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ASSESSMENT ON POLYMER AND METAL MATRIX COMPOSITES IN STRUCTURAL APPLICATIONS

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Abstract: Due to deterioration and damage of the structures all over the world, strengthening is needed to sustain the structures and to increase the life living capacity and some of them are designed to have a serviceability about 60 to 80 years of life which demands repair and maintenance services. Composites play a vital role in strengthening of old and damaged structures. To enhance the ductility, load carrying capacity, flexural strength existing structural members such as beams, columns, slabs etc. are strengthened with different types of composite material. This paper presents the assessment on use of Polymer Matrix Composites (PMC) over strengthening of structural members also the applications and engineering properties of Metal Matrix Composites (MMC) are critically reviewed.

Index Terms **- Composites, MMC, PMC, Structural member.**

I. INTRODUCTION

During the last decades, cities witnessed increased rates of population growth and transportation has become heavier and more frequent. This has led to increased load bearing capacity demand on bridges. The dynamic changes that occur in our daily lives change the loading type or impose more loads on existing structures. Furthermore, some structures are deficient due to design errors or mistakes during construction. Other structures need upgrading due to temporary overload. To keep these deficient structures in service, they are upgraded, replaced or their use is restricted. These solutions are usually costly and ineffective. Hence strengthening is usually needed for several reasons to keep the structures sustainable. Previous strengthening of RC structural members are done by steel plates which are heavier in weight and demands maintenance costs due to corrosion effects. The concept of using the fiber for strengthening of the beam is growing rapidly.

Now-a-days strengthening of structures with hybrid composites are more popular technique in structural applications across a worldwide Large number of researches have been carried out in the previous years related to the hybrid Fiber Reinforced Polymer (FRP) system such as Glass Fiber Reinforced Polymer (GFRP), Carbon Fiber Reinforced Polymer CFRP for RCC beam on crack initiation and propagation, improving cement properties by using silica and admixtures, variation of fiber length and thickness. Though some researches have been done on reinforcement using Polymer composites like GFRP and CFRP, conventional steel bars. However, many researches are performed experimentally and numerically on the analysis of RC beam wrapped with GFRP, CFRP laminates. Engineering properties of MMC material and Polymers along with their applications are discussed.

II. POLYMER MATRIX COMPOSITES

PMC's are also considered as plastic composites and are non-metallic material can be mounded into any shape form. Fibers and resins are used as reinforcement and matrix medium which is stronger than the other conventional materials. The matrix phase of the material contains polyester, epoxy, vinyl ester resins and fiber phase contains carbon fibers, glass fibers, aramid, and basalt etc. PMC's generally have stress strain curves from linear to failure.

The addition of both reinforcement and matrix generally form the whole composite material. The tensile curve of the fiber is elastic-brittle and matrix is elastic-plastic and combined curve of composite is shown in Fig. 1

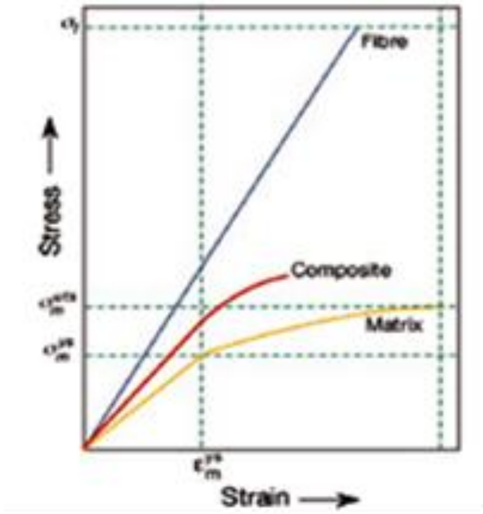

Figure 1. Tensile curve of Fiber, Matrix and Composite

Fiber Reinforced Polymer (FRP) sheets have been widely accepted and getting popular due to their durability, design and construction flexibility. FRP plates or sheet material are just like applying wallpapers and are very easy to apply and it can be available in long lengths also while availability of steel plate is limited. It is very much lighter in weight and volume as compared to the steel, the use of FRP composites does not increase dimensions and weight of structural member. Hence due to its less weight make it easy installation and transportable. Laps and joints does not requires in their installation process. These are more corrosion resistance, unlike metals does not rust away. FRP is stronger, stiffer than steel and have maximum stiffness to density ratio 3.5 to 5 times than steel. FRP material can be formed and moulded very easily into any desired shape and also requires less maintenance, if material get damaged then it could be repaired and maintained by addition of an extra number of layer. FRP has long life, large durability and more resistant to fatigue. But on the other side it suffers with a lot of issues such as there are no guidelines and design charts available to be used with structural elements and cost is sometimes considered as the issue. The most of the data is available in the aerospace industry. Also the members strengthened with the FRP material can have the risk of fire, accidental damage. There is lack of expertise in using the techniques and technology for using the FRP composites. The structural properties of general PMC are shown in Table 1.

Table 1: Structural Properties of PMC

Structural Property	PMC
Axial Strength (Mpa)	820-1680
Axial Stiffness (Gpa)	61-224
Transverse Strength (Mpa)	11-56
Transverse Stiffness (Gpa)	3-12
Specific Gravity	1.3-2.5
Specific Strength (axial)	630-670

2.1 Carbon and Glass Fiber Reinforced Polymer

Carbon Fiber Reinforced Polymer (CFRP) is a very strong and light composite material, which consists of carbon fibers embedded in a thermosetting resin known as the matrix having high elastic modulus 221.7 Gpa (equal to that of steel), high tensile strength about 4000 Mpa, low density, good corrosion resistance but expensive than Glass Fiber Reinforced Polymer (GFRP). CFRP are widely preferred in the industrial and structural applications like pumps, load bearing elements and drive shafts. On the other side, GFRP consists of a polymer matrix reinforced with fine glass fibers. The constituents of GFRP are abundant materials, readily available and inexpensive, which makes it cheaper than CFRP. GFRP's have high tensile strength about 2000–3500 Mpa but relatively with low elastic modulus 79.7 Gpa (about one-third of that carbon and reinforcing steel). GFRP's have been widely used in pipes, automobile parts, pressure vessels, manufacturing boats, structural elements and marine structures etc.

III. Metal Matrix Composites

MMC material developed in 1980's due to their wide growth in the field of engineering applications. In these type of composite material, metals are act as matrix which includes Magnesium, Titanium. Aluminum, Copper etc. and high performance ceramics are act as reinforcement medium which involves nitrides, silicon carbide, alumina, magnesium oxide, boron nitride etc. The strength and the other properties of the MMC depends upon its constituents of materials. For example, the percentage volume fraction of ceramics and choice of the matrix together makes the material more adaptable and strong. The structural properties of general MMC are shown in Table 2.

Table 2: Structural Properties of MMC

Structural Property	MMC
Axial Strength (Mpa)	620-1240
Axial Stiffness (Gpa)	130-450
Transverse Strength (Mpa)	30-170
Transverse Stiffness (Gpa)	34-173
Specific Gravity	2.5-3.2
Specific Strength (axial)	250-390

Now-a-days most commonly adopted MMC material is Aluminum MMC reinforced with silicon carbide. Typical types of reinforcement is shown in Table 3.

Table 3: Types of reinforcement used in MMC

Type	Aspect Ratio	Diameter	Examples
Particle	1-4	1-25μm	Silicon Carbide, Boron Nitride, Alumina oxide
Short Fiber	10-1000	1-5μm	Carbon, Silicon Carbide, Alumina ox
Continuous Fiber	>1000	3-150μm	Carbon, Boron, Silicon carbide
Nanoparticle	1-4	<100nm	Alumina oxide, Silicon carbide, Carbon
Nanotube	>1000	<100nm	Carbon

The major characteristics of MMC are such that they are more effective in combined loads of tension, compression or shear, plate buckling, also in transverse and off- axis loads. The strength and stiffness properties of some Fiber reinforced MMC's material with 50 percent volume fraction of ceramics is shown in Table 4.

Table 4: Tensile Strength, Stiffness of different MMC

MMC	Tensile Strength (Mpa)		Stiffness (Gpa)	
	Axial	Transverse	Axial	Transverse
Aluminum 6061-T6	290	290	70	70
Titanium Ti-6Al-4V	1170	1170	114	114
Graphite/ Aluminum	690	30	450	34
Boron/Aluminum	1240	140	205	140
Silicon Carbide/Aluminum	1040	70	130	99
Alumina/Aluminum	620	170	205	140
Silicon carbide/ Titanium	1720	340	260	173
Graphite/ copper	512	31	464	49

In comparison to monolithic metals, MMC's have so many advantages such as fatigue resistance, greater strength to density and stiffness to density ratios, elevated temperature, lower coefficient of thermal expansion, no moisture absorption but also have disadvantages fabrication methods are more complex, newer and advance latest technologies involve higher costs also the service experience is limited. The graphic comparison of the specific stiffness of conventional or monolithic metals and MMC is shown in Fig. 2.

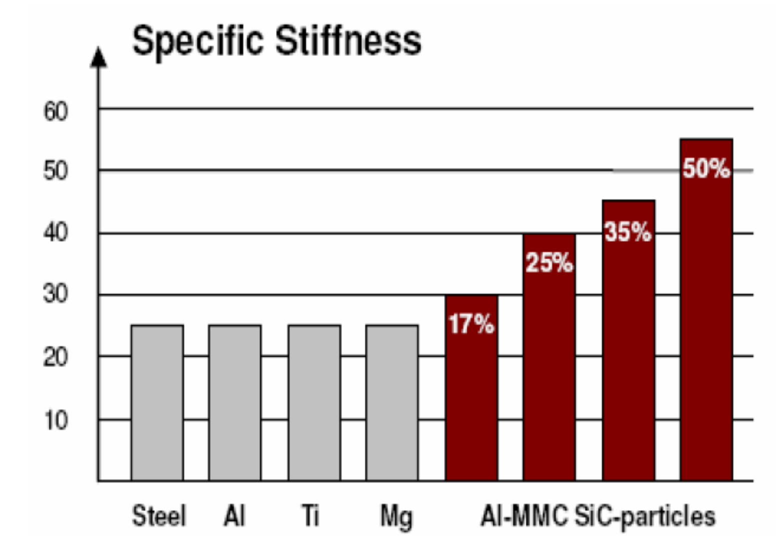

Figure 2. Graphical Representation of specific stiffness of various Metals and MMC

3.1 Applications of MMC

Most commonly MMC's have been widely used because they are based on light weight metal alloys such as aluminium, magnesium and titanium reinforced with ceramic dispersed particles. MMC's used in the production of automobile parts increasingly. Toyota and Honda are one of the most popular automotive companies which started used Aluminium based MMC in their engines. While Honda has used connecting rods of MMC for cylinder block on cars and Toyota Company has used pistons made up of MMC material in their diesel engines. It also used in train valve components to reduce the total weight of bogey in railway vehicles. MMC is used in aircraft manufacturing such as in engines, blades, notably discs and shrouds. Titanium metal matrix composites reinforced with silicon is used for fan blade applications. In area of defence, use of MMC material have been start in missiles which was earlier manufactured by the beryllium. MMC avoids all the problems associated with the beryllium. Where high heat dissipated circuits are generated which causes more heat as compared to the earlier ones. So this requires MMC which is used in high module chips for high thermal conductivity. MMC's have been widely used in different types of sport equipment such as tennis rackets, bicycle parts, frames and wheel rims, golf clubs due to their high strength to weight ratio. MMC is used for frames and rib truss members in space shuttles involved isotropic properties and high structural efficiency. The major concern of MMC in structural applications is light weight and corrosion resistance. It is very easy to obtain the shape in case of built up sections as lightness of material makes the erection and reduction in load transmitted to foundations.

IV. Conclusion

The contribution has been made to study the various class of composites such as PMC and MMC that are available to improve the strengthening of the structural members. So many previous researches are carried over PMC's due to their strong structural properties and are still going on. From the above discussed study, the advance composites which are latest developed such as Metal Matrix Composites possess better structural properties and can be used for further strengthening purposes. There will be good possibility and better expectations for MMC's in future.

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