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Experimental study of concrete beams using the prefabricated cage system

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ABSTRACT

A new steel reinforcement that can be used instead of reinforcing concrete members is introduced. The proposed reinforcement is called the Prefabricated Cage System (PCS) is an alternative to the rebar cage used in traditional reinforced concrete for faster, easier, and more reliable construction. Prefabricated Cage System is fabricated by perforating hollow steel tubes or steel plates. The resulting Prefabricated Cage System acts as transverse and longitudinal reinforcing steel, working compositely with the surrounding concrete to resist the applied loads. The economic benefits gained from using Prefabricated Cage System reinforcement are studied. The cost and time savings earned in structures with Prefabricated Cage System reinforced columns have been analyzed. The cost and time savings have been evaluated in a case study considering various interest rates and structural lifetimes.

In this study, the various designs for the openings and the minimum percentage of steel used for the Prefabricated Cage Member for attaining the various Mechanical strength are to be found out.

Keywords: *Prefabricated Cage System (PCS)1, Prefabricated Beams2, Conventional Beams3.*

1. INTRODUCTION

Reinforced concrete has been a widely used and highly valuable building material over the last several decades as new designs and applications arise. It combines the tensile or bendable strength of metal and the compression strength of concrete to withstand heavy loads. This material, however, has noticeable limits when placed in areas that experience earthquake activity. The beam is a structural member which is acted upon by a system of external loads at right angles to the axis. Prefabricated cage system (PCS) is a new non-conventional steel reinforcement system that can be used in reinforced concrete beams. Prefabricated cage system is expected to perform as an integral system performing the function of reinforcement. The system is supposed to be a superior alternative to existing conventional reinforcement system in RCC beams.

A new system for reinforcing concrete members named prefabricated cage system has been developed. The prefabricated cage system is claimed to be stronger, safer, more ductile, simpler in construction, and more efficient as compared to the existing reinforcing systems such as regular rebar reinforced concrete and composite sections. Prefabricated cage system is a monolithic prefabricated reinforcement which will be able to more efficiently perform the role of both longitudinal and lateral reinforcements in the member.

Prefabricated Cage System is fabricated by perforating hollow steel tubes or steel plates. The openings can be provided on steel plates or tubes either by punching or cutting. PCS reinforcement is prefabricated off-site and then placed inside the formwork eliminating the time consuming and costly labor associated with cutting, bending, and tying steel bars in traditional rebar construction.

1.1 Reinforcement Systems

There is a variety of reinforcement methods currently used in the field, with rebar cages being the most commonly utilized method. Other methods include welded wire fabric (WWF) and concrete-filled tubes (CFT). Recently an alternative method, known as prefabricated cage system (PCS) reinforcement.

1.2 Prefabricated Cage System (PCS)

To improve structural performance and reduce total construction time, a new reinforcement system, termed prefabricated cage system (PCS) was invented to perform the functions of both longitudinal. and transverse reinforcement in reinforced concrete members in PCS, longitudinal and lateral reinforcement is connected monolithically and made from one solid steel plate and rolling it into a cylinder with a continuous weld along the edge.

Fig-1 Prefabricated cage and sectional view of the prefabricated cage system

2. PRODUCTION

Rebar cages consist of individual reinforcing bars and transverse ties. The bars come to Pre-bent to the site specifications, but are not preassembled in any way. The cages are assembled on-site by attaching the transverse hoops or spirals to the longitudinal bars with small steel ties. The ties are twisted around the bars to hold them in place. This is a labor-intensive process and can result in inaccuracies during assembly. The Prefabricated Cage Reinforced Concrete beams are produced by cutting out uniform rectangular openings on a cold-formed steel sheet or tube.

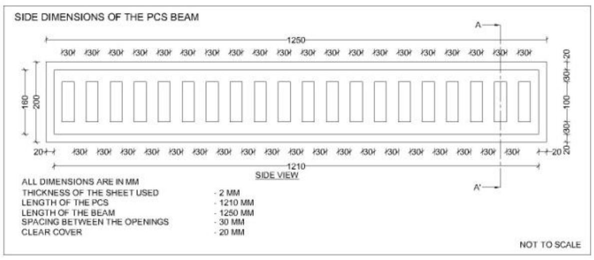
The vertical continuous strips perform the function of stirrups, while the horizontal strips act as main longitudinal reinforcement. Since the PCRC beams are fabricated in industries using CNC cutting, better quality control can be maintained. PCS is fabricated by perforating hollow steel tubes or steel plates. The openings can be provided on steel plates or tubes either by punching or using cutting methods such as a laser, plasma cutting, flame cutting, milling, or abrasive jet cutting.

The resulting PCS acts as transverse and longitudinal reinforcing steel, working compositely with the surrounding concrete to resist applied loads. PCS reinforcement is prefabricated off-site and then placed inside the formwork eliminating the time consuming and costly labor associated with cutting, bending, and tying steel bars in traditional rebar construction.

2.1 Materials

- Cement used is Type I Portland cement conforming to ASTM C150.
- Coarse aggregate with a maximum size of 12mm and a specific gravity of 2.60 was used in saturated surface dry (SSD) condition. The aggregate gradation falls within the limits of ASTM C33 standard.
- Fine aggregate complying with ASTM C33 gradation limits possessing a fineness modulus of 2.5 and a specific gravity of 2.6 was also utilized in SSD condition.
- Cold Rolled sheets - CR Sheet (2.0mm) confining to IS 513.

2.2 Selection of Dimensions and Thickness of Sheet for PCS Beam



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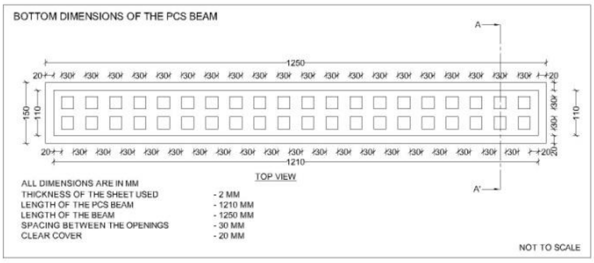

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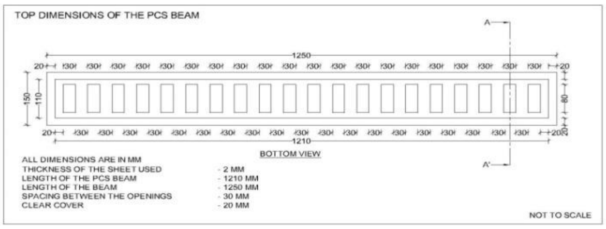

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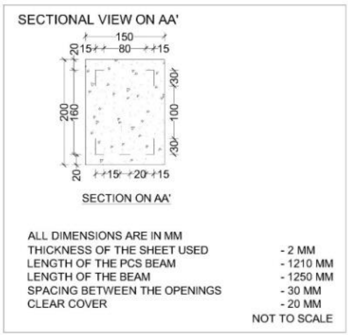


(d)

Fig-2 Plan for the Dimensioning of PCS beam

3. EXPERIMENTAL PROGRAM ON TESTING OF BEAMS

The details of the testing beam specimens given in the previous chapter. The capacity of the beam, the cross-section and length are kept constant for all the specimens. The variable parameter, is the amount of reinforcement steel and steel sheet.

3.1 Testing Preparation and Arrangement

The load test of the beam is carried out in the beam testing frame of the maximum capacity of 50T.the beams are taken out for testing at the end of 7day and white washed as described earlier and kept ready. To measure the deformation of the beam dial gauges of least count of 0.01mm accuracy are fixed to the middle of the beam bottom as shown in the figure. The points were the dial gauge reading is to be taken are cleaned well.

3.2 Test Setup and Instrumentation

The test setup and instrumentation are given in figure 4.4 and figure4.5.the beam specimens are tested in a beam testing frame of capacity 30T and the load is measured using proving ring and read using the calibration chart of the load device. The dial gauges used for measuring the deformations are of maximum measuring capacity of 25mm with a least count of 0.01mm.

3.3 Instrumentation

The following measurements were recorded during the test.

- The load W applied to the beam – The testing was done on a loading frame of capacity 30T. Loading was done by means of hydraulic jack of capacity 25T. The load was measured by using a proving ring of capacity 50T.
- Deflections within the region of pure bending between the two points were measured using dial gauge at least count of 0.01mm.

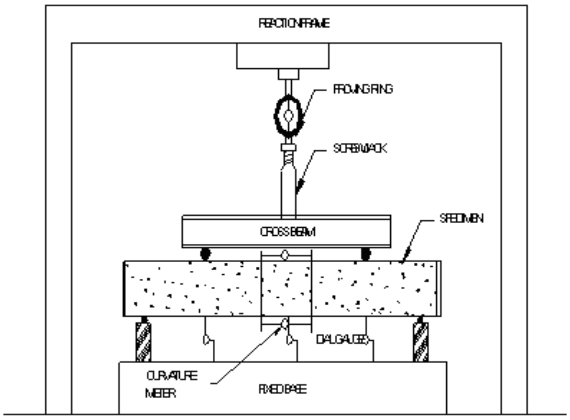


Fig-3 Experimental setup

3.4 Test Procedure

Beam specimens were tested under two-point loading. Details of test setup are shown in photographs. The load was applied in increments of 5KN and deflections were noted. The load that produced the first crack and the load that produced the ultimate flexural crack were accurately recorded.

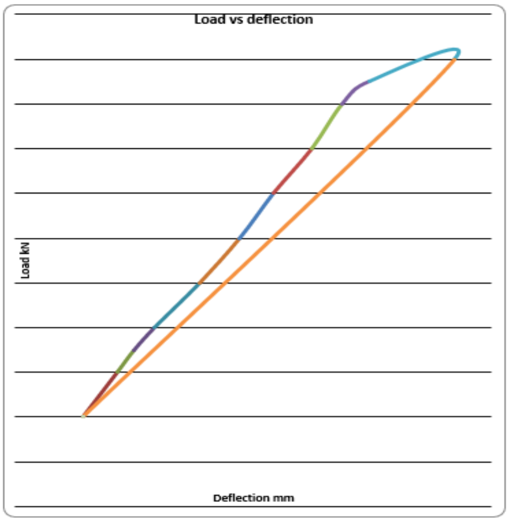
Fig-4 Test setup of beam

3.5 Results

A typical load and deformation measurement are in table 5.1 to table 5.4 for all beam specimens RC and PCS for every two specimens respectively.

Table-1 Testing Observations Beam (PCS)

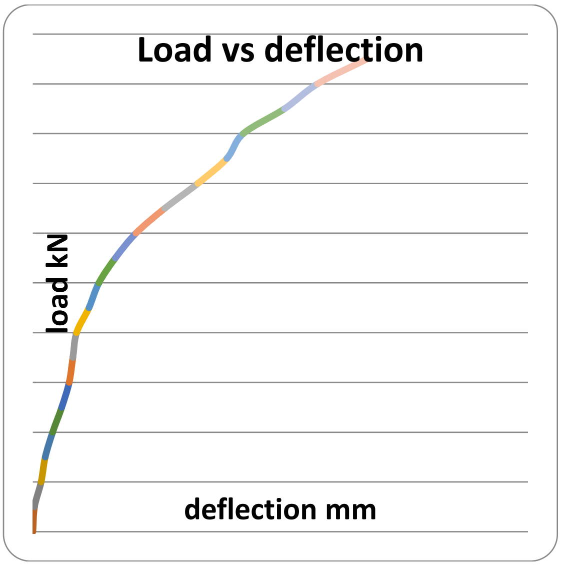
S. No.	LOAD (IN KN)	DEFLECTION (IN MM)
1	0	0
2	10	0.5
3	20	1.05
4	30	1.7
5	40	2.3
6	50	2.8
7	60	3.35
8	70	4.2
9	80	5.45



Graph-1 Load vs. Deflection

Table-2 Testing Observation Beam (PCS 2)

S.No.	LOAD (IN KN)	DEFLECTION (IN MM)
1	0	0
2	10	0.1
3	20	0.24
4	30	0.44
5	40	0.53
6	50	0.8
7	60	1.25
8	70	2
9	80	2.55
10	90	3.45
11	95	4.05



Graph-2 Load vs. deflection

3.6 Behavior of the Specimens in Flexure

In all the beams, as the load increased cracks appeared in the flexural zone. Further increase of load caused additional cracks on either side of the crack which occurred at the initial stages. Then the cracks have been found to propagate up the beam and at this stage some shear cracks also noticed. The relation between load and deflection is nearly linear till the first crack load. In the post-cracking stage, the slope of the curve is different from that of the pre-cracking stage with the post-cracking slope being lesser. Large deflections were observed in these beams which indicate the ductile behavior of these specimens. At 80% of ultimate load, many flexural cracks cum shear cracks were formed. This cracking process continued until the test was stopped for safety reasons. It was difficult to define the point of failure during testing of these PCRC beams. The beams continued to carry the maximum loads up to the point at which the test was stopped.

3.7 Failure Mechanism

The behavior of all beams was noted during the test. The failure mechanism of the beam specimens was excessive deflection accompanied by the formation of the plastic hinge between the loading points in the compression zone.

Fig-4 Crack Pattern

The fig-5 Crack pattern of PCS beams

The crack pattern of each beam is shown in Figure 4. The hair line cracks were formed at 40% ultimate load. In all the beams, the initial cracks were formed at the loading points. On the Further increase in the load, more cracks were formed at the pure bending region in the equal interval and the depth of cracks was increased. At 80% percentage one or two cracks were formed at the shear zone. At ultimate load, the depth of cracks was nearly 85% of the overall depth of the beam and the width of the cracks was also widened.

4. CONCLUSION

The behavior of normal strength concrete beams and concrete beams reinforced with a new reinforcement (PCS) was experimentally investigated. A total of 4 specimens were constructed and tested to investigate the strength and displacement capacity PCS reinforced beams. The behavior of PCS reinforced specimens was compared. The test results indicated PCS reinforced specimens had similar elastic behavior and comparable peak loads. PCS reinforced specimens had the larger residual strength and larger displacement ductility than equivalent rebar specimens. It was concluded that existence of crossties helps prevent buckling of PCS steel and therefore, improves the concrete confinement, beam strength, and displacement capacity.
Overall, PCS is found to be a better alternative for reinforced concrete structures that enables easier, faster, and more reliable construction.

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