THERMO-MECHANICAL BEHAVIOUR OF INSULATED FRP-CONCRETE COMPOSITES AT ELEVATED TEMPERATURE

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Degree of Master of Science

Department of Civil Engineering

University of Moratuwa

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science in Civil Engineering

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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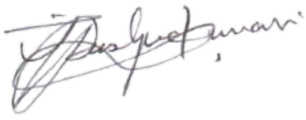
The above candidate has carried out research for the Masters under my supervision

Name of the supervisor: Dr. (Mrs.) J.C.P.H. Gamage

Signature of the supervisor:  Date: 04.11.2020

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ABSTRACT

The Fiber-reinforced polymer (FRP) retrofitting technique has become an efficient method for retrofitting the concrete structures, especially in buildings and bridges. Though FRP has superior mechanical properties, the fire performance remains an obstacle for practical applications. Degradation of mechanical and bond properties of FRP composites was found when it was subjected to elevated temperatures since the glass transient temperature of the adhesive component is around 70°C. At high temperatures, the epoxy resins will soften and eventually ignite, which causes the polymer matrix weaker, and hence a potential concern raises on the structural integrity of FRP bonded concrete composite structures.

When designing the buildings, adequate fire resistance between 2 h and 4 h should be provided depending on the type of building. Though several techniques have been investigated to control the temperature of the CFRP composite structures, controlling the temperature is impossible in large scale civil engineering applications. Therefore, using insulation materials for CFRP-Concrete composites have become an effective solution. However, to achieve 2 hours of fire endurance, 40-50 mm thickness of insulation is required. Though there are many fireproofing materials for CFRP composites, the available Insulation materials in the market are very high cost which is not affordable in countries like Sri Lanka. Hence, a cost-effective insulation system for CFRP composites is required.

In this study, two types of solutions are proposed to make the CFRP retrofitting projects economical without affecting structural integrity. In such a way as the first solution, and alternative CFRP bond arrangement was investigated by bonding the CFRP laminates in a groove within the nominal cover of the member. A test program was carried out to compare the thermal and structural performance of grooved and external bonding techniques. A total of 15 CFRP-Concrete specimens were exposed to different fire scenarios with and without insulation. A numerical model was also developed to predict the effects of sensitive parameters on thermo-mechanical

performance under standard fire. A reduction of up to 36% of Insulation requirement was observed by using this method with less than 4% flexural capacity reduction.

In phase 2, a cement-based Insulated plaster was developed using EPS particles as the base material. An experimental program was conducted, and ten different trial mixes were prepared to study the mechanical and thermal behaviour of the EPS-cement mortar with different mix proportions. Replacement of fine aggregates by EPS particles from 0% to 200% was examined in this study. It was noted that the mechanical properties of the mortar reduce with increasing EPS particles and the thermal properties increases with increasing EPS particles. A reduction up to 69% and 53% were noted in thermal conductivity and density, respectively due to the replacement of aggregates with EPS in the conventional mortar. Two types of mix proportions were selected for further study and the effect of particle size and water/cement ratio was studied. Finally, the mix with 200% replacement of fine aggregates by EPS was selected as the ideal mix to provide an insulation for CFRP composites. And it was discovered that 125% replacement plaster can be used as a external wall plaster to improve the thermal comfort within buildings.

In the next phase of this research, the developed plaster was applied to the masonry walls. A heat transfer model was developed to assess the performance of the developed mortar using EPS blend to enhance the thermal comfort within the buildings. The internal wall temperature with different plasters was compared with the conventional cement-sand plaster. A reduction of 18% and an increment of 20% were noted in the decrement factor and time lag, respectively in the wall panels with the developed EPS-Cement plaster.

LIST OF PUBLICATIONS

Journals

1. Selvaratnam, A., Kahandawa Arachchi, K.A.T.Y. and Gamage, J.C.P.H. 'Investigation on an economical and effective bond arrangement of CFRP strengthened concrete members for fire safety' *submitted to Fire Safety Journal.*

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1. Selvaratnam, A., Gamage, J.C.P.H. (2020) 'A Review on Thermo-mechanical behaviour of CFRP-Concrete composites at elevated temperature and available insulation systems', *Lecture Notes in Civil Engineering*, Volume 94. pp. 9. http://doi.org/10.1107/978-981-15-7222-7_43.

International Conferences

1. Aaruga, S., Chandrathilaka, E.R.K. and Gamage, J.C.P.H. (2019), 'Finite element Modelling on Flexural Performance of CFRP strengthened reinforced concrete curved beams', *5th International multidisciplinary engineering research conference,* Moratuwa, Sri Lanka. http://doi.org/10.1109/MERCon.2019.8818797.

2. Selvaratnam, A. and Gamage, J.C.P.H. (2019), 'Effect of steel reinforcement ratio on flexural enhancement in CFRP-strengthened concrete curved beams', *10th International Conference on Sustainable Built Environment*, Kandy, Sri Lanka,12-14 December 2019.

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4. Selvaratnam, A., Gamage, J.C.P.H. and De Silva, G.I.P. (2020) 'EPS blended cementitious plaster for improved thermal comfort in buildings' *11th*

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1. Selvaratnam, A., Kahandawa Arachchi, K.A.D.Y.T.., Selvaranjan, K. and Gamage, J.C.P.H. 'Behaviour of CFRP-strengthened concrete curved beams subjected to out-of-plane bending'
2. Selvaratnam, A., Kahandawa Arachchi, K.A.D.Y.T., Gamage, J.C.P.H. and De Silva, G.I.P. 'Development of a cost-effective insulation system for CFRP/Concrete composites using recycled EPS-Cement blend'.
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4. Kahandawa Arachchi, K.A.D.Y.T., Selvaratnam, A., Gamage, J.C.P.H. and De Silva, G.I.P. 'Deevelopment of an innovative insulated plaster using Bottom Ash to enhance thermal comfort in buildings.'
5. Kahandawa Arachchi, K.A.D.Y.T., Selvaratnam, A., Gamage, J.C.P.H. and Attanayake, V. 'Invetsigating on developing a cementitious insulation using Bottom ash for CFRP/Concrete composites'

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