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Review on Potential of Geopolymer for Concrete Repair and Rehabilitation

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Abstract. Cracking, spalling, surface deterioration, seepage and other concrete damage of the existing infrastructure have raised concern among residents, local authorities and developers. Dealing with concrete infrastructure rehabilitation is an important issue due to most of infrastructures today are concrete based. To simply patch up the spalling concrete as temporary solution and sooner or later, the cracks will return to haunt. This paper reviewed the current research and studies on concrete repair materials, highlighting the properties of geopolymer. It covers geopolymer repair materials which addressed in the field of concrete infrastructure rehabilitation. Geopolymer had good repair characteristics and displays the potential as an excellent repair material.

1 Introduction

Nowadays, concrete infrastructure rehabilitation is very costly due to various factors. For example, in Malaysia, almost every concrete bridges require maintenance in order to repair and strengthening the structure with an insufficient annual budget [1]. The existing infrastructures were given a little attention to durability issues long years ago and this is one of the factors affecting the damaged concrete structures. However, the continuous development among researchers is a good opportunity to take in order to solve the current issue towards implementing sustainable and cost effective repair material.

Geopolymers or known as alkaline activated material is a newly developed binder which is made from alumina silica source materials activated with an alkaline solution [2-6]. Investigations and studies related to the use of geopolymers in the field of concrete infrastructure rehabilitation are required [7].

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Instead of complying an excellent mechanical properties as repair material, geopolymer also shows the ability and promoted an excellent bond strength to the old concrete, environmental friendly and even more cost effective. In this preliminary study, the papers related to the used of geopolymer as repair material were reviewed.

Bond strength between repair material and substrate is the crucial property of repair material. Some researchers normally will investigate and make a comparison between geopolymer mortar and commercial products [8-11]. Slant shear test is one of the approached method highlighted by the previous researchers in order to evaluate the performances of the repair material [12]. However, bond strength depends not only on the characteristics of the repair material but also on the surface roughness of concrete substrate. Roughness or called as surface treatments will increase the bonding between repair material and the substrate.

Some researchers published their studies on bonding of repair materials to a concrete substrate where the preparation of the substrate surface with different techniques is mentioned [13,14]. However, the differences also been observed on the concrete mix of the repair materials, the age of the specimens, the curing scheme, and the repair technique itself. The purpose of this paper is to give an overview of the most recent studies using geopolymer as a repair material at different condition and approached.

2 Geopolymer repair material

In recent years, the rapid growth in research and development related to geopolymer has indicated the potential to implement at various applications and so as in the field of concrete infrastructure rehabilitation. A number of researchers explored the geopolymer as a repair material. The bond strength of the geopolymer is reported higher bonding strength than comparable portland cement based repair [4], commercial repair products [5,6] and repair epoxies [7]. Moreover, geopolymeric binders had very high bond strength even at early ages. Fly ash based geopolymer shows the potential to be developed as an excellent repair materials so far. In addition, the interface zones between between substrate and geopolymer were homogenous at contact zone. Instead of engineering properties is comparable to the existing repair material, the cost of the geopolymer is also reported to be the cheapest [5].

However, the value of geopolymer as repair material could be enhanced and applied in a various applications. Geopolymer is used as repair and strengthening material in the forms of slurry for crack injection, mortar for section restoration, jacketing, filling and etc, and as concrete for section restoration and jacketing. Different application required different properties of repair material [11]. However, good bonding between repair materials and concrete substrate is very important in the concrete repairs.

3 Patch repair

This method is widely used to restore the original conditions of the concrete structures. The compatibility between repair material and concrete substrate required some specific requirement (Table 1). The method to patch the spalling concrete starts with preparing the concrete surface and end up with curing process (Fig 1).

Table 1. Compatibility between substrate and repair material [15]

Properties	**Relationship between repair mortar (Rm) and concrete substrate (Cs)**
Compression, tension and flexure strength	Rm ≥ Cs
Modulus in compression, tension and flexure	Rm ≈ Cs
Coefficient of thermal expansion	Rm ≈ Cs
Adhesion in tension and in shear	Rm ≥ Cs
Curing and long term shrinkage	Rm ≥ Cs
Strain capacity	Rm ≥ Cs
Creep	Dependent on whether creep causes undesirable or desirable effects
Fatigue performance	Rm ≥ Cs

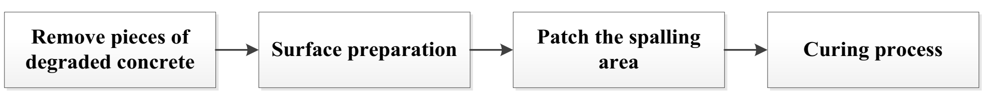

Fig. 1. General patch repair procedure

Roughning the surface of the concrete substrate is the factor affecting the performance of repair material instead of cleaning the concrete substrate surface. The different types of surface preparations has been investigated to improve the bonding between substrate and repair material. The bonding strength between repair material and concrete substrate was evaluated using slant shear test method as per ASTM C882 (Fig 2).

The bond strength (S) for the slant shear strength was calculated by dividing the maximum load (P) by the bond area (A). The ACI Concrete Repair Guide specifies the acceptable bond strength for repair work should be in the ranges between 6.9 – 12 MPa [16]. Instead of the shear strength value, the bond failure modes can be categorised into several types (Fig. 3).

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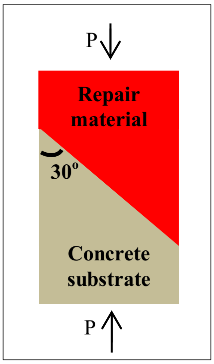


Fig. 2. Schematic diagram of the slant shear test

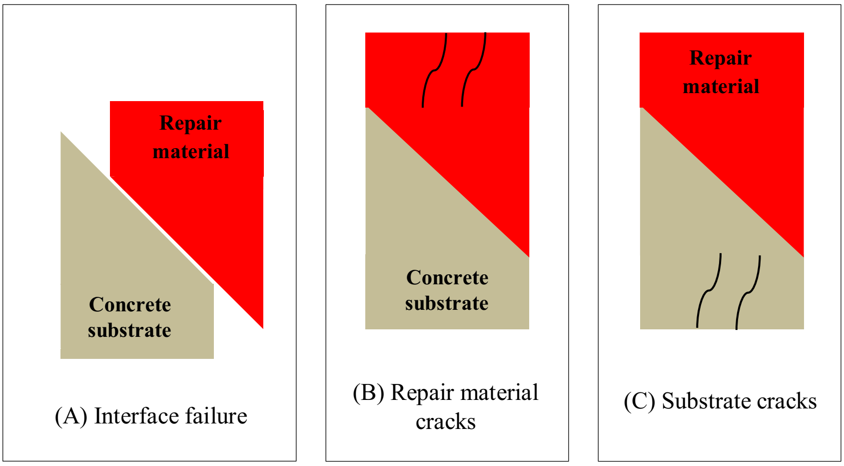


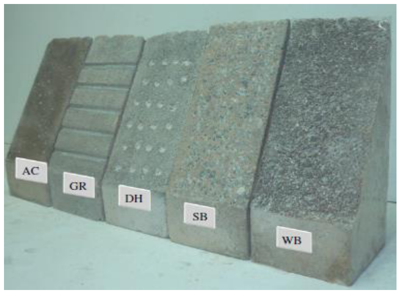
Fig. 3. Failure type

4 Surface preparation

In the field of rehabilitation and strengthening the bond strength between the substrate and repair material generally presents a weak bond [12]. A good bond is one of the main requirements for successful repair. However, the surface preparation of the concrete substrate will courage and enhance the bonding [17].

Some researchers reported that sand blasting is the best surface preparation methods. However, sand-blasting was attributed to the polishing effect. Other surface preparation such as grinding, wire-brushing, drill holes, and etc is done by some researchers. Bassam et al. [18] indicate that low bond strengths were obtained with substrate surfaces treated by this method except for sand blasting. Chemical products are also used to increase the substrate surface roughness. Pacheco et al. [9] mentioned an acid etching method is used to prepare the bond surface, but carefully washed is required to ensure the removal of $CaCl_2$ which results from the reaction between HCl and $Ca(OH)_2$.

Table 2. Different surface preparation of the concrete substrate

Repair materials	Samples	Description
Ultra High Performance Fiber Concrete [18]		Slant shear test specimens with five different surface textures namely sand blasting, wire brushing, drill holes and grooves. Sand blasting shows the best.
Geopolymer [9]	 	Substrate concrete with etched surface and cast against metallic formwork. Bond strength is not affected by low roughness surface treatment of concrete substrate.
Portland cement [19]		Smooth as-sawn, wire-brushed, hand-chiselled, and acid etching were used in order to prepare the surface of old concrete samples. Acid etching is the best.

5 Conclusion

The aims of this paper are to overview the current research of repair materials. Thus, with the sustainable and comparable properties, geopolymer display a high potential for improvement and developed as an excellent repair material. Continuous investigation related to the used of geopolymer is required in order to champion in the concrete infrastructure rehabilitation.

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