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THE EFFECT OF GLASS FIBER ON FLY ASH BASED GEOPOLYMER CONCRETE USING RECYCLED AGGREGATES

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Abstract – *This study highlights the role of glass fibre in Geopolymer concrete made of fly ash and recycled aggregates. The recycled aggregate is sourced from the storage of waste materials at Chandigarh University concrete laboratory. The recycled aggregates were incorporated as a partial substitute for natural coarse aggregate in geopolymer concrete at 50, 80, and 100 percent by weight, and the results were compared to natural coarse aggregate with the same ratios. Class F fly ash is utilised as the source material for the Geopolymer, which is made using 14 M sodium hydroxide and Na2SiO3 alkali activators and brought in from local sources as the binder material. At 7 and 28 days, ordinary geopolymer concrete and reinforced glass fibre geopolymer concrete were tested for indirect tensile, flexural, and compressive strengths. The compressive, indirect tensile and flexure strengths of geopolymer concrete decrease when the recycled aggregate content excesses, according to the findings. Recycled aggregates show greater shrinkage compared to non-recycled aggregates. However, because the lower shrinkage of geopolymer concrete compensates for the higher shrinkage of recycled aggregates, it can not be considered an issue. This results in shrinkages that are substantially lower than those expected for Geopolymer concrete of equivalent strength.. Because of the chemical reaction between the alkali activated geopolymer paste and fly ash which forms a polymerization process, we can say that compressive strength after 24 hours of curing will not increase significantly with the increasing age of concrete. Ar glass fiber (alkali resistant) with a length of 36 mm was added as a supplement to the GPC with different ratios (0.5-3.5%) by weight of concrete. The results show that 0.5% glass fiber has no effect on the compressive strength, while 1%, 1,5%, 2%, and 2.5% of glass fiber have a very impressive impact on geopolymer. On the other hand, 2.5% and 3% glass fiber reinforced polymers have almost the same result, which means that the strength graph goes down by adding more fibers)*

Key Words*: *Geopolymer concrete, ar glass fiber,recycled aggregates, compressive strength, fly ash, indirect tensile strength.

1.INTRODUCTION

The advancement of science and technology is a continuous process that contributes to the expansion of infrastructure across the world. Any country's growth is dependent on its infrastructure, and concrete plays a vital role in most infrastructures. Thus, we can't imagine any progress without it. This eventually increases the demand for cement. Cement manufacturing in India has increased in recent years, from 207 million metric tonnes in 2010 to 480 million metric tonnes in 2019. According to these estimates, India is the world's second-largest cement manufacturer.

On the other hand, Palomo reported [1], the annual global utilization of concrete is figured out that in 2050, it is expected to reach over 18 billion tonnes. Cement manufacturing operations emit a considerable amount of CO_2, which has an effect on global warming. Approximately 1600 metric tons of green-house gases (CO_2, CH_4, and N_2O) are produced by cement industries around the globe. McCaffrey [2] estimated that ordinary portland cement production is increasing at a rate of around 3% each year, and this significantly affects global warming. In the last few years, researchers have been making an attempt to develop sustainable and environmentally-friendly solutions for producing a spacious amount of concrete for the global construction industry. Many materials and approaches have been investigated in order to discover a viable replacement for portland cement that can be used as a partial or total replacement. Davidovits [3] proposed that waste or by-product materials containing aluminium (Al) and silicon (Si), such as husk ash and fly ash (FA), can be employed with an alkaline to interact as a source material for geological roots to demonstrate a new binder. The binders were then named geopolymers by him. Which we can say is concrete without cement. Because geopolymer concrete has a high early strength, their setting timeframes can be managed, and they stay magnificent for a long time without needing to be repaired, they are suitable for construction and repairing infrastructures, as well as precasting units [4]. Geopolymer concrete has a lot of features, including early strength, moderate consolidation, stability to freeze-thaw, sulphate resistance, and resistance to corrosion [5]. The geopolymer binder is a cementious substance with low carbon dioxide. These high alkaline binders do not generate a combined alkaline reaction. They do not rely on limestone calcination to release CO_2. This technique has the potential to reduce CO_2 emissions from cement and aggregate companies by up to 80%. [6]. In addition, fibre adhesion as a replacement for traditional steel reinforcement has been a key breakthrough in the building industry over the years. Because steel reinforcement is becoming more expensive, artificial and natural fibres are being investigated that can be used in concrete reinforcing. Fibres can slow the progression of shrinkage cracks in concrete mixes and improve the post-crack strength of the material [7]. Concrete's workability is reduced while using fibers, but its density, compressive, tensile, and flexural strengths are improved [8,9]. Furthermore, with significant construction progress around the world, some of the preliminary concrete structures need to be repaired, rebuilt or demolished due to major damage. Recycled concrete is a type of recycled aggregate created by crushing leftover concrete, which can then be partially or totally replaced with natural aggregates to create new concrete, and it is an efficient method of converting waste concrete [10]. Seventy-five to eighty percent of concrete is made up of aggregates, thus using recycled materials has a great deal of potential. Natural aggregate can be replaced with recycled aggregate to reduce the amount of natural aggregate needed. However, due to the presence on their surfaces of a considerable variety of influential porous mortars and microcracks, recycled aggregates have a low visible density, absorption of high water, unbalanced gradation, poor crush resistance, low impact strength, and low durability [11]. In addition, RCA is frequently combined with organic and inorganic materials. The presence of recycled aggregates has a negative impact on the workability, mechanical characteristics, and durability of recycled concrete, limiting its widespread use in concrete production [12]. However, more research based on the impact of glass fibres on geopolymer concrete with reused aggregates is needed.

This study compares the effect of ar (alkali resistance) glass fibre on Geopolymer concrete made from fly ash with recycled particles to standard geopolymer concrete with natural aggregates, adopting the Compressive Strength Test (ASTM-C39), Flexural strength (IS: 516-1959), and Split Tensile Strength (IS: 5816-1999). As a binder in this experimental investigation into GPC, caustic soda and sodium silicate were chosen. On the other hand, the mass ratio of (Na2SiO3/NaOH) has a big impact on GPC's performance and mechanical characteristics. According to the available research, a range between 1.3 and 2.8 is suitable for practical use. However, in order to maintain the GPC's economy, a medium value of 1.5 was chosen for this study, along with extra water and plasticizer. And the other important issue is to achieve the optimum result while making GPC is choosing an adequate ratio between 0.3 to 0.6 for the trial use of (AAL) to (FA). The goal of this study is to determine the best AAL-to-FA ratio for achieving optimum compressive strength. Alternatively, finding an optimum added water content into the caustic soda or NaOH solution to reduce the cost with no characteristic changes, and also choosing the appropriate amount of glass fiber among different percentages used in the current experiment to achieve the optimum result. And also, in this research, 50,80 and 100 percent recycled aggregates has been investigated to find the suitable percentage of NCA replacement to reduce the cost, and also, the amount of waste is increasing globally.

2. Experimental setup

Materials

Ar (alkali resistance) glass fiber: Glass fibres are formed of silicon oxide with a slight fraction of other oxides added. They are famous for their great strength, good temperature tolerance, stain resistance, and low cost. Glass fibres are typically spherical and straight, with diameters ranging from 0.005 to 0.015 mm. They may also be combined together to form a bundle of glass fibres with a diameter of up to 1.3 mm. In this experiment, ar glass fibre was utilised, which is a glass fibre with enhanced zirconium oxide to assist resist alkalinity attack and is appropriate for use in concrete.

Fig. 1. Ar glass fiber

Fly ash: is a waste of melted charcoal combustion, collected by mechanical or electrostatic separators from thermal power plant flue gases. The raw material for the Geopolymer is Class F fly ash, which was acquired from a local area near the Mohali-Kharar flyover in India. Such kind of F.A complies with ASTM C 618; table (1) shows the chemical composition of fly ash which is determined by X-Ray fluorescence analysis.

TABLE 1. composition of fly ash

Symbol	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O
Content	0.08	1.27	25.39	47.69	0.16	0.37	1.56
Symbol	MnO	Fe_2O_3	L.O.I	CaO			
Content	0.14	11.72	3.34	7.93			

Alkaline materials: Geopolymer concrete is a kind of concrete which can also be made without the use of Portland cement. Fly ash containing (Al) and (Si) can be combined with an alkaline to function as a source material for geological roots to generate binder. In this paper, caustic soda (NaOH) and sodium silicate (Na2SiO3) are being used as alkaline materials to produce an alkaline solution. Figure (2-3) illustrates Caustic soda pellets and sodium silicate liquid, while table (2) illustrates their chemical composition.

Fig. 2. Caustic soda (NaOH)

Fig. 3. (Na2SiO3)

TABLE 2 .Chemical composition of sodium hydroxide and sodium silicate.

NaOH constituent	percentage	Na_2SiO_3 constituent	percentage
Carbonate	2.00	Silica	34.78
chloride	0.01	Sodium oxide	16.22
Sulphate	0.05	H_2O	49
Lead	0.001	Total solids	51
Iron	0.001	-	-
potassium	0.10	-	-

Coarse aggregates (RCA): Recycled aggregates are constituted of crushed, graded inorganic particles collected from building and demolition waste. In the present paper, the recycled aggregates are sourced from the storage of waste materials at Chandigarh University concrete laboratory. The recycled aggregates were incorporated as a partial substitute for natural coarse aggregate in geopolymer concrete at 50, 80, and 100 percent by weight, and then compared to natural coarse aggregate at the same ratios. The disintegrated concrete was carefully crushed and irrigated, with 60 percent 10 mm, 20 mm, and 40%, with maximum grain size of 40 mm. According to ASTM C 128, RCA has a specific gravity of 2.2 to 2.6, whereas NCA has a specific gravity of 2.7.

Fig.4. Recycled coarse aggregates

Fine aggregates: In the present paper, the fine aggregate that was used during the experiment was clean river sand that flowed through a 4.75 mm sieve and remained on a 0.075 mm sieve having a specific gravity of 2.66 and a grading zone III following IS 383:1870. The physical properties of (N.A), RCA and fine aggregates are mentioned in Table 3.

TABLE 3. Physical properties of aggregate

properties	Natural coarse aggregates (N.A)	Fine Aggregates (F.A)	Recycled coarse aggregates (RCA)
B.d (Kg/m3)	1522	1650	1250
Sp. Gravity	2.7	2.66	2.5
W. ab (%)	0.6	0.9	4.8
F. M	7.08	2.4	7.47

Superplasticizer: They are known as water reducers, and they allow for a 30% reduction in water content. The need for water rises whenever fly ash is increased, leading to poor workability, which affects the target strength. To tackle this disadvantage, a superplasticizer is necessary to provide the appropriate degree of workability. As per previous literature, 1 to 3 liters per cubic meter of superplasticizer was proposed. Hence, in the present study, 2% superplasticizer by weight of fly ash has been used. The properties of the above superplasticizer are mentioned in below table 4.

TABLE 4. properties of superplasticizer

properties	**Observed value**
Specific gravity	1.15
PH	6.5-9
Appearance	Brown free flowing liquid
Chemical base	Modified naphthalene formaldehyde

3. Mix proportions and methodology

Now that we are familiar with the properties of materials used in this study, which we have already explained previously, first of all, we will go through the preparation of alkaline activators. In this experimental study, following the mix design condition, NaOH was 80 kg/m^3 at 14 M and Na_2SiO_3 was 120 kg/m3 at 14 M. Although alkaline solutions of 10, 12, 16, and 20 M have already been produced and used for fly ash activation in earlier research, we found 14 M to be much more effective. The solution was prepared using clear drinking water, and the weight ratio of alkaline liquid to fly ash was set at 0.5. The activator was created by combining a solution of Na2SiO3 and NaOH of 97 percent pure crystalline sodium hydroxide, and sodium silicate. 24 hours before utilization, sodium hydroxide solution was prepared to regulate the rise in temperature due to its dissolution in the water. To make the alkaline liquid, sodium silicate (Na2SiO3) solution and Caustic soda (NaOH) were integrated together. The source material for the Geopolymer, which is brought in from local sources as the binder material, is fly ash of class F. The recycled aggregates are sourced from the storage of waste materials at Chandigarh University concrete laboratory. The glass fibre was added in various quantities of 0.3 percent, 1%, 2%, 3%, and 3.5% by weight of concrete. After the chemicals were combined with the aggregate, the glass fibre was added to the mixture. Ar glass fibres are famous for their excellent strength, temperature resistance, alkali resistance, and corrosion resistance.

3.1 The impact of added water on the compressive strength of GPC employing NCA.

To know the effect of adding extra water into sodium hydroxide solution to reduce the cost with no characteristic changes and also to preserve concrete workability, four mixed designs were set. One without added water and the other samples with 10, 20 and 30 kg per cubic meter of additional water were made. These mixed designs are presented in Table 5.

Table.5 show the effect of extra additional water

sample	GPC1	GPC2	GPC3	GPC4
Fly ash	400	400	400	400
NaOH	80	80	80	80
Na_2SiO_3	120	120	120	120
F.A	505	505	505	505
Superplas -ticizer	8	8	8	8
C.A	1178	1178	1178	1178
Additional water	0	10	20	30
unit	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3

3.2 The influence of sodium hydroxide solution concentration on the compressive strength of GPC

In this step, four mixed designs were adjusted to explore and optimise the empirical effect of the concentration of caustic soda solution on the compressive strength of GPC.Table (6) reflects these hybrid designs.

TABLE.6 *show the effect of Sodium Hydroxide concentration*

sample	GPC 40	GPC 45	GPC 50	GPC 55
Fly ash	400	400	400	400
NaOH	80	80	80	80
Na_2SiO_3	120	120	120	120
F.A	505	505	505	505
S.P	8	8	8	8
C.A	1178	1178	1178	1178
Additional water	10	10	10	10
Unit	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3
NaOH (M)	10	12	14	16

3.3 The effect of alkali activator solution to fly ash weight ratio on GPC employing NCA.

Strength starts to rise when the ratio of solution (NaOH + Na_2SiO_3) to fly ash rises. Based on the results of the previous phases, this section investigates the influence of the weight ratio parameter of alkaline activator liquid along with fly ash on compressive strength and efficiency improvement. 4 mixed designs were adjusted. In order to keep the test conditions constant, the ratio of Na_2SiO_3 solution to NaOH in all designs was 1.5 and the concentration of caustic soda or NaOH solution was 14 Mole. The mixed designs of this section are presented in Table 7.

TABLE.7 show the Effect of AAS to Fly Ash by weight ration

sample	GPC M10	GPC M12	GPC M14	GPC M16
Fly ash	400	400	400	400
NaOH	80	80	80	80
Na_2SiO_3	120	120	120	120
F.A	505	505	505	505
S.P	8	8	8	8
C.A	1178	1178	1178	1178
Additional water	10	10	10	10
Unit	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3
AAL/FA	0.4	0.45	0.5	0.55

3.4 Effect of $NaOH/Na_2SiO_3$ ratio by weight on compressive strength of GPC.

One of the important elements to consider while making geopolymer concrete is the Caustic Soda to sodium silicate ratio. The solution alkaline activator along with the fly ash weight ratio was set at 0.5. Table 8 represents the mixed design of this step.

TABLE. 8 shows the effect of $NaOH/Na_2SiO_3$ by weight

sample	GPC1	GPC1.5	GPC2	GPC2.5	GPC3
Fly ash	400	400	400	400	400
NaOH 14(M)	100	80	66	59	50
Na_2SiO_3	100	120	134	143	150
F.A	505	505	505	505	505
S.P	8	8	8	8	8
C.A	1178	1178	1178	1178	1178
Additional water	10	10	10	10	10
Unit	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3
$NaOH/Na_2SiO_3$	1	1.5	2	2.5	3

3.5 The effect of recycled aggregate on the compressive strength of GPC

In the current study, recycled aggregates were utilised as a component substitute for natural coarse aggregate in geopolymer concrete at 50%, 80%, and 100% by weight and then compared to natural coarse aggregate. The mixed design of this step is presented on table 9.

sample	GPC(0)	GPC50	GPC80	GPC100
Fly ash	400	400	400	400
RCA	-	589	942	1178
F.A	505	505	505	505
NCA	1178	589	237	-
NaOH	80	80	80	80
Na_2SiO_3	120	120	120	120
S.P	8	8	8	8
Additional water	10	10	10	10
Unit	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3
RCA(%)	0	50	80	100

3.6 Glass fiber's effect on geopolymer concrete using recycled aggregates.

This section includes the main aspect of the research, which is to investigate the effect of glass fibers on geopolymer concrete. Glass fibers were added in different amounts of 0.3, 1, 2, 3 and 3.5% based on the weight of the concrete. After mixing the chemicals and aggregates, glass fibers were added to the mixture. Five mixed designs were set using natural coarse aggregates. In all designs, the sodium silicate solution to Caustic soda ratio is 1.5, and the Caustic soda solution concentration is 14 M. The mixed designs of this section are presented in Table 10.

TABLE.10 show the effect of Gf on GPC

admixure	GPC (0.3)	GPC (1)	GPC (2)	GPC (3)	GPC (3.5)
Fly ash	400	400	400	400	400
NaOH	80	80	80	80	80
Na_2SiO_3	120	120	120	120	120
F.A	505	505	505	505	505
S.P	8	8	8	8	8
C.A	1178	1178	1178	1178	1178
Additional water	10	10	10	10	10
Unit	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3
Glass fiber(%)	0.3	1	2	3	3.5

4. **Preparation of samples**

First, alkaline activating solutions were prepared to make the samples. For this purpose, in the first step, sodium hydroxide solution with a specific concentration was prepared in each section. This solution is then mixed with sodium silicate and superplasticizer solutions, and then mixed according to the mixing designs of each section. To manage the temperature rise resulting from sodium hydroxide dissolving in water, the solution was prepared 24 hours before usage. Following that, on the days of the experiment in the laboratory, natural coarse and fine aggregates were integrated for around 4-5 minutes in a laboratory pan mixer. Then, fly ash was added in the prescribed amount and lasted for approximately 2 minutes. Then, after dry mixture, alkaline solution and superplasticizer were applied to the dry material and again mixed for another five minutes. The same procedure was done along with recycled aggregates with specified mix designs to make comparisons. After completion of mixing, slump and compaction factor tests were performed to distinguish the workability of fresh concrete mix, as per the BS EN 12350 guidelines. The 150 mm diameter concrete cubes were filled to compressive strength test following the BS EN 1230-6. The 15cm diameter and 30 cm height concrete cylinders were tumped to the split tenslie test in adherence with BS EN 12390-6. In addition, the prisms with dimensions of 100*100*500 mm were cast for flexural strength testing in accordance with the BS EN 12390-5 protocol. All specimens were appropriately cast in three layers and laid out horizontally. Each layer was carefully tamped and vibrated for 10 seconds before putting in the oven for thermic curing at a temperature of 90 ^{0}C for 24 hours. Geopolymer concrete samples were stored at normal room temperature after heat curing and checked for 7 and 28 days since being reported.

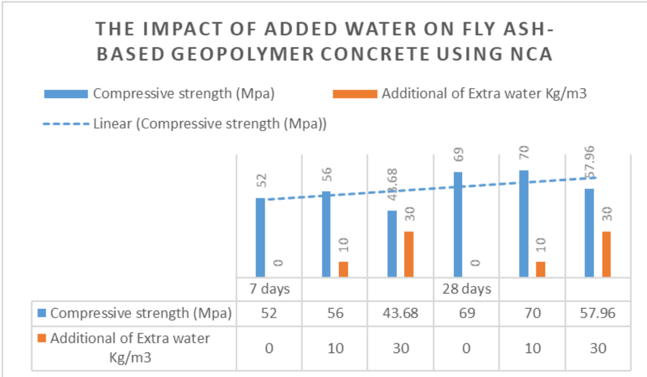
Figure 5. during preparing GPC

5. Result and discussion

5.1 The effect of added water on fly ash-based geopolymer concrete using NCA

Figure 5 is showing the result of added excess water on geopolymer concrete which is based on compressive strength. The result implies that the amount of extra water in a mixed design has a major effect on geopolymer concrete's compressive strength. The 7 and 28 day compressive strength of samples that did not add water to their composition were measured as 52 and 69 MPa, respectively. By adding water to 10kg/m³, the maximum compressive strengths of 7 and 28 days were measured at 56 and 70 MPa. By adding more water to the concrete composition, the compressive strength was reduced, so that in the case of 30 kg/m³ of additional water, the compressive strength of 7 and 28 days was reduced by approximately 16 and 14%. The reason can be related to the parameter of weight ratio of water to dry blending, in which water contains the total weight of water in the concrete mix, and dry blending includes the weight of all dry matter participating in geopolymerization, including aluminosilicate source, available dry matter in the solution of sodium silicate, and Caustic soda. Increasing this ratio (more than the optimal ratio) significantly reduces the compressive strength of GPC. This can be due to the low performance of the geopolymer concrete and the formation of pores due to the dryness of the geopolymer concrete. According to the results, in this experimental study, the additional extra water which was used was 10kg/m³.

Figure. **Figure. 5:** show the Effect of extra additional water on FA using NCA.

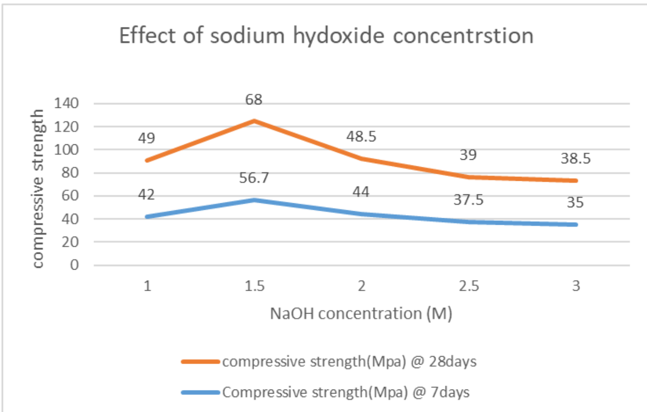


	7 days			28 days		
Compressive strength (Mpa)	52	56	43.68	69	70	57.96
Additional of Extra water Kg/m3	0	10	30	0	10	30

5.2 The impact of the concentration of sodium hydroxide solution on the compressive strength of GPC

The study's findings reveal that the accumulation of sodium hydroxide solution has an effect on the compressive strength of geopolymer concrete and also the optimization of this parameter are shown in Figure (6). The minimum compressive strength of 7 and 28 days in the case of employing sodium hydroxide 10 mol was determined at 48.5 and 52 MPa, respectively. Based on the findings, when the sodium hydroxide solution concentration was raised from 10 to 14 mol/L, the compressive strength of 7 and 28 days increased, resulting in higher compressive strength. However, there was no significant increase in compressive strength with increasing the concentration from 14 to 16 mol. This could be because by increasing the content of caustic soda solution above the ideal limit of 14 mol, more hydroxide ions will accelerate in the aluminosilicate gel immediately after the resumption of the first stages of geopolymerization. This can interrupt the geopolymerization reaction and reduce the process of increasing the compressive strength or even reduce the compressive strength of GPC. According to the results, to continue the experiment, a 14 mol concentration of sodium hydroxide was chosen.

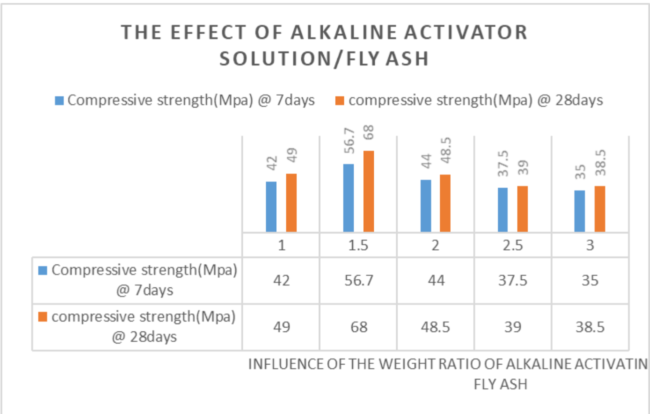
Figure. 6 Effect of sodium hydroxide concentration



5.3 The effect of alkali activator solution along with fly ash weight ratio on GPC employing NCA.

Figure (7) shows the findings of a study on the influence of the weight ratio of alkaline activating solution to fly ash which is determining the compressive strength of geopolymer concrete based on fly ash (7). As the results show, this parameter has a considerable impact on the compressive strength of GPC. At a ratio of 0.4, the compressive strengths of 7 and 28 days were measured at 50 and 56 MPa. By increasing this ratio to 0.5, the compressive strength of seven and 28 days increased by approximately 18 and 21% and the maximum compressive strength of 7 and 28 days was obtained. On the other hand, increasing this ratio increases the amount of alkaline activating solution and consequently increases the quantity of geopolymerization and the creation of more geopolymer gel, which results in increased compressive strength of geopolymer concrete. Consequently, when this ratio was increased to 0.55, the 7 and 28-day compressive strength dropped to around 14 and 17%, respectively. The reason for this can be related to the increase in the ratio of water to dry blending, by increasing this ratio. According to the results, 0.5 was selected as the optimal ratio for this experiment.

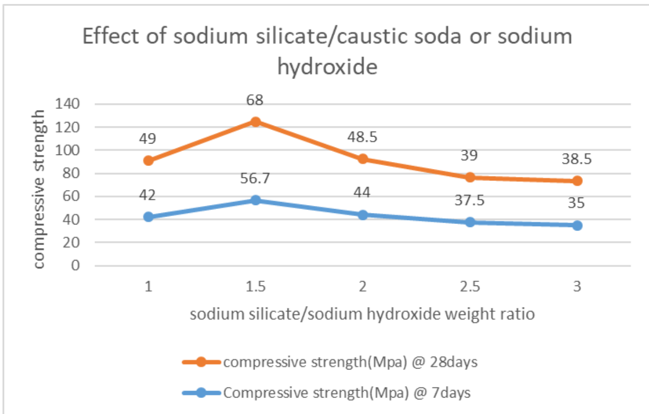
Figure. 7. Effect of AAL/FA



5.4 The impact of the weight ratio of sodium silicate solution to sodium hydroxide on the compressive strength of geopolymer concrete.

Figure (8) depicts the effects of the NaOH/Na2SiO3 weight ratio on the compressive strength of GPC. When the weight ratio of sodium silicate solution to caustic soda is equal to one, the compressive strength of 7 and 28 days is 42 and 49 MPa, respectively. With increasing relative to 1.5, the compressive strengths of 7 and 28 days increased significantly (35 & 40%) to 56.7 and 68 MPa. Further on, by increasing this ratio to 3, the compressive strength decreased significantly, so that in the ratio of 3, the compressive strength of 7 & 28 days decreased by 28% & 30%, in comparison to1.5. As a result of this study, 1.5 was measured as the optimum ratio for this experiment. The role of the alkaline activating solution, especially sodium hydroxide, is to dissolve the silicon and aluminum in the aluminosilicate sources and to produce SiO4 and AlO4 to produce the geopolymer gel. Adding a silicate solution such as sodium silicate to the solution increases the amount of SiO4 and the quantity of geopolymerization reaction. Geopolymer concrete's compressive strength is increased. Adding a small portion of sodium silicate solution (less than the ideal ratio) decreases the compressive strength because of the lower silicon content in the solution and, consequently, the lower SiO4 content. But on the other hand, adding an excess amount (more than the optimal ratio) of sodium silicate also reduces the compressive strength because, in this case, excessive amounts of SiO_4 are produced, while the amount of AlO4 in the composition is constant (or limited) so that the Al/Si from the optimal range, the compressive strength decreases.

Figure.8 Effect of sodium silicate/caustic soda or sodium hydroxide.



5.5 The effect of recycled aggregates on the compressive strength of geopolymer concrete.

The impact of recycled aggregate on the compressive strength of geopolymer concrete with 50%, 80% and 100% replacement by weight is illustrated in table (11). You can see that GPC enhances compressive strength by almost 9-14% from 7 to 28 days. Using 100% NCA, the other studies reported a 9% increase in compressive strength. On the other hand, the study revealed that the compressive strength of geopolymer concrete was higher than reduced by increasing the recycled aggregate content between 7 and 28 days, approximately 15% & 18%. This low rate is due to the fact that most of the geopolymerization reactions occur within the first few days of curing in GPC.. The result shows that GPC used 100% NCA following the mix design which was already presented in table (9). The average stress rate became 54.65 Mpa in 7 and 28 days. On the other hand, for the same mix design, three types of recycled aggregates were carried out. By replacing 50% of the recycled aggregates, the average compressive strength for 28 days becomes 35 and 42 Mpa, and by increasing the RCA content to 80%

replacement, the result shows for 7 and 28 days, 32 and 39 Mpa. Finally, if we use 100 percent recycled aggregates, the result shows that the average stress of 54 and 65 Mpa using 100% NCA decreased to 31 and 37 Mpa gradually.

TABLE.11 show the effect of RCA on Compressive strength

Sample type	Replacement %	Compressive strength at 7days	Compressive Strength at 28days
GPC 0	0	54 MPa	65MPa
GPC 50	50	35 MPa	42 MPa
GPC 80	80	32 MPa	39 MPa
GPC 100	100	31 MPa	37 MPa

5.6 Use of glass fiber along with RCA in geopolymer concrete and it is impact

This section shows the compressive, tensile, and flexural strengths of geopolymer concrete prepared with three different types of recycled aggregates; 50%, 80%, and 100% replacement with NCA. On the other hand, we have added glass fiber with different proportions by weight of concrete, which is gradually 0.3%, 1%, 2%, 3% and 3.5% to know the influence of glass fibre on geopolymer concrete based on fly ash. The results are mentioned in table (12).

Table (11) illustrates the result of employing recycled aggregates with different components of 0%, 50%, 80% and 100% replacement, whereas the author used glass fiber as an admixture by weight of concrete gradually 0.3% with 50%.80% and 100% RCA. For 7 & 28 days, the average compressive strength was 45 and 49.56 Mpa, respectively, and the average tensile strength was 5.99 and 6.1Mpa. Finally, for flexure strength, the results shown for 7 and 28 days using 50% RCA with 0.3% glass fiber was 9,2 and 12.3Mpa. Similarly, for 80% replacement of RCA with NCA by adding 0.3% glass fiber, the compressive strength for 7 and 28 days becomes 37 and 46.02 Mpa, and the average tensile strength becomes 5.1 and 5.6 Mpa. Finally, the flexure strength for 7 and 28 days is shown at 4.9 and 5.1 Mpa. Finally, the flexure strength is shown at 8 and 8.7 Mpa. The author continued the experiment by adding 2% glass fiber with 50%, 80%, and 100% replacement of RCA and reported the results, and so on with 3% glass fiber and finally 3.5% glass fiber admixture with different proportions of RCA replacement varying from 50%, 80%, and 100% to determine the compressive, tensile, and flexural strengths, which the results are shown in table (12). According to the results gained from the experiment, adding glass fiber as an admixture to geopolymer concrete based on fly ash using recycled aggregates, the optimum result for adding glass fiber was 3%, which shows a 16% increase in compressive strength and an 18% increase in tensile strength, and finally a 21% increase in flexure strength. As the admixture percentage increased to 3.5%, compressive, tensile, and flexure strengths decreased gradually by 3%, 4%, & 8%.

TABLE.12 Glass fiber's effect on FA-based GPC utilizing RCA.

S.No	G.F %	RCA %	Compressive Strength (MPa) 7-28days	Tensile Strength (Mpa) 7-28 day	Flexure Strength (Mpa) 7-28 days
1	0.3	50	49-56	5.9-6.1	9.2-12.3
2	0.3	80	37-46	5.1-5.6	9.1-12
3	0.3	100	35-37	4.9-5.1	8-8.7
4	1	50	52-58	6.2-6.5	9.5-12.6
5	1	80	37.2-45	4.8-5.2	9-11.5
6	1	100	32-35.7	4.3-4.85	7.8-8.1
7	2	50	55-59	6.3-6.7	9.7-12.8
8	2	80	39-46.2	5-5.3	9.3-12
9	2	100	35.7-41	4.5-4.9	8.2-8.9
10	3	50	56-62	6.5-7	9.99-13
11	3	80	42-49	5.5-5.9	8.7-9.1
12	3	100	37-43	5-5.2	8.6-8.99
13	3.5	50	50-55	6-6.5	9-12
14	3.5	80	40-45	5-5.4	8.1-8.8
15	3.5	100	33-37	4.8-5	7.8-8

Appendix

Abbreviations

1. RCA: Recycled coarse aggregates
2. NCA: Natural coarse aggregates
3. IS: Indian standard
4. GPC: Geopolymer concrete
5. ASTM: American society for testing and materials
6. AAL: Alkali activator liquid
7. FA: Fly ash
8. LOI: Loss of ignition of fly ash
9. XRF: X ray fluorescence
10. B.d : Bulk density
11. Sp gravity: specific gravity
12. W ab : water absorption
13. F.M : fineness modulus
14. G.F: Glass fiber

CONCLUSIONS

In this experimental study, which evaluated the strength properties of glass fibers, the effect of glass fibers was evaluated using F.A, geopolymer concrete containing recycled aggregates. On the other hand, fly ash geopolymer binders have the ability to completely replace cement in concrete and prevent the earth from warming by using waste materials such as fly ash in appropriate proportions and achieving the best value. In addition, some of the most effective properties that affect the compressive strength of geopolymer concrete have been investigated in the present study. Based on the performance, the following conclusions were made.

1. Addition of glass fibers in geopolymer concrete led to changes in the compressive ,tensile and flexure strengths of geopolymer concrete. Utilization of 3% glass fiber by weight of concrete gained the maximum strength among the other proportions which was seen 16% increasing at compressive strength, 18% increase at tensile strength and 21% increasing in flexure strength. As the admixture percentage increased, compressive, tensile and flexure strengths decreased gradually 3%,4% and 8%.
2. Geopolymer concrete strength decreased while the RCA % increased, for 50% replacement the compressive strength decreased between 25 -33%. This issue can be solved by adding fiber and It is because of the loose mortar around the RCA which is not allowing the proper bonding between aggregates and alkali activator solution along with the fly ash.
3. The optimum weight ratio for sodium silicate along with caustic soda for making GPC was 1.5, which gained the maximum compressive strength. On the other hand, the weight ratio of alkaline activating solution to fly-ash plays a key role in gaining the maximum strength of concrete. Among the different ratios, 0.5 leads to the highest compressive strength.
4. Molarity of the AAL also plays vital role for gaining the maximum strength. According to the obtained result geopolymer concrete with 10M alkaline solution gained the minimum strength and with 14 to 16M alkaline solution achieved the maximum strength.
5. Addition of excess water to solids shows a huge effect on the properties of geopolymer concrete especially on compressive, by adding excess water to 10kg/m^3 the maximum compressive strength of geopolymer concrete gained.
6. Increasing the temperature of oven during curing geopolymer upto(80- 90)°C gained the maximum strength among the different concrete specimens, hence with further increasing the temperature to (100 - 120)°C no remarkable changes was seen.

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