EFFECT OF RICE HUSK ASH TO THE PERFORMANCE OF CONCRETE BLOCK

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Abstract

The laboratory results of an investigation on the properties of concrete block containing Rice Husk Ash were presented in this paper. Materials used in the investigation were Ordinary Portland cement (OPC), rock chipping, quarry dust and RHA. Concrete samples were cast with different RHA replacement level at 0, 10, 15 and 20%. Several tests were carrying out i.e. XRD, TGA/DTA analysis, compressive strength and water absorption in order to determine concrete block chemical and mechanical properties. In conclusion, it was found that the optimum RHA replacement level is 15%. Conversely, compaction and percentage of RHA in concrete block are also discussed in this study as an influencing factor to the performance of concrete block.

Key Words: concrete block, rice husk ash, compressive strength, water absorption

1. INTRODUCTION

In Malaysia, the demand for rice has increased due to population growth which exceeds 2.3%. Paddy milling operation normally produces approximately 78% rice and 22% rice husk from the initial weight of paddy (Beagle, 1978). Raw of rice husk contains about 50% cellulose, 25% to 30% lignin and 15% to 20% of silica (Ismail and Waliuddin, 1996). When subjected to high temperature burning, the rice husk will converted to RHA, a highly reactive pozzolan with silica content of 85% to 90%. When rice husk is burnt at temperature 550ºC to 800ºC, amorphous silica will be formed which contributes to pozzolanic property which could enhance strength and durability of concrete (Jauberthie et al., 2003).

The presence of crystalline silica from open-field burning or uncontrolled combustion of rice husk produces RHA that has no or little pozzolanic property and contributes to enormous environmental threats such as lowering of air quality (Nehdi et al., 2003). The utilization of RHA as a partial cement substitute in the production of concrete block will lead to lower consumption of cement. Since cement is mainly produced from clay and lime stone, the use of RHA and other by-product pozzolans could somehow contribute towards the preservation of our non-renewable resources (Sabir et al., 2001). According to Oyetola and Abdullahi (2006) reported that RHA replacement level in excess than 30% could lead to reduction in strength. The increase in replacement level leads to an increase in water demand, which requires higher water content. Naidu et al. (2003) stated that the use quarry dust as partial sand replacement, in combination with silica fume enhances the properties of concrete and increases the pull-out force. Dusts content up to 10% in concrete has improved properties of concrete and this was attributed to the filler effects of the dust. The strength characteristics of concrete block could be influenced by many factors. The proportion of fine aggregate is a major contributor in giving cohesiveness, which is essential in order to obtain adequate green strength in block-making. Thus, the overall grading should be parallel with amount of water in the mix. Improper grading could lead to inability to obtain adequate compaction, hence it is impossible to obtain desired strength. Moreover, the use of sophisticated vibration equipment also helps to enhance the properties of blocks. According to Baiden and Asante (2004), different orientation produced different strength properties although the same compaction method or vice-versa has been used. Time of mixing also could influence the strength characteristics of the concrete block. This paper focuses on the laboratory testing of the effects of RHA inclusion as partial cement replacement material on the performance of concrete block. Towards this end, the properties investigated were namely compressive strength and water absorption.

2. RESEARCH SIGNIFICANCE

Several factors were determined that contributed to the performance of concrete block. The following sentences stated as below are research significance for these investigate.

a) Reduce the density of the block and replace present aggregates used in the block- making which is from granite is one of the most commonly used stones.
b) From the respective research, confidently this study can fulfill the fast-growing population demand and give credits to the construction industries such as speed up the construction due to larger size of block and minimal workforce involves.

c) Utilization of RHA in the concrete block reduces the cement content. This is the only way to conserve the lack of these non-renewable sources namely cement.

3. MATERIALS AND METHOD

3.1 Materials

3.1.1 Coarse and fine aggregates

In the present investigation, aggregates were supplied by Quad Quarry Sdn. Bhd, Penang Island, Malaysia. Several tests were conducted to characterize the properties of the aggregates used. The rock chippings used were those passing through 10 mm size and retained on 5 mm size was used. In the case of quarry dust, the samples passing through 2.36 mm sieve and retained on 300µm were used. Figure 1 presented the materials used in block production.

3.1.2 Ordinary Portland cement

The Ordinary Portland cement (OPC), has been used in this experimental work. Typical properties and compositions of the Ordinary Portland cement are tabulated in Table 1. The OPC was produced by LAFARGE Cement Sdn. Bhd, marketed with a commercial brand of Blue Lion.

3.1.3 Water

Water is a key ingredient in the manufacture of concrete. Even though the quantity of water is the vital influence of concrete properties, but its quality, however, also plays a significant role. The water that is supplied in the concrete laboratory was used throughout the investigation.

3.1.4 Superplasticizer

The GLENIUM C380 superplasticizer was used throughout the investigation. According tp Arshad (2009), the specific gravity of superplasticizer is 1.07-1.16 while the pH in the range of 6 to 7.5. Though, the colour of the superplasticizer is Light brown.

3.1.5 Rice Husk

The RHA was achieving from Agrilectric Power Plant in Pinang Island, Malaysia. Rice husks were burnt at temperature 700ºC at 6 hours to obtain the ash. The RHA was then ground using ball mill and the specific surface area of the RHA was determined using BET nitrogen adsorption is 11770 m^2/kg. The loss of ignition (LOI) of the RHA was 3.03%. The chemical compositions of the RHA are prearranged in Table 2.

3.2 Tests conducted

3.2.1 X-ray Diffraction (XRD)

In this investigation, the raw materials were analyzed by XRD instrument named BRUKER AXS D8 ADVANCE. Small amount of sample was place on the sample holder then directly taken to characterize. XRD patterns were scanned in steps of 0.0034^o in a range of diffraction angle from 5^o to 70^o of 2θ, using Copper (Cu) as X-ray source with wavelength (λ) of 1.5406 nm.

3.2.2 Thermogravimetric analysis and differential thermal analysis

The amount of calcium hydroxide, (CH) in RHA can be measured by Thermogravimetric analysis (TG) and differential thermal analysis (DTA). The test was performed to investigate the total percent of weight loss due to evaporable free water found in pores of different types of cement paste mixed. In this investigation, cement paste is heated at a controlled rate and the weight loss is recorded at various temperatures. When the hardened cement paste is heated gradually it will lose weight due to three major phases which is dehydration, dehydrolaxation and decomposition of its components. As at certain temperature intervals the above mentioned processes can occur, by referring to the standard peaks, they can be easily identified.

3.2.3 Compressive strength

Specimens with ordinary Portland cement concrete (control) and OPC replaced by rice husk ash at 0%, 10%, 15% and 20% replacement levels were cast. During moulding, the cubes were mechanically vibrated. After 24 hours, the specimens were removed from the mould and subjected to water curing for 7-, 14-, 28-, and 60 days. The specimens were tested for compressive strength using compression testing machine. The load shall be applied to the specimen at any convenient rate up to 35kN/mm^2 per minute. At half of the expected maximum load, rate should be adjusted to 15kN/mm^2 until failure load was reached. The tests were carried out on triplicate specimens and the average compressive strength values were recorded.

3.2.4 Water absorption

Two alternative standard methods were specified in BS EN 771-3:2003 ; the 5-hour boiling test and the vacuum test. In this study, the 5-hour boiling test was adopted. Before the test was conducted, specimens were dried at least for 48 hours at 110°C. The specimens were then cooled to room temperature and weighed.

3.2.5 Production of the Block Samples

Correct water-cement ratio was verified during preliminary study to suit the mix ratio. Four replacement levels were adopted i.e. 0, 10, 15 and 20% and concrete block size 390 x 190 x 100mm according to BS EN 771-3:2003. From the trial mix, it is concluded that the percentages of cement, sand, quarry dust and aggregate is 12, 32, 44 and 12% respectively. The compaction of samples was performed using a combination of wooden tamper and KANGO hammer. All samples were then covered with wet polythene sheet before being demoulded at the age of 24 hours. Once those, all samples were subjected to curing by means of sprinkling with twice a day until the age of testing at 7, 14, 28 and 60 days. The summary of the procedure can be seen in Figure 2. A total number of 240 blocks were prepared for this research work. The results of mix design are tabulated in Table 3.

3.3 RESULTS AND DISCUSSION

3.3.1 X-Ray Diffraction Analysis

XRD analyses were performed on selected cement paste samples to identify the differences in the formation of $Ca(OH)_2$ at different curing ages. The XRD analyses are illustrated in Figure 3. It is easily noticed that CH or $Ca(OH)_2$ is one of the hydration products during the hydration process. The intensity peaks of $Ca(OH)_2$ appeared at 2θ of 18.00, 34.10, 47.11, 50.80 and 54.36º. The XRD patterns generally show the intensity peaks decreased when RHA was incorporated into the cement pastes. It can be seen that the intensity peaks of $Ca(OH)_2$ from the XRD patterns is the highest at 14 days. At later ages particularly at 60 days, there is a significant reduction in intensity peak of $Ca(OH)_2$ due to consumption of CH in cement containing RHA. Factors affecting the pozzolanic reactivity are the fineness and amorphous silica content in the RHA. It was determined that the properly burnt RHA can be used to produce good quality cement replacement material. It was also noticeable that $Ca(OH)_2$ decreased significantly with the increase of RHA content until 20% of replacement level.

3.3.2 Thermal Analysis

The weight loss peaks of the pastes in DTG curves involved four processes during heating, as shown in Figure 4. At temperature up to 128ºC, evaporable water loss within the pore-structure in every cement paste. This peak is eliminated if the samples are oven dried at 105ºC before the heating process. When the temperature varies between range of 105ºC and 1000ºC chemically combined hydrated water from the gel structure is then lost. Due to temperature changes, dehydration process occurred with a gradual decrease in weight. Dehydrolaxation of calcium hydroxide appears in the range of temperature between 449 to 578ºC. Finally, calcium carbonate will decompose in the approximate temperature ranged between 731 to 766ºC to produce CO_2 and CaO. The reaction between CO_2 and CaO formed calcium carbonate when exposed in the atmosphere. Therefore, attention has to be taken in order to prevent carbonation of $Ca(OH)_2$. Table 4 represents dehydrolaxation and decomposition peak temperatures at different curing ages. By comparing the DTA curves, it shows the same reduction trend and can be observed in Figures 4. For example at 14 days, RHA cement paste loss its evaporable water at low temperature which is at 119ºC. Decomposition probably occurs at 742 to 765ºC. It can be seen that this quantitative measurement of CH by TGA clarifies that pozzolanic reaction occurs. This is shown by the decrease of $Ca(OH)_2$ percentage with curing age. At 14 days there was reduction (2.99%) occurring in $Ca(OH)_2$ while the total weight loss of $Ca(OH)_2$ is 15.79%. This was followed by further curing age at 28 days where 3.51% reduction of $Ca(OH)_2$ occurred from total weight loss. It was found that 1.62% of $Ca(OH)_2$ was reduced from the subsequent curing age.

3.3.3 Strength and relative strength of concrete block

The relationship between the relative strength and the replacement level of RHA on concrete block is demonstrated in Figure 5. Relative strength is defined as the ratio of the strength of the concrete block at 7, 14, 28 and 56 days. A comparison has been made between 7 and 56 days relative strength data. Based on the figure, the OPC provide 17.03%, 10RHA (26.03%) followed by 15RHA (29.85%) while 20RHA achieve 21.81% respectively. This can be concluded that 15RHA performs the highest relative of strength. Details of relative strength in percentage are tabulated in Table 5. According to the results, this influence is due to pour filling effect as a result of pozzolanic reaction in the RHA unit block. The pozzolanic reaction produces calcium silicate hydrates which fill the pores and leads to higher strength development. These processes continue as long as un-reacted RHA, calcium hydroxide and moisture are available. Consequently, there is a tendency that the long-term strength of the concretes block containing RHA could be higher than the OPC due to the pozzolanic reaction activity. Strength development may be influenced by several factors such as water/cement ratio, cement/binder content, curing condition, type of binder and others.

3.3.4 Water Absorption

Table 6 represents the details of water absorption for different types of block unit i.e. OPC, 10RHA, 15RHA and 20RHA. It was observed that the water absorption for all samples in the range of 1.09 to 4.17% at 14 days of curing age. Comparison has been made at 28 days between the block where 15RHA shows the least percentage (0.36%) of water being absorbed. While, water absorption increased in every replacement level at this curing age. At later age, water absorption for other block continues to reduce except for OPC. This block with no replacement tends to increase in water absorption. The greatest reduction goes to 20RHA at later age for 4.87%. Therefore, there is reduction about 3.45% in water absorption when cement is replaced by 15% RHA, whereas in case of 10RHA shows there is only a small reduction 1.70% of water absorption at later age. These results clearly establish that partial replacement of RHA contributes to the improvement of concrete durability. The reduction in water absorption may be due to the smaller size of the siliceous particles which could fill the voids that exist in concrete block. Thus, this leads to partial closure of these voids. It can be concluded that filler effect takes place in the concrete block containing RHA. Concrete block with high amount of RHA lowers the percentage of water absorption as compared to the block with no RHA replacement.

3.3.5 Effect of the Different Replacement Level of RHA

The effect of mineral admixtures on the strength varies significantly on its properties and replacement level. Pozzolanic effect or pore size refinement takes place when an additional calcium silicate hydrates form in the hydrated cement. This occurs due to RHA which is known as highly siliceous material reacting with $Ca(OH)_2$ in the present of moisture or water. In this particular research area, 10 to 20% of RHA were used to replace OPC mass by mass. Optimum replacement is achieved at 15% of RHA. At an early age, slow pozzolanic reaction occurs in the RHA block. This shows that OPC block gives higher strength compared to RHA block. Reduction in $Ca(OH)_2$ content in 15RHA cement paste confirms the occurrence of pozzolanic reaction. RHA has a high potential use as a cement replacement material. The beneficial effects may arise from the higher fineness of RHA which has greater pozzolanic effect and the smaller size particles that could fill in the voids and lowers the water absorption percentage. Thus, increase the compressive strength of concrete block containing RHA.

4. FURTHER RESEARCH

Further investigations are required to emphasize on other mechanical properties such as flexural, splitting tensile and durability of the block i.e. sulfate resistance, thermal insulation, deformations characteristics of masonry and various on mortar properties study.

5. CONCLUSIONS

1. In general, block strength increases with the curing age. At early age, OPC gives highest strength result compared to RHA block. This could be attributed to dilution effect from the combination of low cement content and slow pozzolanic reaction in RHA block.
2. There is a tendency that the long-term strength of the concretes block containing RHA could be higher than the OPC due to the pozzolanic reaction activity. Pozzolanic reaction produces calcium silicate hydrates which fill the pores and leads to higher strength development.
3. In the case of water absorption, the graph trend increases gradually with the increase of RHA content. At early age of curing OPC gives lowest water absorption percentage. Meanwhile, at later age the percentage of water absorption shows that OPC block gives the highest result compared to RHA block. The probable explanation is that amount of cement used could have been sufficient to initiate and sustain both hydration and the subsequent pozzolanic reactions. These are translated into lower values of water absorption at 60 days of curing.

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Table 1. Typical properties and compositions of Ordinary Portland Cement

Typical properties		
Surface area	m^2/kg	290 to 390
Setting time- initial	minutes	80 to 200
BS EN 196-1 Mortar compressive strength 2 days 7 days 28 days	 N/mm^2 N/mm^2 N/mm^2	 21 to 31 40 to 50 52 to 62
Apparent particle density	kg/m^3	3080 to 3180
Bulk density	aerated settle	1000 to 1300 1300 to 1450
Colour	Y value	27.5 to 37.5
Sulphate	SO_2 (%)	2.5 to 3.5
Chloride	Cl (%)	Less than 0.03
Alkali	Eq Na_2O (%)	0.40 to 0.65
Tricalcium silicate	C_3S (%)	40.0 to 60.0
Dicalcium silicate	C_2S (%)	12.5 to 30.0

(Resources: Ordinary Portland cement, CEM 142, 5N, Lafarge Cement)

Table 2. Chemical compositions of Rice Husk Ash

Chemical analyses	**Weight percentage, %**
SiO_2	90.0
Al_2O_3	0.39
Fe_2O_3	0.37
CaO	0.46
MgO	0.88
K_2O	3.10
Na_2O	0.07
P_2O_5	1.60
MnO	0.039

Table 3. Mixes Proportion of concrete block

Materials	**OPC**	**RHA10**	**RHA15**	**RHA20**
Cement	96.04	86.40	81.60	76.80
Quarry dust	352.14	352.14	352.14	52.14
Chipping 10mm	96.04	96.04	96.04	96.04
Water	67.24	67.24	67.24	67.24
RHA	-	9.64	14.44	19.24

Table 4. Peak temperature for decomposition and dehydrolaxation.

Decomposition of $CaCO_3$ and Dehydrolaxation of $Ca(OH)_2$		
Curing age, (days)	Decomposition peak temperature, (°C)	Dehydrolaxation of peak temperature, (°C)
7	750 – 766	449 – 518
14	742 – 765	448 – 515
28	742 – 770	463 – 512
60	731 – 742	454 – 515

Table 5. Effects of RHA on relative strength

Time (age)	**Relative strength, (%)**			
	OPC	**RHA10**	**RHA15**	**RHA 20**
7	82.97	73.97	70.15	78.18
14	92.14	83.88	76.04	85.15
28	94.05	85.18	81.79	91.52
60	100	100	100	100

Table 6. Relative water absorption in percentage to the curing age

Time (age)	**Increment / Reduction of Water Absorption, (%)**			
	OPC	**RHA10**	**RHA15**	**RHA 20**
7	0.00	0.00	0.00	0.00
14	-1.09	-4.17	-2.19	-3.25
28	3.41	0.43	0.36	2.15
60	1.46	-1.70	-3.45	-4.81

*(-) negative sign shows reduction.

Figure 1. Materials used in this production of block

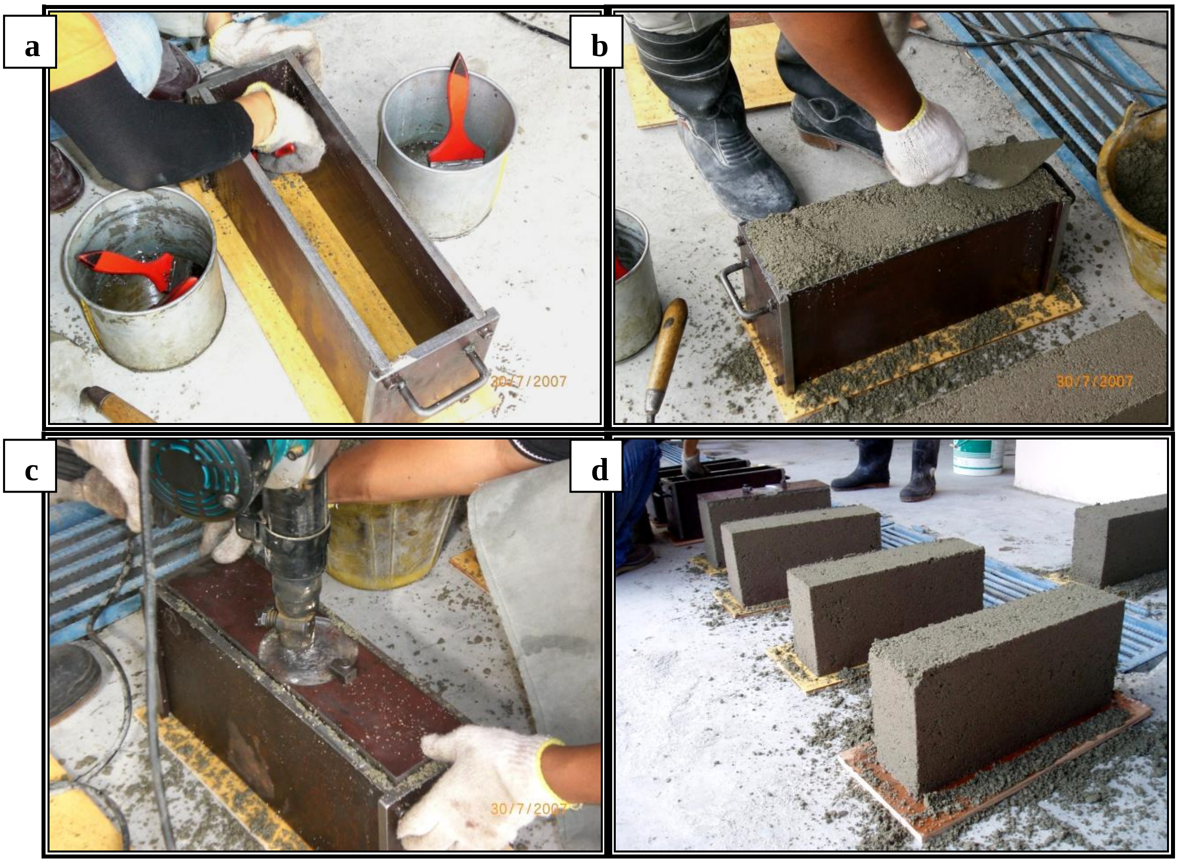

Figure 2. Procedure used for production of concrete block; (a) mould was greased using oil; (b) mould was filled until the brim; (c) compacted sample; (d) finished block

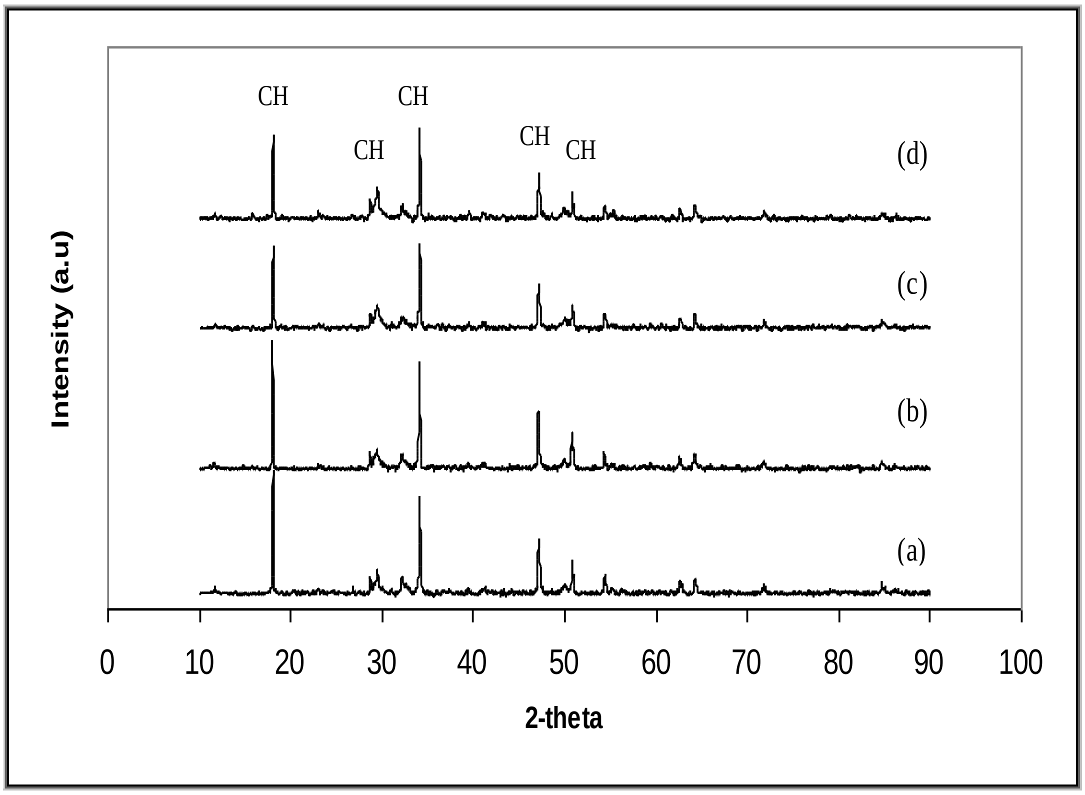

Figure 3. XRD pattern for RHA15 cement paste; (a) 7-d; (b) 14-d; (c) 28-d; (d) 60-d

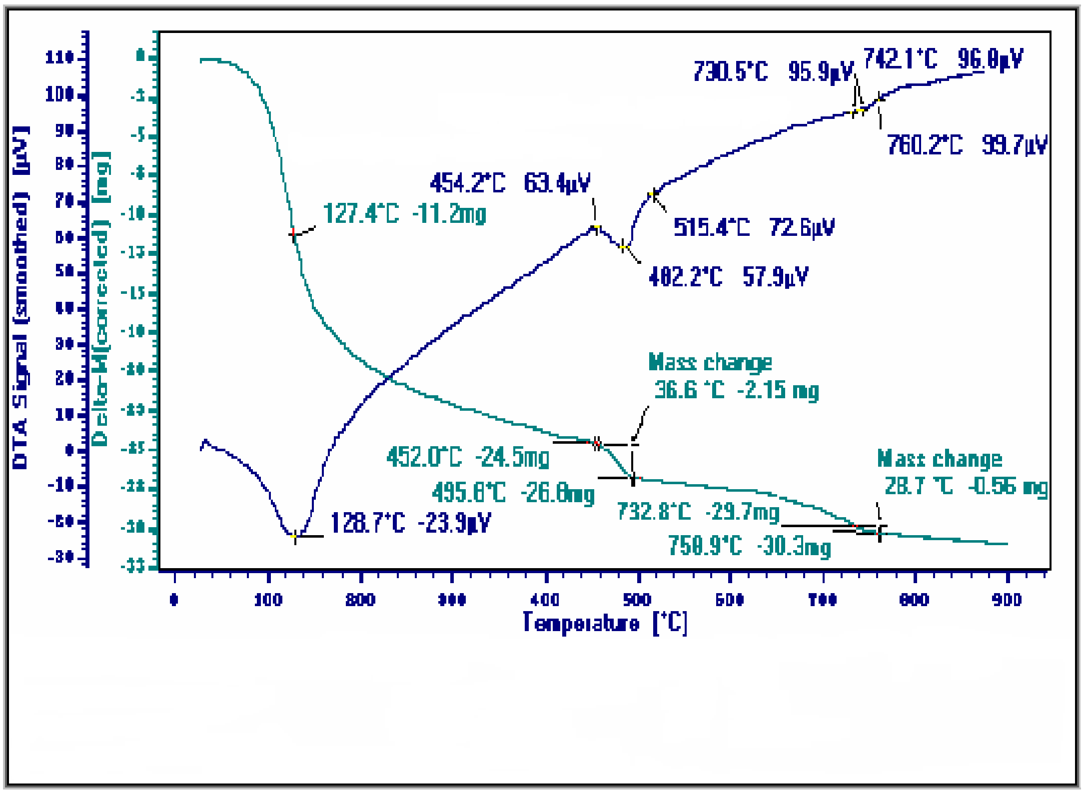

Figure 4. Thermogravimetric and differential thermal curves of RHA cement pastes

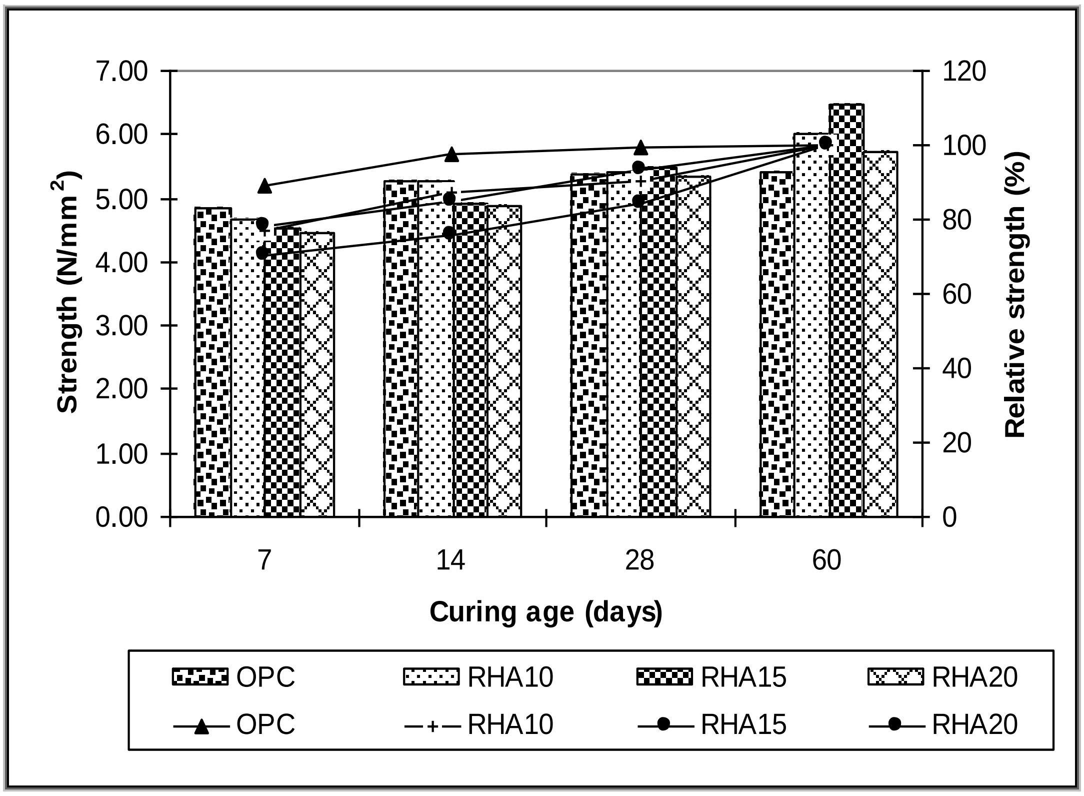

Figure 5. Relationship between strength and relative strength for different types of block
(1 N/mm^2 = 145 psi)