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Production of Groundwater Resistance Mortar Using Glass Sand and Polypropylene Fibres

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ABSTRACT

Concrete structures that are submerged in water suffer from attacks by harmful salts and acids such as sulfates and chlorides. Therefore, using waste like polypropylene (PP) fiber to prevent environmental accumulation and glass sand (GS) (rich in silica) may help solve this problem. This study aims at the possibility of replacing 25, 50, and 75% of the fine aggregate with GS and using PP fibers at a rate of 1% of the total volume to produce sustainable mortar. The mechanical and physical properties, including compressive strength, flexural strength, splitting tensile strength, and density, were investigated. The water absorption was also monitored using indirect tests for an indication of the permeability of the mortar. The tests were evaluated on different curing ages (7, 14, 28, and 90 days) by two types of curing mediums: tap water and groundwater. The results indicated that at age 28 days, the specimens cured by groundwater and containing 25% and 50% of GS and 1% PP fiber improved the compressive strength by 7.5% and 7.4%, respectively, while the splitting tensile strength improved by 6.17% and 6.38%, and the flexural strength improved by 11.42% and 10.71%, respectively. In contrast, the specimens containing 75% GS and 1% fiber exhibited a clear reduction in compressive, splitting, and flexural strengths, reaching 7.7%, 6.36%, and 11.44%, respectively. However, the mean reduction of density and water absorption was 4.17% and 0.22%, respectively. The findings of this research introduced a comprehensive understanding of the groundwater-resistant mortar using GS and PP fibers.

1. INTRODUCTION

Over the years, the accumulation of waste has become a serious problem due to the difficulty of disposing of it and the increase in resulting pollution due to the industries expanding in the world. This led to the increased production of adverse waste [1]. These solid wastes involve wood, iron, glass, rubber, ceramics, and plastic. According to the requirements of the World Bank for solid waste management, most countries in the Middle East and low-income countries produce some 1.3 billion tons of solid waste every year which is estimated to rise to 2.2 billion tons around 2025 [2]. Wastes like polyethylene and PP have increased in Malaysia due to incorrect consumption of waste materials. Current rates of waste use are as follows: polyethylene (4.6 ton/day), PP (12.8 ton/day) [3, 4]. India consumes 8 million tons of plastic items year (2008), rising to 12 million tonnes by 2012. Plasticized PVC is wasted greatly because it is utilized to make pipes, window framing, floor coverings, roofing sheets, and wires [5]. Various campaign methods, including landfill, ocean disposal, and burning, have been implemented to mitigate the environmental impact of waste garbage.

However, the outcomes are disappointing. Landfilling hinders plant growth, ocean disposal generates floating garbage, and burning emits poisonous gasses (smoke). Burning plastics or carbon-containing materials releases CO and CO_2 gasses. CO over 35 ppm is harmful [6, 7].

Therefore, engineers and researchers are trying to look for solutions that reduce such solid waste to make the environment cleaner by focusing on providing scientific information on the recycling of this solid waste in a way that maintains the ecological balance. Recently, research indicated the possibility of using glass effectively in concrete by directing the use of glass waste in the concrete production as a partial replacement of cement or sand, where it can be used as a binder that takes an important role in the reaction during hydration in addition to being a filler [8-12].

Concrete specimens that contain glass as a partial replacement of fine aggregates yielded higher compressive strength values than the mixtures in which glass was used as a partial replacement of cement [9]. Other studies indicated that the use of GS as a partial replacement of cement by (10-20%) led to a barely noticeable increase in compressive strength [13-15]. While Esmaeili and Al-Mwanes [16] studied the high-performance glass concrete manufactured from GS that was used as a partial replacement of cement with differing addition rates. The results obtained indicated that the concrete resulted has high mechanical property included compressive, splitting, and bending strength. In addition, the ability of chloride to penetrate the resulting type of concrete decreased, which led to the resistance of this type of concrete to the chloride ion. The main ingredient in glass is silica. Milled (ground) GS as a partial cement substitute in concrete could improve sustainable, energy-efficient, and cost-effective construction of infrastructure. While grinding waste glass into microparticles, pozzolanic interactions with cement hydrates are expected to yield secondary calcium silicate hydroxide (C-S-H), the remaining portion, which has not undergone complete reaction, will function as a filler that seals the pores or diminishes their size, so resulting in denser and more resistant concrete [17]. GS particles can enhance the mechanical characteristics of concrete through their pozzolanic activity [18]. It is important to highlight that GS, which has a particle size of 100 micrometers or smaller, demonstrates a reactive characteristic that is comparable to the pozzolanic reaction observed in concrete [19]. The particles that are finer than 1.18mm show signs of less expansion than normal fine aggregates after conducting an expansion test. When glass is crushed to finer particles of 5 microns, it was found that concrete specimens achieved an increase in compressive strength, which can be accounted for in terms of the pozzolanic nature of fine GS [20]. Wang et al. [21] conducted investigations on the effect of using glass as fine aggregate with three different mixtures, and obtained compressive strengths of 21, 28 and 35 MPa, with replacement ratios of (0-80) %. The obtained results indicated that the compressive strength decreased in a significant way when the replacement ratio was raised to more than 20%. Because of the high brittleness of ordinary concrete, which has low flexural, fracture, and strength properties, it is easy to break after it affects its durability. Therefore, concrete reinforcement is resorted to using fibers that contribute to a clear reduction in the brittleness of concrete and the development of durability [22, 23].

Europe produces around 29 million tons of plastic trash annually, mostly thermoplastic PP and polyethylene (PE). PP representing 19% of European plastics, is harder and more thermally and chemically resistant than PE despite being less dense. PP is used in food wraps, automotive parts, toys, and pipe manufacturing. Nearly 25% of European plastic garbage is thrown away [24]. Landfilled plastic is both a missed opportunity for renewable energy production or recycling and a direct harmful impact on the environment, such as garbage from the oceans entangling ocean organisms or microplastics produced by the degradation of larger waste plastic and transported through the atmosphere even to remote locations with known health risks [25]. Bagherzadeh et al. [26] investigated the effect of using PP fibers in different proportions and different lengths to improve the performance of lightweight concrete. The lengths of the used PP fibers were (6, 12) mm with proportions (0.15, 0.35%) of the cement weight. In comparison with the non-reinforced lightweight concrete, the lightweight concrete enhanced with PP fibers 12 mm long and at a rate of 0.35%, gave an increase of 30.1% in the flexural strength and a 27% increase in splitting tensile strength. Increasing the presence of fibers in the LWC mixture, in addition to the ability of PP fibers help to prevent the occurrence of capillary cracks. All the above-mentioned reasons combined led to improving the quality of the mechanical properties of concrete. Furthermore, Patel et al. [27] explained that research for evaluating the performance of reinforced concrete with PP fibers concluded that the presence of fibers in ordinary concrete allows failure due to spalling, while the nature of failure in fiber-reinforced concrete is swelling in the transverse direction. As far as the compressive strength is concerned, it is improved by (8-16%), as well as the splitting tensile strength. Cho et al. [28] compared the post-cracking behavior of steel fiber-reinforced concrete with PP-reinforced concrete. It has been shown that the use of PP fibers delays stress reduction after cracks occurred in concrete which improves the flexural properties. Also, after the stabilization of cracks, concrete containing PP fibers can withstand any increase in residual load despite the presence of large wide cracks [29, 30]. This research combines the use of glass waste as a percentage of sand at rates of (25, 50, and 75%) and observes the effect of this on the properties of concrete. In addition to the use of PP fibers to improve the splitting tensile strength of the mixtures used. Ahmed et al. [31] investigated the effect of using PP fibers as a partial replacement of sand to produce concrete, where six concrete mixtures were made via using PP fibers as a partial replacement of sand with percentages (0, 8, 16, 24, 32 and 40) %. The laboratory results showed a decrease in unit weight and compressive strength with the increase in the percentage of PP fibers. The percentage of replacing 40% achieved the lowest compressive strength.

The purpose of this study is to exploit waste such as GS to reduce its negative cumulative impact on the environment and produce sustainable concrete with better characteristics compared to traditional concrete, where glass sand contains high silica in its composition, which improves the mechanical properties of the produced concrete. Since concrete suffers from weak tensile strength, exploiting PP fiber waste to improve the mechanical properties of concrete is necessary. Several mechanical tests, such as compressive, flexural, and splitting tensile strengths, were conducted. In addition, physical tests such as water absorption and weight density were conducted to further cover the effects of the waste materials used. In summary, we attempt to decrease the harmful effects of groundwater-containing salts on concrete hydraulic structures by combining the two waste materials and eliminating pollution. The solution suggested through this study is to use a sustainable solution represented by adding waste glass as a percentage of fine aggregate with PP fibers to concrete exposed to groundwater containing harmful salts such as chlorides and sulfates.

2. EXPERIMENTAL PROGRAM

2.1 Material characterization

2.1.1 Cement

The ordinary Portland cement type I is used in this study. The physical and chemical properties of cement are displayed in Table 1 and Table 2, respectively. The cement used in this study meets the Iraqi standard specification No. 5/1984 [32].

2.1.2 Fine aggregate

The sand used in this study passed from a sieve (4.75) mm. The absorption, specific gravity, and sulfate content were (2.65, 0.67%, and 0.15%) respectively. It is conformed to Iraqi Standard No. 45 of 1984 [33].

2.1.3 Glass sand (GS)

The GS was obtained directly from the Sika Iraq company. The GS obtained had a specific gravity of 2.58. The sieve analysis shown in Table 3, while Table 4 shows the chemical composition of GS.

Table 1. Physical properties of ordinary Portland cement

Physical Properties	Test Results	Limit of Iraqi Specific NO.5/1984
Specific surface area (Blain method(m^2/kg)	250	230Min.
Setting time (vicar's apparatus) Initial setting time (hr: min) Final setting time (hr: min)	45	0:45Min.
Compressive strength (MPa)3-day 7 day	10	10Min.
Soundness (Autoclave method) (%)	15	15Min.
Physical properties	23	23Min.

Table 2. Chemical properties of ordinary Portland cement

Oxide Composition	Abbreviation	Content by Weight (%)	Limit of Iraqi Specification NO. 5/1984
Lime	CaO	-	-
silica	SiO_2	-	-
Aluminum	Al_2O_3	-	-
Iron oxide	Fe_2O_3	-	-
magnesia	MgO	5	(5) Max.
sulfate	SO_3	2.5	(2.8) Max.
Loss on ignition	L.O. I	4	(4) Max.
Insoluble	I.R	1.5	(1.5) Max.
Lime	L.S. F	1.02-0.66	(0.66-1.02%)

Table 3. Sieve analysis of GS used

Sieve Size (mm)	Accumulated Passing %
19	100
13.2	99
9.5	88
6.7	54
4.75	30
2.36	8
1.18	2
0.6	1
0.3	1
0.15	1
0.075	0

Table 4. Chemical composition of GS used

Compound	Clear Glass
SiO_2	68.1
Al_2O_3	0.9
Fe_2O_3	0.6
CaO	14.5
MgO	1.8
K_2O	0.8
Na_2O	12.2
SO_3	0.4

Table 5. Properties of superplasticizer

Properties	Value
pH value	10±1.0
Specific gravity	1.2kg/l
Appearance	Liquid

2.1.4 Superplasticizer

Superplasticizer is used for the improvement of the workability of mixtures which is reduced because of using admixtures like PP fibers. The properties of the admixture that is used as a superplasticizer are shown in Table 5.

2.1.5 Polypropylene fibers (PP)

PP fibers, manufactured by (already-made method) used in current study. Table 6 shows the properties of PP fibres used. Original PP fibers length 60mm were cut into 30mm lengths by a scissor as shown in Figure 1.

2.1.6 Water

In this investigation, tap water used in mixing. Two types of specimens curing used, part of the specimens cured by tap water and another part cured by groundwater, Table 7 shows the properties of groundwater used in this study.

Table 6. Properties of PP fibers

Property	Value
Fibers length	60 mm
Density	0.91 gm/cc
Melting point	160-170℃
Resistance to acid & alkali	94.40%
Fibers type	Monofilament
Crack elongation	15%
Young's modulus	5Gpa
Tensile Strength	600Mpa

Figure 1. PP fibers used

Table 7. properties of groundwater

Types of Ions	Concentration (ppm)
Chloride	30,000
Sulphate	6,000
Magnesium	1,500
Sodium	15,000
Calcium	1,500

2.2 Mix design

After making a lot of experimental mixtures to obtain a slump rate ranging between (18-22) cm, the appropriate mixtures were reached for the research are shown in Table 8. Depending on ACI 211 [34], the materials mentioned are mixed dry, then water and plasticizer were gradually added.

Table 8. Mixes proportion details (kg/m^3)

Mix No.	Cement	Sand	GS	PP Fiber	Sp	Water
M1	607.93	1447.31	0	0	0	304.76
M2	567.77	1429.87	0	16.34	6.8	312.22
M3	571.26	1053.59	351.2	16.34	16.82	310.79
M4	571.26	640.3	640.3	16.34	13.01	310.79
M5	565.07	313.7	941.09	16.34	13.01	310.79

The mixtures were arranged according to the percentage of GS used.

M1: Mix containing (GS=0, PPF=0).

M2: Mix containing (GS=0, PPF=1%).

M3: Mix containing (GS=25%, PPF=1%).

M4: Mix containing (GS=50%, PPF=1%).

M5: Mix containing (GS=75%, PPF=1%).

where, GS: Glass sand and PPF: Polypropylene fibers.

3. METHODOLOGY

The mixing proportion was selected depended on the ACI 211 [34]. While the compressive strength test conducted based on BS EN 1015-11 [35]. The standard ASTM C496/C496M-11 [36] used to test the splitting tensile strength. The flexural strength tests were conducted following ASTM C348-14 [37]. The density of specimens test conducted according to ASTM C138/C138M-14 [38]. ASTM C1403-15 [39] used to determine the water absorption of specimens. The molds were carefully cleansed, with the inner surfaces lubricated to prevent mortar adherence upon hardening. The molds were filled with mortar and compacted using a vibrating table to eliminate any trapped air. The upper surfaces of the specimens were smoothed using a trowel and left in the laboratory for 24 hours. Ultimately, specimens were removed from the molds and placed in a water tank for 7, 14, 28, 56, and 90 days to undergo the curing process before being tested.

4. RESULTS AND DISCUSSIONS

4.1 Compressive strength

According to the amount of GS and PP fiber, 60 compression specimens with dimensions of 50×50×50 mm were prepared. In the case of each combination, 3 specimens (7, 28, 56, and 90) days of age were prepared and tested. Each value obtained is an average of three readings measured based on three specimens. The results showed that the improvement in compressive strength was clear for specimens containing 25 and 50% GS and 1% PP fiber, especially at ages 28 and 90 days in both types of treated water, as shown in Figures 2 and 3. The compressive strength increases for specimens cured by tap water were 2.84 and 4.26%, while the improvement for specimens cured by groundwater was 2.67 and 4.21% for replacement percentages of 25 and 50% GS, respectively. The presence of PP fiber in mortar in small ratios plays a positive role in improving the mechanical properties of mortar, as the fiber bridges the components of the specimens and thus works to delay the occurrence of failure [40]. It also increases the ductility of the specimen and thus reduces the specimen's brittleness, which reduces the rate of failure [6]. The observed enhancement in strength in specimens containing GS can be primarily attributed to the filler effect and the pozzolanic activity of the material. GS particles tend to fill the voids in the mortar specimens. In addition, the GS produces pozzolanic reactions [41]. However, the specimens treated with groundwater were slightly lesser. The decrease in compressive strength due to the attacks of sulfate ions provided by groundwater, which lead to the creation of expansive substances such ettringite and calcium aluminate hydrate. The weakening of the concrete is also caused by the removal of salts that have accumulated in the voids of the mortar [42]. When the percentage of glass ratio increased to 75%, the compressive strength decreased at all ages for example at 28 days decreased by 3.94% for curing with tap water and 4.24% for curing with groundwater. This decrease in compressive strength is attributed to the high brittleness of glass causing cracks that affect the adhesiveness between the waste glass and cement paste [43]. The reduction in compressive strength at 75% GS is attributed to the poor connection between the GS particle and the mortar paste, where the increased GS ratio caused agglomerates to prevent mortar homogeneity. The fracture toughness of glass [KIC=0.70MPa-m$^{0.5}$] is smaller than that of natural sand [KIC=1.77MPa-m$^{0.5}$] so increasing the GS dramatically affects the strength [44].

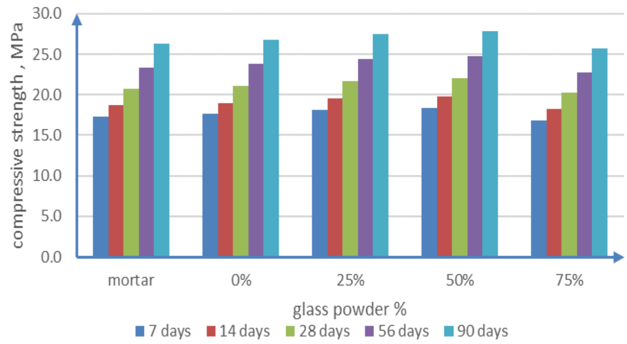

Figure 2. Compressive strength for mortar specimens exposed to tap water

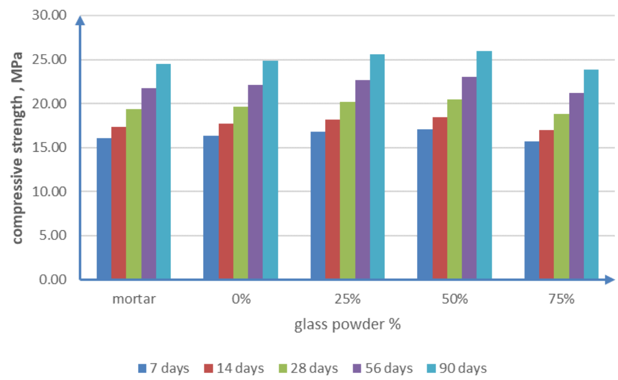

Figure 3. Compressive strength for mortar specimens exposed to groundwater

4.2 Splitting tensile strength

A total of 75 specimens with dimensions of (100×300) mm cylinders were made. For each mix, 3 specimens with (7, 28, 56, and 90) days' ages are prepared. Each value obtained is an average of three readings measured on three specimens. In terms of the type of treated water, all specimens containing GS and PP fibers (except for those containing 75% GS) witnessed an improvement in splitting tensile strength when treated with tap water, better than the specimens treated with groundwater as shown in Figures 4 and 5. This improvement increased with the increase in the age of treatment (except for those containing 75% GS). After 28 days of curing, the specimens with 25 and 50% GS showed an increase of 4.19 and 5.93% when cured with tap water. The same mixes cured by groundwater showed an increase of up to 4.45 and 5.78% compared to the specimens without GS (M1). Additionally, when cured with tap water and groundwater, the splitting tensile strength of specimens containing 75% GS decreased by 2.6% and 2.7%, respectively. The splitting tensile strength specimens exhibited similar behavior to compressive strength specimens, irrespective of the presence of waste materials. The primary scientific explanation for this behavior is practically the same reason. This behavior is attributed to the leaching of lime compounds, which in turn leads to an increase in porosity and a reduction in strength [45-47].

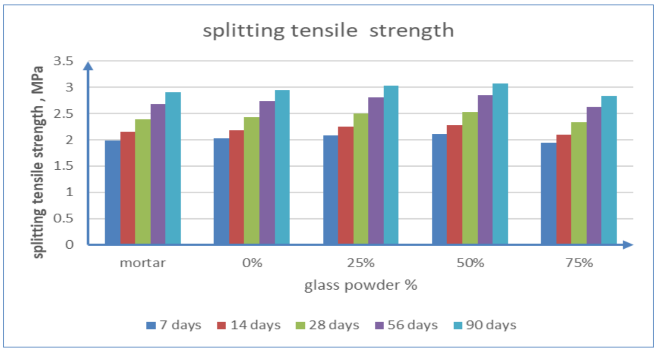

Figure 4. Splitting tensile strength for mortar specimens exposed to tap water

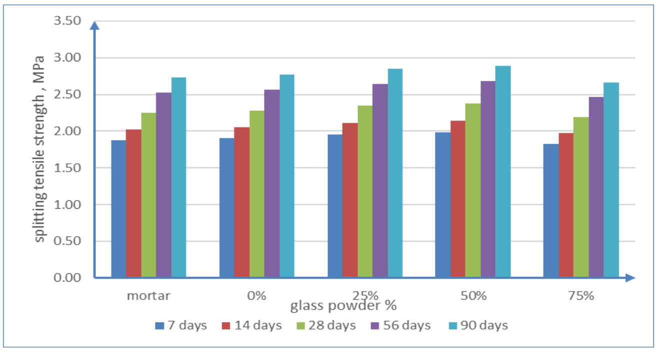

Figure 5. Splitting tensile strength for mortar specimens exposed to groundwater

4.3 Flexural strength

75 specimens with dimensions of 100×100×500mm prisms were made. For each mix, 3 specimens with (7, 28, 56, and 90) days' ages were prepared and tested. The results exhibited that the flexural strength improvement increased with the age of curing. The same is applied to the compressive and splitting tensile strengths of specimens cured by tap water. Whereas specimens that were exposed to groundwater curing showed an increase in flexural strength at an early age compared with the first one, as shown in Figures 6 and 7.

At age 90, the specimens showed a reduction, and this behavior is attributed to the leaching lime compounds, which in turn led to an increase in porosity and a reduction in strength [46, 47]. The increment of flexural strength specimens cured by tap water reached 17.5, 30, and 38.75%, while the increment of specimens cured by groundwater reached 29.76 to 38.38% for specimens containing 0, 25, and 50% GS, respectively, compared with traditional mortar specimen. It is noted that in all mechanical tests, the results at 90 days were the highest compared to other ages. That is attributed to the fact that the superplasticizing impact on ground glass is less pronounced compared to Portland cement. This is because cement immediately begins to weaken and react when water is added to the mixture, whereas glass sand requires a longer time to initiate its pozzolanic reaction [48].

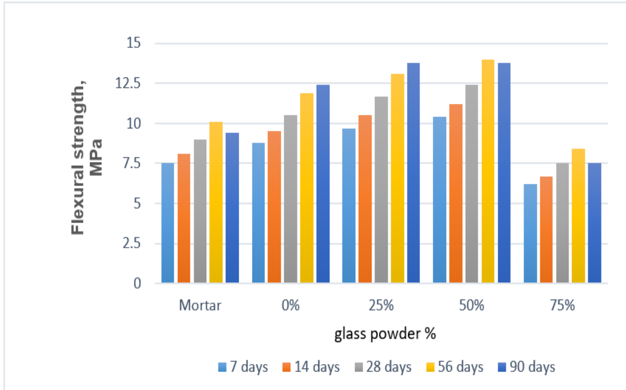

Figure 6. Flexural strength for mortar specimens exposed to tap water

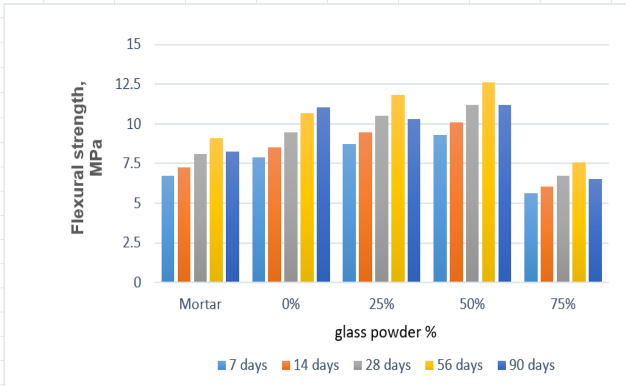

Figure 7. Flexural strength for mortar specimens exposed to groundwater

4.4 Density

The test cube densities' evolution is shown in Table 9. A reduction in the density of mortar with a higher percentage of GS is noted. The highest density is reordered for mortar specimens (free of GS and PP), where the density reached 2360 and 2265.6 kg/m^3 for specimens cured by tap water and groundwater, respectively. The results indicated that the density reduction increased with the GS ratio increase, with the lowest density recorded at 75% GS (2160 and 2073.6 kg/m^3) for tap and groundwater curing. The difference between the lowest and highest values of density is 200 and 192 kg/m^3 for tap and groundwater curing. The reduction is due to the difference between the specific weight of GS and the specific weight of natural sand [49]. The presence of salts and sulfates in groundwater is thought to be a contributing cause of the decrease in mortar density. This is due to corrosion that occurs on the outer crust of the specimens, which gradually extends to deeper layers, resulting in mechanical and physical weakening of the specimens [42].

Table 9. Density of specimens according to GS content exposed to tap water and ground water

Mix No.	Density (kg/m^3) Tap Water	Density (kg/m^3) Groundwater
Mortar	2360	2265.6
GS 0%	2333	2239.68
GS 25%	2320	2227.2
GS 50%	2192	2104.32
GS 75%	2160	2073.6

4.5 Water absorption

At 28 days of age, a water absorption test was conducted to evaluate the water absorption of the specimens. To ensure unidirectional flow throughout the test, four sides of the specimens from each mixture were covered with silicone rubber. Then they were left in the oven for 48 hours at 110℃. The weight of the dry specimens was subsequently measured in air and then dipped with the uncoated side into the water for one hour. Finally, the specimens were taken out of the water bath, and their weight was measured to calculate the weight of water absorbed. The water absorption of concrete is a significant indicator of its durability. Concrete with low water absorption has better protection from reinforcement inside it. Park et al. [50] observed that glass is naturally an impermeable material. So, it could be presupposed that the existence of glass particles in concrete could decrease the permeability of the concrete mix. However, the values gathered from this study indicated that when the glass contents increased, the mixtures were more absorbent. The percentage increase in absorption for specimens containing 50 and 75% GS and cured by tap water was 6 and 12.5%, respectively, compared with 2% for specimens containing 25% GS. The same specimens cured by groundwater exhibited 15.7 and 9.5% increments in absorption, as shown in Table 10. The increase in water absorption may be due to several possibilities, including the fact that the particle size of GS is larger than that of cement, and therefore its presence created voids surrounding the granule itself, and those voids were filled with water. In addition, the type of curing water used may have affected the structure of the concrete specimens produced. Concrete is more brittle and water-permeable when treated with groundwater. the results in the same trend with study [6].

Table 10. Water absorption of specimen according to GS content exposed to tap water and groundwater

Mix No.	Water Absorption % for Tap Water	Water Absorption % for Groundwater
Mortar	7.00	7.21
GS 0%	7.08	7.30
GS 25%	7.14	7.35
GS 50%	7.45	7.67
GS 75%	7.87	8.10

5. CONCLUSION

In the present study, GS with 25%, 50%, and 75% was utilized as a partial sand replacement via using PP fibers in 1% of a mixed volume exposed to tap water and groundwater curing. The following conclusions can be drawn:

(1) The compressive strength increases for specimens cured by tap water were 2.84 and 4.26%, while the improvement for specimens cured by groundwater was 2.67 and 4.21% for replacement percentages of 25 and 50% GS, respectively. The presence of PP fiber in mortar in small ratios plays a positive role in improving the mechanical properties of mortar. However, the specimens treated with groundwater were slightly lesser. When the percentage of glass ratio increased to 75%, the compressive strength decreased at all ages for example at 28 days decreased by 3.94% for curing with tap water and 4.24% for curing with groundwater.

(2) All specimens with GS and PP fibers (excluding those with 75% GS) improved splitting tensile strength with tap water, better than groundwater. This improvement improved with cure age (excluding those with 75% GS). Tap water-cured specimens with 25 and 50% GS increased 4.19 and 5.93% after 28 days. Groundwater-cured specimens increased by 4.45 and 5.78% compared to those without GS. Curing with tap water and groundwater decreased the splitting tensile strength of specimens containing 75% GS by 2.6% and 2.7%, respectively.

(3) The increment of flexural strength specimens cured by tap water reached 17.5, 30, and 38.75%, while the increment of specimens cured by groundwater reached 29.76 to 38.38% for specimens containing 0, 25, and 50% GS, respectively, compared with traditional mortar specimen. It is noted that in all mechanical tests, the results at 90 days were the highest compared to other ages.

(4) The highest density is reordered for mortar specimens (free of GS and PP), where the density reached 2360 and 2265.6 kg/m^3 for specimens cured by tap water and groundwater, respectively. The results indicated that the density reduction increased with the GS ratio increase, with the lowest density recorded at 75% GS (2160 and 2073.6 kg/m^3) for tap and groundwater curing, respectively.

(5) The values gathered from this study indicated that when the glass contents increased, the mixtures were more absorbent. The percentage increase in absorption for specimens containing 50 and 75% GS and cured by tap water was 6 and 12.5%, respectively, compared with 2% for specimens containing 25% GS. The same specimens cured by groundwater exhibited 15.7 and 9.5% increments in absorption.

(6) Possibility of produce mortar has a density of 2192 kg/m^3 and has a good mechanical property will open the gates to produce parts of the construction materials like the interlock bricks and light curbstone used in roads shoulders.

It is clear from these results that GS could strengthen the mechanical properties of the mortar produced (Rich of silica) if it is used at a suitable level of replacement. The results indicated that the ratio of 50% GS was the best ratio in all mixes and curing types depnds on the improvement in mechanical properties gained such as the compressive and flexural strengths, which is recommended to be the optimal ratio, and may help to utilize the glass waste to produce new concrete or mortar eco-frindly to the environment.

6. RECOMMENDATION AND FUTURE STUDIES

(1) Focusing on exploiting GS and PP waste in different shapes and sizes, in addition to higher quantities than those used in this study, with the addition of materials that compensate for the decrease in resistance, such as nano-silica (NS) or silica fume (SF), may be an appropriate field to open a new horizon in producing environmentally friendly and more

sustainable concrete and mortar.

(2) GS and PP are difficult to decompose, so researchers must consider finding more opportunities to rid the environment of them, by recycling them to produce environmentally friendly concrete or mortar.

(3) There is a need to study the effect of using waste GS on workability, creep and shrinkage of concrete or mortar.

(4) Future studies could exploit the high percentage of silica in GS to produce more durable concrete or mortar to resist the friction occurring in bridge columns resulting from the flow of river water.

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NOMENCLATURE

Abbreviations

PPF	Polypropylene Fiber
GS	Glass Sand
PVC	Polyvinyl Chloride
CO	Carbon Monoxide
CO_2	Carbon Dioxide
ACI	American Concrete Insttitute
CSH	Calcium Silicate Hydroxide