ARTIFICIAL LIGHTWEIGHT AGGREGATE MADE WITH NGHI SON FLY ASH

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Abstract: *The study focuses on the production of fly ash lightweight aggregate. The basic physical properties and mechanical characteristics of lightweight aggregate produced are analyzed systematically. Factors affecting the efficiency of pelletization process such as type of binder, moisture content, process duration and alkali content are evaluated. Further, characterization of aggregates was evaluated based on the specific gravity, gradation, density and aggregate crushing strength. It is observed from the test results that different aggregates were found to be maximum when the angle of pelletizer is set to* 36^0 *with a speed of 55 rpm.*

Keywords: *Geopolymer aggregate, fly ash, lightweight aggregate, Nghi Son fly ash.*

1. Introduction

Fly ash from thermal power plant is being beneficially utilized for various engineering purpose including the production of pozzoland cement, fly ash bricks, lightweight blocks as well as producing artificial lightweight aggregates [1]. The production of artificial fly ash lightweight aggregate is effectively carried out by two techniques namely granulation and compaction. The processing of agglomeration theory was developed in 1940's [2]; Granulation technique involves in the formation of solid pellets by addition of moisture and further with the application of rotating force. Whereas, the compaction techniques involve the formation of pellet and well compacted by using briquettes apparatus for hard pressing. Fly ash aggregates produced can be used either as such as produced in cold-bonding method or by further strengthening using sintering at high temperature beyond 900ºC. The sintering process envisages the particles to fuse together at higher temperature range of 900^0C to 1200ºC. Most disc or pan type pelletizer machines were easy to operate and produce different gradation of aggregates as compared to other type of pelletizer machines. The fabricated disc pelletizer machine adopted in different research studies showed that the angle can be adjusted between 36º to 45º, speed of 45 to 55 rpm, diameter of 0.5m and side depth of 0.25m. Cold-bonded, autoclaving and sintering process were the three different methods adopted for further hardening of a pellet. Normally class F fly ash is always preferred for sintering process and

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class-C fly ash for cold-bonding process [3]. Efficiency of pellet depended on the fineness value of fly ash [4]. Also, the previous study showed that the effects of binder material did not result in the change in chemical composition but enhanced the microstructure of the aggregate thereby improving the mechanical properties of aggregates. [5]. The cold-bonded fly ash aggregate was studied on the partial replacement of cement as fly ash and replacement of sand with fly ash to study the properties of concrete [6]. The water absorption of lightweight aggregate concrete reported to be substantial and thus affects the strength of concrete [7]. The increase in speed of pelletizer resulted in less water absorption of the artificial aggregate [8]. The reduction of porosity of lightweight aggregate was not fully followed by the crushing strength of aggregate and its additional influencing mineral changes and internal thermal stress [9]. The effects of curing in cold-bonded fly ash aggregate were examined in normal water and auto clave curing and showed a reasonable improvement in strength [10]. The crushing strength of hardened pellet was higher for smaller sized aggregates compared to larger size. Moisture content of fly ash aggregate varies from 15% to 35% (high); however, with increased moisture muddy balls are formed instead of smaller pellets. The porosity of fly ash lightweight aggregate was found to be reduced with curing and resulted in gradual reduction in the water absorption [11]. The strength of lightweight aggregate concrete depended on the strength of fly ash aggregate and improved bonding effect on aggregate/cement matrix in the transition zone [12]. The motivation of the present study is on the production of different type of geo-polymer based aggregate and to identify the factors influencing the efficiency of production such as duration, strength of NaOH added in fly ash and type of binder used. Also, the relative assessment of the fly ash aggregates was made from specific gravity, water absorption, bulk density, gradation and individual crushing strength properties.

2. Experimental procedure

2.1. Materials

Fly ash obtained from Nghi Son thermal power plant was used as raw material for aggregate production. The efficiency and strength properties of aggregate were evaluated with the addition of binders such as cement and metakaolin and alkali activator. The physical and chemical properties of various raw materials used in aggregate production are provided in Table 1.

Table1. *Physical and chemical properties of various binder materials used*

Observation	fly ash	Cement	Meta kaolin
Specific gravity	2.1	3.13	2.52
Blaine's fineness: m^2/kg	400	325	800
Chemical properties (%)			
SiO_2	46.64	18.5	41.4
Al_2O_3	26.13	5.24	30.5
Fe_2O_3	6.22	5.9	1.0

CaO	1.96	60.9	0.3
MgO	1.91	1.1	1.8
SO_3	1.01	1.5	0.9
Na_2O	0.13	-	0.9
K_2O	4.33	-	-
Loss on ignition	10.41	0.8	18.16

The water content for pelletization was optimized at 25% of total binder and alkali activator (sodium hydroxide) of molarity 8M, 10M and 12M was used. The mixed combination for various types of aggregates produced with different fly ash - binder proportions are given in Table 2.

Table 2. *Mix combination for various types of fly ash lightweight aggregate*

Mix type	Fly ash (%)	Cement (%)	Meta Kaolin (%)	Water content (%)	Molarity of NaOH	Note
F1	100	-	-	25	8M	Hot air oven at 100^0C
F2	100	-	-	25	10M	
F3	100	-	-	25	12M	
NC1	80	20	-	25	8M	
NC2	80	20	-	25	10M	
NC3	80	20	-	25	12M	
NK1	80	-	20	25	8M	
NK2	80	-	20	25	10M	
NK3	80	-	20	25	12M	
C1	80	10	-	25	-	Nomal water curing
C2	80	20	-	25	-	
C3	80	30	-	25	-	

2.2. Agglomeration process

The manufacturing of fly ash lightweight aggregate was carried out using Nghi Son fly ash with the addition of cement and metakaolin and alkali activator. A specially fabricated disc pelletizer as shown in Figure1 was used in this study which has a disc diameter of 500 mm and depth 250 mm. The angle of the disc can be adjusted between 35° to 50° and speed of 55 rpm.

Figure1. *Fabricated disc pelletizer machine*

2.3. Curing process

Alkali based fly ash aggregates show accelerated strength improvement at higher temperature due to effective polymerization. In the study, effective curing was also carried out in hot air oven at 100ºC for a period of 7 days as shown in Figure 2.

Figure 2. *Hot air oven machine*

2.4. Crushing strength test

The crushing strength of individual fly ash aggregate was determined by loading the aggregates in diametral direction using a CBR testing machine (shown in Figure 3). A total of 30 samples of the same aggregate size were tested for crushing strength in each type of aggregates. The size of the aggregate used for testing consists of 18 mm and 20 mm diameter. The crushing strength of the pellet was determined using the formula given below:

$$\sigma = \frac{2.8 * P}{\pi * X^2}$$

Where X is the distance between the two plates, P is the fracture load (N) and σ is the crushing strength (MPa) [13].

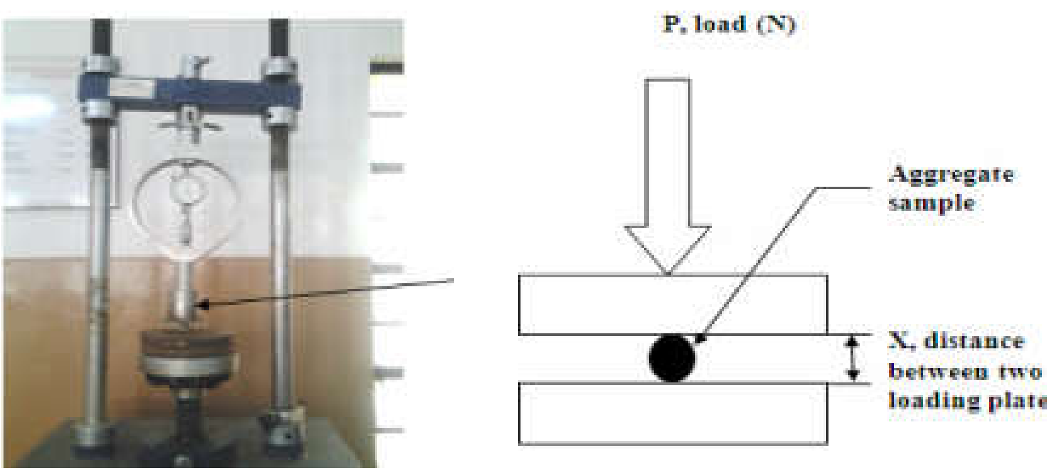

Figure 3. *Crushing test machine*

3. Result and discussions

3.1. Efficiency of pelletization

Efficiency of aggregate production depends on the amount of raw fly ash converted to fly ash balls during agglomeration of moist fly ash particles in a pelletization process.

The test results on the specific gravity, density and water absorption of different fly ash aggregates in the study are given in Table 3. It is noted that the specific gravity of NC3 was observed to be higher (2.10) than other types of aggregates. The lowest specific gravity (1.67) was observed for fly ash aggregates without binder (F1). Furthermore, the test results on the water absorption of fly ash aggregate without alkali (C3) showed the least value (14%) and were higher (38%) for fly ash aggregate with alkaki (F1).

Table 3. *Physical properties of various fly ash aggregates produced (ASTM C127-73)*

Aggregate mix	Specific gravity	Loose bulk density (Kg/m^3)	24h Water absorption (%)
F1	1.67	705.35	38
F2	1.85	821.84	31
F3	1.94	867.71	28
NC1	1.97	795.36	21
NC2	2.06	890.68	19
NC3	2.10	910.65	17
NK1	1.87	949.68	21
NK2	1.85	907.65	20
NK3	1.82	860.11	18
C1	1.75	730.35	36
C2	1.78	715.44	32
C3	1.82	832.75	14

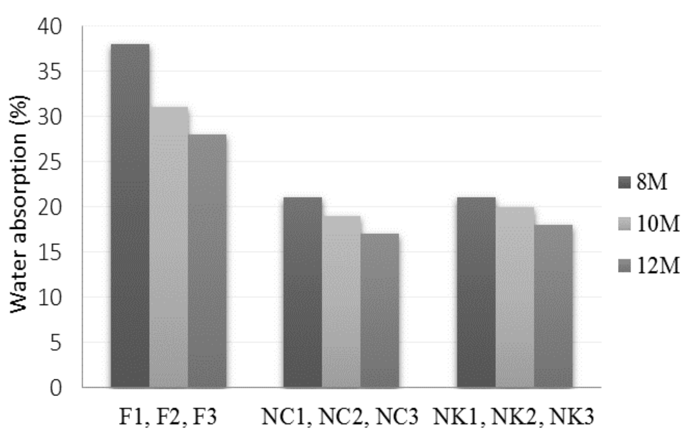

Figure 4. *Water absorption of various types of fly ash aggregate containing binder*

3.2. Strength properties of fly ash aggregate

The test results on the crushing strength of individual fly ash aggregate are given in Table 4. It was also observed from the results that the strength of fly ash aggregate increased with higher alkali concentration. The highest crushing strength of 13.42MPa was recorded for fly ash - Metakaolin (NK3) at 28 days curing (100^0C hot air oven curing) compared to other aggregate (Table 4).

Table 4. *Individual crushing strength of various types of fly ash aggregates at 7 days and 28 days curing*

Aggregate mix	Maximum crushing strength (MPa)	
	7 day	28 day
F1	2.31	2.44
F2	4.53	5.32
F3	6.57	7.76
NC1	4.47	5.23
NC2	6.10	6.25
NC3	8.50	12.56
NK1	4.32	7.85
NK2	6.15	11.56
NK3	7.81	13.42
C1	1.20	2.40
C2	1.37	2.87
C3	3.56	3.50

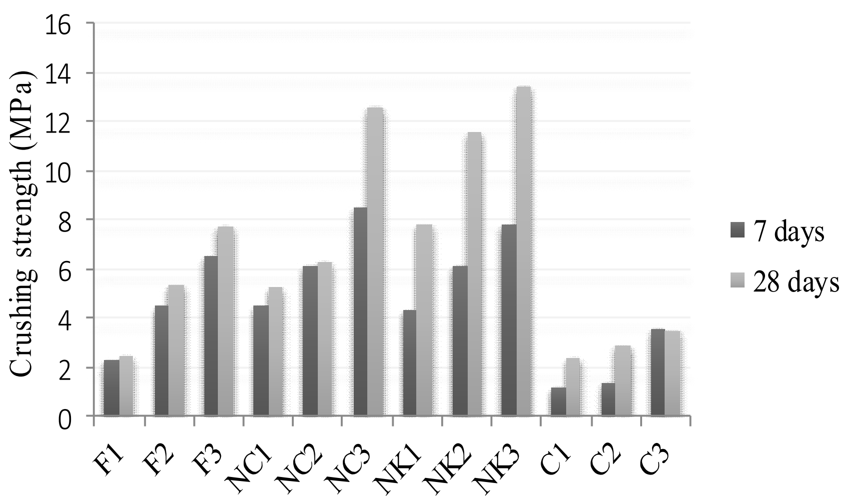

Figure 5. *Crushing strength of various types of fly ash aggregate containing binder*

4. Conclusions

The following conclusions are made from the experimental study on the different types of fly ash aggregate:

a) Compared to Nghi Son fly ash aggregates with cement binder, the ternary blends of fly ash - cement - Metakaolin exhibited higher production efficiency as well as higher strength.

b) The addition of NaOH in fly ash aggregates provided higher strength at shorter curing time with reduced water absorption.

c) The crushing strength of Nghi Son fly ash aggregates (NK3) at 12M of NaOH recorded a maximum strength of 13.42 MPa at 28 days oven curing with water absorption of 18%.

d) It can be concluded that for all fly ash aggregates with binder, the addition of NaOH at higher concentration (12M) exhibited higher strength gain due to geopolymerisation reaction and the rate of hardening was effective when the specimens were cured at higher temperature (hot air oven at 100^0C).

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