AmirKabir University of Technology
(Tehran Polytechnic)

AmirKabir Jounrnal of Science & Research
Civil and Enviromental Engineering (ASJR-CEE)

Vol. 48, No. 1, Spring 2016, pp. 17-20

Ultimate Strength of Concrete Beams Strengthened by CFRP Fabric and Laminates, at High and Freezing Temperatures

Dr. Mahmood Naderi[1*], Siamak Smeali zadeh[2]

1- Associate Professor, Engineering Faculty,Imam Khomeini International University Qazvin
2- Postgraduate Student, Engineering Faculty,Imam Khomeini International University Qazvin

(Received 13 February, 2013, Accepted 20 September, 2014)

ABSTRACT

The use of Carbon Fiber Reinforced Polymer (CFRP) laminate systems, for strengthening of structures has gained popularity in recent years.Previous researches indicate that one of the difficulties facing this system is its behavior under high and freezing temperatures. this study investigates the behavior of concrete beams strengthened by CFRP fabrics and laminates, under high and freezing temperatures. in this studies, 24 non-reinforcement concrete beams of 30 x 100 x 100 mm sizes were cast using three different concrete strength. After curing, these beams were strengthened using both flexible and hard CFRP sheets. After setting and hardening of the glue used to adhere the CFRP sheets on to the concrete beams, they were exposed to -20°C, +50°C and +80°C temperatures, before undergoing the four point flexural test. Results of study indicate that while the failure of the CFRP sheets at room temperature seems to be due to the flexural cracking, the mode of failures at very low and high temperatures is due to the shear stresses. It may be said that, in addition to the effect of low and high temperatures on the adhesion between the CFRP sheet and substrate concrete, the materials properties involved in this systems are also seriously affected by the extreme temperatures. Examination of the ultimate strength of the strengthened beams also indicates that as the temperature reaches the glass transition temperature of the glue, the reduction in the ultimate strength becomes noticeable. Comparison of the experimental results with the related results of the analytical method, is also presented in this paper.

KEYWORDS:

CFRP, Strengthening, Temperature, Concrete beam, Debonding, Ultimate strength.

* Corresponding Author, Email: naderi-m@ikiu.ac.ir

1- INTRODUCTION

Retrofitting of structures has become more important in recent years. Although there are many reasons for this but deterioration, increasing design mistakes and practical errors are among the main causes. Furthermore, many of the existing structures need to be strengthened in order to carry the additional loads that were not foreseen in the design stage [1].

From an environmental and economical point of view, it is generally preferred to strengthen an xisting structure instead of demolishing it and subsequently rebuilding it.Strengthening of a structure is in most cases less expensive and less interfering compared to rebuilding. It should also be noted that the time needed for the strengthening is much less than the time needed for the rebuilding of a structure during which the use of the structure has to be postponed [2]. One of the recent developments in the strengthening industry is the use of externally bonded Fiber Reinforced Polymer (FRP) reinforcement for strengthening of existing structures, such as reinforced concrete, steel, timber and masonry structures. Last decade FRP has become increasingly popular as a strengthening material given the increasing number of FRP strengthening applications worldwide[3]. Among the systems used for the Researches on the behavior of the FRP systems in 2003 showed that amongst others,there is a lack of available data about the behavior of FRP strengthened structures in the case of fire and when subjected to thermal effects, like elevated temperatures and freeze thaw cycling [4].

Based on the studies carried out by some researchers, it was shown that the bond between FRP and the concrete is completely destroyed near or at Tg temperature. Furthermore, it was shown that due to the differences in the coefficient of thermal expansion between concrete and FRP under different environmental temperatures, the behavior of the strengthened structure can vary considerably [6].

The main aim of this paper is to show the results of the research done on the behavior of the concrete beams which were strengthened by rigid and flexible CFRP systems and exposed to high temperatures as well as to freezing. The studies included the manufacture of 350×100×100 mm non-reinforcement concrete beams that were strengthened by the rigid and flexible CFRP layers and then were tested under flexural loading after exposing to cyclic temperature changes. The ranges of the temperatures included -200°C, 500°C, 800°C, cycles. The system of loading was 4 point loading and the ultimate strength of the strengthened beams was recorded for comparison with the strengthened concrete beams which were kept under normal room temperature.

Knowing that in a strengthened concrete section the base concrete, epoxy adhesive and CFRP laminate have to withstand the service temperature changes in a manner that no de-bonding occurs between the described layers, the nature and the expansion coefficients of the materials involved, play major role in the successful performance of the system.

2- EFFECT OF TEMPERATURE ON THE MATERIAL PROPERTIES

the effect of high temperature on the properties of materials alone can be very significant. For example, some researchers concluded that the effect of temperature on the concrete material properties is mainly related to the evaporation of water from the concrete and to changes in the chemical composition and physical structure of the concrete. It is reported that at 90°C, the compressive strength is reduced to about 65% to 90% of the initial strength [7].

It should be noted that the information about the behavior of CFRP laminates and the epoxy glue under high temperature is scarce and therefore, the prediction of the service life of the CFRP strengthened concrete sections is very difficult and for this reason it is hoped that the information provided in this paper can be useful for practical purposes.

3- FAILURE OF FLEXURAL FRP STRENG-HENED CONCRETE STRUCTURES

When concrete starts cracking, tensile stresses in the concrete have to be taken over by the FRP and will result in a peak in the tensile stress in the FRP reinforcement at the intersection with the crack. The peak in the tensile stress in the FRP will be transferred to the concrete at both sides of the crack tip (end of the crack at the FRP reinforcement) by interfacial shear stresses[8].(Figure 1)

Because of the slanting shape of shear cracks, both a difference in horizontal (w) and in vertical (v) displacement will occur between the two sides of the crack (Figure 2). The difference in vertical displacement will induce tensile stresses perpendicular to the concrete surface at one side of the crack, which could, in combination with the shear stresses in the

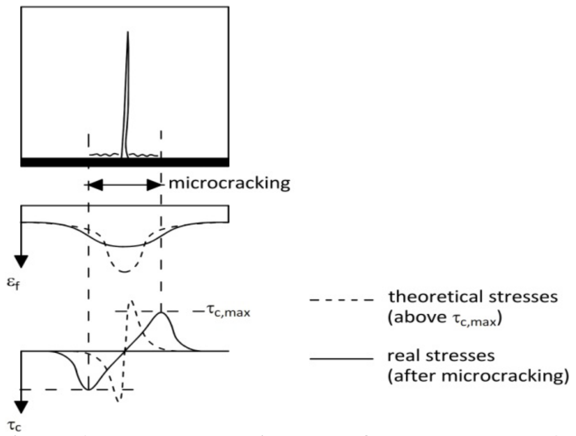

Figure 1. Local debonding near flexural cracks [8]

concrete,lead to the initiation of debonding of the FRP reinforcement. This generally occurs in the areas with a combination of a high shear force and a high bending moment, as the shear cracks in this region are less inclined[8].

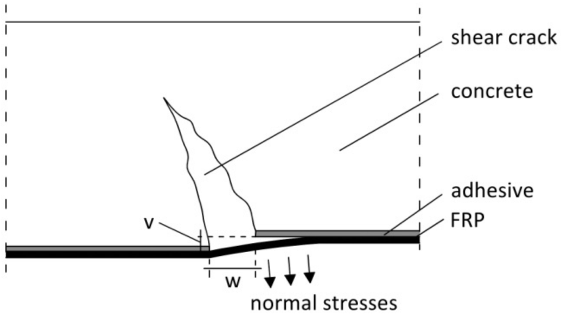

Figure 2. Debonding at shear cracks [8]

4- TEST SETUP

In the present research, 30 concrete beams were prepared and were strengthened by flexible and rigid CFRP fabric and laminates. The strength of the concrete used ranged from 20 to 40 MPa. The temperature considered ranged from -20°C +80°C. ASTM C884/C884M-98 was used to expose the samples to cyclic freeze-thaw tests[9]. The duration of any cyclic temperature changes was 48 hours.

5- EXPERIMENTAL RESULTS

beam strengthened with CFRP fabric in 3 concrete grades showed higher ultimate strenght toward beams strengthened with CFRP laminates at +20°C & +80°C.beam strengthened with CFRP in 3 concrete grades and 2 type CFRP showed lower ultimate strenght toward beams been in +20°C.

Failure of concrete beams which were kept in +20°C occurred by flexural cracks at middle of the span.(Figure 3)

Failure of concrete beams which were kept in other temperatures is due to high shear tension and

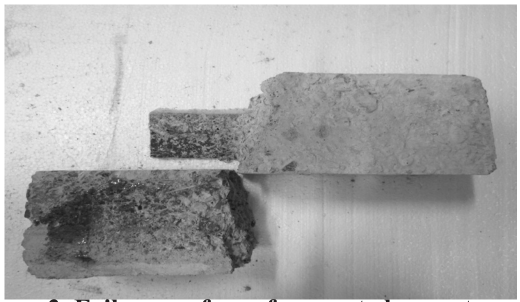

Figure 3. Failure surface of concrete beam strengthened with CFRP fabric in +20°C

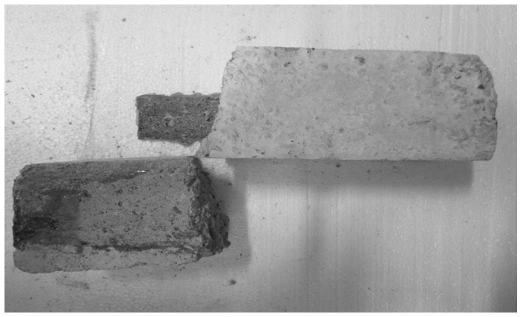

Figure 4. Failure surface of concrete beam strengthened with CFRP fabric in +50°C

Figure 5. Failure surface of concrete beam strengthened with CFRP fabric in +80°C

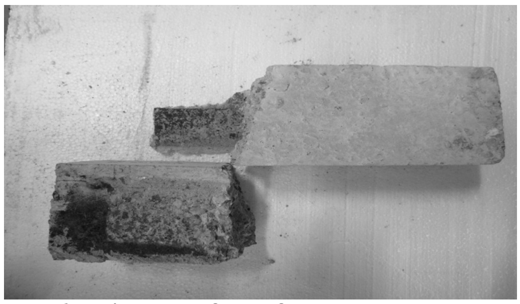

Figure 6. Failure surface of concrete beam strengthened with CFRP fabric in -20°C

occurred under the loading point in one third of the span of the beam.(Figure 3)

6- CONCLUSIONS

From the results obtained it can be concluded that:

1. Increase in the temperature affects both behavior and the ultimate strength of the CFRP strengthened concrete beams.

2.The type of failure in concrete beams

strenghened by CFRP fabric & laminates is that at -20°C & +20°C debonding occured in the concrete leaving a thin layer of concrete attached to the adhesive whereas at +50°C & +80°C debonding occurred in the concrete adhesive interface, leaving hardly any concrete attached to the adhesive

3. Compared with the respective rigid CFRP strengthened concrete beams, the flexible CFRP strengthened concrete beams showed less in reduction in their ultimate strength.

7- REFERENCES

[1] ACI 440.2R-02. , "Guide for the design and construction of externally bonded FRP systems for strengthening concrete structures.", American Concrete Institute;2002.

[2] Ernst L. Klamer & Dick A. Hordijk , "The influence of temperature on RC beams strengthened with externally bonded CFRP reinforcement",.

[3] Tuakta, C. and Buyukozturk, O. , "Deterioration of FRP/concrete bond system under variable moisture conditions quantified by fracture mechanic",Composite Part B: Engineering, Vol.42, No.2, pp.145-154, 2011.

[4] Harries, K. A., Porter, M. L., and Busel, J. P. , "FRP materials and concrete - search needs.",Concrete International, 25(10), 69-74, 2003.

[5] Karbhari, V. M., Chin, J. W., Hunston, D., Benmokrane, B., Juska, T., Morgan, R., Lesko, J. J.,Sorathia, U., and Reynaud, D. , "Durability Gap Analysis for fiber-reinforced polymer composites in civil infrastructure.", Journal of Composites for Construction, 7(3), 238-247,2003.

[6] Plecnik, J. M., Bresler, B., Cunningham, J. D., and Iding, R. , "Temperature ffects on epoxy adhesives.", Journal of Structural Division, 106(1), 99-113, 1980.

[7] Bažant, Z. P. and M. F. Kaplan. , "Concrete at high temperatures: Material properties and mathematical models.", Concrete design and constructions series. Essex, Longman Group Limited, 1996.

[8] Matthys, S. , "Structural behaviour and design of concrete members strengthened withexternally bonded FRP reinforcement.", Diss. Ghent University, 2000.

[9] ASTM C 884/C 884M – 98, " Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-ResinOverlay",.