study for six different support conditions for varying width of flight by A. Baqi [2], gives that the behavior of dog-legged stair slab depends both on the type of the supports and width of flight and landings. Since the complex behavior of stair slab is still not well understood, a comprehensive test study is therefore needed to establish the behavior of dog-legged stair slabs.

III. CASE STUDY

The present study deals with analytical modeling of dog-legged stair slab with supported at extreme edges of landing using ABAQUS/CAE. The deflection and stresses at different sections of the slab have been determined. Variation of the deflection and the stresses, along the longitudinal span of the slab, has been presented graphically.

Finite Element Modeling:

The recent advancement and availability of high speed computers has facilitated to obtain numerical solution of a wide range of engineering problems. Among the various techniques, the finite element method is considered to one of the powerful tools. Analytical modeling of Dog-legged stair slabs has been done using ABAQUS/CAE Software as shown in Fig. 1.

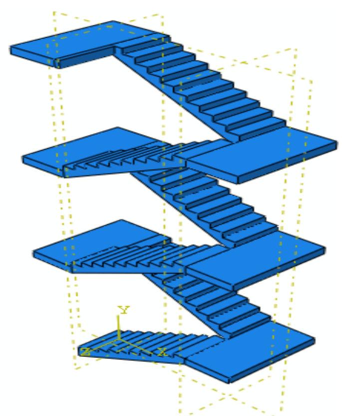

Figure 1: Reinforced Concrete model of stair case

The present analysis has been therefore, carried for the stair slab for the following geometry given in Table-1

TABLE-1
Geometry of the Dog-legged Stair Case

Storey Height	3000mm
Width of Landing	1000mm
Width of Flight	1000mm
Tread	270mm
Riser	150mm
Length of going (horizontal plane)	2700mm
Thickness of waist slab	200mm

IV. RESULTS AND ANALYSIS

Here we will discuss the analytical results of the stair slab for Landing slab simply supported at the extreme edges and a selected Landing and Flight width of 1m. As mentioned above, the result are presented for a selected portion of the stair slab i.e. III[rd] flight and IV[th] flight as shown in Fig. 2. The results for Mises Stresses and Deflection are presented here in graphical form for typical longitudinal sections.

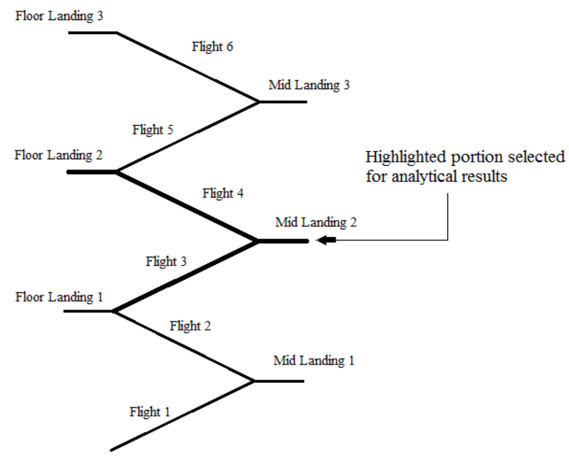

Figure 2: Side view of dog-legged stair case

Analyzing Landing slab simply supported at the extreme edges:

STRESSES

Stresses in Longitudinal direction:

Fig 3. shows that the stresses in concrete along the Longitudinal section at flight-3 vary maximum in mid span and near both the kinks. The stresses in concrete along Longitudinal section at flight-4 also vary increasingly in the same pattern with maximum value near mid span and higher values near kinks. This is quite obvious as the moment are critical at mid span and near the kinks.

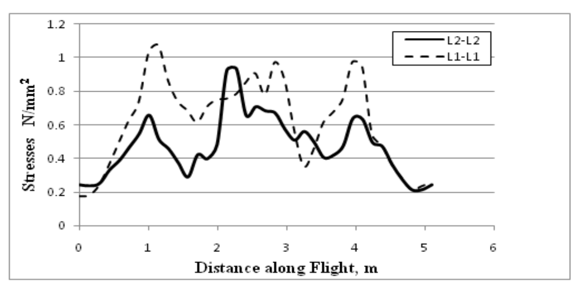

Figure 3: Stresses along Flight-3 (L1-L1) and Flight-4 (L2-L2)

DEFLECTION

Deflection in Longitudinal direction :

Figure 4. shows deflection in the longitudinal direction on the inner edges of the flight-3 and flight-4, respectively. The deflections undergo vertical downward displacement. The maximum deflection at mid-section in the flight-3 is 3.8 mm and in the flight-4 is 4.6 mm.

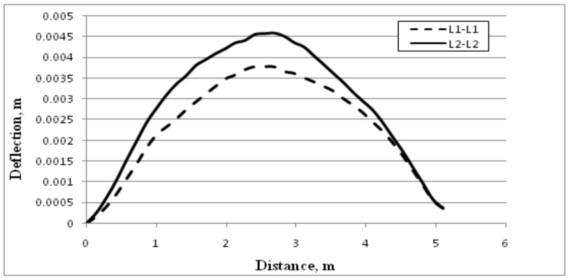

Fig 4: Deflection along Flight-3 (L1-L1) and Flight-4 (L2-L2)

V. CONCLUSIONS

Stair slab loaded with uniformly distributed load has a tendency to lean downwards. The deflection is maximum along outer edges and its value decreases as we move towards inner edge. The deflection is zero at the fixed ends and the support. The effect of continuity of the material at landing level is clearly seen as the critical value of deflection and stresses are obtained near mid span as well as near the kinks both at uprising and downward slope of landings. Contrary to this, the conventional methods pay attention only on the mid span and not near the kinks.

REFERENCES

[1] Aslam, M. 2004, "Analysis of Two Flight Staircase by Finite Element Method", M. Tech. (Civil Engg.) Dissertation, Department of Civil Engineering, Aligarh Muslim University, Aligarh, India.

[2] Baqi, A. and Zaid Mohammad 2013, "Effect of U-Turn in Reinforced Concrete Dog-Legged Stair Slabs", World Academy of Science, Engineering and Technology International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:7, No:6.

[3] British Standard 1989, Structural Use of Concrete Part-I (Code of Practice for Design and Construction), BS 8110 Part 1: 1985, British Standards Institution, May.

[4] Building Code 2005, Requirement for Structural Concrete (ACI-318-05),American Concrete Institute.

[5] I. Ahmed, A. Muqtadir and S. Ahmed 1995, "A Design Basis for Stair Slabs Supported at Landing Level", Journal of Structural Engineering, ASCE,Vol. 121(7), July, pp.1051-1057.

[6] I. Ahmed, A. Muqtadir and S. Ahmed 1996, "Design Provisions for Stair Slabs in the Bangladesh Building Code", Journal of Structural Engineering, ASCE, Vol. 122(3), March, pp.262-266.

[7] Indian Standard 2000, Plain and Reinforced Concrete-Code of practice (IS-456: 2000) Bureau of Indian Standards, New Delhi, July.