Experimental Study on the Behavior of Sandwich Beams

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Abstract— The Objective of the sandwich beams are used to reduce the self-weight, deflection and shear which being the major concern in case of conventional reinforced concrete beams subjected to loading. In this project work ,sandwich beams that are cast by the inclusion of thermo-col and weld mesh in the place of steel re-bars that are used in reinforced concrete beams has been the subject of several studies devoted to determine the influence of the main parameters. Due to the small value of span-depth ratio, the strength of beams are usually controlled by shear ,the yield strength and ultimate capacity of sandwich beams subjected to bending is to be determined through experimental methods. The experimental works are conducted to understand the various modes of failure that could occur due to the possible combination of shear and bending moment acting at a given section of a sandwich beams. Apart from highlights the experimental set-up, typical crack patterns, failure modes and load deflection behavior to be reported.

Key words: Sandwich Beams, Thermo-Col, Wire Mesh, Crack Patterns

I. INTRODUCTION

Sandwich theory describes the behavior of a beam, plate, or shell which consists of three layers - two face sheets and one core. The most commonly used sandwich theory is linear and is an extension of first order beam theory. Linear sandwich theory is of importance for the design and analysis of sandwich panels, which are of use in building construction, vehicle construction, airplane construction and refrigeration engineering.

Some advantages of sandwich construction are:

- Sandwich cross sections are composite. They usuallyconsistof a low to moderate stiffness core which is connected with two stiff exterior face-sheets. The composite has a considerably higher shear stiffness to weight ratio than an equivalent beam made of only the core material or the face-sheet material. The composite also has a high tensile strength to weight ratio.
- The high stiffness of the face-sheet leads to a high bending stiffness to weight ratio for the composite.

The behavior of a beam with sandwich cross-section under a load differs from a beam with a constant elastic cross section as can be observed in the adjacent figure. If the radius of curvature during bending is large compared to the thickness of the sandwich beam and the strains in the component materials are small, the deformation of a sandwich composite beam can be separated into two parts, Deformations due to bending moments or bending deformation, and deformations due to transverse forces, also called shear deformation.

Sandwich beam, plate, and shell theories usually assume that the reference stress state is one of zero stress. However, during curing, differences of temperature between the face-sheets persist because of the thermal separation by the core material. These temperature differences, coupled with different linear expansions of the face-sheets, can lead to a bending of the sandwich beam in the direction of the warmer face-sheet. If the bending is constrained during the manufacturing process, residual stresses can develop in the components of a sandwich composite. The superposition of a reference stress state on the solutions provided by sandwich theory is possible when the problem is linear. However, when large elastic deformations and rotations are expected, the initial stress state has to be incorporated directly into the sandwich theory.

II. METHODOLOGY

A. Specimen Details

Testing was carried out on 12 beams, Beams were simply supported on constant effective span of 1200 mm. 12 numbers of beams were tested under two point concentrated symmetrical loads. All the beams were having constant overall span and width of 400 mm and 150 mm respectively.

B. Material Properties

1) Cement

The cement used in the study is ordinary Portland cement of 53 grades supplied from Ultra Tech cement factory. It is tested for physical properties as per IS 12269: 2013 standard. The preliminary test results of the cement are tabulated.

a) Properties of Cement

- Properties: Values
- Specific gravity: 3.15
- Fineness: 95%
- Normal consistency: 35%
- Initial setting time: 30mins
- Final setting time: more than 30 mins

C. Fine Aggregate

Locally available river sand conforming to Grading zone II of IS 383 –1970 was used in the study. Used as a filler. It accounts 60-80% of volume & 70-80 % of weight of concrete and defines concrete dimensional stability. Soil passing through less than 4.75 mm was used. The physical properties of soil are tabulated.

a) Properties of Fine Aggregate

- Properties Values
- Specific gravity of FA 2.64
- Zone II

D. Coarse Aggregate

Locally available crushed blue granite stones conforming to graded aggregate of nominal size 20 mm as per IS 383 – 1970 is used. Properties of aggregates have large 21 impact on the strength, durability, workability and economy of concrete. The physical properties of soil are tabulated.

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E. *Properties of Coarse Aggregate*

- Properties Values
- Specific gravity 2.71
- Impact value 21.40%
- Crahing value 11%
- Deval's value 1.10%
- Abrasion value 19%

III. TEST SETUP AND INSTRUMENTATION

A. *Purpose of Mix design*

Design of concrete mixes involves determination of the proportions of the given constituents namely cement, water, coarse and fine aggregates, fly ash. Polypropylene and admixture Workability is specified as the important property of concrete in the fresh state and compressive strength and durability are important properties of hardened concrete. Hence the mix design is generally carried out for a particular compressive strength of concrete with adequate workability so that the fresh concrete can be properly placed and compacted to achieve the required durability .In special situations concrete can be designed for flexural strength for any other specific property of concrete.

1) *Stipulations for Proportioning*

- Grade designation: M30
- Type of cement: OPC 53 grade
- Max nominal size of aggregate: 20mm
- Min cement content: 320 kg/m3
- Max w/c ratio: 0.45
- Workability: 100 mm (slump)
- Exposure condition: Mild
- Degree of supervision: Good
- Type of aggregate: Crushed angular
- Max cement content: 450 kg/m3
- Chemical admixture: Super-plasticizer

B. *Specimen Details*

Nine specimens (Beams) were cast and tested up to failure divided into three groups (G1 to G3) to investigate the effects of three variables on shear strength of beams which are:

- Conventional beam
- Weld mesh and thermo-coal without reinforcement
- Weld mesh and thrmo-coal with reinforcement

1) *Specimen Preparation*

Fig. 1: Specimen Preparation

All the beams were rectangular in cross-section with 200mm width. The overall depths of the three beams were; 400mm respectively. The shear spanto- depth ratio was 0.75. The effective span-to-depth ratio was 1.5. The overall length (L) of the beam was 70mm respectively. The effective cover to the reinforcement was 50mm with a clear cover of 25mm in all the beams. The horizontal shear reinforcement was 0.2 and 0.3%, distributed uniformly over the total depth (UN) and uniformly distributed over 0.3d (CN).

2) *Beam Flexural and Shear Reinforcement*

All the beams were provided with 1.5% flexural reinforcement. The flexural reinforcement was extended or bent up at the supports to ensure adequate anchorage length. 6mm diameter mild steel bars were used as corner reinforcement. The vertical shear reinforcement was 6mm diameter two-legged stirrups (equal to 0.15% of the cross-section), which corresponds to the minimum shear reinforcement as per IS code. The spacing of the stirrups was 250mm c/c. In addition to the minimum vertical shear reinforcement,

The horizontal reinforcement was also provided. Two percentages of the horizontal shear reinforcement, 0.2% and 0.3%, were adopted to study the effect of their distribution. In one case, the “horizontal shear reinforcement distributed uniformly over the total depth of the beam”, designated as UN, and in another case, the “horizontal shear reinforcement distributed uniformly over the middle 0.3d of the beam”.

C. *Batching, Mixing and Casting Process:*

1) *Batching:*

This process was done by prepare the mixture compounds through taking the specific weights depend on size of the mix, a sample of Batching process

2) *Mixing:*

The mixing process for to conventional concrete, this is mainly due to very low (w/c) ratio. The overall mixing time is about 30 minutes. The mixing process can be illustrated in the following steps:

- Feeding the fine and coarse aggregate in mixer and mix for 1 minute.
- Add some water to the premix for absorption purpose and mixing for 1 minute, then wait 3 minutes.
- Add the binders (cement) to the premix and mixing for 2 minutes.
- Add half of superplasticizer to mixing water.
- Add water (with half of superplasticizer) to premix slowly over 2 minutes.
- Wait 1 minute, and then add remaining superplasticizer to premix.

Continue mixing as the cement changes from a dry powder to a thick paste. This process takes about 15 minutes and it is may vary between 29 min.

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3) *Casting:*

The molds were already put in a horizontal manner on the vibrating table, the inside face were oiled, the strain gages fixed on the mid space of steel bars and placed inside the molds and fixed properly. Three specimens (beams) with different geometry and same concrete type with six cubes, three cylinders and three prisms were casted just after

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mixing process was completed. The casting process was done by placing the concrete inside the molds in three layers and each layer was vibrated four about 1 minute for both types (HSC and NSC), while for (UHPC) the vibration time for each layer was 3 minutes due to the high consistency. At end of the third layer, the concrete surface was finished and leveled by a steel trowel. The casting and testing direction of beams was the same direction, the casting data

D. Testing Procedure:

Tests on Hardened Concrete:

- Cube Compression Test
- Flexure Test
- Split Tensile Test

E. Cube Compression Test:

The tests are required to determine the strength of concrete for the required grade of concrete:

- Representative samples of concrete shall be taken and used for casting cubes 15 cm x 15 cm x 15 cm or cylindrical specimens of 15 cm dia x 30 cm long.
- The concrete shall be filled into the moulds in layers approximately 5 cm deep. It would be distributed evenly and compacted either by vibration or by hand tamping. After the top layer has been compacted, the surface of concrete shall be finished level with the top of the mould using a trowel; and covered with a glass plate to prevent evaporation.
- The specimen shall be stored at site for 24+ ½ h under damp matting or sack. After that, the samples shall be stored in clean water at 27+20C; until the time of test. The ends of all cylindrical specimens that are not plane within 0.05 mm shall be capped.
- Just prior to testing, the cylindrical specimen shall be capped with sulphur mixture comprising 3 parts sulphur to 1 part of inert filler such as fire clay.
- Specimen shall be tested immediately on removal from water and while they are still in wet condition.
- The bearing surface of the testing specimen shall be wiped clean and any loose material removed from the surface. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load cube as cast, that is, not to the top and bottom.
- Align the axis of the specimen with the steel platen, do not use any packing.
- The load shall be applied slowly without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen to the increased load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and any unusual features noted at the time of failure brought out in the report.

F. Split Tensile Test:

- The split tensile test was conducted as per IS. The size of cylinder is 300mm length150mm diameter.
- The specimen were kept in water for curing for 7 days, 14 days and 28 days and on removal were tested in wet condition by wiping water and grit present on the surface.
- The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder along the vertical diameter.
- The maximum load applied to the specimen was then recorded and the appearance of the concrete for any unusual features in the type of failure was noted.
- Average of three values was taken as the representative of batch. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder along the vertical diameter.
- To find split tensile strength following equation has used. Figure 3 shows the testing of split tensile test.
- Split tensile strength = 2P/ (π DL)

Fig. 2: Split Tensile Test

IV. RESULT AND DISCUSSION

A. Initial Crack Load:

Weldmesh with thermocol beam = 80kN
Weldmesh and thermocol with reinforced beam = 96kN
Conventional beam = 120 kN

B. Ultimate Load:

Weldmesh with thermocol beam = 111 kN
Weldmesh and thermocol with reinforced beam = 120 kN
Conventional beam = 140 kN

C. Flexural Strength:

Weldmesh with thermocol beam =19.425 N/mm^2
Weldmesh and thermocol with reinforced beam =21.175 N/mm^2
Conventional beam = 24.5 N

V. CONCLUSION

The idea of lightweight concrete beams and weldmesh and thermocol added concrete beams were proposed the main conclusions were,

- The failure of beams is by the diagonal strut failure.
- Comparing to normal concrete beams light weight concrete beams show poor behavior in deflection, cracking and the design became non conservative.
- Addition Weldmesh and thermocol of to lightweight concrete beams improves its performance in cracking and deflection.
- The load at which cracking start is increased significantly.

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- The inclusion of weld mesh and thermo-col in concrete mix provides effective shear reinforcement in beams
- Both the first crack strength and ultimate strength in shear increase with the provision of web reinforcement

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