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Scrutiny Report on Flexural Deficient Reinforced Concrete Beams Retrofitting with Ultra High Molecular Weight Polyethylene

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Abstract: This context aims to investigate and give scrutiny report on flexural strengthening of RC beams with the help of ultrahigh molecular weight polyethylene. The experimental phase of this study is to explore the flexure behavior of RC beams by contrasting control RC beams with retrofitted RC beams. Here UHMW PE was used as a retrofitting material. It is one type of geosynthetic. UHMW PE (Ultra High Molecular Weight Polyethylene) is an extremely tough plastic with high abrasion and wear resistance. The versatility of polyethylene has made it a popular plastic for countless industrial applications that require durability, low friction, and chemical resistance. UHMW PE sheet were bounded externally using EPOXY and hardener. RC beams were made weak in flexure and then retrofitted to detect the flexure action considered. Two sets of beams were considered Set-1 consisting of three control samples with 100%,70%and 40% of flexural reinforcement. Set-2 consists three samples with 100%,70%and 40% flexural reinforcement and retrofitted with UHMW PE. The results showed that the retrofitting samples had more capacity to carry load than those of control samples. Thus, retrofitting is a feasible solution to overcome the stresses in the structure. This study also involves ultimate carrying load capacity, failure mode and pattern of cracks of the beam are also investigated.
Keywords: Retrofitting, Ultra High Molecular Weight Polyethylene (UHMW PE), Epoxy Resin and Hardener, Flexural Strength

I. INTRODUCTION

A durable concrete is one that performs satisfactorily under expected exposure conditions for the specified life of the structure. Throughout their service life, reinforced concrete structures also undergo modifications and enhancements in their performance. The key factors which cause changes in their use are recent design requirements, deterioration caused by steel corrosion due to exposure to intense climatic conditions, and occurrences such as earthquakes. There are two possible solutions in such circumstances redesign and retrofitting. Whole structure replacement may result in drawbacks such as material and labour expenses, a greater effect on the environment and discomfort due to delay of structural operation, e.g. traffic problems. Repair and upgrading the structure by retrofitting is often better when applicable. The development of strong epoxy glue over the past decade has led to a technique that has great potential in the area of structure upgrading. The method includes applying UHMW PE laminating sheets on the concrete surface[1]. The plates or laminates then act composite with the concrete and help to bear the loads. Laminating sheets can be comfortable compared to steel for numerous reasons. The installation is simpler and there will be no need for temporary support until the adhesive yield’s strength because of low weight. They can be mold into complicated ways on-site and can also be easily cut to length on-site. Some retrofitting solutions are possible: ounces that have typically been used for a long time, such as adding new shear walls, adding infill walls, wing walls, buttresses, jacketing of RC members, propping up, sleeving, steel collars, bonding steel plates. Nevertheless, there are trendy ways of retrofitting the structure with many additional benefits with increased study and introduction of new materials and technologies[2]. One of them is the development of Geo-synthetic sheets. It has proved to be a suitable product for engineering repairs and upgrades.

A. Benefits for Retrofitting

1) Structures which are designed only for gravity loads.
2) The reliability of the actual construction can be lower than originally planned.
3) Inadequate planning.
4) Designer's lack of understanding.
5) Lack of review of our country's seismic zone map.

II. RESEARCH SIGNIFICANCE

A wide-range research in the area of retrofitting has been observed in modern years. The current work concentrates on reinforcing beams that do not have flexure resistance capability when the structure faces unexpected impacts such as earthquakes. By decreasing the percentage of flexure reinforcement, the beam weak in the flexure perception was achieved. The failure behaviour of beams was observed as well as the ultimate load-carrying beam capacity[3].

III. DESIGN PROCEDURE

The design calculation for the conventional beam and retrofitted beams are different because in retrofitting beams UHMW PE is wrapped at the bottom of the beam. It improves the flexural strength of the flexural deficient beam. So, the design calculations may differ. Aiming to calculate the neutral axis depth of the retrofitted beam. It equates to the equilibrium forces as below[4];

$$C_u = T_u + T_{uhmw\ pe}$$

Where, C_u is compressive force, T_u is tensile force of steel, $T_{uhmw\ pe}$ is tensile force of the Ultra high molecular weight polyethylene.

$$0.36 \times f_{ck} \times b \times x_u = (0.87 \times f_y \times A_{st}) + (A_{uhmw\ pe} + f_{uhmw\ pe})$$

Where, f_{ck},is characteristic compressive strength of concrete; b is breadth of beam; x_u, is neutral axis depth; f_y,characteristic strength of steel: A_{st} is area of main reinforcement; $A_{uhmw\ pe}$ is area of UHMW PE; $f_{uhmw\ pe}$ is ultimate stress of UHMW PE[5].

IV. EXPERIMENTAL PROGRAMME

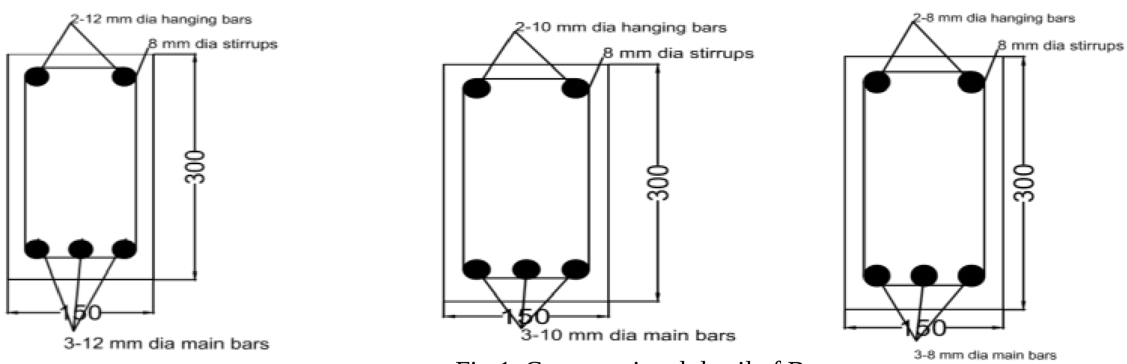

Fig 1. Cross sectional detail of Beam

In this study M40 grade of the concrete is used for casting the all beams with fe500 grade of steel reinforcement. The main steel reinforcement provided in varying percentages. The reason for varying the reinforcement is to make the beams weak in flexure[6]. This variation in some fixed proportions like hundred percentage, seventy percentage and forty percentage. The length of the beam is 2200 mm, the cross sections are 150mm width and 300mm depth. The beams are divided into two sets. Set one consists three conventional beams weak in flexure control specimens (BWFC) with varying reinforcements named as BWFC 100, BWFC 70 and BWFC 40. The details are shown in fig 2, fig 3 and fig 4.

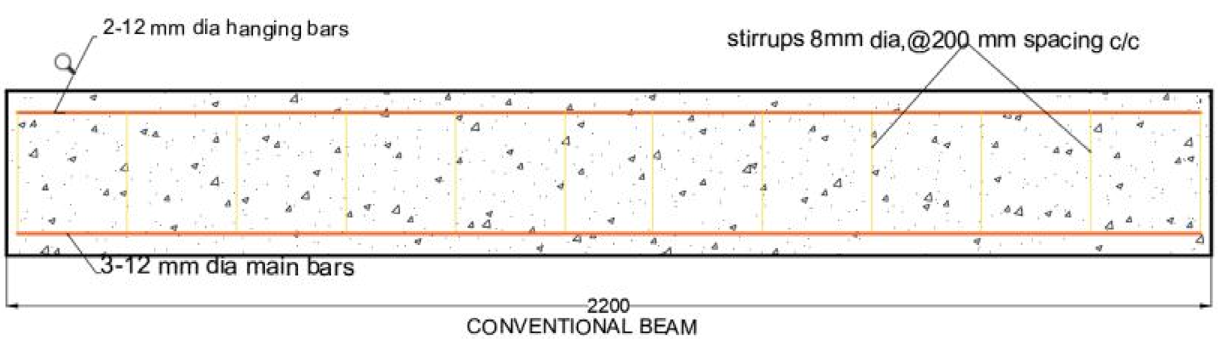

Fig 2. Detailing of BWFC 100%

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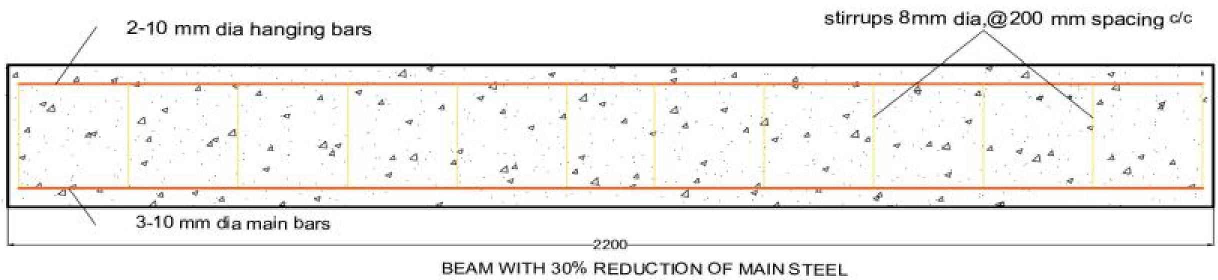

Fig 3. Detailing of BWFC 70%

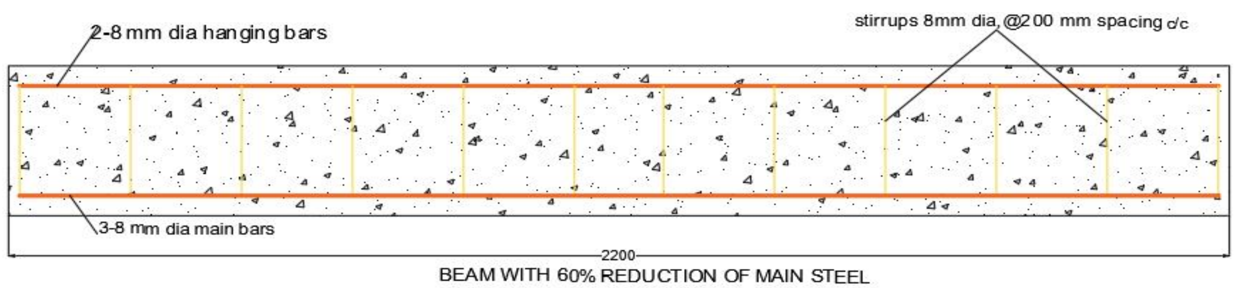

Fig 4. Detailing of BWFC 40%

Similarly, set two consists three retrofitted beams weak in flexure retrofitted specimen with varying reinforcements (BWRC) named as BWFR 100, BWFR 70 and BWFR 40. These Beams Are Retrofitted with UHMW PE with the help of epoxy. The details are shown in fig 5, fig 6 and fig 7.

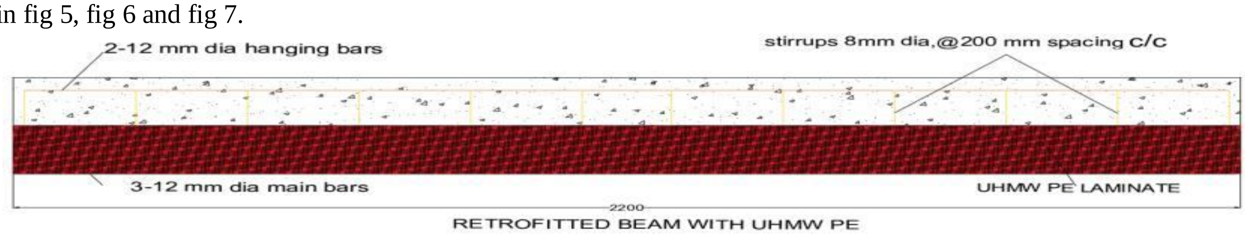

Fig 5. Detailing of BWRC 100%

Fig 6: Detailing of BWRC 70%

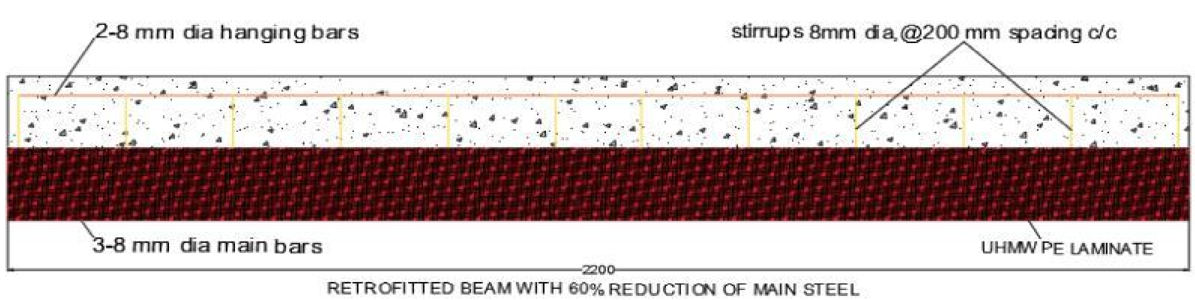

Fig 7. Detailing of BWRC 40%

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A. Casting of beams

Firstly, it is necessary to cast all six beams according to the design consideration. In which three beams are considered conventional, and the remaining three beams are regarded as beams of retrofitting. All beams are casted here according to the mix design. The next step of the process is to weigh the materials by the required quantity per meter cube after material procurement. The beam volume is obtained as 0.1 m^3, since we can observe the proportions of the concrete mix per meter cube. So, the required volume of material quantities must be measured before casting beams. In this study cement is replaced with cementitious material like fly ash by 30%[7]. Now all coarse aggregates, fine aggregates, cement and fly ash need to be thoroughly blended by adding water content after providing steel reinforcement in Fig8 after measuring materials according to the necessary amounts.

(a) (b) (c)

Fig 8. (a) Tying of reinforcement cage; (b) reinforcement in casting box; (c) casting of beam

The concrete paste, which is thoroughly mixed, must be poured into the beam box in the shape of layers after putting the beam support cage in the beam box. After the first two layers have been filled, we need to position the vibrator inside the concrete to prevent air voids. And it's necessary to keep the vibrator after filling the next layer of concrete mix again to avoid the air voids. At last, with the aid of a trowel, we will level the beam's top surface. The beams are required for demolishing within 24 hours of casting as shown in fig8. And all the control and retrofitted specimens need to be covered with the help of gunny bags to perform curing for up to 28 days. But in this study 30% of cementitious material fly ash was replaced. Because of that for achieving the target mean strength the concrete takes 56 days curing.

V. DETAILED PROCESS FOR FIXING OF UHMW PE:

Initially the surface of the beam grinded with concrete grinding machine to make the concrete uneven surface removed for UHMW PE fixation. Furthermore, we must ensure the necessary safety measures while using the grinding machine, such as wearing the gloves on the hands, the security apron and the protective mask. Now, the surfaces of the beams need to be thoroughly cleaned with brush or blower[8]. The UHMW PE has to cut according to the dimensions needed for retrofitting, the minimum sheet measurements are 450 mm for each tube, approximately 2200 mm. The next step of the process after cutting the UHMW PE sheet is to thoroughly combine Epoxy hardener and resin with the ratio of 1:1 for 10 to 15 minutes[9]. Then apply on the beam's cleaned surface where the UHMW PE must be attached.

Table 1: Properties of UHME PE

DESCRIPTION	ULTRA HIGH MOLECULAR WEIGHT POLYETHYLENE
Fibre thickness(mm)	0.5
Modulus of elasticity (GPa)	175
Tensile strength (MPa)	2400
Ultimate strain	0.019
Specific Gravity (g/cm^3)	0.935

According to the epoxy resin supplier's requirements and instructions after application on the concrete surface, epoxy life should be preserved for about 30 minutes and then the epoxy adhesive converted in to a sticky shape. Then it is important to apply the UHMW PE on the surface. To gain the bonding strength, all retrofitted beams were kept dry curing for 7 days. To define the crack pattern, the control and retrofitted beams must be washed white and the grids must be drawn by 5 cm×5 cm grid panel[10].

VI. TEST PROCEDURE

In order to know the total load carrying capacity, the regulated and retrofitted beams are checked under two-point bending pressure. The platform was positioned at a distance of 100 mm from the left edge of the frame and put at a distance of 100 mm roller support from the right edge of the board. The standards of assistance are the same for all samples examined as shown in Fig 9. The concrete test frame strength is 200 tons.

Fig 9. Loading frame

The system used to test managed and retrofitted beams. Using the crane, the beams are raised and put on the supports. Therefore, in order to avoid eccentricity, the bottom and top surfaces of the beams should have uniform surface. Two loading points in the form of solid steel billets were provided with equal distance. Then I was placed with sectional girder beam to apply the loading of the two points on the beam. To note the load values, the loading cell was placed on the girder. The LVDT was placed at the beam's middle bottom surface to measure the mid displacement[11].

A. Failure Mechanism of Tested Specimen (Conventional)

The BWFC 100 was tested. The maximum carrying load capacity was measured as 189kN with a deflection of 25.65mm. The sample specimen pattern of cracks shown in fig 10. cracks were propagated from the bottom surface of the beam, and the flexural cracks was obtained in middle portion of the beam and also observed some of the shear cracks also. Based on this test both shear and flexural cracks ware observed.

Fig 10. Failure pattern of BWFC 100

The BWFC 70 was tested and the total carrying load capacity was measured 138kN. The deflection was 23mm. in this test the beam was mainly affected by owing to shear and flexure cracks. And also observed the cracks propagated from the supports at the angle of 45^0. Based on this observation the failure of the beam occurs by both shear and flexure cracks.

The BWFC 40 was tested. The ultimate carrying load capacity was attained at 97kN. The deflection was in this beam the main tension reinforcement was reduced from 100 % to 40%. For satisfying the flexural deficiency condition. in this test at middle of the beam noticeable flexural cracks were formed. As shown in fig11.

Fig 11. Failure pattern of BWFC 40

B. Failure Mechanism of Tested Specimen (Retrofitted)

The BWRC 100 was tested and the carrying load capacity was 263kN and the deflection was 17.63mm. the beam was mainly affected by shear cracks and less effected by flexural cracks were found. The BWRC 100 Has Been Designed to Withstand Flexural Strength. The retrofitting was helped to improve the flexural strength .in this test the shear cracks were propagated at angle of 45^0.

The BWRC 70 was tested and the carrying load capacity was 216kN with a deflection of 17.1mm. The beam was mainly affected by shear cracks instead of flexural cracks because of retrofitting.

The BWRC 40 was tested and the ultimate carrying load capacity of 161kN and a maximum deflection of 18.1mm. Since the main tension reinforcement of this specimen has been limited to 40%. From fig. 12 the UHMW PE may be found to have been delaminated from the beams layer. Some of the shear cracks also observed by testing the specimen. All the test results are listed below.

Fig 12. Failure pattern of BWRC 40.

Table 2: Test results of all specimens

Beam	Ultimate load (kN)	Deflection(mm)	Failure mode
BWFC 100	189	25.6	Flexure and shear
BWRC 100	263	17.6	UHMW PE rupture +Shear
BWFC 70	138	23.0	Flexure and shear
BWRC 70	216	17.1	UHMW PE rupture +Shear
BWFC 40	97	26.0	Flexure and shear
BWRC 40	161	18.1	Delamination+ flexural rupture

VII. RESULTS AND DISCUSSION

All the specimens were tested under the loading frame. All the beam specimens are simply supported. the set up of beam in loading frame as show in fig10. The two-point load was placed at a distance of 700mm from the both ends of supports. The deflection was measured by LVDT. Different Parameters are observed after testing the Specimens i.e. load vs deflection, failure mode and crack patterns. And also compared the conventional and retrofitted specimens' results.

A. Load Versus Deflection Response

The fig. 13 shown below drawn for comparison of the flexural strength and deflection of the control specimen BWFC 100 and retrofitting specimen BWRC 100. The flexural strength of the BWRC 100 was improved 39.15 % and also the stiffness increased.

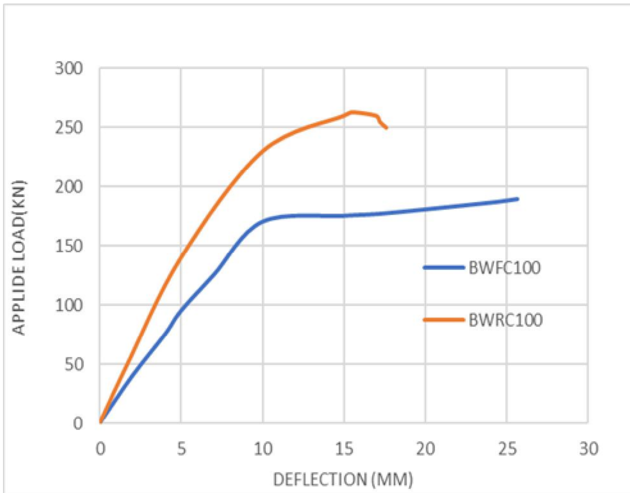

Fig13. Flexural strength comparison of BWFC 100 and BWRC 100

The fig. 14 shows the comparison of flexural strength and deflection of the BWFC 70 and BWRC 70. BWRC 70 shows the better results compare to the BWFC 70. The carrying load capacity was increased 56.52% and deflection was comparatively less. BWRC 70 shows less magnitude of deflection.

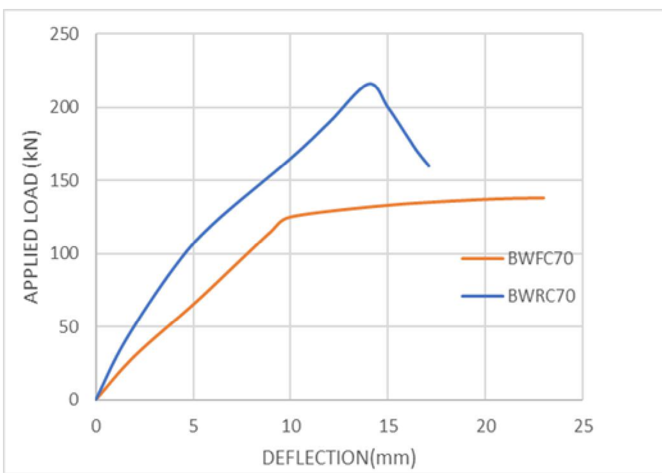

Fig14. Flexural strength comparison of BWFC 70 and BWRC 70

The retrofitted beam BWRC 40 was increased 65.97% flexural strength than the BWFC 40. Its Proves that the Retrofitted Beams has Significant Strength and Stiffness with Less magnitude of deflection.

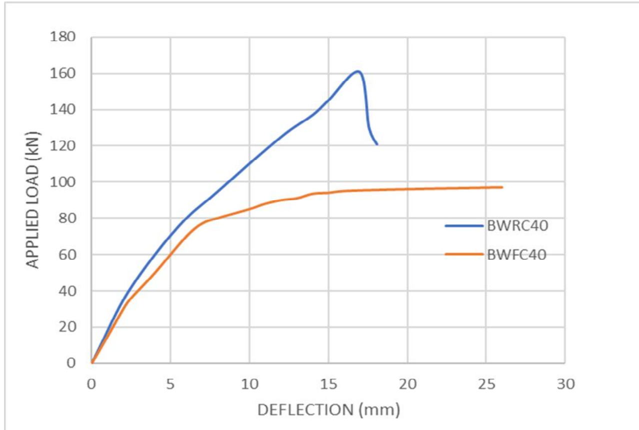

Fig15. Flexural strength comparison of BWFC 40 and BWRC 40

The fig. 16 shows that the set one consists three specimens BWFC 100, BWFC 70 and BWFC 40. The comparison of three beams flexural strengths. It conforms that the flexural strength of BWFC 100 more than the BWFC 70 and BWFC 40.

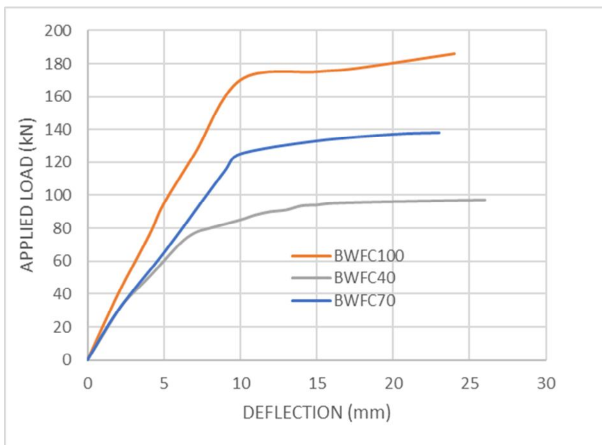

Fig16. Flexural strength comparison of all control specimens

The fig17 shows that the set two consists retrofitted specimens BWRC 100, BWRC 70 and BWRC 40. The flexural strength of BWRC 100 was more than the remaining two retro fitted beams.

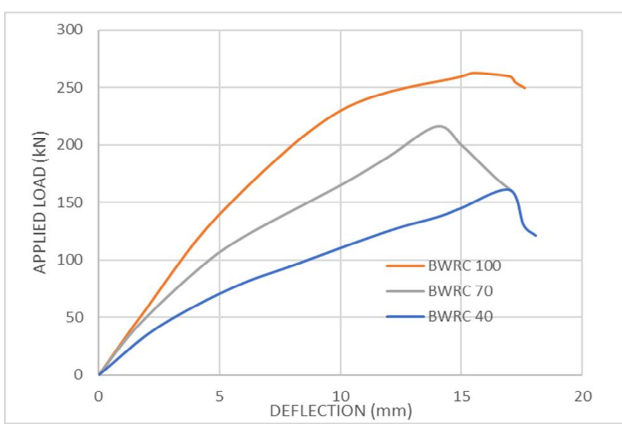

Fig17. Flexural strength comparison all retrofitted beams

VIII. CONCLUSIONS

The conceptual and practical study of reinforced concrete beams utilizing UHMW PE regulation and retrofitting. flexural deficient beams by decreasing the main tension reinforcement from 100% to 70% and 40% are tested and the process of beam failure also observed. From this report, the following conclusions are drawn from this study:

A. The retrofitted beams were shown less magnitude of deflection when compared to the control beams.
B. The carrying load capacity of retrofitted beams more compared to the control beam.
C. Because of externally bound UHMW PE, the flexural strength of the retrofitted beams has been improved.
D. For conventional beams, the exposure of flexural cracks was found significantly higher compared to the retrofitted beams at early load test intervals. There have also been some shear cracks identified.
E. The major shear cracks are identified at an absolute 263kN load in BWRC100.
F. The UHMW PE sheet delaminated and flexural fracture occurred at an ultimate load of 161kN in BWRC 40.
G. The ultimate carrying capacity of BWRC 100 was 39.15 percent was increased than BWFC 100.
H. The ultimate carrying capacity of BWRC 70 was 56.52 percent was increased than the BWFC 70.
I. The ultimate carrying capacity of BWRC 40 WAS 65.97 percent was increased than the BWFC 40.
J. To increase the flexural strength of beams, retrofitting with UHMW PE sheets has been proposed.
K. Cement replaced with 30% of cementitious material like fly ash, the target mean strength achieves in 56 days of curing.

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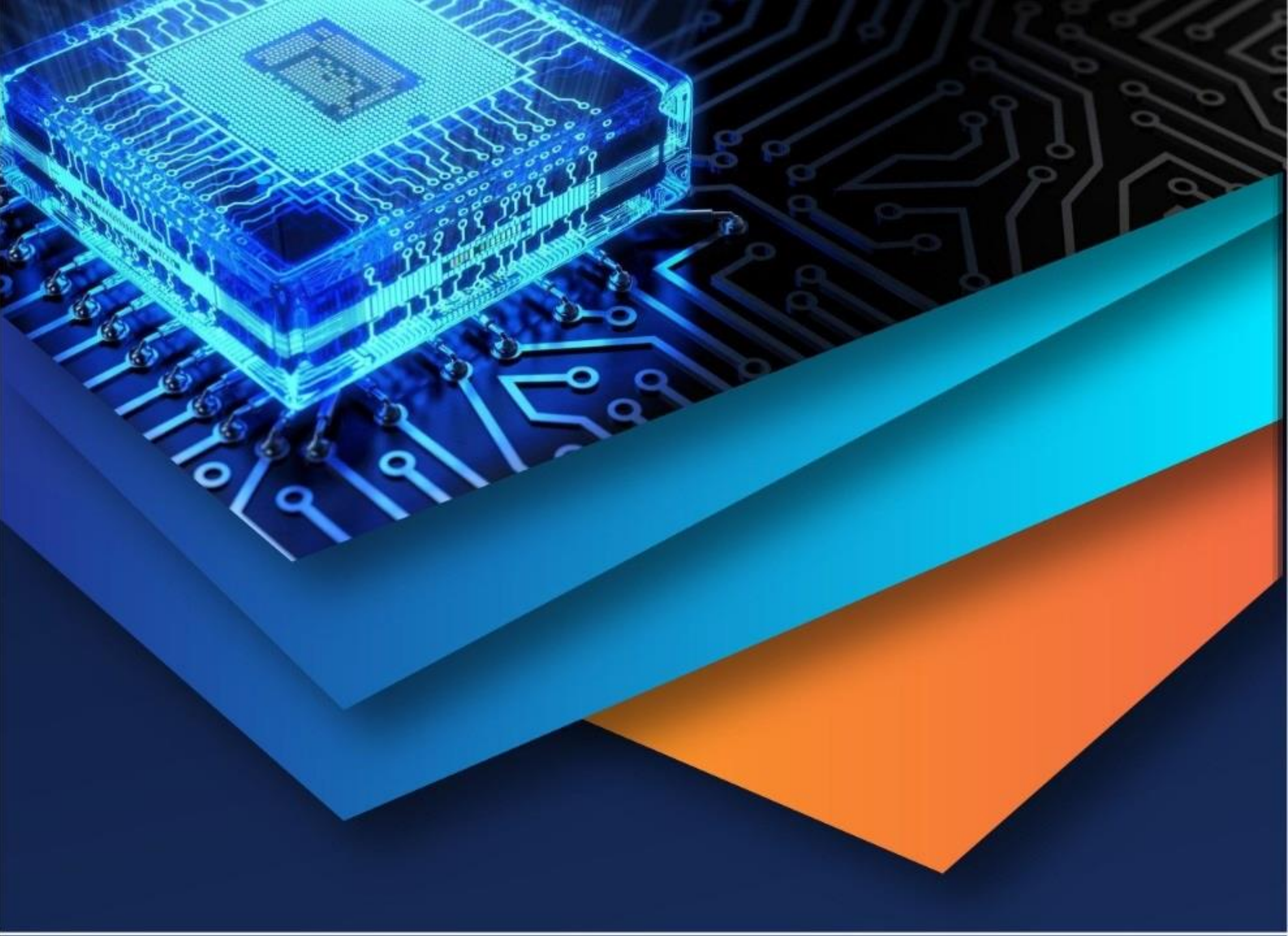

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