Metal and Polymer Matrix Composites : A Review

Asheesh Sawhny, Richa Singh, Mukta Bansal, Saurabh Sharma, Saurav Paul, Pankaj Priyadarshi

Rama Dental College Hospital & Research Centre, Rama University, Mandhana, Kanpur, Uttar Pradesh- India 209217

Abstract— Strengthening system for RC structural members have been adopted from the previous years to prevent the structures from degradation and damaging. Till a date so many strengthening techniques have been introduced such as improving the cementitious properties by adding the various types of composites, steel fibers or by wrapping the damaged element with steel plates or Fiber Reinforced Polymer (FRP) plates act as a reinforcing the structural element. This paper throws the review of strengthening of RC beams wrapped with various types of Polymer Matrix Composites (PMC) such as Glass and Carbon Fiber Reinforced Polymers (GFRP/CFRP) also the assessment on structural properties of newly developed material Metal Matrix Composites (MMC) are critically reviewed.

Keywords: Composites, CFRP, FRP, GFRP, MMC, PMC, RC Beams

INTRODUCTION

Now-a-days PMC's have been widely preferred for strengthening system. Different structural elements such as columns, beams, slabs etc. are reinforced with various types of polymers involve Carbon, Glass, Basalt, Aramid, Steel fibers. After rapid growing of these composites, slowly metals are involving to act as a composite material. Later in the 1980's MMC's were introduced to serve their purpose in different areas of engineering and widely preferred in aerospace applications. After gaining worldwide popularity now adopted in different countries such as France, Italy, Denmark, China etc. Now India has also greater influenced on this material and various organizations are still conducting research on its development. After gaining popularity in aerospace industry, now it have been preferred in automobile industry, defense area, electronic and structural applications. MMC may be developed and produced to get mechanical, thermal, electrical properties for specific applications.

In structural composite, some Metals are reinforced with higher performance dispersed ceramics also called as modern ceramics. Metals act as a matrix medium and ceramics act as reinforcing medium. Various Metals for matrix involve Titanium, Aluminum, Magnesium etc. and ceramics working as a reinforcement involve alumina oxide, boron nitride, silicon carbide etc. Similarly, in CFRP/ GFRP involves epoxy, resin working as a matrix and Glass fibers /Carbon Fibers working as a reinforcement medium. Most commonly used MMC material is Aluminum MMC reinforced with ceramic material of silicon carbide.

Plastic composites or PMC's have advantages such as more corrosion resistant, long durability and flexibility, due to its less weight and superior properties, researchers carried their investigations on a

ISSN: 0975-3583, 0976-2833 VOL12, ISSUE 06, 2021

great extent. PMC's generally have axial and transverse strength varying from 820 to 1680Mpa and 11-56Mpa. On the other side MMC's have advantages like no moisture absorption, greater strength to density ratios, higher stiffness to density ratios etc. and more effective in plate buckling, transverse and off axis loads and combined loads of shear, tension or compression. MMC's have axial and transverse strength varying from 620 to 1240Mpa and 30-170Mpa.

CFRP and GFRP are the most general polymers used in strengthening purpose such as vide variety forms are available by using this material as sheets or by prefer them as a rebar's in structural elements. CFRP and GFRP involves carbon and glass fibers which forms the reinforcement part in composite material and polyester, vinyl ester and epoxy resins form the matrix part bonded at the interface. CFRP have good physical and mechanical properties that form the composite more functional and consistent. CFRP sheets are light weight material, high tensile strength can extent up to 7Gpa, high chemical inertness, high corrosion resistant. But these sheets are relatively expensive as compare to the GFRP also at room temperature, carbon fibers are free from dampness or different types of acids, bases and solvents. These carbon fiber sheets have low coefficient of thermal expansion and high electrical conductivity or failure occurs in a brittle manner. On the other side, GFRP have better insulating properties, higher corrosion resistant, having tensile strength varies from 2500 to 3000Mpa. In comparison with the CFRP, GFRP having low elastic modulus 79.7Gpa and equal to one third of that carbon and reinforcing steel, while CFRP have elastic modulus 221.7Gpa which is almost equal to that of steel. On the other hand, Aluminum base MMC's that are reinforced with boron and silicon carbide having tensile strength 1240Mpa and 1040Mpa. GFRP's mainly preferred in structural elements, automobile parts, and marine structures whereas CFRP's are widely preferred in load bearing elements, drive shafts and pumps etc.

The strengthening technique in which RC beams wrapped with hybrid composites are more commonly used to investigate their flexural behavior. With the use of hybrid composites, it greatly enhanced the ductility, increase the load carrying capacity, improving flexural and shear capacities to prevent from the RC beam from developing cracks. Many scholars carried the analytical and experimental research over hybrid composites for strengthening and optimizing the structural performance.

This paper focuses the experimental and analytical work in which Finite Element Analysis of RC beams externally bonded with GFRP/CFRP sheets are reviewed also the analysis and mechanical properties over MMC material are critically reviewed.

LITERATURE REVIEW

N. Attari, et al, (2011) studied the numerical behavior of controlled RC beam strengthened with GFRP, CFRP and hybrid FRP sheets. One control beam and 6 RC strengthened beams were made and tested through four point bending. Different strengthening combinations were carried out by the use of single layer, double layer and triple layer of CFRP, GFRP and hybrid FRP sheets in U shape. Results for ductility factor, strength, stiffness and mode failure were discussed for every strengthening

ISSN: 0975-3583, 0976-2833 VOL12, ISSUE 06, 2021

schemes. It was noted that single layered hybrid composite or glass fiber alone improves ductility as compared to other strengthening schemes.

K. Vijai, et al, (2013) carried the comparison between experimental and analytical investigation on the behavior of RC beams laminated with CFRP. The nonlinear analysis was carried in ANSYS software. The 4 beam specimens were prepared including two beams were control beam of different sizes and the other remaining two beams were strengthened with CFRP at bottom side of the beam or in U shape pattern. Examined parameters were load vs deflection relationship and cracks. The research output shows that with use of laminates increase the load carrying capacity of beam. The load carrying capacity of the beam laminated with CFRP in U shape was found to be high as compared to beam laminated with CFRP only at bottom side.

Rami A. Hawileh, et al, (2014) introduced to strengthened the RC beam with Hybrid FFP system. This paper deals with hybrid GFRP and CFRP sheets bonded externally to the RC beam specimen. The results were obtained through experimental and analytical investigations also comparison made between them. One ordinary reference RC beam and 4 RC beams using different arrangements of CFRP, GFRP and hybrid FRP sheets were made. The data such as load deflection curves, modes of failure, and load vs strain relationship were examined. It was noted that beams laminated with single CFRP sheet have less ductility at failure loads as compared to the GFRP/Hybrid FRP sheet. The conclusion was made that for achieving the strength in structural element and to improved ductility choose the most favorable combination of hybrid sheets.

Shweta S. Shetty, et al, (2015) had performed the analytical analysis on RC beam laminated with GFRP. 3D beam was modelled in ANSYS under two point loading. One reference beam and 3 RC beams with GFRP laminate were modelled and analyzed by ANSYS software. The analysis based on varying parameters such as different thickness of the laminates and varying width of the beam. Stress intensity variation and load vs deflection relationships were examined. It was concluded that with the increase in width of the beam, deflection of the beam was reduced also the RC beams laminated with GFRP improves load carrying capacity of the beam.

K Saravana Raja Mohan, et al, (2017) they studied about the flexural response of the FRP – RC beams. They carried out experimentally and then numerical model is developed using FEM software ANSYS. GFRP and CFRP laminates are wrapped to sides and tension face of the beam. Various parameters such as crack patterns, reasons for deboning of the fiber from the structure, energy absorption capacity, and percentage of strength increase in member were examined. On the basis of these parameters it was concluded that the ultimate load of the FRP beams increased as compared to the ordinary beam. The load deflection curve showing the area gives computed value of the energy absorption capacity. Energy absorption capacity shows greater improvements in the FRP beams as compared to the ordinary RC beam.

Liang Huang, et al, (2018) in this paper review, author studied about the flexural performance of U shape hybrid GFRP/CFRP- RC composite beams experimentally. Beam specimen having length

1800mm, width 100mm and depth 160mm were constructed. One control beam and 4 hybrid beams were carried for testing under four point bending. Different patterns of GFRP/CFRP encasing in U shape profile and steel rebar were included. Various parameters such as load deflection relationship, different failure modes, energy absorption capacity, ductility, load strain relationship of the beams were studied. It was observed that due to the increase in the thickness of the hybrid FRP encasings, ultimate load and ductility of the hybrid FRP composite beams were also increased. Cracks, yielding and ultimate loads for all hybrid beams were enhanced considerably as compared to the one ordinary RC beam.

S Santhosh Kumar, et al, (2009) studied the variations in behavior of elastic properties of Aluminum Alloy Metal matrix composite with different volume fractions of Silicon carbide. The elastic properties of Aluminum MMC were determined from ultrasonic velocities like shear and longitudinal velocity. Examined elastic properties included elastic modulus, Poisson’s ratio shear modulus and bulk modulus. The results indicated that with the increase in volume fraction of silicon carbide, the determined elastic moduli were found to be increase in a nonlinear manner. Also the elastic moduli were determined on the basis of some predicted theories.

C.K. Tan, et al, (2012) performed the theoretical and experimental investigation on mechanical properties of Aluminum alloy reinforced with two different types of reinforcement such as silicon carbide and alumina oxide. Different weight fractions for both silicon carbide and aluminum oxide were mixed with aluminum alloy to form composite material. The test specimens of both materials aluminum alloy reinforced with aluminum oxide and aluminum alloy reinforced with silicon carbide were prepared and tested to determine the physical and mechanical properties of both materials. On the other hand theoretical calculations using equations were made to determine the mechanical properties of composites. The observed parameters were strength to density ratio, density, tensile strength, hardness and wear rate. It was found that the comparison for both composite material shown that aluminum alloy reinforced with silicon carbide have higher tensile strength and hardness as compared to the aluminum alloy reinforced with aluminum oxide. Graphical plots shown the good agreement between the predicted and experimental results.

K. L. Meena, et al, (2013) presented the experimental investigation on mechanical behavior of aluminum MMC’s reinforced with particles of silicon carbide material. For determination of mechanical properties of Aluminum MMC, MMC plates and bare were used. The composition was made up of aluminum and different mix percentages of Silicon carbide ranging from 5%, 10 %, 15% and 20 % respectively. The particle sizes of mesh 400, 300 and 220 were adopted. The observing parameters were examined such as hardness, impact strength, density, ultimate tensile strength, elongation, breaking strength, and area reduction. The graphical plots of parameters shown that with higher the mesh size and weight fraction of particles, more will be gain in tensile and breaking strength and also there will be minimizing percentage area reduction as well as percentage in elongation. Hardness and density was also increased due to the increase in weight fraction and mesh

ISSN: 0975-3583, 0976-2833 VOL12, ISSUE 06, 2021

size of particles

P. Chandrashekhar, et al, (2013) conducted the experimental investigation and numerical analysis by finite element simulation using DEFORM software. This paper deals with the deformation characteristics on solid disc made up of aluminum MMC reinforced with different percentages of Silicon carbide material. The material properties such as Poisson's ratio, ultimate tensile strength and hardness for AMC reinforced with silicon carbide of 5% wt and 13%wt were included. The results were obtained on the basis of stress and strain plots for both percentages of silicon carbide content.

K.S. Shivakumar, et al, (2015) had performed the finite element analysis of aluminum Silicon Carbide MMC using ANSYS. Two dimensional element was adopted for the nonlinear analysis considering the fiber volume fraction of Silicon Carbide. Stress Strain behavior for varying fiber volume fractions were observed. It was noted that stress strain curves becomes almost linear when volume fraction of silicon carbide is above 40 percent.

Dr. Sumathy Muniamuthu, et al, (2016) carried their research on Aluminum MMC reinforced with Alumina Oxide. This paper deals with the use of MMC and to improve their mechanical properties. The properties that were analyzed such as impact strength, tensile strength and hardness. Alumina oxide were taken in different weight proportions at 2%, 4%, 6% and 8%.in base Aluminum MMC. It was found that ultimate tensile strength, hardness and impact strength tends to be increased with the increase in alumina oxide particles, but elongations tends to be reduced.

D M Nuruzzaman, et al, (2016) had taken the investigation on properties of aluminum Silicon Carbide Metal Matrix Composites. Specimens of ASC consisting of three different composition 10%, 20% and 30% of silicon carbide were prepared and tested under compaction load. Matrix material was aluminum powdered and reinforcement material was silicon carbide particulates with different volume fractions. The parameters analyzed were density and hardness. It was noted that with higher percentage of silicon carbides increase the hardness as well as density of the composite.

Akhil R (2018) had studied about the trending applications of Metal Matrix Composites. This paper deals with their mechanical behavior along with different usages of MMC material in automotive field. Comparison of MMC with PMC's were also discussed in terms of mechanical properties. The chemical composition of MMC with physical and mechanical properties such as density, compressive strength and elastic modulus were also included. The research output shows that MMC demands

have been widely increasing due to their advance development and improved mechanical, thermal properties in the aerospace industry. Due to their lower cost, light weight and improved performances MMC's been used in different wide variety of applications such as in aircraft production, electronics, space shuttles, automobile, defense, supporting goods, and railroad.

CONCLUSION

An attempt has been made to study the use of MMC and PMC as a strengthening material for RC beams. From the above discussed studies and research works carried out in the previous years shown that ductility and load bearing capacity of RC beams can be improved more efficiently by using the

ISSN: 0975-3583, 0976-2833 VOL12, ISSUE 06, 2021

combination of GFRP/CFRP sheets. Hence it is found that due to the combination of high stiffness and strength CFRP sheets when combined with the high deformation GFRP sheets gives better performance as compare to the use of GFRP and CFRP sheets alone. Similarly, MMC possess better mechanical properties by changing their orientation of fiber structures and their fiber volume fraction and can be used with the combination of polymer composites for improving further strengthening.

REFERENCES

1. N. Attari, S. Amziane, and M. Chemrouk, “Flexural strengthening of concrete beams using CFRP, GFRP and hybrid FRP sheets,” Construction and Building Materials, vol. 37, pp. 746–757, 2012.
2. P. Jayajothi, R.Kumutha and K. Vijai, “Finite Element Analysis of FRP Strengthened RC Beams Using ANSYS,” Asian Journal of Civil Engineering, vol. 14, no. 14, pp. 631-642, 2013.
3. R. A. Hawileh, H. A. Rasheed, J. A. Abdalla, and A. K. Al-tamimi, “Behavior of reinforced concrete beams strengthened with externally bonded hybrid fiber reinforced polymer systems,” Material Description, vol. 53, pp. 972–982, 2014
4. S. S. Shetty and K. M. Malipatil, “Analytical Analysis on Reinforced Concrete Beam Strengthened by FRP Laminate using ANSYS,” vol. 3, no. 05, pp. 1209–
1212, 2015.
5. Arun Vignesh, S & Sumathi, A & Saravana Raja Mohan, K. “Flexural behavior of RCC beams with externally bonded FRP”, IOP Conference Series: Earth and Environmental Science, 2017
6. L. Huang, C. Zhang, L. Yan, and B. Kasal, “Flexural Behavior of U-shape FRP Profile-RC Composite Beams with Inner GFRP Tube Confinement at Concrete ”, Elsevier science Publishers Ltd, Composite Structures, vol. 184, no. October, pp. 674–687, 2018.
7. S. Kumar, C. Water, and S. B. Vummethala, “Elastic modulus of Al – Si / SiC metal matrix composites as a function of volume fraction, IOPscience , 2009.
8. D. Sujan, Z. Oo, M. E. Rahman, M. A. Maleque, and C. K. Tan, “Physio-mechanical Properties of Aluminium Metal Matrix Composites Reinforced with Aluminium oxide and SiC,” International Journal of Material and Metallurgical Engineering, vol. 6, no. 8, pp. 678–681,
2012.
9. K. L. Meena, A. Manna, and S. S. Banwait, “An Analysis of Mechanical Properties of the Developed Al/ SiC- MMC,” American Journal of Mechanical Engineering ,vol. 1, no. 1, pp. 14–19, 2013.
10. D. Verma, P. Chandrasekhar, S. Singh, and S. Kar, “Investigations into Deformation Characteristics during Open-Die Forging of SiC p Reinforced Aluminium Metal Matrix Composites,” 2013.

ISSN: 0975-3583, 0976-2833 VOL12, ISSUE 06, 2021

11. K. S. Shivakumar Aradhya, Mrityunjay R. Doddamani, "Charaterization of Mechanical Properties of SiC MMC using Finite Element Method," American Journal of Material Science, vol. 5, no. 3, pp. 7-11.
12. D M Nuruzzamman, F F B Kamaruzaman, "Processing and mechanical properties of aluminum-silicon carbide metal matrix composites," IOP Conf. Ser.: Mater. Sci. Eng, 2016.
13. S. Muniamuthu, "Investigation on Mechanical Properties of MMC," vol. 7, no. 6, pp. 474–482, 2016.
14. Akhil R, "A Study on Recent Trends in the Applications of MMC ," vol. 6, no. V, pp. 172–180, 2018