Review on Use of FRP Composite System with RCC Beam and Column

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Abstract

Fibre reinforced polymer (FRP) composite system are used in many applications. This paper briefly reviews the history of FRP composite system and RCC beams and columns. The various applications of fibre reinforced polymer (FRP) are also reviewed. This review paper also deals with the various techniques of applying fibre reinforced polymer (FRP) composite system. Several recently published articles and technical papers dealing with fibre reinforced polymer (FRP) composites are critically reviewed. The purpose of this review paper is to study the retrofitting procedures technically and select the fibre reinforced polymer (FRP) composite material for experimental comparison of RCC beams and column with and without applying FRP composite system.
Keywords: FRP, CFRP, GFRP, Epoxy Resin

I. INTRODUCTION

In 1990s, the Federal Emergency Management Agency (FEMA) and the State of California grew concerned about seismic evaluation and rehabilitation guidelines due to the need of integrated standards of seismic retrofitting. Many of the experimental and analytical studies on retrofitting strategies were conducted after this time. Due to the active research there was a significant development in seismic retrofitting and rehabilitation procedures. Consequently the retrofitting procedure could be selected as per importance of structure and the desired structural performance during seismic event with particular relapse intervals.

Fibre reinforced polymer is a composite material made of a polymer matrix reinforced with fibres such as glass, carbon, aramid or basalt. Fibre reinforced polymers (FRPs) are a class of advanced composite materials that originated from the aircraft and space industries. They have been used widely in the medical, sporting goods, automotive and small ship industries. FRP has high strength to weight ratios, and excellent resistance to corrosion and environmental degradation. It is very flexible and forms all kinds of shapes and is easy to handle during construction. Many of the advantages in these materials have proven to be revolutionary in terms of time constraints and durability of these structures. The FRP composite material is generally used as a retrofitting material to the existing structure. The high strength and light weight of these materials and the fact that they are now available in the form of very thin sheets provide an attractive and economical solution for strengthening existing concrete bridges to increase their ductility, flexure and shear capacity in response to the increasing demand to use heavier truck load. The higher material cost is typically offset by reduced labour, use of heavy machinery, and shut-down costs, making FRP strengthening systems very competitive with traditional strengthening techniques. The development in India through the last several years indicates that there is a further scope for collaboration of technology and the available indigenous materials and application of FRP. FRP sheets are mainly of two types as,

- Carbon fibre reinforced polymer (CFRP)
- Glass fibre reinforced polymer (GFRP)

There are also some other retrofitting techniques available depending upon the condition and type of structure. The selection of investigation method for applying retrofitting techniques mainly depends upon technical, financial and sociological conditions. There are some other factors affecting the selection of investigation methods as per Thermou and Elnashai 2002 as,

- Cost versus importance of the structure
- Available workmanship
- Duration of work/disruption of use
- Fulfilment of the performance goals of the owner
- Functionally and aesthetically compatible and complementary to the existing building
- Reversibility of the intervention
- Level of quality control
- Political and/or historical significance
- Structural compatibility with the existing structural system
- Irregularity of stiffness, strength and ductility
- Adequacy of local stiffness, strength and ductility

- Controlled damage to non-structural components
- Sufficient capacity of foundation system
- Repair materials and technology available

In further study the FRP composite material used will be CFRP sheets, GFRP bolts, epoxy resin. Many existing structures located in seismic regions are inadequate based on current seismic design codes. In addition, a number of major earthquakes during recent years have underscored the importance of mitigation to reduce seismic risk. Seismic retrofitting of existing structures is one of the most effective methods of reducing this risk. In recent years, a significant amount of research has been devoted to the study of various strengthening techniques to enhance the seismic performance of RCC structures. The main aim of the review paper is to study the concepts of the CFRP and GFRP composite system to be used in the existing structure RCC beams and columns. In further study the tests will be conducted as compressive strength, flexural strength, split tensile test, to compare the results with different variants as samples by using FRP composite material and without using FRP composite material to RCC beam and column structure.

II. EXAMPLES FROM THE LITERATURE

A. Review Paper 1:

Nicholas Lawler and Maria Anna Polak thoroughly present the technology of FRP shear bolts for punching shear of reinforced concrete slabs. The technology is used to protect previously built reinforced concrete slab against brittle punching shear failure. The FRP shear bolts technology requires drilling small holes in existing RC slab around the perimeter of a column, inserting bolts into the holes, and anchoring the bolts at both external surfaces of the slab. The anchorage technique for the FRP rods was developed is based on the crimping the rod ends with the aluminium fitting. The specimens were subjected to stimulated gravity loading and the improving performance and benefits of using FRP in punching shear retrofit of reinforced concrete slab in corrosive environments were stated in the study. Further, it is stated that the tightness of the bolts against the slab surface affects the slab performance and the bolts will prevent punching shear effect and allows for ductile failure of the slab.

B. Review Paper 2:

In this paper R. Jafarzadeh, J. M. Ingham and their colleagues presented a statistical model for calculating retrofit net construction cost (RNCC) and confined masonry (CM) buildings. The model was developed on the bases of regression analysis. The historical data for the model was collected from total number of 183 CM school retrofit projects in Iran. The two main variables studied in the research were quality of mortar and confining concrete element which were appreciably influencing the value of RNCC. As per their research the increase of 1% of total floor area and seismic weight would increase RNCC by 0.85% and 0.18% respectively. Also the strengthening of flexible diaphragms presence of low quality mortar also shows appreciable increase in the value of RNCC. The research was only limited for the retrofit school projects in Iran and only based on the predicted and collected historical data related to the respective school projects.

C. Review Paper 3:

The research is related to the circular columns confined with FRP. The research was based on the experimental investigation which was conducted by Omar Chaallal, Munzer Hassan and Michel LeBlanc. In this research half scale concrete columns were retrofitted with externally bonded with fibre reinforced polymer (FRP). Using various parameters such as FRP confinement ratio, the unconfined concrete strength and the elastic and mechanical properties of FRP various comparisons in terms of confined and unconfined strength was done respectively. For experimental investigation the diameter of circular column was varied and the length was kept constant. The layers of carbon fibre reinforced polymer (CFRP) were taken up to two layers and extra overlap of 75mm was applied. The CFRP used in the investigation has tensile strength of 3.65GPa and modulus of elasticity of 231GPa. The grades of concrete were M15 and M35. Concrete mixes were used without adding admixtures to it. The experimental research concludes with the appreciable increase in confined concrete strength and load carrying capacity of low strength concrete as M20 and less. FRP with high modulus of elasticity and high tensile strength can substantial increase the confined concrete strength by developing passive confining pressure.

D. Review Paper 4:

The research by B. Shan and Y. Xiao was related to RC column subjected to simulated earthquake loading. The RC columns were retrofitted with FRP and the behaviour of respected column was analysed. The analysis of FRP retrofitted RC columns based on the axial loading creep behaviour with different degrees of simulated earthquake damage. Based on the previous maximum lateral displacement, the damage degree and residual strains in FRP after lateral loading are assessed. In the creep model the normalized damage index DM and immediate strain of damage columns are present. The creep model is verified with the test results of fibre wrapped concrete columns by researchers Naguib and Mirmiran (2002) and other authors. The practical design parameters were identified that may affect creep of hybrid columns. 0.85 was the acceptable maximum damage index (DM) level according to the proposed creep model.

E. Review Paper 5:

Dong Sheng Gu, Gang Wu and their colleagues present their research related to confinement effect of FRP on circular columns. The effect of type and amount of fibre reinforced polymer (FRP) is also studied in the research. The concluding part of the research is as the plastic hinge region and the drift capacity of FRP retrofitted columns were greatly affected by amount of confining fibre reinforced polymer (FRP). The drift capacity will increase with the increase in aspect ratio. Also, the energy dissipation increases with greater axial load level and confinement stiffness.

F. Review Paper 6:

The research is related to the retrofitting of RC square columns with fibre reinforced polymer (FRP). The research was conducted by Yu Fei Wu, Tao Liu and Leiming Wang in China. In this research the test were conducted to investigate the effect of new retrofitting technique. The new technique developed was to horizontally insert small fibre reinforced polymer (FRP) bars in the plastic hinge zone of the RCC beams and columns. The FRP rods of 6 to 8mm diameter were used to insert in the plastic hinge zone of the beams and columns. The research combines the new technique of using FRP rods with the historic technique of column jacketing. Using this methodology, prevent buckling of longitudinal reinforcement, increase ductility in plastic hinge zone of beams and columns. This research can be carry forward by using FRP rods as reinforcement in RC beams, columns and slabs.

III. PROPERTIES

In fibre reinforced polymer (FRP) composite system there are mainly two types as carbon fibre reinforced polymer (CFRP) and glass fibre reinforced polymer (GFRP). FRP has high strength to weight ratios, and excellent resistance to corrosion and environmental degradation. It is very flexible and forms all kinds of shapes and is easy to handle during construction.

The CFRP is used in the form of sheets having ultimate tensile strength of 2300 N/mm2 and ultimate tensile strain of 1.50%. Epoxy resin of 65MPa compressive strength and having young's modulus of 2300 N/mm2 is used as an injecting material in composite system. The GFRP material is used in the composite system in the form of rods in plastic hinge zone of RCC beams and columns. The GFRP rod having ultimate tensile strain and strength of 2.4% and 2040 N/mm2 and young's modulus of 93100 N/mm2 respectively used in studies. The epoxy mortar having compressive strength of 79MPa is used in the further research.

IV. APPLICATIONS

Fibre reinforced polymers (FRP) are a class of advanced composite materials that originated from the aircraft and space industries. They have been used widely in the medical, sporting goods, automotive and small ship industries. FRP composite material provide an attractive and economical solution for strengthening existing concrete bridges to increase their ductility, flexure and shear capacity in response to the increasing demand to use heavier truck load.

Generally, the FRP composite material is used as a retrofitting material to the damage beams and columns of RC structure. The FRP bolts are used as reinforcement to the plastic hinge zone of structure and FRP sheets are used for jacketing the RCC beams and columns. The FRP mesh can also be a replacement to the steel reinforcement in slab.

V. CONCLUSION

In this particular review paper we have studied that the fibre reinforced polymer (FRP) composite material can be used as retrofitting material for damaged structures. The FRP material has high strength to weight ratio and appreciable resistivity to corrosive and degrading environment.

As the tensile strength of the GFRP rod is appreciable it can be used in the plastic hinge zone of beams and columns in further studies. The CFRP sheets can be used to reduce the increasing effects of cracks and also to increase the compressive, tensile and flexural strength of RC beams and columns respectively in further research. Epoxy mortar and resin have to be used for proper bonding of FRP composite materials.

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