IGNEOUS CONCRETE UTILIZING VOLCANIC ASH

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ABSTRACT

Green concrete is the latest development in the field of construction technology which offers a sustainable and eco-friendly solution as a building material. The cement used in conventional concrete is responsible for releasing high amount of carbon dioxide which is harmful for the environment. The concept of green concrete renders replacement of cement partially or fully by various materials which are either by-products in the production process of other materials or recycled waste. In this paper we focuses on replacing a different percentage of the cement with pozzolanic materials and also replacing the coarse and fine aggregate with locally volcanic materials to produce an eco-friendly and sustainable concrete. Thus, Four trail mixes were casted for estimating the concrete materials and proportion, also fifteen mixes were casted with some variables .

Two types of coarse aggregate were used (dolomite and volcanic rock) to show the effect of volcanic aggregate on concrete properties. Fly Ash was used with 10% replacement of the cement , Volcanic ash was used with (20 % to 80%) replacement of the cement , the water cementation ratio equal 0.3, Super plasticizer (visocrete-3425) was used with constant ratio 1% of the cement. Ordinary Portland cement was used in all mixes with constant cement content equal 500 kg/m³.

Slump test were prepared on concrete in its fresh phase, hardened concrete tests

(compression strength, bond strength, and bending strength) were prepared to identify the mechanical properties of concrete, the results show that using volcanic ash as a replacement of the cement nearly does not affect the slump of concrete, but on the other hand enhances the mechanical properties of concrete.

Keywords: Igneous Concrete, Green Concrete, Environmental Issue, Pozzolana

Cite this Article: Mohamed Y. Elsheikh, Ahmed A. Elshami, Ali ELrefaei and Ibrahim Abdel Mohsen, Igneous Concrete Utilizing Volcanic Ash, *International Journal of Civil Engineering and Technology*, 11(4), 2020, pp. 73-90.

<https://iaeme.com/Home/issue/IJCIET?Volume=11&Issue=4>

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1. INTRODUCTION

Concrete is the most common building material which has widespread uses in construction industry. It has high strength, long term durability and mechanical properties which enables it to become a most usable material with a pool applications. Despite having numerous advantages, it has certain limitations [AL-zubiad 2017, Wang 2017]. Conventional concrete is not considered as a sustainable product as the material components used in the composition of concrete are not produced in an eco-friendly manner and they cause harm to the environment. Cement is one of the components of concrete, which is responsible for producing more than 6% of all CO₂ emission which contributes to the global warming (Greenhouse has). CO₂ emissions from 1 ton of concrete produced vary between 0.05 and 0.13 tons. 95% of all CO₂ emissions from a cubic meter of concrete are from cement manufacturing. [Admure, 2017].

To overcome this negative impact, Green concrete was introduced. It was first invented in Denmark in 1998 . It is an eco-friendly concrete, which involve negligible amount of CO₂ emissions at its production stage causing no environmental destruction. It utilizes waste materials as one of its components. The numerous advantages of Green Concrete, which makes it the most suitable material for construction industry are,

It reduces the dead weight of structures, helps in completing the construction task faster by lowering down the overall construction period, helps in reducing the CO₂ emissions by 30%, helps in reuse the waste materials, offers a good thermal and fire resistance and also shows a higher compressive strength as compared with the conventional concrete. [Mehta, 2015].

Different scholars and scientist has invested their time and effort in studying the feasibility of green concrete as an eco-friendly, durable and strongest building material. Marble powder , Quarry Dust and paper pulp from industrial waste as a substitute or cement and fine aggregate has been used according to [Dhoka, 2013]. Fine aggregate has been replaced with marble sludge powder and quarry dust and studied the effect on the properties of concrete according to [Malpani, 2014]. The use of cleaner technologies in concrete production has been presented according to [Suhendro (2014)]. He has completely replaced cement with fly ash and other natural pozzolanas. He has also discussed the concept of green concrete and material development of nanosilica in Indonesia. The using of polymer concrete with epoxy resins and waste glass as aggregate has been synthesized according to [Kou, Chi Sun Pon, 2013]. The economic factors which makes green concrete acceptable commercially has been identified according to [Meyer, 2005]. Danish Centre for green concrete which is a co-operative venture involving all sectors related to the use and production of concrete has presented a paper on reducing the environmental impacts of concrete by using energy saving and recycled waste materials. They have employed four ways to produce green concrete _ use of conventional residual products like fly-ash, stone dust from crushing of aggregate, concrete slurry from washing of equipment used in concrete mix plant, sludge from sewage treatment plants and

cement with reduced environmental impacts [Damtoft, 2007]. The potential use of high volumes of incineration ash from sewage sludge in controlled low strength materials has been identifies according to [Horiguchi, 2007]. Natural pozzolana (50% of the mass of cementitious material) named as (High Volume Natural Pozzolana (HVNP), which has shown the 28 days strength of M20 concrete to be 38 MPa has been applied according to [Uzal, 2007].

The materials which can be used as a substitute for regular component includes, fly ash, granulated blast furnace slag, recycled concrete, demolition waste, micro silica, glass powder, marble powder, quarry dust and other pozzolana. The recycled material or the industrial waste can be selected based on the availability around the construction site to reduce energy and transportation cost [Khan, 2020]

One way to obtain green concrete is to use raw binder instead of clinker. One solution is the utilization of volcanic ash in concrete (Touil 2017, T.Blaszczynski (2014), Meyer.C (2005)) or other pozzolanic material as silica fume which are waste from industries.

Pozzolanic material is an inert silicious material which, in the presence of water, will combine with lime to produce a cementitious matter with excellent structural properties.

Pozzolanic material used in concrete technology has three main functions; filling the voids between the next larger class particles (cement), reduce the heat of hydration and reacts with Ca(OH)_2 forming CSH. [Ibrahim 2015, Khedr.S.A(1994), Ghassan(2010), Uzal.B (2007)]. Indeed the interfacial transition zone can be improved by the addition of pozzolanic materials like silica fume, fly ash and volcanic ash reacts with Ca(OH)_2 crystals forming CSH. Silica fume particles consume Ca(OH)_2 available in transition zone and make it dense and uniform [Sengul 2005].

Moreover replacing cement with mineral admixtures seems to be a feasible solution to shrinkage problems. Mineral admixtures greatly reduced the heat of hydration, particularly when two or three types of mineral admixtures were added at the same time. The addition of supplementary cementitious materials such as silica fume reduces both pore sizes and porosity and increase compressive and flexural strengths and durability performances. [Ibrahim 2015, Sengul 2005 , Djerbi (2008), Johari (2011), Harlad Justnes (2016)].

This Paper Discusses the importance of a new types of green concrete which called igenous concrete in the present day context and highlights its merits over conventional concrete which otherwise posing a serious threat to the environment through global warming. Igneous Concrete is a new type of green concrete with the replacement of the cement with different ratios (from 20 to 80) % of the natural volcanic ash and pozzolana.

Igneous rocks which are divided into two main categories; plutonic (intrusive) rock and volcanic (extrusive). Intrusive rocks result when magmas cools and crystallizes slowly within the Earth crust. A common example of this type is granite. Extrusive rocks results from magma reaching the surface either as lava or fragmental ejecta, forming rocks such as pumice and basalt [Orchared 1976].

The size of crystals in an igneous rock is an important indicator of the conditions where the rock formed. If the magma cools extrusively, or near the surface of the earth, this process occurs at lower temperatures. In this situation, the crystals do not have much time to form, so they are very small. If the magma cools intrusively, or deep inside the earth, the temperature is much warmer. The cooling process takes place more slowly, and the crystals have time to grow and become large. When magma flows on the surface of the earth, this lava cools suddenly, and there is no time for crystals to form [Orchared 1976].

Andesite is the name used for a family of fine-grained, extrusive igneous rocks that are usually light to dark gray in color. It is rich in Plagioclase feldspar minerals and may contain

biotite, pyroxen, or amphibole. Andesite usually does not contain quartz or olivine. [Hobart 2015]

Andesite is typically found in lava flows produced by startovolcanoes. Because these lavas cooled rapidly at the surface, they are generally composed of small crystals [Buzzle.com].

2. RESEARCH SIGNIFICANCE

Producing an economic and local type of concrete which called igneous concrete by replacing different ratios of cement by volcanic ash and pozzolana, preserving the environment from the CO₂ emissions from the cement manufacturing, , studying the mechanical properties of the igneous concrete, and analysis the results of igneous concrete tests on its fresh and hardened statement.

igneous concrete used in this paper is an economic and local concrete produced in Egypt.

The area of study is located approximately 50 km north-west of Hurghada along the western cost of the Red Sea. It is underlain mainly by the Dokhan Volcanics and both Older and Younger Granites. In these area, the Dokhan Volcanic rocks cover about 100 km² including north of Gebel Dokhan along Wadi Um Sidra and further north along Wadi Um Asmer. The Older Granites are the oldest rocks and comprise quartz diorite, granodiorite, and adamellite. These granitic rocks have not been dated. The Dokhan volcanic successions are, rhyolites, quartz porphyry, ryodacites, andesite, decites, basalts and tuffaceous rocks, at three localities namely Wadi Zareib, Gabal Nugara and Wasif. [Stern 1985].

Figure 1 Dokhan Volcanic rocks in Egypt

Figure 2 Dokhan Volcanic outcrops in the Eastern Desert of Egypt

3. MATERIALS AND EXPERIMENTAL PLAN

3.1. Aggregates

A natural igenous sand and two types of coarse aggregates are used in this research according to Egyptian Specification (1109:2008).

These types are igneous rock and dolomite as shown in Fig.3 , with a maximum nominal size of (8 mm to 12mm)

The Andesite (Igneous rock) was obtained from “Aish EL Malaha and Gebel Nuegara”(EYGPT) according to Egyptian Standards (4756-1/2013).

Table 1 Main properties of aggregates.

Type	Specific Gravity	Unit weight Kg/m ³	Fineness Modulus	Maximum Nominal Size(mm)
Igneous Sand	2.65	1650	3.00	.....
Dolomite	2.6	1600		8-12
Volcanic rock	2.65	1650		8-12

Dolomite

Andesite (Igneous rock)

Figure 3 Types of coarse aggregates used in the mixes

3.2. Portland cement

One type of cement was used in this study (Ordinary Portland cement) of.

According to Egyptian specification (ES 2421:2009). Chemical composition, physical and mechanical properties of the used cement are shown in Table. 3, 4 and 5.

Table 2 Chemical composition of the Portland cement.

Oxide composition	Content (wt %)
Lime (CaO)	62.7
Silica (SiO ₂)	20.20
Alumina (Al ₂ O ₃)	6.00
Ferric Oxide (Fe ₂ O ₃)	3.30
Magnesia (MgO)	2.00
Sulphuric Anhydride (SO ₃)	2.20
Loss on Ignition (LOI)	1.70
Insoluble Residue (IR)	1.40
Total	99.50

Table 3 Compounds of cement.

Compounds	Content %
Tricalcium Silicate C ₃ S	50.36
Dicalcium Silicate C ₂ S	20
Tricalcium Aluminate C ₃ A	10.323
Tetracalcium Alumina Ferrite C ₄ AF	10.323

Table 4 Physical and Mechanical properties of Portland cement .

Property	Test result	Specifications
Cement Fineness (Blain Apparatus) (cm ² /gm)	3600	Not less than 2750
Initial setting time (min)	75	Not less than 45 min
Final setting time (min)	240	Not more than 10 hours
Compressive strength 2 days (Mpa)	24.2	Not less than 20 Mpa
Compressive strength 28days (Mpa)	53.8	Not less than 52.5 Mpa

3.3. Pozzolanic admixtures

The particle sizes in fly ash vary from less than 1 µm (micrometer) to more than 100 µm with the typical particle size measuring under 20 µm. Only 10% to 30% of the particles by mass are larger than 45 µm. The surface area is typically 300 to 500 m²/kg, although some fly ashes can have surface areas as low as 200 m²/kg and as high as 700 m²/kg. For fly ash without close compaction, the bulk density (mass per unit volume including air between particles) can vary from 540 to 860 kg/m³ (34 to 54 lb/ft³), whereas with close packed storage or vibration, the range can be 1120 to 1500 kg/m³ (70 to 94 lb/ft³).

A natural Volcanic Rocks was obtained from “Aish EL Malaha and Gebel Nuegara”(EYGPT) according to Egyptian Standards (4756-1/2013). It was crushed until passing from Sieve No.170 mm as shown in Fig.4 with specific gravity of 2.65 and unit weight of 1650 Kg/m³ was used in this research.

Figure 4 Mineral Volcanic Ash

3.3.1. X-ray diffraction analysis volcanic ash

Figure (5) collects XRD patterns obtained for volcanic ash samples. It is evident that, composition for volcanic ash is the Quartz, Albite and Microcline.

Table 5 X-Ray fluorescence for volcanic ash.

Oxide Content *												
Sample name	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	L.O.I**	TOTAL
Volcanic Ash	67.04	14.90	2.59	3.27	1.72	0.25	3.26	3.28	0.26	0.16	2.83	99.56

Table 6 X-Ray diffraction composition for volcanic ash.

Compound Name	Chemical Formula
Quartz	Si O ₂
Albite	(Na _{0.98} Ca _{0.02}) (Al _{1.02} Si _{2.98} O ₈)
Microcline	K Al Si ₃ O ₈
Microcline	K Al Si ₃ O ₈

Figure 5 X-ray diffraction for Volcanic ash

3.4. Super plasticizer

A high performance superplasticizer concrete admixture. It is a third generation superplasticizer for homogenous concrete, it meets the requirements for superplasticizers according to ASTM-C-494 types G and F and BS EN 934 part 2 : 2001.

It is suitable for concrete mixes which require high early strength development, powerful water reduction, it is also used for precast concrete, concrete with highest water reduction(resulting in high density and strengths, and for SCC, its density is 1.08 kg/lit.

Figure 6 Super plasticizer (viscocrete 3425).

3.5. Concrete and experimental program

Three groups (A, B and C) of igneous concrete and normal concrete, with a total number of 15 mixes were prepared and investigated to satisfy the main objectives of the paper, beside the five reinforced concrete beam mixes and the four trial mixes to investigate the materials and their proportions. igneous rocks and dolomite were used as coarse aggregate with different ratio.

Clean water was used and water/ cementitious ratio of 0.3 was used to produce igneous concrete.

Table 7 Experimental plan.

	Mix		Coarse Aggregate		Fine Aggregate		Cement		V.A		F.A		Viscocrete
			Type	Content Kg/m ³	Type	Content Kg/m ³	Ratio %	Content Kg/m ³	Ratio %	Content Kg/m ³	Ratio %	Content Kg/m ³	Ratio %
Group A	M0	N	Dolomite	1226.11	Sand	613.055	100	500	0	0	0	0	1%
Group B	M1	V1	Volcanic rock	1258.61	Volcanic	629.3	80	400	20	100	0	0	1%
	M2	V2	Volcanic rock	1274.86	Volcanic	637.43	70	350	30	150	0	0	1%
	M3	V3	Volcanic rock	1291.11	Volcanic	645.55	60	300	40	200	0	0	1%
	M4	V4	Volcanic rock	1307.36	Volcanic	653.68	50	250	50	250	0	0	1%
	M5	V5	Volcanic rock	1323.61	Volcanic	661.8	40	200	60	300	0	0	1%
	M6	V6	Volcanic rock	1339.86	Volcanic	669.93	30	150	70	350	0	0	1%
	M7	V7	Volcanic rock	1356.11	Volcanic	678.05	20	100	80	400	0	0	1%
Group C	M8	F1	Volcanic rock	1258.61	Volcanic	629.3	80	400	10	50	10	50	1%
	M9	F2	Volcanic rock	1274.86	Volcanic	637.53	70	350	20	100	10	50	1%
	M10	F3	Volcanic rock	1291.11	Volcanic	645.55	60	300	30	150	10	50	1%
	M11	F4	Volcanic rock	1307.36	Volcanic	653.68	50	250	40	200	10	50	1%
	M12	F5	Volcanic rock	1323.61	Volcanic	661.8	40	200	50	250	10	50	1%
	M13	F6	Volcanic rock	1339.86	Volcanic	669.93	30	150	60	300	10	50	1%
	M14	F7	Volcanic rock	1356.11	Volcanic	678.05	20	100	70	350	10	50	1%

N: Normal concrete with only dolomite, sand and cement.

V: Igneous concrete with volcanic aggregate and different ratios of volcanic ash and cement.

F: Igneous concrete with 10% fly ash, volcanic aggregate and different ratios of volcanic ash and cement.

V.A: Volcanic ash

F.A: Fly ash

100 mm cubes and 150 × 150 × 750 mm reinforced prisms were casted for compression and flexural test respectively, 100 × 200 mm cylinders were also used for Pull out test.

All the test specimens were demolded after 48 hours and then stored under the water in curing tanks with room temperature (20±2) as shown in Fig. (8)

Figure 8 Specimens used in the work and Curing process.

Compression test after 7, 28, and 120 days was carried out, flexural and pull out test were carried out after 28 days.

4. RESULTS

Table 8 Results of Fresh and Hardened Concrete Test

Group	Mix		Compressive strength Kg/cm ²			Bond strength Kg/cm ²	Bending strength Kg/cm ²	Fresh Concrete (Slump Test) cm
			7 days	28 days	120 days	28 days	28 days	
A	M0	N	320	420	600	120	134.5	20
Group B (volcanic ash)	M1	V.A 1	470	550	980			20
	M2	V.A 2	370	420	940			18
	M3	V.A 3	380	520	930	105	126.5	19
	M4	V.A 4	350	420	820			20
	M5	V.A 5	320	380	730			18
	M6	V.A 6	270	350	800			19
	M7	V.A 7	260	410	780	95	121.5	19
Group C (Fly ash)	M8	F.A1	430	480	850			20
	M9	F.A2	480	540	890			17
	M10	F.A3	450	500	810	100	121.5	19
	M11	F.A4	360	600	850			17
	M12	F.A5	380	450	750			16
	M13	F.A6	280	520	780			18
	M14	F.A7	280	360	720	93	114	16

4.1. Slump test

4.1.1. The effect of different ratios of V.A on the Slump:

As the volcanic ash ratio increases from (0 to 80) % as a replacement of the cement, the slump of the concrete nearly does not affected as shown in Fig. (9)

Figure 9 shows the effect of different ratios of volcanic ash on the slump of concrete

4.1.2. The effect of 10% constant ratio of F.A and different ratio of V.A on the Slump:

As the volcanic ash ratio increases from (0 to 70) % as a replacement of the cement with a 10 % constant ratio of fly ash, the slump of the concrete slightly decreasing non linearly as shown in Fig.(10)

Figure 10 shows the effect of different ratios of volcanic ash with a 10% constant ratio of fly ash on the slump of concrete

Figure 11 Shows comparison between the slump of group A, B and C

As the volcanic ash ratio increases, the slump of concrete for group C (fly ash) mixes are slightly decreasing as shown if Fig. (11).

4.2. Mechanical properties

4.2.1. Compressive Strength

4.2.1.1. The effect of different ratios of V.A on the compressive strength

Figure 12 The compressive strength increases nonlinearly as the ratio of volcanic ash increases till 40 % as a replacement of cement , and nearly stay constant with a large ratios (50-80) % of volcanic ash as, all compared with M0

Figure 13 The compressive strength increases nonlinearly as the ratio of volcanic ash increases till 40 % as a replacement of cement , and nearly stay constant with a large ratios (50-80) % of volcanic ash, all compared with M0

Figure 14 The compressive strength shows a significant nonlinear increase till 40 % of the volcanic ash as a replacement of cement , and also shows a normal increase with a large ratios (50-80) % of volcanic ash, all compared with M0

4.2.1.2. The effect of 10% F.A + different ratios of V.A on the Compressive strength

Fig. (15) The compressive strength shows a significant nonlinear increase till 30 % of the volcanic ash as a replacement of cement , and nearly stay constant with a large ratios (40-70) % of volcanic ash, all compared with M0

Fig. (16) The compressive strength shows a significant nonlinear increase till 30 % of the volcanic ash as a replacement of cement , and nearly stay constant with a large ratios (40-70) % of volcanic ash, all compared with M0

Figure 17 The compressive strength shows a significant nonlinear increase till 30 % of the volcanic ash as a replacement of cement , and shows a normal increase with a large ratios (40-70) % of volcanic ash, all compared with M0

4.2.1.3. The effect of age on the compressive strength of group B

Figure 18 The compressive strength raises slowly after (7 and 28) days , and then shows an incredible increase at the long age (120-days)

4.2.1.3. The effect of age on the compressive strength of group C

Figure 19 The compressive strength raises slowly after (7 and 28) days , and then shows an incredible increase at the long age (120-day)

4.2.2. Bending Strength

4.2.2.1. The effect of different ratios of V.A (Group B) on the Bending strength:

Figure 20 The bending strength shows a nonlinear decrease as the ratio of volcanic ash increases as a replacement of the cement, as compared with M0

4.2.2.2. The effect of 10% F.A + different ratios of V.A on the Bending strength

Figure 21 The bending strength shows a nonlinear increase till 30% of volcanic ash as a replacement of the cement, as compared with M0

4.2.3. Pull out Strength

4.2.3.1. The effect of different ratios of V.A (Group B) on the Pull out strength

Figure 22 The pull out strength slightly shows a nonlinear decrease as the ratio of volcanic ash increases as a replacement of the cement, compared with M0

4.2.3.2. The effect of 10% F.A + different ratios of V.A (Group c) on the Pull out strength

Figure 23 The pull out strength slightly shows an increase till 30% of volcanic ash as a replacement of the cement, and then decreases nonlinearly till 70%, all compared with M0

4.2.4. Scanning Electronic Microscope (SEM) examinations for high cement concrete as affected by fly ash using volcanic ash.

Scanning electron microscopy was carried out in faculty of agriculture at Mansoura University for concrete samples using electronic microscope type JEOL JSM-651OLV, of magnification 5000 and 6500 .

4.2.4.1. For Mix F1&F7 (10% F.A + 10% V.A + 80% Cement) & (10% F.A + 70% V.A + 20% Cement)

Since 10% F.A + 10% V.A revealed a positive effect on the compressive strength of concrete, it was of interest to identify its effect by SEM examinations at different curing ages. Fig. (24) present the SEM analysis of the 10% F.A + 10% V.A + 80% Cement samples cured for 120 days. SEM technique has been adopted to recognize the extent of the CSH formation, i.e. the extent of the hydration process. Fig. (24) for (10% F.A + 10% V.A + 80% Cement) concrete shows that moderate effect on the compressive strength and no cracking is evident, i.e. a moderate calcium silicate hydrate CSH formation .Fig. (25) reveal that effect of 10% F.A + 70% V.A + 20% Cement has enhanced the hydration process converting calcium hydroxide CH to CSH with 10% F.A + 70% V.A + 20% Cement concrete, but it has higher effect on the compressive strength of concrete.

Fig. (25) demonstrate the effect of 70% V.A on the hydration process with (10% F.A) that reveal no cracking with concrete. The SEM examinations support the hydration product under the effect of 70% V.A is accompanied by growth and rearrangement of the reaction products into a confined space, thus no expansion and no internal pressures to give trans granular cracking with a significant increasing in concrete strength.

Figure 24 SEM For Mix F1

4.2.4.2. For Mix S7 (10% F.A + 70% V.A + 20% Cement):

Figure 25 SEM For Mix F7

5. CONCLUSIONS

1. The different ratios of volcanic ash (Group B) nearly doesn't affect the fresh concrete properties (Slump), comparing with the bench mark mix (Group A).
2. The 10 % fly ash (Group C) slightly decreasing the fresh concrete properties (Slump), comparing with the bench mark mix (Group A).
3. $F_{cu-28day} = (0.4-0.6) F_{cu-120days}$ (Igneous Concrete) (Group B and C).

4. $F_{cu-28day} = (0.7) F_{cu-120days}$ (Normal Concrete) (Group A).
5. $F_{cu-7day} = (1.15-1.3) F_{cu-28days}$ (Igneous Concrete) (Group B).
6. $F_{cu-7day} = (1.2-1.4) F_{cu-28days}$ (Igneous Concrete) (Group C).
7. $F_{cu-7day} = (1.3) F_{cu-28days}$ (Normal Concrete).
8. The V.A1 (M1) Mix which consists of 80% cement, 20% volcanic ash gives the highest compressive strength = 98 MPa.
9. The compressive strength still nearly constant as the volcanic ash increases till 40% as a replacement of the cement, then the strength decreases.
10. At (80, 70 and 60) % (Cement ratio) the (Group B) mixes gives the highest compressive strength, compared to other groups, After 28-days.
11. The 10% Fly ash mixes (Group C) raise the compressive strength by (25-35)% Comparing with the normal mix (Group A), After 28-days.
12. At (80, 70, 60, 50, 40, 30 and 20) % (Cement ratio) the (Group B) mixes gives the highest compressive strength, compared to other Groups, After 120-days.
13. The 10% fly ash mixes (Group C) raise the compressive strength by (25-50)% Comparing with the normal mix (Group A), After 120-days.
14. For group B and C there are a slight different between $F_{cu-7day}$ and $F_{cu-28days}$.
15. For group B and C there are a huge different between $F_{cu-28day}$ and $F_{cu-120days}$.
16. For (Group B) Mixes, as the volcanic ash increases the bending moment decreases comparing with the bench mark mix (Group A)
17. For (Group C) Mixes with constant 10% F.A, as the volcanic ash increases the bending moment decreases comparing with the bench mark mix (Group A)

REFERENCES

- [1] A. Admure, V. Nagarakar, S. Padalkar, S. Bhamre, A. Tupe, Experimental study on green concrete, Int. Res. J. Eng. Technol. (IRJET), 4 (4) (2017), E-ISSN: 2395 – 0056, p-ISSN: 2395-0072.
- [2] A.B. AL-zubiad, K.M.Shabeeb, A.I.Ali, “Study The Effect of Recycled Glass on The Mechanical Properties of Green Concrete”, Sciencedirect, Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES17, 21-24 April 2017, Beirut Lebanon.
- [3] B. Suhendro, Toward green concrete for better sustainable environment, Procedia Eng. 95 (2014), 305-320.
- [4] B. Uzal, L. Turanli, High-volume natural pozzolana concrete for structural applications, Materials. J. 104 (5) (2007) 535- 538.
- [5] C. Meyer, Concrete as a green Building Material, Department of Civil Engineering and Engineering Mechanics, Columbia University, New York, 2005.
- [6] Djerbi A., Bonnet S., Khelidj A., Baroghel-Bouny V., 2008, “Influence of traversing crack on chloride diffusion into concrete”, Cement and Concrete Research, Vol.38, N°6, pp.877-883.
- [7] Egyptian Specification (1109:2008).
- [8] Egyptian Standards (4756-1/2013), composition, specification and conformity criteria for common cements.
- [9] Ghassan, A.H., Hilmi, B.M., 2010, “Study on properties of rice husk ash and its use as cement replacement material”, Mater.Res.13, 2 Sao Carlos, June, 2010.

- [10] Harlad Justnes, 2016, “How SCMs Improve Concrete Durability”, A fundamental View, Fourth International Conference on Sustainable Construction Materials and Technologies, SCMT4, Las Vegas, USA, August 7-11, 2016.
- [11] Hobart King, “Igneous Andesite Rock”, WWW.Geology.com, June, 2015.
- [12] <https://www.statista.com/statistics/219343/cement-production-worldwide/>.Accessed,January 24, 2019.
- [13] Ibrahim A. S AL-Jumaily, Nahla Naji, Qays Kareem, “ An Overview of pozzolanic materials on properties of concrete ”, International Journal of enhanced Research in science Technology & Enginnering, ISSN : 2319-7463, Vo/4 Issue3, March-2015.
- [14] J.S. Damtoft, M. Glavind, C.M. Petersen, Danish Centre for Green Concrete, in Proceedings of CANMET/ACI International Conference, San Fransisco, 2001.
- [15] Johari, M.A.M., Brooks.J.J., Kabir.S., Rivard.P., 2011, “Influence of Supplementary Cementitious Materials on Engineering Properties of High Strength Concrete”, Const. Build. Mater.J. 25 (5), 2636-2648.
- [16] Khedr, S.A., Abou-Zeid, M.N. (1994), “Characteristics of Silica fume Concrete, Journal of Materials in Civil Engineering”, 6 357-375.
- [17] M.C. Dhoka, Green Concrete Using Industrial Waste of Marble Poeder, Quarry Dust and Paper Pulp, Int. J. Eng. Sci. Invention, 2 (10) (2013) 67_70, ISSN (online): 2319_ 6734, ISSN: 2319-6726.
- [18] Meyer, C. (2005), “Concrete as Green Building Material”, NewYork. Department of Civil Engineering and Mechanics, Colombia University.
- [19] N. Mehta, A. Sehraya, A. Malik, Green concrete: An innovative approach to sustainable development, Int. J. Adv. Eng. Sci. Res., 2 (9) 1_11 (2015) ISSN: 2349 _ 3607 (online), ISSN : 2349 _ 4824
- [20] Orchared, D.F., “Concrete Technology”, Properties and Testing of aggregate, 3rd Edition, Applied Science Publishers, 1976, London, pp. 1-5.
- [21] “Properties of Andesite”, WWW.Buzzle.com/articles/properties-and-uses-ofandesite-rock.html.
- [22] R. Malpani, S.K. Jegarkal, R. Shepur, R. Kiran, Effect of Marble Sludge Powder and Quarry Rock Dust as Partial Replacement for Fine Aggregates on Properties of Concrete, Int. J. Innovative Technol. Explor. Eng. (2014), 4 (1) 2, ISSN: 2278-3075.
- [23] S.C Kou, Chi Sun Pon, A novel polymer concrete made with recycled glass aggregates, fly ash and metakaolin, Constr. Build. Mater. 41 (2013) 146_151.
- [24] Sarah Khan, Naveen Maheshwari, Gauri Aglave, Rishabh Arora, 2020, Experimental design of green concrete and assessing its suitability as a sustainable building material, Department of Civil Engineering, Mangalam University, India.
- [25] Sengul, O. (2005), “ Effects of pozzolanic materials on the mechanical properties and chloride diffusivity of concrete ”, PhD thesis, Istanbul Technical University, Istanbul, Turkey.
- [26] Stern, R.J., Hedge, C.E., “Geochronologic and Isotropic Constraints on late Precambrian Crustal Evolution in the Eastern Desert of Egypt”, Am.J.Sci, 1985, pp. 97-127.
- [27] T. Horiguchi, T. Kilkuchi, Y. Nakagawa, Physical properties of CLSM using high volumes of incineration ash from sewage sludge, Special Publication 242 (2007).
- [28] T.Blaszczyński,M.Król, “Durability of Green Concrete”, Proceedings of 8th International Conference AMCM 2014, Wroclaw, Poland, Pp, 530-540, June, 2014.

- [29] Touil B., Ghomari F., Bezzar A., Khelidj A., Bonnet S., 2017, ‘‘Effects of temperature on chloride diffusion in saturated concrete’’, ACI Materials Journal, vol 114 N°05, doi : 10.14359/51688929.
- [30] Uzal, B., Turonli, L., and Mehata, P.k., (2007), ‘‘High volume material pozzolan concrete for structural applications’’, Material Journal 140 (5). Septamber, 535-538.
- [31] Wang, T.2017.U.S. and world cement production 2017, Statistic. Statista.