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The Mechanical Properties of Waste Malaysian Clay as a Cemnet Replacement Material in Concrete

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ABSTRACT

The aim of this study is to investigate the feasibility of using waste flower pot powder as partial replacement in concrete. Waste flower pot powder is also known as burnt clay or calcined clay or fire clay. They are mainly formed by siliceous and aluminous compounds. Cement is replaced by waste flower pot powder in different portion 5%, 10% and 20% by weight. The mechanical properties of this concrete such as density, compressive strength, flexural strength and PUNDIT (Ultrasonic Pulse Velocity Test) was compared to the conventional concrete. Pozzolanic properties of waste flower pot powder have proven the potential use of waste flower pot powder material to produce environmental friendly concrete.

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INTRODUCTION

Cement is one of the most important components of concrete. Cement manufacturing is the largest producer of carbon dioxide (CO_2) accounting for over 50% of all industrial CO_2 emissions. Funcso (2013) mentioned about 30% of cement used globally is needed to be replaced with supplementing cementititous materials to achive, a zero percent increase in CO_2 emission from cement manufacturing. According to huge amount of natural resources are been vanished as the usage of cement which raises a serious environmental concern in Malaysia. Reduction of Portland cement without reducing performance of concrete is very important for huge projects that need a lot of cement.

Today, pozzolan and cementitious materials plays an important role in concrete. Wastes of industries and constructions which have pozzolanic or cementitious property, not only can reduce environmental pollution and energy consumption of construction industry but also make it cheap. There are proven record shown partial replacement of cement with pozzolanic material up to 20%-30% can produce almost equivalent as conventional concrete.

The most promising option to lower costs (and environmental impact) is to blend conventional Portland cement with pozzolanic materials. Pozzolans occur in natural deposits or can be obtained as by products in agri-industrial applications. They have drawn the attention of cement manufacturers for their good performance as cement replacement materials. Pozzolanic materials are siliceous (SiO_2) or siliceous (SiO_2) and aluminous (Al_2O_3) materials, which in themselves have little or no cementation value, but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide ($Ca(OH)_2$) progressive on hydration, at ordinary temperature to form compounds, possessing cementations properties.

The waste flower pot is made of clay from Kinta Valley know as ball clay. Ball clay is a mineral formed from the weathering and transportation by water of parent rocks which are deposited in ancient river basins from where it is now extracted. Ball clay is a variety of kaolinite, like china-clay. It differs from china-clay in having high plasticity and less refractoriness. In chemical composition, ball clays usually contain three dominant minerals: from 20-80% kaolinite, 10-25% mica, and 6-65% quartz. Basically for kaolinite clay when been heated at 700^oC – 800^oC converts kaolinite clay (weakly pozzolanic) to metakaolin (highly pozzolanic). According to Tanker (2010) heating destroys the crystal structure of the clays, which results in amorphous or disordered alumina silicate structure. Amorphous substances react with lime to produce calcium silicate hydrate and/or calcium aluminate hydrate at the brick-lime interface. It has been shown

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Australian Journal of Basic and Applied Sciences, 9(7) April 2015, Pages: 302-306

that the calcination temperature of clay has signification effect on the pozzolanic activity depending on the type of the clay mineral.

Materials and Experimental Procedure:

The calcined clay material used was collected in the form of waste/rejected flower pot from Ipoh, Perak. In the laboratory, these pots are grind until it become finest with the available equipment in lab. The powdered pots passing the sieve 300µm were used for this experiment.

Total 4 nos. grade 30 concrete mix using DOE method was prepared where, the conventional mix, 5%, 10% and 20% of cement replacement (Table 1). For each mix 18 nos. cube specimens (100x100x100) and 12 nos. prism specimens (100x100x500) were prepared for experiment. The maximum size coarse aggregate used for the experiment is 20 mm and fine aggregate using river sand.The specimens cured in water were test on 1 day, 3 days, 7 days, 14 days, 28 days and 40 days.

Table 1: Concrete Design Mix.

Concrete Design Mix	Clay (kg)	Cement (kg)	Water (kg)	Sand (kg)	Aggregate (kg)	Total (kg)
Conventional	0	40.5	22.68	90.83	102.49	256.50
5% Clay	2.27	38.20	22.68	90.83	102.49	256.50
10% Clay	4.05	36.45	22.68	90.83	102.49	256.50
20% Clay	8.10	32.40	22.68	90.83	102.49	256.50

RESULTS AND DISCUSSION

Chemical Content:

The chemical content is as shown in Table 2. Pozzolanic properties were measured and shown in Table 3. Pozzolanic properties confirm to ASTM C618. When it is compared with cement, heated clay has higher siliceous (SiO_2) and aluminous (Al_2O_3) content which would be the important cementations properties.

Density:

From the figure 1, the bar chart of concrete density of normal concrete, 5%, 10% and 20% clay concrete shows the consistency of concrete density between 7 days, 28 days and 40 days even though there are a little amount of difference value between the age tested. But as for 5% clay concrete, a huge difference of density of the concrete occurs when it reaches to 40 days. The density of this concrete seems to be decreasing by leaving a big gap between 7 days and 40 days.

Table 2: Chemical composition.

Component	Control Cement (%)	XRF analysis of Clay from Beruas (%)
SiO_2	19.26	65
Al_2O_3	5.32	24
Fe_2O_3	3.6	2.9
K_2O	0.5	2.2
MgO	2.36	1.6
Na_2O	na	0.069
CaO	63.34	0.17
P_2O_5	na	0.036
Loss On Ignition (LOI)	na	8.55

Table 3: Table Comparison of PozzolanicProperties and ASTM C618.

Parameter	ASTM in Percent	Clay in Percent
SiO2+ Al2O3 + Fe2O3	>70	95.9
SO3	<3.0	NA
L.O.L	<10	8.75
Autoclave expansion	<0.8	NA
Moisture content	<3.0	NA

It can be summarized as when increasing of the age of the specimen, the concrete density will be increasing even though the increasing value is not constant. This is because of the curing factor during specimen is cured inside the water curing tank which cause the increasing weight of the specimen. The second factor is that the test specimen might not much be dry enough perfectly to obtain the dry weight. Therefore the inaccuracy actual value of concrete density specimen occurs for every concrete mix with the increase of the age.

Compressive Strength:

The compressive strength test is one of the important tests for the concrete mix. A concrete is really good at compressive strength and weak in flexural strength. This test will show the capability of the concrete strength towards the mix design in various types by using a different percentage of clay.

Australian Journal of Basic and Applied Sciences, 9(7) April 2015, Pages: 302-306

Base on plotted Figure 2 the compressive strength all the specimen fulfil the design grade 30 at 28 days. If we see it generally the best concrete would be 5% Clay since it achieved the highest strength where else technically 20% Clay would be good since it has fulfilled the criteria of design and economical. Concrete with 10% Clay and 20% Clay concrete tested initially it show a very low strength but from day 14 it show it have gain strength almost equally with normal concrete.

Result shows 5% clay, compressive strength has magnificently increase far beyond the expectation of the other three specimens. On the 7 days of age, this sample has increase the strength as nearly reach the strength of design. By the age of 28 days, the value of compressive strength has increase passing the value strength of normal, 10% and 20% clay concrete. When it comes to 40 days, the strength rise up more than what has been expected. This may occurred because of the curing process where the concrete reacts in hydrolysis and hydration process.

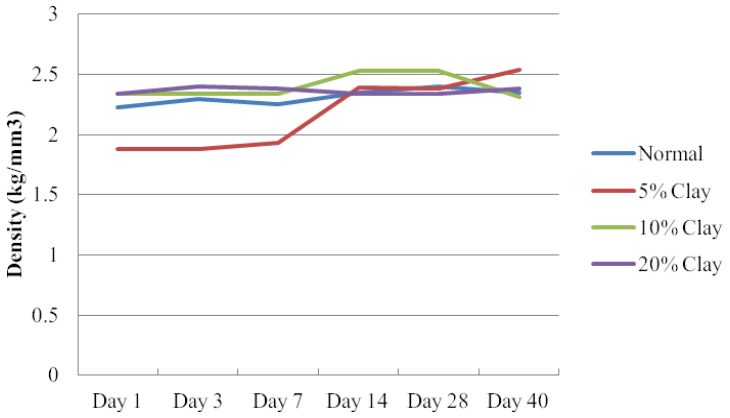

Fig. 1: Density concrete between four sample specimens.

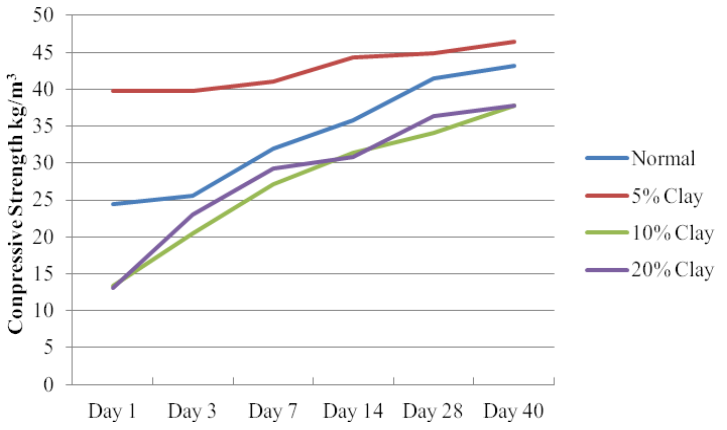

Fig. 2: Compressive strength concrete between four sample specimens.

Flexural Tensile Strength:

The performance of flexural strength usually more depends on the density and the strength of the concrete where obtaining weight before flexural test is run shows the tested concrete density is in good condition. From the data analysis obtained, flexural strength too experiences the increase of strength process. According to the Graph 3 from the bar chart shown shows that the equal increase of strength between 1, 3, 7, 14, 28 and 40 days is the normal concrete. The comparison between the 10% and 20% clay concrete, on the beginning 7 days of tested the flexural strength of the both specimen increased higher than normal concrete. When it reach 28 days of tests, the flexural strength of the both specimen increased higher especially for the 20% clay concrete where it rises over the 10% clay concrete. But when it comes to the age of 40 days of tests, the 20% clay concrete show the decreased of the flexural strength. From the 40 days of testes result shows that the stronger concrete in flexural strength is the normal concrete.

The increasing of flexural strength which is inconsistent has given a guide where if there is an existence of different quantity types of cement content in every specimen mix, then the features or the characteristics of the strength will be also different between one to another. A material of

Australian Journal of Basic and Applied Sciences, 9(7) April 2015, Pages: 302-306

concrete mixture which plays the important role in concrete strength is the aggregate and cement. So, if there is a change in the quantity of cement content, then there will also be a change of the reading strength.

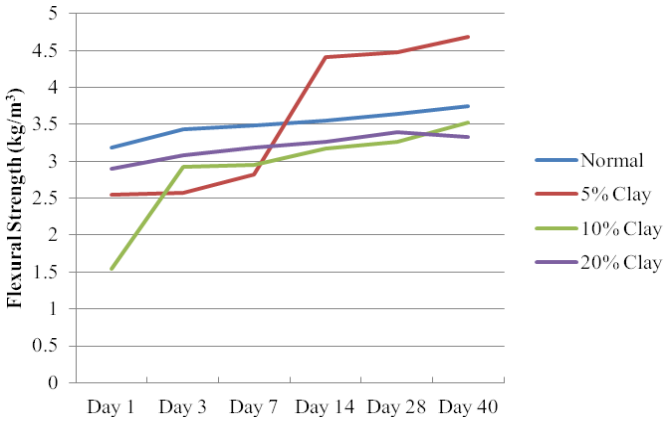

Fig. 3: Flexural strength concrete between four sample specimens.

Ultrasonic Pulse Velocity Test Analysis:

From the experiment and the data result shows that the value for all concrete specimens is in good and excellent rate (figure 4). Starting from day 1 to 28 days shows the results of good rating, and by the age of 40 days of tests, it increase up going for an excellent rate. This shows that the increase density of the concrete, the higher will be for the pulse velocity of the concrete. From the result shown here, it can be summarizing as the more percentage of clay use in the concrete mix, the higher the pulse velocity. This is because pulse velocity move inside the concrete where it interacts with the particles of the concrete. If the concrete is in solid, compacted and the bond between each particles of the aggregate, cement, sand is good without any air bubbles inside, the faster it will be for the pulse velocity to pass through the concrete which in result in good quality.

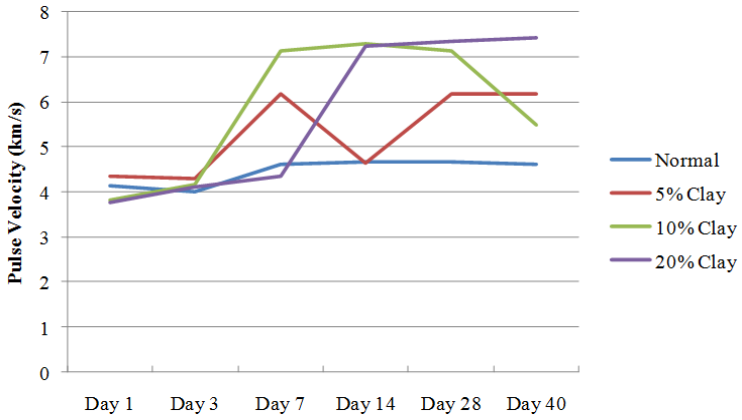

Fig. 4: Pulse velocity concrete between four sample specimens.

Conclusion:

Base on the test that have been carried out it has proven that partial replacement of cement using waste material of flower pot up to 20% of the cement weight is equal or better from the aspect of engineering properties and the durability. Even though the best replacement would be 5% Clay, using 20% Clay would be good enough for an economical and sustainable concrete.

The main material that contributed to achieve such result is burnt clay. So material from recycle clay brick and flower pot can be combined for the future study. It's also suggested replacement up to 30% is tested so that a zero percent increase in CO_2 as mentioned by Funcso (2013) can be achieved.

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