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Recycling of Brick Waste for Geopolymer Mortar Using Full Factorial Design Approach

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Abstract: Recently a full factorial design is an experiment allows the investigator to study the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable. The objective of this study is to identify the significant factors and interactions involved in maximizing compressive strength of geopolymer mortar when brick waste activated is used as cement. In this respect, experimental factors at two levels, which are alkaline activator type (Na_2SiO_3+ NaOH), curing temperature (40°C - 60°C) and cure duration (7-28 days), are selected as possible applicants affecting the compressive strength.According to the full factorial analysis, at the 60 °C curing temperature level when brick waste activated is added to mortar, the compressive strength will be good enough after 28 days. The physic - mechanical analysis shows an excellent agreement between the measured and the estimated values for both the compressive strength and only slight deviations were noticed for high curing temperature. The use of appropriate values of matrix strength and consideration of the improvement in mechanical behavior allow a good agreement between the experimental values and the estimated values .The results demonstrate that brick waste after activation can be used in construction industry.

Keywords: Brick waste, Experimental design, Geopolymer mortar, Curing temperature

Introduction

Globalization and the constant development of countries require the application of new and improved infrastructure to meet the needs and requirements, but without commit the resources of future generations [Kossi Ayenagbo et al , 2012]. Alkaline activation of aluminosilicate materials is known from the thirties of the last century. Alkali-activated materials (geopolymers) are good alternative to Portland and blended cements [Pavel Rovnanik et al , 2016].

Waste brick (WB) powder is a material with pozzolanic properties. Pozzolanicity is dependent on several characteristics, of which the main ones are the amount of amorphous phase, particle size distribution, and specific surface area [Pavel Rovnaník et al , 2018]. WB powder can be successfully used as a precursor in alkali activated materials or geopolymers [Jan Fořt et al , 2018]. These are generally composed of aluminosilicates with specific properties and an alkaline solution as an activator. Waste-based materials and by-products used in building industry are considered to be environmentally friendly, hence common aluminosilicate precursors are fly ashes from power plants, palm oil fuel ash, ash from biomass, slag, waste brick powder, waste glass, stone dust, incineration products of sludges, and similar materials containing amorphous silica and/or aluminosilicates [L.J. Provis et al , 2015].

Rakhimova and Rakhimov used blended binder prepared from granulated blast furnace slag (GBFS) and brick waste powder (BP) at different ratio by alkali-activation using mixed solution of sodium silicate, sodium hydroxide and sodium carbonate. The compressive strength of mixture with GBFS/BP ratio 60/40 was higher than for one component binders. The compressive strength reached 120 MPa when GBFS and BP were milled together [N.R. Rakhimova et al ,2015]. Mortars prepared using alkali-activated brick powder as binder and

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siliceous sand as aggregate, cured at 65 °C for 7 days, exhibited 30-50 MPa compressive strength, 12-20% open porosity (decreasing with increasing sodium silicate used for activation) and pore size increasing for increasing sodium silicate [Enrico Sassoni et al , 2016]. Bilim et al .(2018) reported that curing conditions had a significant effect on the mechanical behavior of the hardened state of alkali-activated slag paste. This paper investigates the effect of curing conditions on compressive strength of geopolymer mortar when brick waste activated and used as cement. In this respect, experimental factors at two levels, which are alkaline activator type (Na_2SiO_3+ NaOH), curing temperature (40 °C – 60 °C) and cure duration (7-28 days), are selected as possible applicants affecting the compressive strength.

Experımental Investıgatıon

Method

Materials

Brick Waste (BW): The waste brick used was from a local manufacturing unit which was crushed in a laboratory mill. The waste brick powder has a density of 2.55 and a Blaine fineness of 3036 cm^2/g comparable to that of cement.

Sand: The sand used for making mortars is standardized sand, conforming to the requirements of EN 196-1.

The alkaline activator solution. The alkaline activator used in this study was a combination of sodium silicate (Na_2SiO_3) and NaOH. The NaOH was in pellet form with 100.5% purity and 10M solution was fixed . NaOH solution was prepared by dissolving the pellets in one liter of distilled water in a volumetric flask and stirred it. The Na_2SiO_3 consisted of 10.6% Na_2O, 26.5% SiO_2, and 62.9% H_2O (with a SiO_2/Na_2O weight ratio of 3 and a specific gravity of 1.39 at 20 ºC. The properties of the materials used are shown in Table 1.

Table 1.Chemical composition of Brick Waste

Compositions (%)	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	SO_3	Na_2O	K_2O	Cl^-	PAF
Brick Waste (%)	62.54	8.78	14.31	5.98	2.62	0.46	0.77	2.01	0.026	2.5

Preparation of Mortar Samples

To develop the alkali-activated brick waste materials were mixed with an alkaline solution. The activating solution was prepared by dissolving sodium hydroxide pellets with water and a sodium silicate solution. Brick waste was used at proportions of 100 % by weight. Therefore, these mortars were designed as MWB.

Geopolymer mortar mixes were prepared after replacing cement totally by the same amount of BW activating it by alkaline solutions of sodium hydroxide and sodium silicate. Geopolymer mortars were prepared using 1: 3 proportions of BW and standard sand. For the mixing procedure, NaOH solution, base water and binder of filler were first mixed for 5min in a pan mixer. Sand was then added and mixed for 5min.Finally, soduim silicate solution were included and were mixed for another 5min.This mixing procedure was test and found to produce high strength geopolymer. Subsequent to mixing, were molded in 2.5 cmx 2.5cmx 10cm prismatic , which were to a precured treatment that consisted of subjecting them to a relative humidity of 100% , with a temperature of 40°C and 60 °C for a period of 24 hours, in order to accelerate the activation process of mortar. After curing then subjected at an elevated temperature, the mortars were put in laboratory to cool down and demoulded the next day and kept in 25 °C room until testing age. The specimens were tested at the age of 7days and 28days. The reported results were the average of three samples.

Compresive strength: The mortar compressive strengths test were determined using prismatic specimens of square section 2.5 cm × 2.5 cm and length 10 cm in accordance with EN 196-1.

Results and Discussion

Modeling the compressive strength

When plotting the observed values of the quadratic model as a function of the predicted values (that is, the relationship between the predicted area and the actual area measured, it is found that the points are placed above the first arithmetic that is desirable.

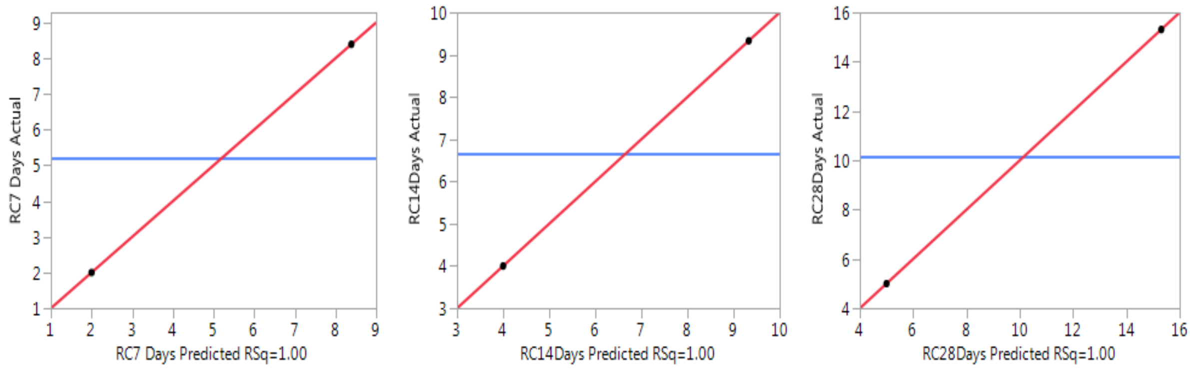

Figure 1. Graph of the values observed according to the expected values
(Compressive strength at 7days, 14 days and 28 days)

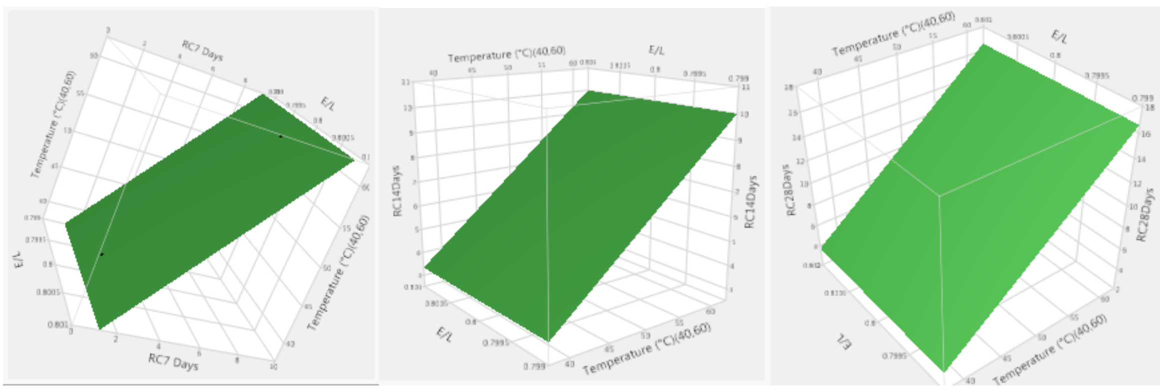

Figure 2. Evolution of compression strength as a function of curing temperature
(Compressive strength at 7days, 14 days and 28 days)

Fig. 2 shows the evolution of the compressive strengths as a function of the couring temperature. It can be clearly stated that the storage temperature strongly influences the compressive strength. An increase in the compressive strength was observed with the increase of the cooking temperature.

According to the results of estimate of coefficients drawn: the temperature effect is larger than the effect of the percentage interaction of brick waste. To simplify the model, we will eliminate this term from the equation. therefore the compressive strength response can be summarized in the following empirical model:

- Compressive strength at 7 days = 5.195 +3.195[T (°C) -50]/10
- Compressive strength at 14 days = 6.665+2.665[T (°C) -50]/10
- Compressive strength at 28 days = 10.155+5.155[T (°C) -50]/10

Conclusion

By designing three geopolymer concrete mixtures, this paper studied the effect of curing temperature in the alkali-activated brick waste and glass powder mortar and their influence of mechanical resistances .The following conclusions are drawn:

1. For the polymerization the heat is required to the geopolymer mortar;
2. The mechanical strength increases with the incorporation of brick powder at early age;

3. At 60 °C, such strengths are improved, especially for the mix with 100% brick fines;
4. The interaction between the percentage of brick waste and the dosage of activans and the influence of these last two combined with the cooking temperature are more consistent with the mechanical response and development of mortar strength.

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