Development of Pervious Concrete Using Geopolymer

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Abstract— Pervious concrete is one of the most extensively used materials in the concrete industry for stormwater management, pollution control, noise reduction, and sustainable design. From an aesthetic sense, pervious concrete pavement does not look good or function like typical concrete pavement. This study discusses the pervious concrete, its applications, related to geopolymer, motivation for the research work, and defines the objectives based on the literature studies. The rectangular and circular cubes are prepared for testing compressive strength of concrete. The aim of study to find out performance of mix design of pervious concrete using geopolymer.

Keywords- pervious concrete, geopolymer, concrete pavement, compression test, GGBS.

I. INTRODUCTION

PERVIOUS CONCRETE

Pervious concrete comprises cement, coarse aggregate, and water. As there is no fine aggregate, it can also be referred to as "no-fines" concrete. In other words, it can be called "gap-graded concrete," "porous concrete," or "permeable concrete." The pervious concrete consists of interconnected pores of varying sizes, ranging from 2 mm to 8 mm, with the void content varying from 15% to 25%. This type of concrete has a revolutionary approach to controlling, managing, and treating stormwater runoff. When used on pavements, it is the best system to catch stormwater runoff because it reduces pollutants. Therefore, the stormwater percolates into the ground and recharges groundwater tables. Pervious concrete is made using large aggregate with little fine aggregates. The concrete paste then coats the aggregate and allow water to pass through the concrete slab. Pervious concrete is traditionally used in parking areas, areas with light traffic, residential streets, pedestrian walkways, and greenhouse. It is an important application for sustainable construction and is one of many low impact development techniques used by builders to protect water quality. Cement, coarse aggregate, admixture, and water were used to make pervious concrete.

II. APPLICATIONS

Pervious concrete is often appropriate for usage in pathways, driveways, parking lots, sidewalks, tennis courts, decks in swimming pools, greenhouse floors, shoulders, drains, noise barriers, and rain gardens, which are the general applications of pervious concrete. Pervious concrete has also been used as a surface course, a drainable base course, and a drainable shoulder in addition to these applications. In recent years, its use as a surface course for stormwater management has become increasingly popular.

III. GEOPOLYMER

Following water, concrete is the world's second most widely utilized substance. The demand for Portland cement is increasing as the demand for concrete as a building material develops. In the medium term, India's cement demand is expected to grow at a rate of 10% per year due to housing and infrastructure developments. Furthermore, according to recent statistics, the cement industry accounts for 7% of total CO2 emissions. Davidovits coined the term "geopolymer" in 1978 to describe a class of mineral binders with an amorphous microstructure and a chemical composition. It achieved structural strength by polycondensing silica and alumina precursors, but it did not form Calcium-Silicate-Hydrates (C-S-H) for matrix formation and strength-like ordinary Portland/pozzolanic types of cement. In recent history, geopolymer binders have been the best alternative to cement binders. Its performance in a hostile environment is promising, and it could be helpful in situations where cement concrete is vulnerable. Geopolymers are made up of two primary components: source materials and alkaline liquids. Fly ash, silica fume, slag, rice-husk ash, red mud, and other by-product materials based on alumino- silicate, rich in silicon (Si) and aluminum (Al) are the source materials. To initiate geopolymerisation, soluble alkali metals, usually sodium or potassium are used to form alkaline liquids. A mixture of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) is used to make sodium-based alkaline liquids. A solution of potassium hydroxide (KOH) and potassium silicate (K2SiO3) is utilized to make potassium-based alkaline liquids. Geopolymers are used in various applications, such as fire-resistant materials, coatings, adhesives, and the containment of toxic wastes. However, the construction industry has been the most promising application for geopolymers as environmentally friendly concrete.

IV. MATERIALS AND METHODS

The mix design proportions were taken as per IS 10262:2009 and quantities were determined in accordance with Indian standard method. Analytical grade sodium hydroxide (NaOH with 98% purity) and sodium silicate solutions (Na2O=14.7%, SiO2=29.4% and water=55.9% by mass) were used as the alkaline activators. In order to avoid the effect of unknown contaminants in the mixing water, the sodium hydroxide lakes were dissolved in distilled water. The activator solution was prepared at least one day prior to its use. To improve the workability of fresh concrete, a commercially available polyoxylene based super plasticizer was used. A combination of locally available aggregates, i.e., granite type coarse aggregate and fine sand, in saturated surface dry condition, were mixed together. The grading of this combined aggregate had a fineness modulus of 4.5. The aggregates and the fly ash were mixed dry in a pan mixer for 3 minutes. The alkaline solutions and the super plasticizer were mixed together, then added to the solid particles and mixed for another 3 to 5 minutes. The fresh concrete had a stiff consistency and was glossy in appearance. The fresh concrete mixture was then cast in 100x200 mm cylinder steel mold in three layers. Each layer received 60 manual strokes and vibrated for 10 seconds on a vibrating table. Immediately after casting, the samples were covered by a film to avoid the loss of water due to evaporation during curing at an elevated temperature. The specimens were cured in an oven or steamed chamber at a specified temperature for a period of time in accordance with the test variables selected.

Fly ash to coarse aggregate ratio =1:6

1.Aggregates

(Sample 1) – 10 mm – 12 kg

(Passing through 12.5 mm and retained on 10 mm)

(Sample 2) – 20 mm – 12 kg (Retained on 20 mm)

(Sample 3) – 10 & 20 mm – 12 kg

(Retained on 20 and 10 mm)

1. Aggregates

Coarse aggregates are generally obtained by blasting in stone quarries or by breaking them by hand or by crushers. Machine - crushed stones consist of stones of various sizes whereas Hand - broken aggregates consist of only single size stones. 10mm and 20mm size aggregate is used.

2. Cement

A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together.

3. Water

Water is required to wet the surface of aggregates to develop adhesive quality as the cement paste binds quickly and satisfactorily to the wet surface of the aggregates than to a dry surface. Also, water is needed to make plastic mixture of the various ingredients so as to impart workability to concrete to facilitate placing it in the desired position. Ultimately, by chemically reacting with cement, water helps to produce the desired properties of the concrete.

4. Admixture

The addition of mineral admixtures reduces the permeability and improves the durability of concrete structures.

Fig. Polypropylene

5. Chemicals used

- Sodium hydroxide (NaOH)
- Sodium Silicate Solution (SiO2)
- Potassium hydroxide (KOH)
- Potassium silicate (K2SiO3)

6. Fly Ash

Fly was collected from chemical industry. Pervious concrete is designed to have voids or gaps within the mixture, allowing water to pass through it easily. Fly ash, which is a by-product of coal combustion, is often used as a partial replacement for Portland cement in pervious concrete mixtures. The incorporation of fly ash helps to improve the workability, durability, and environmental sustainability of the concrete. Quantity of fly ash used for preparing concrete mix is as follows:

(Sample 1) – For 10 mm aggregates – 2 kg fly ash is used

(Sample 2) – For 20 mm aggregates – 2 kg fly ash is used

(Sample 3) – For 10 mm & 20 mm aggregates – 2 kg fly ash is used

Fig. Casting of geopolymer pervious concrete

Fig. Prepared cube

VII. RESULTS

POROSITY TEST:

Pervious concrete is prepared with 0% fine aggregates, that is no fine aggregates are used to prepare pervious concrete. Due to absence of fine aggregates, the void ratio of pervious concrete is comparatively higher than any other type of concrete. This interconnected void space allows water from the surface to percolate and prevent storm water runoff along with recharging the ground water table. The permeability of concrete shows its ability to allow water to percolate. Following are the test results of pervious concrete.

Porosity (%) = (Volume of Voids / Total Volume) x 100.

Aggregate size	Sample no.	Porosity (%)
10mm	1-1	15.54
	1-2	20.28
	1-3	17.28
20mm	2-1	20.33
	2-2	24.27
	2-3	28.60
10&20mm	3-1	25.08
	3-2	27.92
	3-3	29.80

Table. Result of Porosity test

COMPRESSION TEST:

Pervious concrete is designed to have a relatively low compressive strength compared to traditional dense concrete. This is because pervious concrete contains a significant number of voids, which are necessary to allow water to pass through the material. The voids in pervious concrete reduce its overall strength but enhance its permeability. The compressive strength should be measured at 28 days using cylindrical specimens with a diameter of 4 inches and a height of 8 inches. The test should be performed using a compression testing machine. The compressive strength of pervious concrete can vary depending on several factors, including the specific mixture proportions, curing conditions, aggregate properties, and testing procedures. On average, the compressive strength of pervious concrete typically ranges from 2 to 10 Mpa (megapascals) or 100-400 psi (pounds per square inch).

F = P/A

F=The compressive strength

P= Maximum Load

A= Cross- Sectional Area.

VI. CONCLUSION

1. The 30 % addition of fly ash in pervious concrete mixture is best to achieve good compressive strength. If the percentage of fly ash is increasing than the compressive strength of cube is decreasing.
2. Reduction in aggregate size decreased the porosity and water permeability of pervious concrete and thus strength of pervious concrete increased.
3. Porosity of concrete is reasonable for compressive strength and permeability of water. The use binder material also affects the strength of geopolymer pervious concrete.
4. Geopolymer pervious concrete has lesser CO2 emission than OPC cement up to 90%.
5. Geopolymer previous concrete has better thermal insulation properties.
6. It providing a viable use for 'waste' materials which are often disposed in landfill.

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