Experimental Study on Torsional Reinforcement of Reinforced Cement Concrete Slab with Various End Conditions

V. Selvan, R. Sundararajan

Abstract- Reinforced concrete is the principal material for military engineering and nuclear power plant containment. Reinforced concrete slabs are used in floors, roofs and walls of buildings and as the decks of bridges. The floor system of a structure can take many forms such as in situ solid slab, ribbed slab or pre-cast units. By providing torsion reinforcement, corners are usually prevented from being lifted up. In such cases the corners have to be suitably reinforced at top and also at bottom otherwise cracks are liable to be formed at the corners.

The present investigation is intended to study the influence of torsion reinforcement in reinforced concrete slab with end condition all ends discontinuous under uniformly distributed load. Slabs with torsion reinforcement varying from 0% to 30% were casted and tested. Increasing in the torsion reinforcement controls the deflection of the slab element. As the torsion reinforcement increases the corners are being held down. At the maximum of 30% of main reinforcement was provided as torsion reinforcement corners are not held down completely and there is a considerable decrease in central deflection also.

Index Terms—Torsion reinforcement, central deflection, Slabs

I. INTRODUCTION

Torsion is a basic structural action to be considered in the design. But due to its complex nature and occurrence with other basic forces, it is ignored by the designers. Increased service loads, aging of structures, Manmade havocs, natural calamities and updates in the codes have necessitated many of the structures to be retrofitted. Reinforced concrete slabs are used in floors, roofs and walls of buildings and as the decks of bridges. Reinforcement detailing of a slab is done based on its support conditions. Slab may be supported on walls or beams or columns. Slab supported directly by columns are called flat slab.

Slab supported on two sides and bending takes place predominantly in one direction only is called One Way Slab. On the other hand, when slab is supported on all four sides and bending take place in two directions are said to be Two Way Slab. The slabs having ratio of longer length to its shorter length (L_y/L_x) greater than 2 is called one way slab otherwise as two way slab. In one way slab main reinforcement is parallel to shorter direction and the reinforcement parallel to longer direction is called distribution steel. In two way slab main reinforcement is provided along both direction. In two way slab the corners may be held down by restraints or may be allowed to lift up. Additional torsion reinforcement is required at corners when it is restrained against uplifting.

The present investigation is intended to study the influence of torsion reinforcement in reinforced concrete slab with end condition all ends discontinuous under uniformly distributed load. For the present work, slabs with torsion reinforcement varying from 0% to 30% of the main reinforcement required for short span bending moment were casted and tested. By varying torsion reinforcement the corner lift was measured.

II. EXPERIMENTAL WORK

Slabs with various torsion reinforcement were cast using M20 grade of concrete.

2.1 Materials and Concrete mix

Ordinary Portland cement of 53 grades of specific gravity 3.15 was used for all the specimens cast. The Fine Aggregate used for casting was clean river sand and it was clean and dry. The specific gravity of fine aggregate was 2.71. The fineness modulus of the fine aggregate was 2.4.

The coarse aggregate used was broken granite-crushed stone of size 10 mm. The specific gravity of coarse aggregate was 2.84. The bulk density of coarse aggregate was found to be 1640 kg/m^3. Potable water available in the structural engineering laboratory was used for casting all specimens of this investigation. The quality of water was found to satisfy the requirements of **IS-456 -2008.** 1: 1.5: 3 mix proportion was adopted. Weight batching was adopted. For every 50 Kg of cement 75 Kg of sand and 150 Kg of coarse aggregate were used. Water cement ratio of 0.5 was adopted as hand compaction was done. To improve the workability of concrete this water cement ratio was adopted. For each batch of mixing 25 liters of water was added. Reinforcement confirming to IS: 1786 were used as reinforcing rods. Main reinforcement of 6 mm diameter was used. Weld mesh of 3 mm diameter with was used as torsion reinforcement. Concrete cubes of 150mm x 150mm x 150 mm size are casted and tested before the testing of slab. Steel moulds were used in casting these companion specimens.

2.2 Design Details

The size of the square slab specimens was 1000 mm x 1000 mm x 60 mm (thickness). The reinforcement was provided in the form of 6 mm diameter Grade I steel 125 mm centre to centre spacing. This gives the area of reinforcement as 254.47 mm^2 in each direction. The clear cover to the reinforcement is 15 mm. The reinforcement details are shown in Fig. **2.2**.

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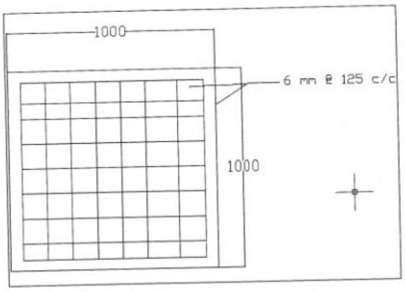

Fig 2.2 Reinforcement Details

The descriptions of the square slabs are shown below. Minimum Reinforcements are provided in the form of 6 mm diameter Grade I steel having yield strength of 252 N/mm^2 was used as a main reinforcement and both 6 mm diameter Grade I steel and weld mesh made up of mild steel of yield strength of 250N/mm^2 were used as torsion reinforcement. Description of the specimen is shown in the table 2.2

TABLE 2.2 DESCRIPTION OF THE SPECIMEN

Sl.No.	Description of the specimen	% of torsion reinforcement
1	Slab 1	0
2	Slab 2	10
3	Slab 3	15
4	Slab 4	20
5	Slab 5	25
6	Slab 6	30

2.3. Casting And Curing Of Specimens

2.3.1. Preparation of concrete mix

Predetermined quantities of the constituent materials of RCC were weighed using a 300 Kg platform balance. Cement and sand were mixed first then the coarse aggregate was added and the materials were mixed thoroughly until uniformity was achieved. Then the required quantity of water was added slowly and wet mixing was done. Wet mixing was completed within 5 minutes.

2.3.2. Casting of slabs

A paper was spread on the cleaned and surface leveled solid concrete floor of the laboratory. On this paper the 60 mm depth wooden mould of slab was placed. The inner sides of the mould were oiled so as to avoid the adhesion of cement mortar. The reinforcement was placed inside the mould on the cover blocks which were made of cement mortar of 1:2 mixes. The fresh reinforced concrete was put inside the mould in convenient layers and was compacted by compaction rod and the surface was made plane by toweling. The corner provide with full torsion reinforcement was marked.

2.3.3. Casting of companion specimens

The inner surfaces of the moulds were cleaned thoroughly just before casting and a thin coat of oil was applied to this surface to avoid the adhesion of cement mortar.
For casting the standard specimens, moulds were filled with concrete in 3 layers. Each layer was well compacted by standard steel rod. The following companion specimens were cast along with each slab.

Cubes of 150mm size - 3 Nos. per batch.

These specimens were removed from the moulds 24 hours after casting.

2.3.4. Curing of R.C.C slabs

The slabs were removed from mould twenty four hours after casting and were cured under wet gunny bags over 27 days. The gunny bags were watered twice a day, taking special care to see that all parts were watered uniformly.

2.3.5. Curing of companion specimens

The companion specimens were removed from mould twenty four hours after casting and all the specimens were kept near the slab and were cured under wet gunny bags, along with the slabs. Thus the same curing conditions were adopted for both the slabs and their companion specimens.

2.4. testing and instrumentation

2.4.1 Preparation of specimens before testing

Each specimen was removed from the curing yard in the previous day of the day of testing manually and it was white washed. Then the slab was lifted and erected in position for testing.

2.4.2 Loading frame

The slabs were tested in a 100 ton capacity self straining loading frame. The applied jack load was measured by means of proving ring of 50 ton capacity**.** The magnitude of the applied load was obtained from the calibration chart of the proving ring.

2.4.3 Test set up

The test set up is shown in Figs 2.4.3. Each slab was simply supported on framework made of ISMC 300 with 10cm bearing on all the sides while the corners of the channels were supported by concrete cubes of size 150 mm x 150 mm x 150 mm. Three concrete cubes were placed as a column to raise the frame work to a height of 450 mm so that we can fix the LVDT under the slab to measure the central deflection of the slab.

Fig.2.4.3 Test Setup

In uniformly distributed load, top surface of the slab was filled with sand to a height of 10cm to have uniform distribution of load on the slab. Over the sand filling, cubes were arranged in pyramidal shape. Load was applied through mechanically operated hydraulic jack of capacity 15 ton on the top layer of the cubes. To avoid the punching effect of the hydraulic jack, steel plates were used.

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2.4.4 Measurement of Load and Deflections

Proving ring capacity 15 tons was used to measure the load applied to the slab specimens. The applied load was measured by the load cell. The applied load was computed from the calibration chart.

The central deflection was measured by LVDT fixed at centre of the slab at the bottom of the slab specimens. And the corner lift was measured by the dial gauges of least count 0.01. The positions of the dial gauges were shown in Figs.4.1 to 4.5 and in Figs 4.9 to 4.15 for various cases.

2.4.5 Marking of the first crack

Crack patterns were observed manually during loading. The first crack was noted and the place where it initiated was marked. The corresponding loading was also noted down.

2.4.6 Marking of the crack patterns

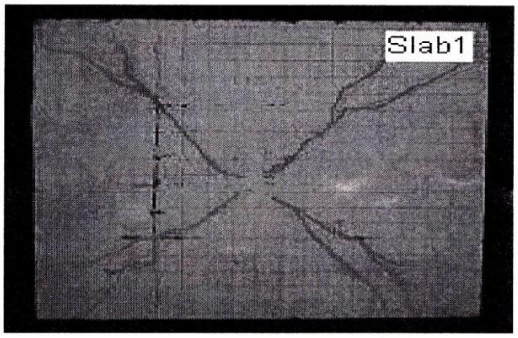

Fig 2.4.6 Tested Slab

The slab was removed immediately after the testing and the crack lines were marked.

2.4.7 Testing on companion specimens

Cubes of size 150mm that had been cast along with the slabs were tested on the same day on which the respective slabs were tested to ascertain the compressive strength of the concrete used in the slabs. The cube test were carried out in a Compression Testing machine of 300 tone capacity and these tests were carried out as per IS code recommendation.

III. RESULTS AND DISCUSSION

The corresponding corner uplift and central deflection were noted for each incremental load upto ultimate load and the results were plotted. The behavior of torsion reinforcement from 0% to 30% was compared with 0% and 75% and the graphs were plotted. The average cube compression strength attained from the companion specimens tested was 35 N/mm^2.

3.1. TEST SPECIMENS

The results obtained from the test specimens were plotted in the graph.

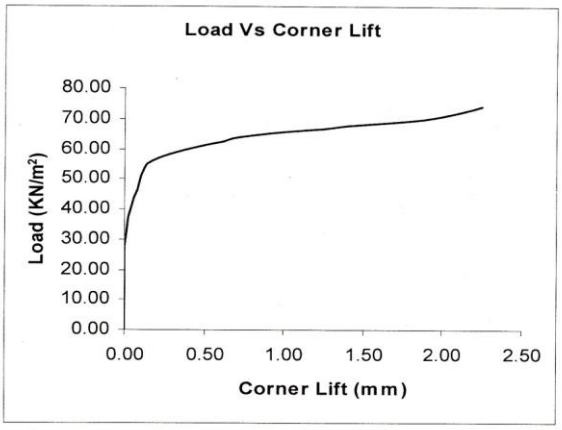

Fig.3.1 Load vs. Corner lift (Simply supported Slab)

Fig.3.1 shows the load vs. corner lift of simply supported slab without torsion reinforcement. Uplift of corner starts at a load of 30 KN/m^2. Maximum uplift 2.4 mm was obtained at ultimate load of 75 KN/m^2.

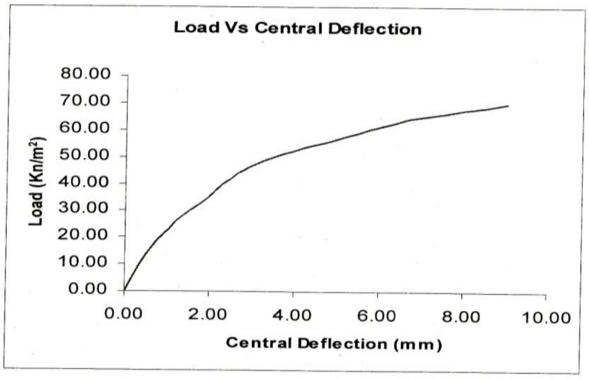

Fig.3.2 Load vs. Central Deflection (Simply supported Slab)

Fig.3.2 shows the load vs. Central Deflection of simply supported slab without torsion reinforcement. Maximum central deflection of 9 mm was reached at failure load.

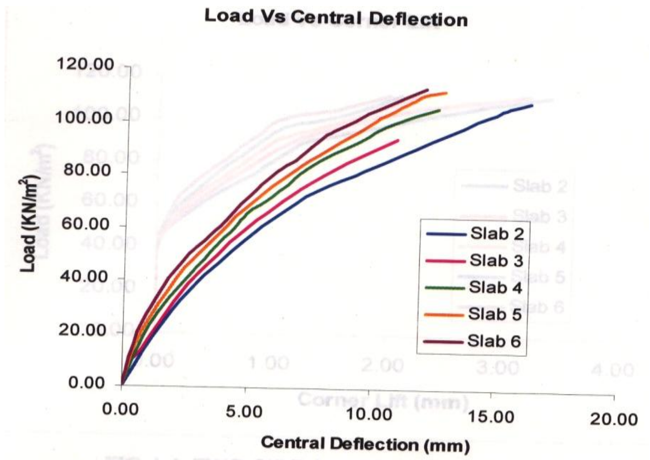

Fig 3.3 Load Vs. Central Deflection (Two side continuous Slabs)

Fig.3.3 shows the load vs. Central Deflection of two adjacent side continuous slabs with provision for torsion reinforcement. As the percentage of torsion reinforcement increases there is corresponding decrease in central deflection.

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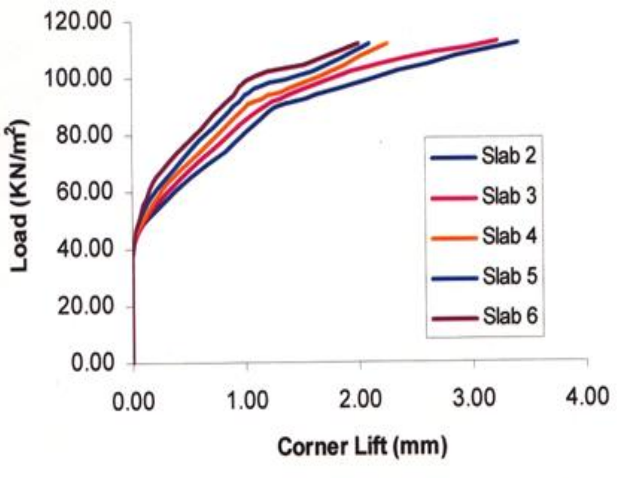

Fig 3.4 Load vs. Corner Lift (Two side continuous Slabs)

Fig.3.4 shows the load vs. Corner lift of two adjacent side continuous slabs with provision for torsion reinforcement. As the percentage of torsion reinforcement increases there is corresponding decrease in corner lift. The corner lift starts around a load of 40 KN/m^2 for all the slabs.

IV. CONCLUSIONS

Slabs with torsion reinforcement varying from 0% to 30% were casted and tested. Increasing in the torsion reinforcement controls the deflection of the slab element. The corners are being held down based upon the quantity of torsion reinforcement provided. Torsion reinforcement shall be provided at any corner where the slab is simply supported on both edges meeting at that corner and is prevented from lifting unless the consequences of cracking are negligible. It shall consist of top and bottom reinforcement, each with layer of bars placed parallel to the sides of the slab and extending from the edges a minimum distance of one fifth of the shorter span. The area of reinforcement per unit width in each of these four layers shall be three quarters of the area required for the maximum mid-span moment per unit width in the slab.

As the torsion reinforcement increases the corners are being held down. Increasing in the torsion reinforcement controls the deflection of the slab element. At the maximum of 30% of main reinforcement was provided as torsion reinforcement corners are not held down completely. Due to increase in torsion reinforcement there is a considerable decrease in central deflection also.

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