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HEAT AND FIRE PROTECTION OF FIBER REINFORCED POLYMERS, (FRP)

Ibrahim Mahfouz[1], Bahira Abdulsalam[2] and Hatem Ibrahim[3]
[1] Chair of the Egyptian FRP Code Committee, Egypt

[2] CIISolutions Composite Infrastructure Innovation Solutions Corp, Canada
bahira.abdulsalam@compositeinfrastructure.com

[3] Guide house consulting, Washington, D.C., USA

Abstract: Two field applications of concrete structures strengthened using FRP systems subjected to elevated heat and fire are presented. The first field application deals with the strengthening of a reinforced concrete bridge having FRP layers exposed to excessive heat exceeding 120 degrees C, during the application of the asphalt layers. The FRP laminated strips installed on the top surface of the concrete bridge were protected using a 70 mm thick heat protection layer possessing adequate compressive strength capable of resisting the high intensity of the truck loads. Several heat protection materials where tested, and the one that was chosen was capable of fully protecting the FRP layers. The bridge has been successfully in use for a number of years.
The second field application presents the case of fully protecting a number of reinforced concrete columns against fire in a major project in K.S.A. It should be noted that the strengthening demands of such columns where 100%. Extensive experimental studies were carried out in order to be able to choose the best fire protection system which will be capable of fully protecting the FRP strengthening works against fire for a specified fire rating of the structure of two hours. The results obtained for the fire protection system used in this project was proven to be capable of providing full fire protection of the FRP strengthening system for more than two hours.

INTRODUCTION This work presents two case studies; the first case deals with the choice of heat insulation material for CFRP works used for the structural strengthening of the expansion of Lebanon square bridge in Cairo Egypt. The second case study presents fire protection of CFRP works for the Holy Mosque in Mecca Saudi Arabia.
Needless to say that one of the main problems that hinders the efficient utilization of FRP strengthening systems in the construction fields are the problems associated with excessive heat and the fire resistance of FRP systems. Recognizing the fact that CFRP composites cannot sustain the exposure to elevated temperature above the glass transition temperature of the epoxy resin, T_g, (which for most commercially available epoxy resins varies from 60 to 80), excessive heat above these values can adversely affect the efficiency of the CFRP strengthening works, while fire will defiantly result in a total loss of CFRP strengthening works if not properly protected. As such, the adverse effects of heat and fire on CFRP strengthening works must be carefully assessed and must be considered during the design of any strengthening works involving CFRP. Accordingly, special heat and fire protection measures must be included as an essential and integral part of the design of CFRP strengthening works. Several means of protecting FRP works against excessive heat are commercially available; however, such systems are not

generally suitable for all cases involving heat protection since in some cases the heat insulating material must possess dual properties of both adequate compressive strength and high heat insulation. Such cases include but are not limited to the strengthening of the upper surfaces of structures carrying heavy loads such as bridge decks and industrial floors.

1 CASE STUDY I STRENGTHENING OF LEBANON SQUARE BRIDGE IN CAIRO EGYPT

This project presents the development of a heat insulation material for CFRP work for the structural strengthening of the bridge possessing adequate compressive strength and high heat insulation. For this project Prof. Dr. Ibrahim Mahfouz was the CFRP Consultant.

1.1 CFRP Heat Insulating Materials Capable of Resisting Truck Loads

The preceding requirements of providing heat insulating material possessing relatively high compressive strength was encountered during the strengthening of the upper surface of the box girder bridge Lebanon square Bridge in Cairo Egypt. As a result of a comparative study for the determination of the most suitable strengthening method to be employed that satisfies the project's constraints. It was found that strengthening using CFRP is the best if not the only strengthening method that can satisfy all the design requirements. However, the problem of heat insulation was the main obstacle in the acceptance of such a proposal. A field and laboratory tests were carried out with the objective of modifying the properties of the commercially available heat insulating materials to be capable of resisting a high compressive stresses resulting from the truck loads. Three different types of mortars having thicknesses of 50 and 70 mm were chosen. The heat resistance of the various thicknesses of three mixes were tested on the bridge site, as shown in Figure 1.

FIGURE 1: HEAT RESISTANCE TEST

1.2 Experimental Testing of Heat Insulated CFRP Laminated Strips with Hot Asphalt Layers

The tests were carried out by applying hot relatively thick asphalt layers having temperature of about 120 C on the top of the modified 50 mm & 70 mm heat insulating layers that cover and protect CFRP laminated strips, as shown in Figure 1. The temperatures of the asphalt layers were raised to 180 c and kept at the temperature values corresponding to the probable temperature resulting from the actual applications of asphalt layers during the pavement works.

1.3 Analysis of Test Results

The analysis of the test results reveals that the 70 mm thick "VC" type mortar gave the best heat resistance performance. However, it was decided to use the "Perlite, PRC" type mortar since the compressive strength of the VC mortar did not satisfy the specified characteristic compressive strength. The results of the compressive strength of the PRC mortar are given in Figure 2. The values given in this figure satisfy the characteristic compressive strength requirements of the project.

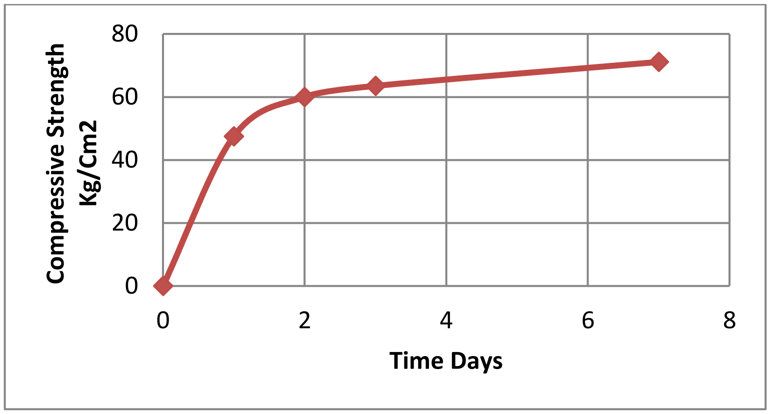

Figure 2 : Compressive Strength of the Heat Protection Layer

Based on the test results obtained, a heat insulation mortar that satisfies all the strength and insulation requirements was chosen. The thickness of the layer was taken equal to 70 mm. It is noted that during the application of the asphalt layers, continuous monitoring of the temperatures at a number of locations of the CFRP laminated surfaces were made using previously installed thermocouples on the surface of the CFRP strips. The monitoring system was used to regulate the rate of application of the asphalt layers such that the temperature of the CFRP layers does not exceed the T_g temperature of the epoxy resin of 60 º C used. It is noted that the recorded temperature during the application of the asphalt layers did not exceed the temperature of 40º C, previously obtained during the pre-installation tests. However, the temperature continued to rise and reached a peak value of 51 º C after 6 hours, but was followed by a gradual drop of temperature. The temperature recorded in the following day showed stable condition within the acceptable limits. The results are shown in Figure3.

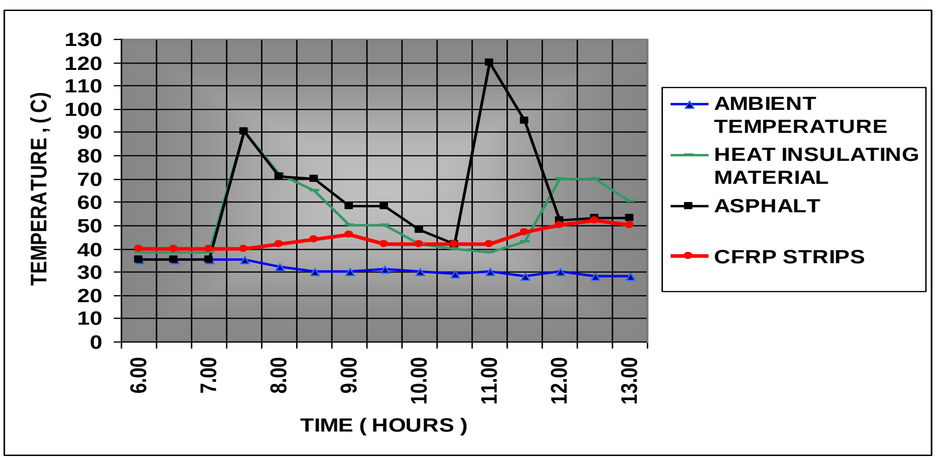

Figure 3: Recorded Temperature during the Application of Asphalt Layers

2 CASE STUDY II: FIRE PROTECTION OF THE CFRP WORKS EL-HARAM, MECCA. K.S.A.

For this project Prof. Dr. Ibrahim Mahfouz was the CFRP Consultant. The fire testing was carried out at Warringtonfiregent Laboratory, Gant, Belgium.

2.1 El-haram Innovative CFRP Strengthening Fire Protection System

For any FRP strengthened structural element having an increase in its load carrying capacity greater than 40%, the CFRP strengthening works must be fully protected against fire exposures, otherwise a total loss of CFRP strengthening works shall be expected resulting in a total collapse. As such, any fire protection system that cannot meet the preceding important condition shall be totally unacceptable. Accordingly, heat and fire protection measures must represent an integral part of the design of CFRP strengthening works. In this regard, extensive studies on the fire protection systems available worldwide, not only in the construction fields but also in other related fields were carried out during the design stage in KSA. As a result, fire protection systems were proposed and tested at Warringtonfiregent Laboratory, Gant, Belgium. The results revealed that the adopted fire protection system was capable of providing full fire protection satisfying fire resistance rating of more than 120 minutes, as shown in Figure 4.

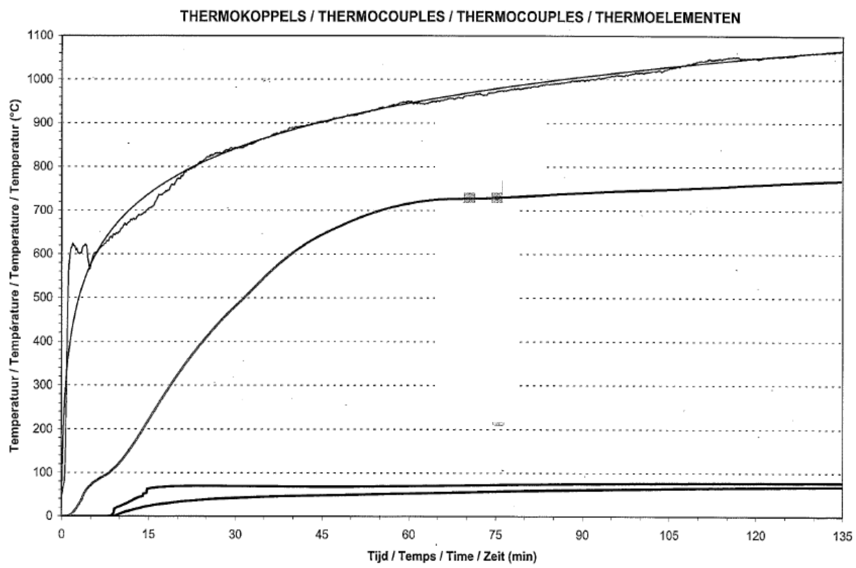

Figure 4: Results of the Fire Exposure Tests

2.1.1 Innovation

These two projects are considered to be unique regarding the excessive heat and Fire Resistant Technologies employed for protecting FRP strengthening works.

2.1.2 Lessons Learned

Lessons learnt through the tests led to the development of enhanced forms of the proposed system. It is expected that the enhanced systems should be capable of providing fire rating exceeding 120 minutes.

2.2 Acknowledgement

The author(s) would like to acknowledge the contribution of the Warringtonfiregent Laboratory, Gant, Belgium

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