EXPERIMENTAL INVESTIGATION OF REINFORCED CONCRETE BEAM WITH OPENING FOR COMBINED BENDING AND SHEAR

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Abstract - In the modern method of construction of building, pipes and ducts for services like water supply, sewage, air conditioning, electricity, telephone and computer networks are to be placed in appropriate positions. Usually, these pipes and ducts are connected and kept below the beam soffit and for aesthetic purpose these are covered by false ceiling thus introducing the dead space. This research aims at providing transverse openings in the beam so that the utility pipes and service ducts can be passed through the opening which may result in systematic accommodation of pipes and ducts and also provide economic savings in the construction of multi-storey buildings. This paper deals with the analysis and design of such beams under the loading case of bending and shear.

Index Terms - ANSYS, voided beam, transverse openings, normal stresses, deflection, compressive strength.

1   Introduction

For modern construction, the provision of providing transverse openings in the reinforced concrete beam would be a facility to allow the passage of utility pipes and ducts through the structure. This type of design would provoke and promote the structural designers to lower the height of the structure and to make structure better in design and at economical cost. In case of small buildings the savings would not be significant, but in case of high rise building savings in a single storey multiplied by no. of stories would result in substantial savings in total height, length of electrical wires and ducts, air conditioner pipes, plumbing material, partition surfaces and load on foundation. Due to the abrupt change in the cross section of the beam and introduction of opening in the beam the normal beam behaviour would change to a complex one. The opening corners would subject to high stress which would lead to cracking of beams. Also reduction in the stiffness of the beam would lead to excessive deflection under the service load. Thus proper detailing with sufficient amount of special reinforcement is to be provided for such beams to avoid the adverse effects on the strength and serviceability of the beam. Presently no design criteria is been mentioned in any of the code which is used for design of concrete building structure.

2   METHODOLOGY

An experimental investigation is to be carried of reinforced concrete beam with openings for combined bending and shear. The specimens of reinforced concrete beam with and without openings are to be casted. Casting and testing is been done at the TOM (testing of material) lab of Dhole Patil college of Engineering under the guidance of Mrs. Pranjali Kulkarni, HOD, civil department. The values of the peak load and maximum deflection are recorded. Similar specimens are also designed analytically in finite element tool ANSYS and the values of the maximum stress and deflection are obtained. According to these values the appropriate designing of the reinforcement is done in the beams and tested. Methods of analysis are:

A. Analytical approach using FEM tool ANSYS.
B. Experimental testing of beams.

3   EXPERIMENATL WORK

3.1   COMPRESSIVE STRENGTH OF CONCRETE

Cubes of standard size 150x150x150mm size are casted and tested practically for its crushing/compressive strength so as to validate the strength of M25 grade concrete. In total 27 cubes are casted. 9 cubes are casted per day out of which each set of 3 is tested on 3rd, 7th and 28th day respectively. The average values of 3, 7, 28 days is calculated. Average values of the strength obtained of all the cubes are shown in table 1 followed by its graphical representation seen in Fig.1. Fig.2 shows the casted cubes followed by its testing as shown in Fig.3.

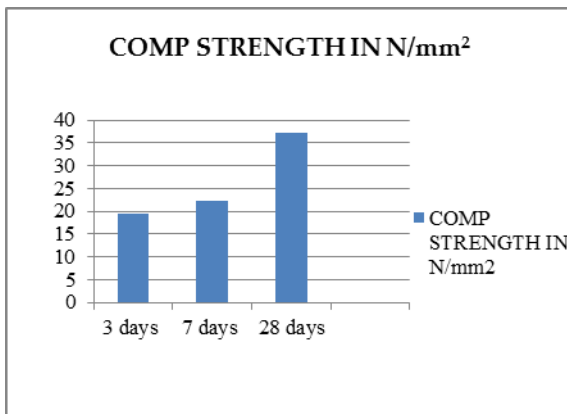| Average values of the compressive strength of cubes	
3 days	19.32 N/mm^2
7 days	22.34 N/mm^2
28 days	37.22 N/mm^2

Table 1

Fig.1 Chart showing the increase in strength with the time of curing.

Fig.2 Casting of cubes.

Fig. 3 Testing of Cubes.

3.2   Scaling and casting of beams

A standard RCC beam of size 230mm x 450mm having length 2.5m is been considered from a residential plan and designed using IS 456. Two different openings sizes of 100mm and 150mm are taken into consideration at different locations along the length of the beam. Fe415 steel and M25 concrete are used. As casting curing and transporting of such beams is difficult, it is scaled down to a size which is easy for practical purpose. Beam is scaled down to a size of 65mm x126mm and having length 700mm. Similarly openings are scaled down to a size of 28mm and 42mm respectively.

Initially 3 beams are casted and tested on the UTM without any reinforcement in it having one, two, three openings respectively on each beam of size 28mm so as to identify the cracking pattern due to which the beam fails. Fig. 4 shows the formwork of the beams and placing of PVC pipes so as to form the required openings. Fig. 5 shows the casting and testing of the beam with 3 openings. The cracking pattern of the beam can be seen in this figure.

Fig. 4 Formwork prepared on site.

Fig. 5 Casting and testing of beam with three opening.

3.3 Loading condition

The beam is placed over the jaws of the UTM and fixed over it. The centre of the beam is marked and on equal distance from the centre rolled steel sections are placed on each side. Over these rolled steel sections a mild steel plate is placed over which the central point load is applied by the UTM. This procedure is followed so as to apply a two point load as per IS specification of applying a point load. Fig. 6 shows a typical arrangement of the loading condition made.

Fig.6 Typical arrangement of two point loading condition.

4 Analytical approach

The beams will be modelled in the Finite Element Method tool ANSYS and loading will be provided as shown above in the two point form. The results will be noted and compared to the experimental results. So as to take the worst cases into consideration the openings are kept at the centre of the beam where the bending moment is maximum and at a distance from support where the shear force is maximum. List of models to be prepared are:

- Solid beam without hole.

- Beam with 100mm circular hole at L/2 distance.
- Beam with 150mm circular hole at L/2 distance.
- Beam with two 100mm circular holes at 175mm from both ends.
- Beam with two 150mm circular holes at 175mm from both ends.
- Beam with three 100mm circular holes at L/2 distance and other two at 175mm from both ends.
- Beam with three 150mm circular holes at L/2 distance and other two at 175mm from both ends.
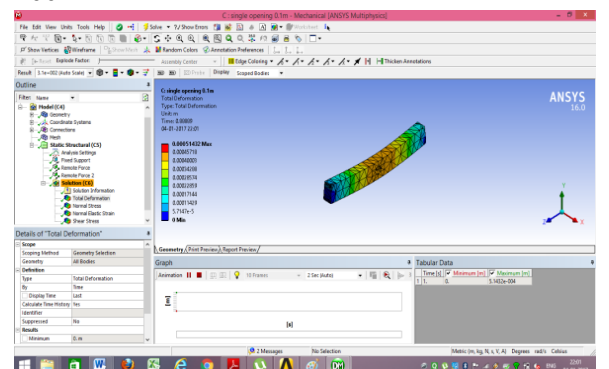
5 Results

Sample models been prepared in ANSYS with one, two, three openings along with the values of maximum deflection and stresses are as shown below:
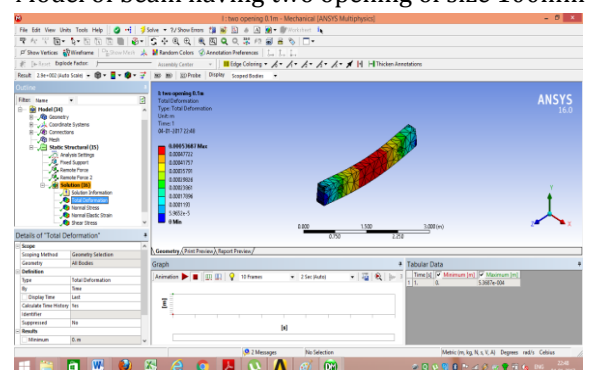
- Model of the beam without any opening
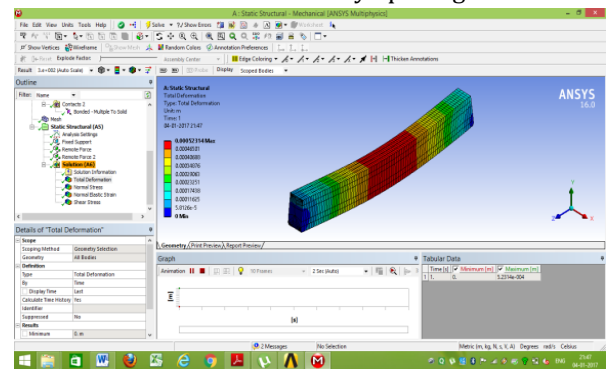
Results: Maximum Deflection: 0.00052314m
Maximum Stress: 3.7952e7 Pa
Maximum Strain: 0.00013948

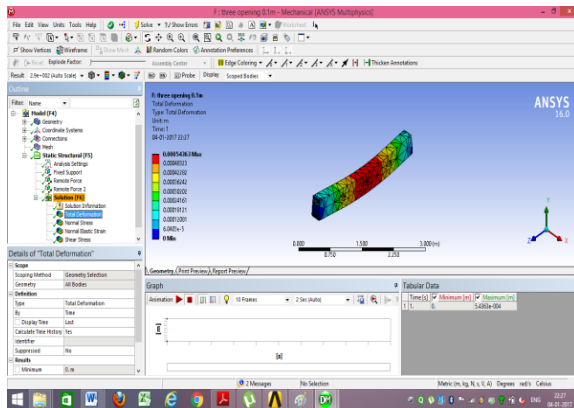- Model of beam having a single opening of size 100mm

Results: Maximum Deflection: 0.00051432m
Maximum Stress: 3.289e7 Pa
Maximum Strain: 0.00014326

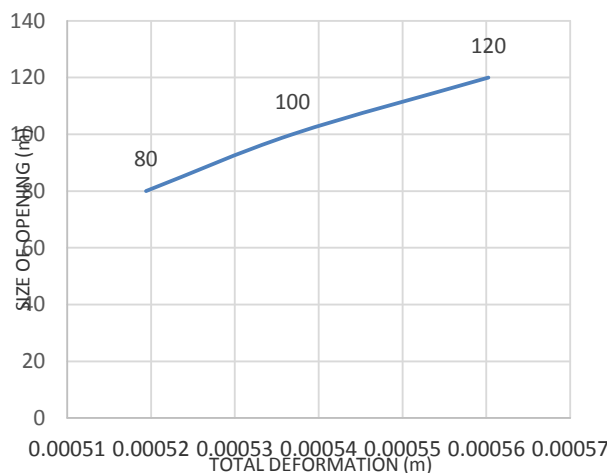- Model of beam having two opening of size 100mm

Results: Maximum Deflection: 0.00053687m
Maximum Stress: 2.9977e7 Pa
Maximum Strain: 0.00019766

- Model of beam having three openings of size 100mm

Results: Maximum Deflection: 0.00054363m
Maximum Stress: 3.0668e7 Pa
Maximum Strain: 0.00020148

Graph showing total deformation vs. size of opening.

6 Conclusion

- Deformation in beam without opening is less as compared to beam with opening.
- Total deformation increases with the increase in size of opening.
- Due to the openings total deformation, normal stress, strain increase thus additional reinforcement is to be provided and its design are need to be recommended in IS codes.

- The crack pattern which the beam will undergo on the action of practical loading condition or during flexure test is obtained.
- Special reinforcement is to be designed to avoid the inclined cracks undergone by the beam due to the provision of openings in the beam during the test.
- After provision of designed reinforcement the beam is tested practically for flexure test and also models of the same would be designed and tested analytically in ANSYS so as to validate the obtained results.

Acknowledgement

7 References

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