UNIVERSITI TEKNOLOGI MARA

BEHAVIOUR OF ULTRA HIGH PERFORMANCE FIBRE-REINFORCED CEMENTITIOUS COMPOSITES FOR ENHANCING THE FIRE ENDURANCE OF STRUCTURAL MEMBERS

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CONFIRMATION BY PANEL OF EXAMINERS

I certify that a panel of examiners has met on 4th of April 2016 to conduct the final examination of Sobia Anwar Qazi on her Doctor of Philosophy thesis entitled "Behaviour of Ultra High Performance Fibre-Reinforced Cementitious Composites for Enhancing the Fire Endurance of Structural Members" in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiners recommends that the student be awarded the relevant degree. The panel of Examiners was as follows:

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ABSTRACT

Fibre-reinforced polymer (FRP) strengthened and unstrengthened reinforced concrete (RC) structures are susceptible to intense deterioration when exposed to elevated temperatures, particularly in the incident of fire. FRP has the tendency to lose bond with the substrate due to the low glass transition temperature (T_g) of epoxy; the key component of FRP matrix. Previously, various types of high performance cementitious composites (HPCC) were explored for the protection of RC structural members against elevated temperature. However, there is an inadequate information on the influence of elevated temperature on the ultra high performance fibre-reinforced cementitious composites (UHPFRCC) containing ground granulated blast furnace slag (GGBS) and/or fly ash (FA) as a replacement of high alumina cement (HAC) in conjunction with hybrid fibres (basalt and polypropylene (PP) fibres). This could be a prospective fire resisting material for the structural components. The influence of elevated temperatures on the compressive, flexural and tensile strength of UHPFRCC, made of HAC-GGBS and hybrid fibres, was examined in this study along with complete microstructural, chemical and thermal analysis. Total fourteen (14) mixes were developed. Besides control sample (without fibres), three other samples, containing 0.5%, 1% and 1.5% of basalt fibres by total weight of mix and 1 kg/m^3 of PP fibres, were prepared and tested. Another mix was also prepared with only 1 kg/m^3 of PP fibres. Nine (9) more mixes were developed with the replacement of GGBS with FA. Each of the samples were retained at ambient temperature as well as exposed to 400°C, 700°C and 1000°C followed by residual mechanical (compressive, tensile and flexural), thermal (TC, TG and DSC analysis) and microstructural (XRD, ESEM and MIP) testing after 28 and 56 days of conventional curing. Investigation of results disclosed that the use of hybrid fibres significantly helped to improve the ambient temperature compressive and flexural strength of UHPFRCC, which was found to be 80 MPa and 14.3 MPa respectively. However, the optimum residual compressive strength was marked by UHPFRCC– CP (with PP fibres only), equally after both curing days (28 and 56 days), i.e. 41%. In addition, the highest residual flexural strength, after 28 and 56 days of curing, was marked by UHPFRCC– CP and UHPFRCC– CB2 (1 kg/m^3 of PP fibres + 1% of basalt fibres) i.e. 39% and 48.5% respectively. Through statistical analysis by response surface methodology (RSM), regression models were also developed for UHPFRCC based on the factors affecting residual mechanical strength. After residual mechanical testing, UHPFRCC-CP and UHPFRCC-F2B1 were selected as best mix to be cladded over full scale Carbon fibre reinforced polymer (CFRP)-strengthened and unstrengthened RC columns and tested under ASTM E119 fire. Total seven short RC column specimens were cast, using grade 40 concrete, including unstrengthened and CFRP-strengthened with and without two different types of UHPFRCC cladding. The size of the full-scale columns was 200 mm x 200 mm x 2640 mm. Results have shown that cladded UHPFRCC proved to be the potential fire resistant coating for RC columns and increased the time of failure significantly for both CFRP strengthened and unstrengthened RC columns. Among both types of claddings, UHPFRCC-CP found to be the most effective in protecting unstrengthened as well as CFRP-strengthened columns. Besides, it also increased the time to reach the T_g of CFRP composite by 20 minutes as compared to the unprotected CFRP-strengthened column.

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CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND

Consolidation of research studies, in the recent decades, has postulated the fibre-reinforced polymer (FRP) composite as one of the efficient strengthening/retrofitting materials for reinforced-concrete (RC) structures. In addition to that, nowadays, FRP is also widely used where upgradation of the building facility is required or repair is needed due to the aging of building materials, vehicle collision, fire/explosion, earthquake or forcible changes in the structural system such as by removal of walls/columns or removal of slab openings. This is because of the fact that FRP bears lower maintenance costs, high strength-to-weight ratio and electrochemical corrosion resistance. FRP provides an excellent alternative for the restoration instead of demolishing and then re-building RC structures, which is not always economically possible for developing and under-developing countries.

Besides, in the developing and under-developing countries, fire-fighting aspects are inadequate especially in high- rise buildings. This is because of economic constraints, which makes it difficult to cope with fire in high-rise buildings. High-rise building fires are more injurious as compared to other structure fires as illustrated in Table 1.1.

In Malaysia, Fire and Rescue Department of Malaysia (FRDM) reported an average of 92 cases per day i.e. 33,640 fires in 2013 throughout the country, compared to 29848 fires in 2012. This was the highest annual figure documented with the constant upward trend since 2007 (FRDM, 2014), as shown in Figure 1.1. Nevertheless, a stable trend in the fire incidents was obvious from 2009 to 2012 (Rahim, 2015), followed by a severe increase of fire incidents in 2012 resulting in the death of 72 civilians, although this was the lowest number of fatalities for the last seven years (FRDM, 2014), however, the death statistics indicated were the immediate casualties at the place of incidence and the definite number of fatalities as a result of fire are absolutely greater. Overall, as mentioned by Rahim (2015), the death statistics due to fire eruptions were stable though the occurrence of these events