PAPER • **OPEN ACCESS**

The Influence of Pre-Heated Treatment to Improve Adhesion Bond Coating Strength of Fly Ash Based Geopolymer Ceramic

To cite this article: L Jamaludin *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **374** 012046

The Influence of Pre-Heated Treatment to Improve Adhesion Bond Coating Strength of Fly Ash Based Geopolymer Ceramic

L Jamaludin[1], M M A B Abdullah[1], K Hussin[1] and A Abdul Kadir[3,1]
[1]Centre of Excellence Geopolymer & Green Technology (CEGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia
[2]Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia
[3]Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia

E-mail: liyanajamaludin@unimap.edu.my

Abstract. The study focus on effect of pre-heated ceramic surface on the adhesion bond strength between geopolymer coating coating and ceramic substrates. Ceramic substrates was pre-heated at different temperature (400 °C, 600 °C, 800 °C and 1000 °C). Fly ash geopolymer coating material potential used to protect surface used in exposure conditions after sintering at high temperature. Fly ash and alkali activator (Al_2O_3/Na_2SiO_3) were mixed with 2.0 solids-to-liquid ratios to prepare geopolymer coating material at constant NaOH concentration of 12M. Adhesion test was conducted to determine the adhesion bond between ceramic substrates and fly ash coating material. The results showed the pre-heated ceramic substrates effect the adhesion bond of coating compared with untreated substrates with increasing of strength up to 20 % for temperature 600 °C.

1. Introduction

Alkali activated materials from the waste such as fly ash, kaolin, slag, rice husk and volcano ash has been considered by many researchers as an alternative to cementitious materials for protective coating materials especially in ceramic industry [1]. Alkali activated materials or geopolymer are formed when alumino-silicates dissolve in a strong alkaline solution, reorganize, and precipitate in a hardened state [2, 3]. Good corrosion resistance, imperviousity to water and air, good chemical and physical stabilities at moderately high temperature and high strength keeping in view of using this method to protect ceramic surface. This is due to surface deteriorations and corrosion become major problem for wear of ceramic products. Fly ash coating material was deposited as forming layer on ceramic substrates. Fly ash is a finely solid waste generated from coal-fired thermal power stations during the combustion of coal. At present, about 80% of total power generation in the world based on thermal power plants which consume CO_2 to atmosphere which effect the greenhouse emissions. Due to environmental concern, new ways of utilizing fly ash being explored in order to protect the environment and provide useful ways for its utilization and disposal.

In the ceramic industry, several problems posed by slips and engobes are prone to pinholes and crawling [4]. Pinholes refers as very small opening that appear on the surface of ceramic glaze and will result on reveal of clay body [4]. Ceramics are finding an increasing range of applications,

IOP Conf. Series: Materials Science and Engineering **374** (2018) 012046 doi:10.1088/1757-899X/374/1/012046

however, the limitations for their use often relate to surface phenomena such as fracture initiation effects, environmental degradation and complex tribological interactions [5]. Commonly in ceramic industry, clay are pre-heated at temperature more than 900 °C to increase strength of ceramic [6]. Fly ash with geopolymer formulations prepared with mixing alumino-silicate with the alkaline activator solution has been applied as protective coating material that suitable for high temperature applications such as fire resistant panel [7]. Geopolymer has good bonding structure of amorphous inorganic polymer which has excellent bonding agent properties and shows high bond strength in an early stage [8]. The geopolymerisation process occurs due to the mixing of fly ash, sodium silicate and sodium hydroxide as the alkaline activator, which produces aluminosilicate gel that acts as a binder [9].In order to curb this problem, geopolymeric application is used to replace traditional method of ceramic glaze processing by possessing several better characteristics especially increasing of adhesion strength. This paper summarizes the influence of pre-heated ceramic substrates on the adhesion strength of geopolymer coating substrates.

2. Materials and methods

2.1. General procedures

Ceramic substrates with dimensions of 9 mm in thickness, 55 mm in width and 110 mm in length were used. The pre-heated treatment process was performed by heating ceramic substrates at temperature range from 400 °C to 1000 °C for 1 hour. The fly ash was supplied by YTL Cement Corporation, Malaysia. Class F fly ash used as aluminosilicate source to produce geopolymer coating material by using sodium hydroxide added to sodium silicate solutions. The best ratio of fly ash/alkaline activator choose is 2.0 at specific constant ratio of Na_2SiO_3/NaOH solution of 2.5. The NaOH solution was prepared by dissolving sodium hydroxide pellets in deionised water, the concentration of the NaOH was kept constant at 10 M.

2.2. Coating sample preparation

Geopolymer coating material was prepared by mixing alkaline activator with fly ash powder. The mixture was applied at ceramic substrates before and after pre-heated treatment by brushing method. After coating, samples were placed at room temperature for drying process for 1 hours.

2.3. Testing and analyzing

The chemical compositions of material was analyzed by using X-ray Flourescence (XRF). Adhesion strength was evaluated for characterizes the performances of ceramic substrates after applying with fly ash geopolymer coating materials. The adhesive strength of the coated samples was measured with an Elcometer F106/3, adhesion tester according to ASTM D4541. The average of three measurements was evaluated as adhesion strength. A minimum of three specimens were tested to evaluate the strength gain for the specimens after pre-heated ceramic substrates.

3. Results and discussions

3.1. Chemical compositions analysis

Table 1 shows the main composition of fly ash and ceramic substrate. Fly ash contains silica dioxide (SiO_2) with 35.7 wt % and calcium oxide (CaO) contributes 20.8 wt % in the fly ash. The composition analysis indicated that ferum (III) oxide (Fe_2O_3) has 19.91 wt % followed by aluminium oxide (Al_2O_3) has 15.4 wt %. Ceramic substrates analysis contains high silica dioxide (SiO_2) with 66.5 wt % and 19.1 wt% of alumina (Al_2O_3). The high SiO_2 content proved to silica availability lead to faster conversion of solid aluminosilicate sources to geopolymer gel [10] in order to determine geopolymer gel structure and reaction mechanisms. As geopolymer source materials, the rich of chemical composition of SiO_2 and Al_2O_3 is important in synthesised in geopolymerization process which link to the strength performance such as adhesive strength [11].

3.2. Effect of pre-heated ceramic substrate on adhesion strength bond of coating samples

Figure 1 shows adhesion strength analysis of coating samples on the pre-heated ceramic substrates. The geopolymer coating with unheated ceramic substrates shows lowest adhesion strength which is 1 MPa while highest adhesion strength contributes at pre-heated ceramic substrates at temperature 600 °C with 4.7 MPa strength. At temperature 700 °C to 1000 °C, the adhesion strength starts decreased from 4.3 MPa to 3.2 MPa. The decreasing strength of coating due to the ceramic sample tend to bend due to excessive of high temperature. Pre-heated treatment of ceramic substrates with different temperature will adequate different strength of interfacial interactions with geopolymer material coating due to the good penetration of coating material with ceramic substrates after pre-heated process compared with unheated substrates [11-13]. The ceramic substrates pores minimizes the surface deteriorations and will results successful adhesion bond strength between substrates and coating material. From the results obtained, the temperature affecting the adhesion strength due to bonding between matrix and geopolymer which indicates high strength of coating surface substrates. This phenomenon occurs due to coating material cannot diffuse very well on the overly high sintered substrate surface [14-16].

Table 1. Chemical compositions of fly ash and ceramic substrate.

	Chemical Compositions (wt%)							
	Al_2O_3	SiO2	CaO	Fe_2O_3	SO_3	K_2O	TiO_2	MnO
Fly ash	15.4	35.7	20.8	19.91	3.55	1.85	1.13	0.11
Ceramic substrate	19.1	66.5	8.91	1.12	-	1.39	0.67	1.42

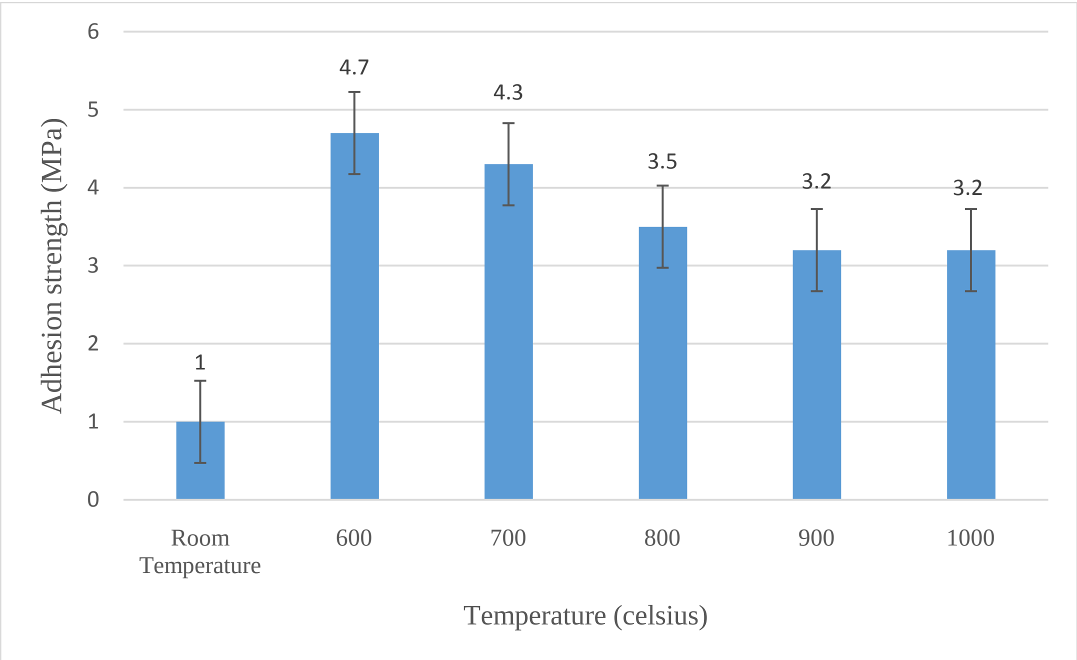

Figure 1. Adhesion strength of coating samples on the pre-heated ceramic substrates.

4. Conclusions

The optimum pre-heated temperature of ceramic substrates for fly ash geopolymer coating in this study is 600 °C which lead to high adhesion bond strength is 4.7 MPa. Pre-heated treatment of ceramic substrates with different temperature will adequate different strength of interfacial interactions with

IOP Conf. Series: Materials Science and Engineering **374** (2018) 012046 doi:10.1088/1757-899X/374/1/012046

geopolymer material coating due to the good penetration of coating material with ceramic substrates after pre-heated process compared with unheated substrates.

5. References

[1] Jing Z, Matsuoka N, Jin F, Yamasaki N, Suzuki K and Hashida T 2006 *J Mater Sci* **41** 1579–84
[2] Duxson P, Fernandez-Jimenez A, Provis J L, Lukey G C, Palomo A and van Deventer J S J, 2007 *Journal of Materials Science* **42** 2917-33
[3] Davidovits J 1991 **37** 1633-56
[4] Elimbi A, Tchakoute HK and Njopwouo D 2011 *Constr Build Mater* **25** 2805–12
[5] Al Bakri Abdullah M M, Jamaludin L, Kamarudin H, Binhussain M, Ruzaidi Ghazali C M and Ahmad M I 2013 *Advanced Materials Research* **686** 227-233
[6] Lee W K W and van Deventer J S J 2002 *Colloid and Surfaces A* **211** 49–66
[7] Mustafa Al Bakri A M, Kamarudin H, Khairul Nizar I, Bnhussain M, Zarina Y and Rafiza A R 2012 *Advanced Materials Research* **341-342** 189-193
[8] Shahedan N F, Abdullah M M A B, Hussin K, Sandu I, Ghazali C M R, Binhussain M, Yahya Z and Sandu AV 2014 *Materiale Plastice* **51**(3) 258-262
[9] Rowles M and O’Connor B 2003 *Journal of Materials Chemistry* **13** 1161–1165
[10] Ruzaidi C M, Mustafa Al Bakri A M, Binhussain M, Siti Salwa M S and Alida A, Muhammad Faheem M T and Azlin S S 2014 *Key Engineering Materials* 540-545
[11] M A Bakri A M, Kamarudin H, Khairul Nizar I, Bnhussain M, Zarina Y and Rafiza A R 2012 *Advanced Materials Research*, **341-342** 189-193
[12] Burduhos Nergis D D, Abdullah M M A and Vizureanu P 2017 *European Journal of Materials Science and Engineering* **2** 111-118
[13] Temuujin J, Minjigmaa A and Rickard W 2011 **107** 287-292
[14] Jun N H, Minciuna M G, Abdullah M M A, Jin T S, Sandu A V and Ming L Y 2017 *Revista de chimie* **68**(10) 2367-72
[15] Popovici A, Corbu O, Popita GE, Rosu C, Proorocu M, Sandu AV and Abdullah MMAB 2015 *Materiale Plastice* **52**(4) 588-592
[16] Puskas A, Corbu O and Kollo SA 2017 *Modern technologies for the 3rd millennium* p. 239-244

Acknowledgements
The financial support from Center of Excellence Geopolymer & Green Technology (CEGeoGTech), Universiti Malaysia Perlis is gratefully acknowledged.