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The Effect of Aggregate Type on Strength Characteristics of Geopolymer Concrete

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ABSTRACT

Constructions of buildings and complex structures have increased in the world, with this course, cement usage have increased. Cement production is known to cause, carbon dioxide emission into the atmosphere in large scale, which forms about 65% of the greenhouse gases leading to adverse effects on the climate particularly global warming. To this effect research efforts are now being geared towards finding suitable alternatives to conventional Portland cement. In this investigation, geopolymer concrete in which alkali activated cement served as the binder was considered using locally available materials. Such concretes are considered greener than the conventional concrete. Specifically, the study looked at the effect of aggregate type on the strength characteristics of geopolymer concrete. The aggregates used were granite and limestone while the source materials used was Rice Husk Ash (RHA). Sodium Hydroxide and Sodium Silicate were used as the alkali activator. The results of the comprehensive strength tests conducted showed that strengths recorded were generally low, however, geopolymer concrete in which limestone were used as coarse aggregates performed better than those with granite. According to my result and findings in chapter four, the geopolymer concrete cannot be applicable to advance or complex structures. Although it can be considered for not too complex structures.

Keywords: Effect, Aggregates type, Strength Characteristics, Geopolymer Concrete

INTRODUCTION

Concrete is one of the most commonly use materials in constructions. Concrete is a composite materials for construction which generally composes of cement, coarse aggregates, fine aggregates and water. Ordinary Portland Cement (OPC) is widely used as a binder for concrete mixing. The emission of greenhouse gases such as carbon dioxide, CO_2 into atmosphere from the manufacturing of cement has contributed to the greenhouse effect issues. Therefore, an alternative binder is emerged in order to take care of the greenhouse gases emissions' issues. Research on geopolymer was initiated by Glukhovsky (Sarker et al., 2014). The development of a new binder material using inorganic materials was introduced by Joseph Davidovits in 1972 (Davidovits, 1979). There are several types of inorganic materials that can be used, for instance fly ash and steel fiber. Although geopolymer concrete can be propduced from a wide variety of inorganic waste materials, Rice Husk Ash is being considered in this study as the source material while the aggregate types being considered are limestone and granite. The reason why Rice Husk Ash is being considered is because disposing such is often a problem. Rice Husk Ash is used as a substitute source material to make the binder needed for geopolymer concrete manufacture.

AIM AND OBJECTIVES

The main objective of this research is to determine the effect of aggregate type on the strength characteristics of Rice Husk Ash based geopolymer concrete. This research is conducted along with the following sub-objectives:

1. Chemical analysis of the RHA obtained at Landmark University.

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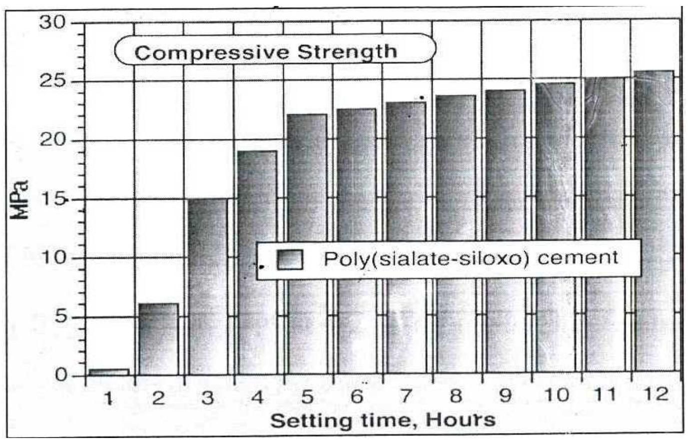
2. Preparing Rice Husk Ash based geopolymer concrete containing coarse aggregate from crushed granite stones and limestone using a suitable particle size distribution.
3. Investigating compressive strength, strength development of geopolymer concrete produced under accelerated oven curing conditions mimicing 7 days, 14 days and 28 days.

LITERATURE REVIEW

Davidovits was the first to introduce the term 'geopolymer' in 1970s (Davidovits, 1979) but the technology of alkali activation was credited ti Kuhl way back in 1908 (Kuehi, 1908). A major research was subsequently led by Glukovsky in 1950s (Glukovsky, 1959), whereby he ventures into the commercial-scale production of geopolymer. From there onwards, geopolymer has gathered many interests from the academics world to conduct studies and research on the feasibility of producing a synthetic alkali aluminousilicate material for various types of application. The potential of municipal solid waste Rice Husk Ash (IBA) as the sole precursor to synthesize geopolymer was investigated. Ground IBA power was mixed with water glass and sodium hydroxide solution. After curing, the hardened samples were characterized by FTIR and NMR together with Salicylic acid/methanol extraction (SAM) to identify chemical composition of hardened binder. It was found that the IBA binder consists of one third of alkalis-modified C-S-(A)-H and some geopolymer gel with zeolite-like Nano-structures. The IBA was first oven-dried at 105 °C for 3 days and ground into fine particles with a rotating ball mill for 30 mins. Ground IBA was sieved and particles larger than 150μm were rejected. The chemical composition of the aforementioned IBA powder was determined by X-ray fluorescence (XRF), as summarized in Table 1. Similar to meth-kaolin, IBA contains high percentage of silicon and some aluminium, but is also high calcium content, which may influence the reaction route of geopolymer as stated in Provis (2014).

In early 1983, Chairman, Mr. James Stewart, and Mr. W. Kirkpatrick, of Lone Star Industries Inc. (then America's leading cement manufacture), were traveling in Europe and learned about my new geopolymer binders. Lone Star Industries and Shell Oil Company had just announced the formation of the QUAZITE Corporation to develop, produce, and market a new class of materials that were expected to have a wide-ranging impact on construction, architectural, and engineering application. QUAZITE materials were made from mineral aggregates combined with polymers and monomers. In others word, QUAZITE was an organic polymer concrete. Shell Oil supplied the chemical expertise in organic polymers for QUAZITE, while Lone Star supplied the mineral aggregates. By enlisting my new inorganic geopolymer, Lone Star took the opportunity to challenge Shell Oil's chemical expertise. In August 1983, with James Sawyers as Head of Lone Star's research laboratory in Houston, Texas, we started to develop early high strength geopolymer binders and cements based on both geopolymer and hydraulic cement chemistries. Within one month, Lone Star Industries Inc. formed the development company PYRAMENT, which was exclusively dedicated to the implementation of this new class of cement. Few months later, Lone Star separated from the Shell Oil deal.

It was discovered that the addition of ground blast furnace slag, which is a latent hydraulic cementitious product, to the poly (isolate) type of geopolymer, accelerates the setting time and significantly improves compressive and flexural strength. The first Davidovits/Sawyer patent was filed in Feb. 22, 1984, and title <<Early High-Strength Mineral Polymer>> (US Patent). The corresponding European Patent, filed in 1985, is titled << Early High-Strength Concrete Composition>> and these patents disclose our preliminary finding from the research carried out in August – September of 1983. Geopolymer cements are acid-resistant cementitious materials with zeolite properties, developed for the longoterm containment of hazardous and toxic wastes (US Patents 4,859,367; 5,349,118). Geopolymerization involves the chemical reaction of aluminousilicate oxides (A13+ in IV-V fold coordination), with alkali and calcium polysilicates, yielding polymeric Si-O-Al bonds, for instances:



High – early strength of (K, Ca) - Poly (sialate-siloxo) cement

Chemical Composition of IBA

formular	SiO_2	Al_2O_3	Na_2O	K_2O	TiO_2	Fe_2O_3	CaO	MgO	P_2O_5	SO_3	LOI
IBA (%)	32.75	8.57	2.87	1.24	1.57	10.02	29.06	1.75	4.77	3.01	-

Sodium Silicate solution (water glass) was supplied by International Scientific Pte Ltd with chemical composition: Na_2O 9.65%, SIO_2 29.16. Sodium hydroxide (NaOH) pellets were provided by Schedolco Pte Ltd and a purity of 99+&.

MATERIALS AND METHODS

Materials

The materials used in this project work are Rice husk Ash, geopolymer, sodium silicate, sodium hydroxide, demineralized water, limestone, fine aggregate, cement, granite.

Rice Husk Ash

Rice husk ash (IBA) accounts for 80% to 90% by weight of the total incinerator ash and is much less toxic. Typical composition of IBA are Silica, Calcium, Ferrous Metal, Iron Oxide and Aluminum oxide (Environmental Protection Agency, 2014).

Geopolymer

Geopolymer is a synthesis alkalis-aluminousilicate binder former through the reaction of solid aluminousilicate in highly concentrated aqueous alkaline solution (P. Dixson, 2007). It comprises of tetrahedral silicate and aluminate units linked in three dimensional structure by covalent bonds, with negatives charges associated with tetrahedral Al (III) charge-balanced by alkali cations. Starting materials essentials for the formation of geopolymer consists of two main parts, the reactivesolid aluminousilicate, and the alkali activator solution. Reactive solid aluminousilicate is typically derived from industrials by-product such as fly ash abd alkali activator solution is commonly alkali metal hydroxide or silicate solution (Proves. 2014)

Silicate

This combines together with Sodium Hydroxide, and acts as an activator.

Sodium Hydroxide

Demineralized Water

The ions and minerals present in the water were removed before used.

Limestone

Limestone is used as coarse aggregate in the mixing of the geopolymers concrete.

Fine Aggregate

The sand used was collected from a leftover materials used in a previous research work.

Cement

The cement used in this project is the ordinary Portland cement.

Granite

The granite (coarse aggregate) used was collected from suppliers.

AREA OF THE STUDY

This work will be carried out in the Geotechnical and Concrete Laboratories respectively.

INSTRUMENTS FOR DATA COLLECTION AND PRIMARY DATA

The ash from rice husk that is grounded is obtained and used as cement replacement. This is a data that will be used.

Concrete Moulding

1. Slump Test

Fresh concrete was casted in slump cones in minute numbers, and compacted by batch. This is done to determine the workability before being cast into concrete cub moulds. Air voids is reduced by compacting the cubes in the mix. The cubes were positioned due to type. There were cement + Limestone and Rice Husk Ash + Limestone.

2. Curing

The concrete cubes were weighed using beam balance, also the cubes were tested using Pro-Ikon cube concrete load testing machine.

Compressive strength was calculated using the following equation

$\infty C = F/A$

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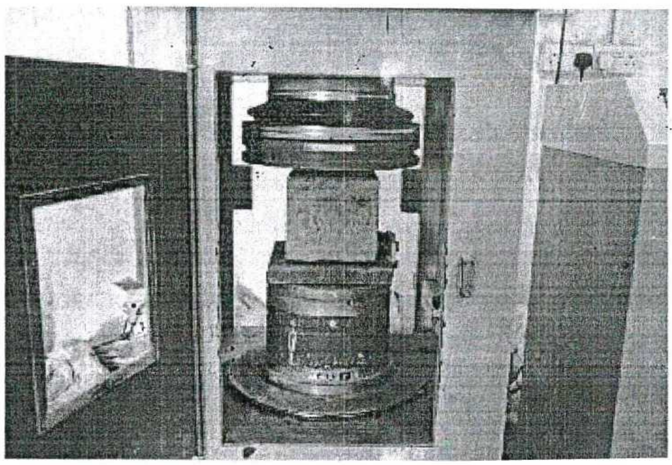
Where;
∞C = Compressive Strength (N/mm²)
F= Failure Load (N)
A= Area of bed-face (mm²)

RESULTS AND DISCUSSION

Cube Crushing Test

This is a destructive testing method of concrete. This test is conducted to determine the strength of concrete. The volume size of cube used is 100mm³



Placing of cube in between the compression testing machine

Cement with limestone type aggregate cube table result

Durability testing days	7			Average (KN)	Fcu (N/mm²)	14			Average (KN)	Fcu (N/mm2)	28			Average (KN)	Fcu (N/mm2)
LS	94	98	96	96	9.60	136	144	148	143	14.27	211	216	226	218	21.77

Where LS= Limestone

After the crushing test of three different cement with limestone type aggregate cones due to 7, 14, 28 curing hours respectively, there is increase in strength respectively also.

1. The average strength for 7 hours' type is 9.6N/mm²
2. The average strength for 14 hours' type is 14.27N/mm²
3. The average strength for 28 hours' type is 21.77N/mm²

Cement with granite type aggregate cube table result

Durability testing days	7			Average (KN)	Fcu (N/mm²)	14			Average (KN)	Fcu (N/mm2)	28			Average (KN)	Fcu (N/mm2)
Gravel	101	105	105	104	10.37	135	138	144	139	13.90	196	208	214	206	20.60

After the crushing test of three different cement with granite type aggregate cones due to 7, 14, 28 curing hours respectively, there is increase in strength respectively also.

1. The average strength for 7 hours' type is 10.3N/mm²

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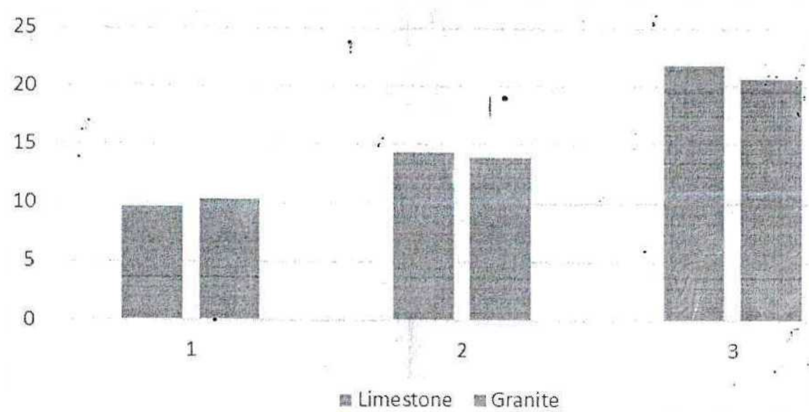
2. The average strength for 14 hours' type is 13.9N/mm^2
3. The average strength for 28 hours' type is 20.6N/mm^2



Average Strength (KN) for 7, 14, 28 hours with Cement respectively

RHA with Sodium Silicate with Sodium Hydroxide (NaSO$_3$ + NaOH = Alkaline Activator) with Limestone

Durability testing days	7			Average (KN)	Fcu (N/mm^2)	14			Average (KN)	Fcu (N/mm2)	28			Average (KN)	Fcu (N/mm2)
LS	87	84	90	87	8.70	109	114	104	109	10.90	138	148	143	143	14.30

Where LS = Limestone, RHA = Rice Husk Ash

Just like mixture of cement with limestone, mixture of rice husk ash with alkaline activators (sodium silicate with sodium hydroxide) and limestone increases in strength as the curing time increase.

1. The average strength for 7 hours' type is 8.7N/mm^2
2. The average strength for 14 hours' type is 10.9N/mm^2
3. The average strength for 28 hours' type is 14.3N/mm^2

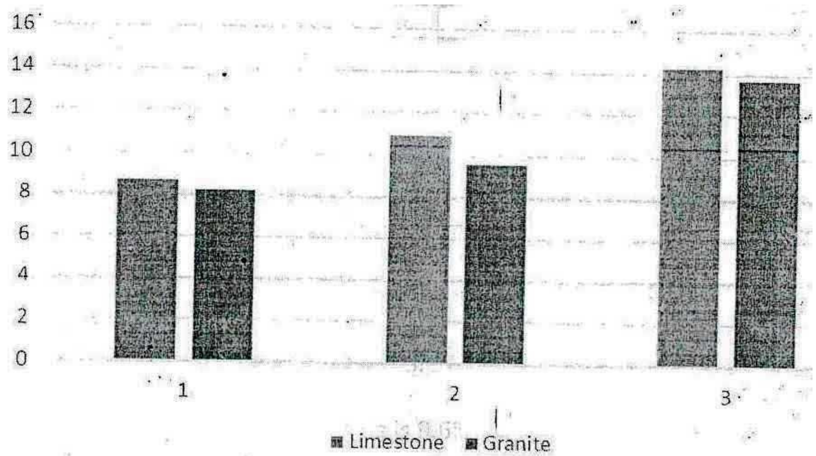
Table 4.4: RHA with Sodium Silicate with Sodium Hydroxide (NaSO$_3$ + NaOH = Alkaline Activator) with Aggregates

Durability testing days	7			Average (KN)	Fcu (N/mm^2)	14			Average (KN)	Fcu (N/mm2)	28			Average (KN)	Fcu (N/mm2)
Gavel	79	80	78	82	8.20	93	98	96	96	9.57	133	135	133	134	13.34

Where LS = Limestone, RHA = Rice Husk Ash

Also, after the crushing test of three different cement with granite type aggregate cones due to 7, 14, 28 curing hours respectively, there is increase in strength respectively too.

1. The average strength for 7 hours' type is 8.2N/mm^2
2. The average strength for 14 hours' type is 9.6N/mm^2
3. The average strength for 28 hours' type is 13.37N/mm^2



Average Strength (KN) for 7, 14, 28 hours with RHA respectively

CONCLUSION

The following are the concluded points based on the result this project research generated.

1. The strength of the two types of geopolymer concrete i.e. geopolymer concrete prepared with limestone as coarse aggregate and those prepared with limestone, increase with curing time.
2. Generally, the geopolymer concrete prepared with limestone as coarse aggregate performed better than the geopolymer concrete prepared with granite, however, compressive strengths recorded were generally low in both cases.

RECOMMENDATION

1. Future investigations should consider increase in curing days, as this could improve the compressive strength of the geopolymer concrete.
2. The influence of molar ratio and specific gravity of the alkali activator should be studied in future research works.

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ACT A214R-02 Standard evaluation of Strnght Test Results of Concrete, American concrete institute.

ASTM C33 Standard Specification for concrete Aggregates, American Society for Testing and Materials.

ASTM C39 Standard test method compressive strength of cylindrical concrete specimens, American Society for Testing and materials.

ASTM C143 Standard Test Method foer SIlump of Hydraulic –Cement Concrete, American Society for Testing and Materials.

ASTM C618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use in Concrete, American Society for Testing and Materials.

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