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A Review on Fire Damaged Cement and Geopolymer Slabs Retrofitted with AFRP Laminates.

G. Singaravelu[1] and Dr.M. Murugan[2]
[1] *Post Graduate student, Department of Civil Engineering, Government College of Engineering Tirunelveli, Tamil Nadu, India.*
[2] *Assistant Professor, Department of Civil Engineering, Government College of Engineering Tirunelveli, Tamil Nadu, India.*
Corresponding Author: G Singaravelu

ABSTRACT:
This paper presents a performance of fire damaged cement and geopolymer slabs retrofitted with AFRP laminates and discussed on the behaviour of cement and geopolymer slabs by fire and tests, leading to a plan for the rehabilitation of the slabs. Fire is one of the most severe hazards which reinforced concrete (RC) buildings may be encountered during their service lives. Fire Hazard leads to loss of lives and properties and many more. It also damages the structure and fails concrete too. Subjecting of concrete to high temperature causes the spalling of concrete. Effects of temperature on concrete are:100 deg. C = No effect or negligible, 200 – 250 deg. C = 25% Loss in efficiency and 500 – 600 deg. C = Completely loss of efficiency. Therefore, most of the fire-damaged RC members need proper restorations to satisfy their structural requirements by efficient repair and strengthening solutions. Recent years have seen a viable strengthening solution for fire-damaged RC members by externally bonding FRP composites using epoxy resin. The FRP composites offer advantages such as high-strength to weight ratio, excellent corrosion resistant, ease and rapid installation, etc.... In this study, the effect of fire-damaged geopolymer and conventional concrete RC slabs retrofitted AFRP laminates is to be studied.
KEYWORDS: *AFRP, Fire hazards, Spalling of concrete, FRP, Epoxy resin.*

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I. INTRODUCTION

Fiber Reinforced Polymer (FRP) composite is defined as a polymer that is reinforced with fiber. It represents a class of materials that fall into a category referred to as composite materials. Composite materials are made by dispersing particles of one or more materials in another material, which forms a continuous network around them. Strengthening reinforced concrete (RC) beams with openings by using aramid fiber reinforcement polymers (AFRP) on the beams' surfaces offers a useful solution for upgrading concrete structures to carry heavy loads. Fibers Provide strength and stiffness Glass, Basalt, Carbon, Aramid Matrix (polymer) Protects and transfers load between fibers Polyester, Epoxy, Vinyl Ester, Urethane Fiber Composites Matrix Creates a material with attributes superior to either component alone. Many of the existing reinforced concrete structures throughout the world are in urgent need for rehabilitation, repair and retrofitting because of deterioration due to various factors like corrosion, lack of detailing, failure of bond between beam-column joints, accidental fire, seismic effects, etc.These materials have a high ratio of strength to density, exceptional corrosion resistance and convenient electrical, magnetic and thermal properties. However, they are brittle and their mechanical properties may be affected by the rate of loading, temperature and environmental conditions. The use of FRP in engineering applications enables engineers to obtain significant achievements in the functionality, safety and economy of construction because of their mechanical properties. Carbon, glass, aramid, and basalt are examples of FRPs. These types have varying qualities depending on the composition, therefore they can be utilized for different purposes.

II. LITERATURE REVIEW

Williams et.al (2006) investigated Experimental and numerical study of performance of unloaded, intermediate-scale, insulated FRP strengthened RC slabs. Four slabs specimens were strengthened and insulated and their internal temperatures were monitored during exposure to the ASTM E119 standard fire. Two different FRP strengthening systems and three different fire protection schemes were considered. According to ASTM E119 fire endurance criteria, a 4-h fire endurance rating can be achieved with 38mm of any of the four insulation schemes examined herein. A smaller thickness of insulation system 1 provided approximately 2 h of fire protection for a 150mm thick reinforced concrete slab.

Chen and Wan (2008) experimentally investigated the Evaluation of CFRP, GFRP and BFRP material systems for the strengthening of RC slabs. The test result showed that there was almost no strengthening effect for an RC slab when cross-shape strengthening scheme was used, except for CFRP, where the modulus of elasticity is high. There was slight improvement when using two layers of BFRP. This was also demonstrated in ANSYS analysis. There were different failure modes when FRPs were used.

Wu et. al (2009) experimentally studied the Blast testing of ultra-high performance fibre and FRP – retrofitted concrete slabs. A series of blast tests has is to be carried out to investigate the blast resistance of reinforced concrete slabs constructed with: (a) normal reinforced concrete (NRC); (b) reinforced concrete augmented with FRP plates; (c) ultra – high performance concrete without reinforcement (UHPFC); and (d) ultra – high performance concrete with reinforcement (RUHPFC). The test result indicated that the plain UHPFC slab suffered less damage than NRC slabs when subjected to similar blast load which confirms that UHPFC is a more effective material for blast design.

Haddad et. al (2010) conducted experimental study on Repair of heat damaged reinforced concrete slabs using fibrous composite materials. From this study, heating high strength RC slabs at 600°C for 2 hours caused extensive cracking and upward cracking that was accompanied with a sustained loss in flexural capacity and the corresponding ductility, stiffness and toughness. Slabs repaired with CFRP & GFRP gained up to 158% and 125% of control slabs ultimate load carrying capacity with substantial increase stiffness, first crack load and decrease in mid-span deflection at ultimate load.

Hadded et.al (2011) experimentally investigated on Repair of heat damaged reinforced concrete slabs using fibrous composite materials. Recuring the heat damaged slabs for 28 days allowed recovering the original stiffness without achieving the original load carrying capacity. Other slabs, recured then repaired with steel fiber reinforced concrete (SFRC) layers, regained from 79% to 84% of the original load capacity with a corresponding increase in stiffness from 382% to 503%, whereas those recured then repaired with CFRP and GFRP sheets, regained up to 158% and 125% of the original load capacity with a corresponding increase in stiffness of up to 319% and 197%, respectively. RC slabs repaired with SFRC layers failed in flexural through a single crack, propagated throughout the compression zone, whereas those repaired with CFRP and GFRP experience yielding failure of steel prior to the composites failure. up to 158%, 125% and 84% of the control slab's ultimate load capacity.

Ju-Hyung Ha et.al (2011) conducted Experimental study on hybrid CFRP-PU strengthening effect on RC panels under blast loading. To estimate the hybrid composite's blast resistant capacity, nine 1000 x1000 x150 mm RC panel specimens retrofitted with either CFRP, PU, or hybrid composite sheets were blast tested. The blast load was generated by detonating a 15.88 kg ANFO explosive charge at 1.5 m standoff distance. The data of free field incident and reflected blast pressures, maximum and residual displacements, and steel and concrete strains, etc. are measured from the test. Also, the failure mode and crack patterns were evaluated to determine the failure characteristic of the panels. The results from the experiments showed that the hybrid composite has better blast resistant capacity than ordinary retrofit FRPs.

Huo et.al (2012) investigated Experimental study on dynamic behavior of concrete after exposure to high temperature Up to 700℃. The test result showed that high temperature and strain rate has remarkable effect on the dynamic increase factor (DIF) for the fire damaged concrete. The effect of high temperature on DIF or the fire damaged concrete decreased as the temperature increased.

Liu Ming et.al (2013) experimentally investigated on Strengthening and retrofitting of the industries building after fires. . The reinforcement project is three-storey of the industries building, the total height of the industries building is 14,200mm, the clear height of one storey is 7,500mm, the building area is 1,500 square meters, structural mode is reinforced concrete frame structure. The structural members were damaged seriously due to fire In January 2010, strengthening the damaged members was proposed in order to ensure the safety of the structure. Enlarging section reinforcement method, Polymer Mortar and gluing CFRP methods were adopt to strengthen the beams, columns and floor slab depending on the damage degree of the concrete member. Idea of dealing with the industries building damaged by fire can provide us a good reference of repairing the similar industries building.

Cristina lopez et.al (2013) experimentally investigated on Fire protection system for reinforced concrete slabs strengthened with CFRP laminates. This shows a better strength can be achieved and the fire resistance tests on CFRP – strengthened RC slab strips proved.

Prabin kumar et.al (2014) experimentally investigated on effect of fire exposure on cracking, spalling and residual strength of fly ash geopolymer concrete. This shows a better resistance to spalling and cracking of geopolymer concrete in comparison to cement concrete specimen in fire. The geopolymer concrete retained higher percentage of strength than OPC concrete specimen.

Jawahar and Mounika (2016) experimentally investigated the Strength properties of fly ash and GGBS based geopolymer concrete. The result of this investigation showed that GGBS blended FA based GPC mixes attained enhanced mechanical properties at ambient room temperature curing itself without the need of heat curing as in the case of only FA based GPC mixes. The increase in GGBS replacement in GPC mixes enhanced the mechanical properties at ambient room temperature curing at all ages. Keeping in view of saving in natural resources, sustainability, environment, production cost, maintenance cost and all other GPC properties, it can be recommended as an innovative construction material for the use of constructions.

Raongjant and Jing (2016) experimentally investigated the One-way slab of structural insulated panel strengthened with FRP. Strengthening by FRP sheets could increase the load bearing capacity and flexural of SIP panel slabs. FRP sheets improve the ductility and Tensile strength.

Brea willaiams et.al (2017) conducted experimental and numerical study conducted to investigate the performance in fire of insulated FRP strengthened concrete slabs. Four different supplemental fire insulation systems are examined through standard fire tests, and a numerical model to predict member behavior in fire is presented. The result showed that providing sufficient insulation thickness is important in minimizing cracking and preventing possible delamination of the fire protection layer and concrete cover.

Shashidhar et.al (2017) experimentally investigated on behavior of concrete when exposed to fire and retrofitting. BEAM: 33% strength was decreased in mix 1 after exposed to fire. 26% strength was decreased in mix 2 after exposed to fire.38% strength was decreased in mix 3 after exposed to fire. SLAB: Mix of 65% cement & 35% GGBS was used to cast for slab.10% strength was decreased in slab after exposed to fire.RETROFITTING:16% strength was increased in mix 1 of beam after retrofitting to concrete structures which are exposed to fire.9.09% strength was increased in mix 2 of beam after retrofitting to concrete structures exposed to fire.9.09% strength was increased in mix 3 of beam after retrofitting to concrete structures exposed to fire.

Abbaszadeh et.al (2017) conducted Performance of Two-way RC Slabs Retrofitted by Different Configurations of High Performance Fibre Reinforced Cementitous Composite Strips. Considering the promising results gained from several studies using cementitious composites with strain hardening behaviour (High Performance Fibre Reinforced Cementitious Composites, HPFRCC) for repair and retrofitting concrete flexural members, in this paper the possibility of using HPFRCC for retrofitting two-way RC slabs is investigated. A total of five two-way slabs were made and tested to failure. Three slabs were retrofitted with a variety of different types of retrofit configurations and two other slabs, having low and conventional reinforcement ratios, were used as control slabs.

lei and jing (2017) conducted Performance Analysis of Drilling Test of Aramid Fiber Composite. . Aramid fiber-reinforced polymer (AFRP) is a typical difficult material to machine. In this paper, three types of drills with different cutting edge shapes were compared to analyse the influence of drilling on cutting force, cutting temperature and machining quality. The results showed that the tool geometry has a great influence on the drilling performance of AFRP. Due to poor drilling quality, 8-face drill and twist drill are not suitable for drilling AFRP drilling tools. The machining quality of Brad & Spur drill is relatively good, which can meet the drilling requirements of AFRP.

Xiangqing Kong et.al (2018) experimentally investigated on numerical evaluation of blast resistance of RC slab strengthened with AFRP. In order to precisely evaluated the retrofitting effectiveness of the Aramid Fiber Reinforced Plastic (AFRP) sheet on the blast response of reinforced concrete (RC) slab, a refined non-linear finite element model is proposed for simulating of the structural response of RC slab strengthened with AFRP under blast loads. The complicated material models are applied in the simulation considering the high strain rate effects of the materials as well as the dynamic interfacial behavior between AFRP and concrete. Also, a appropriate erosion criterion technique is specially applied to capture the fracture and material separation process during the detonation of the explosive. Then with the calibrated model, numerical simulations of RC slabs strengthened with AFRP to blast loadings are carried out. The numerical results of strengthened and non-strengthened RC slab (i.e., conventional slab) are compared to investigate the retrofitting effectiveness of AFRP on blast-resistant performance of RC slabs.

Bhattacharyya et. al.(2019) investigated on retrofitting of fire damaged concrete structures : Characterization of Materials. Porosity of the material governs the strength to a great extent. Thermal expansion of the individual components is Non-Uniform. The change in the gel-space ratio, deteriorates the concrete strength.

Wenxian et.al (2019) investigated on Repair of Fire-Damaged Reinforced Concrete Flexural Members. The mechanical properties of both concrete and steel reinforcement, and the load-bearing capacity of reinforced concrete (RC) structures are well known to be temperature-sensitive, as demonstrated by the severe damage that major fires cause in buildings, followed in extreme cases by their collapse. In this paper, after a recall on the performance of RC beams and slabs in fire, different repair techniques are considered, among them externally bonded reinforcement, near surface-mounted fiber-reinforced polymers (FRP), bolted side plating, jacketing with high- and ultra-high performance concretes or mortars, and damaged-concrete replacement.

Meng et.al (2019) experimental and Numerical Investigation of Blast Resistant Capacity of High Performance Geopolymer Concrete Panels. In this study, the mechanical properties of a novel high performance alkali-activated geopolymer concrete under both static and dynamic loads were studied. The ground granulated blast-furnace slag powder (GGBS) and silica fume were used to manufacture this geopolymer concrete. It is found that the steel wire mesh reinforced geopolymer concrete slabs achieved a more uniform strain distribution, which means a better structural performance against blast loadings as compared to the conventional C30 concrete slab under the same blast loads. The numerical investigation was then conducted to elaborate the results.

Waleed & Haitham (2020) investigated on Rehabilitation of fire damage reinforced concrete bubbled slabs. The test results specified that a significant improvement in flexural strength can be reached when used CFRP strips to rehabilitation RC bubble slabs. Ultimate load of rehabilitated bubble slabs reaches to 79-105% from reference bubble slabs.

Zhao & Sanjayan (2020) experimentally investigated on geopolymer and portland cement concretes in simulated fire. High-strength Portland cement concrete has a high risk of spalling in fire. Geopolymer, an environmentally friendly alternative to Portland cement, is purported to possess superior fire-resistant properties. However, the spalling behaviour of geopolymer concrete in fire is unreported. In this paper, geopolymer and Portland cement concretes of strengths from 40 to 100 MPa were exposed to rapid temperature rises, simulating fire exposures. Two simulated fire tests, namely rapid surface temperature rise exposure test and standard curve fire test, were conducted. In both types of test, no spalling was found in geopolymer concretes, whereas the companion Portland cement concrete exhibited spalling. The paper concludes that, when compared at the same strength level, the geopolymer concrete possesses higher spalling resistance in a fire than Portland cement concrete due to its increased porosity.

Zheng-Ang Sui et.al (2020) experimentally investigated on flexural behavior of fire damaged prefabricated RC hollow slabs strengthened with CFRP versus TRM. , carbon fiber reinforced polymer (CFRP) and textile reinforced mortar (TRM) strengthening techniques were proposed to retrofit and strengthen fire-damaged prefabricated concrete hollow slabs. A total of six slabs, from an actual multi-story masonry building, were tested to investigate the flexural performance of reinforced concrete (RC) hollow slabs strengthened with TRM and CFRP. The investigated parameters included the strengthening method (CFRP versus TRM), the number of CFRP layers, and with or without fire exposure. One unstrengthened slab and one TRM strengthened slab served as the control specimens without fire exposure. The remaining four slabs were first exposed to ISO-834 standard fire for 1 h, and then three of them were strengthened with CFRP or TRM.

Hassan Intesha (2020) The rehabilitation of fire damage reinforced concrete bubble slabs. Spalling failure did not occur when RC bubble slabs exposed to 200 C. In 300 C and 400 C at fire 30 minutes spalling occur. Damage of spalling in 300 C more than 400C by 32% at same fire duration. Ultimate load of bubble slab exposed to200 C at 30 and 60 minute reach to 88-103% from reference bubble slab keep without exposed to fire flame. Ultimate load of rehabilitated bubble slab reaches to 79-105% from reference bubble slab keep without exposed to fire flame. Rehabilitated tested slabs failed by concrete crushing at top fibers.

Ramamohana et.al (2020) Investigation on Performance Enhancement of Fly ash-GGBFS Based Graphene Geopolymer Concrete. the properties of fly ash and ground granulated blast furnace slag (GGBFS) combination based geopolymer concrete containing graphene oxide are investigated. The effects of graphene oxide (GO) addition and GGBFS inclusion on the compressive strength, modulus of elasticity of geopolymer concrete were investigated in this paper. The scanning electron microscope (SEM) was conducted to provide a thorough insight into the microstructure's characterization. Rapid chloride permeability test (RCPT) was also conducted to estimate the chloride ion resistance of graphene-modified geopolymer concrete. The experimental results depicted that 3% addition of graphene oxide with 30% GGBFS replacement produced an increase in compressive strength and modulus of elasticity values by 38.51% and 28%, while the chloride ion permeability by 65.44% respectively compared to mix without graphene oxide.

Meikandaan and Ramachandharamurthy(2020), Investigation on Performance Enhancement of Fly ash-GGBFS Based Graphene Geopolymer Concrete. control beams (without GFRP overlays) and damaged and then repairing beams with GFRP overlays by varying different parameters (damage degree, GFRP overlay width,). All beams have to be tested under simply supported condition. The testing has to be done under two point loading using the load frame over a span of 1500 mm. The most investigated parameter in this experimental study is to determine increase in load carrying capacity of strengthened beam. To evaluate the strength of damaged RC beams with externally bonded GFRP laminates was the target of this project.

III. CONCLUSION

Following are the major conclusions derived from the literature study

- Wrapping of FRP laminates on the of slab provides higher strength than other wrapping configurations.
- Hybrid bonding techniques improved the strength of the structure significantly than conventional strengthening techniques.
- The geopolymer concrete outperformed ordinary Portland cement concrete in fire.

- The fibre thickness is crucial at high temperatures to avoid cracking and delamination of the fire protection layer and concrete cover.
- Increased FRP thickness at the bottom layer increases the performance of the RC slabs under impact loading.

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