International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 15 (2017) pp. 4806-4810

Rehabilitation of Distressed Concrete Beams Using External Prestressing – Experimental Study

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Abstract

Concrete structures showing distress due to one or more reasons; require remedial and strengthening measures, if the structure is to satisfy the serviceability and strength requirements. Provision of externally welded reinforcement to tension faces of RC flexural members and prestressing the same is proved to be an effective strengthening technique. This work reports the results of analytical and experimental study carried out on the use of this technique for strengthening and rehabilitation of distressed RC beams. Beams subjected to varying degrees of initial distress are strengthened with various levels of prestressing and tested to destruction. The performance of beams evaluated in terms of first crack load, stiffness characteristics, crack propagation, failure load, ultimate deflection, ductility and failure mode are discussed. The trussed beam exhibits delayed first crack. Stiffness characteristics of the beams are improved. Prestressing of tie rods also exhibits improvement in the load bearing capacity and stiffness characteristics. The load bearing capacity of the rehabilitated beam – the first crack load, service load as well as ultimate load – are increased considerably compared to the parent RC beams.

Keywords: Prestressing; strengthening; rehabilitation; distressed RC beams; Stiffness; ductility;

INTRODUCTION

A. General

Engineering failures are global phenomenon. Many of them could be attributed to human negligence and might have been avoided. Others are caused by vagaries of nature such as storms, floods and earthquakes. It has been observed by numerous research and practical investigations that field concreting is extremely influenced by inadequate and inappropriate compaction and curing.

B. Reasons for frequency and severity of failures

Loss of control by the designer over execution of design. Non traditional 'fast track' approaches in construction with misunderstood communications and unclear lines of responsibility. New materials and methods without the benefit of trial and error experience. Misuse of computers. Expanding litigation – more time is spent on writing contracts rather than engineering.

C. Forensic Engineering

Forensic engineering is a recent development in Civil Engineering and has a vast potential. Lessons learnt and knowledge gained from past failures has contributed substantially to the design, construction, manufacture and operation of engineered facilities and products. The most significant contribution from information transfer has been towards the avoidance of repetitive failures. External prestressing is a prestressing system in which the concrete structural members are prestressed longitudinally using tendons located completely outside the concrete section, today; external prestressing is considered one of the most powerful techniques for strengthening or rehabilitating existing concrete bridge structures. Also, because of the construction speed and economy associated with the use of external tendons, it is becoming popular in the construction of new concrete bridges.

The following are the advantages of an external tendon system.

• More economical construction.

• Easier tendon layout, placement and consolidation of concrete.

• Better corrosion protection as compared to a conventional tendon system.

• Reduction in prestressing force losses.

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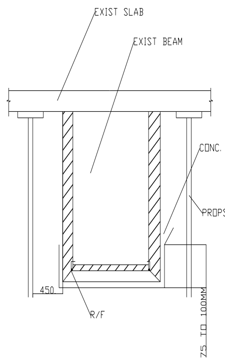

Figure 1: Typical Beam Repair

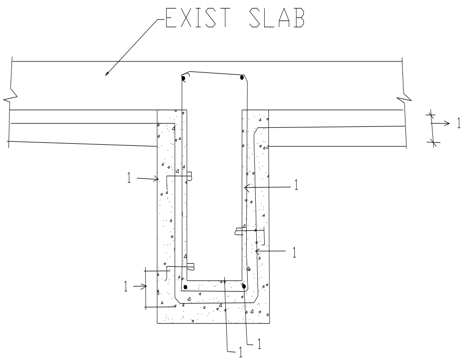

Figure 2: Jacketing/Shotcreting Details For Beams

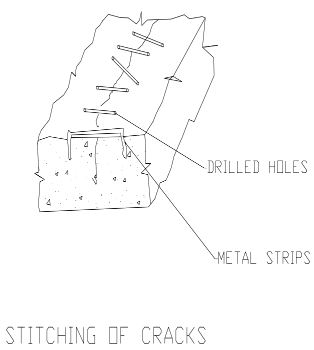

Figure 3: Stitching of Cracks

EXPERIMENTAL PROGRAMME

A. Materials Used:

Ordinary Portland cement concrete of proportions 1:2:4 by weight with w/c ratio 0.5 were used for the casting of beams. Ordinary Portland cement conforming is IS269-1976. Natural river sand passing through IS 2.36 mm sieve and crushed blue granite chips passing through 20 mm and retained on 10 mm IS sieves were used for casting of test beams. The test beams were of cross section 230 mm x 150 mm and an effective span of 2650 mm. All the beams were provided with conventional main tension reinforcement with a clear cover of 25 mm. Each of the beams was deliberately under reinforced with 2 Nos. 8 mm and 1 No. of 10 mm Fe 415 bars in tension. Shear reinforcement in the form of 8 mm two legged stirrups spacing of 150 mm c/c was provided over the entire span. Companion cubes of size 150 x 150 x 150 mm were also cast along with test beams. The beams were cast using steel moulds. Concrete obtained from an electrically operated mixer machine was poured into the mould with the reinforced case aligned in the correct position inside the mould. The concrete was placed into the form work layer by layer and rammed thoroughly and tamped fully and finished at top neatly to have uniform top surface. The wet concrete was covered with fully set gunny bags for 24 hours. After 24 hours, side form work was removed. The specimen was cured with wet gunny bags up to 7 days and the beam was cured for 28 days.

PREPARATION OF SPECIMEN

The specimen surface were coated with while cement based paint and allowed to dry fully. This is done in order to mark the desired loading point support positions and also to have clarity on the crack propagation observation. Beams were tested in a self straining loading frame of 300KN capacity. Two steel columns were erected over a girder placed on rigid footing. The column head were placed with an arrangement on one side as roller and another side as a hinge with two plates and a pin at the centre. The beam was placed on these supports. Loading was done using hydraulic jack. The hydraulic jack was fixed with proving ring with dial gauge capacity 250 KN. Incrementally applied load, two points static loading scheme were employed.

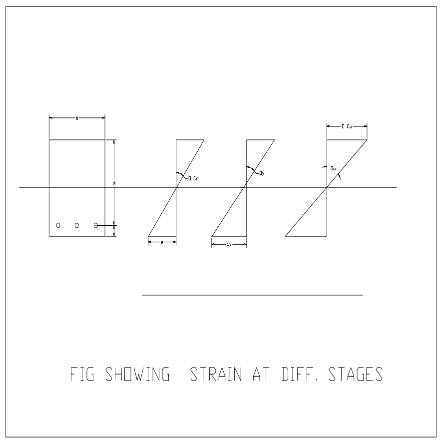

Figure 4: Strain at Different Stages

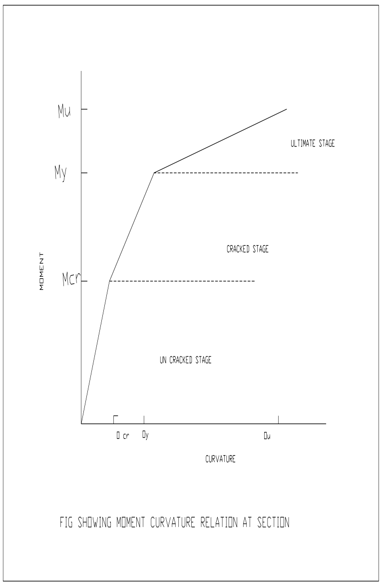

Figure 5: Moment Curvature Relation at Section

TESTING

A. Placing of Specimen

The specimen surface were coated with while cement based paint and allowed to dry fully. This is done in order to mark the desired loading point support positions and also to have clarity on the crack propagation observation. Beams were tested in a self straining loading frame of 300KN capacity. Two steel columns were erected over a girder placed on rigid footing. The column head were placed with an arrangement on one side as roller and another side as a hinge with two plates and a pin at the centre. The beam was placed on these supports. Loading was done using hydraulic jack. The hydraulic jack was fixed with proving ring with dial gauge capacity 250 KN. Incrementally applied load, two points static loading scheme was employed.

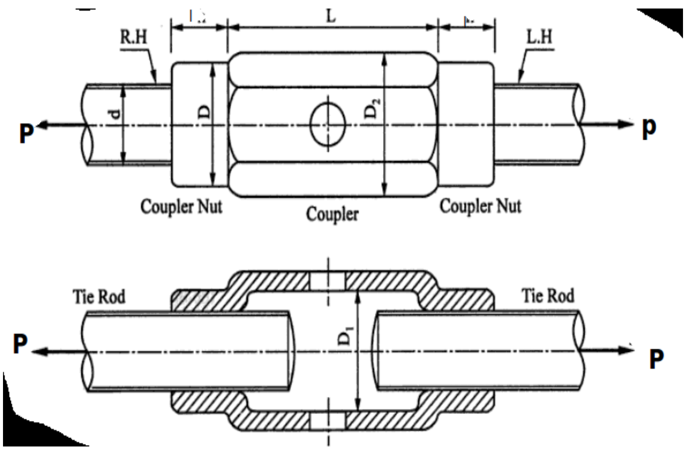

Figure 6: Screw Threads

The pressure was applied manually through jack, the increment of loading was kept as 5 division of dial gauge in the proving ring. At every increment of load, the deflection readings were taken at supports under the load point and the mid span. The number and type of cracks were observed and recorded. All the measurements were taken regularly through the entire load increment, until the failure of test beams.

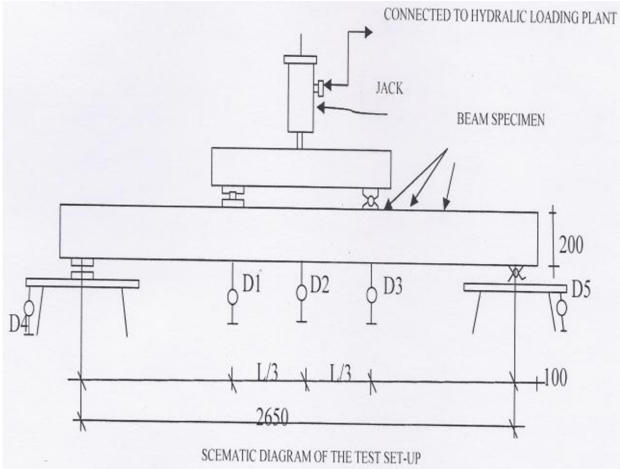

Figure 7: Schematic Diagram of the Test Set-Up

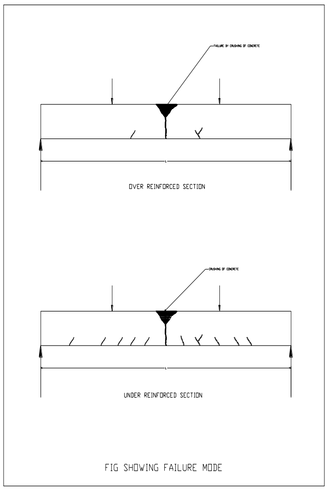

Figure 8: Failure Mode

B. Compressive strength of Cubes

The specimens were tested for compressive strength on compression testing machine provided with two steel bearing platens with hardened faces. The specimen cube is placed in the machine that the load is applied to the opposite sides of the cubes as cast. The load is applied without shock and increased at a rate of approximately 140 kg / cm / min until the resistance of the specimen to the increasing load breakdown and no greater load can be sustained.

Table 1: ULTIMATE LOAD CARRYING CAPACITY OF BEAM

Load Divisions	Left Support	Center Support	Right Support	Remarks
0	1332	475	1690	Appearance of First crack
5	1331	582	1696	
10	1331	790	1706	
15	1331	1178	1706	
20	1328	1597	1707	
25	1335	2256	1707	
27	1336	2956	1711	
Reset	1336	160	1711	
30	1338	734	1712	
31	1338	1369	1712	

Table: 2 Design dimensions of screw threads, bolts and nuts according to IS: 4218 (Part IV) 1978

Designation	Pitch	Major or nominal diameter d = D	Effective or Pitch diameter (dp) mm	Minor or core diameter		Depth of thread (bolt) mm	Stress area mm^2
				Bolt	Nut		
M 1	0.25	1.000	0.838	0.693	0.729	0.153	0.460
M 1.2	0.25	1.200	1.038	0.893	0.929	0.158	0.732
M 1.4	0.3	1.400	1.205	1.032	1.075	0.184	0.983
M 1.6	0.35	1.600	1.373	1.171	1.221	0.215	1.27
M 1.8	0.35	1.800	1.573	1.371	1.421	0.215	1.70
M 2	0.4	2.000	1.740	1.509	1.567	0.245	2.07
M 2.2	0.45	2.200	1.908	1.648	1.713	0.276	2.48
M 2.5	0.45	2.500	2.208	1.948	2.013	0.276	3.39
M 3	0.5	3.000	2.675	2.387	2.459	0.307	5.03
M 3.5	0.6	3.500	3.110	2.764	2.850	0.368	6.78
M 4	0.7	4.000	3.545	3.141	3.242	0.429	8.78
M 4.5	0.75	4.500	4.013	3.580	3.688	0.460	11.3
M 5	0.8	5.000	4.480	4.019	4.134	0.491	14.2
M 6	1	6.000	5.350	4.773	4.918	0.613	20.1
M 7	1	7.000	6.350	5.773	5.918	0.613	28.9
M 8	1.25	8.000	7.188	6.466	6.647	0.767	36.6
M 10	1.5	10.000	9.026	8.160	8.876	0.920	58.3
M 12	1.75	12.000	10.863	9.858	10.106	1.074	84
M 14	2	14.000	12.701	11.546	11.835	1.227	115
M 16	2	16.000	14.701	13.546	13.835	1.227	157
M 18	2.5	18.000	16.376	14.933	15.294	1.534	192
M 20	2.5	20.000	18.376	16.933	17.294	1.534	245

CONCLUSION

In this paper, it is investigated experimentally the use of external prestressing tendon as strengthening or upgrading concrete flexural members. The nominal flexural strengths of the beams were increased up to 20- percentage and the induced deflections were reduced to 39 percent as a result of external prestressing. It can be used very effectively to control the crack and to reestablish the service load deflections of concrete flexural members subjected to service loading conditions. External prestressing reduces the crack widths or closes the cracks completely and leads to stiffer service load deflection response and reduce the deflections of live load.

The use of an external tendon system to strengthen the existing concrete beams is conceptually different from that used in the traditional design and casting of beams, in the design of new concrete beam, external tendons constitute the primary reinforcement. Hence the analysis and design could be achieved using methods similar to unbonded post-tensioned construction.

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