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RETROFITTING WITH BASALT FIBER: IS GREENER THAN EVER- A REVIEW

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Abstract

Maintenance, repair and rehabilitation of civil engineering structures is an important aspect post construction. The industry often is looks for optimal solutions in terms of finance as well as eco friendliness of the materials and process used. There is an augmented scope for the usage of green materials in the structural health monitoring system which causes less harm to the environment. The word green retrofit aims at reducing the emissions of carbon and usage of other harmful materials to the environment. One such naturally occurring eco-friendly material is Basalt Fiber. The Basalt fibre reinforced polymer performs on par with contemporary materials. This paper presents a short review on potential characteristics of Basalt fibers as a retrofitting material for various civil engineering structures. The increased trend of using greener materials for a sustainable environment led to this research. Repair & retrofitting is looked into, by investigating basalt fiber's mechanical behavior under various conditions and explore the possibilities of using it as an efficient & Sustainable material.

Keywords: Basalt Fiber; Eco-friendly; Retrofitting.

1.0 Introduction

The most common words used in this domain are Repair, Rehabilitation and Retrofitting. Generally these words are inappropriately used even though they confer a different meaning. Repair is to restore the structure to its previous condition. It performs same as earlier in an aesthetic way and doesn't cover the strength aspect of the structures .Rehabilitation of a building is to restore a structure to a useful state by means of repair, modification, or alteration not only in an aesthetic way but also keeping the strength aspects of the structures whereas retrofitting refers to enhancing the capacity of structural elements.

The statistics of the occurrence of Indian earthquake in the past two decades reveals that one earthquake of magnitude greater than 8.0 takes place every year and out of 97 such occurrences, the average magnitude is between 6.0 to 8.0 on the Richter scale [**Jain**, **S. K. 1998].** According to the new version of India Map of seismic zones, the earthquake resistant design code of India [**IS 1893-1 2016]** assigns 4 levels (Zone II to Zone V) of seismicity for India in terms of zone factors. Jacketing is the most common method adopted in strengthening individual members or elements in the structure. Jacketing techniques are of several types namely steel jacketing, steel concrete jacketing, fibre reinforced polymer composite jacketing and jacketing with high tension materials

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like carbon fibre, glass fibre, basalt fibre, natural fibers etc.

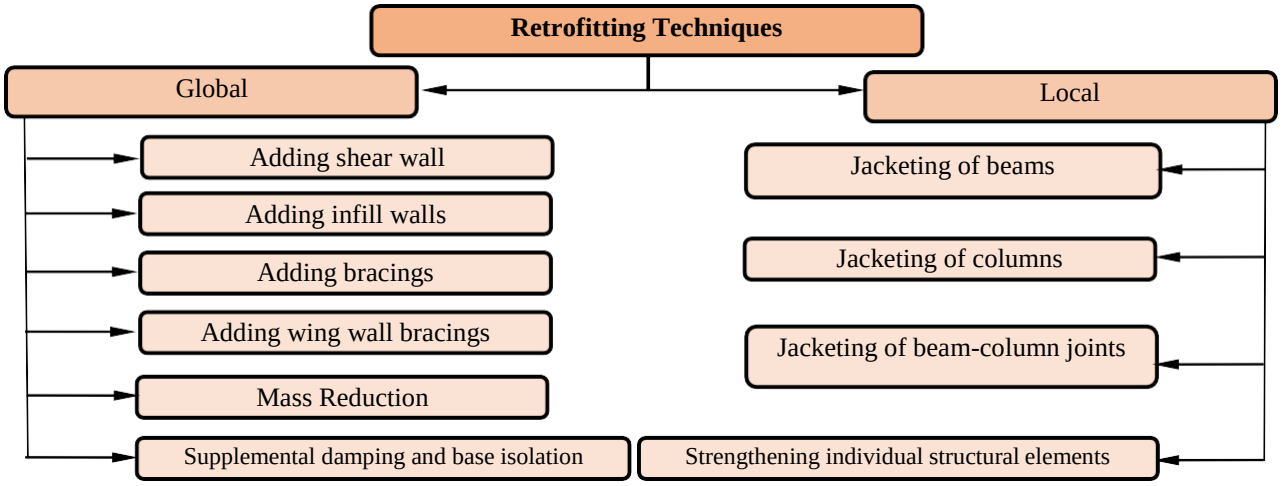

Fig: 1 Classification of Retrofitting Techniques

1.1 Fiber Reinforced Polymer

Fibre reinforced polymer (FRP) is a composite consisting of large number of small, continuous, unidirectional, multidirectional, nonmetallic fibers as shown in the figure 2. They are packed in a polymer or resin matrix and are a very commonly used jacketing material.

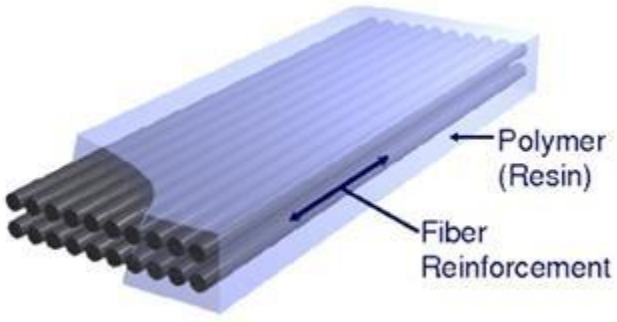

Fig :2 schematic description of unidirectional composite
(Courtesy Nanni, A. 2004)

In recent times, the fibre reinforcing composites are used in retrofitting and rehabilitation of existing structures. The application of the composites is increased since new advanced forms of FRP's are developed. In new buildings, it is used as a primary reinforcing material replacing steel in reinforced concrete. It has also been found to be most promising material.

Fibre Reinforced Polymer (FRP) composites offer mechanical insulation and thermal properties

[Bedon C 2016]. Fibre reinforced polymer is a composite which is made by combining the fibers like carbon, Aramid, Basalt and glass with the polymer matrix **[Hag-Elsafi, O, 2001].** FRP is commonly used in automobile, aerospace and marine industries as low and high strength material. FRP had also found its place in the construction industry in a non-structural and non-reinforced application like finishing, cladding and decoration **[Weaver 1999].** The construction industry is one of the largest sectors in the world and in the recent past years it is ranked second in consuming the polymer composites **[Kendall,D 2007].**

The Mechanical properties of the FRP make them advantageous over the other materials and are

- High strength to weight ratio
- High durability, Resistance to damping
- High stiffness
- Resistance to damping
- High flexural strength
- High corrosion resistant, High Electromagnetic Permeability
- Unlimited availability in terms of geometry and sizes.
- Easy Procedure for installation and application, Short period for execution.

The disadvantages are

- They are difficult to apply on moist surfaces and at low temperatures.
- Poor fire resistance.
- Low reversibility and lack of vapour permeability.

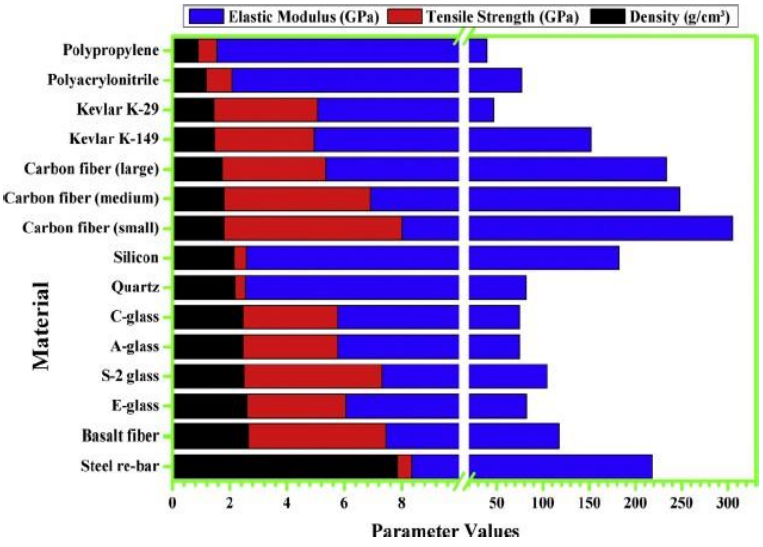

Fig:3 Mechanical properties of various fibres [Dhand,V 2015]

1.2 Types of Fibers used in FRP

FRP is a composite which consists of Fibre and polymer. The type of fibre used in these composites plays an important role in influencing the performance of the FRP. There are various types of fibers and they find application in many areas.

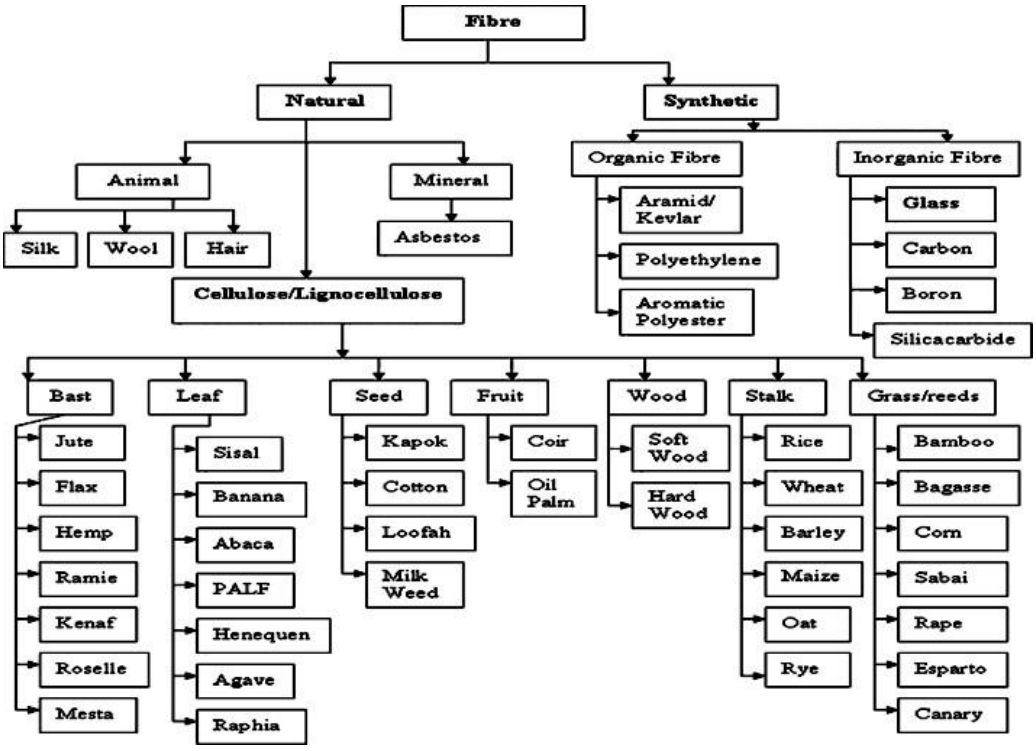

Fig: 4 Various types of Fibers [Jawaid,M 2011]

Carbon fibre is superior in tensile strength compared to all other fibers. Basalt fibre, when compared with Glass fibre, possesses better stiffness and strength and has more ductility compared to carbon fibre, making it a suitable as reinforcing material.

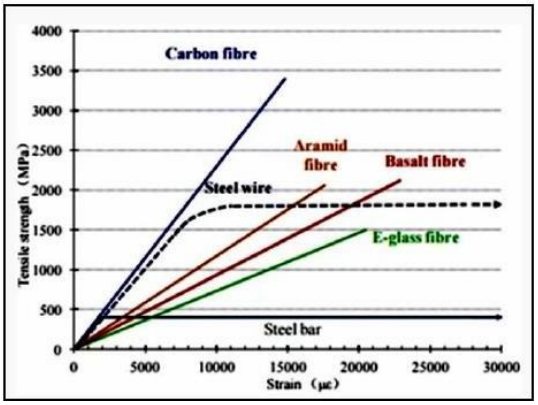

Fig: 5 Tensile stress vs. strain of different Fibres

1.3 Green Material:

Basalt is a natural and environmental friendly material. Basalt is an igneous rock which comprises of various minerals like plagioclase, pyroxene and olivine. Basalt fibers (BF) are made from a single stone which is crushed washed and heated in an oven at a high temperature, through a platinum-rhodium alloy [**Czigány, T. 2005**]. BF is also known as green industrial material. It is informally known as the "Nonpolluting green material of the 21st century" .Basalt fibers are inert and 100% natural and the products do not react with air and water and they are also non-combustible. When Basalt fibers come in contact with other chemicals, harmless reactions are produced which do not damage the environment and health **[Jamshaid,H 2016].**The ozone depletion potential of basalt fiber is zero **[Willoughby, J 1987]** and emission of CO_2 to the atmosphere is less**.** Basalt fibers along with resin when recycled same material is obtained .As the melting point of the basalt fiber is about 1500^{o} C, the other composites present i.e. the resin turn to ashes during the process **[Kamenny V 2015]**

1.4 Energy Consumption:

The energy required for the production of basalt fiber is around 5 kWh/kg in an electric furnace and the amount for steel is around 14 kWh/kg **[Fazio P 2011]. C**ommercially available manufacturing methods estimate the primary energy intensity of Carbon fiber is 50.8–79.4 kWh/kg [**Suzuki T 2005**] and glass fiber is 3.6–8.89 kWh/kg [**Cebon, D 1992**, **Pellegrino, J 2022].** Base composites of basalt can replace steel (9.6 kg of steel can be replaced by 1kg of basalt) and the mechanical properties are comparable. As a result lighter buildings can be achieved by using basalt rebar instead of steel rebar. This will lead to energy savings in terms of production of Basalt Fiber.

Table 1: Comparison of Energy consumption in manufacturing

Fibre	**Basalt**	**Steel**	**Carbon**	**Glass**
Energy Consumption in manufacturing process (kWh/kg)	5	14	50.8-79.4	3.6-8.89

1.5 Cost Comparison of Materials

The major drawback in the carbon composite industry is the expense of production, resulting in less usage **[Dhand V 2015,Czigany T 2006].** BF is less expensive. It is a high strength and a cost-effective material [**Botev, M. 1999**, **Dalinkevich A 2009, Liu,Q 2006, Militky J 2002]** which is used as reinforcement material and used for other applications in the construction Industry [**Manewa A 2016].**

Table 2: Cost Comparison of fibers

Parameter	Carbon Fiber	Basalt Fiber	Glass Fiber
Chopped Fiber	14-17 USD /kg	2.01-2.96 USD /kg	2.01-2.96 USD /kg
Roving	5-33 USD /kg	0.4-4 USD /kg	0.8-1.1 USD /kg
Grid/Fabric	17.50 USD /square meter	4.40-5.60 US / square meter	14.93-25.99 USD / square meter
Rebars	0.5-20 USD /meter	0.5-15 USD /meter	0.27-2 USD /meter

1.6 Chemical Composition

Basalt fiber has higher chemical stability, thermal, and mechanical properties than glass fibers [**Artemenko, S. E. (2003)**]. Fiber property of the basalt fiber differs amongst countries as it is a natural product thus chemical composition varies with mining region **[SubramanianR V 1980]. M**echanical properties of the basalt fiber are influenced by high amounts of silicon oxide (SiO_2) and aluminum (Al_2O_3) and similarly heat resistance of the Glass depends on the amounts Iron oxide. Other properties like thermal and chemical resistance are influenced by different oxides **[Deak,T 2009].** Table 3 shows the comparison of chemical compounds between basalt fiber, E-Glass fiber and S-Glass Fibre.

The chemical composition of these E and S type of Glass fiber consist of compounds which are either Eco-friendly and cause minimum damage to the Eco-system.

Table 3: Comparison of chemical compounds in glasses and basalt (in weight % = w %)

Parameter	**Na_2O [wt%]	*MgO [wt%]	*Al_2O_3 [wt%]	*SiO_2 [wt%]	**K_2O [wt%]	*CaO [wt%]	**TiO_2 [wt%]	***FeO/Fe_2O_3 [wt%]
Basalt	2.5-6.4	1.3-3.7	16.9-18.2	51.6-57.5	0.8-4.5	5.2-7.8	2.1	-
E-Glass	0.8	0-5	12-16	52-56	0.2-0.8	16-25	0.41	< 0.3
S-Glass	0-0.3	9-11	24-26	64-66	-	0-0.3	-	< 0.3

*Eco Friendly, **Acceptable, ***Not Eco Friendly

2. 0 CONCLUSIONS

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1 Carbon fibre has good required Mechanical properties for construction industry but it is the need of the hour for the industry to get sustainable in its construction process as well as materials used. Henceforth other than mechanical property, Cost Effectiveness and Environment friendliness of the material itself along with the footprints in the manufacturing process are to be closely monitored in choosing the right fibre for the future.

2. To overcome the Ecological liabilities of Carbon Fibers some of the options are Glass fibers and Basalt Fibers. The chemical compositions of both glass fibre and basalt fibre show compounds that have minimum detrimental effects on the Environment. The energy consumption during the process of manufacturing also is found to be very much similar. However the glass fibers are more brittle than basalt fibers.
3. The abundance of the totally unexplored basalt rock in the Deccan plateau region of India has opened up a whole new market to produce an alternate material for fibers in Indian Construction Industry. There are quite a few developments in research suggesting the success of the basalt fibers used in Retrofitting as well as new construction.
4. It would be safe to conclude that Basalt Fibre performs at par with glass fibers. The mechanical performance of the basalt fibre are relatively lower than carbon fibre, but the cost effectiveness and environmental sustainability of the Basalt fibers makes it a case to provide tough competition to Carbon fibre.

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