International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 11 | Nov 2020 www.irjet.net p-ISSN: 2395-0072

A Review on Recent Materials in Structural Retrofitting: Synthetic Polymers

Gyan Prakash Sharma[1], Dr. Prof. Rakesh Patel[2]

[1]M.Tech Scholar, SIRTS, Bhopal (M.P), India
[2]Head of Department, Department of Civil Engineering, SIRTS, Bhopal (M.P), India

***

Abstract - The Era itself tells about the development made in construction materials from basic earth to timber, timber to metals, metals to polymers and polymers to hybrid composites. This advancement has attracted many structural engineers to draw the attention towards the most unexplored field of retrofitting. Retrofitting is the remedy employed in existing seismic vulnerable structure to improve its performance and durability. Thus, requires strong, light weight, flexible and easy available options in materials to fulfil the retrofitting needs. This paper covers the development made in local retrofitting techniques using modern material which includes Synthetic Fibres, Fibre reinforced polymers (FRP) and Thermoset matrix and compares their feasibility on the basis of their field performance. The applications of these materials had been proven in many retrofitting strategies such as local jacketing, wrapping and joint confinement etc. and have opened the infinite sky for future implementations.

***KeyWords*: Retrofitting, Synthetic fibres, FRP, Thermosets, Jacketing, Confinement.**

1. INTRODUCTION

Recent developments in material technology has made various engineering scheme go easy and economical. It has made such an impact that many industries like construction are changing their strategies year by year. With the development of Polymer Engineering, repair and retrofitting of exisiting building has become a major part in construction industries. Synthetic Polymers in the form of fibres are heavily employed in cement industries to increase its performance. Similarly, Polymer in form of fibre reinforced sheets, mesh and grids are readily available for different commercial use. The Amalgam of conventional material with modern material has shown tremendous advantages and possibility in construction industries. Retrofitting of old existing structure has been widely influenced by these developments in past few years. The aftermath of an earthquake and natural weathering agents imparts many changes in existing structure. They decrease its performance and durability. Thus role of retrofitting comes to play. Retrofitting scheme can help many old existing building to be utilized for a considerable period of time which is far better and economical compared to demolish that structure and to build a new one. It has been proven that use of conventional materials in member retrofitting has altered various aspect of seismic strengthening which has to be tackled in order to make a seismic resistant structure. The main problems in conventional materials are their strength to weight ratio, long curing, slow rate of strengthening and low resistance to chemical attacks. Synthetic Polymers can sort out the strength to weight ratio as their specific gravity is lowest among the recent construction materials. They also possess high young modulus and have high resistance to chemical attacks. It is flexible and is available in different forms as per requirement. Therefore, it is widely accepted in remoulding, repair and construction industries.

In the field of retrofitting, synthetic Polymers are used as Fibre Reinforced Polymers composite (FRP), shredded fibres and as thermosets. Fibre reinforced Polymers as a hybrid material was introduced in 1937. It was successfully used in Avionic design in the same year. Thus, turned a huge attraction for its mechanical and chemical properties. Application of FRP in architectural and construction industries started in 1950s but it was primarily produced for Aviation industries. With the passage of time, in 1970s, polymer industries surpassed steel industries which forced many think tanks to reschedule the available modern material with conventional materials. Retrofitting techniques using synthetic polymers has gained a huge attraction in recent years and is now widely used in member retrofit schemes. This paper covers the recent development in repair and retrofitting schemes using synthetic polymers, with a view to improve its seismic performance by blending different forms of available polymer. The main objective of this article is to present an overview of their utility, depending upon strengthening characteristics required in old seismic deprived existing structures.

1.1 Retrofitting of Concrete Structures

Retrofitting term is associated with repair and rehabilitation of old existing structures, but it has more significance. Retrofitting is defined as addition of new technology to existing system such that it improves its serviceability, efficiency and life span of old system. Retrofitting of Concrete structures has played an important role in restoration of our old heritage structures. Natural calamities like earthquake imparts huge loss due to unpredicted seismic motion to many existing buildings. Old building lacking of modern standards gets most vulnerable to serious damages and results in irreparable loss of life as well. It has been noticed that the majority of such buildings can be safely utilized, if they can be fixed by retrofitting schemes. Various studies has acknowledged that retrofitting of these seismic altered structure can cater the economic consideration and instant shelter problems in that areas instead of demolishing and replacing the structure. Therefore, retrofitting of structure has gained a great appreciation in many developing countries which offers less input capital for maximum sustainable benefits.

1.2 Classification of Retrofitting Schemes

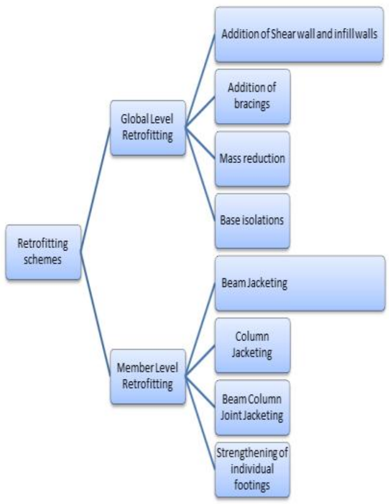


Figure-1

1.2.1 Global Retrofitting

These schemes are employed when the entire horizontal load resisting system is deemed to be deficient compared to current standards. The basic approach in this scheme utilizes increase in stiffness with limited ductility. A proper investigation of deficit structure is required in order to achieve desired ratio between strength and ductility. Global retrofitting includes addition of shear wall, infill walls, base isolations and addition of steel bracings.

1.2.2 Local Retrofitting

Local retrofitting is widely accepted as cost effective technique, as only deficit members are considered for retrofitting. In this scheme the main principle employed is to increase the shear strength of column in order to make strong column weak beam design. It also ensures increase in flexural strength with desired ductility. The most common strategies used are Jacketing and wrapping of individual members.

1.3 Trending Materials in Retrofitting

Various materials have been used till date. The selection of the material depends upon the required strength parameter of the member such that its serviceability and strength increases simultaneously and making the structure fit for future use. Materials in retrofitting can be classified as Conventional materials and Advance materials. Conventional materials are those which are employed to make structure itself example cement, steel, Concrete, RCC, Shotcrete, Ferrocement etc. Similarly, those materials other than basic conventional materials having better physical and chemical properties and can be employed to match the member's strengthening needs, is advance material. Advance Materials in retrofitting includes Fibre reinforced polymer, hybrid steel polymer composites, Carbon fibre, Polypropylene fibre and thermosets etc.

1.3.1 Fibre Reinforced Polymer (FRP)

The main ingredient to get FRP is to mix a synthetic or natural fibre in a matrix of resin and mould in a required shape. Fibre plays a vital role in governing its mechanical properties. Concentration and strength parameter of fibres both impacts the strength parameters of final product. Synthetic Fibres like Carbon or aramid fibre, glass fibre, Kevlar, polypropylene fibres etc are widely accepted for their qualitative strengths. These fibres are low in density; hence their quantity for a given weight is maximum. They also offer non corrosive properties and have good resistance to alkalies, chlorides and other chemicals. FRPs are available in different shape as a sections, grid, mess and strips. On the type of fibre used in FRP, it is designated as Carbon fibre reinforced polymer(CFRP) and Glass fibre reinforced polymer (GFRP).

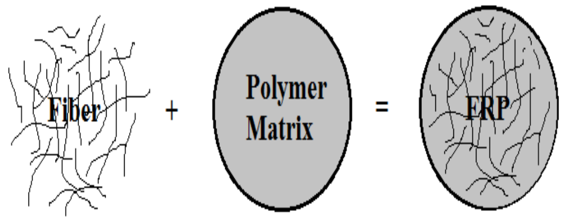


Figure-2

1.3.2 Carbon Fibre Reinforced Polymer (CFRP)

CFRP is an extremely strong and light fibre-reinforced plastic which contains carbon fibres as strengthening reinforcement. Carbon fibres are obtained when poly acrylonitrile fibres, Pitch resins, or Rayon are carbonized through oxidation and thermal pyrolysis at high temperatures. It is expensive but commonly used wherever high strength and rigidity is required. The Carbon Fibre-Reinforced Polymer (CFRP) materials have a high potential for manufacturing effective strengthening systems to increase the flexural or shear strength of RC beams. The CFRP materials have a very low weight to volume ratio, are almost immune to chemical attacks, corrosion and possess high tensile strength. Carbon Fiber Reinforced Polymers are widely used in industrial masonry structure for the retrofitting of old structures that have been already damaged due to earthquakes, chemical reaction, environment effect etc. Carbon fiber reinforced polymers (CFRPs) are one the stiffest and lightest composite materials, they are much substantial than other conventional materials in different fields of applications.

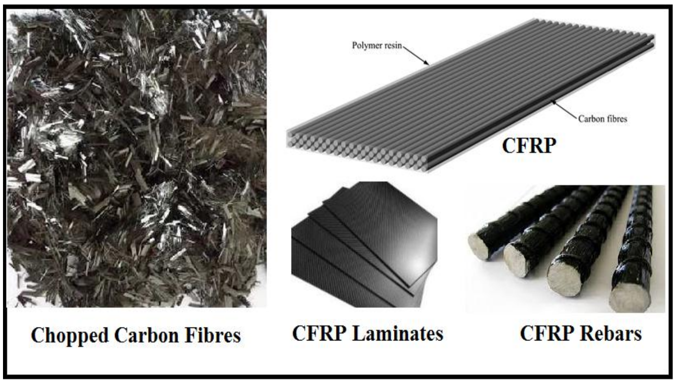


Figure-3

1.3.3 Glass Fibre Reinforced Polymer (GFRP)

This synthetic polymer is an alternative solution to cope with the expensiveness of carbon fibre by compromising small lag in strength and stiffness. Glass fibre reinforced polymer is a FRP made of glass fibre as reinforcement. Glass fibre are strong and tough and are considered less brittle compared to carbon fibre. Glass fibre has attracted a wide variety of field application due to its economic consideration compared to its mechanical properties. Glass fibres has been extensively used in Aeronautics, Automobiles, Sports Product etc, which has attracted its effectiveness utilized in construction industries too. GFRP has been effectively used as a reinforcement alternative in hydraulic structures like Piers and Bridges. Further it is gaining its popularity in repair and rehabilitation of old existing structure due to its economic cost consideration.

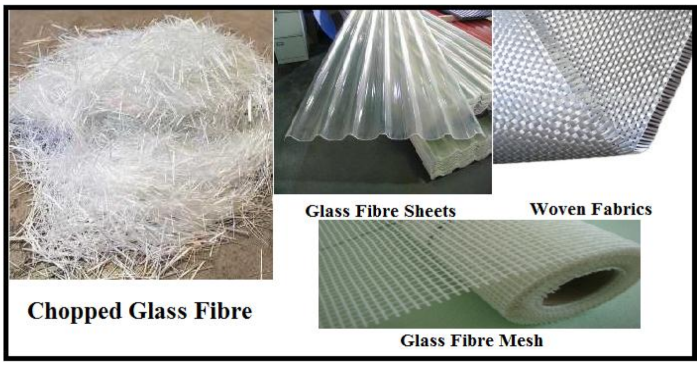


Figure-4

1.3.4 Polypropylene Fibre

For ages fibers have been used in various constructions. Polypropylene fibers are next generation synthetic fibres which are economical, durable and easily available. Polypropylene is a byproduct of petroleum. Polypropylene fibres are noncorrosive, hydrophobic, resistant to alkali, chemicals and chlorides. Therefore does not affect the water cement ratio when mixed with concrete. Polypropylene is the lightest synthetic polymer having specific gravity 0.91, therefore, the count of fibre for a given weight is maximum. Studies and researches shows its compatibility with thermosets. Polypropylene fibre when used in concrete act as secondary reinforcement. It has also been successfully used as crack arresters. Polypropylene fibre with thermosets increases the mechanical properties of the composite increasing its overall strength and toughness. It also imparts elasticity to the composite material.

Figure-5

1.3.5 Polyethylene Terephthalate Fibre

Polyethylene terephthalate fibre **(PET)** belongs to group of thermoplastic polymer of polyester family. It is one of the most recycled thermoplastic. PET is a transparent polymer which possess decent mechanical and good chemical and thermal resistant properties. Comparatively it is heavier than polypropylene, but due to its high production and recycling, its availability in market is more. Thus, making the product economical than all other thermoplastics. PET fibre in concrete has shown better resistance to chemical attacks.

Figure-6

1.3.6 Boron Fibre

These fibres are manufactured by a chemical vapour deposition technique. Boron can be deposited on a tungsten wire core and on a glass filament core. Thus fibres of nominal diameter in the range 0.1–0.2 mm can be obtained. They possess very high tensile strength, low density, high modulus of elasticity and almost neutral to chemicals. Boron fibres are extremely stiff (i.e five times stiffer than glass fibres) thus, behaves like a brittle material and are difficult to weave, braid or twist. Short length boron fibres can be employed in resin for high performance composite matrix. These fibres have been not employed much under retrofitting schemes till today. It is mainly due to its high cost and unavailability which has greatly limited their use in experimental aircraft and space applications.

1.3.7 Aramid Fibre

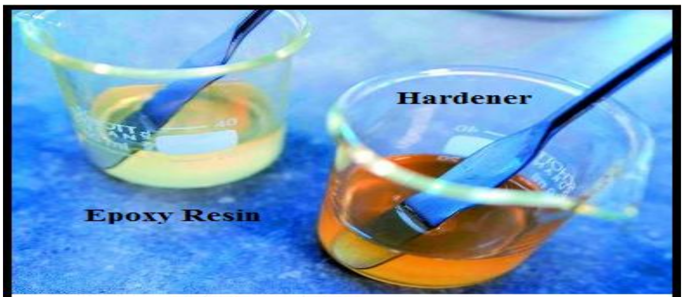
The term 'Aramid' is derived from the contraction of two words, i.e Aromatic Polyamide. Aramid fibres is a synthetic fibre obtained from aromatic polyamide polymer by spinning the liquid polymer to solid fibre from an aqueous chemical blend. These fibre offers very high tensile strength, high elastic modulus, excellent thermal stability and good resistance to fatigue. It also provide excellent vibration damping factor and does not sustain combustion easily if exposed to fire. The main application of aramid fibre is in reinforcing and enhancing the mechanical properties of the required final product. Aramid fibres are used in making different sports accessories, avionic designs, naval designs, protective shields like bullet proof jackets etc. Due to it's unmatchable characteristics compared to other synthetic fibres, their prices are high too. But researches and studies are in the line, justifying its use in FRP can uplift the characteristics of the structure due to its high durability. The most common brands in aramid industries includes Kevlar, Twaron and Nomex.

Chopped Aramid Fibres

Figure-7

1.3.8 Thermosets

It is a type of synthetic polymer that is irreversibly hardened by curing from a soft solid or viscous liquid prepolymer or resin. Curing is performed either by heat or suitable radiation or mixing with a catalyst, generally called as Hardeners. Thermosets are stronger than thermoplastic due to its inheritance of crosslinking i.e three dimensional bond network. It possess good mechanical properties and have good resistance against chemicals and moisture. Thermosets are readily available in semi-solid or viscous form, thus needs proper mouldings arrangements to be utilized at best. Thermosets needs expert supervision since its careless handling may results in loss of money and can degrade the aesthetical appearance of existing structure body. The main application of thermosets in construction industries includes sealant, adhesive, matrix for FRP, thermal insulations, repair and retrofitting of existing buildings. Some of the widely used thermosets in retrofitting strategies are Epoxy Resins and Vinyl Ester Resins.



A Type of Thermosets

Figure-8

1.3.9 Composite Matrix

Composite matrix is a unique material in which the base binder is resin. Studies had been proved that it binds majority of the construction materials except some plastics. Composite matrix is a mixture of different fibres, steel reinforcement and resins. This Polymer matrix is cured either by external heat or by adding suitable hardener as substitute. Resins are type of thermosets which gain its strength when a suitable heat is provided for curing. This matrix permits to be designed as per requirement same as per case of concrete designing. Size and shape of the fibres vigorously affect the strength and workability of the composite It requires expert supervision to implement on site since its improper handling can result in major economic loss due to its high market rates. Composite matrix have been successfully used for grouting and crack filling purposes in structures and are in race for proper retrofitting strategies in recent years.

Figure-9

2. A Review on Recent Researches in Retrofitting of Structures.

Rajashekhar Siddappa Talikoti et al (2019), investigated the durability of Aramid fibre reinforced cube specimen subjected to acid attacks (diluted hydrochloric acid) and high temperature. In his work he concluded that use aramid fibre as FRP resulted in significant rise in compressive strength upto 40%. In fire test, weight loss in cubes was reduced by 60%, with increase of 50 % in compressive strength. Thus, it is clear that Aramid fibre as FRP can increases the durability and performance of the structure.

Uttam Wayadande et al (2018), has carried the experimental study for comparing the effect of CFRP wrapping on Columns of different shape. Total nine columns (Circuler, Square and Rectangular) were tested against CTM. The ramification of his experimental research concludes that use of CFRP as a jacketing material enhanced the load carrying capacity of columns by 41%,39%and 39%.

Sultan Erdemli Gunaslan et al (2017), concludes the application of FRP composites offers essential properties which gets add up when retrofitted with existing structure. FRP composite as a wrapping material has significant impact on compression strength of existing concrete member and also increases the ductility of the concrete member.

Ahmed R. Abdulrahman et al (2020), in his investigation both CFRP and GFRP sheets were used as confining material. His work was majorly focused on comparing square and circular columns wrapped with both types of sheets. The outcome of his experimental effort concludes that the load carrying capacity was high in circular columns for both the wrapping sheets. He also concluded that the strains shown by circular columns was also high compared to square columns. Thus, ductility increased when confined by FRP sheets.

Soo Yeon Seo (2016), performed Sprayed FRP on concrete columns for seismic strengthening. The optimum thickness was around 4mm for the design matrix. Fibre(chopped glass fibre) to resin ratio was kept 1:2. In his finding maximum shear strength of specimen when strengthened by Sprayed FRP performed reinforcement effect and a significant increase of 31% was figured out. He also concluded that this technique provides both strength and deformability to the structure.

Saira P.N et al (2017), investigated various natural and synthetic fibres in FRP to retrofit beams with jacketing scheme. Natural fibres like coir fibres, banana fibres, jute fibres and cotton fibres were used. Similarly, Glass fibre was used in synthetic fibres. The study results in increase in flexural strength with both types of fibres. Glass fibre FRP showed the maximum flexural strength with rise of 47%. Among the natural fibres, Banana fibre was more effective to tackle toughness.

3. CONCLUSIONS

New materials with good mechanical and chemical properties will automatically make its place in different fields of application. From the review of recent literatures on Fibre Reinforced Polymer, it is clear that wrapping or confining CFRP or GFRP sheets with adhesive increases compressive strength as well as ductility upto some extent. Addition of fibres not only improves confinement strength but also imparts shear strength to the members. Use of FRP in seismic strengthening has gained a huge attraction due to its instant strength gain, low density and long durability against chemical and weathering action. But due to expensiveness FRP composites are still finding its way in regular building materials. Another factor which hampers the reliability of FRP is lack of standards and guidelines for making a perfect strategy at different retrofitting sites. Further studies are required in order to cutoff the expensiveness by using optional fibres such as Polypropylene fibre, Polyethylene terephthalate fibres etc and economical adhesive resins. Increase in Epoxy industries will definitely pull down the high rates of FRP. There is no dilemma that Synthetic Polymers & FRP products have a broad future coming ahead in civil engineering.

References

1. **Vui Van Cao et al (2020**) “Damage-Based Seismic Retrofitting Approach for Nonductile Reinforced Concrete Structures Using FRP Composite Wraps”, Hindawi, ISSN: 1687-8086,Volume 2020 ,Article ID 7564684.

2. **I. Bedirhanoglu et al (2019**) “EFFECT OF PRE-DAMAGEON THE SEISMIC BEHAVIOUR OF FRP RETROFITTED SUB-STANDARDSHORT COLUMNS” APFIS 2019, researchgate.net.

3. **Daniel A Pohoryles et al (2019**) “Seismic Retrofit Schemes with FRP for Deficient RC Beam-Column Joints” Journal for composites for construction, Volume 23 Issue 4- August 2019.

4. **Rajashekhar Siddappa Talikoti et al (2019**), "Strength and Durability Study of Concrete StructuresUsing Aramid-Fiber-Reinforced Polymer." mdpi.

5. **R.Nandhini et al (2020**)," Retrofitting of concrete structure using fibre reinforced polymer: A Review", INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 9, ISSUE 02, FEBRUARY 2020. ISSN 2277-8616.

6. **Amsa et al (2018), "**Experimental study on polypropylene fibre reinforced concrete", irjet.net, Volume -5, ISSN: 2395-0056.

7. **Dr.T.Ch.Madhavi et al (2014), "**Polypropylene Fiber Reinforced Concrete-A Review", www.ijetae.com,ISSN 2250-2459.

8. **Subha Javgal et al (2019**)," A Comparative Study of the Behavior of CFRP and GFRP Laminates in a Plate Specimen Using Modified Virtual Crack Closure Technique". Procedia structural integrity, Volume 14, pages 907-914.

9. **M. Krishnamoorthy et al (2017**), "Durability studies on polyethylene terephthalate (pet) fibre reinforced concrete". Journal of Civil engineering, Science and Technology.

10. **Dinberu Mola Yemam et al (2017), "**Mechanical Properties of Epoxy Resin Mortar with Sand Washing Waste as Filler". Material basel, mdpi.

11. **Priyanka Sarker et al (2011) , "**Fiber reinforced polymers for structural retrofitting", Journal of Civil Engineering (IEB)