STRENGTH AND BEHAVIOUR OF R.C.C STM WITH AND WITHOUT INFILL EFFECTS

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Abstract – The present investigation signifies the strength and behavior of reinforced cement concrete strut and tie with and without infill effects. The reinforced cement concrete and brick masonry were used as an infill material in between strut and ties. The specimen was tested under single point loading and strength and deformation have been recorded. Theoretical values of strut and tie strength and deformation are calculated by using ANSYS finite element analysis software. The experimental values are compared with FEM results and it's showing good agreement. The strength of strut and tie with reinforced cement concrete infill indicates 31% higher than the masonry infill. Finally all the specimens were failed in support due to shear.

Keywords: STM, ANSYS, infill, concrete

Introduction

Concrete structural members having more depth when comparable to span this are generally termed as STM models. In this member the distribution of strain across depth of the cross section will be nonlinear and the significant amount of load is carried to the support by a compression strut and tension as tie. This strut and tie has been modeled to check the strength and behavior of R.C.C strut and tie model. The structural member can be broadly divided into two regions as B (Bernoulli region) where the strain regions are linear and D (Distributed regions) where the strain distribution is non-linear. The current IS code are doesn't recommended any design procedures for strut and tie model. We are using AASHTO LFRD codes for calculate the strut and tie capacity. The theoretical values of strut and tie strength and deformation have been calculated by FEM package. The analysis has been done by Finite Element Analysis.

Finite Element Modeling of Strut And Tie Model

FEM have been developed for all the experimentally tested strut and tie model that had either with infill or without (RCC and brick masonry) infill and subjected to centre concentrated load. The deflection at supports or mid-node deflections obtained through Finite Element simulation are compared to the corresponding experimental deflection values. For this study, the commercially available FE package ANSYS was used. A suitable mesh style and Finite Element was identified by comparing the deflection values of Finite Element model constructed by different possible elements with the closed form solution given by Timoshenko in 1953. The study was made with the following mesh styles and element types.

1. Brick element hexagonal mesh

2. Solid 45 tetrahedron mesh

3. Concrete 65 with hexagonal mesh

4. Concrete 65 with tetrahedron mesh

5. Shell 63 with hexagonal mesh

6. Shell 63 with tetrahedron mesh

All specimens have a triangular size of 800mm length and cross sectional area is 80mmX80mm. The poison ratio and young's modulus of the concrete were taken as 0.18 and 20,000N/mm^2 respectively. The 0.05N/sq.mm was the central concentrated load applied for all the models. The deflection produced by these models of Finite Element, at two points, at mid span and supports were compared with the closed form solution. The result has been indicated the brick element was found suitable. The central deflections obtained by finite element models were closer to that of experimental deflection. Based on the Finite Element model the following conclusions could be made at the initial stage. The deflection obtained by this model gives closer result when compared with the Timoshenko equation than any other mesh style and elements. The observed experimental values have been compared with the deflections obtained by finite element model corresponding to load in the pre-cracking stage and found to be closer with the experimental values. Fig 1 & Fig 2 shows the meshing of the STM specimens.

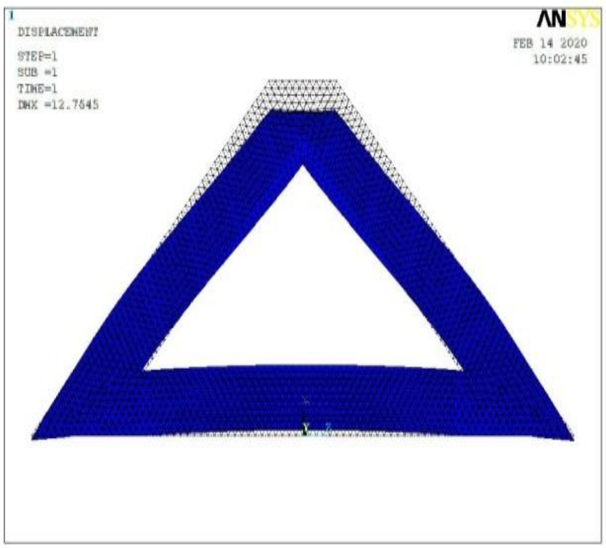

Fig.1 FEM Meshing profile of STM 1

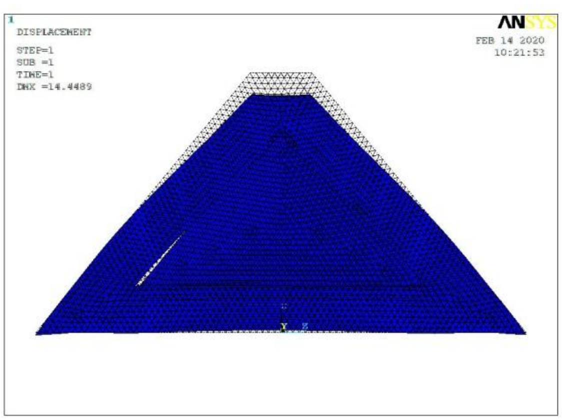

Fig.2 FEM Meshing profile of STM 2M

Materials and Mix Used

For all the specimens Ordinary Portland Cement of 53 grade of specific gravity 3.15 is used. Clean river sand is used for casting of Fine Aggregate. The specific gravity of Fine Aggregate was 2.71 and the fineness modulus was 2.4. The broken granite stone of size 10mm was used as coarse aggregate. The specific gravity and bulk density of coarse aggregate are 2.84 & 1640 Kg/m^3. In the structural engineering laboratory the bore well water available is used for casting all the specimens of this investigation. The quality of water should satisfy the requirements of IS-456-2000.For main tension reinforcement 1 No's 10 mm diameter of 415 N/mm^2 yield strength was used. Reinforcement cages and bearing plates were provided at loading points and supports to disperse the concentrated forces, thereby avoiding localized distress of concrete.

Casting of Strut and Tie model and its companions

A concrete mix of 1 (cement): 2.825(fine aggregate): 4.175(coarse aggregate) with water cement ratio by weight 0.59 was used for making the standard concrete specimens and for Strut and Tie model. Sand and cement was mixed first and then coarse aggregate was added and the materials were mixed thoroughly until uniformity was achieved. The required quantity of water is added slowly and wet mixing was done. For the compaction of the cylinders and prismatic specimens a controlled internal vibration was used. Three STM of size 1000mmX80mmX80mm specimens with a and without infill were cast flat-wise and compacted using vibration table in three layers. Before demoulding the specimens were kept under room temperature for 24 hours. Using the wet gunny bags all the specimens were cured and the specimen details are hollow specimen, brick infill specimen and concrete infill specimen as shown in Fig 3, Fig 4 and Fig5.

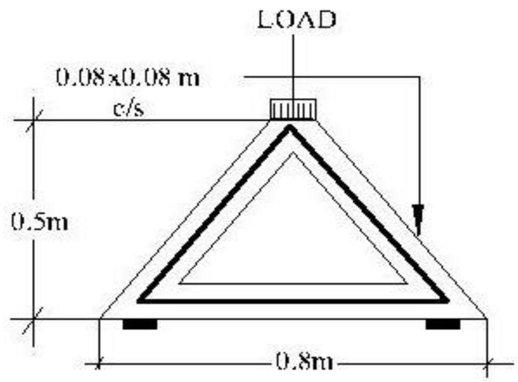

Fig 3 Specimen STM 1

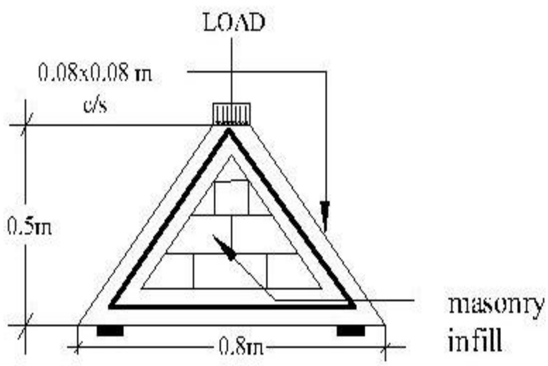

Fig 4 Specimen STM 2M

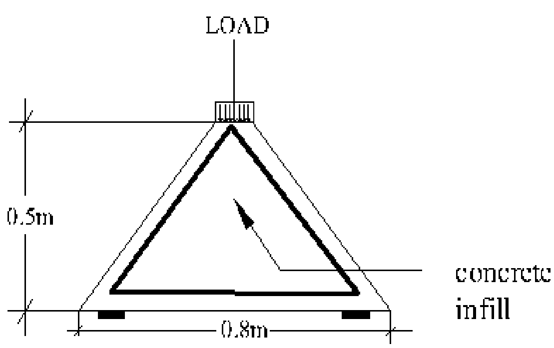

Fig 5 Specimen STM 3C

Experimental Setup

The strut and tie models were tested in a 100T capacity of Universal Testing Machine (UTM). All the specimens were tested to failure under single-point loading system. The beam test setup is shown in Fig 6 and Fig 7. Each of the specimens was mounted on roller supports on a UTM. Were obtained by placing the loading head on the top surface at the centre of the beam and the load is distributed through a spreader beam. A small pre load was applied slowly to ensure that the specimen was properly seated and the deflecto-meters were functioning properly. Then the load was removed and again reapplied and removed slowly. Successive load was applied in increments of 10KN. At each load increment the deflections at the mid-span and under the loading points were recorded. The first-crack load was observed during the test and the crack propagation is carefully marked. All the specimens were loaded to failure. The main specimens (Strut and Tie) models were casted with and without infill were tested to failure.

Fig 6 Test setup of Concrete Infill Specimen

Fig 7 Test setup of Masonry Infill Specimen

Cubes of size 150mm that had been cast along with the slabs were tested on the same day on which the respective slabs were to ascertain the compressive strength of the concrete used in the

STM. The cubes were carried out in a Compression Testing Machine of 200 ton capacity and these tests were carried out as per the recommendations of Indian Standard Codes of Practice. The modulus of elasticity of reinforced concrete Strut and Tie model was determined by conducting compression test on cylinders that has been cast along with the Strut and Tie models. The tests were conducted in a Universal Testing Machine (UTM) and the deformations corresponding to the various loads were measured by using dial gauge. As per IS-code recommendations these tests were carried out. All the specimens are tested in UTM under single point loading. The support condition is simply supported.

Behavior of Strut and Tie model during testing

Formation of Cracks

All STM specimens were tested and all of them failed in shear at right support. All specimens were loaded to failure. The STM specimens collapse due to excessive destruction of concrete in the shear span. The crack patterns and failure of test specimens are shown in Fig 8, Fig 9 and Fig 10. The numbers written along the cracks indicate the termination of cracks observed at a particular stage. Up to about 40% of ultimate load no cracking was observed in any STM specimens. The first vertical shear cracks were formed in the concrete infilled STM specimen between 50% to 60 of the ultimate load a sudden major inclined crack was formed. The first crack was usually a suddenly inclined shear crack originating from the outer bottom corner of the opening. With the further increase of load cracks propagated towards the support while crack originating at the top inner corner of the opening propagated upward towards the load bearing plate. At higher loads, diagonal shears mode in some beams. This is verified by the test results showing retired almost load carrying capacity. An almost stable position of all existing cracks was observed at ultimate load stage. The stable position was identified on the beams. Finally, specimen failure occurred by concrete destroyed in either the reduced compression zone at the head of the inclined crack and the region adjacent to the loading block or by fracture of the concrete along the inclined cracks.

Fig 8 Failure crack pattern of STM 1

Fig 9 Failure crack pattern of STM 2M

Fig 10 Failure crack pattern of STM 3C

Load-Deflections

Load deflection for all the STM specimens recorded and values are compared with FEM deflection values are shown in Table (1). The variation at the earlier stage is linear until the first crack is reached. It is also observed that the stiffness of the beam depend largely on the extent to which the openings interrupt the vertical load path. The concrete infill shows stiffer than other two specimens. The STM 1 rate of deflection higher, STM 2M indicates brittle behavior and STM 3C recorded less rate of deflection. The FEM deflection values are higher compared to experimental values.

Table 1 Comparison of Load Vs Deflection

S.No	Specimen Details	LOAD (KN)	Deflection values	
			ANSYS (mm)	EXP (mm)
1	STM1	10	03.3	2
		20	06.7	3
		30	10.1	6
		38	12.7	8
2	STM2M	10	03.2	1
		20	06.5	2.1
		30	09.8	4.3
		40	13.5	6.5
		44	14.4	8
3	STM3C	10	02.1	0.9
		20	04.2	1.6
		30	6.4	2.8
		40	8.5	6.1
		50	10.6	8.3
		59	12.6	10.9

Effects of Infill in the First Crack Load and Ultimate Load

The first crack for STM 1specimens without infill were observed at 40% of the ultimate load, for brick masonry infill shows the first crack load was found between 40% to 45% the ultimate load. The concrete infill STM 3C specimens shows higher load value than other specimens, it was found between 55% to 65% the ultimate load.

There is 10% to 20% increase in ultimate load for reinforced concrete infill specimen when compared with brick masonry in fill specimen. Thus the experimental results show that there is higher increase in the ultimate load and the first crack load for the reinforced concrete Strut and Tie specimens. The ultimate load and theoretical calculated are shown in Table (2).

Table 2 Comparison of Ultimate load, Theoretical Vs Experimental

SI. no	Specimen Details	Theoretical Load (KN)	EXP load (KN)	Nature of failure
1	STM1	40	42	Shear Failure
2	STM2M	44.8	48	
3	STM3C	56	59	

The STM 1 specimen failed due to shear and it occurred at left support of the specimen. The FEM analysis results also show the same during the ultimate load. The failure profile of the experimental as well as FEM as shown in Fig 11 and Fig 12.

Fig 11 Experimental failure profile of STM 1

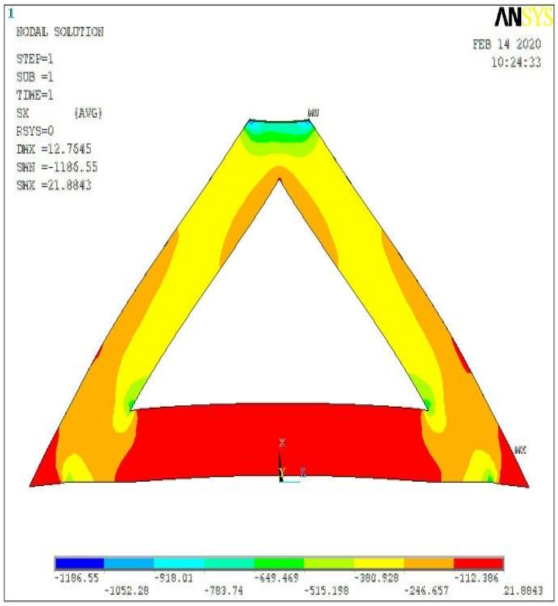

Fig 12 FEM Failure profile of STM 1

The STM 2M specimen carries higher ultimate load compared to STM 1model due to masonry in fill effects. The failure also similar to STM 1 but slightly bending action is absorbed during elastic range. The failure profile of experimental and FEM as shown in Fig 13 and Fig 14.

Fig 13 Experimental Failure profile of STM 2M

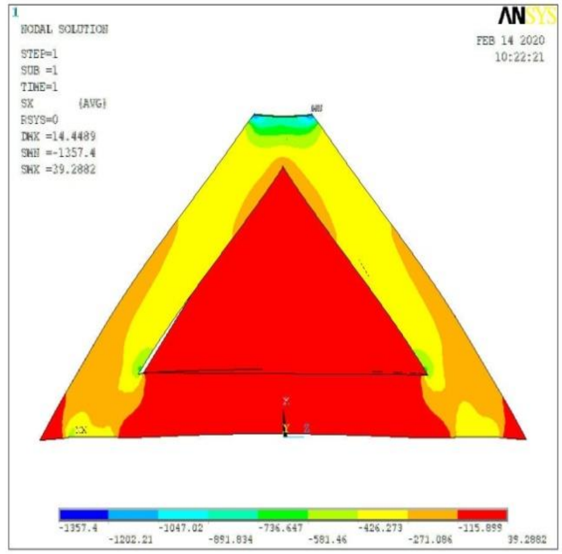

Fig 14 FEM Failure profile of STM 2M

STM 3C specimen is recorded the highest ultimate load among other two specimens. Ultimate load of STM 3C is 51% and 22% higher than STM1 and STM 2M respectively. Failure takes place in shear only. The failure profiles of the STM 3C specimen and FEM nearly same, shown in Fig 15 and Fig 16.

Fig 15 Experimental Failure profile of STM 3C

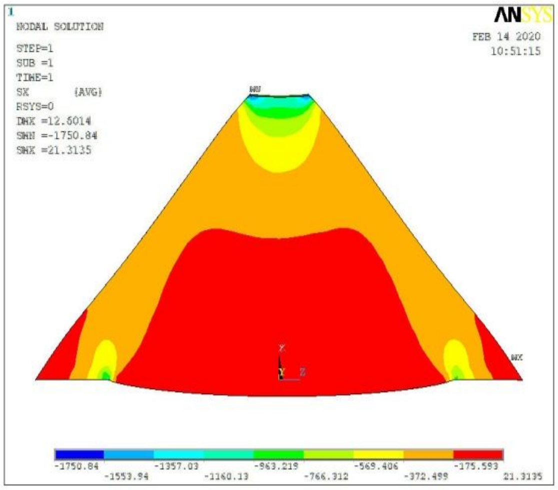

Fig 16 FEM Failure profile of STM 3C

Conclusion

1. All STM specimens were fails due to shear only

2. The infill material will improve the ultimate load.

3. The STM infill provides more stiffness to the strut and tie.

4. Brick masonry infill shows strut and tie action during failure.

5. The ANSYS FEM theoretical results give failure mode and ultimate close to the experimental results.

Suggestion for further work

1. The experimental investigation may be carried out with different and with other different materials.

2. Different locations of opening in the web may be tried with the STM model.

3. Experimental investigation may be carried out to study the long term behavior.

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