Strengthening of the structures by using CFRP and its effect to the various structural members

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Abstract - Carbon fiber reinforced polymer or carbon-fiber-reinforced plastic is a very strong and light fiber-reinforced polymer which contains carbon fibers. It increases stiffness up to 10% and the ultimate tensile strength 3000 MPa more than 10 times mild steel. Carbon fiber sheet is used in building to strengthening the members, to increase stiffness and ductility of structure and to make the structure more serviceable. It is commonly used where high strength and more rigidity is required. The main objective of this paper is to critically review the strengthening of the structures by using CFRP and its effect to the various structural members.

Keywords - Retrofitting, Flexural Strength, Carbon fiber reinforced polymer, stiffness, deflection.

INTRODUCTION

Retrofitting is a technique of repair and rehabilitation to modify existing structures to make them more resistant to the seismic activity, vibrations, ground motion etc. There are various materials used in strengthening the structures which are affected due to the earthquake and other factors. The various materials like carbon fibre reinforced polymer, glass fibre reinforced polymer, steel plates etc. Carbon fibers have their own benefits over other fiber reinforced polymer. Carbon fiber is preferred because of light weight, high strength, good durability, high fatigue endurance, competitive cost and ease of installation. The objective of this paper to review the strengthening of the structures by using CFRP and its effect to the various structural members.

Strengthening Effect of CFRP on Reinforced Concrete Beam.

As per the effect of the carbon fiber reinforced polymer on the reinforced concrete beam, engineers and scientists had initially used CFRP for strengthening. Significant researches have been conducted to investigate the use of composites in protecting concrete from impact force.

Myeongjung Kim et al, 2017; studied the strengthening effect of CFRP bands that were wrapped at certain intervals in the beams were analyzed. The thickness of the CFRP band was 2mm and 8mm.The normal concrete beam 150mm wide, 200 mm high and 1200mm long was subjected to multiple strikes with a load of 461 kg from 300mm height. Until the beam was observed to fail. The drop weight test was carried out in a Drop Weight Test Machine developed at Kangwon National University. The deflection of the central point of the beam was measured by the LVDT and strain in various positions of the steel bars were recorded by the strain gauges. The impact force between the hammer and the beam was recorded by a load cell placed at the load hammer .The results shows that application of the CFRP around the beams is beneficial in shear strengthening. The failure pattern can be seen in figure 2.

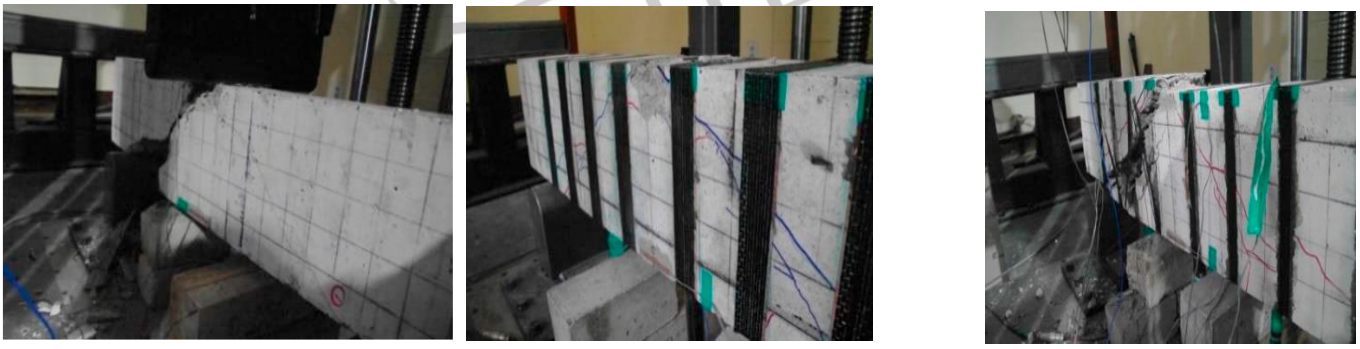

Fig.2. Failure pattern in the beams

Yasmeen Taleb Obaidat et al, 2009; also studied effect on RC beams by introducing different length CFRP strips. This paper presented the results of an experimental study to investigate the behaviour of structurally damaged full-scale reinforced concrete beams retrofitted with CFRP laminates in shear or in flexure. In this paper twelve beams were tested under four point bending after curing six months. The beams were divided into two groups. For group RF, focus was on flexural behaviour, and for group RS focus was on shear behaviour. For group RF, two beams were used as control beams. The other six were preloaded until flexural cracks appeared and then retrofitted with CFRP. Three different lengths of CFRP were used, with two nominally equal beams for each length. Finally, the retrofitted beams were loaded until failure and the results were compared with the control beams. For group

RS, two beams were used as control beams, and the other two were preloaded until shear cracks appeared and then retrofitted and finally tested to failure and finally conclude that the increase in maximum load of the retrofitted specimens reached values of about 23 % for retrofitting in shear and between 7% and 33 % for retrofitting in flexure. The crack width for the retrofitted beams is decreased compared to the control beams. Experimental results showed that increasing the CFRP plate length in flexural retrofitting can make the CFRP more effective for concrete repair and strengthening. This means that insufficient strengthening lengths do not produce the intended strengthening effect.

Strengthening effect of CFRP on Beam-column joint.

S. H. Alsayed et al 2010; epoxy-bonded CFRP sheets have been used with different schemes for the upgrading the shear strength and ductility of Knee or corner reinforced concrete beam-column joints. In this paper the thickness and length of CFRP sheets have been increased, and the results of CFRP repaired and strengthened specimens were compared with their corresponding control specimens through hysteretic loops, load-displacement envelopes, joint shear distortion, ductility, and stiffness degradation and it was observed that CFRP sheets improve the shear resistance, ductility, and deformation capacity of the seismically deficient RC corner joints to a great extent.

S. H. Alsayed et al 2010 epoxy-bonded CFRP sheets have been used with different schemes such as control, strengthened, repaired specimens at the joints for the upgrading the shear strength and ductility of exterior beam-column joints. The author compared the results of different scheme through hysteretic loops, load-displacement envelopes, joint shear distortion, ductility, and stiffness degradation and found that CFRP sheets are very effective in improving shear resistance and deformation capacity of the exterior beam-column joints and delaying their stiffness degradation.

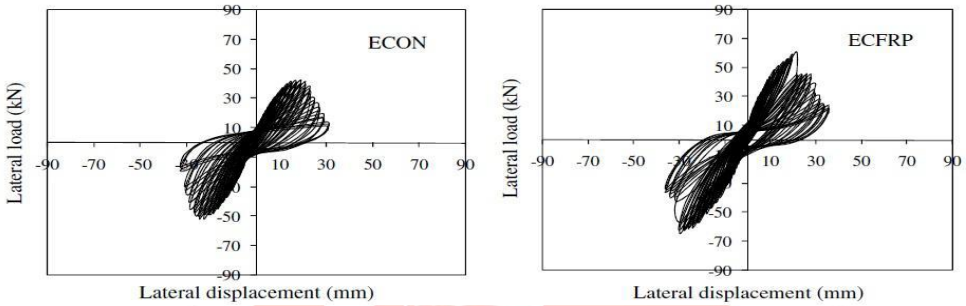

Fig 3 Load-Displacement Curve for Control and strengthen specimens (S. H. Alsayed et al 2010)

Carbon fiber Reinforced polymer

As already said that CFRP is having high strength, durability and one more thing it is easy to install. Carbon fibres are produced when polyacrylonitrile fibres (PAN), Pitch resins, or Rayon are carbonized (through oxidation and thermal pyrolysis) at high temperatures. It is commonly used whenever high strength and rigidity is needed.

Fig 1. Unidirectional and bi directional Carbon fibre sheet

Table.1 **Properties of Carbon fiber sheet**

Fiber material	High strength carbon
Areal Weight	245 gm/m2
Fabric width	500 mm
Nominal thickness	0.115mm
Ultimate Tensile Strength	3800 Mpa
Tensile Modulus	≥2750Mpa
Tensile Modulus per unit width	76 KN/mm/ply
Ultimate Rupture strain	1.25 %

Advantages

1. Low weight: The CFRP is much less dense and therefore lighter than the equivalent volume of steel. The properties of CFRP material are particularly important when installation is done in cramped locations. The use of fiber composites does not increase the weight of the structure and dimensions of the member.
2. Mechanical strength: CFRP can provide a maximum material stiffness to density ratio of 3.5to 5 times that of aluminum or steel. CFRP is so strong and stiff for its weight, it can out-perform the other materials.
3. Formability: The material can take up irregularities in the shape of the concrete surface. It can be molded to almost any desired shape.
4. Chemical resistance: CFRP is less reactive, making it ideal as a protective covering for surfaces where chemical.
5. Joints: Laps and joints are not required.
6. Corrosion resistance: Unlike metal, CFRP does not rust away and it can be used to make long-lasting structures.
7. Low maintenance: Once CFRP is installed, it requires less maintenance. The materials fibers and resins are durable if correctly specified, and require little maintenance. If they are damaged under loading, it is relatively simple to repair them, by adding an additional layer.
8. Durable: It has high resistance to fatigue and has shown excellent durability over the last 50 years.
9. Easy to apply: The implementation of CFRP plate or sheet material is very easy like applying wallpaper, once it has been rolled on carefully to remove entrapped air and excess adhesive it may be left unsupported. Fiber composite materials are available in very long lengths while steel plate is generally limited to 6 m. These various factors in combination lead to a significantly simpler and quicker strengthening process than when using steel plate.

Application

1. Aerospace Engineering: - It is used in wings and fuselage component of airplane. The A380 is the first commercial airline to have a central wing box made of CFRP. It has high strength to weight ratio used in micro air vehicles.
2. Automotive Engineering: - It is used in high end automobile racing vehicles in body panel due to increase strength and decrease weight.
3. Civil Engineering: - It is used in building to strengthening the joint and to increase stiffness and ductility of structure. It increases stiffness up to 10% and the ultimate tensile strength 3000 MPa more than 10 times mild steel.
4. Carbon Fiber microelectrodes: - It is used as single carbon fiber with dia 5-7 μm is sealed in a glass capillary and also used in amperometry or fast scan cyclic voltammeter for detection of biochemical signaling.
5. Sports goods: - It is used in tennis, badminton racquets sport kite spare, high quality arrow shafts, hockey stick, fishing rod. In 2006 cricket bats with thin carbon fiber layer on the back were introduced and used in competitive match including Ricky ponting and Michal Hussey but it banned from all 1st class matches by ICC in 2007.

Limitation

1. It is very expensive which limits its use in sometimes.
2. In case of pre-stressing construction it cannot be used due to difficulties in anchorage of strands.
3. It has no endurance limit when exposed to cyclic loading.
4. In case of automotive application, its use is limited for creating body panel.

Conclusion

On the basis of the existing literature it can be concluded that the flexural strength of the beams increases by introducing the CFRP to them and Crack width decreases. Stiffness of the CFRP-retrofitted beams also increases. Strength of the beams increases with the increase of the length of CFRP sheets .It has been found that CFRP sheets are very effective in improving shear resistance and deformation capacity of the exterior beam-column joints and delaying their stiffness degradation.

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