**Comparative study and evaluation of the compressive strength and mechanical wear resistance of colored geopolymer concrete based on fly ash as a binder**

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Abstract— The purpose of this study is to conduct a comparative evaluation of the compressive strength and mechanical abrasion resistance of colored geopolymer concrete based on fly ash as a base material. Three percentages of 1%, 2% and 3% of three colored oxides were considered, which are red iron oxide, green chromium oxide and yellow iron hydroxide from fly ash. High plasticizer of the mixture to obtain workability in addition to a small amount of water. The results of the study showed that the compressive strength and abrasion resistance had the best performance when the percentage of addition was 1% for the red and yellow colors and 2% for the green colour, which achieved the highest results and the best mechanical wear resistance aluminum oxide.

*Keywords— Geopolymer concrete, fly ash, pigments, mechanical properties and wear resistance.*

# Introduction

Davidovits used the term "geopolymer" in 1978 to designate a broad category of materials characterized by inorganic molecular networks [1]. Thermally active natural sources, such metakaolin, or industrial byproducts, like fly ash or slag, are the mineral sources of silicon (Si) and aluminium (Al) in geopolymer concrete. These two waste products can be dissolved in alkaline activating solutions, thereafter they are polymerized into molecular chains and transformed into a binder. According to Rangan, "the polymerization process involves a very quick chemical reaction of silicon and aluminium metals under alkaline circumstances, producing a three-dimensional polymeric chain and ring structure". Due to the outstanding properties of geopolymer concrete, such as its cohesiveness at room temperature, non-toxicity, impermeability, improved heat resistance, and resistance to all inorganic solvents, researchers have begun to examine employing it in structural components [2]. Fly ash was employed in place of Portland cement when Luhar and Khandelwal researched the behaviour of geopolymer concrete, the concrete was cured at 75°C for 24 hours, and the researchers discovered that the compressive strength could be increased while also reducing harmful emissions [3].

# It was possible to create a variety of colored concrete by adding this colored powder to grey concrete in Southern California, according to a proposal made by F.D. Contractors, a Davis Group company, to manufacture colored concrete for the first time. Industrial iron oxide was derived from chemical processing residues. In 2004, coatings made of synthetic Fe2O3 weighed 200 million pounds [4]. Colored geopolymer concrete may be extensively used in some construction applications, such as interlocking pavement bricks, curbstone and concrete paving blocks. Other researchers who have studied colored concrete, such as Awadly et al.[5], have discussed the impact of adding colored pigments on the various properties of concrete. Numerous researchers have investigated the use of fly ash as a cement substitute [6]. Our work has investigated the compatibility of mixing colored pigments with geopolymer concrete. This study's objective is to evaluate the colored geopolymer concrete's quality using compressive test and mechanical wear test.Materials and Methods of tests

## Materials and Tests

## Fly ash

The term used to describe "fine inorganic and burned by-products", that are taken from the furnace to the flue gas particulate cleaning and collection system in coal-fired power stations. In this work, used  fly ash according to the specifications of ASTM C 618 type C[7], the results of the chemical and physical tests for fly ash are displayed in TABLES I and II show the results of chemical and physical tests for fly ash according to the requirements of ASTM C 618 type C[13].

1. Chemical Composition Analyses of Fly Ash Type C By XRF (% By Mass).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Oxides | SiO2 | Al2O3 | Fe2O3 | CaO | MgO | K2O |
| Content% | 36.93 | 18.76 | 5.85 | 26.9 | 5.96 | 1.49 |
|  |  |  |  |  |  |  |
| Oxides | SO3 | TIO2 | L.O.I | Na2O | P2O5 | / |
| Content% | 0.94 | 0.73 | 1.78 | 0.31 | 0.35 | / |

1. Fly Ash Physical Characteristics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Characteristics | Surface area, cm2/g | Nature of material | Specific weight% | Color |
| Outcomes | 6560 | Powder | 2.33 | gray to light white |

1. *NaOH*

### *NaOH is commonly available in flaky form and is highly pure (<98%) when dissolved in distilled water as ASTM E291 [8]*

### Sodium Silicate

### *Na2SiO3 utilized in this work is a common supply in the Iraqi market and was procured by the United Arab Emirates.*

1. *Fine aggregate*

Sand from the Ekhedir region is mostly used as fine aggregate. The results of the fine aggregate's chemical and physical test showed that it  conformityes to IQS No. 45/1984 specifications [9].

1. *Coarse aggregate*

### *To create the mixtures for this work, traditional gravel from the Al-Nabai zone was used as the coarse aggregate. The examination's results demonstrate its compliance with IQS 45/1984 [9].*

*Super-plasticizer (high range) admixture*

In accordance with ASTM C494[10], naphthalene formaldehyde solfanate ,super- plasticizer was employed to increase workability. The qualities of plasticizer are displayed in TABLE III..

1. Properties of a Plasticizer

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Technical properties | Basis | Color | pH | Density (kg/L) | Chloride content |
| Descriptions | Naphthalene formaldehyde sulfonate | Dark brownish | 7–11 | 1.181 ± 0.01 | Nil |

1. *Extra water*

### *Tap water, which is appropriate for concrete mix, was used as additional water for all colored geopolymer concrete mixtures.*

### Pigments

In this work, 3 different types of pigments (powder) they were imported from China, red Fe2 O3, green Cr2 O3, and yellow FeOOH,.Were used in varying amounts (0%, 1%, 2%, and 3% by weight of Fly ash) in the mixtures. The fineness value of the pigments was displayed in TABLE V.

TABLE V. Fineness (Surface Area) of Pigments

|  |  |  |  |
| --- | --- | --- | --- |
| Pigment | Red  Fe2O3 | Yellow FeOOH | Green Cr2O3 |
| Fineness (cm2/g) | 6580 | 12720 | 8178 |

*B) Geopolymer concrete mixtures with various colours*

Table VI a and VI b show the mix design of colored geopolymer concrete mixtures are displayed [11].

TABLE VI a: Colored Geopolymer Concrete Mixes\*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **MIX.** | **FA**  **kg** | **Alkaline liquids,**  **kg** | **Sand Kg** | **Gravel kg** | **Extra**  **water**  **kg** |
| Ms | 15 | 5.316 | 22.185 | 45.075 | 1.425 |
| Mr1% | 14.85 | 5.316 | 22.185 | 45.075 | 1.425 |
| Mr2% | 14.7 | 5.316 | 22.185 | 45.075 | 1.425 |
| Mr3% | 14.55 | 5.316 | 22.185 | 45.075 | 1.425 |
| Mg1% | 14.85 | 5.316 | 22.185 | 45.075 | 1.425 |
| Mg2% | 14.7 | 5.316 | 22.185 | 45.075 | 1.425 |
| Mg3% | 14.55 | 5.316 | 22.185 | 45.075 | 1.425 |
| My1% | 14.85 | 5.316 | 22.185 | 45.075 | 1.425 |
| My2% | 14.7 | 5.316 | 22.185 | 45.075 | 1.425 |
| My3% | 14.55 | 5.316 | 22.185 | 45.075 | 1.425 |

\*Where Ms: Referance geopolymer concrete, Mr: Geopolymer concrete with red pigment, My: Geopolymer concrete with yellow pigment, and Mg: with green pigment.

TABLE VI b: Colored Geopolymer Concrete Mixes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **MIX.** | Pigments kg | Admixture kg | Na2SiO3/NaOH | Molarity of NaOH |
| Ms | 0 | 0.585 | 2.5 | 14 |
| Mr1% | 0.15 | 0.585 | 2.5 | 14 |
| Mr2% | 0.3 | 0.585 | 2.5 | 14 |
| Mr3% | 0.45 | 0.585 | 2.5 | 14 |
| Mg1% | 0.15 | 0.585 | 2.5 | 14 |
| Mg2% | 0.3 | 0.585 | 2.5 | 14 |
| Mg3% | 0.45 | 0.585 | 2.5 | 14 |
| My1% | 0.15 | 0.585 | 2.5 | 14 |
| My2% | 0.3 | 0.585 | 2.5 | 14 |
| My3% | 0.45 | 0.585 | 2.5 | 14 |

*C) Prepare alkaline solutions*

*1) Preparing NaOH Solution*

The weight of NaOH solid was predicted to be 404 g dissolved in 596 g of distilled water to reach a solution with a concentration of 14 moles based on ASTM E291 [8] and Hardjito and Rangan[11].

1. *Preparation of alkaline liquids for mixtures*

For the purpose of obtaining the alkaline solution, Na2SiO3and NaOH solution were combined in a ratio of 1:2.5 while taking into account the solution's earlier preparation (24 hours prior to the mixture's components) [12].