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STRENGTHENING OF REINFORCED CONCRETE BEAMS CRACKED IN SHEAR

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ABSTRACT

This paper presents an experimental investigation for the ultmiate shear strength of cracked beams stiffened by steel plates in the shear regions. Twelve beams of 150e150e900mm were tested using third-point loading test. Thes beams were reinforced in such a way to insure failure due to shear only, i.e., no shear reinforcement was provided for these beams. One concrete batch was used for casting al beams. The twelve beams were divided into three sets and were tested as follows:

In the first set, beams were loaded to failure to establish their ultimate load capacities. In the second set, beams were stiffend by steel plates attached to their sides by epoxy resin in the shear regions, then they were loaded to failure.

For the third set, beams were loaded to 65 percent of their average ultmiate load capacity obtained in the first set. Then the load was sustained at that level and steel plates were attached to beam sides in the cracked shear regions. After four days, the load was continued to failure. Mid-span deflection was recorded at each load increment using a dial gage reading to 0.01mm. From the test result, the load capacity of the repaired beams was found to be 50 to 60 percent more than the original load capacity obtined in

1. INTRODUCTION

Existing structures usually face many problems after they have been in service for some time. These problems are of many types such as design, construction, enviremental, accidental and misuse of the structure. such problems reduce the structural capacity and can cause shear and bending cracks.

Remedial measures are usually sought to improve the structural capacity of the cracked members. During the past two decades research has been conducted on damaged and weakened reinforced concrete elements repaired by epoxy injection, butstill, there is no theoritical analysis available to estimate the improved capacity of the treated members or at least a percentage increase in the capacity has not been given. Lunoe and Willis[(1)] applied steel strap reinforcement to girders of rigid frames to strengthen their difficiiency in diagonal tension strength. Their method is applicable to members without roof decking where straping can be easily applied. No estimate was given for the diagonal tension strength of the treated girders. Hewlett and Margan[(2)] tested ten beams cracked in tension and shear fo static and repeated loads. The treatment was done by injecting epoxy resin into the cracks. They concluded that if crack widths are too great, the resin repair will not then hold. Conversily, if the cracks are too narrow for proper resin penetration (less than 0.1mm wide), there will be no improvement in beam stiffness. This method of repair does not increase the capacity of the treated beam compared with the original beam. Chung[(2)] conducted tests on reinforced concrete beams to investigate the effectiveness of epoxy injection in repairing the bond between the steel bars and the concrete in reinforced concrete members. He concluded that the bond strength can be restored provided that the adequate penetration of epoxy resin into bar-concrete interface can be achieved. Cusens and Smith[(4)] studied the adhesiveness of joints between a concrete beam and external steel plates. Specimens were tested under simple and sustained static load and in fatigue. They concluded that the shear strength of adhesion to steel was generally at least 13 N/sq.mm. Fatigue performance was found to be satisfactory with million cycles in the stress range

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of 4.5N/sq. mm, also they found a little effect from temperature cycling between-7 Deg. C. and ,35 Deg. C. they concluded that the thickness of the adhesive layer should be more than 1mm to develop full strength.

The objective of this research presented in this paper was to study the perfermance and effectivness of the repaired reinforced concrete beams using steel plates bonded to their sides, along the cracked shear regions, by means of epoxy resin. This method is simple, cost less and can be easily applied to existing members, cracked in shear. Moreover, it improves their ultimate

2. MATERIALS AND BEAM SPECIMENS

The concrete mix propotioning was 1:1.6:3.7 for cement, sand and coarse aggregates, respectively. Coarse aggregates used was from crushed stone and the sand was from local resoureses. Ordinary portland cement was used and was manufactured according to libyan specifications. One concrete batch was used in casting all beams and was provided by a local producer. Quality control cubes were prepared during the casting process and their average 28 day strength was 34 N/sq.mm. The water cement ratio was kept constant at 0.55. Slump of the used concrete was 80mm. Beams were cured with wet purlaps for a period of 28 days. A total of twelve beam were casted, a typical general layout and steel reinforcement are shown in Fig.1.

3. REPAIR PROCEDURE

Epoxy resn was used to attach the plates to the concrete. This epoxy product is called "SIKADUR IMPREGNATION" and its properties are given in the Appendix.

The same procedure of attaching the plates to beam faces was used in sets 2 and 3, where the concrete surface was well cleaned with rough paper to produce rough surface and then the epoxy resin was uniformly spread ١٢١٢ the cleaned surface of the concrete producing a layer of about 1.5mm thick. The steel plates were then attached to the beam faces by using four clamps and left for four days to develop the epoxy required bond strength.

4. TEST PROGRAM

The beams were loaded at third point loading as can be seen from Fig.2 using a universal testing machine. The rate of loading was kept constant during the test. load verses mid-span deflection were recorded for each beam. Mid-span deflection was measured using a dial gage reading to 0.01mm. The twelve beams were divided into three sets for testing and they were tested as follows:

4.1 First Set of Beams

After 100 days of casting the first set of beams (four beams) were tested to failure without any steel plates attached to them. The ultimate load capacity (average of four) was found and it was assumed to represent the failure load for nonrepaired beams.

4.2 Second Set of Beams

In this set four beams were tested to failure having steel plates attached to the shear regions as can be seen from Fig.3. The plates were attached to the beams according to the method described in section 3. The ultimate failure load of this set was recorded as well as load and mid-span deflection readings.

4.3 Third Set of Beams

The last set was loaded to about 65 percent of their ultimate failure load capacity of the first set. Then the beams were treated by attaching steel plates at the shear regions as described before while the load was kept stationary 65 percent of the ultimate capacity After four days the load was contuined to failure. Load and mid-span deflection readings were recorded.

5. TEST RESULTS

5.1 First Set of Beams

All beams of the first set were failed in shear at it was expected. Fig.4 shows a typical failure mechanism of these beams. The failure load (average of four) was 10.05 tons and the corresponding average mid-span deflection was 1.91mm.

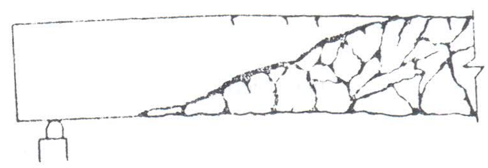


Fig 4. Typical failure mechansim of the first set.

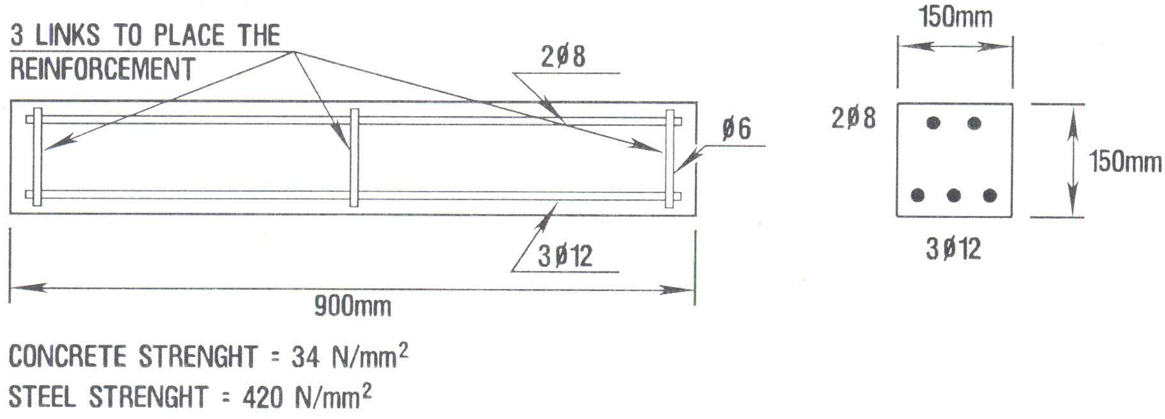


FIG1. DETAILS OF TEST SPECIMEN

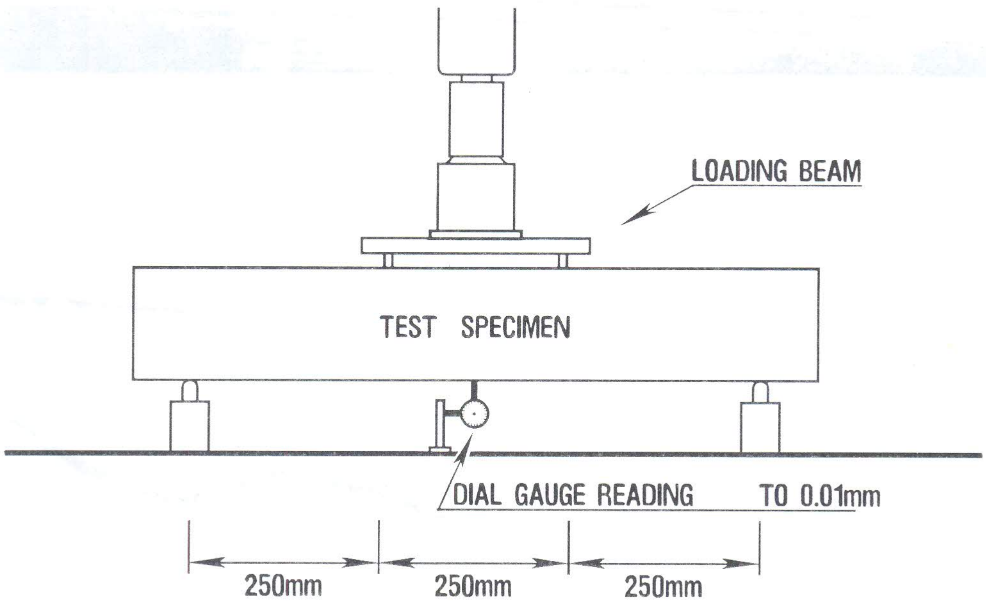


FIG2. SPECIMEN UNDER TEST

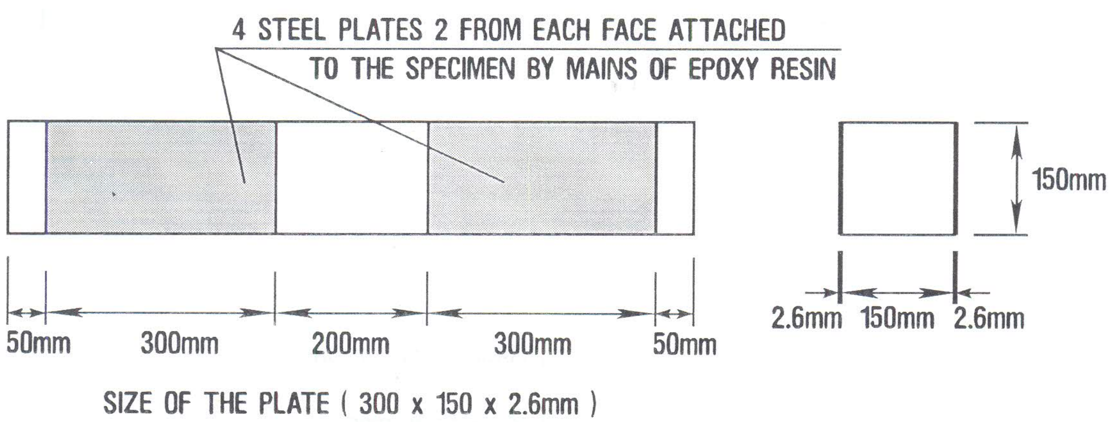
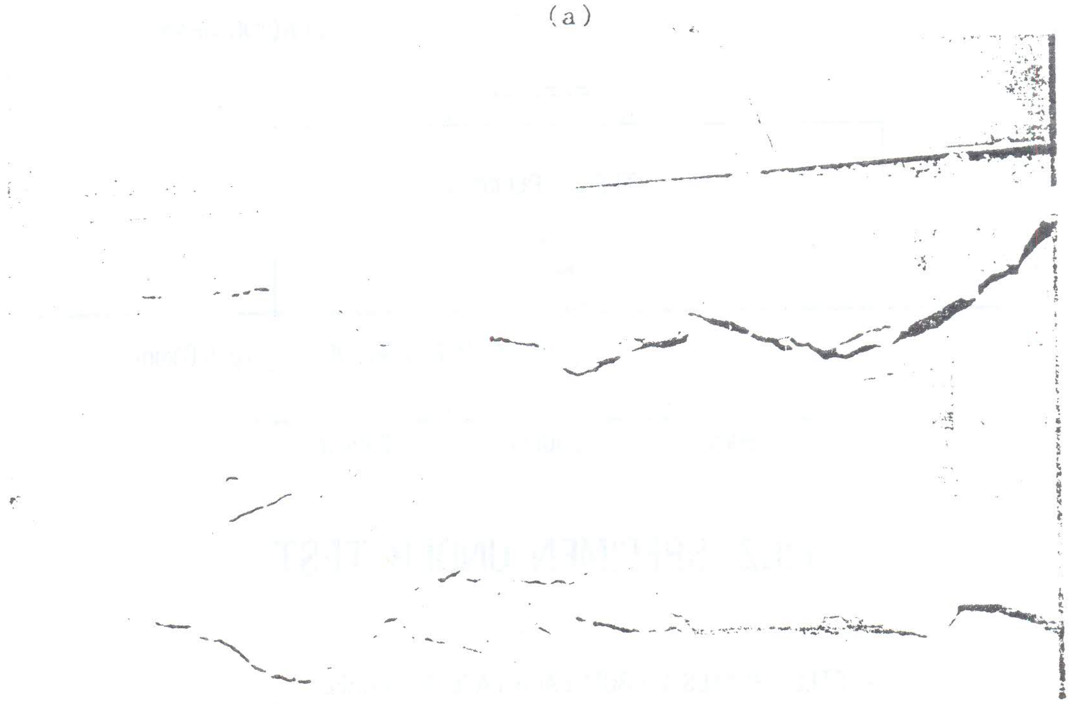


FIG3. LAYOUT OF REPAIRED SPECIMEN

(a)



(b)

Fig. 5: Typical Failure mechansim of the second set.

(a) Bottom view of cracked specimen.

(b) Closer view of the same specimen.

2.5 Second Set of Beams

The failure load (average of four) was recorded to be 16.0 tons and the corresponding average mid-span deflection was 2.28mm. Fig.5 shows the typical configuration of the failure mechanism.

5.3 Third Set of Beams

The failure load was 15.4 tons and the average mid-span deflection was 2.69mm. Fig.6 shows a typical failled beam, and it can be seen that the failure mode of this set is similar to that of the second set.

6. DISCUSSION OF RESULTS

Load-deflection curves for the three sets are given in Fig.7. This figure reveals that when beams are repaired by steel plates (sets 2 and 3), the stiffness of these beams in increased after they were loaded to 65 percent of the ultimate load of the first set. Also, the deflection of the third set was increased due to creep, while the load was sustained at that level.

The test results of the three sets show that, the repaired beams are different from the original beams in a number of ways. A comparsion of results for the three sets indicate that:

6.1 The ultimate load capacity of the repaired beams were on the average of 150 to 160 percent of the original capacity.

6.2 The mode of figure of the original beams diagonal tension whiles in the repaired beams, the diagonal tension was prevented by the steel plates and instead splitting failure was occurred as shown in Fig.5.

6.3 Results of the second and the third sets of beams, indicate that the ultimate load capacity was not significantly affected by the 65 percent loading prior to repair.

7. CONCLUSIONS

The limited test results reported here have led to the following conclusions:

7.1 Ultimate shear capacities of repaired beams were found to be approximately 50 to 60 percent more than the original capacities.

7.2 The repair at loading of 60 percent of the original beam capacity gave approxmatily the same improvement as that at zero loading.

7.3 Steel plates used here to strengthen beams in shear can be applied practically to existing cracked structures.

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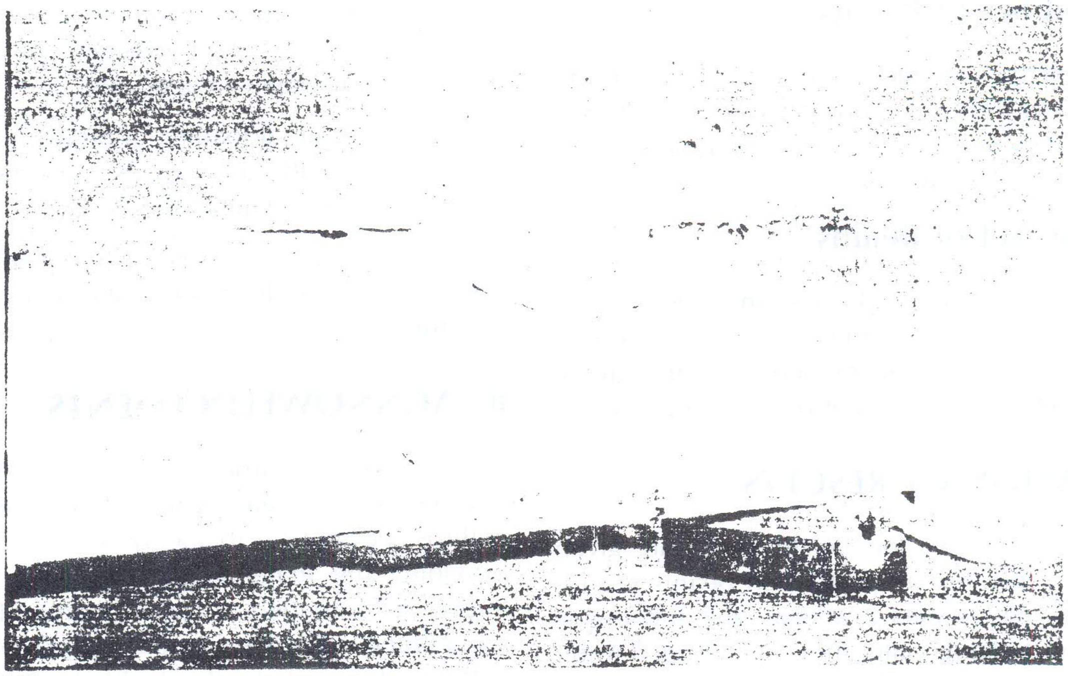

Fig. 6: Typical failure mechansim of the third set (bottom view).

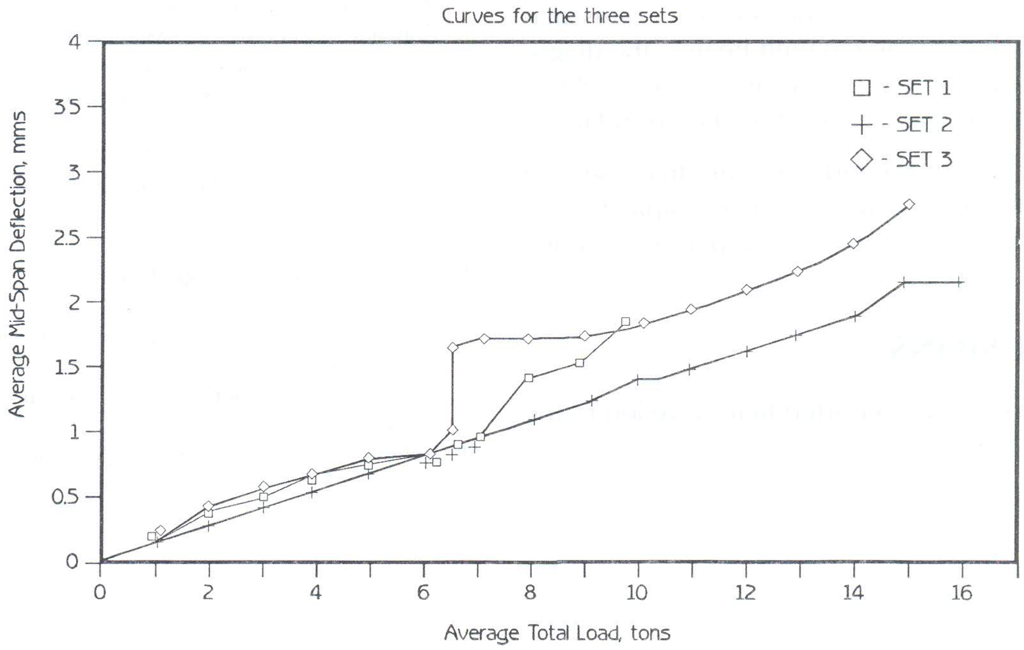

Fig. 7: Average load-Deflection