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May ALLAH swt Guide Us All To Truth and Keep Us On The Straight Path…

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A	Cross-sectional area of sample
A	The water absorption of concrete samples
A_f	Area of the fracture surface
A_L	Area of slant shear;
AT	Area of bond plane
D	Number of scale divisions during the period
D	Depth of penetration
F	Flow
F_T	Tensile (pull off) force at failure
h	Applied pressure
K_w	Water permeability coefficient
L	Sample thickness
M	Gain in mass
P	Maximum force;
P	The porosity of concrete samples
P_{in}	Pressure at inlet
P_{out}	Outlet pressure equal
Q	Volume flow rate
Q	Density of water
S	Bond strength;
S_{po}	Pull off bond strength
T	Splitting tensile strength
T	Test point time period

T	Time of penetration
V	Total porosity, fraction
V	Applied voltage
W_d	Mass after oven dry
W_{ssd}	Mass of sample in saturated surface dry condition in air
W_{ssw}	Mass of saturated sample in water
μ	Viscosity of the gas

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS EN	British European Standards Specifications
$Ca(OH_2)$ or CH	Calcium hydroxide
COV	Coefficient of variation
C-S-H	Calcium-Silicate-Hydrate
DSF	Densified silica fume
GPOFA	Ground-POFA
GUSMRC	Green - Universiti Sains Malaysia - Reinforced Concrete
ISAT	Initial surface absorption test
OPC	Ordinary Portland cement
POFA	Palm oil fuel ash
RSM	Response surface methodology
RCPT	Rapid chloride penetration test
SiO_2	Silicon dioxide
SP	Superplasticizer
TPOFA	Treated-POFA
UHPFRC	Ultra-High performance fiber reinforced concrete
UHPFRCC	Ultra-High performance fiber reinforced cementitious composites
UPOFA	Ultra-fine POFA
V	DC voltage
W/B	Water/binder ratio
W/C	Water/cement ratio

CIRI IKATAN ANTARAMUKA DAN SIFAT-SIFAT KEJURUTERAAN SERTA PENGANGKUTAN BENDALIR ANTARA KONKRIT BIASA DENGAN KOMPOSIT BERSIMEN BERTETULANG GENTIAN BERPRESTASI ULTRA TINGGI HIJAU

ABSTRAK

Pemulihan struktur konkrit pada masa kini digunakan secara meluas dan dipertingkatkan kerana sering terdedah kepada muatan mekanikal dan persekitaran. Diatas kebimbangan itu, kaedah dan cara kerja pemulihan dititik beratkan atas sebab untuk menghasilkan cara yang berkesan bagi menguatkan sifat struktur asal. Pengunaan komposit bersimen bertetulang gentian berprestasi ultra tinggi (UHPFRCC) sebagai bahan baik pulih dimasa kini menunjukkan keputusan yang memberangsangkan dimana ia tinggi dalam sifat mekanikal dan sifat ketahanlasakan. Walaubagaimanapun, produk ini dianggap sebagai tidak ekonomik dan kurang mesra alam disebabkan tinggi kandungan simen bagi mencapai kekuatan mekanikal ultra tinggi. Sebagai penyelesaian, UHPFRCC hijau baru yang mana telah dipatenkan sebagai Universiti Sains Malaysia konkrit hijau bertetulang (GUSMRC) telah dicipita. Konkrit ini diklasifikasikan sebagai bahan bina mesra alam atas sebab ia menggantikan 50 peratus jumlah simen dengan bahan pozolanik, iaitu POFA ultra halus (UPOFA). Berdasarkan objektif kajian ini iaitu untuk menyiasat ikatan anataramuka dan sifat kejuruteraan bendalir antara konkrit lama dan bahan baikpulih baru, GUSMRC telah digunakan sebagai bahan baikpulih baru dimana dua jenis kekasaran permukaan digunakan iaitu letupan pasir dan berlurah manakala konkrit normal digunakan sebagai konkrit lama. Kekuatan ciri sifat ikatan antara kedua-dua

kekasaran permukaan dikaji. Tambahan lagi, sifat kejuruteraan bendalir bahan baikpulih dikaji keatas sampel tunggal dan komposit (bahan baikpulih). Bagi sampel komposit, dua jenis keadaan penuangan digunakan iaitu lapisan dan separuh-separuh. Keputusan akhir menunjukkan GUSMRC diterima sebagai bahan baikpulih kerana ia mengurangkan nilai kadar sifat kejuruteraan bendalir. Sifat ikatan juga turut berjaya dimana kekuatan ikatan tertinggi telah dicapai. Tekstur letupan pasir mendahului kesemua sifat ikatan antaramuka sebagai tekstur terkasar dan paling berkesan sebagai baikpulih permukaan berbanding dengan jenis berlurah.

INTERFACIAL BONDING CHARACTERISTIC AND FLUID TRANSPORT PROPERTIES BETWEEN NORMAL CONCRETE SUBSTRATE AND GREEN ULTRA-HIGH PERFORMANCE FIBER REINFORCED CEMENTITIOUS COMPOSITES

ABSTRACT

Rehabilitation of concrete structure has been widely used and upgraded nowadays as the existing structures exposed to the severe mechanical loading and environment. Based on the concerns stated, the method and procedure of rehabilitation works are taking into consideration in order to produce an effective way to strengthen the properties of existing structure. The application of ultra-high performance fiber reinforced cementitious composites (UHPFRCC) as rehabilition or repair material nowaday show an excellent feedback as it is high in mechanical and durability properties. However, this product is considered as uneconomical and less environmental-friendly as the requirement of total volume of cement is high in order to achieve the ultra-high mechanical strength. As a solution, a patented green UHPFRCC, which has been known as green Universiti Sains Malaysia Reinforced Concrete (GUSMRC) was developed. This concrete is classified as eco-friendly construction material as it replaced 50 % of cement total volume by pozzolanic material, ultra-fine POFA (UPOFA). As the objectives of this study were to investigate the interfacial bonding and fluid transport properties between the old concrete and newly repair material, GUSMRC was applied as the new repair material with two different types of surface treatment/roughness; sand blasting and grinding, where as the normal concrete substrate acted as an old concrete. Interfacial bond strength characteristic were evaluated between these two surface textures. In addition, the fluid transport properties of repair material was also assessed on the monolithic samples and the composite samples (repair material). For composite samples, two types of layering condition were applied; overlay and half-half condition. The final results showed that GUSMRC was successfully accepted as a repair material to reduce the fluid transport values of old concrete. The bonding properties were also successfully accepted with an excellent quality of bond strength. The sand blasting surface treatment led all the bonding properties results; the roughest and more effective surface treatment compared to grinding.

CHAPTER ONE

INTRODUCTION

1.1 Background

Concrete is the single most widely used material in the world since the ancient times as it has been applied in the construction of buildings, bridges, highways, retaining walls and so on. However, the quality, safety, maintenance and cost are the main issues that have been highlighted by the structural engineering expertise. For example, world is facing unexpected aggressive environment attacks or natural disasters that may damage or fully destroy the concrete structures. This situation is a tremendous challenge to any government since it jeopardizes human life and country's economic planning.

Since concrete is acknowledged as a non-everlasting construction material, the rehabilitation of it is widely applied on the old and damage heritage structures (Bruhwiller *et al.,* 2008; Voo *et al.,* 2012; Tayeh, 2013; Zmetra, 2015). Raupach (2006) concluded that the increasing number of concrete structures worldwide contributes to the development of new materials and methods of rehabilitation in producing the highest quality and also to cure the old / damage structures. In rehabilitation, the main aspects that have been highlighted before newly material and method are applied on structures are the mechanical properties of repair material, the durability properties of repair material and the properties of bonding agent / surface treatment chosen between the old structures and newly repair material (Bruhwiller *et al.,* 2008; Momayez *et al.*, 2005; Pattnaik, 2015).

Ultra-high performance fiber reinforced concrete (UHPFRC) is designed and widely used nowadays in replacing and upgrading the conventional concrete such as normal reinforced concrete. This type of concrete is chosen because it is extremely high in mechanical strength and durability properties (Graybeal, 2011; Fardis, 2012; Nabaei and Nendaz, 2015), which helps to reduce the maintenance in the future (Habel *et al.*, 2007; Bruhwiller *et al.*, 2008; Nabaei and Nendaz, 2015). On the other hand, the production of this type of concrete requires a high volume of cement in order to achieve the ultra-high strength requirement; up to 700 to 1000 kg/m^3 (Larrard and Serdan, 2002; Spasojevic, 2008; Tayeh, 2013). Therefore, it is claimed as an uneconomical concrete (Larrard and Serdan, 2002; Spasojevic, 2008; Zeyad, 2013; Aldahdooh, 2014). The high demand of cement in developing this material could increase the greenhouse gases emission (Zainurul, 2013). In year 2008, the cement production was recorded almost 2.8 billion tons worldwide (Zeyad, 2013). Based on that concern, many researchers suggest to use pozzolanic reactive properties of agro waste to reduce the cement usage (Kou and Xing, 2012; Zainurul, 2013; Aldahdooh, 2014; Aktham, 2015).

In year 2011, Malaysia produced 18.9 million tons of palm oil, which was the world's second largest producer after Indonesia (MPOB, 2011). As a result, this agro waste material, palm oil fuel ash or POFA, was disposed in the landfills. The unstoppable disposal of this agro waste material contributes to the high environmental pollution due to the emission of CO_2 gas (Tangchirapat *et al.,* 2007; Vande *et al.,* 2008; Zainurul, 2015). Therefore, many researchers investigate the potential of this agro waste to be applied on new sustainable products in the future (Rukzon and Chindaprasirt, 2009; Sata *et al.,* 2007; Tangchirapat *et al.,* 2009; Megat Johari *et al.,* 2012a; Altwair *et al.,* 2012).

1.2 Problem statement

When concrete structure is considered damage or even worst over its entire life cycle, the rehabilitation process such as extracting, processing, construction, operation, demolition and recycling is carried out to keep the sustainability and the heritage of the structure. The application of repair treatment between the interfacial zone of substrate and repair material is considered as the most important mechanism in rehabilitation works, where the newly repair material should strength the existing structure in mechanical and fluid transport properties. According to Mather and Warner (2003), half of the rehabilitation works or specifically the repair structures are considered as "fail" where old concrete and repair concrete separated after the composite process. Meanwhile, for the durability performance, statistics show that nearly 75% of the repair material properties were weak in durability (Vaysburn *et al.*, 2000; Naderi, 2008). As a result, different considerations are studied by researchers around the world and the focus are the surface treatment/roughness between the composite samples and the layering technique for rehabilitation works (Russel, 2004; Momayez *et al.*, 2005; Tayeh, 2013).

Ultra-high performance fiber reinforced concrete (UHPFRC) is invented as an alternative to replace and upgrade the existing conventional concrete that has been used such as normal reinforced concrete. With the compressive strength achieved more than 150 MPa at 28 days of age, UHPFRC is considered as the most suitable concrete to be adapted as high load receiver structure such as skyscraper building and the bridges (Damtoft *et al.*, 2008; Scrivener and Kirkpatrick, 2008). In addition, UHPFRC is also high in durability and fluid transport properties; almost impermeable type of concrete that is suitable to be adapted in aggressive environment attack and also for rehabilitation works. UHPFRC applications have