Analysis of Steel Concrete Composite Waffle Slab With Opening

Midhun m s

Student, Cochin institute of science and Technology ,KTU, Eranakulam ,India

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Abstract - *Waffle slabs stands as an excellent option for architects when larger spans in a building has to be covered with the least possible number of columns. As such , waffle slabs are evolving as a new trend and is becoming a big challenge for structural engineers. Therefore it is necessary to study about its structural behavior.This paper studies about the response of waffle slabs with openings and the behavior of slabs when span between I beams are altered . The effect of varying size of openings are studied . the location of the opening is fixed at the centre of the slab. The span between beams are also varied and the responses of waffle slab to such a change is studied. it is concluded that the provision of openings has a significant impact on the strength of the waffle slabs and it may reduce the strength by 38%. Varying the size of span between the I beams has lesser impact as compared to the effect of openings. It reduces the strength only by around 20%. Special considerations has to be done while providing holes in the waffle slab. Proper retrofitting techniques has to applied so that places near the hole may not fail immediately due to stress concentration.*

Key Words: **waffle slab , composite steel concrete slab , size of opening ,stress concentration, finite element analysis**

1.INTRODUCTION

From the beginning of their existence, man has started to build. Even though the purposes varied, man has tried to employ a few major important concepts while constructing any new building. A few of them are structural stability, functional viability and economy. Continued focus on he improvement of the above said factors have led to the formation of the newest or modern designs and construction methods of various components or elements of a building; such as floors, wall, ceilings and roofs. For instance, the design and construction of floor slabs are usually solid, adequately reinforced in 2-direction and concreted. The construction of these slabs usually requires much formwork, high number of reinforcement provided in both ways (top and bottom) and high volume of concrete which resulted in an ample time or duration of construction. But over the recent decades, engineering researches have brought forth new designs that have led to new construction methods of floor slabs. These modern designs now give birth to entirely new construction methods that totally differ from the traditional way of constructing a solid slab. Hollow floor slabs, are the new type of slabs which require less reinforcement, less formwork and less concrete as a result of the holes, space, foams and balls that are incorporated in the slab. These now require a different method of on-site construction of such slabs to achieve its design which could enhance time savings during construction. Not only does the waffle slab system add up to the economical consideration, it also yields to the structural weight and efficiency of materials such as steel and concrete. This attractive structural system brings about speed and versatility in application with its higher stiffness and smaller deflections. Usually a combination of flat flange plate, the system contains an array of equally spaced parallel ribs or grillage in an orthogonal assembly with large square voids or recesses between the ribs. This system is an efficient and better way of constructing slabs for new homes or industrial buildings. This is done by interlocking components which ensure maximum control of every concrete pour. It also allows for greater accuracy of specifications of concrete quantities, reduction of waste and provides a boost to building site efficiency.

1.1 Objectives

The main objectives of this study are

- To study about the variation in the strength of the waffle slab when a rectangular opening is provided . the location of the opening is fixed at the centre of the slab.
- To compare the results obtained for a waffle slab with openings to a waffle slab without openings and find out the percentage reduction in the strength of the slab.
- To find the limiting size of the openings.
- To study about the variation in strength of the slab once the span of the I beams are altered.
- To compare the results obtained for a waffle slab with altered span of I beams with the validation or base model and find out the percentage variation in the strength of the slab.

1.2 Design of slab and I beams.

The material properties as well as the dimensions of the slab and I beams were taken from the journal[11].

Here the slab model has a span of 2250 mm in each direction. The plan and section are shown in fig 1.a and 1.b

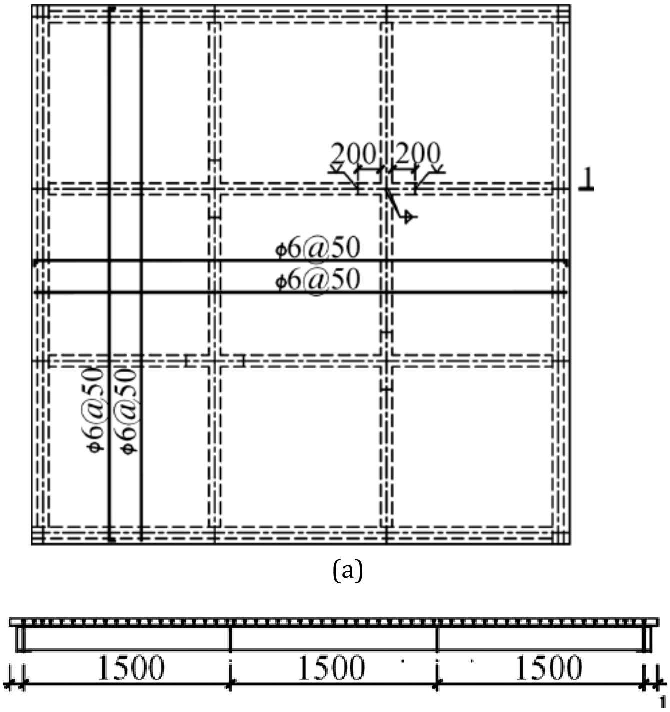

Fig 1.a plan of the slab. 1.b section

The dimension of the I beam are also adopted from the journal [11].

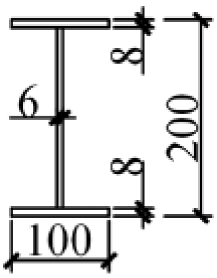

Fig 2 I beam cross section details.

2. NUMERICAL STUDY

The numerical study was carried out for three cases

A. Validation

The objective of validation is to ensure that the present study will produce reliable results. The numerical analysis and experimental analysis conducted in the journal [11] is studied and a similar model is constructed with similar material properties . conducting such a validation study will ensure that the future numerical analysis which are to be conducted will lie within the permissible error limits, if the validation turns out to be positive

B. Study with holes of varying size

The objective of this study is to analyze the effect of presence of hole in the waffle slab. Holes of varying size of rectangular shape is provided in the centre of the slab the variation in the strength of the slab as the hole size increases, is studied.

C. Study with varying span between I beams.

The objective of this study is to analyze the effect of variation of span between the slabs while keeping the hole size constant. The study aims to obtain the load deflection curve for varying spans of I beams.

In all the cases ,The concrete was modeled using three dimensional 8- noded solid elements SOLID65 . The connection between I beam and concrete slab was simulated using weak spring elements. CONTA 173 and TARGET 170 elements were used to make surface to surface contacts. Symmetric boundary conditions were used as the model was symmetric about all the axis. only one fourth of the real waffle slab was modeled to reduce the computation required.

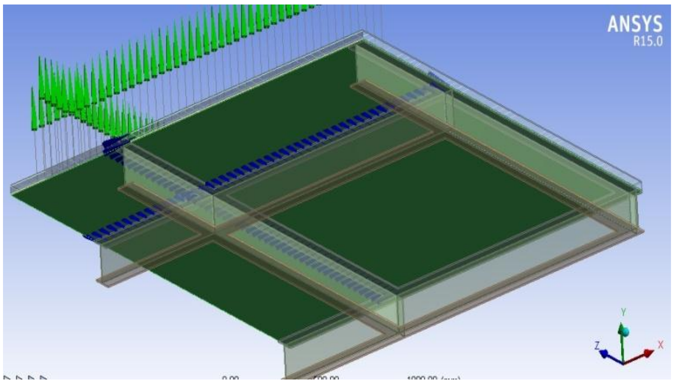

Fig 3 model of the slab without hole.

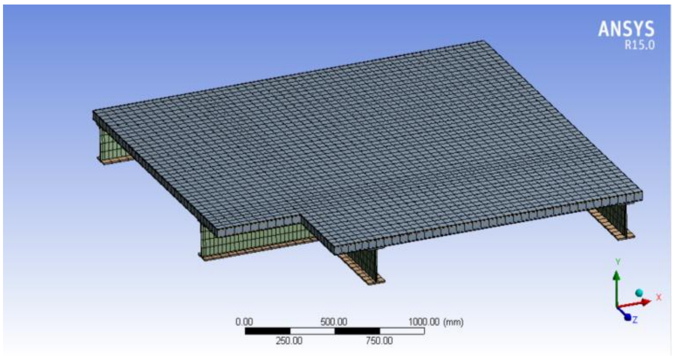

Fig 4 meshed model of slab with hole

3. Results and Discussion

Table 1 total result comparison

CASE	SIZE	ULTIMATE LOAD(N)	% REDUCTION
VALIDATION		995600	-
HOLE	1000	834000	16.23
	1100	646830	35.03
	1200	616000	38.12
	1300	612000	38.52
	1400	611000	38.62
SPAN	1500	881000	11.5
	1600	811000	18.54
	1700	802000	19.44
	1800	792000	20.44
	1900	785000	21.15

3.1 Validation

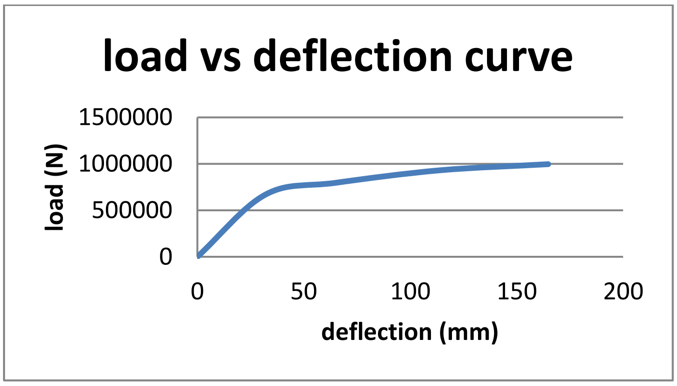

Chart 1 validation results

The maximum deflection obtained is 164.82mm and the maximum load achieved is 995.6KN . as compared to the journal result of 988.4KN the error in the result is 0.72% .the result obtained from the finite element analysis lies well within the permissible error limits.

3.2 HOLE SIZE

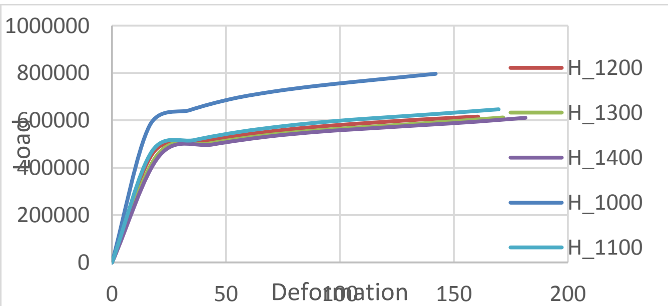

Chart 2 variation in strength with varying hole size

The comparative study reveals that compared to the validation model, there is a considerable strength reduction in the case of slabs with holes. The position of the hole is maintained at the centre of the slab to simplify the modeling procedure. Even though providing holes may decrease the strength, it may be necessary to provide them.

1. For case 1 of hole size 1000mm, the ultimate load achieved was 834KN and the maximum deflection was 177.04 mm. the total reduction in the strength of the slab was19.94% . but 797 KN is still considerably large load to with stand .this is due to the fact that the self weight of the slab gets reduced and the steel I beams which are good in tension are placed at the tension zone.
2. For case 2 of hole size 1100mm, the ultimate load achieved was 646.83KN and the maximum deflection was 169.68mm. the load withstanding ability have considerably reduced when compared to case 1. But still such large holes can be still provided as it can still carry up to 646.83KN.
3. For case 3 of hole size 1200mm, the ultimate load achieved was 616KN and the maximum deflection was 160.65 mm. the load withstanding ability have not considerably reduced when compared to case 2.
4. For case 4 of hole size 1300mm, the ultimate load achieved was 612KN and the maximum deflection was 171.64 mm. the load withstanding ability have not considerably reduced when compared to case 3 . There is only a slight variation in the strength of the slab.
5. For case 5 of hole size 1400mm, the ultimate load achieved was 611KN and the maximum deflection was 181.45 mm. the load withstanding ability have not considerably reduced when compared to case 4 . There is only a slight variation in the strength of the slab.

6. 3.3 SPAN SIZE

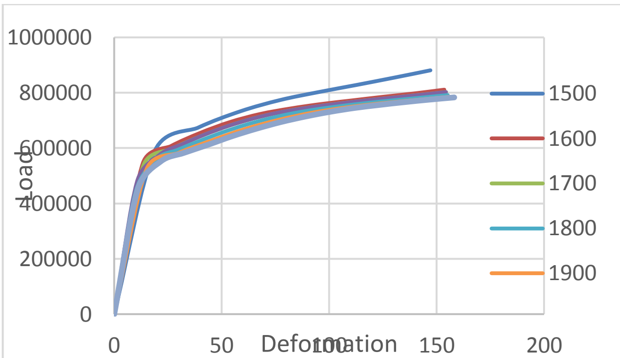

Chart 3 variation in strength with variation in span between I beams

In this study, the size of the hole was fixed as 1000mm. the span of the I beams were varied. The comparison results gives an interpretation that the reduction in strength is of very low margin.

1. for case 1,with a span of 1500mm, the maximum load achieved was 881KN and the maximum deflection was 147.09mm. as compared to the validation model, only a small reduction of 11.5% is there.
2. for case 2,with a span of 1600mm, the maximum load achieved was 811KN and the maximum deflection was 153.55mm . as compared to the validation model, the reduction in the strength is 18.54%.
3. for case 3,with a span of 1700mm, the maximum load achieved was 802KN and the maximum deflection was 154.32mm . as compared to the validation model, the reduction in the strength is 19.44%. the reduction in strength as compared to case 2 is of very low margin.
4. for case 4,with a span of 1800mm, the maximum load achieved was 792KN and the maximum deflection was 155.13mm . as compared to the validation model, the reduction in the strength is 20.44%. the reduction in strength as compared to case 3 is of very low margin.
5. for case 5,with a span of 1900mm, the maximum load achieved was 785KN and the maximum deflection was 155.85 mm . as compared to the validation model, the reduction in the strength is 21.15%. the reduction in strength as compared to case 4 is of very low margin.

4. CONCLUSION

4.1 Hole Size

From the comparison table it can be interpreted that a hole size of 1400mm reduces the strength of the waffle slab by 38.62% only. If higher loads are acting, the hole size may be limited to 1000mm. this high load carrying capacity is achieved mainly due to the presence of I beams which add considerable strength to the waffle slab structure.

4.2 Span Size

Varying the span of I beams does not have significant impact on the strength of the waffle slab as compared to the effect of holes. By increasing the span , higher economy can be achieved without compromising much on the load carrying capacity of the waffle slab.

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