ISSN:2348-2079

Volume-6 Issue-2

International Journal of Intellectual Advancements and Research in Engineering Computations

A study on abrasion resistance in geopolymer concrete pavement

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Abstract: **Cement is the world's most reliable construction material. The rate of consumption and production of Ordinary Portland Cement (OPC) increases, which leads to environmental pollution by the emission of carbon dioxide (CO_2).In this study cement is replaced by class F fly ash in concrete which will be activated by sodium hydroxide and sodium silicate solution, act as a binding material. This study is focus on abrasion resistant of geopolymer concrete in pavement application. On the other hand the comparison is made between the conventional concrete pavement and geopolymer concrete pavement.**

Keyword: Geopolymer, Fly ash, sodium hydroxide, sodium silicate, Abrasion resistance.

I. INTRODUCTION

Concrete is one of the most widely used construction material, it is usually associated with Portland cement as the main component for making concrete. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for Ordinary Portland cement to manufacture concrete.

When used as a partial replacement of Ordinary Portland cement, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of Ordinary Portland cement to form the calcium silicate hydrate (C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of Ordinary Portland cement up to 60% by mass, is a significant development.

In this respect, the geopolymer technology proposed by Davidovits shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of reducing the global warming, the geopolymer technology could reduce the carbon-di-oxide emission to the atmosphere caused by cement and aggregates industries by about 80%.

II. PROPERTIES OF GEOPOLYMER CONCRETE

Non- toxic and bleed free

Higher resistance to heat and resist to all inorganic solvents

Higher compressive strength

III FLY ASH-BASED GEOPOLYMER CONCRETE

Geopolymer concrete is manufactured using source materials that are rich in silica and alumina. While the cement-based concrete utilizes the formation of calcium-silica hydrates (CSHs) for matrix formation and strength, geopolymers involve the chemical reaction of alumino-silicate oxides with alkali polysilicates yielding polymeric Si–O–Al bonds.In this experimental work, fly ash is used as the source material to make geopolymer paste as the binder, to produce concrete.

The manufacture of geopolymer concrete is carried out using the usual concrete technology methods. As in the Portland cement concrete, in fly ash-based geopolymer concrete, the aggregates occupy the largest volume, i.e. about 75-80% by mass. Sodium-based activators were chosen because they were cheaper than Potassium-based activators. The sodium hydroxide was used, in flake or pellet form. It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use.

The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. The concentration of sodium hydroxide solution can vary in the range between 8 Molar and 16 Molar. The mass of water is the major component in both the alkaline solutions. In order to improve the workability, a melamine based super plasticizer has been added to the mixture.

IV. MATERIALS

The materials used for making fly ash-based geopolymer concrete specimens are high-calcium dry fly ash as the source material, aggregates, alkaline liquids, water, and super plasticizer.

Fly Ash

Fly ash is the residue from the combustion of sub-bituminous coal collected by mechanical or electrostatic separators from the flue gases of lignite power plants.There are about 75 thermal power plants in India and the total production of fly ash is nearly as much as that of cement (75 tons). But our utilization of fly ash is only about 5% of the production.

Most of the fly ash available globally is high-calcium fly ash formed as a by-product of burning anthracite or bituminous coal. Although coal burning power plants are not considered to be eco-friendly, the extent of power generated by these plants is on the increase due to the huge reserves of good quality coal available worldwide and the low cost of power produced from these sources. Therefore, huge quantities of fly ash will be available for many years in the future.

Since fly ash is produced by rapid cooling and solidification of molten ash, a large portion of components comprising fly ash particles are in amorphous state. The amorphous characteristic greatly contributes to the pozzolanic reaction between cement and fly ash. One of the important characteristics of fly ash is the spherical form of the particles. This shape of particle improves the flow ability and reduces the water demand.

ASTM broadly classifies fly ash into two classes.

Class F: Fly ash normally produced by burning anthracite of bituminous coal, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only.

Class C: Fly ash is normally produced by burning lignite or sub-bituminous coal. Some Class C fly ash may have Calcium oxide content in excess 10%. In addition to pozzolanic properties Class C fly ash also possesses cementitious properties.

Cement

Cement is the important binding material in concrete. Portland cement is the common form of cement. It is the basic ingredient of concrete, mortal, and plaster.

Coarse Aggregate

A maximum size of 20mm is usually selected as coarse aggregates up to 20mm may be used in concrete.

Aggregates

Local aggregates, comprising 20 mm, and less than 20 mm coarse aggregates and fine aggregates, in saturated surface dry condition, were used. The coarse aggregates were crushed granite-type aggregates and the fine aggregate was fine sand. Coarse aggregates were obtained in crushed form majority of the particles were of granite type.

The quality is tested using the crushing and impact test. The fine aggregate was obtained from the sand dunes in uncrushed form. These are purchased from local suppliers.

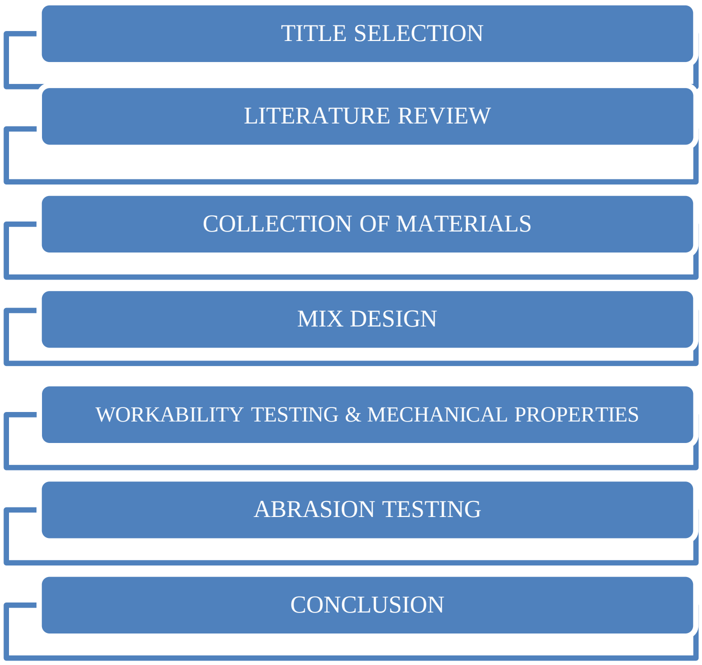
Alkaline Liquid

A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. Sodium- based solutions were chosen because they were cheaper than Potassium-based solutions.

The sodium hydroxide solids were of a laboratory grade in pellets form with 99% purity, obtained from local suppliers. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets in water. The mass of sodium hydroxide solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, sodium hydroxide solution with a concentration of 8M consisted of 8x40 = 320 grams of sodium hydroxide solids (in pellet form) per litre of the solution, where 40 is the molecular weight of sodium hydroxide. Note that the mass of sodium hydroxide solids was only a fraction of the mass of the sodium hydroxide solution, and water is the major component.

Sodium silicate solution (water glass) obtained from local suppliers was used. The chemical composition of the sodium silicate solution was Na_2O=8%, SiO_2=28%, and water 64% by mass. The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid.

V. METHODOLOGY



Chemical composition of fly ash

Oxides	Percentage
SiO_2	60.54
$Al_2 0_3$	26.20
Fe_2O_3	5.87
CaO	1.91
MgO	0.38
K_2O+Na_2O	1.02
SO_3	0.23
Loss on ignition	2.0

Properties Of Aggregates

Propert y	Coarse Aggregate	Fine Aggregate
Specific gravity	2.78	2.63
Water absorption	0.50	1%
Fineness modulus	7.21	2.40
Bulk density	1675	1570
source	Crushed stone	River sand

VI. MANUFACTURE OF TEST SPECIMENS

MIX DESIGN

The mix design for M40 grade concrete is designed
Volume of 3 cube= $(3\times15^3) / 100^3 = 0.0101\ m^3$
Wt of the batch (3 cubes)= 0.0101 × 2400=24.24 kg
Total weight of the batch = 24.24 + 2.424 kg (10% excess)
= 26.664 kg

Combined aggregate = 75% – 80%
We take it as 77%.
Weight of combined aggregate= 26.664 × 77/100
= 20.53 kg We take fine aggregate as 6.84 kg and
Weight of alkaline and fly ash = 26.664 – 20.53
= 6.134 kg
= 6.134 kg

Alkaline solution /Fly ash = 0.30 – 0.45

We take it as 0.35
Weight of fly ash = 6.134 / (1+0.35)= 4.544 kg
Weight of alkaline solution = 6.134 – 4.544 =1.59 kg

Sodium silicate / Sodium hydroxide = 2.5

Weight of sodium hydroxide solution = 1.59/ (1+2.5)
= 0.454kg
Weight of sodium silicate solution = 1.59 – 0.454= 1.136 kg

Properties of Sodium silicate solution

Specific gravity	1.56-1.66
Na_2O	**15.5-16.5**
SiO_2	31-33
Weight ratio	2
Molar ratio	2

Properties of Sodium hydroxide (NaOH)

Molar mass	40 g/mol
Appearance	White solid
Density	2.1gr/cc
Melting point	318^0C
Boiling point	1390^0C
Amount of heat liberated	266 cal/gr
Storage	Air tight container

VII CONCLUSION

Based on the experimental work, the following conclusions are drawn:

1. The slump value of the fresh fly-ash based geo-polymer concrete increases with the increase of water added beyond 0.35.
2. The slump of the normal concrete is 30 mm is relatively less than fly ash class C based geo-polymer concrete with the concentration of NaOH in 8 M is 28 mm.
3. The fresh fly ash-based geopolymer concrete is easily handled up to 120 minutes without any sign of setting.
4. Longer curing time produces higher compressive strength of fly ash-based geopolymer concrete.
5. However, the increase in strength beyond 24 hours is notmuch significant.
6. The compressive strength of the fly ash based geopolymer concrete decreases with the increase in water content.
7.The compressive strength of fly ash class C based geo-polymer concrete with the concentration of NaOH in 8M is 33 N/mm^2 at 28 days strength is less than the compressive strength of normal concrete is 42 N/mm^2 at 28 days strength.

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