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Behaviour of Rc Structural Elements With Laced Reinforcement

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ABSTRACT:

Reinforced concrete due to its special properties like high compressive strength, fire resistant, durability etc., is considered as most widely accepted construction material in construction industry, but by placing reinforcement in some conventional forms, the properties of reinforced concrete elements showing significant poor results compared to some other alternative techniques of placing reinforcement. By using same percentage of steel and by altering pattern or position of reinforcement, the behaviour of reinforced concrete elements differ which will give significant upper bound results. Among the alternative techniques, Laced Reinforced Concrete (LRC) is most adaptable method of placing reinforcement and can be implemented in the structural RC elements like slabs, beams and floors. By introducing these inclined laced bars the concrete confinement area increases and this maintains structural integrity. By providing these inclined bars perpendicular to the direction of propagation of crack, formation of cracks are arrested. RC element incorporated with LRC can resist impact loads, earthquake loads and blast loads. This dissertation work deals with two types of structural elements and describes the behaviour of parameters like ultimate load carrying capacity, deflections, and crack width by adopting the RC elements with LRC. In first series the investigations conducted on four beam elements of 1.5m length, 0.15m x 0.3m cross section area.. The deflections and crack width are taken at each and every step load by using dial gauge having least count of 0.01mm and hand hold microscope having least count of 0.02mm. The test results are tabulated and the graphs are drawn between load vs. deflection and moment vs. crack width and are compared with their companion specimens. The aim, by adopting LRC had fulfilled by attaining

improved ductility, high member strength, reduced crack width and deflection.

INTRODUCTION Blast loads due to terrorist attacks and chemical and nuclear outbreaks are very often taking place all over the world causing the structures to collapse. For the structures imperiled to suddenly applied loads and imposed loads structural integrity and ductility are fundamentally required. By implementing the LRC to the structural elements, ductility and structural integrity and better concrete confinement of the element enriches. Design of blast resistant structures with conventional methods are highly uneconomical, therefore to produce cost effective solution by considering safe and serviceability taking into account to resist blast and impact loads achieved, by adopting LRC. In Reinforced concrete beams with conventional stirrups, shear span to depth ratio is less than 2.5, ductile failure is not promising due to the effect of diagonal cracking, this can be achieved by implementing the Laced reinforcement, and apart from this it also increases the ductility, tensile strength and ultimate strength of concrete. Spall of concrete takes place of any element with conventional concrete at failure load, but greater confinement of concrete can be obtained with laced reinforcement which maintains high structural integrity so the spall of concrete is restricted and the specimen will fails at the ultimate load with small cracks.

Laced reinforcement as a Lattice girders reinforcement are three dimensional metallic structures consist of an upper chord, two lower chords and one continuous diagonal bars which are tied to the chords at a specified nodes or specified angles. Laced reinforcement as a lattice girder reinforcement gives additional structural integrity by its truss action so that members can with stand higher ultimate loads without spall of concrete at failure. In precast industries this lattice girder reinforcement widely used in amalgamation with Hybrid concrete construction (HCC), which is insitu and precast concrete combination to obtain the benefits from these two method constructions. In precast industry the lattice girder reinforced slabs are casted in two stages, in first stage nearly 50-60mm thick concrete is casted in industry (casting yard) and the remaining thickness of slabs are casted after erecting at the site of construction. The projections from the lattice girder slab provides additional stiffness while erecting and also maintains composite action between first and subsequent concrete layers.

2.LITERATURE REVIEW:

Anandavalli et al., has performed experimental studies on "Behaviour of a blast loaded laced reinforced concrete structure". From these studies, the authors concluded that, when the structures that are designed for reverse loads such as blast and earthquake loads LRC is economical, in comparison with R.C.C. At a deflection corresponding to 2^0 support rotation the concrete in compression crushes. The structural elements without shear reinforcement loses its structural integrity at 2^0 support rotation due to lack of confinement of concrete. The structural members with conventional two legged closed stirrups loses its structural integrity at 4^0 support rotation and the structural members arranged with laced reinforcement due to its truss action, the reinforcement in the members will resist up to 12^0 until tension failure of reinforcement take place. Here the authors have conducted tests with lacing angles between 45^0 to 60^0. In this study two storage tanks were constructed, first tank is donor and the second one is acceptor tank which is laced reinforced structure. In donor tank explosives are placed and the separation distance between two tanks are reduced with the aim that explosions caused in the donor structure would not damage the acceptor structure. The test is monitored by placing pellets on beams and roof of the acceptor tank for measuring strains and deflections. From the experimental investigations the cracks pattern of the acceptor slab followed the expected yield line pattern. From the experimental results the deflections for roof slabs are less and the acceptor structure is serviceable after explosion. The reduction in existing provision of separation distance from $2.4W^{1/3}$ to $0.7W^{1/3}$.

Srinivasa Rao et al., conducted the experimental investigations on "seismic behavior of laced reinforced concrete beams". This paper mainly focuses on the ductile property of laced reinforced concrete (LRC). The lacing reinforcement is placed in plane of principal bending and these bars are kept in position with the help of transverse bars. When the shear span to the depth ratio is less than 2.5, ductile failure of the beam will not happen with the use of conventional stirrup reinforcement. By altering pattern of shear reinforcement with inclined bars improved ductility can be achieved. After conducting tests on 20 LRC specimens, keeping flexural reinforcement same and changing different forms of shear reinforcement like inclined welded, inclined tied, single leg lacing and rectangular lacing with normal and fiber reinforced concrete, under static and cyclic loading conditions it was concluded that inclined lacing with or without fiber reinforcement given better results compared to remaining specimens. By providing laced reinforcement ductile failure achieved when the specimens are subjected to cyclic loading. As there is no unified procedure for finding ductility, here ductility evaluation is done as per park and sheik et al which suggests that 75% of peak lateral load gives the yield deformation and ultimate deformation corresponding to 85% of peak lateral load. Conventional reinforcement in combination with laced shear reinforcement gives additional confinement at plastic hinge locations. As the cost of fabrication increase by using laced reinforcement it can be reduced by adopting tack welding to the lacing.

Stanleyc. Woodson et al led the experimental study on “Stirrup Requirements for Blast – Resistance Slabs”. The study aimed to evaluate effective placing or varying parameters has significant effect on strength and deformation characteristics on one way slabs. Here by considering three varieties of stirrup configurations, ten one way slab elements were investigated to find the shear capacity by inducing uniform pressure. The study focuses on three parameters like configuration of stirrups, stirrup spacing and stirrups interactions. Here the stirrup configuration are varied with U- shaped, double leg and single leg stirrups provided with hook angle of 135^0. After obtaining the results, the authors conclude that closed stirrups provided to the specimen has shown more deflections. Here the author finally concludes that, closely spacing of single legged stirrups is suitable method to resist against blast loads and it is cost effective solution than laced reinforcement. Here dobbs and dede state that members arranged with laced reinforcement due to its truss action, the reinforcement in the members will resist up to 12^0 until tension failure of reinforcement take place.

3. PROCEDURE OF TESTING SPECIMENS

In this methodology, the equipment used was loading frame provided with hydraulic jack which transfers the static imposed loads to the specimen.

1. The marking are prepared on the test specimens at a distance of 100mm from both faces, for locating the seating position on the supports.

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2. The markings are also made for location of point of application of load and point of placement of dial gauge for recording deflections.

3. Then the specimen is placed on the supports, so that markings made on the specimen should coincide with supports. In this dissertation work the supports considered are simply supports made with heavy steel girders.

4. After making all the adjustments, the machine is started and required settings are made in the input window. The loading frame used in this dissertation work had a capacity of 100T but here it is set to 50T.

5. Then the soleden of the hydraulic jack is moved downward until a gap of 4-5mm is maintained between soleden and specimen and in the input window set the step load for 10kN.

6. After load transfer started deflections and maximum the crack width are noted at every subsequent step load.

7. After recording the deflections and the crack width at previous step load, we continue for next step load.

8. When the specimen had failed due to the applied load it has reached its ultimate load, then the load is released.

9. Then the failure pattern is observed and it is photographed.

10. The input window is shown in below figure. It consists of

a) Sample no.

b) Maximum load in Tons.

c) Step load in Tons

d) Raising ramp in seconds

e) Step load holding time in seconds.

f) Current load in Tons.

g) Current step

h) Total steps

Step by step Procedure of loading frame operation:

1. First switch on the mains.

2. Secondly, switch on the motor.

3. On the input window set the sample no, maximum load, step load, raising ramp in seconds, step load holding time in seconds.

4. The movement of soleden is done by changing the mode to manual mode, then the soleden of the hydraulic jack is moved downward until a gap of 4-5mm is maintained between soleden and specimen.

5. After the sole den reaches the required distance the solden should be kept in neutral mode

6. Before starting system the mode is changed from manual to auto. Then system have to be started.

7. An icon will blink after completing every step load on the input screen, which specifies us, to continue for next step load.

8. By clicking on the 'yes' the next step load will be applied on the specimen.

9. If the specimen had failed due to the applied load it has reached to its ultimate load and no more load transferring takes place.

10. After specimen had failed, the system should be stopped.

11. The mode is changed from auto to manual and the solden is raised upward so that load is released and keep the solden in neutral.

12. Then stop the motor

COMPARISION AND DISCUSSION OF TEST RESULTS

The results obtained from the tests are tabulated at every step load and presented in chapter 4. In first series the comparison of test results between the specimens adopted with two legged vertical shear reinforcement and laced reinforced reinforcement of 4mm and 6mm diameter. In the second series comparison made between conventional bottom mesh reinforcement (S1) and laced reinforcement as lattice girder reinforcement with full (S2) and two stage(S3) casted slabs.

Table 5.1 Principal test results of beams

Name of Specimen	Design load(kN)	Ultimate load(kN)	Deflection(mm) at		Crack width(mm) at	
			Design load	Ultimate load	Design load	Ultimat e load
B1	100	110	3.99	4.55	0.36	0.4
B2	100	170	2.59	5.70	0.22	0.80
B3	100	160	2.95	6.10	0.20	1.24

B4	100	200	2.19	6.10	0.06	1.12

Table 5.2 Principal test results of slabs

Name of Specimen	Design load (kN)	Ultimate load (kN)	Deflection(mm) at		Crack width(mm) at	
			Design load	Ultimate load	Design load	Ultimate load
S1	75	140	4.075	19.4	----	3.4
S2	75	160	1.79	14	----	3.2
S3	75	150	1.755	14.8	----	2.9

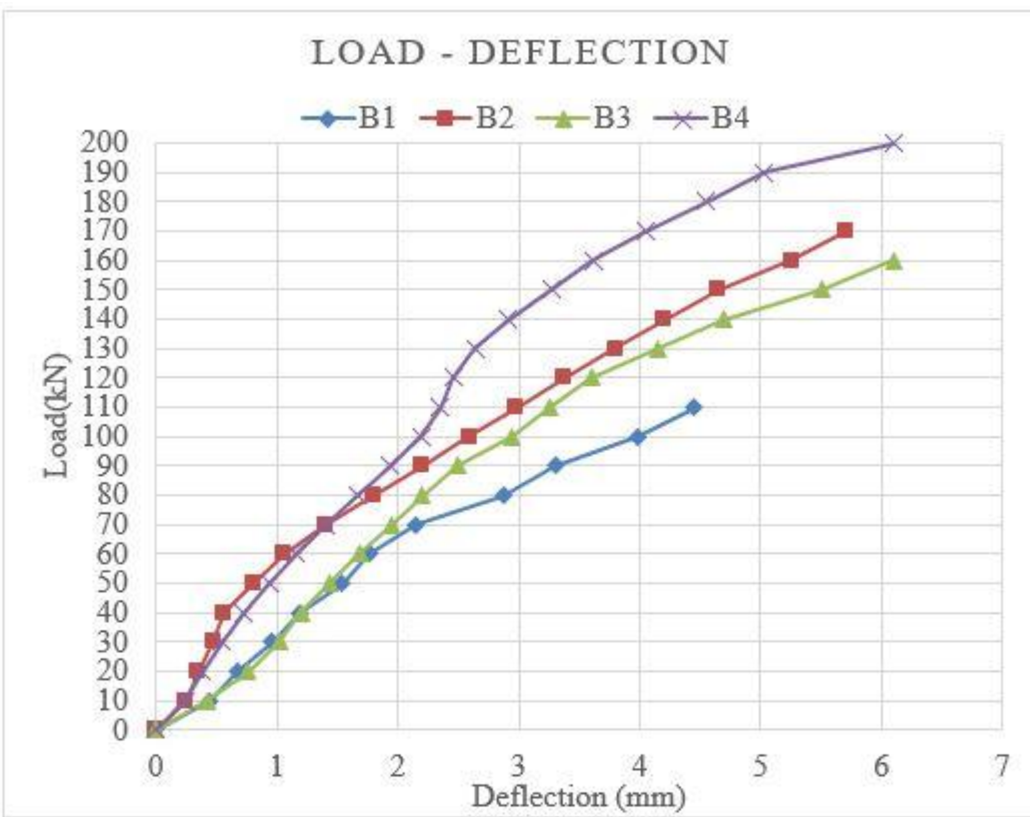

Fig. 5.1 Load - deflection graph for B1, B2, & B4

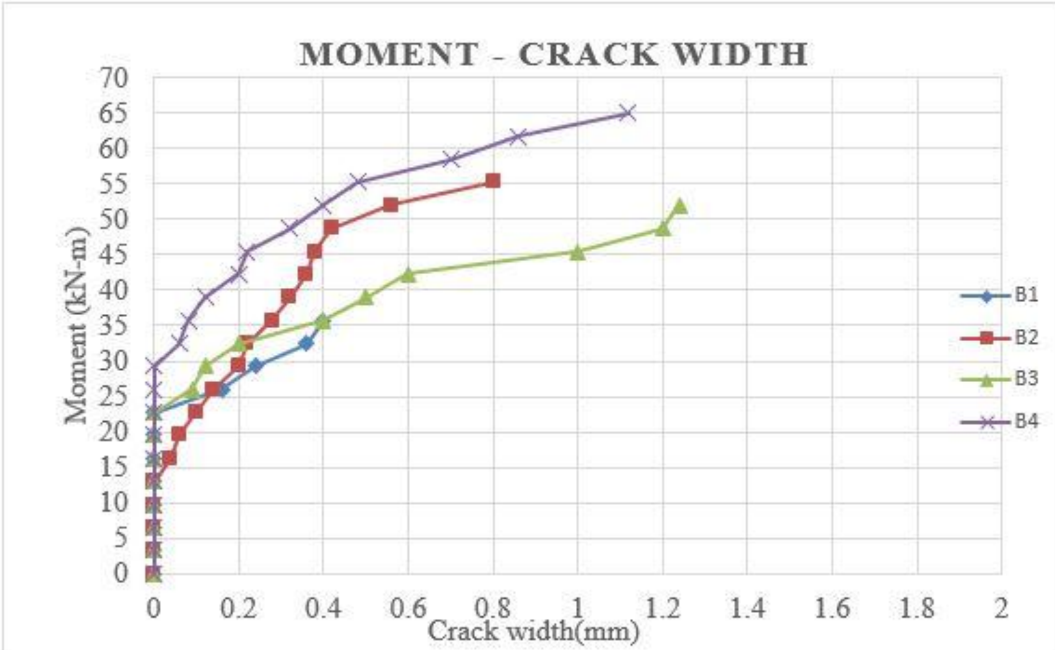

Fig. 5.2 Moment - Crack Width for B1, B2, & B4

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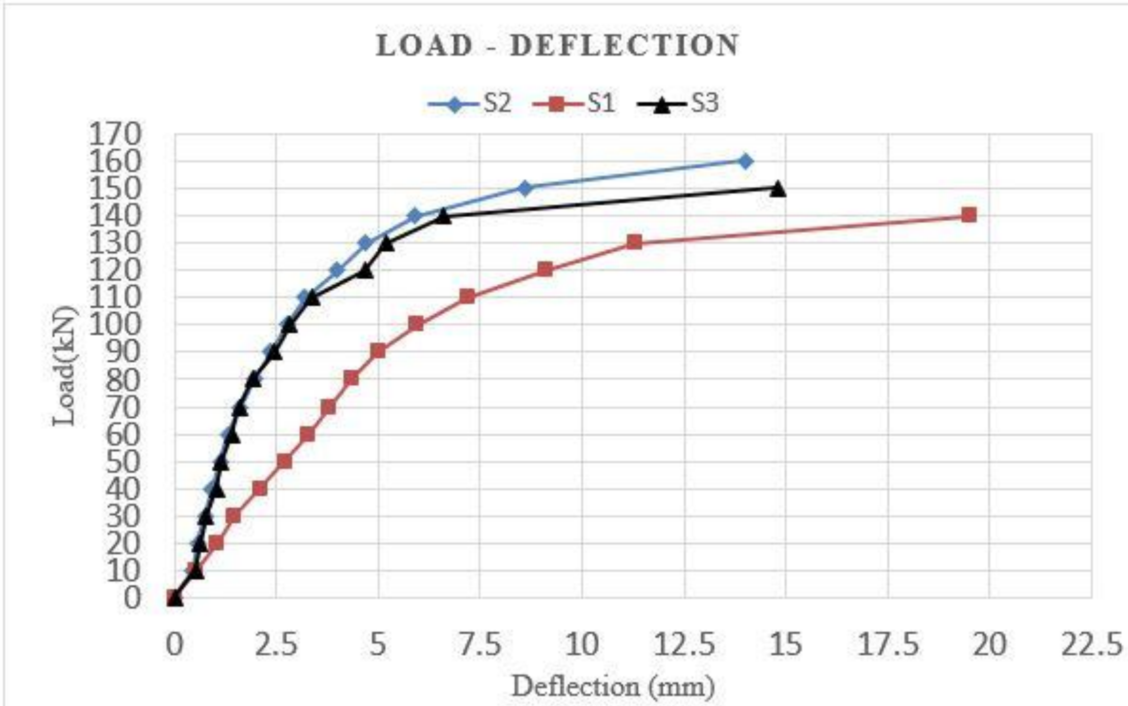

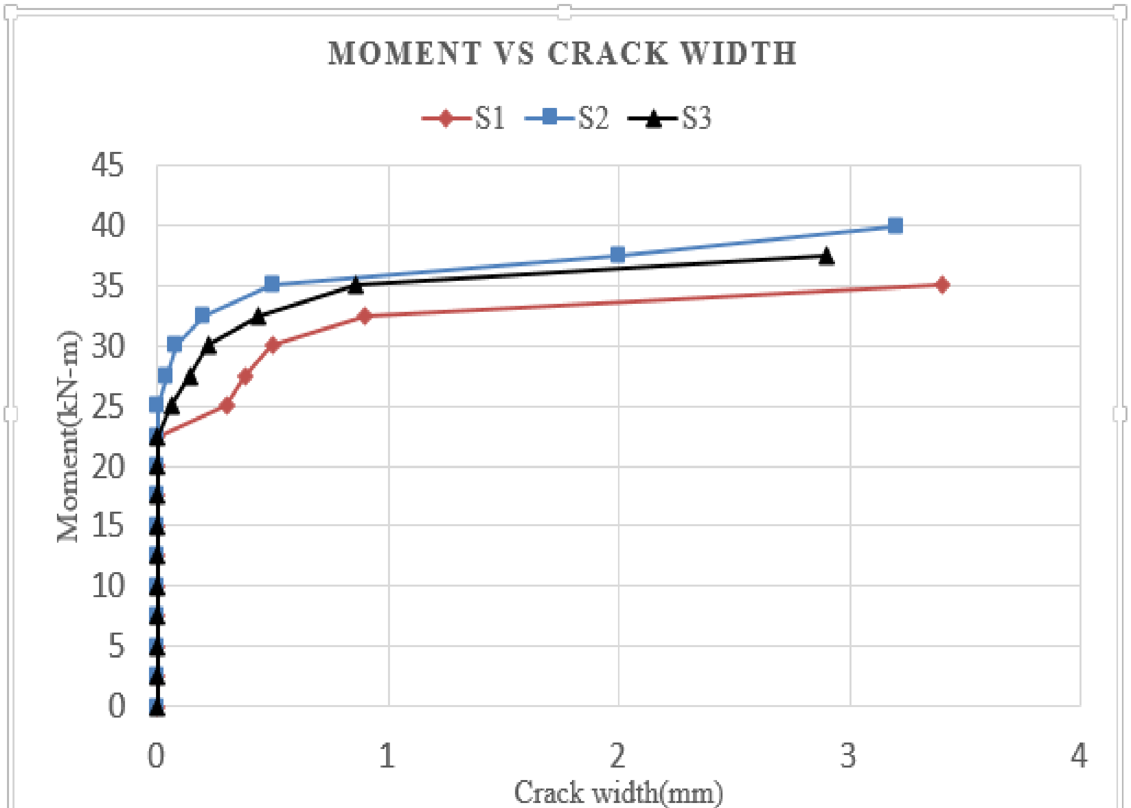

Fig. 5.3 Load – Deflection and Moment – Crack width of S1, S2 & S3

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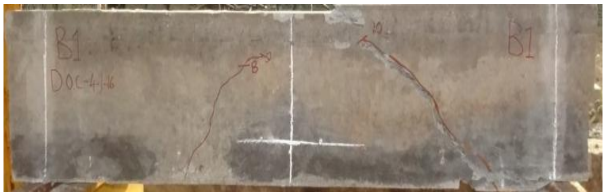

Fig. 5.4 Modes of cracks for B1 at failure

Fig. 5.5 Modes of cracks for B2 at failure

Fig. 5.6 Modes of cracks for B3 at failure

Fig. 5.7 Modes of cracks for B4 at failure

Fig. 5.8 Modes of cracks for S1 at failure

Fig. 5.9 Modes of cracks for S2 at failure

Fig. 5.10 Modes of cracks for S3 at failure

From all the comparison tables, graphs and failure patterns, the specimens:

Beam Specimen B1: For specimen B1, the deflections at design load (100kN) and ultimate load (110kN) is 3.99mm and 4.55mm and crack width at design load and ultimate load are 0.36mm and 0.4mm. In this the specimen the first crack observed at 80kN with increment of loads shear cracks are formed, and these cracks are propagated to full depth and failed in shear.

Beam Specimen B2: For specimen B1, the deflections at design load (100kN) and ultimate load (170kN) is 2.59mm and 5.7mm and crack width at design load and ultimate load are 0.22mm and 0.8mm. In this the specimen, the first crack is flexural crack observed at 50kN with increment of loads shear cracks are also formed, and these cracks are propagated to full depth and failed in flexure with partial shear.

Specimen B3: The specimen B3 is provided with laced reinforcement of 4mm in the replacement of conventional reinforcement it has failed at an ultimate load of 160kN. In this the first crack formed at 80kN. The deflections at design load (100kN) and ultimate load (160kN) is 2.95mm and 6.10mm and crack width at design load and ultimate load are 0.2mm and 1.24mm. The beam B3 has shown nearly similar results compared to B2, though the percentage of shear reinforcement was 58% of B2 only.

Specimen B4: The specimen B4 is provided with laced reinforcement of 6mm in the replacement of conventional reinforcement it has failed at an ultimate load of 200kN. In this the first crack formed at 100kN. The deflections at design load (100kN) and ultimate load (160kN) is 2.19mm and 6.10mm and crack width at design load and ultimate load are 0.06mm and 1.12mm. The beam B4 has shown greater results compared to B2, and the percentage of shear reinforcement was same for B2 and B4. The type of failure is shear failure. Due to more concrete confinement and truss action the member attains more structural integrity and reached greater ultimate loads.

Specimen S1: For specimen S1, the deflections at design load (75kN) and ultimate load (140kN) are 4.075mm and 19.5mm. At design load there is no crack formed and at ultimate load a crack of 3.4mm is obseved. In this the specimen the first crack observed at 100kN. It has shown limited ductility when compared to the S2 and S3. Initially flexural cracks appeared but it had failed in punching shear.

Specimen S2: The full casted slab with lattice girder reinforcement the deflections at design load (75kN) and ultimate load (160kN) are 1.79mm and 14mm. At design load there is no crack formed and at ultimate load a crack of 3.4mm is observed. In this the specimen the first crack observed at 110kN. It has shown high load carrying capacity and achieved higher ductility when compared to the S2 and S3. Initially flexural cracks appeared but it had failed in punching shear.

Specimen S3: The two stage casted slab with lattice girder reinforcement the deflections at design load (75kN) and ultimate load (150kN) are 1.755mm and 14.8mm. At design load there is no crack formed and at ultimate load a crack of 2.9mm is observed. In this the specimen the first crack observed at 100kN. It has shown high load carrying capacity and achieved higher ductility when compared to the S2 and S3. Initially flexural cracks appeared but it had failed in punching shear. It has achieved high ductility when compared to the S1. The behavior of stage wise casted slab is merely coinciding with the behavior of full casted slab. Initially flexural cracks appeared but it had failed in punching shear.

COMPARISION OF RESULTS FOR BEAMS:

B1 has been provided without conventional shear reinforcement. It has been failed at 110kN if the same beam is provided with conventional shear reinforcement it has reached its ultimate load at 170kN shows the importance of the shear reinforcement in beams. Here we are choosing another pattern of shear reinforcement which is provided in the replacement of conventional shear and it is provided in the longitudinal direction connecting to top and bottom main bars and is inclined 50 degrees throughout the length of the beam. The same laced reinforced pattern is used for B3 & B4 with 4 mm and 6mm diameter respectively.

By using this kind of laced reinforcement B3 has failed at 160kN which is 10kN less by conventional shear but here amount of shear steel is used was 58% of B2.

While B4 has reached its ultimate load at 200kN which was 30kN more than B2 at same time the amount of steel used was only 3% more than B2.by altering the pattern of shear reinforcement the load carrying capacity was increased to 17.5% of B2.

DEFLECTION:

For B1 at design load the deflection was 3.99, by using conventional shear reinforcement in B2 it has deflection at design load was 2.59 and for B3 it was 2.95 which has 13.9% more deflection

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than B2 and for B4 the deflection was 2.19 which is 15.5% less than B2, at failure load B2 the deflection was 5.7 mm at that load B4 has deflection of 4.05 mm which is 30% less compared to B2.

CRACK WIDTH:

For B1 without shear reinforcement the first crack width started at 80kN at that load B2 has a crack width of 0.14 mm, for B3 it has 0.09 and for B4 there is no crack formed at that load. At design load the crack width for B1 was 0.36, for B2 0.22, for B3 0.2 which is 10% less by B2 and for B4 it is 0.06 which is a first crack and it is 72% less by B2.

Discussion of test results for slabs specimens:

✓
he ultimate load carrying capacity of S2, S3 had been increased to 15% and 7.5% when compared to S1 respectively.

✓
t design load, the deflection of S2 , S3 was reduced by 56% and 57% of S1 respectively

✓
t ultimate load of S1, the deflection of S1 is 19.4 at that load the deflection of S2 and S3 is 5.92 and 6.8 which is 69.7% 65.12 less by S1

✓
t ultimate load S1, the crack width for S1 was 3.4mm at that load crack width for S2 and S3 was 0.5mm and 0.86 which is which is 85.3% and 74.7 % less by S1.

✓
t each load increment, deflections of S2 and S3 has nearly 0.4 to 0.7 times of S1.

✓
t each load increment, crack widths of S2 and S3 has nearly 0.1 to 0.4 times of S1.

CONCLUSIONS

1. The specimens with laced reinforced beams have failed at greater ultimate load which is 10 to 20% more than their companion specimens.

2. In case of lattice girder slabs ultimate load carrying capacity is 10 to 15% more to their companion specimens

3. At design load and ultimate loads, the deflections of laced reinforced beams reduced T by 10 to 15% and 30% to their companion specimens respectively.

4. At A design load and ultimate loads, the deflections of lattice girder reinforced slabs are reduced by 55 to 60% and 65 to 70% to A their companion specimens respectively.

5. At design load and ultimate loads, the crack widths of laced reinforced beams reduced A by 36% and 72% to their companion specimens respectively.

6. At ultimate loads, the crack widths of lattice girder reinforced slabs are reduced by 75 to 80% to their companion specimens.

7. The specimens of both series with laced reinforcements showed more ductility than the companion specimens.

8. The members achieved greater structural integrity and spall of concrete restricted due to truss action with the provision of laced reinforcement

9. Laced reinforcement due to its truss action which gives more structural integrity, so that the member can withstand higher ultimate loads without spall of concrete at failure.

10. From the experimental investigation laced reinforcement with lacing angle of 50^0 for beams and slab specimens with respect to principal reinforcement achieved the improved ductility, lesser deflections and Control in crack width than their companion specimens, so these are preferable lacing angles to RC elements.

11. Lattice girder reinforcement with 2 stage casting gives a closer test results when compared to full casted lattice girder slabs.

12. From load vs. deflections and Moment vs. crack widths graphs shows close resemblance between full casted and casted in two stages slab elements, by this we can conclude that lattice girder reinforcement can be used in precast industry in order to maximize the benefits of both precast and cast insitu methods.

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