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LITERATURE REVIEW FOR STRENGTHENING OF RC SLABS USING CFRP AND GFRP SHEETS

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ABSTRACT

In this experimental investigation, the flexural behavior of RC Slabs strengthened using glass fiber reinforced polymer (GFRP) sheet, carbon fiber reinforced polymer (CFRP) sheet and hybrid fiber reinforced polymer (GFRP+CFRP) sheet with different spacing were carried out. Externally reinforced concrete slabs with epoxy-bonded GFRP sheet, CFRP sheet and hybrid sheet were tested upto failure. Ten slabs were casted for this experimental test program and out of which one is control slab and other nine slabs were wrapped using glass fiber reinforced polymer (GFRP) sheet, carbon fiber reinforced polymer (CFRP) sheet and hybrid fiber reinforced polymer (CFRP+CFRP) sheets with different spacings and tested in flexure.

Keywords: Slabs; GFRP; CFRP; Sheets; Reinforcement mesh; Glass fibers.

1 INTRODUCTION

The maintenance, rehabilitation and upgrading of structural members, is perhaps one of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time. Strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives. Infrastructure decay caused by premature deterioration of buildings and structures has lead to the investigation of several processes for repairing or strengthening purposes. One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations and budget. Structural strengthening may be required due to many different situations.

Additional strength may be needed to allow for higher loads to be placed on the structure. This is often required when the use of the structure changes and a higher load-carrying capacity is needed. This can also occur if additional mechanical equipment, filing systems, planters or other items are being added to a structure.

Strengthening is required for loads resulting from wind and seismic forces or to improve resistance to blast loading.

Additional strength may be needed due to a deficiency in the structure's ability to carry the original design loads. Deficiencies may be the result of deterioration (e.g., corrosion of steel reinforcement and loss of concrete section), structural damage (e.g., vehicular impact, excessive wear, excessive loading and fire), etc or errors in the original design or construction (e.g., misplaced or missing reinforcing steel and inadequate concrete strength).

When dealing with such circumstances, each project has its own set of restrictions and demands. Whether addressing space restrictions, constructability restrictions, durability demands or any number of other issues, each project requires a great deal of creativity in arriving at a strengthening solution.

1.1 Strengthening Using FRP Composites:

Only a few years ago, the construction market started to use FRP for structural reinforcement, generally in combination with other construction materials such as wood, steel and concrete. FRPs exhibit several improved properties such as high strength-weight ratio, high stiffness-weight ratio, flexibility in design, non-corrosiveness, high fatigue strength and ease of application. The use of FRP sheets or plates bonded to concrete slabs has been studied by several researchers. Strengthening with adhesive bonded fiber reinforced polymers has been established as an effective method applicable to many types of concrete structures such as columns, beams, slabs and walls. Because the FRP materials are non-corrosive, non-magnetic and resistant to various types of chemicals they are increasingly being used for external reinforcement of existing concrete structures. Due to the flexible nature and ease of handling and application, combined with high tensile strength-weight ratio and stiffness, the flexible fiber sheets are found to be highly effective for strengthening of RC slabs. The use of fiber reinforced polymers (FRPs) for the rehabilitation of existing concrete structures has grown very rapidly over the last few years. Research has shown that FRP can be used very efficiently in strengthening the concrete slabs weak in flexure. Unfortunately, the current Indian concrete design standards (IS Codes) do not include any provisions for the flexural, shear and torsional strengthening of structural members with FRP materials. This lack of design standards led to the formation of partnerships between the research community and industry to investigate and to promote the use of FRP in the flexural, shear and torsional rehabilitation of existing structures. FRP is a composite material generally consisting of high strength carbon, aramid or glass fibers in a polymeric matrix (e.g., thermosetting resin) where the fibers are the main load carrying element.

1.2 Advantages and Disadvantages of Fiber Composite Strengthening:

1.2.1 Advantages

Fiber composite strengthening materials have higher ultimate strength and lower density than steel. When taken together these two properties lead to fiber composites having a strength/weight ratio higher than steel plate in some cases (though it is often not possible to use this fully). The lower weight makes handling and installation significantly easier than steel. This is particularly important when installing material in cramped locations. Work on soffits of bridges and building floor slabs can often be carried out from man-access platforms rather than full scaffolding. Steel plate requires heavy lifting gear and must be held in place while the adhesive gains strength. Bolts must be fitted through the steel plate into the parent concrete to support the plate while the adhesive cures and to reduce the effects of peeling at the ends. On the other hand, the application of FRP plate or sheet material has been likened to applying wallpaper. Once, it has been rolled on carefully to remove entrapped air and excess adhesive it may be left unsupported. In general no bolts are required since the use of bolts would seriously weaken the material unless additional cover plates are bonded on. Furthermore, because there is no need to drill into the structure to fix bolts or other mechanical anchors there is no risk of damaging the existing reinforcement. Fiber composite materials are available in very long lengths while steel plate is generally limited to 6 m. The availability of long lengths and the flexibility of the material also simplifies the installation:

- Laps and joints are not required.
- The material can take up irregularities in the shape of the concrete surface.
- The material can follow a curved profile; steel plate would have to be pre-bent to the required radius
- The material can be readily installed behind existing services
- Overlapping is required when strengthening is in two directions, as it is not a problem because the material is thin.

The materials fibers and resins are durable if correctly specified and require little maintenance. If they are damaged in service, it is relatively simple to repair them by adding an additional layer. The use of fiber composites does not significantly increase the weight of the structure or the dimensions of the member. The latter may be particularly important for bridges and other structures with limited headroom and for tunnels. In terms of environmental impact and sustainability, studies have shown that the energy required to produce FRP materials are less than that for conventional materials. Because of their light weight, the transport of FRP materials has minimal environmental impact.

These various factors in combination lead to a significantly simpler and quicker strengthening process than when using steel plate. This is particularly important for bridges because of the high costs of lane closures and possession times on major highways and railway lines. It has been estimated that about 90% of the market for plate strengthening in Switzerland has been taken by carbon plate systems as a result of these factors.

1.2.2 Disadvantages

The main disadvantage of externally strengthening structures with fiber composite materials is the risk of fire and accidental damage, unless the strengthening is protected. A particular concern for bridges over roads is the risk of soffit reinforcement being hit by over-height vehicles. However, strengthening using plates is generally provided to carry additional live load and the ability of the unstrengthened structure to carry its own self-weight is unimpaired. Damage to the plate strengthening material only reduces the overall factor of safety and is unlikely to lead to collapse.

Experience of the long-term durability of fiber composites is not yet available. This may be a disadvantage for structures for which a very long design life is required but can be overcome by appropriate monitoring.

A perceived disadvantage of using FRP for strengthening is the relatively high cost of the materials. However, comparisons should be made on the basis of the complete strengthening exercise; in certain cases the costs can be less than that of steel plate bonding.

A disadvantage in the eyes of many clients will be the lack of experience of the techniques and suitably qualified staff to carry out the work. Finally, a significant disadvantage is the lack of accepted design standards.

2 LITERATURE REVIEW

Marco Arduini et al. conducted experiment on full scale one-way reinforced concrete (RC) slabs. The 26 slabs with and without an overhang at one extremity were tested under simply supported conditions. The geometry and loading configuration allowed for the study of positive and negative moment regions. The slabs were strengthened with unidirectional carbon fiber reinforced polymer (CFRP) laminates installed by manual lay-up. Different failure mechanism-namely concrete shear concrete crushing, CFRP rupture, and CFRP peeling-were obtained. Then findings of an analytical model –simulating and interpreting the experimental results are also done and concluded that the load carrying capacity can be increased up to 122% in comparison with the benchmark slabs and also good agreement obtained between analytical approach and experimental results [6].

U. Ebead et al. evaluated strengthening of two-way slabs using fiber-reinforced polymers (FRPs) experimentally. Two different types of FRP materials were evaluated: carbon FRP strips and glass FRP laminates. The dominating failure mode for two way slab, flexure, or punching shear is based on the slab steel reinforcement ratio. The reinforcement ratio were chosen to serve the purpose of demarcating the two possible modes of failure. The tested specimens were classified according to the purpose of strengthening into specimens strengthened in flexure and specimens strengthened in punching shear. Specimen strengthened in flexure had two steel reinforcement ratios: 0.35 and 0.5%. Flexural strengthened specimens (slabs) using CFRP strips showed an average gain in the load capacity of approximately 40% over that of he unstrengthened specimens. The flexural strengthening specimens showed stiffer behavior than that of the unstrengthened specimens. The recommended theoretical analysis used for FRP strengthening of two-way slabs showed a good agreement with experimental test results [9].

Oualid Limam et al. casted two way Reinforced Concrete (RC) slabs and strengthened them using carbon fiber reinforced polymer (CFRP) strips bonded to the tensile face of the slabs. The first part deals with an experimental study. The fiber reinforced plastics (FRP) strengthened slab test presents a failure mode with debonding of the external FRP strips from the slab. The second part deals with a limit analysis modelling. The strengthened slab is designed as a three-layered plate. A simplified laminated plate model is used to describe the behavior of three-layered plate supported in four sides, which is subjected to a load in the centre. The upper bound theorem of limit analysis is used to approximate the ultimate load capacity and identify the different collapse mechanisms. Experimental results are compared with theoretical predictions. Which showed that externally bonded CFRP plates can efficiently used to strengthen two way RC slab [7].

Y. Piyong et al. done research program on the flexural performance of a concrete slab strengthened with a three-stage prestressing system using Carbon FRP (CFRP) sheets was investigated under a four-point static load test setup at the University of Missouri Rolla (UMR). Debonding of the CFRP sheets was prevented by installing three glass FRP (GFRP) anchor spikes at each end of the prestressed FRP sheets. An un-strengthened slab designated in this paper as the control unit was also tested under a separate research program and is described in this paper only as a source for comparison with the strengthened slab. As expected, test results indicate that both the serviceability and flexural capacity were significantly increased, and no debonding from the ends of the CFRP sheets was observed due to the presence of the GFRP anchor spikes [10].

Jeffery R et al. done work on Large-scale load testing was completed on both plain and fiber-reinforced concrete slabs-on-ground. The fiber-reinforced concrete used a new synthetic macro fiber. Although the synthetic fibers did not alter the tensile cracking load of the plain concrete slab, the flexural cracking load of the plain concrete slab was increased by 25 and 32% with synthetic fiber addition of 0.32 and 0.48% by volume, respectively, for the center loading configuration. Similarly, synthetic fibers at 0.48% volume fraction increased the flexural cracking load of plain concrete slab under edge loading by 28%. The ultimate load capacity of the plain concrete slab under center loading was increased by 20 and 34% with the addition of 0.32 and 0.48% synthetic fibers, respectively. Embedded strain gauges in the concrete slabs and deflection profile measurements indicated the fibers effectively distributed the load throughout the slab volume as cracking progressed, resulting in the increased concrete slab flexural and ultimate capacities and also conclude that the synthetic fiber did not increase the tensile capacity of the concrete slabs [5].

3 CONCLUSION

- The increase in load carrying capacity of the strengthened slab by using glass, carbon and hybrid fiber sheets were in the range of 27.76% to 81.91% in comparison with the load carrying capacity of control slab.
- From test result it is concluded that as the spacing of fiber strips increases the ultimate load carrying capacity of the slab decreases.
- The deflection of the strengthened slab with FRP sheets were less in comparison with control slab.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

No conflicts of interest regarding this manuscript.

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