EFFECT OF SKEW ANGLE ON UPLIFT AND DEFLECTION OF RCC SKEW SLAB

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Abstract

The study deals with the finite element modeling of simply supported skew slab with varying skew angles using ANSYS software. The behavior of the simply supported skew slab under point load applied at the centre depends on the ratio of short diagonal to its span. Skew slabs with ratio of short diagonal to span less than unity show lifting of acute corners whereas slabs with ratio of short diagonal to span greater than unity do not. Skew slab specimen with ratio of short diagonal to span less than unity is considered here for studying the effect of skew angle on the behavior of skew slab. The dimensions of skew slab were taken from available experimental data. In this paper skew angles varying from 0º to 30º were taken for the study. After the nonlinear finite element analysis of all skew slabs it is revealed that when skew angle increases the uplift at both the acute corners also increases. The result also suggests that the load carrying capacity increases with increase in skew angle.

Keywords: *Reinforced concrete, Finite element analysis, Skew slab, Uplift*

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1. INTRODUCTION

Reinforced concrete skew slabs are widely used in bridge construction when the roads cross the streams and canals at angles other than 90 degrees. They are also used in floor system of reinforced concrete building as well as load bearing brick buildings where the floors and roofs are skewed for architectural reasons or space limitations. Skew slab bridges may be required to maintain the geometry of the road or keep the road straight at crossing or for any other reason.

To model the complex behavior of reinforced concrete analytically in its nonlinear zone is difficult. This has led engineers in the past to rely heavily on empirical formulas which were derived from numerous experiments for the design of reinforced concrete structures. The Finite Element Method (FEM) is an analytical tool which is able to model RCC structure and is able to calculate the nonlinear behavior of the structural members. For structural design and assessment of reinforced concrete members, the nonlinear finite element analysis has become an important tool. The method can be used to study the behavior of reinforced and pre-stressed concrete structures including both force and stress redistribution.

In the present work finite element modeling of RCC skew slab has been done in ANSYS. The behavior of the simply supported skew slab under point load applied at the centre depends on the ratio of short diagonal to its span. Skew slabs with ratio of short diagonal to span less than unity show lifting of acute corners whereas slabs with ratio of short diagonal to span greater than unity do not. This is because the reactions act at the obtuse corner only when the ratio of short diagonal to its span less than unity and it is well within supports when ratio of short diagonal to span is greater than unity [6]. So skew slabs with ratio of short diagonal to span less than unity is used here for studying the effect of skew angle on the uplift and deflection of skew slabs.

2. GENERAL DESCRIPTION OF STRUCTURES

Here, the modeling of skew slabs is based on experimental data obtained from the study on Flexural behavior of reinforced concrete skew slabs by Sharma B.R. [6]. In this study two skew slab specimens were considered. Specimen 1 having ratio of short diagonal to span less than unity and Specimen 2 having ratio of short diagonal to span greater than unity. The dimensions of Specimen 1 are used in this study. Skew slab Specimen 1 has been modeled with skew angle of 16.49º, the support length and span is kept as 1200 mm and 2470 mm respectively with M25 grade concrete. Thickness of slab has been kept as 70 mm. Length of short diagonal of the slab is 2420 mm which is less than span 2470 mm. Fig -1 shows the dimensions of specimen 1. Slab has been reinforced with main reinforcement of 8 mm diameter for steel bars @ 100 mm c/c at the bottom face of the slab at right angles to the supports and distribution reinforcement of also 8 mm diameter tor steel bars @ 125 mm c/c laid over main reinforcement, parallel to the supports [6].

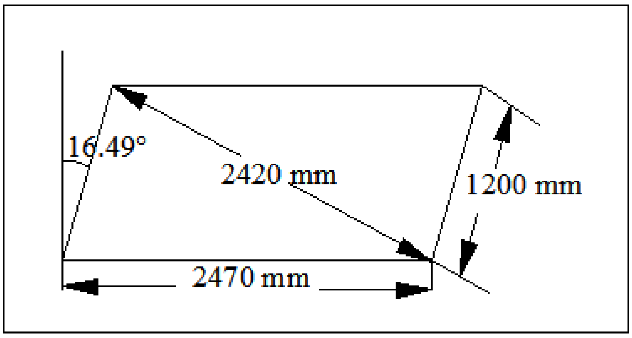

Fig -1: Dimensions of Experimental Test Specimen 1 [6]

In addition to 16.49° skew angle, 0°, 20° and 30° are also considered here for studying the effect of skew angle on the uplift and deflection of skew slab.

3. FINITE ELEMENT MODELLING

ANSYS, commercially available Finite Element (FE) software, of version 12.1 was used for the analysis of skew slabs. Concrete generally exhibits large number of micro cracks, especially, at the interface between coarse aggregates and mortar, even before it is subjected to any load. The presence of these micro cracks has a great effect on the mechanical behavior of concrete, since their propagation during loading contributes to the nonlinear behavior at low stress levels and causes volume expansion near failure. Some micro cracks may develop during loading because of the difference in stiffness between aggregates and mortar. Since the aggregate-mortar interface has a significantly lower tensile strength than mortar, it constitutes the weakest link in the composite system. This is the primary reason for the low tensile strength of concrete. The response of a structure under load depends largely on the stress-strain relation of the constituent materials and the magnitude of stress. The stress-strain relation in compression is of primary interest because mostly for compression members are cast using concrete. The actual behavior of concrete should be simulated using the chosen element type. For the present type of model solid65 and Link 8 elements were chosen. The Solid65 element was used to model the concrete. The solid element has eight nodes with three degrees of freedom at each node-translation in the nodal x, y and z directions. The element is capable of plastic deformation, cracking in three orthogonal directions, and crushing. The geometry and node location for this element type are shown in Fig -2.

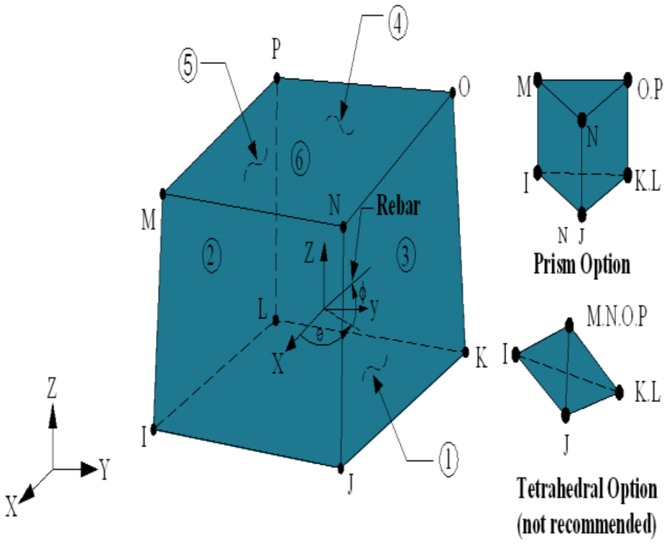

Fig -2: Solid65 element

A Link 8 was used to model the steel reinforcement. Two nodes are required for this element. Each node has three degrees of freedom at each node-translation in three nodal x, y and z directions as shown in Fig -3. The element is also capable of plastic deformation.

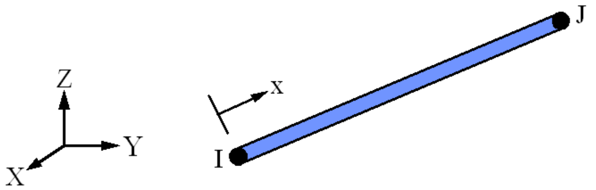

Fig -3: Link 8 element

3.1 Nonlinear Analysis

In nonlinear analysis, the total load applied to a finite element model is divided into a series of load increments called load steps. At the completion of each incremental solution, the stiffness matrix of the model is adjusted to reflect nonlinear changes in structural stiffness before proceeding to the next load increment.

The usefulness of the finite element method for nonlinear analysis very much depends on various numerical parameters which influence the solution. Different methods are available in ANSYS for solving non-linear equations such as, linear method, Full Newton-Raphson Method, Modified Newton-Raphson method etc. Among these the Full Newton-Raphson Method and Modified Newton-Raphson Method are more commonly used methods. In our present study, Full Newton-Raphson method is used for solving the simultaneous equations. It is an iterative process of solving the non-linear equations.

Skew slabs having skew angle 0º, 16.49º, 20º and 30º are modeled in ANSYS and are presented in Fig -4, Fig -5, Fig -6 and Fig -7 respectively.

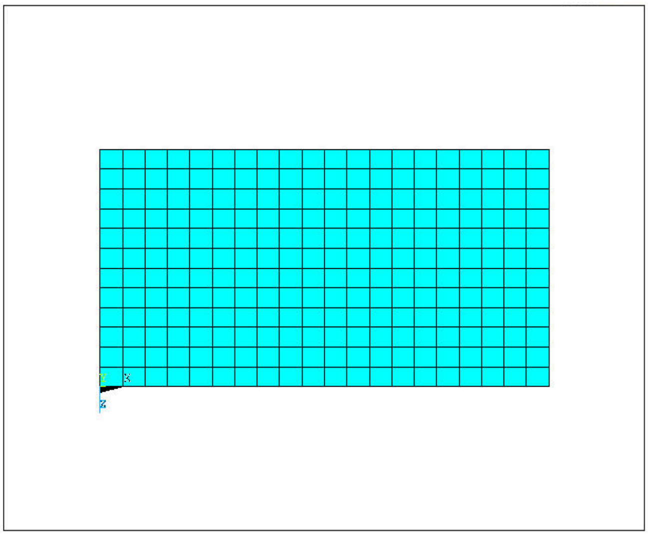

Fig -4: FE Model of Skew slab with 0º skew

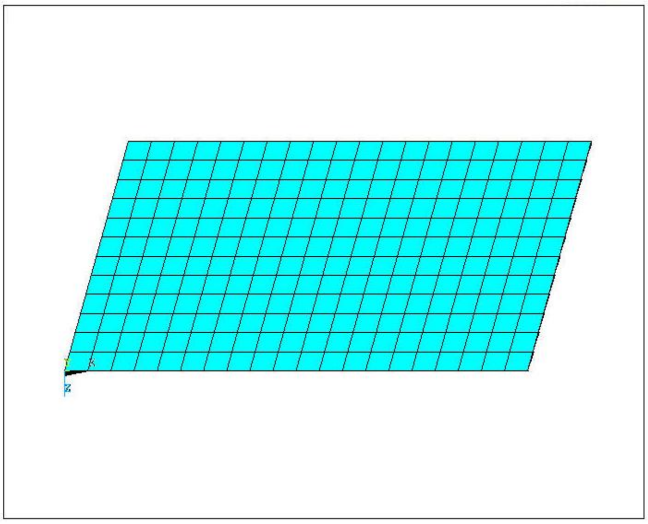

Fig -5: FE Model of Skew slab with 16.49º skew

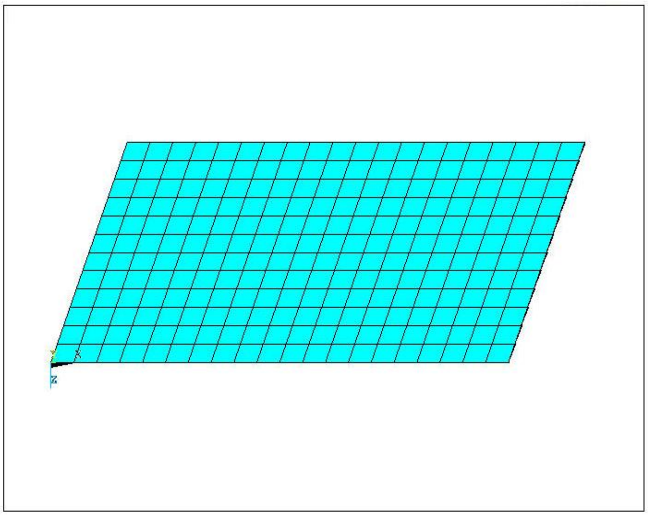

Fig -6: FE Model of Skew slab with 20º skew

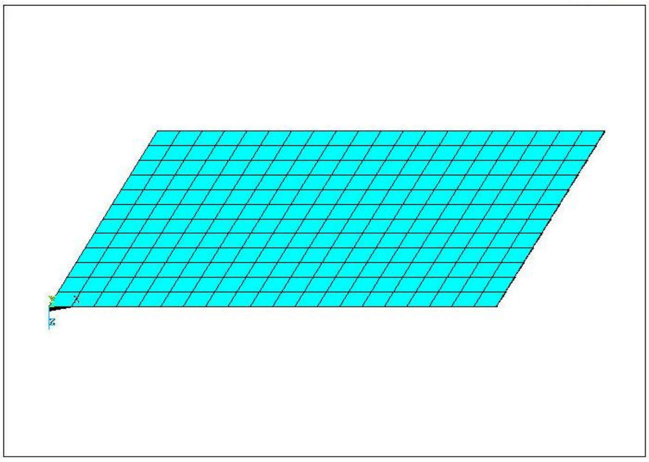

Fig -7: FE Model of Skew slab with 30º skew

4. RESULTS AND DISCUSSIONS

In FE Model skew slab specimens loads have been applied at the centre of the slabs as done in case of experiment. The load on the structure has been gradually increased in the steps till failure. When the FE non linear analysis is completed, the results can be obtained from the Post processing part of ANSYS. The load-deflection and uplifts values at every step have been recorded.

4.1 Validation of FE Results

Experimental results [6] available for skew slab with skew angle 16.49º are compared here with obtained FE results corresponding to skew slab with 16.49º skew angle.

The load v/s deflection and load v/s uplift graphs comparing the experimental and finite element analysis results are presented in Chart -1 and Chart -2 respectively.

From Chart -1 and Chart -2, the FE model and Experimental results shows almost same results. The ultimate load and corresponding deflection for FE model are 27.6kN and 29.983mm respectively whereas the ultimate load and corresponding deflection came from experimental result was 25kN and 29.3mm respectively. When analyze these data, the FE results shows, the load is increased by 2.6kN and deflection is increased by 0.683mm. Maximum uplift obtained from experimental data was 1.65mm whereas that for FE model was 1.324mm. Experimental data suggested that both LHS and RHS acute corners have same uplift but FE Model result suggested that up to ultimate load both acute corners have same uplift and after that they shows slight difference from each other. But from Chart -2 it is clear that, there is no noticeable change between LHS and RHS uplift values. So it can be concluded that FE model result shows good agreement with the experimental result.

4.2 Load v/s Deflection Comparison

From Chart -3, it is observed that when skew angle increases from 0º to 30º the load carrying capacity of slab also increases. The ultimate load for 0º, 16.49º, 20º and 30º is 19.9kN, 27.6kN, 28.4kN and 34.5kN respectively.

Skew angle 0° indicates that the slab is rectangular in shape. It can be seen from the Chart -3 that the structure behaved linearly elastic up to the value of load 19.9kN. The deflection corresponding to 19.9kN is 29.004mm. After 29.004mm deflection started increasing without any significant decrement in load. The 40mm deflection is reached with the load value of about 17.2kN.

Considering graph corresponding to 16.49° in Chart -3, it can be seen that the structure behaved linearly elastic up to the value of load 27.6kN. The deflection corresponding to 27.6kN is 29.983mm. After 29.983mm deflection, load started decreasing with increase in deflection. The 40mm deflection is reached with the load value of about 24.2kN.

For skew angle 20°, it can be seen that the structure behaved linearly elastic up to the value of load 28.4kN. The deflection corresponding to 28.4kN is 29.011mm. After 29.011mm deflection, load started decreasing with increase in deflection. The 40mm deflection is reached with the load value of about 25.2kN.

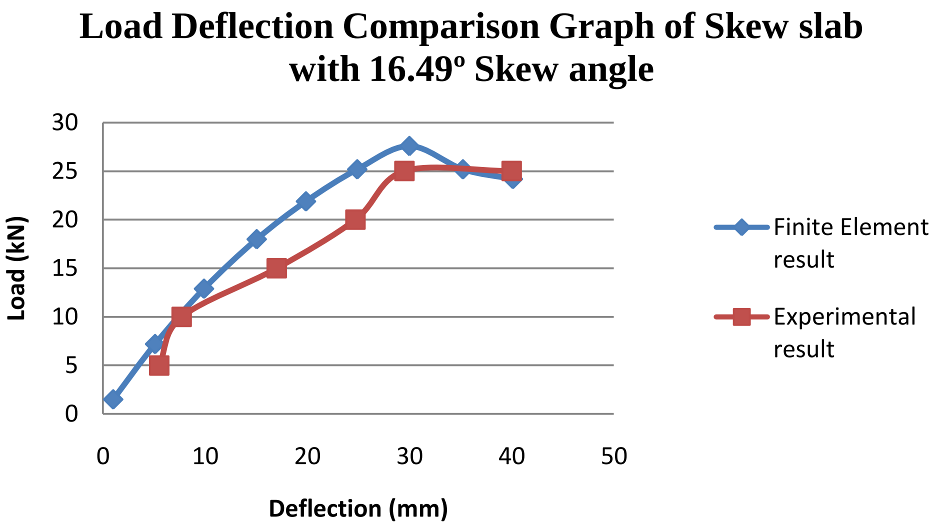

Chart -1: Load v/s Deflection Comparison Graph of Skew slab with 16.49° skew

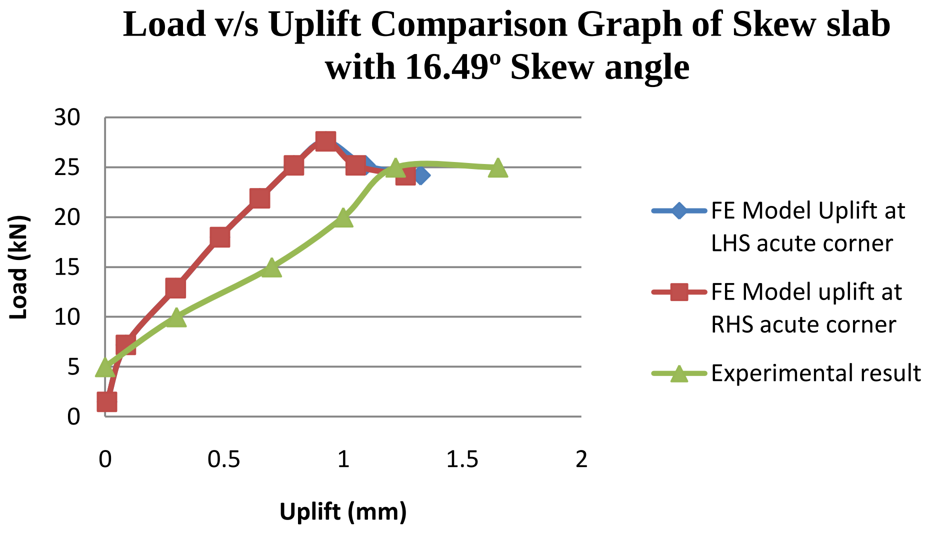

Chart -2: Load v/s Uplift Comparison Graph of Skew slab with 16.49° skew

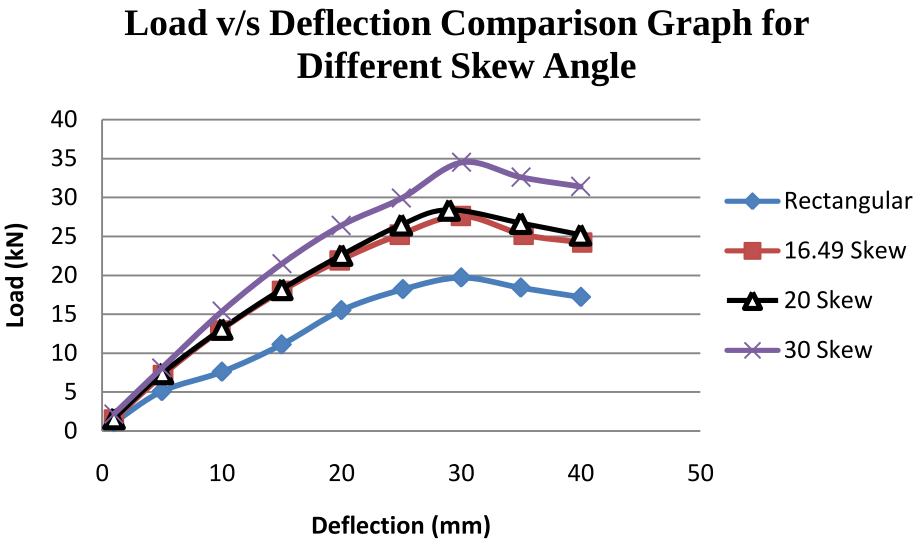

Chart -3: Load v/s Deflection Comparison Graph of Different Skew angle

For skew angle 30º, it can be seen that the structure behaved linearly elastic up to the value of load 34.5kN. The deflection corresponding to 34.5kN is 30.045mm. After 30.045mm deflection, load started decreasing with increase in deflection. The 40mm deflection is reached with the load value of about 31.4kN.

4.3 Load v/s Uplift Comparison

The graph representing load v/s uplift at LHS and RHS acute corners for skew angles 0º, 16.49º, 20º and 30º are shown in Chart -4 and Chart -5 respectively.
For 0º skew angle, the maximum uplift occurred was 0.0131mm in both the corners. This obtained value is very less compared to other skew angles. So the uplift at the corners for a rectangular slab is negligible.

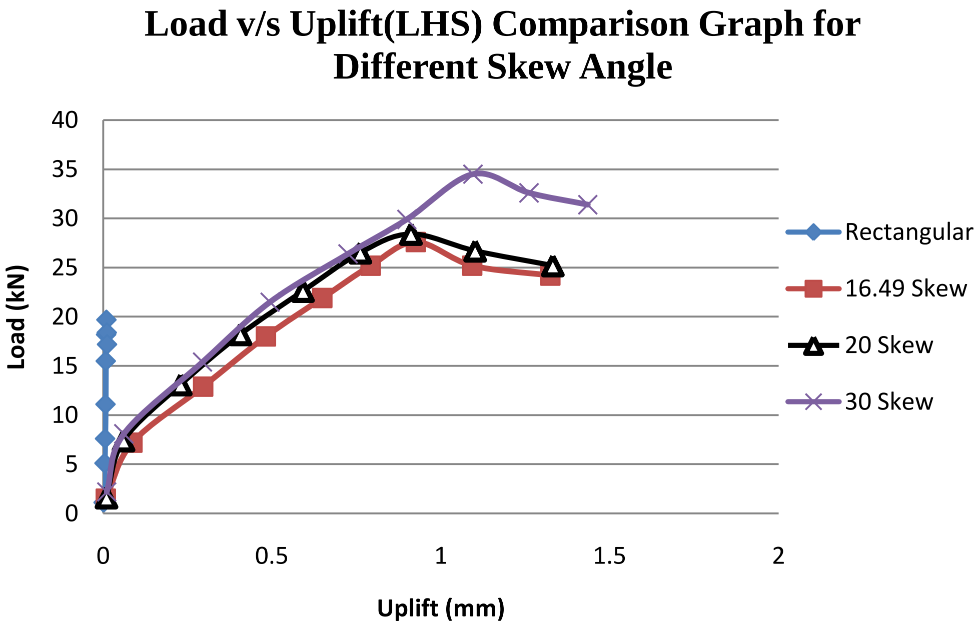

Chart -4: Load v/s Uplift (LHS) Comparison Graph of Different Skew angle

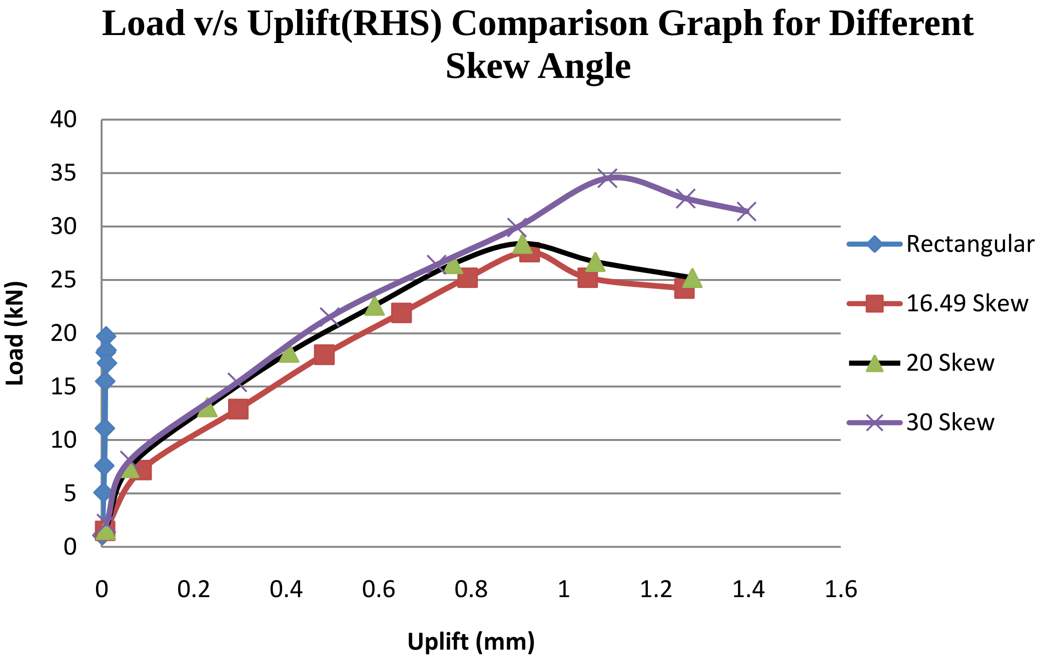

Chart -5: Load v/s Uplift (RHS) Comparison Graph of Different Skew angle

For 16.49º skew angle, up to the ultimate load i.e. 27.6kN, uplift at both LHS and RHS acute corners were same. After that they show slight difference from each other.

Up to the ultimate load i.e. 28.4kN, uplift at both LHS and RHS acute corners were same for skew slab with 20º skew angle. After that, uplift started increasing rapidly and both corners started to exhibit slight difference in uplift values.

For 30º skew angle also, up to the ultimate load i.e. 34.5kN, uplift at both LHS and RHS acute corners were same. After that they show slight difference from each other.

Here, all the slabs excluding rectangular slabs exhibits slight difference in uplift values after ultimate load. But this variation in uplift at both LHS and RHS acute corners are negligible.

From Chart -4, it is observed that when skew angle increases from 0º to 30º the uplift at LHS acute corner also increases. The maximum uplift for 0º, 16.49º, 20º and 30º is 0.011mm, 1.324mm, 1.331mm, and 1.435mm respectively.

From Chart -5, it is observed that when skew angle increases from 0º to 30º the uplift at RHS acute corner also increases. The maximum uplift for 0º, 16.49º, 20º and 30º is 0.011mm, 1.261mm, 1.279mm, and 1.396mm respectively.

5. CONCLUSION

The results of FE model of the skew slab with skew angle 16.49º have found to be same as that of the experimental result. So it can be concluded that FE model results holds good with the experimental results.

The maximum deflection for skew slabs decreases with the increase in skew angle. This indicates that the load carrying capacity of skew slab increases with increase in skew angle. The uplift at acute corners of skew slab increases with increase in skew angle.

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