STAIR SLABS SUPPORTED AT LANDING LEVEL

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Abstract

Stair is one of the most important functional elements of a building. This paper reports the development of a new design guideline for the stair slab, supported on the structural member spanning at right angle to the direction of the flight. The study is based on finite-element analyses of two common types of stairs, dog-legged and open-well stairs. The stair slabs, usually supported on walls or beams at landing levels, derive significant rigidity from such supporting arrangement. This results in an efficient distribution of moment along the length of the flight. This distinctive feature of stair slab is not recognized by the leading codes of practice. In order to establish the characteristic behaviour of stairs of the aforenamed types, a sensitivity study for the geometric parameters of the stair slab has been carried out. Based on the findings of the present study, a new design rationale for stair slab has been proposed. the guidelines presented here enable straightforward estimation of the design forces, which are generally overestimated by 300-400% when determined by the conventional design practices.

Keywords: Stair with landing; dog-legged stair; open-well stair;

1 Introduction

Owing to their inherent supporting arrangements, the stair slab with supports on three sides at landing level have a very efficient way of transferring load. The leading codes of practice do not provide proper appreciation to the actual behaviour of stair slab of this type. Regarding the design of stairs, the American Concrete institute (ACI) Code (1989) does not provide any recommendation for the restraining effect on the stair slab owing to its support conditions. The British Code (CP 110, Code 1972), on the other hand, provides some reduction in the effective span of a stair slab. Reduction in the effective span as suggested by the British Code, obviously results in some saving in the design.

Finite-element investigations of stair slabs, built monolithically with structural members spanning at right angle to the direction of the flight have been carried out. The behaviours of both dog-legged and open-well type (see Fig.1) of stair have been studied. The influences of the various geometric parameters on the design forces have also been studied. Based on the findings of this study, a guideline for the estimation of design forces is proposed.

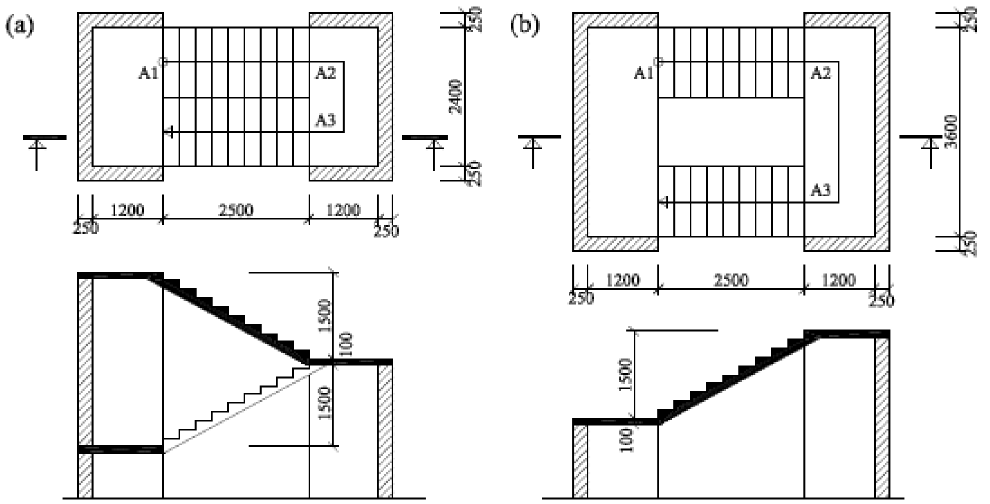

Fig. 1 Typical Dimension of Dog-Legged Stair (a), Open-Well Stair (b)

2 Finite element analysis

2.1 Finite – element model

For this purpose, the finite-element mesh has been used with thin shell linear element (stiff63) of Ansys. This element has four nodes with six degrees of freedom per node. Shear deformation is neglected in this thin shell element. The nodes along the walls (see Fig.1) at both landings were restrained against vertical displacement. The mesh comprised of 161 nodes in 128 elements was chosen as an optimum choice

2.2 Assumptions:

The study was carried out with the following assumptions: (1) Double flight stairs having intermediate landing of the dog-legged and open-well types are analyzed. Typical dimensions considered for the dog-legged stair and the open-well stair are as shown in Fig.1. For the purpose of analysis, three consecutive flights have been considered. Symmetry conditions were applied at both the terminal landings (see Fig.2). The results of the intermediate flight is considered for discussion in the subsequent sections, since it was contemplated that this particular flight would be free from any undue effect of the boundary conditions imposed at the terminating landings. (2) Waist slab and landing slab were assumed to have the same thickness. (3) The material was assumed to be linearly elastic, homogeneous, and isotropic. (4) Both live and dead loads were applied as gravity loads. A live load of 4,8 kN/m^2, a dead load for 100 mm thick slab (for a material unit weight of 25 kN/m^3). (5) A bending moment, producing compression at the top is considered positive. Bending in the longitudinal direction, which produces stresses in x-direction is termed as M_X. Similarly, moment-producing stresses in y-direction is designated as M_Y.

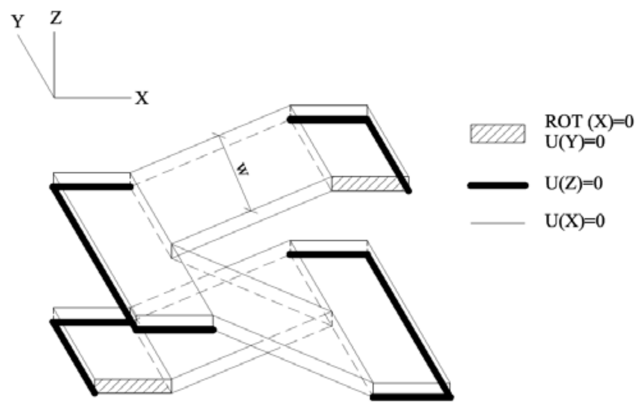

Fig. 2 Boundary Conditions for a Three-Flight Analysis

3 Parametric study

The effects of varying the geometrical parameters on the overall behaviour of stair have also been studied. The parameters considered are: (1) length of the landing slab - *a*, (2) horizontal projection of the waist slab - *b*, (3) height of the flight - *h*, (4) width of the flight - *w*, (5) opening *c* of an open-well stair (see Fig. 1b).

In addition to the variation of the aforementioned geometrical parameters, three different distributions of live load were also considered. In the first case, full live load was applied on the waist slab and on the lower landing (of the second flight), and the upper landing was loaded with full live load. Loading case 2 was composed of full live load on all panels. The third loading case was considered with full live load on the waist slab portion of the second flight, while the two landing slabs of the second flight were loaded with dead load only. As in the previous case, the first and third flights were completely loaded with full live load.

Tab. 1 Variation of Width of Flight w in Dog-Legged Stair

t [mm] (1)	a [m] (2)	b [mm] (3)	l=(2a+b) [m] (4)	h [m] (5)	w [m] (6)	w/b (7)	Maximum positive moment [kNm/m] (8)	Efective span b_e [m] (9)	(b_e/b)x100 (%) (10)
100	1,2	2,5	4,9	1,5	1,05	0,42	4,51	1,860	74,40
100	1,2	2,5	4,9	1,5	1,20	0,48	5,06	1,970	78,80
100	1,2	2,5	4,9	1,5	1,35	0,54	5,38	2,031	81,26
100	1,2	2,5	4,9	1,5	1,50	0,6	5,73	2,096	83,86

Tab. 2 Variation of Parameter w in Open-Well Stair

t [mm] (1)	a [m] (2)	b [mm] (3)	l=(2a+b) [m] (4)	h [m] (5)	w [m] (6)	c [m] (7)	Maximum positive moment [kNm/m] (8)
100	1,2	2,5	4,9	1,5	0,90	1,2	5,28
100	1,2	2,5	4,9	1,5	1,20	1,2	6,56
100	1,2	2,5	4,9	1,5	1,50	1,2	8,15

4 Proposal for design guideline

The critical locations for moment, are identified as: (1) midspan of the flight, for a positive moment in the longitudinal x – direction , (2) kink location, for a negative moment in the longitudinal direction, (3) landing slab, (a strop adjacent to the kink line of half the width of the landing, a, for moment in lateral y – direction.

4.1 Dog-legged stair

Because of the sensitivity of the various geometrical parameters, it is difficult to specify a general rule to quantify the maximum positive moment. However, it will be sufficiently conservative to assume an effective span equal to 90% of the going of the stair slab.

$$M_{ult} = \frac{1}{10} q b^2$$

4.2 Open-well stair

The midspan positive moment, for an open-well stair is sensitive to the parameters *c* and *w* (the width of the flight). However, an effective span equal to the going of the stair would produce a positive moment, which may be deemed satisfactory for the common range of these parameters.

$$M_{ult} = \frac{1}{8} q b^2$$

5 Conclusions

Behavioural studies on the two different types of stair slab commonly used in the residential and office buildings have been made in this paper. The codes of practice do not give proper appreciation to the distinctive feature of the stair slabs where the landings are supported by walls in three sides. In absence of specific guidelines, the practicing engineers have a tendency to follow the design rules specified for a more general type of stair. This results in a gross overestimation of the design forces. On the basis of a finite-element investigation, supported by experimental evidence, guidelines have been developed for simple and straightforward design of stair slabs.

Acknowledgements

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References

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