STRENGTHENING OF TWO WAY RC SLAB USING POLYPROPYLENE FABRIC

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***ABSTRACT*: A study is conducted on the strengthening of two-way RC slabs with newly developed polypropylene fabric reinforced polymer (PFRP) composites. Control slabs of 1mx1m is tested under an applied 9-point load and at the salient points the displacements are measured. Slabs with PFRP as tensile reinforcement is placed in both the directions and tested. Another set of slabs with PFRP with additional anchorages at failure crack region, which was observed from testing the previous set of slabs, is tested. The load-displacement graph is plotted for all 3 types and comparison of load capacity of all the 3 different slab types are commented.**

***Keywords*: Polypropylene Fabric, Anchorages, RC Slabs.**

1. INTRODUCTION

Reinforced concrete slabs are among the most commonly used structural elements. They have been used in many forms for structural systems such as flat plates, flat slabs, waffled slabs, and two-way slab with beams. The main motivation for the strengthening of reinforced concrete slabs is that at a given time the slabs may be subjected to forces and displacements higher than those considered in the initial design during its lifetime. It can be due to changes in the prescribed design forces due to an increased seismicity of the area or the intended design force and/or displacement capacity of a structural member may be insufficient.

Fibre-reinforced polymers (FRPs) systems is used as the additional tensile reinforcement. Use of FRP systems is the knowledge gained from a comprehensive review of experimental research, analytical work, and field applications. Polypropylene fabric (PFRP) is a latest stuff in general compared to carbon, glass and aramid, and fulfill to be gifted stuff for intensification. Much research has been done on RC slabs confined with common FRP jackets, such as carbon, glass and aramid. Insufficient research has been done on FRP jackets made from polypropylene and thus it is important to research their efficiency on concrete members as a strengthening material in civil engineering.

2. LITERATURE REVIEW

Priti A. Patel et al [1] has made an attempt to increase concrete ductility and energy absorption by introducing polypropylene fibre reinforced concrete. An experimental investigation explored properties such as compressive strength, flexural strength, split tensile strength and shear strength of polypropylene fibre reinforced concrete. No significant change is found for compressive strength but flexural, split tensile and shear strength improves greatly, when compared to the plain concrete. The primary objectives of this investigation were to determine the benefits of using polypropylene fibre reinforced concrete (PFRC). Compressive Strength enhancement ranged from 8% to 16%, splitting tensile strength varies from 5% to 23% for PFRC. The maximum increase in flexural strength of PFRC is 36%. The percentage increase in shear strength of the polypropylene fibre mix varies from 23% to 47%.
Piti Sukontasukkul [2] made use of two different methods (ASTM C1018 and JSCE SF-4) to measure the toughness of steel and polypropylene fibre reinforced concrete subjected to bending. Results indicated that in the JSCE method, the information obtained by only one specified deflection toughness seemed to be insufficient in reflecting the characteristics of the load-deflection curves of both FRCs. On the other hand, in the ASTM method, the obtained information using the four toughness values at different deflections appeared to better clarify the characteristics of both FRCs.
The differences in the load-deflection responses of both fibers were essentially due to the properties of the fibres themselves. Both SFRC and PFRC behaved differently under bending. Due to the properties of the fibres, the behavior of PFRC was clearly a double-peak response while the behavior of the SFRC was a single-peak response and hence the toughness varies for both. ASTM method captured and reflected the true toughness properties of both SFRC and PFRC quite well. On the other hand, the JSCE method, with single value toughness, was not quite sufficient in reflecting the real toughness properties of the PFRC.
Elsharkawy et al [3] casted eleven half scale T-shaped post-tensioned simple beams and tested in four points bending under the effect of a repeated load using a displacement control system up to failure. The test parameters were the fibers' type (steel and polypropylene) and content, as well as the prestressing ratio (partially or fully). Key test results showed considerable enhancement in the crack distribution, crack width and spacing, concrete tensile strength and flexural stiffness in all beams with steel fibrous concrete. On the other hand, beams containing polypropylene fibers demonstrated a slight decrease in the flexural strength and a slight increase in flexural stiffness. Generally, it can be concluded that steel fibers proved to have higher structural efficiency than polypropylene fibers, when used in the tested specimens. It was noted that the steel fibers and the polypropylene fibers did not affect the beams pre-cracking behavior and the beams failure mode. They showed that the analytical model proved to be valid and can be

used with confidence to conduct future parametric studies aiming at establishing design oriented conclusions in the field.
Fathima and Varghese [4] presented the results of an experimental study investigating the effects of steel fibres and polypropylene fibres on the mechanical properties of concrete. The main aim of this experiment is to study the strength properties of steel fibre and polypropylene fibre reinforced concrete of M30 grade with 0%, 0.25%, 0.5%, and 0.75% by volume of concrete. This study consisted of compressive strength test and split tensile strength test on hybrid fibre reinforced concrete with 0.5% polypropylene fibres and 0.75% steel fibres. The steel fibre reinforced concrete yield higher splitting tensile strength with addition of 0.75% steel fibre by volume of concrete. The polypropylene fibre reinforced concrete yield higher splitting tensile strength with addition of 0.5% polypropylene fibre by volume of concrete. The steel fibre reinforced concrete yield higher compressive strength with addition of 0.75% steel fibre by volume of concrete. Fibre reinforced concrete with crimped steel fibre of 25mm length with aspect ratio 50 yielded better compressive and flexural strength than hooked end steel fibre of 30mm length with aspect ratio 50.
S.P. Singh et al [5] gave the results of an investigation conducted to evaluate the strength and flexure toughness of Hybrid Fibre Reinforced Concrete (HyFRC) containing different combinations of steel and polypropylene fibres. An experimental programme was done in which beam specimens of size 100 x 100 x 500 mm were tested under four point static flexural loading to obtain the flexural strength of HyFRC. In addition, cube specimens of size 150 x 150 x 150 mm were also tested to obtain its compressive strength. The specimens incorporated steel and polypropylene fibres in the mix proportions of 100-0%, 75-25%, 50-50%, 25-75% and 0-100% by volume at a total volume fraction of 1.0%. The flexural toughness parameters were obtained using procedure laid down in ASTM C-1018 C, JCI Method, ASTM 1609/C 1609 M and Post Crack Strength (PCS) Method. The results indicate that concrete containing a fibre combination of 75% steel fibres + 25% polypropylene fibres can be adjudged as the most appropriate combination to be employed in HyFRC for compressive strength, flexural strength and flexural toughness.
Parveen and Ankit Sharma [6] made a study to investigate the effect of variation of polypropylene fibres ranging from 0.1% to 0.4% along with 0.8% steel fibres on the behaviour of fibrous concrete. The mechanical properties of the concrete such as compressive and tensile strength have been investigated. The result shows that addition of polypropylene fibre has a little effect on the compressive strength, but there was significant increase in the tensile strength with increase in fibre volume fraction. The present investigation shows an increase of 47% of split tensile strength and 50% of flexural strength. The result shows that ultimate load mainly depended on percentage volume fraction of fibre.

3. MECHANICAL PROPERTIES OF POLYPROPYLENE FABRIC

Polypropylene fabric is a high performance, strength polypropylene fiber arrangement for structural intensification. It is single directional fiber, golden light brown in color, as shown in Figure 1 and its properties are presented in Table 1.

Table 1: Properties of Polypropylene fabric (HT 2513)

Properties	Polypropylene Fabric (HT 2513)
Fiber orientation	Uni-directional
Weight of fiber (g/m2)	250
Fiber thickness (cm)	0.2
Ultimate elongation (percentage)	2.6
Primary fiber tensile strength (Mpa)	2100
Tensile modulus (Gpa)	100

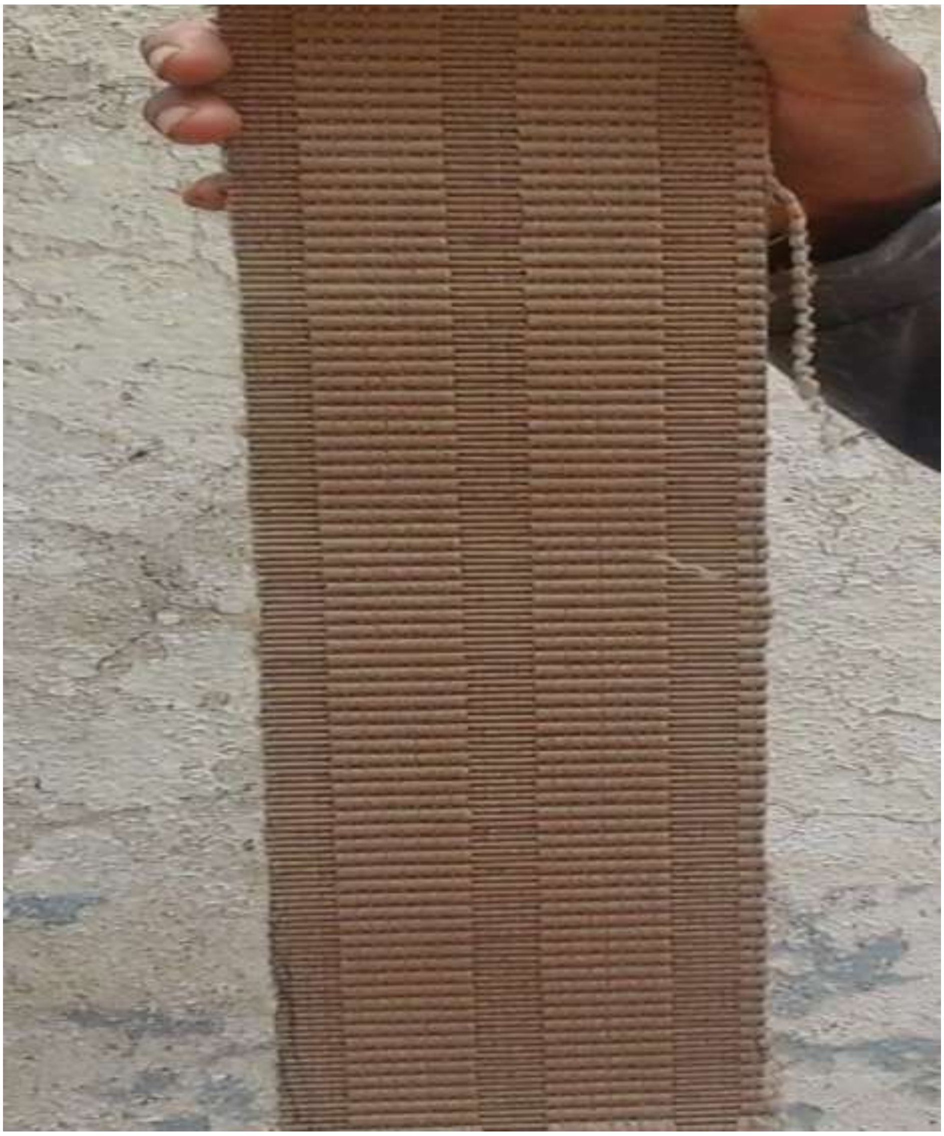

Figure 1: Polypropylene fabric.

4. EPOXY

The chemicals used for the bonding of PFRP to the slab are of 3 types:

(a) Primer: Master Brace P 3500
Primer is used to coat upon the surface of slab which is rigid for ensuring better adhesion.
(b) Concressive: Master brace 1446
MasterBrace 1446 is a thixotropic paste adhesive based on a two component solvent free epoxy resin system it may also be used as a polymer repair mortar and will bond to a wide variety of building and construction materials including concrete, masonry, timber and metals.
(c) Saturant: Master Brace 4500
Master Brace 4500 is a 100% hard, long life blue pigmented, epoxy resin for saturation which will enhance the adhesion and prevents debonding.

5. ANCHORAGE SYSTEM

A MS plate is used as a fixture with a specified diameter of hole, through which certain diameter of anchor bolt runs into the base material such as brickwork, blockwork, stones and reinforced hardened concrete. The main purpose of the plate used is to hold the FRP sheets against the load and prevent de-bonding. The plate used should be ductile enough to transfer the load such as mild steel and can be cut into desired dimensions. It should not be a brittle material which can fracture or break itself at higher load. Mild steel plate is used as anchor plate in this research work.

Anchor bolts used in this research work is from HILTI. It is a 3inch long 8mm diameter HST wedge anchor bolts. MS Plate of 65×200mm dimension and 3mm thickness is used as a fixture or anchor plates. The specifications are given in Table 2. Totally 24

Anchor bolts and 4 MS plates were used per slab and their arrangement is shown in Figure 5.

Figure 2: Wedge Anchor bolts and Plate

Table 2: Specifications of the Anchor bolts and plates.

Dia. Of Anchor bolts (HST) in mm	Dia. of drill bit used in mm	Depth of Drill hole (h1) in mm	Effective anchorage depth (heff) in mm	Spacing of anchor bolts in mm c/c
8	8	60	47	70
Anchor plate (MS plate)		200×65×3 mm		

6. SLAB SYSTEM

The test specimen slabs are designed from the standards and provisions of Indian code of practice IS 456:2000. The concrete grade chosen is of M20 grade and steel is Fe 415. The slabs had cross section of 1.07m by 1.07m, and a thickness of 90 mm. The reinforcement details of the test specimens are shown below in Figure 3.

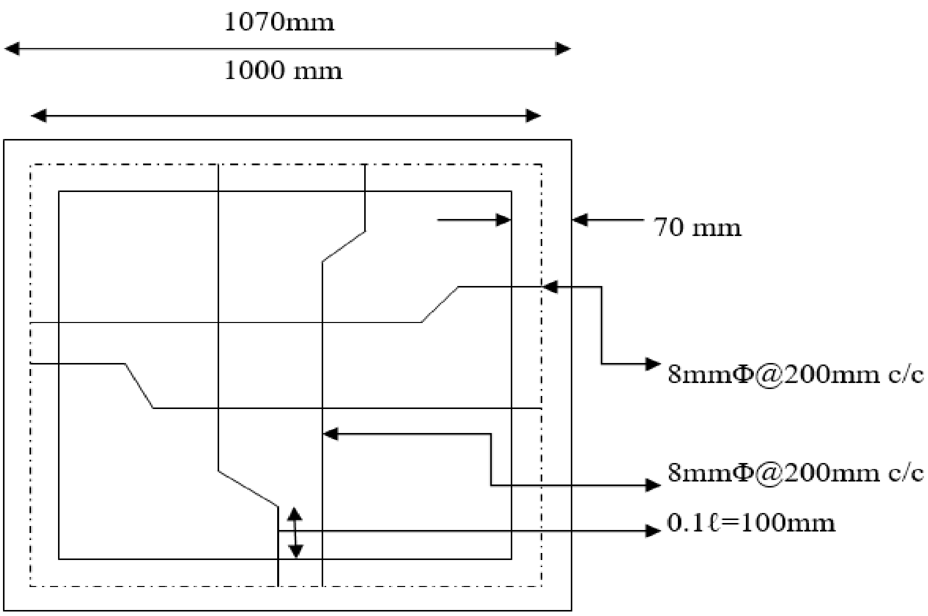

Figure 3: Reinforcement details of Slab specimen.

7. METHODOLOGY

FRP was wrapped on the tension side of the slab using the cross wrapping technique. In the cross wrapping technique, PFRP sheets were bonded onto the tension side of the slab at the midsection sparing one fourth span at the supports in a cross type manner. Since the fibers PFRP sheets were unidirectional, the sheets were bonded along the longitudinal as well as the transverse direction. In the case of cross wrapping technique, the FRP sheets were cut to the desired width and bonded along the longitudinal and transverse directions as shown in Figure 4.

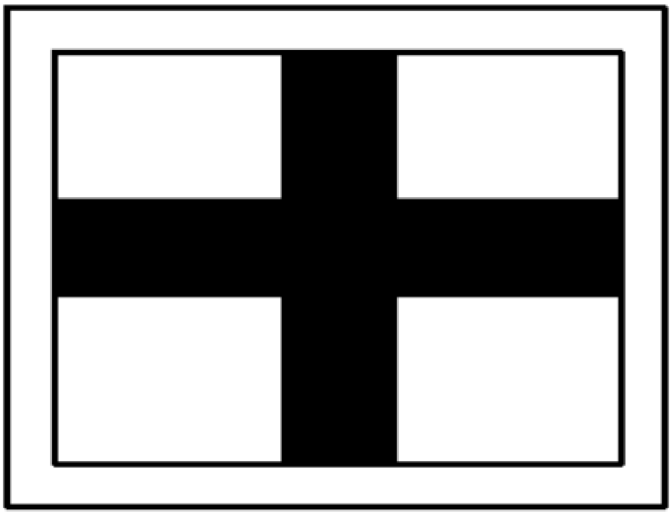

Figure 4: Externally bonded PFRP sheet without anchorage system

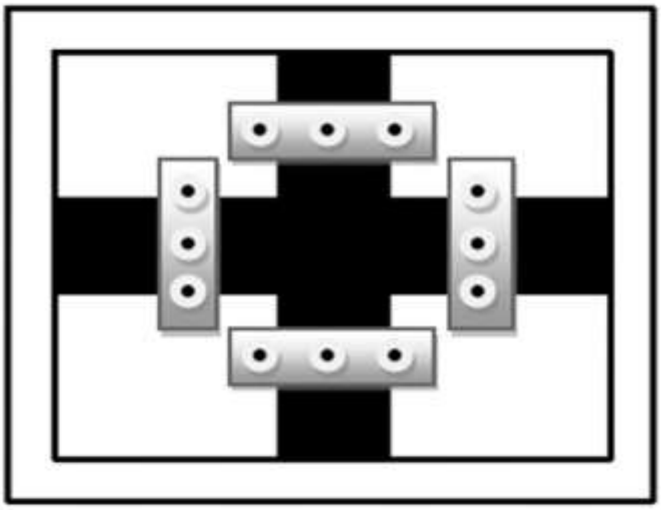

Figure 5: Externally bonded PFRP sheet with anchorage system

8. EXPERIMENTAL SETUP

Specimens was subjected to flexural test. The same test was carried out for both control as well as strengthened slabs. The setup was conceded out with a 25 T load frame, loading jack was fixed on top to apply load. To give the UDL effect to the slab, loading channels were used such that the loads that were centrally applied were uniformly distributed on the slab. All the slabs are tested under 9-point load in the loading frame as shown in Figure 6. The deflection at the bottom of the slab was measured using dial gauge. Totally five dial gauges was used for this experiment which was placed one at the center of the slab and other four at different points as shown in the Figure 7.

Figure 6: Experimental Test Setup

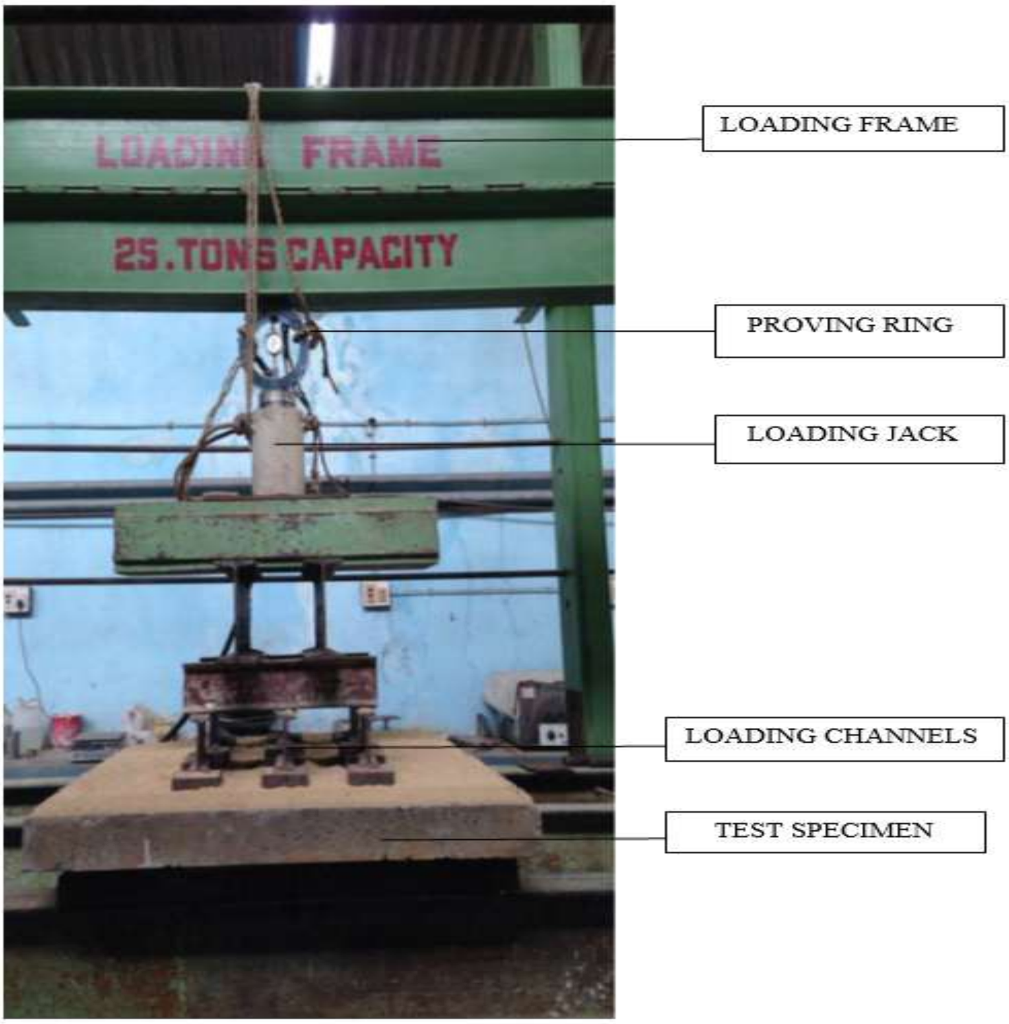

Figure 7: Position of Dial gauge

9. RESULTS

The summary of the test results is provided in Table 2

Table 2: Summary Of Test Results

Specimen name	Type of slab	Type of wrapping	Failure load (kN)	Maximum deflection at mid span(mm)
CS-1	Control slab-1	-	120	19.972
CS-2	Control slab-2	-	118	17.321
PFRS-1	Polypropylene fabric retrofitted slab	Cross type wrapping	184	18.964
PFRS-2	Polypropylene fabric retrofitted slab	Cross type wrapping	184	20.456
PFRS-A-1	Polypropylene fabric retrofitted slab with Anchorage	Cross type wrapping	184	20.158
PFRS-A-2	Polypropylene fabric retrofitted slab with Anchorage	Cross type wrapping	186	20.496

The load v/s deflection curves are plotted as shown below:

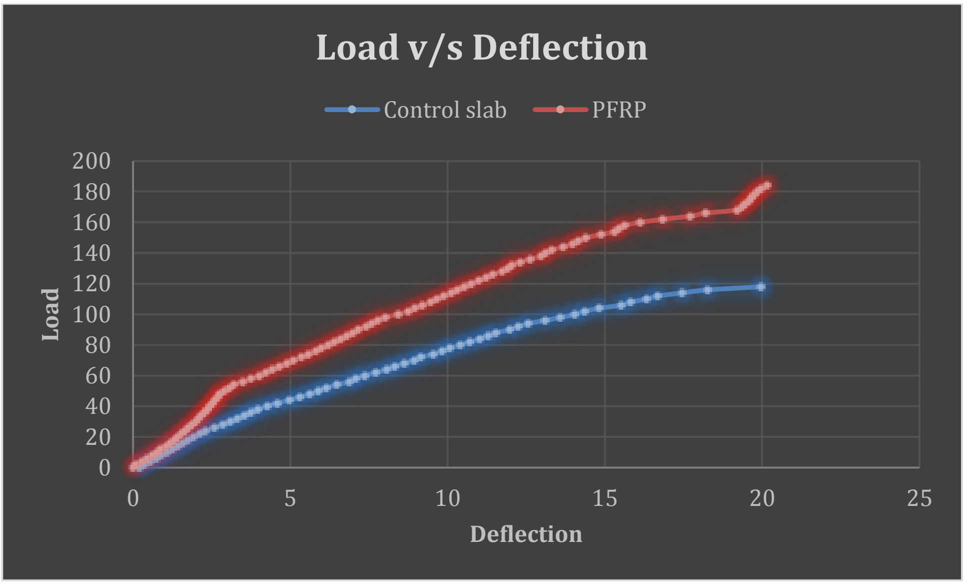

Figure 8: Comparison of the load v/s deflection curves for the control and PFRP retrofitted slabs with anchorage with mid-span deflections.

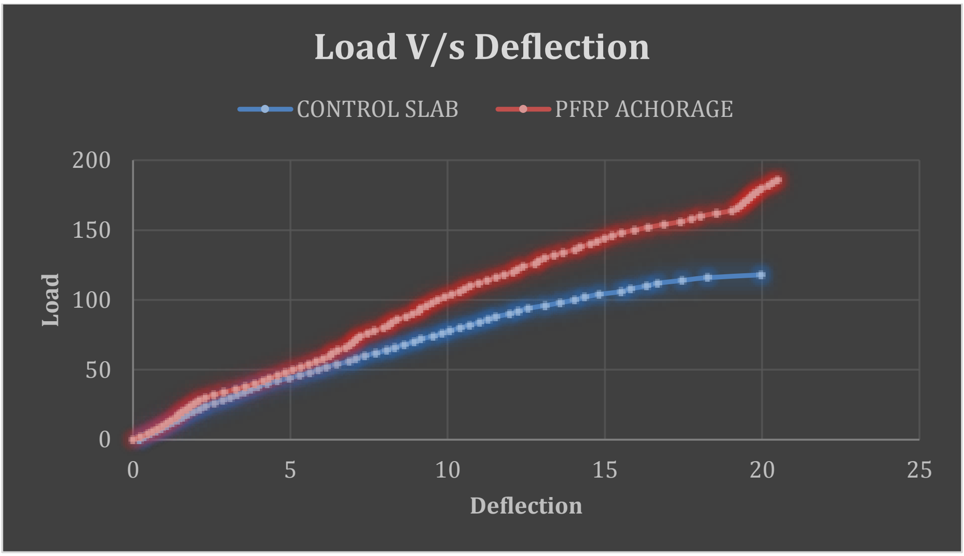

Figure 9: Comparison of the load v/s deflection curves for the control and PFRP retrofitted slabs with anchorage with mid-span deflections.

10. CONCLUSION

Based upon the test results and observations from investigational study undertaken the following conclusions are drawn.

1. Two-way RC slabs strengthened using PFRP with cross wrap technique i.e., PFRS is initiate to be extra efficient and the LCC is to be increased by 53.33% compared to the control slabs.
2. Two-way RC slabs retrofitted with PFRP cross wrap technique with anchorage i.e., PFRS-A were also found to effective in the raise of LCC about 42.9% as compared to control slabs.
3. Stiffness of slabs retrofitted with PFRP sheets i.e., PFRS is increased by 38.4% compared to that of control slabs.
4. The stiffness of slabs retrofitted with PFRP sheets with anchorage i.e., PFRS-A is increased by 39.6% compared to that of control slabs.
5. Mechanical anchorage system provided was not satisfactory and failed in increasing huge LCC and stiffness of PFRP cross wrap retrofitted slabs.
6. The slabs two-way RC retrofitted with PFRP sheets with cross wrap technique with and without anchorage carried about almost same load.
7. Load carrying capacity of retrofitted slabs were more compared to control slabs and also observed that the slabs retrofitted using PFRP fabric without anchorage performed well compared to with anchorage slabs.
8. Thus two-way RC slabs retrofitted with PFRP sheets without anchorage system i.e., PFRS found to be more economical and efficient than retrofitted slabs with anchorage.

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