Permeability of Geopolymer Concrete with and without Geopolymer Paint and Compares by Permeability of Traditional Concrete

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Abstract - This paper firstly mainly study permeability of (Geopolymer concrete and Geopolymer concrete with Geopolymer paint) and study permeability of (traditional concrete and traditional concrete with Geopolymer paint). calculate the reduction occur in permeability of concrete Because usage Geopolymer concrete and Geopolymer paint. to evaluate permeability of Geopolymer concrete. Preparation of four samples and to evaluate permeability of traditional concrete. Preparation of four samples. Secondly determines absorption resistance of Geopolymer concrete and traditional concrete. The results show that geopolymer concrete has very low permeability (impermeability) than ordinary concrete where the permeability factor of Geopolymer concrete, Geopolymer concrete with paint, traditional concrete and traditional concrete with paint is 0.58 $*10^{-6}$, $0.5*10^{-6}$, $0.19*10^{-5}$ and $0.116*10^{-5}$ mm/s respectively, Standard classification of concrete according to the permeability test are low permeability concrete, low permeability concrete, impermeability concrete and impermeability concrete as result the Geopolymer concrete is usage excellent in hydraulic building and under water building as dam, tank, channel, pier and bridge than ordinary Portland concrete, the absorption resistance of Geopolymer concrete and traditional concrete is 0.43 % and 1.34% respectively.

Key Words: permeability and the absorption resistance, Geopolymer paint, Geopolymer concrete, traditional concrete..

INTRODUCTION

In the production of cement the limestone and clay is heated to a high temperature of 1500 degree Celsius in a kiln then these materials fused and form clinker which further crushed to form cement. Thus this processs is very costly and emit large amount of fly ash and carbon dioxide to the environment. Thus in Geopolymer cement the use of fly ash and slaked lime as the binder replaces the cement thus it is a key for the sustainable development.

Geopolymer cements are a group of alkali-activated materials exhibiting superior engineering properties compared to Portland cements. Gives 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 CO_2 emission in to the atmosphere, caused by cement.

Geopolymer was the name given by Davidovits in 1978 to materials which are characterized by chains or networks or inorganic molecules. “Geopolymer”, in general, is defined as a solid and stable material consisting of alumino-silicates formed by alkali hydroxide or/and alkali silicate activation. This was a class of solid materials, produced by the reaction of an aluminosilicate powder such as (Ground Granulated Blast Furnace Slag (GGBFS), fly ash, met kaolin, red mud) and an alkaline liquid such as (sodium silicate solution (Na_2SiO_3), sodium hydroxide solution (NoaH), potassium hydroxide solution (KoH). “Geopolymer passes through three stages. The first stage is the dissolution process, the second stage is condensation process, and the final stage is called polymerization.

Previous research

In year 2016 Ekom Eduok . [1] Study thermal analysis on the creation of an aplite-slag (GGBFS) based geopolymer, the addition of micro silica to increase the silica/alumina ratio and the addition of sucrose as a retarder to shift the geopolymer setting time. The results indicate that increasing the soluble silicate content has a negative effect, but an optimal curing temperature tends to improve the extent of geopolymerization. Additionally, an optimum retarder dosage of sucrose was found to be 1.2% of the total solid content, which lengthened the geopolymerization process by 20.39 minutes

In year 2015 Parthiban. K and Vaithianathan. S [2] studied the strength characteristics of slag based geopolymer at different replacement levels of slag with metakaolin, sodium hydroxide concentration, maintaining the alkaline ratio constant at NaOH: Na_2siO_3 1: 2.5. The tests includes cube compressive strength that approved that the compressive strength of geopolymer concrete increases with the increase in the metakaolin content and sodium hydroxide concentration. The mix with 12M NaOH concentration and (3- 20) % metakaolin replacement shows optimum mix proportioning of the geopolymer concrete.

In year 2014 Sonal P. Thakkar1, Darpan J. Bhorwani2, Rajesh Ambaliya3 [3] discusses various combination of Ground Granulated Blast Furnace Slag (GGBFS) and Fly Ash, as source material, to produce geopolymer concrete at ambient temperature. Who that geopolymer concrete with GGBFS in Fly ash as increases it gains strength and shows good strength at 3, 7 and 28 days even at ambient curing with increase in GGBFS content. While only slag based geopolymer concrete has higher strength at oven curing while rate of gain of strength is slower at ambient temperature as period increases.

In year 2015 Fenghong Fan [4] show that the geopolymer cement cured at appropriate conditions can reach a compressive strength of more than 100MPa and it also has an excellent heat resistance with a remarkable strength after the 500oC heating. In addition, it is found that the studied geopolymer cement possesses a much higher spallation resistance when suddenly cooled down by water after the high temperature heating than the ordinary Portland cement concrete which has a high spallation tendency. These findings indicate that the geopolymer cement may be an excellent construction material for the fire protection and fire-prone structures.

Palomo et al [5], in their study on fly ash-based geopolymers have reported that the type of alkaline solution was the significant factor affecting the mechanical strength of geopolymers. They found that the combination of sodium silicate and sodium hydroxide produced the highest compressive strength.

In year 2014 Parthiban. K* and Saravana Raja Mohan. K [6] investigated has been made to study the variation in the Compressive Strength of slag based Geopolymer concrete by varying the concentration of Sodium hydroxide as 10, 12, 14M and the ratio of alkaline solution (SiO_{3}^{2-} / OH^-) as 1.0, 1.5, 2.0. The compressive strength of the mixes was determined for their 3, 7, 14 and 28 days curing for studying there variation at different age of curing. The test results show that the compressive strength of the Geopolymer mixes increases with the increase in the NaOH concentration and alkaline ratio

D. V. Dao1 and J. P. Forth [7] proved that the strengths of geopolymer mortars increase dramatically when the temperature rises up to 300^{o}C. After that, the strengths gradually reduce when temperature is increased to 1000^{o}C.

Objective and scope

First to evaluate the absorption percentage and permeability of Geopolymer concrete and compression the absorption percentage and permeability ordinary Portland concrete

Significance

This paper aims to reduce the usage of ordinary Portland concrete in hydraulic building and using Geopolymer concrete based slag in hydraulic building because that Geopolymer concrete have very low permbeality and absorption percentage

Materials

The used materials in the present study were ground granulated blast-furnace slag (GGBFS), meta-kaolin (MK), and Red mud (RD) and activator solution (the sodium hydroxide solution NaoH, the sodium silicate solution Na_2SiO_3. Table (1) present the chemical composition of material that measured by X- ray flourresence.

1. Ground granulated blast furnace slag (GGBFS)

Ground granulated blast-furnace slag was obtained by Iron and Steel factory- Helwan, Egypt. The GGBFS is an industrial by-product resulting from rapid water cooling of molten steel. It is known to have advantageous properties for the concrete industry as it is relatively inexpensive to obtain highly resistant to chemical attack and maintains excellent thermal properties. Major components of the investigated slag are SiO_2, CaO, MgO and Al_2O_3 **(Table 1).** The Egyptian slag is characterized by its high content of BaO, MgO and MnO than the common international standard one. GGBFS is off-white and grey in colour and substantially lighter than Portland cement. It was used as the basic aluminosilicate material to manufacture geopolymers.

2. Meta-kaolin (MK):

Kaolin material was extracted from the kaolinitic sandstone deposits existed in an open quarry located in Sinai west of Gebel Gunna by Middle East Mining Company Kaolin contains hydroxyl ions that are strongly bonded to the aluminosilicate framework and can only be altered by the temperature range 550 -750 °C to be metakaolinite. Thus, rearranging the atomic structure to forma partly ordered system with a great reaction potential to alkaline solutions. The main chemical compositions of the studied meta- kaolin are SiO_2 and Al_2O_3. **Table (1)** tabulated the chemical composition of calcined kaolin.

3. Clay brick waste (Red mud (RM)).

Clay brick waste (Red mud (RM)) can be defined as defective and crushed fired clay bricks. It was provided from clay brick factories, Helwan, Egypt. The main chemical compositions of the used RM are silica, alumina, in addition to a minor amount of iron oxides in a descending order of abundance (Table 1).

Figure (1) GGBFS, MK, RM

Table (1) X-ray (XRF) analysis of slag GGBFS, metakilon MK ,red mud RD

Chemical compounds	CaO	SiO_2	Al_2O_3	MgO	Na_2O	SO_3	Fe_2O_3	Other
GGBS	33.07	36.59	10.01	6.43	1.39	3.52	1.48	7.51
MK	0.14	55.01	40.94	0.34	0.09	0.00	0.55	2.93
RD	1.35	73.05	13.41	1.46	1.62	0.74	6.35	2.02

4. Activator solution (NaoH, Na_2SiO_3)

Sodium silicate (Na_2SiO_3) and Sodium hydroxide (NaOH) based alkali activators were used for activating the geopolymerization process. Na_2siO_3 is a white viscous liquid. Its chemical composition is 8.9% Na_2O, 28.7% SiO_2 and 62.5% H_2O (by weight) with specific gravity 1.41. NaOH is on form of white pellets with 99% purity. NaOH solution was prepared at desired molarity and kept in air for one day prior to mixing. With specific gravity 1.32 the concentration of the sodium hydroxide solution used from 12 molar (M) without additional water.

Table (2) the sieve analysis of coarse and fine aggregates

Size	**9.5**	**4.75**	**2.36**	**1.18**	**0.6**	**0.3**	**0.15**
%F.A	100	100	98	85	75	49	23
%C.A	78	22	0	0	0	0	0

Table (3) the physical properties of coarse and fine aggregates

	M.E	**S.G**
F.A	3.39	2.62
C.A	2.93	2.74

Experimental Investigation

1.Mix design of Geopolymer concrete

In the design of Geopolymer concrete mix, total aggregates (fine and coarse) taken as 77% of entire concrete mix by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75 to 80% of the entire concrete mix by mass. Fine aggregate was taken as 30% of the total aggregates.

For The Geopolymer mixture design and testing program was conducted in accordance with ECP and ASTM standards. Mixes containing ratio of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaoH) 2.5:1. With variable water type used in mix and curing (fresh .sea water) , ratio of slag (GGBFS) , Meta kaolin (M.K) and red mud .85:.05 :10 , quantity of binder (GGBFS+ M.K+RM) 550 kg/m^3 , fine aggregate (F.A) : coarse aggregate (C.A) 1:2 And concentration of and sodium hydroxide (NaoH) 12M .

For ordinary concrete Mixes containing ratio of water to cement is 0.53, cement contain 350 kg/m^3 , coarse and fine aggregate contain 1260,630 kg/m^3

For paint geopolymer contain 80% slag, 20% met-kaolin and sodium silicate (Na_2SiO_3) and sodium hydroxide (NaoH) 2.5:1.

2. Preparation of Geopolymer concrete.

To evaluate permeability of ordinary concrete, ordinary concrete with Geopolymer paint, Geopolymer concrete and Geopolymer concrete with Geopolymer paint respectively. Preparation Four samples ordinary concrete two sample without paint (FP_1) and other with Geopolymer paint (FP_2), four samples preparation concrete. Two samples without Geopolymer paint (FP_3) and other with Geopolymer paint (FP_4).

To evaluate absorption percentage for ordinary concrete and Geopolymer concrete preparation of two sample ordinary concrete (FP_1) and two sample Geopolymer concrete (FP_3) .480 g (molarity x molecular weight) of sodium hydroxide flakes dissolved in one litre of water to prepare sodium hydroxide solution of 12M. The mass of NaOH solids in a solution vary depending on the concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was measured as 372 g per kg of NaOH solution of 12 M concentration. The sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day before making the Geopolymer concrete. After solution is prepared the composition is weighed and mixed in concrete mixture as conventional concrete and transferred into moulds as early as possible as the setting times are very low.

3. Mixing and Casting

It was found that the fresh Geopolymer masonry mix was grey in colour and was cohesive. The amount of water in the mix played an important role on the behavior of fresh mix. Davidovits (2002) suggested that it is preferable to mix the sodium silicate solution and the sodium hydroxide solution together at least one day before adding the liquid to the solid constituents. The author suggested that the sodium silicate solution obtained from the market usually is in the form of a dimmer or a trimmer, instead of a monomer, and mixing it together with the sodium hydroxide solution assists the polymerization process.

The effects of water content in the mix and the mixing time were identified as test parameters in the detailed study. From the preliminary work; it was decided to observe the following standard process of mixing in all further studies. Mix sodium hydroxide solution and sodium silicate solution together at least one day prior to adding the liquid to the dry materials. Mix all dry materials in the pan mixer for about three minutes. Add the liquid component of the mixture at the end of dry mixing, and continue the wet mixing for another four minutes. Compaction of fresh concrete in the cube moulds was achieved by compacting on a vibration table for ten seconds. After casting, the specimens were left undisturbed for 24 hours.

4. Curing

Curing is not required for these Geopolymer blocks. The heat gets liberated during the preparation of sodium hydroxide which should be kept undisturbed for one day.

5. Testing produce

The specimens were tested under permeability machine for 72 hour exposed water pressure from one side as shown figure 4, and then evaluate high water in side sample.

Figure 5 as shown permeability machine

Figure 6 as shown permeability sample

6. Results and Dissuasion.

6.1. Permeability of Geopolymer concrete and ordinary concrete

In this investigation, to study the permeability of geopolymer concrete with and without geopolymer paint and compared ordinary concrete with and without Geopolymer paint , eight different sample were prepared tow sample for ordinary concrete (FP_1) , ordinary concrete with geopolymer paint (FP2), geopolymer concrete (FP_3) and geopolymer concrete with geopolymer paint (FP_4) respectively as **table 4**

To calculate permeability factor let parameter in equation

$$\text{permeability factor} = \frac{Cc \times H}{A \times T \times P} \quad mm/s$$

Where:

Cc : volume of water in pipe customization throw 72 hr cm^3

H : high of sample

A : area exposes to water pressure

T : time by second

P : water pressure by cm **(5-6) bar**

Table 2 permeability of all samples.

For ordinary concrete:

Sample 1:

$$\text{permeability factor (K1)} = \frac{4650 \times 15}{225 \times 72 \times 60 \times 60 \times 6 \times 1000} = 0.19 \times 10^{-5} mm/s$$

Where:

Cc: 4650 cm^3 ,H : 15 cm , A: 15*15 cm^2 ,T : 72 hr ,P : 6 bar **(5-6) bar**

Sample 2:

$$\text{permeability factor (K2)} = \frac{4130 \times 15}{225 \times 72 \times 60 \times 60 \times 6 \times 1000} = 0.17 \times 10^{-5} mm/s$$

Where:

Cc: 4130 cm^3 ,H : 15 cm , A: 15*15 cm^2 ,T : 72 hr ,P : 6 bar **(5-6) bar**

For ordinary concrete with geopolymer paint :

Sample 1:

$$\text{permeability factor (K1)} = \frac{2860 \times 15}{225 \times 72 \times 60 \times 60 \times 6 \times 1000} = 0.12 \times 10^{-5} mm/s$$

Where:

Cc: 2860 cm^3 ,H : 15 cm , A: 15*15 cm^2 ,T : 72 hr ,P : 6 bar **(5-6) bar**

Sample 2:

$$\text{permeability factor (K2)} = \frac{2600 \times 15}{225 \times 72 \times 60 \times 60 \times 6 \times 1000} = 0.11 \times 10^{-5} mm/s$$

Where:

Cc: 2600 cm^3 ,H : 15 cm , A: 15*15 cm^2 ,T : 72 hr ,P : 6 bar **(5-6) bar**

For geopolymer concrete:

Sample 1:

$$\text{permeability factor (K1)} = \frac{1400 \times 15}{225 \times 72 \times 60 \times 60 \times 6 \times 1000} = 0.6 \times 10^{-6} mm/s$$

Where:

Cc: 1400 cm^3 ,H : 15 cm , A: 15*15 cm^2 ,T : 72 hr ,P : 6 bar **(5-6) bar**

Sample 2:

$$\text{permeability factor (K2)} = \frac{1320 \times 15}{225 \times 72 \times 60 \times 60 \times 6 \times 1000} = 0.56 \times 10^{-6} mm/s$$

Where:

Cc: 1320 cm^3 ,H : 15 cm , A: 15*15 cm^2 ,T : 72 hr ,P : 6 bar **(5-6) bar**

For geopolymer concrete with geopolymer paint :

Sample 1:

$$\text{permeability factor (K1)} = \frac{1170 \times 15}{225 \times 72 \times 60 \times 60 \times 6 \times 1000} = 0.5 \times 10^{-6} mm/s$$

Where:

Cc: 1170 cm^3 ,H : 15 cm , A: 15*15 cm^2 ,T : 72 hr ,P : 6 bar **(5-6) bar**

Sample 2:

$$\text{permeability factor (K2)} = \frac{1200 \times 15}{225 \times 72 \times 60 \times 60 \times 6 \times 1000} = 0.51 \times 10^{-6} mm/s$$

Where:

Cc: 1200 CM3 ,H : 15 cm , A: 15*15 cm^2 ,T : 72 hr , P : 6 bar **(5-6) bar**

By inspection results show that geopolymer concrete have very low permeability than ordinary concrete. So that usage of geopolymer in hydraulic building , where high of water in side (FP_3)sample geopolymer concrete after exposes water pressure for long 72 hr is 6 cm and permeability factor according equation is while High water of (FP_1) sample is 8 cm and permeability factor according equation is . And notice that geopolymer paint improve ability prevent permeability of sample , where high of water in side sample (FP_2) and high of water in side sample(FP_4) Is 6.4 cm and 4.3 cm respectively but permeability factor of(FP_2) and (FP_4) is respectively.

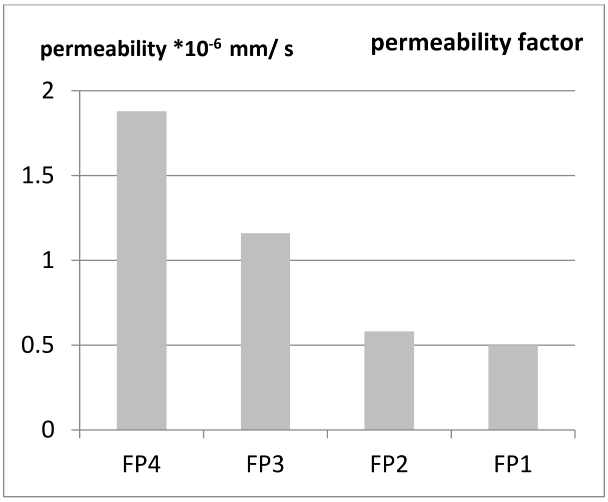

Figure 3 shown permeability of all samples.

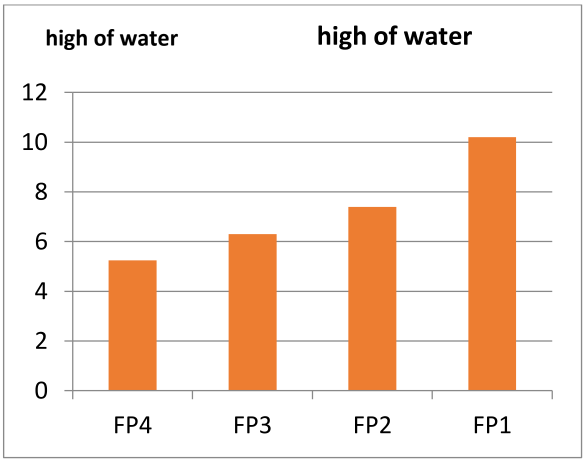

Figure 4 shown high of water in all samples.

6.2. Absorption percentage of Geopolymer concrete and ordinary concrete.

In this investigation, to study the absorption resistance of geopolymer concrete and compared absorption resistance of ordinary concrete (FP_3), (FP_1) respectively as **table 5** . Wight before submargin , Wight after submerge in water for long 24 hr.

$$\% \text{ absorption} = \frac{(W2 - W1)}{W1}$$

Where:.

W_1 : Wight before submargin W_2 : Wight after submerge for long 24 hr.

For ordinary concrete:

Sample 1:

$$\% \text{ absorption} = \frac{(8.375 - 8.257)}{8.257} = 1.43\%$$

Table 4 Mix samples for permeability of all sample .

Materials	Mix_1 (kg/m^3) FP_1	Mix_2 (kg/m^3) FP_2	Mix_3 (kg/m^3) FP_3	Mix_4 (kg/m^3) FP_4
Coarse aggregate	1260	1260	1100	1100
Fine aggregate	630	630	550	550
Slag	0	0	467.5	467.5
Metakoalin	0	0	27.5	27.5
Red mud	0	0	55	55
Cement	350	350	0	0
Sodium hydroxide	0	0	88	88
Sodium silicate	0	0	220	220
External water	175	175	0	0
Paint Geopolymer	without	With	without	With
water High of sample	10.5 cm	7.1 cm	6 cm	5.4 cm
	9.9 cm	7.7 cm	6.5 cm	5.1 cm
Permeability factor mm/s	$0.19*10^{-5}$	$0.12*10^{-5}$	$0.6*10^{-6}$	$0.5*10^{-6}$
	$0.17*10^{-5}$	$0.11*10^{-5}$	$0.56*10^{-6}$	$0.51*10^{-6}$
Standard classification	low permeability		impermeability	

Sample 2:

$$\% \text{ absorption} = \frac{(8.503 - 8.398)}{8.398} = 1.25\%$$

For ordinary concrete:

Sample 1:

$$\% \text{ absorption} = \frac{(8.495 - 8.458)}{8.458} = 0.44\%$$

Sample 2:

$$\% \text{ absorption} = \frac{(8.538-8.502)}{8.502} = 0.42 \%$$

From table 5 shown that Geopolymer concrete is excellent in hydraulic building and building under water as dam ,tank , channel , pier and bridge than ordinary Portland concrete where geopolymer concrete have high absorption resistance (0.43%) compared with absorption of plain concrete (1.34 %)

Geopolymer concrete reduce absorption of concrete to 68% than ordinary concrete .

Table 5 Mix samples for absorption.

Materials	Mix_1(kg) FP_1	Mix_3(kg) FP_3
Wight before submargin (W_1)	8.257	8.458
	8.398	8.502
Wight after submargin (W_2)	8.375	8.495
	8.503	8.538
% absorption	1.43%	0.44%
	1.25%	0.42%

7. Conclusions

The following statements were concluded from the results obtained:

- Geopolymer concrete can be used as an effective replacement for cement concrete thereby reduces environmental pollution as in case of cement concrete.

- The use of Portland cement has been completely eliminated; thereby reduce the emission of CO_2 to the atmosphere which results in the reduction of Green House Gases

- using activators combined from sodium silicate and sodium hydroxide better than using actavitor sodium hydroxide only .

- Geopolymer concrete is excellent in hydraulic building and building under water.

- from resulte can be conclude that the permeability factor of Geopolymer concrete sample FP_3, Geopolymer concrete with Geopolymer paint sample FP_4, traditional concrete sample $FP_1$and traditional concrete with Geopolymer paint sample FP_2 is 0.58 $*10^{-6}$, 0.5$*10^{-6}$, 0.19$*10^{-5}$ and 0.116$*10^{-5}$ mm/s respectively.

- according to Standard classification of permeability concrete can be classificat permeability of sample (FP_1, FP_2, FP_3 and FP_4) is low permeability concrete , low permeability concrete , impermeability concrete and impermeability concrete respectively .

- at usage Geopolymer paint with ordinary concrete sample . permeability reduce 42%

- Geopolymer concrete reduce permeability to 69.5% than ordinary concrete.

- at usage Geopolymer paint with Geopolymer concrete sample . permeability reduce 73.6% than ordinary concrete.

- The geopolymer concrete have high absorption resistance (0.43%) compared with absorption of plain concrete (1.34 %)

-The geopolymer concrete have very low permeability than ordinary concrete.

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