Experimental Behavior of Beams with Aggregate Interlocking Under Flexure

K.Kumara Swamy, P.Poluraju

Abstract: Aggregate interlocking has the ability to transfer the load from one side to other by a narrow irregular crack. Aggregate interlocking and dowel action are the key parameters to transfer the shear strength in reinforced concrete members. In this study, experimental work has been carried out on reinforced concrete beams with and without aggregate interlocking connection through implementing initial crack and simultaneously varying the percentage of longitudinal reinforcement under flexure using four-point loading. The flexural strength of the reinforced concrete beams has been assessed through load-deflection curve, ductility and flexural strength resulted from four-point bending test. From experimental study, it has been observed that by varying the percentage of longitudinal reinforcement, the flexural strength of the beam significantly increased.

Index Terms:Aggregate interlock, Dowel action, four-point bending, Flexural strength, Longitudinal reinforcement.

I. INTRODUCTION

Aggregate interlocking has the capability to transfer the load from one side to other by a small irregular crack. The main work behind this aggregate interlocking connectionhasto transmit the load from one way to another way in the concrete members. Aggregateinterlockingconcept has been first identified generally as a good load transfer system in the past 1990s. It is world widely agreed that the concrete has been used as a favored construction material from many years in the reinforced concrete members. Normally, concrete members have a good load transfer that effects in lesser deflections, minimized the spalling and to avoid the corner breaks in the members. An essential key parameter for transferringloadsin members is shear action. In a reinforced concrete beams, a shear resistance was commonly taken by shear reinforcement with a following elements namely as aggregate interlock connecting crack face and the dowel action of the main reinforcement. It is globally facing the challenge of shear-transfer technique in the shear behavior of reinforcing concrete beams. Researchers are still working for developing a detailed understanding of a shear-transfer technique by applicable experimentation and mathematical assumptions. Dowel action in the bottom reinforcement has not been definitely represented its importance in shear resistance.The literature will be reviewed in the below paragraphs, recognized a work of researchers for explore the range of this present research.

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The failure portion has established by crack expand in tensile zone under integrate bending and shear too sliding surface over the compression zone. The position of the initial crack is particularly determined by the concrete tensile strength sharing in the tension zone. Inclination of the first shear crack was successful to decrease the variability of both together, the shape of the failure section and the failure load. If the aggregate interlock is neglecting in the compression zone to the shear resistance is applicable [1].In the high strength reinforced concrete beams, the aggregate interlock technique is neglected in the members, dowel action was the primary contributor from still its contribution reduces with the growth of concrete strength. In the reinforced members having concrete strength in the domain for 40 to 110 Mpa, optimum dowel force reaches between 53% and 43%.Still, the stress subtracted from shear stress to estimate dowel stress at that portion [2]. While the aggregate interlock reacts with a very important role as a shear carrying technique at small concrete compressive strengths,the shear strength of reinforced concrete beams does not effects at high concrete strengths [3].Dowel action is more leading at very high strengths, and the shear carried by the concrete compression zone remains impartially association with growing concrete compressive strengths.Aggregate interlock results low with a high quantity of web reinforcement by taking the shear. Importantlycover has the independent effect on the dowel force. By eliminating aggregate interlock the total shear 56% will be determined by dowel force. Dowel action always approvals the more ductile sections and a cover directly decides the dowel action. In the reinforced concrete beams with higher compressive strengths will decreases the dowel action [4]. In the cracked reinforced concrete section dowel action is a practical element in the shear mechanism. In the uncracked concrete sections, the major factors for withstanding the related shear force is shear resistance of sections [5].

In a two phase model, requires integration of sliding and crushing of the crack faces are the most practical one. Still the usage of this model is forecast the integration of shear stiffness was matured to aggregate interlock in cracked reinforced concrete is not simple [6].A modern type of aggregate interlocking concrete settled with scattering-filling aggregate process, which is newly developed by him. Mainly coarse aggregatessuspended in the mortar even through there may be some contact in the concrete, but the aggregate interlock with each other clearly and act as good bonding of concrete [7]. The moderate stiffness minimized

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after the existence of diagonal cracks were main in the light weight concrete beams than in normal weight concrete beams and increased with the decrease of maximum aggregate size [8].

The basic tests on aggregate Interlock, are two concrete surfaces from roughness were preceding parallel to each other under different situations [9]. The surface texture of cracked beams with different concrete mixtures was estimated by using VST method [10].The different shaped dowels at different spacing are investigated by the load transfer efficiency [11].Contribution of aggregate interlock technique alone the crackresponse under monotonic loading was discussed [12]. Developed a finite element model for analyzing the load transfer features of an aggregate interlocked connection in a concrete member [13].Doweled systems are more complex load transfer for the improved understanding the desirability of pure shear devices [14].Technique of load transfer by reinforcement concrete bond between cracks and through the aggregate interlock and dowel action at the crack faces [15].In all circumstances the load transfer efficiency was higher during dynamic than static loading. In large sized coarse aggregates has greater load transfer efficiency than smaller sized coarse aggregates. Developed an equation of aggregate interlocking by using the CNCPAVE [16].

II. RESEARCH SIGNIFICANCE

The major center of attention for examine the effect of the inclination of the failure section and of the aggregate interlock on the shear bending resistance, where aggregate interlock was eliminated along the web in failure crack with a design of reinforced concrete members show that beams with different percentages of flexural reinforcement displays different behavior which will be shown in Tables I and II.

Table I: Specimenfactors combination with conventional

Beam code	%steel (*p*)	Grade of concrete
A1	0	M 30
B1	0.6	M 30
C1	0.9	M 30
D1	1.2	M 30

Table II: Specimen factors combination with eliminating aggregate interlock

Beam code	% steel (p)	Grade of concrete
A2	0	M 30
B2	0.6	M 30
C2	0.9	M 30
D2	1.2	M 30

III. EXPERIMENTAL INVESTIGATION

The following test specimens were investigated:

- Four (conventional) specimen with respect to show the natural failure in the reinforced concrete beams.
- Four specimens for which a mild iron steel plate was placed along the revealed failure section to eliminate any contribution of aggregate interlock through the failure crack.Totally, we required 8 specimens to be cast for testing.

A. Specimen parameters

The basic features of the specimens were as follows:

- Fig. 1 shows dimensions of beams (2200×150×300 mm).
- For all beams, parameters kept constant include grade of steel = Fe500HYSD, shear span a = 666 mm, flexural span =666 mm, effective span = 2000 mm, grade of concrete = M30.
- The flexural tension reinforcement consisted of 0% steel and also compression reinforcement consists with 0% steel with the grade of concrete M 30 will be casted the conventional A1 beam.
- For A2 beam will be casted with the reinforcement details given in the above sentence and with eliminating the aggregate interlocking connection. by placing the 5mm thickness iron plate in distance of 360mm from the end with a height of 60 mm from the bottom.
- The flexural tension reinforcement consisted of 0.6% (2 bars) with a size of 12 mm diameter and also the compressionreinforcement consists with 2 bars of 10 mm diameter will be casted the B1 conventional beam.
- For B2 beam will be casted with the reinforcement details given in the above point with eliminating the aggregate interlocking connection.
- The flexural tension reinforcement consisted of 0.9% (3 bars) with a size of 12 mm diameter and also the compression reinforcement consists with 2 bars of 10 mm diameter will be casted the C1 conventional beam.
- For C2 beam will be casted with reinforcement details given in the above point with eliminating the aggregate interlocking connection.
- The flexural tension reinforcement consisted of 1.2% (4 bars) with a size of 12 mm diameter and also the compression reinforcement consists with 2 bars of 10 mm diameter will be casted the D1 conventional beam.
- For D2 beam will be casted with reinforcement details given in the above point with eliminating the aggregate interlocking connection.
- Transverse reinforcement will be Fe415 type steel with the 8 mm diameter of 100 mm horizontal and 250mm vertically bended the steel with the spacing of 200 mm c/c.
- Before concreting an inclined hole will be made of 45^0 by placing the 5mm thickness iron plate in distance of 360mm from the end with a height of 60 mm from the bottom in the mould.

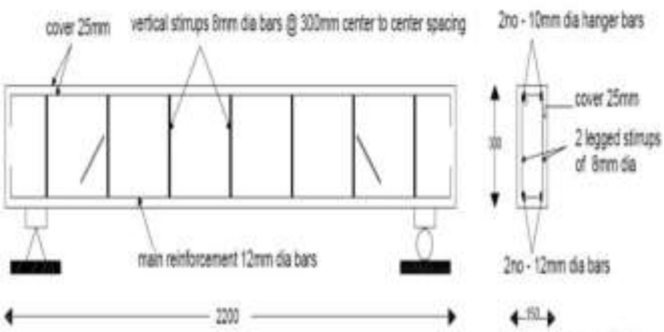

Fig. 1:Schematic diagram of specimen

B. Test Methodology

All beams are tested under four-point testing, periodically after the 28 days of curing completed from the casting under the loading frame which is force controlled with 200 kN capaciaty. Fig. 2 shows test setup of specimen. The load and the displacement of sections were measured electonically with the data acquistion system.

Fig. 3 shows the specimen after completion of testing. Crack pattern was physically recorded in the failure zone at each uploading process.The deflection in specimen was measured by LVDTs which are placed in the middle of the specimen.

Fig. 2: Test setup of specimen

Fig. 3: Specimen after completion of testing.

IV. TEST RESULTS

The testing of the specimens under the loading frame results shows:

1. In a conventional beam A1 shows the sudden failure occurs in the mid span of the specimen and the A2 beam was testing, the initial cracks were started in the shear zone and finally it breaks flexural in mid portion of specimen.
2. In the beams B1,C1, D1 were testing, the beams can bear the load up to some extent with respect to their flexural reinforcements and the cracks can be occurs mainly in the flexural zone.
3. In the beams B2, C2, D2 were testing, the beams will be failed before the failure of the conventional specimens why because these beams are casted with the elimination of aggregate interlocking connection in shear zone.
4. While taking the load-deflection graphs (see Fig. 5) will be graduallydecreased the steepness, where close to failure.
5. A shear cracks will be generated in the bottom part of the calculated compression zone.
6. In the tension reinforcement the cracks appeared the splitting of concrete cover, resulting the dowel action and loss of bonding in concrete.
7. In the increase of deflection in the specimen can gradually decreases the loading force were observed.
8. In the mid span zone, the yielding of flexural reinforcement wasclearly experienced the higher ductility.

The following graphs show the load vs. deflection curves in the Fig. 5.

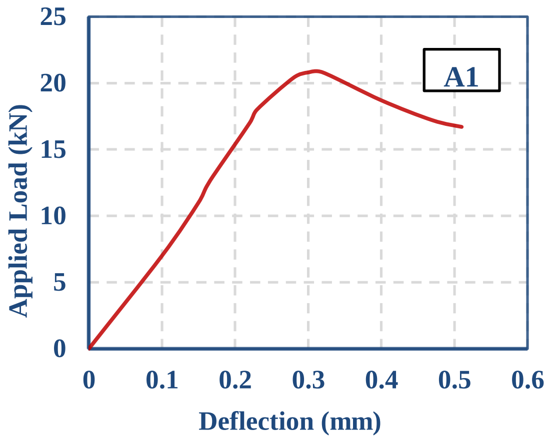

Fig. 5(a):Applied load *vs.* Deflection curve for 0% Reinforcement

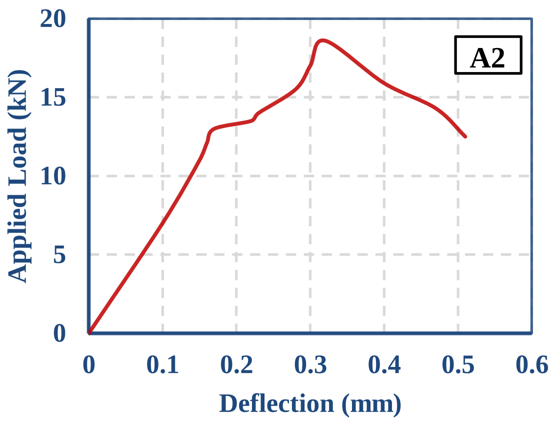

Fig. 5(b): Applied load *vs.* Deflection curve for 0% Reinforcement

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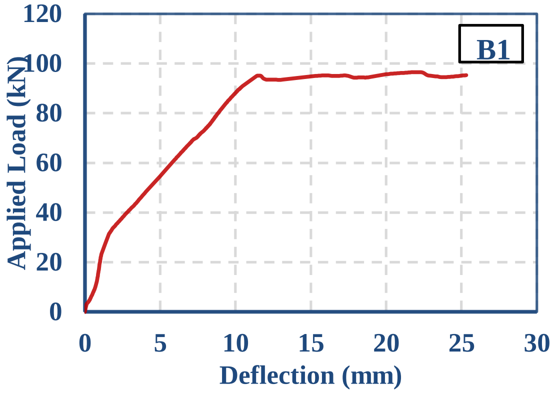

Fig. 5(c): Applied load *vs.* Deflection curve for 0.6% Reinforcement

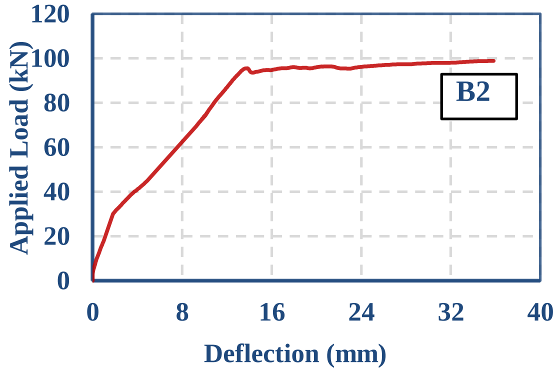

Fig. 5(d): Applied load *vs.* Deflection curve for 0.6% Reinforcement

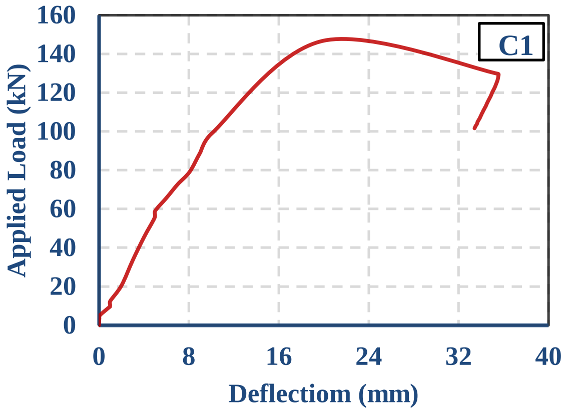

Fig.5(d): Applied load *vs.* Deflection curve for 0.9% Reinforcement

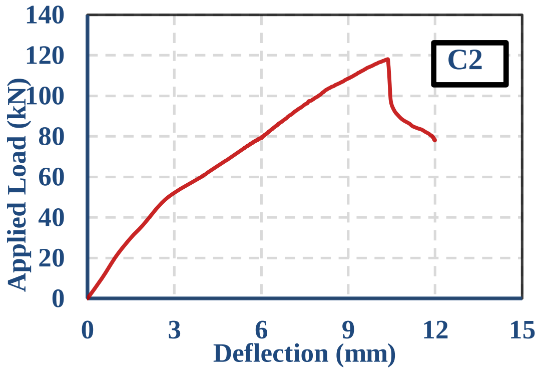

Fig. 5(d): Applied load *vs.* Deflection curve for 0.9% Reinforcement

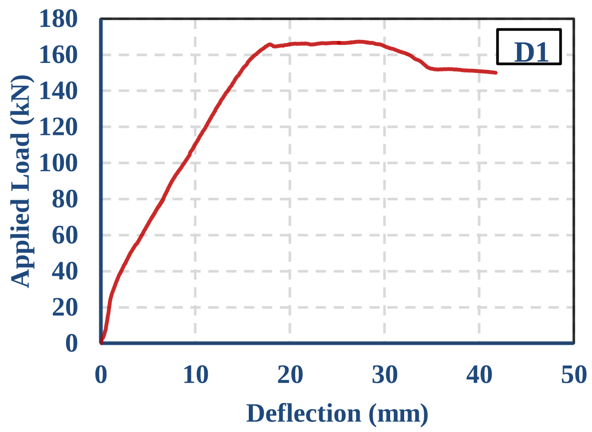

Fig. 5(g): Applied load *vs.* Deflection curve for 1.2% Reinforcement

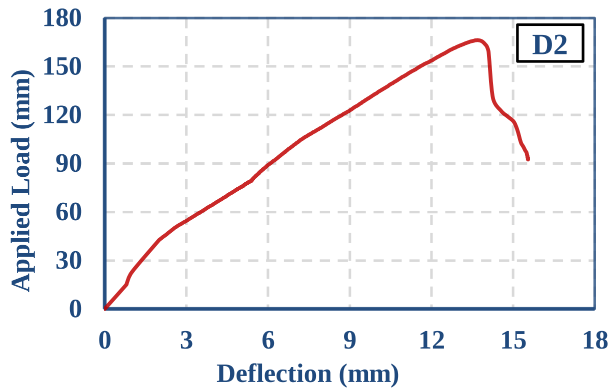

Fig. 5(h): Applied load *vs.* Deflection curve for 1.2% Reinforcement

V. CONCLUSIONS

The following conclusions will be made by basis of results:

1. The cracks developed in the tensile zone of failure section under the both shear and bending.
2. The position of the first crack is primarily affected the concrete tensile strength distribution of tension zone.
3. The location of the first shear crack was effectively reduced the division of both, the failure load and the shape of the failure section.
4. Finally, the principle of aggregate interlock in the compression zone to the shear resistance will be applicable.

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