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METHODS OF STRENGTHENING USINGFIBRE REINFORCED POLYMER COMPOSITE

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ABSTRACT

Strength of the building is generated from the structural dimensions, materials, shape, and number of structural elements, etc. Ductility of the building is generated from good detailing, materials used, degree of seismic resistant, etc. The results generated by the adopted retrofitting techniques must fulfill the minimum requirements on the buildings codes, such as deformation, detailing, strength, etc.The purpose of this research is to investigate the behaviour of reinforced concrete beams strengthened with fibre reinforced polymers. The use of composites prevents large trees from being over harvested near bridge sites and eliminates any potential environmental impacts of treated wood or galvanized steel used in riparian environments.FRP composites provide improved performance benefits over metals due to its inherent properties.

Keywords: Retrofitting, structural functionality, seismic retrofit, Public safety.

1. INTRODUCTION

Whilst current practice of seismic retrofitting is predominantly concerned with structural improvements to reduce the seismic hazard of using the structures, it is similarly essential to reduce the hazards and losses from non-structural elements. FRP composites allow a designer to go next level beyond material substitution – to produce true composite parts and complex shapes. In the past, seismic retrofit was primarily applied to achieve public safety, with engineering solutions limited by economic and political considerations. However, with the development of Performance Based on Earthquake Engineering (PBEE), several levels of performance objectives are gradually recognised. Retrofitting has many more requirements now-a-days. It is widely used in many sectors and most commonly in constructing high rise buildings. Retrofitting is useful for Survivability of a structure, Improvement of structural functionality, Public safety standpoint, Durability of a building by alarming earlier, Reduction of the seismic demand by means of supplementary damping and/or use of base isolation systems, Increase in local capacity of structural elements etc. The strength-to-weight and stiffness-to-weight ratios are the major reasons to use. FRP composites provide value as innovative solutions to customer problems. With all the benefits of FRP composite, acquisition cost may be higher than traditional materials. They provide excellent resistance to chemicals and corrosion and enable FRP composites to thrive in environments that destroy wood, steel or concrete

2. METHODS OF STRENGTHENING USING FIBRE REINFORCED POLYMER COMPOSITE

There are a lot of methods which are used for strengthening by fibre reinforced polymer composites as numerous variety of fibre reinforced composites are possible. Fibre Reinforced Polymer (FRP) composites are the new material of choice. The composite age is revolutionizing our society and impacting our daily lives by giving us products to use that are lighter, more durable and have infinite design flexibility. Organic and inorganic fibres are used to reinforce composite materials. Organic fibres have low density, flexibility, and elasticity. Inorganic fibres are of high modulus, high thermal stability and possess greater rigidity than organic fibres.

A type of FRP composite, Glass fibres are inexpensive, easy to manufacture, possess high strength and stiffness with respect to plastics with which they are reinforced. Metal fibres, another variety of FRP composite are easily produced and are more ductile, apart from being sensitive to surface damage and possess high strengths and temperature resistance. Alumina Fibres offers good compressive strength rather than tensile strength. Its important property is its high melting point of about 2000 C. Boron fibres are basically composites, in which boron is coated on a substance which forms the substrate, usually made of tungsten.Properties of boron fibres generally change with diameter. Their strengths often compare with those of glass fibres, but their tensile modulus is high, almost four to five that of glass.

2.1 Retrofitting using FibreReinforced Polymer (FRP):

Several researchers have investigated the possibility and feasibility of fibre reinforced

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polymer composite jackets for seismic strengthening of columns winding them with high strength Carbon fibre around column surface to add spiral hoops. Carbon fibre is flexible and can be made to contact the surface tightly for a high degree of confinement. Confinement is of high degree because carbon fibre is of high strength and high modulus of elasticity is used. It has also got light weight and rusting does not occur. Jacketing is based mostly on engineering judgment as there is a dearth of guidelines.Fig. 2.1 presents the wrapping of carbon fibre reinforced polymer in stirrups around beam. And Fig.2.2 shows the wrapping of carbon fibre reinforced polymer around vertical column.

2.2Retrofitting by Steel Wrapping:

Rectangular jacketing prefabricated two L-shaped panels are mostly used. The use of rectangular jackets has proved to be successful in case of small size columns up to 36 inch width, but on larger columns, rectangular jackets appear to be incapable to provide adequate confinement. The thickness of steel plates should be at least 6 mm. Gap between steel jacket and concrete column are filled with cementations grout. Two anchor bolts are intended to stiffen the steel jacket and improve confinement of the splice. Free ends of jackets are welded throughout the height of jacket.

Fig. 2.1: *Retrofitting using steel jacketing*

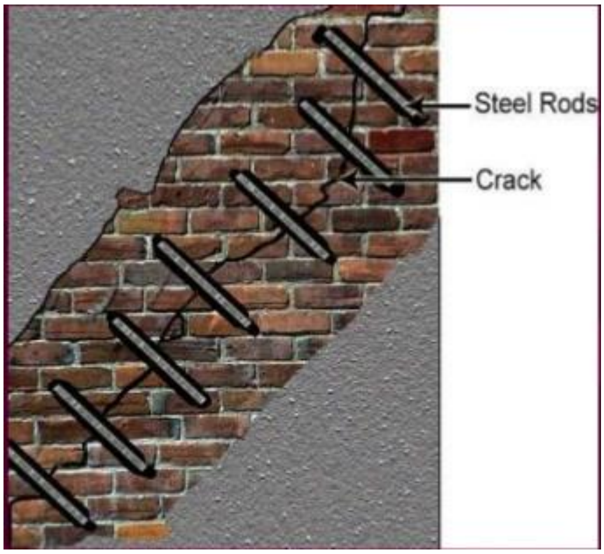

Fig.2.2: *Formation of crack in a structure and reinforcing it with steel rods*

2.3. Retrofitting using Reinforced Concrete (RC) jacketing:

Retrofitting by reinforced concrete jacketing can be employed as a repair or strengthening scheme by passing new longitudinal reinforcement through drilled in the slab and by placing new concrete in beam column joints. Damaged regions of the existing members

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should be repaired prior to their jacketing. The minimum width of jacket should be 10 cm for concrete cast in place and 4 cm for shortcrete. The jacket should match with the existing structure. The minimum area of longitudinal reinforcement is 3Afy, where, A is the area of contact in cm^2 and f_y is in kg/cm^2 and spacing should not exceed six times of the width of the new elements (the jacket in the case) up to the limit of 60 cm. The percentage of steel in the jacket with respect to the jacket area should be limited between 0.015and 0.04 and at least, 12 mm bar should be used at every corner for a four sided jacket. The connectors should be anchored in both the concrete such that it may develop at least 80% of their yielding stress and they should be distributed uniformly.

Fig.2.3: *A column reinforced with RC jacketing*

Fig. 2.3 and Fig. 2.4 show how a column can be reinforced with RC jacketing around it.

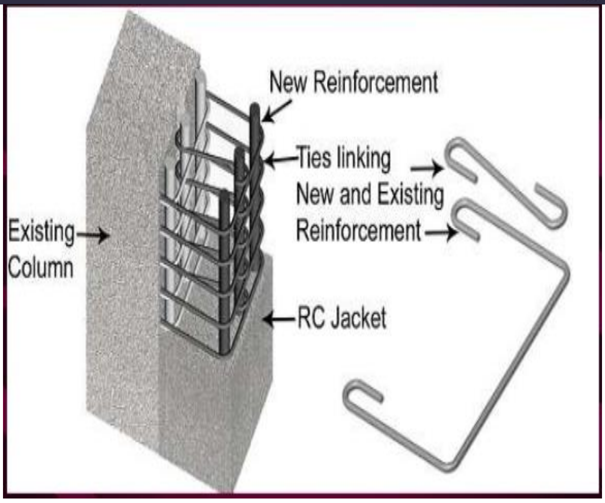

Fig.2.4: *Sectional view of a column with a RC jacketing*

It is better to use reinforced bars anchored with epoxy resins of grouts. In comparison to the jacketing of RC columns, jacketing of beams with slabs is difficult because slab causes hindrance in the jacket.

2.4 Retrofittingusing Ferro Cement (FC) jacketing:

Ferro cement is a composite material consisting of rich cement mortar matrixuniformly reinforced with one or more layers of very thin wire mesh with or without supporting skeletal steel. These are the most commonly used retrofitting material due to their easy availability, durability and their property of being cast to any shape without needing significant formwork. The credit of using ferrocement in the present day goes to Joseph Louis Lambot who in 1848, constructed several rowing boats, plant pots,

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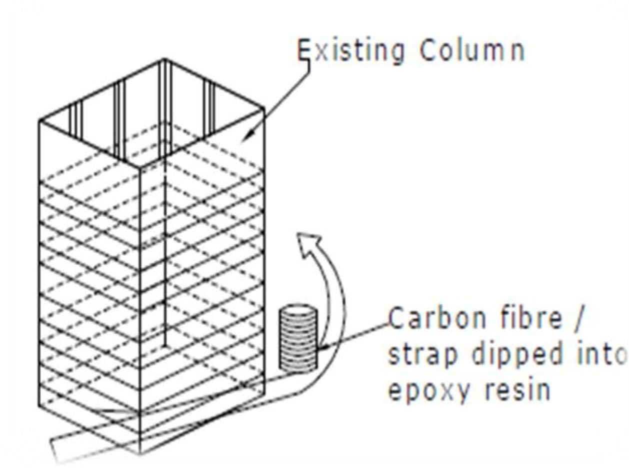
seats & other items from a material he called "Ferciment". The Ferro cement construction has an edge over the conventional reinforced concrete material because of its lighter weight, ease of construction, low self-weight, thinner section as compared to RCC & a high tensile strength which makes it a favorable material for prefabrication also. The respond of ferro-cement in retrofitting is very convenient and as a result it is using mostly in different types of retrofitting works in recent days.The total volume of reinforcement in ferro cement ranges 5-8 percent by volume of structural elements. The reinforcement used in ferro cement is of two types- skeletal steel & wire mesh.

2.5 Retrofitting with Carbon Fibre Reinforced Polymer (CFRP):

The Carbon FibreReinforced Polymer reinforcement is applied in strip form which is more economical compared to wrapping or formingit into bar shape, because it is easier and it also uses less fibretoachieve similar performance. The CFRP reinforced concrete beam gives the requiredresistance and required strength as designed, with behavior similar to those beams which are reinforced with steel bars.



Several types of chemical modifications are employed to improve the interfacial matrix-fibre bonding resulting in the enhancement of tensile properties of thefibre reinforced polymer composites.

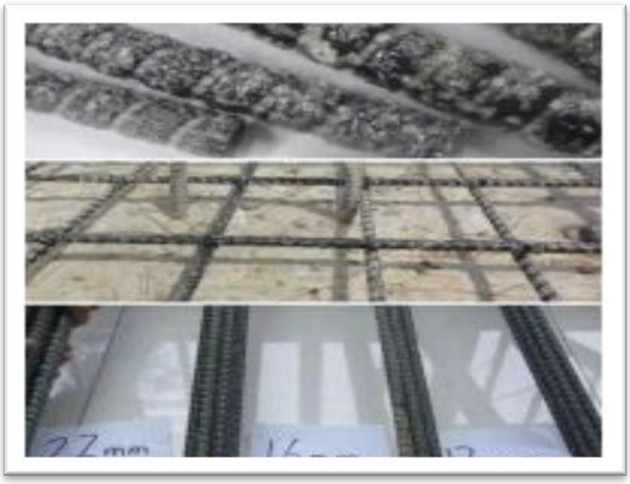


***Fig.2.9:**Retrofitting using fibre reinforced polymer*

3. LITERATURE REVIEW

V. Tagliaferri et al [1] (1985)carried out an experimental and analytical study to verify the effect of machiningparameters on the cut quality and on the mechanical behavior of the material. The test showed that the width of the damage zone is correlated to the ratio between drilling speed and feed rate and the quality of the material at the edge of the hole doesn't influence tensile strength. No correlation seems to exist between the bearing strength and the damaged zone in the case of small zone widths.

Janos Gergely, Chris P. Pantelides and Lawrence D. Reaveley (2000)[2] carried out tests to examine the rehabilitation of RC columns jacketed with carbon fibre reinforced composites for improving shear strength, confinement and have received considerable attention for improving the shear capacity of beam-column using FRP composite materials is in the early stages.

P. J Herrera Franco and A Valadez-Gonzalez [3] (2004)carried out extensive study on the mechanical behavior high densitypolyethylene (HDPE) reinforced with continuous henequen fibre. Using an alkaline treatment and a matrix pre impregnation together with a saline coupling agent fibre-matrix adhesion was strengthened. A maximum value for the tensile strength was obtained for a certain saline concentration but when using higher concentrations, the tensile strength did not increase. The increase in the mechanical properties ranged between 3 and 43%, for the longitudinal tensile and flexural properties, whereas in the transverse direction to the fibre, the increase was greater than 50% with respect to the properties of the composite made with untreated fibre composite. 50% increase in case shear strength was also observed.

N.S Mohan et al [4] (2006)investigated Machining processes are generally used for cutting, drilling, or contouring composite laminates. A series of experiments were conducted using TRIAC, VMC, CNC machining Centre to machinate the composite laminate specimens at various cutting parameters and material parameters. The measured results of delamination are interpreted and analyzed using the commercial statistical software MINITAB14.

Xue Li et al [5] (2007)carried out extensive study on natural fibres a replacement for man-made fibre. This has opened up new industrial possibilities.In this paper different chemical alterations used in natural fibre reinforced plastics have been reviewed like the alkali action, saline,benzylation, acetylation, acylation etc. the main aim of these processes is to provide for a better bond between the surface and polymer matrix. It was observed that natural fibres have lower cost and density in comparison to man-made fibres and are also bio-degradable.

4. OBJECTIVES

Factors that should be considered in selecting the method include the effectiveness of the various retrofitting methods with respect to the required performance improvements, the viability of execution of the retrofitting work, the impact of the retrofitting work on the surrounding environment, the ease of maintenance after retrofitting, economy and other factors. The main objectives of this project are:

- The process by which the retrofitting has been done should be fully optimized.
- The retrofitting method should be selected as per demand of any particular work.
- The retrofitting technique must satisfy the strength and economy criteria of the project.
- Completion of the project should not be delayed.
- Construction cost and maintenance cost should be taken care of.
- The finishing works and the weight of the building should be given utmost importance.

5. ADVANTAGES OF USING FIBRE REINFORCED POLYMER (FRP) COMPOSITE

The advantages of using Fibre Reinforced Polymer (FRP) Composites in trail bridge applications include their light weight, high strength, Flexibility, resistance to corrosion, fast and easy installation. The cost of the composites is less than stainless or high-Carbon alloy steel components that might be used in highly corrosive environments.

- Flexibility: Very flexible during installation: FRP materials provide better flexibility than steel, timber, etc. and hence they can easily be used in any manufacturing process using custom diameter size.
- High strength:The high strength of FRP materials is generally attributed to its high tensile strength (1600-3700 MPa) and comparatively lower values of modulus of elasticity as compared to steel.
- Light weight: FRP composites, due to lower density, can deliver a weight savings of 25 to 50 percent over traditional materials. Composite densities range from 0.045 lb/in^3 to 0.072 lb/in^3 as compared to 0.10 lb/in^3 for aluminium and 0.29 lb/in^3 for steel.
- Resistant to corrosion: The FRP materials do not require any lining, coating, cathodic protection or other forms of corrosion

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protection. The effectual service life is extended.

- Pre-fabricated/Integral Structure: FRP composites allow a designer to go next level beyond material substitution – to produce true composite parts and complex shapes.
- Cost: FRP composites provide value as innovative solutions to customer problems. With all the benefits of FRP composite, acquisition cost may be higher than traditional materials.
- Composite performance: FRP composites provide improved performance benefits over metals due to its inherent properties. The strength-to-weight and stiffness-to-weight ratios are the major reasons to use. They provide excellent resistance to chemicals and corrosion and enable FRP composites to thrive in environments that destroy wood, steel or concrete.

Environmental Advantages:

- Life cycle assessment: In order to systematically consider the environmental aspects, the R&D methodology has to balance the ecological, economic and technological aspects of design and production. Life Cycle Assessment (LCA)is a suitable tool to assess the environmental impacts associated to a product or a service.

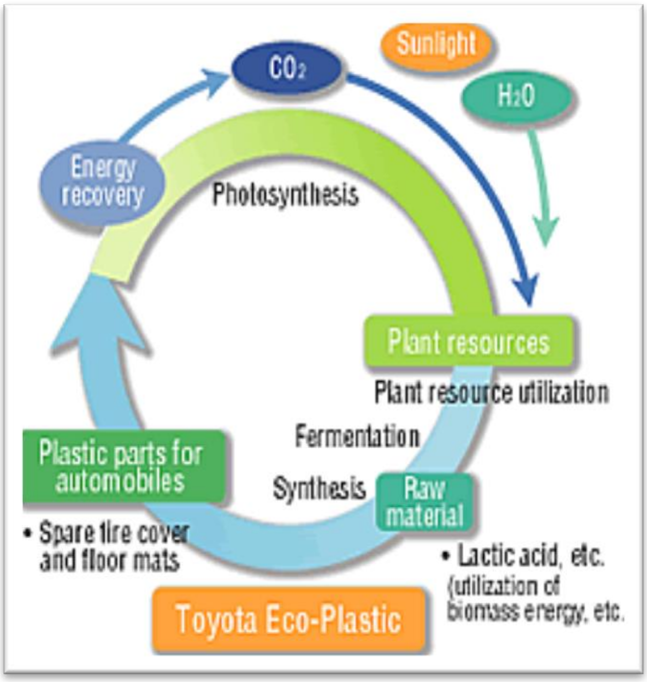

Fig.5.1:*Amount of carbon dioxide absorbed and emitted is equal.*

- Renewability: Bio-plastic materials have ingredients from non-delectable resources and can be derived from a selection of sources. Use of these materials is subject to debate, with certain sources potentially depleting the food chain. There are however a range of non-depleting sources available and these options are all an essential part of the selection process.
- Carbon neutrality: Plant fibres do not contribute towards global warming as their production cycle is usually carbon neutral, i.e. they absorb at least the same amount of CO_2 as they emit. In addition, organic wastes produced during processing can be used as fuel and generate electricity, stock

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feed and housing materials. The following figure shows the amount of carbon dioxide is balanced and the percentage of absorbed and emitted carbon dioxide is equal.

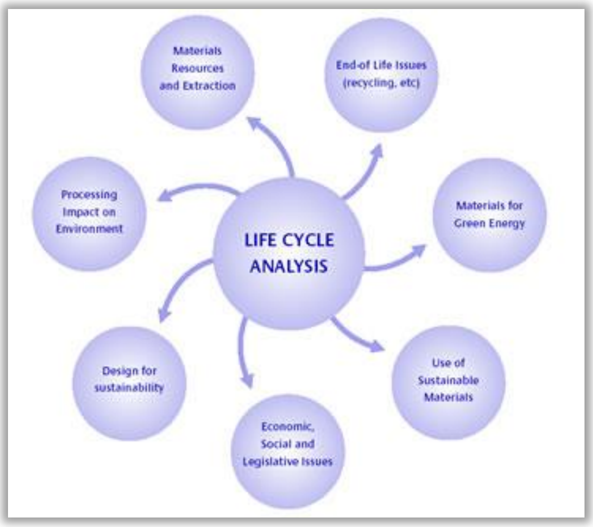

Fig.5.2: *Representation of the Life cycle assessment*

- Bio-degradability: Standard petrochemical derived polymers can last thousands of years. Biodegradable materials are designed to last for the expected life span of a product and then breakdown after use. Additives exist that will enable a standard materials to last for the expected life span of a product and then breakdown after use. Additives also exist that will enable a standard materials to biodegrade though itslong term effects are not fully understood.
- Agricultural residue: The agricultural residue formed after the usage of natural fibres can be replenished and renewed. The use of inexpensive agricultural residues and their hybrids that are 8-10 times cheaper than agricultural fibres is demonstrated to be a better way of getting sustainable materials with better performance. Green renewable composites from poly lactide (PLA), agricultural residues (wheat straw, corn, soy stalks, and their hybrids) were successfully prepared through twin-screw extrusion, followed by injection moulding.
- Health friendly: The fibres are eco-friendly in processing, have no wear of tooling and have no skin problems like GFRP.

Natural fibres such as hemp, sisal, flax, jute and wood-fibres possess good reinforcing capability when properly compounded with polymers. However, bio-based materials may increase eutrophication, phosphate equivalents, stratospheric ozone depletion, nitrous oxide equivalents caused by the application of fertilizers and pesticides during industrial biomass cultivation. The results of the Life Cycle Assessments indicate the ecological dominance of the vehicle's use phase compared to its production and recycling phase. The following figure shows the diagrammatic representation of the life cycle assessment.

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