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Retrofitting Using Fibre Reinforce Polymers. A Review

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Abstract *-Civil engineering structures in their course of lifespan may be subjected to unforeseen supplementary loads accompanying design loads and due to change of global conditions which leads to deterioration or degradation of structure as a whole or may be a structure component is affected, therefore there is a need to upgrade technology and come up with innovative techniques to handle this complications to the existing structures. This barrier can be vanquished or sorted out by a method called Retrofitting. Among numerous types of retrofitting, the most emerging and efficient among all methods is retrofitting by Fiber reinforced polymers (FRP). This study focuses on scrutiny of distinct fiber reinforced polymer materials accessible and their firmness besides regular reinforcing materials, and their usage in most productive areas and this study also concentrated on what are available different configurations of FRP and the approaches for their application are also addressed.*

Key Words: *Basalt Fibers, Carbon fibers, External Bonding, Jacketing, Near Surface Mounting, Retrofitting*

1. INTRODUCTION

Sustainable development has been a topic of debate for many years across the globe. Depletion of natural resources is one of the root causes for this debate which incidentally related to evolution of urbanization and construction. As the age of building or structure is limited, which need to be replaced eventually leads to effective and efficient use of existing structure over its lifespan. Concerning these problems, many findings and solutions end up at one of the methods called ` and other structural components are limited to only certain types of structures and found to be expensive. So, to get better control over this drawback, need for High Performance Fiber Reinforced Cementitious Components (HPFRC's) was raised globally

The FRP is a new type of high-performance material that is composed of a fiber material and a matrix material mixed in a certain proportion and compounded via certain process. FRP's fiber material plays the role of stiffening and strengthening, resin plays the role of bonding. Besides other materials FRP's have high strength, light weight, corrosion resistance and fatigue resistance [1]. Commonly used FRP's are Carbon fiber reinforced polymer(CFRP), Glass fiber reinforced polymer (GFRP), Basalt fiber reinforced polymer(BFRP), and Aramid fiber reinforced polymer (AFRP) [2],[3] which are mainly used in the forms of FRP sheets, plates, bars, cables and grids [4] . FRP'S can be applied by External Bonded (EB) and Near Surface Mounted (NSM) techniques.

2. Material

As we saw the advantages of FRP over traditional methods, now we will review the different FRP Materials and methods of application.

2.1 CFRP

Carbon Fibre Reinforced Polymer is one of the earliest fiber composite materials widely used in fiber reinforced composites because of its high tensile strength and elastic modulus. In comparison with the steel reinforcements, the elastic modulus, fatigue strength, and creep resistance of the CFRP were higher, and its expansion coefficient in the direction is less. CFRP exhibits electrical conductivity thus, it cannot be used in applications requiring insulation. Structural members which require reinforcing have shown good increase in load bearing, flexural resistance and decreased deflections.

D S Adsam Gideon and P Alagusundaramoorthy [5] conducted experiments on high shear span ratio of value 5.2, RC beams reinforced with CFRP using Externally Bonded application technique under two-point loading method. Results specified that the increase in load at yield is 44% and 47% respectively and the increase in ultimate load is 36% and 53% respectively also an increase of 55% and 61% stiffness was achieved when two reinforced were compared to average values of control beams

M.Chellapandian and S.Suriya Prakash [6] experimented use of CFRP for reinforcing heavily damaged columns with eccentric loading and the results showed that the strength was reduced by 26% compared to original column of ultimate load 760KN when severe damage column was repaired using quick set cement but axial displacement reduced by 59%. Reinforcement using the NSM technique of CFRP restored the strength/ultimate load by 102% whereas Hybrid repair specimen (combination of NSM with External bonding of CFRP) resulted in strength increase by 125%. It also reported that bending was also restrained for fibre reinforced columns

2.2 BFRP

Basalt *Fibre Reinforced Polymers are relatively new and is an inorganic fiber material derived from the raw material of the glassy basalt mine formed by volcanic eruption, which is stretched by a spinneret after being crushed and fused at a high temperature around 1400°C. These are non-toxic, natural, eco-friendly, and environmentally safe and possess high strength, stability, and resistance to chemical erosion. Although the tensile strength and elastic modulus of basalt fiber are lower than those of carbon fiber, basalt fiber has advantages with regard to the ductility, cost, corrosion resistance, and high-temperature resistance. Basalt fiber is particularly suitable for seismic structures with a high ultimate strain and good ductility.*

Sim et al [7] examined the four-point loading failure of 10 basalt fiber-reinforced concrete beams. Revealed that the yielding strength and ultimate strength increased by 15% and 20% with one layer of basalt fiber sheet, 26% and 27% with two layers, and 16% and 29% with three layers, respectively

Li-Jun Ouyang1, Wan-Yang Gao2, Bin Zhen3, and Zhou-Dao[8] Lu did a comparative study on column reinforced using BFRP, CFRP and combination of both (inner one is BFRP). It is found that three specimens show almost similar Axial and Flexure strengths and also similar failure mechanisms. A cost comparative study also showed that Basalt fibres are very economical Therefore, BFRP composites are considered as feasible and sustainable alternatives to conventional FRP composites for future strengthening applications of RC structures

2.3GFRP

Glass Fibre Reinforced Polymer is a composite engineering material with the reinforced material of glass fiber and the polymer matrix of synthetic resin. It has a smooth surface, excellent permeability resistance and corrosion resistance similar to BFRP. It is also highly cost-effective. Steel is an isotropic material, and it is very prone to electrochemical corrosion. In contrast GFRP is an anisotropic material with excellent tension performance. However, the elastic modulus of GFRP is low, the creep is large, and the durability is poor.

T. Cadenazzi, G. Dotelli, M. Rossini, S. Nolan, and A. Nanni [9] did a life cycle analysis of a bridge and reported that with the use of GFRP for strengthening concrete bridges from start to end of its life can reduce global warming, photochemical oxidant creation, acidification, and eutrophication by 25%, 15%, 5%, and 50%, respectively.

2.4 AFRP

Aramid Fibre Reinforced Polymer is a high-strength aromatic polyamide synthetic organic fiber with low compressive strength and high tensile strength. But this fibre possesses light weight, high strength, and good corrosion and heat resistance[11]. AFRP is made of aramid fibers arranged in one or two directions, and they are light, soft, durable, insulating, and corrosion resistant. Compared with GFRP, AFRP has higher strength, higher elastic modulus, better heat resistance, and lower density . Most important advantage of AFRP when compared to CFRP is, it is easier to fabricate, has a higher alkaline resistance, and is less expensive

2.5 Hybrid fibre

Hybrid fiber is a composite material with one or more than two types of fibers reinforcing the same matrix, which improves the comprehensive mechanical properties of the single fiber material, increases the fiber utilization rate, and reduces the cost. Polyolefin fiber is the most popular synthetic fiber used for strengthening concrete members.

3. TYPES

3.1 FRP Sheets

This form of fiber reinforcements are mostly used. Made by fabrication of long, continuous fibers. These are affixed to the surface of the concrete members after being impregnated with resin. FRP sheets generally only bear unidirectional stretching. This material acts as good resistance with seawater. Also, studies show that the more the number of layers, the higher the durability. Application involves like jacketing/covering entire the structure, adding strips, applying on only one side of the element i.e. applying to the tension side of beam to resist flexure and applying in side face to resist shear

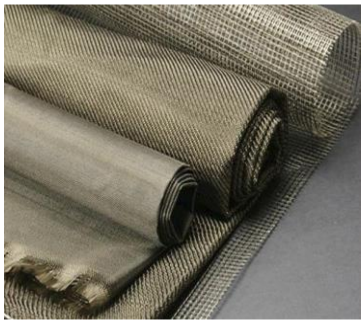

Fig-1: FRP Sheets

3.2 FRP Bars

Structural reinforcing bars made by fabrication via a unidirectional pultrusion molding process. Surface of the FRP bar can be ribbed to enhance the bonding capacity, in contrast to that of a round bar. Density of CFRP bars is only approximately one quarter of that of the steel, which is beneficial for reducing the weight

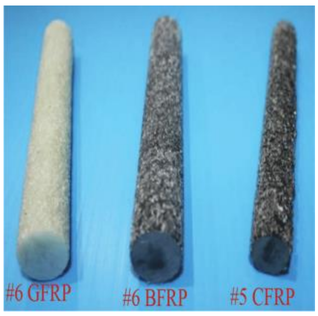

Fig-2: FRP Bars

of the structure

Fatigue resistance of CFRP bars is better than that of steel. But low elastic modulus of CFRP bars results in excessive deflection and wide cracks of concrete structures with CFRP bars, which can be avoided by applying prestress. Compared with steel, FRP bars can reduce the effects of electromagnetic fields on instruments inside the structure as these are antimagnetic

3.3 FRP Grids

FRP grids are lighter and thinner than steel bars composed of high strength fiber and resin with good corrosion resistance. FRP grids have longitudinal and transverse fiber bars, when subjected to tensile forces, which can act as constraints in both directions, having certain strength and stiffness. Method for reinforcing with FRP grid involves fixing the FRP grid on the concrete surface with anchors and then applying a sealing treatment/concrete layer as a protection, which can improve the uniformity of the force transmission, as well as the debonding failure resistance, durability, and fire resistance. FRP grid has excellent durability in cold areas and coastal areas. FRP grid is easy to transport and apply without heavy-lifting equipment.

Fig-3: FRP Grids

4. APPLICATION

There are two main methods of application of FRP to the concrete element. They are Externally Bonded (EB) and Near Surface Mounted (NSM). EB is most widely used. Surface is cleaned and FRP sheets or grids are attached to the surface using resins mostly made of epoxy. Whereas NSM is an improved version of the traditional EB method , it involves placing FRP bars or laminates into pre-cut grooves on the surface of the concrete members with the help of binder. In comparison with EB, NSM FRP exhibits a higher strengthening efficiency and better protection against environmental agents, vandalism, impact loads, and exposure to high temperatures. Debonding due to shear, flexural and stress concentration at joints is the main failure in EB method, whereas rupture of rods in NSM technique is of major concern. A new method which is under much usage is Prestressed bars. External prestressing reinforcement technology can improve the internal force and deformation of the control section and enhance the bearing capacity, cracking resistance, and deformation resistance, because the internal force generated by prestressing on the structure offsets parts of the internal force generated by the loads.

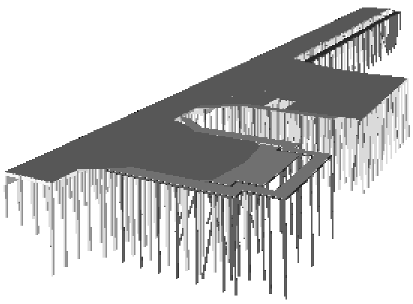

Fig-4: Structural model of San Francisco waterfront piers

5. CASE STUDIES

5.1San Francisco waterfront Piers

San Francisco water front structure which was constructed in late 1910,was built on precast concrete driven piles and consist of concrete deck and concrete beams with concrete deck. A Series of buildings which have historic significance are supported on this pier. As of time passes and as part of redevelopment some of these buildings are to be refurbished and some new structures are to constructed in this water front

As per standards required which are mentioned in building code of san Francisco proposed that structure have to be strengthen in terms of gravity and be able to with stand seismic loads .As age of pier is too high and due to its surrounding marine environment piers are to be repaired. As a solution to problem this ,retrofitting using both glass and carbon FRP has been proposed and adopted for numerous reasons some of them are achieving stability in system because of corrosive environment and other would be it is economical over other methods and other would be non-intrusive nature. The design procedure includes encase top of existing piers with carbon FRP that will intensify plastic rotation capacity and multiply system ductility which in turn reduces the magnitude of seismic load which is essential to sustain

5.2 Belltower of Santa Lucias Church

The medieval bell tower in Serra San Quirico ,Italy was hit by Umbria Marche earthquake in 1977 subjected to heavy damage. There was urgent need to repair this structure in possible way that it should not affect other surrounding residential construction which are of same age .Solution adopted to this problem is, seismic retrofitting by composite materials rather than traditional retrofitting strategies

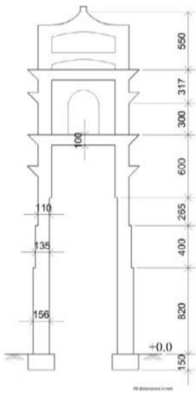

Fig-5: Cross section of bell tower

initially retrofitting by steel reticular system anchored to the inner side of tower was reported, to fulfil the improvement of seismic capacity of tower. But architectural heritage authority found that retrofitting by steel would violated the above prescribed principles and so they rejected it and they have chosen to retrofit by frp was proposed, planned, designed, approved and installed further push over analysis has been performed and evaluated the test results for both retrofitted structure and ordinary building this test results show effective is the FRP intervention

6. CONCLUSION

Although FRP materials are not much effective over large areas compared to traditional steel but they come out to be economical and cost effective when compared with other complements of conventional steel. FRP materials provides solutions to various engineering problems. This study enhances researches about various advantages of FRP materials in various forms

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