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Feasibility Study on Composition and Mechanical Properties of Marine Clay based Geopolymer Brick.

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Abstract.
Geopolymer is an inorganic polymer performed in synthesis process of an aluminosilicate material which activated by alkaline activator solution. Marine clay, considered to be a waste substance which have an important aluminosilicate sources in developing geopolymer synthesis since it contains sufficient amounts of alumina and silica. In this experimental study, local marine clay composition was been identified to determine the amount of alumina and silica. The raw sample compositions were identified by using X-ray fluorescence (XRF). Incorporated with it composition, compressive strength of brick were been tested in aged of 1, 2 and 3 day and compared with local production of cement brick (CB). This research is aimed at determining the properties of Kuala Perlis marine clay in order to verify its suitability as a pozzolana materials as well as the sufficient amount of Al and Si to enhance the properties of geopolymer brick.

Introduction

Geopolymer is a new approach in materials technology recently since it was been named by Davidovits in 1979. The method of solidification is much more popular since it can be applied in various applications[2]. With excellent mechanical properties, low shrinkage, chemical resistant, corrosion resistance, environmental friendly and long span durability[4-7]; it attracted more research on various parameters like silicate activator pH, different molarity of NaOH, alkaline activator ratio and studying the materials that enriched with Si and Al [1, 2, 8-12]. Marine clay, considered to be a waste substance which have an important aluminosilicate sources in developing geopolymer synthesis since it contains sufficient amounts of alumina and silica [12]. A natural pozzolana is an enriched material with aluminious and siliceous that act with sodium hydroxide and sodium silicate [13] to form cementitious properties in low temperature [14].

Different place make different properties of marine clay [4, 14-18]. Marine clay contains a high proportion of calcium, silica, aluminum, iron and other trace metal. Marine clay is microcrystalline in nature and clay minerals like chlorite, kaolinite and illite and non-clay minerals like quartz and feldspar are present in the soil. The soils have higher proportion of organic matters that acts as a cementing agent [4]. Previous research have been studied by Chui and Tay [19] on the use of marine clays as non-conventional construction materials and Akande, Arum [14] used olutu marine clay in producing new matrix cement. An application of Marine clay mixed with palm oil clinker as an artificial aggregate has been discussed by C.M.Chan and R.Robani [20]. Other research have been studied the potential of significant raw materials such as fly ash, kaoline and cement slag as geopolymer concrete, light weight geopolymer aggregate [6, 20, 21] and other application that been studied by Zhang, Yao [7] was as protection coating to marine concrete. This project was focus on solving the issue of increasing waste disposal material as well as to perform new material from synthesis process by mixing marine clay with alkaline activator solution.

In the Table: 1 was showed the chemical composition of different type of Aluminous and siliceous sources by differ researcher.

Table 1: X-ray fluorescence analysis of Al and Si materials used in the geopolymer synthesis

Chemical Composition	A.M Mustafa al Bakri [1]	Phair, J. W et al [2]		Liew, Y. M [3]
	Fly Ash (% by weight)	K-Feldspar (% by weight)	Metakaolinite (% by weight)	Kaolin (% by weight)
SiO2	52.11	67.1	59.6	54
Al2O3	23.59	17.6	33.9	31.7
Fe2O3	7.39	0.2	1.2	4.89
TiO2	0.88	0.01	3	1.41
CaO	2.61	0.2	0.2	<0.05
MgO	0.78	0	0.3	0.7
Na2O	0.42	<0.1	0.17	0.05
K2O	0.8	10.6	0.2	6.05
P2O5	1.31	0.3	0.14	-
SO3	0.49	0	0	-
MnO	0.03	<0.01	0.01	0.11

According to ASTM 618 [22], in producing of cementitiuos material, the minimum requirement of total composition of silicon oxide, aluminium oxide and iron oxide was 70% of total weight. The chemical component determinations and the limits placed on each do not predict the performance of the fly ash or natural pozzolan with hydraulic cement in concrete, but collectively help describe composition and uniformity of the material [22].

Materials and Experimental Details

Raw Material

Marine Clay used in this study was collected along seashore in Kuala Perlis, Malaysia at varies depth 0.3 – 1.0 m. Six (6) spotted point for sampling location. The sample taken have been remarked as MC 01 for sampling at point 1, then MC 02 for sampling at point 2 and continuous marking for other sample. The sample was been dried up in the oven at temperature of 105°C in 48 hours and it been pulverized and sieved in 315 µm sieving pan.

Preparation of alkaline activator Solution

The alkaline liquid that used was a combination of sodium silicate solution and sodium hydroxide solution. The Sodium silicate (Na_2SiO_3) solution was supplied by South Pacific Chemicals Industries Sdn. Bhd. (SPCI) Malaysia. The chemical composition of the Na_2SiO_3 solution was SiO_2 = 30.1%, Na_2O = 9.4% and water = 60.5% by mass with a SiO_2/Na_2O modulus of 3.2, specific gravity at 20°C = 1.4g/cc and viscosity at 20°C = 400cP. The sodium hydroxide (NaOH) solution was prepared by dissolving the NaOH powder made in Taiwan with 99% purity in distilled water . The NaOH solution was prepared with 12 M concentration [1, 3] and cooled down to room temperature .

Mixing Process

In the mixing process, the dry marine clay mixed homogenously with alkaline activator to perform synthesis paste in fixed ratio of 1:2 then the ratio of sodium silicate solution to sodium hydroxide solution, by mass, was fixed at 2.5. The synthesis pastes were mixed with fine aggregate in ratio 1:3 and moulded in the brick mould with dimensioning is according to BS3921 [23]. The samples were cured at a temperature 70 °C for 24 hr and maintained at room temperature until the testing was conducted [1].

Testing
Compression Strength Test

The compressive strength test for geopolymer bricks were carried out according to ASTM C67-07a [24] by using 20T JiNAN Hydraulic Compression Testing Machine at the rate loading of 0.05 kN/s or not exceed 0.15kN/s. The load applied is limited on the strecher face of the brick. The compressive strength is taken as the maximum compressive load it can carry per unit area.

X-Ray Fluorescence

Investigation on chemical compositions on dry marine clays was tested using X-ray Fluorescence (X-RF). This action was taken to analyze the initial composition of marine clay. From this characterization, the entire particle that made marine clay is identified.

Result and Discussion
Chemical Composition of Kuala Perlis Marine Clay

Table 2: Chemical Composition of Kuala Perlis Marine Clay

Chemical Composition	(% by weight)						Average (% by weight)	ASTM C 618 Class N (min =70%)
	MC01	MC02	MC03	MC04	MC05	MC06		
SiO_2	33.5	42.53	35.22	46.21	35.44	41.51	39.07	72.16
Al_2O_3	8.82	11.2	9.26	6.1	7.57	9.37	9.76	
Fe_2O_3	20.19	26.15	23.66	21.91	21.02	21.61	23.33	
CaO	26.3	30.2	25.36	32.14	28.78	28.96	27.29	
K_2O	2.78	1.58	2.13	1.84	2.33	2.18	2.16	
Cl	4.82	5.12	4.56	5.34	5.04	5.12	4.83	
CuO	0.084	0.088	0.068	0.026	0.162	0.017	0.08	
MgO	0.21	0.256	0.221	0.231	0.266	0.248	0.23	

Table 2 shows the chemical composition of marine clay in 6 different areas along the Kuala Perlis offshore. According ASTM C618-13 [22], the total chemical composition that required for cementitious materias on natural pozzolana materials (Class N) was 70% of their total mass. Based on previous research [1, 3, 9], even no reported on the total amount of composition but it can been seeing that the result was good especially in compressive strength.

The result of X-ray Fluorescence on the sample shows that average percent by weight was 72.16 % and its slightly higher than minimum requirement. The chemical compositions of marine clay listed in Table 2 shows the major oxide components are silica (SiO_3), Alumina (Al_2O_3), Iron (Fe_2O_3) and lime (CaO). Other components such as K_2O, ZnO and CuO are present in small quantities. The lime (CaO) present in high percentage was due to existing of shell from death sea creature.

Compressive Strength

Table 3: Compressive Strength of Marine Clay Based Geopolymer Brick

Average Compressive Strength, MPa

Day testing	1D	2D	3D	7D
Marine Clay Brick	4.82	5.95	7.94	9.34
Conversional Cement Brick	3.06	3.49	3.02	3.33

Table 3 shows the compressive test result of the marine clay based geopolymer brick. The average strength of geopolymer brick was achieved at 4.82MPa after 24-h curing [21] . While for the other tested day (2D, 3D, 7D) also shows the progressive increment of the compressive strength compare to conversional cement brick. Hardjito, E.Wallah [21] also reported that because the chemical reaction of the geopolymer paste very fast in polimerisation process, so the compressive strength was not vary for the concrete properties. The cement based product relies on the hydration process which takes more time to gain the strength. According to ASTM C91 [25], the requirement for masonry cement for type M in term of compressive strength was 12.4 MPa. Further study need to be carried out on other properties of the matrix composition such as soundness and durability of paste.

Summary

The total chemical composition of oxide component which are silica (SiO_3), Alumina (Al_2O_3) and Iron (Fe_2O_3) that required in ASTM C618-13 [22] was proved that the average composition of 70% of the weight Kuala Perlis marine clay which mixed with appropriate alkaline activator solution, was gain the compressive strength in early day. Incorporated with marine clay composition, the compressive strength was improved due to suitability of marine clay composition with previous cementitious or pozzalana material.

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