Journal of Engineering
journal homepage: www.joe.uobaghdad.edu.iq
Number 8 Volume 27 August 2021

Civil and Architectural Engineering

Reuse of Glass waste as a partial replacement to fine aggregates in concrete

Ghadeer Jabbar Kassed
Master student
College of Engineer-University of Baghdad
Iraq/Wasit
0780gh0780@gamil.com

Sura Karim Ali
Asst. Prof. Dr.
College of Engineer-University of Baghdad
Iraq/ Baghdad
srak39@yahoo.com

ABSTRACT

As human societies grow, the problem of waste management becomes one of the pressing issues that need to be addressed. Recycling and reuse of waste are effective waste management measures that prevent pollution and conserve natural resources. In this study, the possibility of using glass waste as an alternative was used as a partial weight substitute for fine aggregates with replacement ratios of 10, 20, 30, and 40% by the weight, and formed into test models (15 cm * 15 cm) cube and (15 cm * 30 cm) cylinder, then matured and tested their strength compression and tensile strength at the age of 7 and 28 days and compared with a reference or conventional concrete with a mixing ratio (1: 1.5: 3) as well as testing its workability on fresh concrete. The results showed the possibility of using crushed glass wastes in concrete as a good alternative to fine aggregates, up to 30%. The compressive strength and tensile strength results at this ratio were 92.6% and 80.86% at the age of 28 days, respectively.

Keywords: Recycling, glass waste, workability, compressive strength, tensile strength.

إعادةاستخدام مخلفات الزجاج كبديل جزئي للركام الناعم في الخرسانة

غدير جبار كاصد
طالبة ماجستير
جامعة بغداد /كلية الهندسة

سرى كريم علي
أستاذ مساعد
جامعة بغداد /كلية الهندسة

الخلاصة

كلما أخذت المجتمعات البشرية بالنمو أصبحت مشكلة ادارة النفايات واحدة من القضايا الملحة التي تتطلب معالجة. وتعتبر إعادة التدوير وإعادة استخدام النفايات هي من التدابير الفعالة في إدارة النفايات، والتي بالإضافة إلى منع التلوث، فهي تحافظ على الموارد الطبيعية. في هذا البحث، تمت دراسة إمكانية استخدام نفايات الزجاج كبديل جزئي للركام الناعم في الخرسانة بحد أقصى 4.75 مم. تم استخدام نفايات الزجاج كبديل جزئي للوزن للركام الناعم بنسب استبدال 10 و20 و30 و40٪ من الوزن, وتم تشكيلها في نماذج اختبار (15 سم *15 سم) للمكعب و (15 سم * 30 سم) للاسطوانة ثم نضجت واختبرت قوتها الانضغاطية وقوة الشد في عمر 7 و28 يومًا ومقارنتها بالخرسانة المرجعية أو التقليدية بنسبة خلط (1: 1.5: 3) وكذلك اختبار قابليتها للتشغيل

*Corresponding author
Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2021.08.04

Article received: 9/12/2020
Article accepted: 30/1/2021
Article published: 1/8/2021

على الخرسانة الطازجة. أظهرت النتائج إمكانية استخدام نفايات الزجاج المسحوق في الخرسانة كبديل جيد للركام الناعم حتى نسبة 30% كانت نتائج مقاومة الانضغاط ومقاومة الشد عند هذه النسبة 92.6% و80.86% عند عمر 28 يوم على التوالي. ستساهم هذه النتائج بشكل كبير في تقليل تكلفة الخرسانة المنتجة عن طريق تقليل كمية الركام المستخدم وبالتالي تقليل متطلبات الركام. يقلل الاستهلاك الكلي الأقل من استنفاد الموارد الطبيعية.
الكلمات الرئيسية:إعادة التدوير، نفايات الزجاج، قابلية التشغيل، مقاومة الانضغاط، قوة الشد.

1. INTRODUCTION

Growing urbanization, population growth, and increasing living standards have helped increase the quantity of a variety of solid waste produced by manufacturing, farming, mining, and domestic activities due to technological innovations. Generally, in 2002, the estimated amount of solid waste generated was 12 billion tons in India **(Pappu et al., 2007).**

The construction industry for "green" or environmentally friendly materials includes cement and reinforcement bars, which has led to increased construction costs but may also lead to the reconsideration of traditional materials (**Ganiron 2013).**

Much of this waste cannot be disposed of. In any case, the natural impact can be reduced by the more accessible use of this waste. The goal is to reduce or reuse waste, the latter being the preferred decision for waste. Research into new uses of waste materials is progressing steadily. This research aims to match society's need for the safe and economical disposal of waste. The use of recycled aggregates helps to maintain a clean environment, natural resources, and dumping areas. This current research focuses on the occurrence of these wastes for use in concrete mixtures, especially glass waste, for use in concrete mixtures as a partial substitute for fine aggregates.

1.1 LITERATURE REVIEW

A worldwide trend is the use of surplus materials with pozzolanic properties for concrete construction. The continued generation of solid waste products is well known to raise significant environmental and technological problems. Moreover, the evaluation of the pozzolan activities of cement substitute materials becomes more relevant because of the need for more sustainable cementing goods **(Villar-cociña et al., 2011).**

Innovation is necessary to satisfy the rising demand for innovative and quality products. Concrete is a commonly used material of building composed of cementing material, fine aggregates, coarse aggregates, and required water amounts, where the fine aggregate typically consists of natural sand **(Anwar et al., 2015)**. Innovations in the replacement of content used will achieve sustainability in concrete manufacturing**.**

(Ismail and al-Hashmi, 2009) studied the properties of concrete containing glass waste as fine aggregate, and the results showed pozzolanic strength activity of 80% after 28 days of glass waste. The samples' bending strength and compressive strength with 20% glass waste content were 10.99% and 4.23%, respectively.

(Rahim et al., 2015) studied the three potential uses of glass waste in cement and concrete industries. Use glass waste as a partial substitute for sand in 10%, 20%, and 50% of concrete mixes. While its results can be summarized as follows: First, the use of glass residues as concrete aggregate has a somewhat negative effect on workability, strength, and the work of resisting cement freezing and thawing. The compressive strength of samples with glass dust waste content of 10% was 32.93 MPa, which is higher than that of concrete control sample at 28 days, and glass residues can also be used as a siliceous source in raw materials for cement production. Hence the effect will depend on the amount of glass waste used. So it can be said that if the proportion of glass waste used in raw materials is less, it will have minimal impact.

(Salim, 2017) studied the strength of concrete made by partial replacement of fine aggregate with glass waste. The fine aggregate was replaced by glass waste as (0-40%) with a dosage of 4% to reference concrete. It was noted that the operability increases with the increase in the amount of glass, while the water absorption decreases with the increase in the glass. The experimental test results revealed that maximum improvement was observed at 12% replacement of sand with glass waste on all properties of the studied concrete.

(Liaqat et al., 2018) conducted a series of experiments to find out the properties of the concrete mixtures when replacing the coarse aggregate with the glass powder at (10-40) %. As the results showed the possibility of using glass powder as alternative building materials up to 20% by weight, a marginal decrease in pressure and tensile pressure was observed from the increase in the ratio and confirmed the possibility of overcoming this problem using plasticizers.

(Warnphen et al., 2019) studied the various steps for managing glass waste, which is used as a partial alternative in producing concrete bricks and obtaining the optimum percentage of glass that gives the required strength. Part of the glass waste crushed with fine aggregates has been replaced by 0%, 10%, 20%, 30%, and 100% depending on weight, then it was tested at the age of 7, 14, and 28 days. The results showed the best percentage of substitution, 20%, and the decrease in strength by increasing the percentage.

(Alkizwini, 2020) tested the probability of replacing part of the aggregate, cement, or both with powdered glass and plastic waste at a ratio of (0- 20) percent. They tested the pressure strength of the concrete mixture at 7 and 28 days of age and compared it with the reference mixture (mix ratio of 1:1.5:3), where the results were strong when using the glass as an alternative to the aggregate or cement as an alternative. Sand and cement could be replaced with powdered glass waste (20% sand and 15% cement) without any noticeable difference in compressive strength. As for plastic waste, its results were to reduce the strength of the pressure in concretes a result, and it is advised that concrete with plastic wastes is to be used in civil engineering applications that require low compressive strengths (≤ 25 MPa).

1.2 MATERIALS AND METHODS

1.2.1 Materials

The materials used in this study are cement, fine aggregate, coarse aggregate, water, grinded glass waste as fine partial aggregate replacement. The local Iraqi market locally supplied all materials.

1- Cement

Cement is an essential component of the concrete industry as it is responsible for bonding concrete components. Ordinary Portland cement (Type 1), conforming to IQS Standard No. 5 / 1984, has been used in concrete mixtures.

2- Fine aggregate

The fine aggregate used was obtained from the sands of the clean river of quarries in the Ghriba area in Wasit Governorate. The maximum size was 4.75 mm. Impurities were removed and conform to IOS45:1980. The aggregate was examined through a set of sieves, as shown in **Table1**.

3- Coarse Aggregate

Coarse aggregates used were from quarries in the Ghriba area in Wasit Governorate. The maximum size of coarse aggregate was 20 mm. It conforms to Iraq's standard (IQS No.45/ 1984). **Table 2** shows the sieve analysis of coarse aggregates.

4- Mixing water

Tap water has been used in this study for concrete mixtures and sample preparation.

5-Glass waste

Our research's origin of the glass aggregates is transparent window glass wastes collected from local window glass vendors in Al-Aziziyah city, Iraq. After being collected, the workgroup was cleaned. The next step in preparing the aggregate glass was the cracking process, which was performed manually with the hand hammer and sifted to obtain grades similar to those in natural sand. **Fig. 1** shows a picture of waste glass. The maximum diameter of nominal particle size was 4.75 mm. Sieve analysis is shown in **Table 3** (**Alkizwini, 2020).**

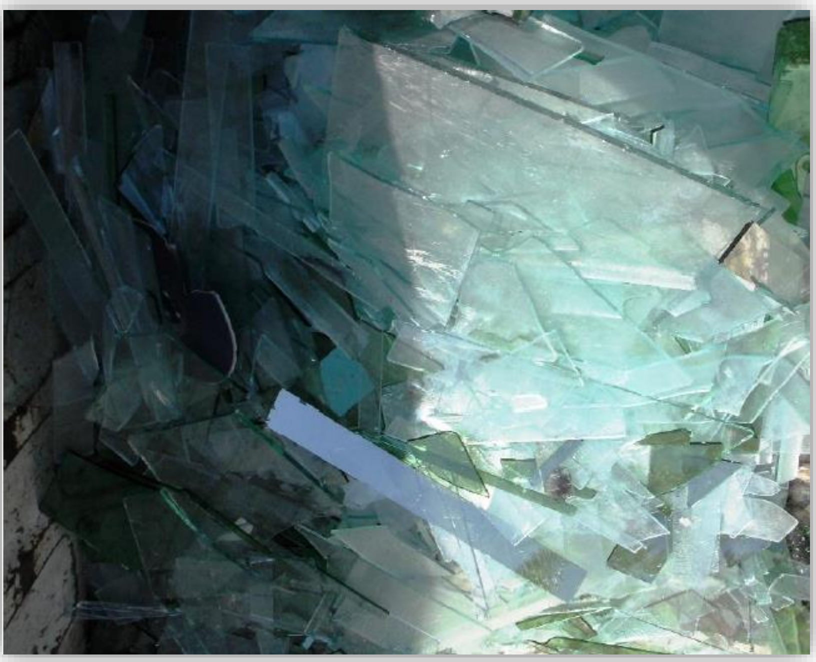

Figure 1. Glass waste.

Table 1. Sieve analysis of fine aggregate.

Sieve size (mm)	Percentage passing %	Limit of IQS No.45/1984
10	100	100
4.75	96	90-100
2.36	77.5	60-95
1.18	64	30-70
0.6	31.3	15-34
0.3	17	5-20
0.15	6	0-10

Table 2. Sieve analysis of coarse aggregate.

Sieve size (mm)	Percentage passing %	Limit of Iraqi standards No. (45/1984)
20	100	100
10	22.5	0-25
5	2.15	0-10

Table 3. Sieve analysis of glass waste.

Sieve size (mm)	Percentage passing %	Limit of IQS No.45/1984
10	100	100
4.75	96	90-100
2.36	70	60-95
1.18	49	30-70
0.6	20	15-34
0.3	15	5-20
0.15	3.5	0-10

1.3 Experimental procedure

All experiments were conducted at room temperature for six months in Al-Ahlia Construction Company, Al-Azizia City, Wasit Governorate. The following laboratory tests (compressive strength and tensile strength) were performed in the construction laboratory of the College of Engineering at the University of Baghdad.

1.4 Program of Testing

A series of standardized tests were performed with variable quantities of total glass waste in proportions (1:1.5: 3) (cement: sand: gravel) (0.5) w/c as follows:

1. A reference mixture is made of 6 cubes (15cm x 15cm x 15 cm) and 6 cylinders (15cm x 30 cm) of concrete.

2. To evaluate the effect of glass waste on the compressive strength of the concrete, 24 cubes (15 × 15 × 15 cm) of concrete.

3.To evaluate the effect of glass aggregates on the tensile strength of concrete, a total of 24 cylinders (150 x 300 mm) were poured into concrete.

The concrete mix was done manually. Coarse aggregate, fine aggregate, cement, and glass waste were mixed for the glass mixture, then water was gradually added, and the samples compacted using a filler rod of 16 mm diameter on three equal layers. These samples were removed from the molds after 24 hours. Then it was kept in the water for curing.

Every group comprises three compressive and tensile strength test samples. The main idea behind splitting every test group into three samples is to ensure the optimal reliability standard and to create a real margin to exclude very unusual points. All tests were conducted at the age of 7 and 28 days. **Table 4** shows the concrete ratio for concrete containing glass waste.

Table 4. Glass waste mix design.

Material	M0%	M10%	M20%	M30%	M40%
Cement (kg/m3)	26	26	26	26	26
Coarse Aggregate (kg/m3)	68.5	68.5	68.5	68.5	68.5
Fine aggregate (kg/m3)	46	41.4	36.8	32.2	27.6
Glass waste (kg/m3)	0	4.6	9.2	13.8	18.4
Water (Lit)	13	13	13	13	13

1.5 Testing Techniques

1.5.1 Workability

Workability is a characteristic of fresh concrete that shows how easy it is to pour and handle concrete. It is a characteristic that expresses the degree of homogeneity of the concrete mixture and its resistance to granular separation.

Clean the inner surface of the mold (cone) shown in **Fig. (2)** and moisturize it well. The mold was mounted on a flat, horizontal board and solid metal plate, and the mold was held firmly in place while filling in three layers. Each layer the third height of the template. A round end compacting rod was used to staple each layer by 25 strokes, and after the final layer was completed, the concrete was separated from the level with a trowel so that the mold was completely filled. The mold in the vertical direction was removed slowly and carefully. The concrete was allowed to fall, and then The slump were calculated by determining the distance between the level of the mold and the highest point in the form after the mold was removed **(Anwar et al., 2015).**

Figure 2. Slump test.

1.5.2 Compressive strength

Compressive strength is the capacity to resists or withstands pressure on a substance or structure. The compressive strength of a material is defined by the capacity of the material to resist defects in the form of fractures. Compressive strength as a function of the concrete relies on many factors linked to consistency, mixing nature, and quality management of the products used in concrete construction **(Rahim et al., 2015)**. The compression testing machine is shown in **Fig. (3**).

The compressive strength is tested as follows:

1. The concrete was poured into the mold on three layers, compact each layer 25 times to compact it properly to reduce the amount of voids.

2. After 24 hours, molds are removed, and test samples are placed in water for processing.

3. After the specified curing period 7 and 28 days, samples are tested using the pressure testing machine.

4. The load is applied gradually until the sample fails.

5. Divide the failure load by the cross-sectional area of the sample to obtain the compressive strength of the concrete.

Figure 3. Compressive strength test.

1.5.3 Splitting tensile strength

The tensile strength of the concrete test's the tension of the structure as it hits its rupture point at which it shatters or loses its stability, which ensures that the structure can endure the highest stress without failure. The tensile strength is a non-quantitative property, meaning the quantity of tested material does not change. Still, it depends on preparing the test sample and the temperature in the medium of the test **(Anwar et al., 2015)**. A tensile testing machine is shown in **Fig. (4).**

Figure 4. Splitting tensile strength test.

1.6 Results and Discussion

1.6.1 Workability

The results of the slump test for waste glass are shown in **Table (5)**. An increase in the workability of concrete made using glass waste as an alternative to fine aggregates was observed with a substitution level of up to 20%, after which a decrease in stagnation was observed, as shown in **Fig. (5).** An increase in workability may be due to the non-water absorbent nature of glass waste compared to natural sand. However, the decrease in stagnation may be due to the effective loss of water from the sample through rapid transport resulting from more voids resulting from the equivalent waste glass instead of natural sand being heavier than the newer, or thought to be influenced by the shapes of the glass grains. Despite this decrease in the stagnation of these mixtures, they have good operational potential (**Ismail and al-Hashmi 2009**).

Table 5. Slump test results of the glass.

Percentage of Glass	Slump (mm)
0%	80
10%	75.5
20%	70
30%	65
40%	55

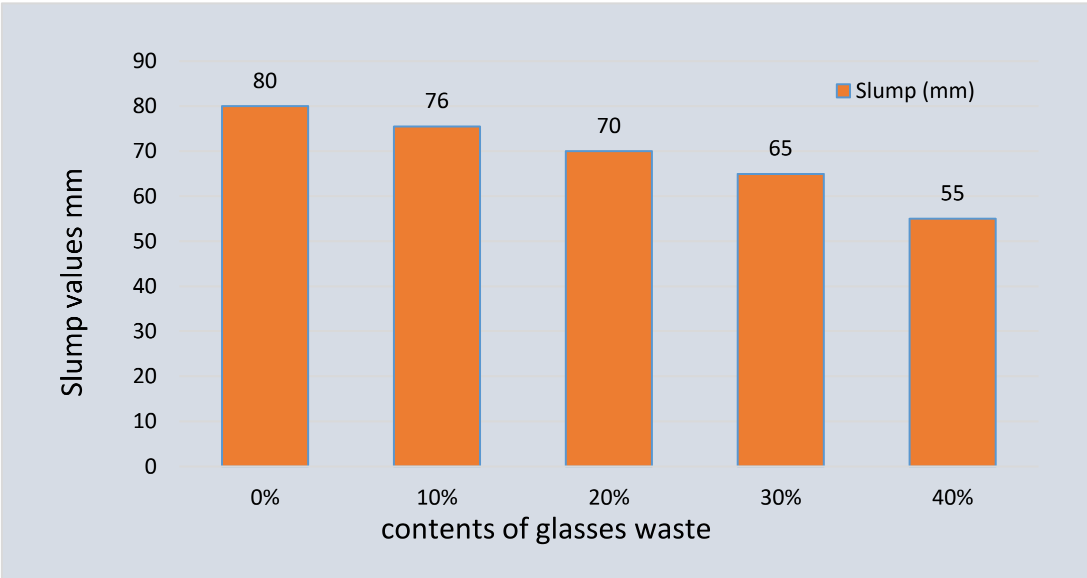

Figure 5. Result of slump test.

1.6.2 Compressive Strength

As previously mentioned, glass residues were initially crushed by hand and then sieved to a maximum size of 4.75 mm. Different proportions (0%, 10%, 20%, 30%, and 40%) of these residues were used to substitute for fine aggregates in concrete, as shown in **Table (6)**. **Fig. (6)** shows that the use of glass waste in concrete increased the compressive strength of the concrete at both ages (7 and 28 days). The maximum effect was recorded at 20%, with increases in compressive strength at 7 and 28 days being 24.14Mpa and 32.04Mpa, respectively. This trend in compressive strength of an increase above the control mixture may be explained by the angular nature of the glass aggregate, which has an area larger surface of naturally round aggregate particles, up to 30% glass waste replaced well and within the values required by design. Then, the compressive strength decreased with the increase in the glass waste due to the weak bond between the glass waste and the cement paste due to the smooth surface of the glass waste. The decrease in compressive strength is also due to excess water in the concrete **(Alkizwini, 2020)**.

Table 6. Compressive strength of concrete with percentage of glass waste.

Percentage Of Glass	Splitting tensile strength (MPa) At 7 days				Splitting tensile strength (MPa) At 28 days			
	Cyl.1	Cyl.2	Cyl.3	Average	Cyl.1	Cyl.2	Cyl.3	Average
0%	2.78	2.88	2.93	2.87	3.65	3.79	3.80	3.85
10%	2.65	2.76	2.83	2.64	3.67	3.39	3.86	3.64
20%	2.41	2.36	2.34	2.44	3.55	3.61	3.34	3.47
30%	1.32	2.15	2.04	2.07	2.76	2.88	2.86	2.85
40%	1.75	1.66	1.58	1.64	1.85	1.98	1.90	1.92

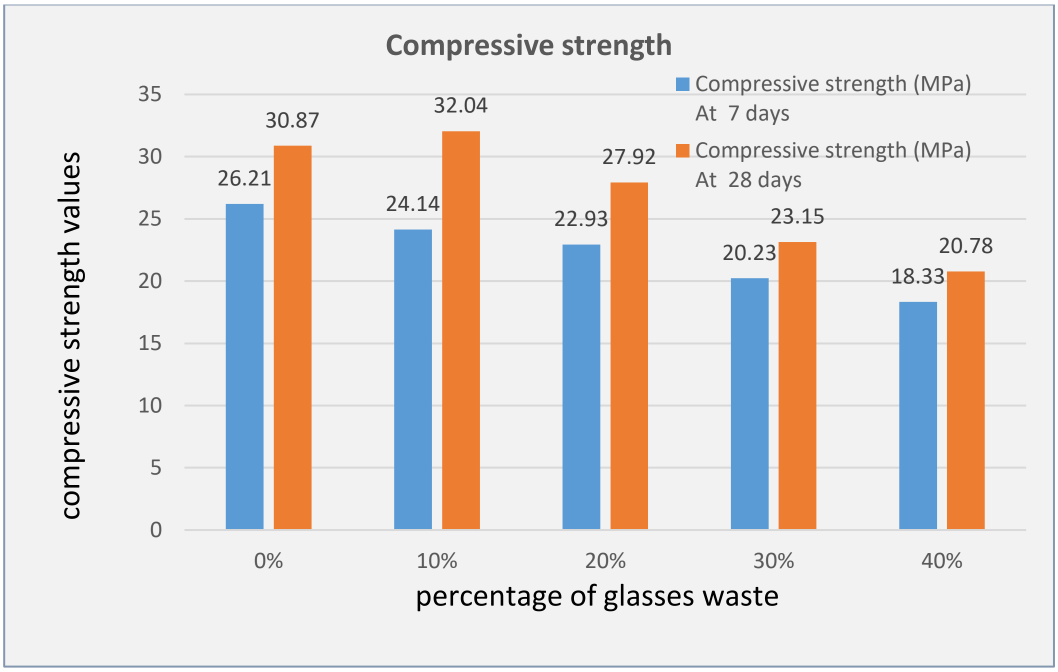

Figure 6. the compressive strength for controlled mix and mixes containing different glass aggregate replacement.

1.6.3 Splitting Tensile Strength

Split tensile strength results for samples with the addition of 10, 20, 30, and 40 wt.% glass waste are shown in **Table (7)**. The results are shown in **Fig. (7).** The development of the split tensile strength of mixtures containing replacement of waste glass is higher than the controlled mixture with age due to the progression of wetting and good bonding strength between the glass aggregate cement paste relative to the controlled mixture. The strongest 28- day break tensile strength values of 3.47 MPa have been obtained according to the results of the test from the concrete mixture produced out of 20% glass soft aggregate, accompanied by a reduction in concrete bending strength with a rising degree of glass waste replacement. This is large because of the same factors, which decrease the compressive strength by adding waste glass. The loss in tensile strength is mostly attributed to the extra water in the concrete. In contrast to natural aggregates, glass waste does not consume more water **(Salim 2017)**.

Table 7. Splitting-Tensile Strength of concrete with percentage of waste glass.

Percentage Of Glass	Splitting tensile strength (MPa) At 7 days				Splitting tensile strength (MPa) At 28 days			
	Cyl.1	Cyl.2	Cyl.3	Average	Cyl.1	Cyl.2	Cyl.3	Average
0%	2.78	2.88	2.93	2.87	3.65	3.79	3.80	3.85
10%	2.65	2.76	2.83	2.64	3.67	3.39	3.86	3.64
20%	2.41	2.36	2.34	2.44	3.55	3.61	3.34	3.47
30%	1.32	2.15	2.04	2.07	2.76	2.88	2.86	2.85
40%	1.75	1.66	1.58	1.64	1.85	1.98	1.90	1.92

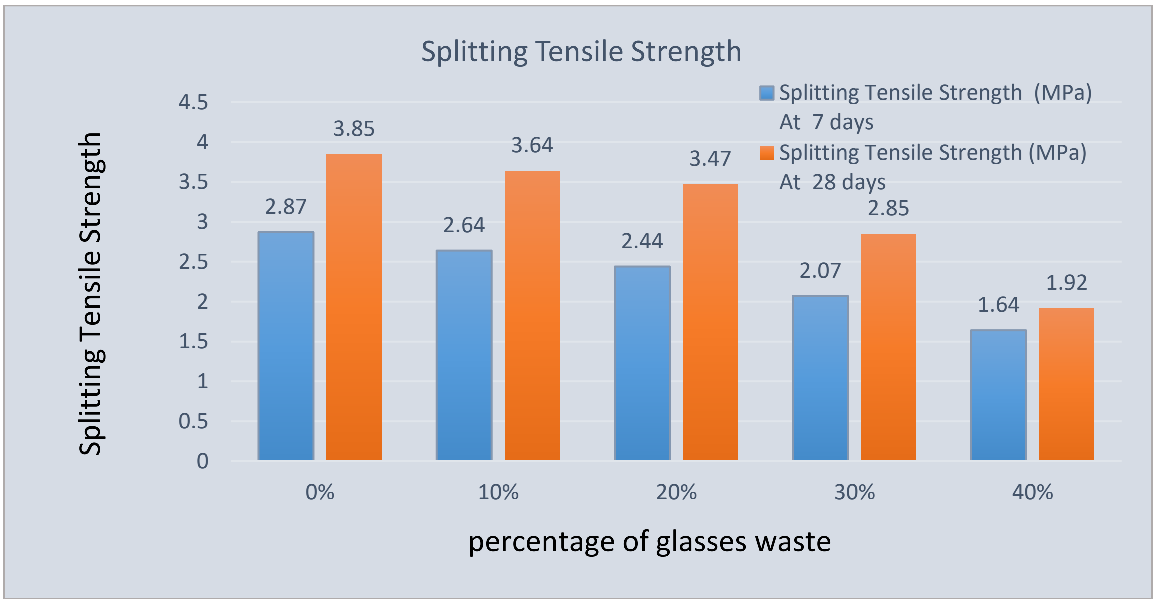

Figure 7. Splitting Tensile Strength for controlled mix and mixes containing different glass aggregate replacements.

1.7 CONCLUSIONS

From the results of this research, the following conclusions can be highlighted and summarized as follows:

1. Recycled glass waste with river sand reduces the harmful environmental impact of river sand quarries and reducing the depletion of normal resources.

2. The results showed that the use of glass waste as an alternative to fines aggregates in the concretes mix led to a relatively slights decrease in the operability of both. They have good operability despite the fact that the low stagnation values of aggregate-containing mixtures. The use of glass waste in concrete will eliminate the problem of disposing of such waste and prove environmentally friendly, paving the way for environmentally friendly concrete.

3. The addition of 20% glass waste to the concrete increased the compressive strength of the concrete, which reached a level comparable to that of normal concrete. This can be attributed to the angular nature of the glass particles facilitating the increased bonding with the cement paste and a rate of 20% for replacing glass powder waste with fine aggregates, which gives maximum compressive strength and tensile strength at 28 days of age.

4. The results showed that the split tensile strength decreases with the increase in the alternative waste content. Mixtures of up to 20% glass waste show a slight decrease in tensile strength compared to the control mixture.

Acknowledgment

The authors would like to thank Al-Ahlia Construction Company, Al-Azizia City, Wasit Governorate for the help, tools, and the place to work. The authors thank the Sanitary Engineering Laboratory and Civil Engineering Department / College of Engineering - the University of Baghdad for their valuable support in completing this work.

REFERENCES

- Alkizwini, R. S., 2020. Reuse plastic and glass wastes as a partial replacement of concrete components, Journal of Engineering Science and Technology, Vol. 15, No. 2.
- Anwar, a., Ahmad, s., Husain, s.m.a. And Ahmad, s., 2015 salvage of ceramic waste and marble dust for the refinement of sustainable concrete. International Journal of Civil Engineering. *6*(9), pp.79-92.
- ASTM C140-02a Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units. Annual Book of ASTM Standards, 2020 ASTM International, West Conshohocken, PA.
- ASTM C496 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, 2017.
- B.S.1881, Part2, 1970. Method for Determination of Compressive Strength of Concrete Cubes, British Standard Institution.

- Ganiron Jr., T. U., 2013. Sustainable Management of Waste Coconut Shells as Aggregates in Concrete Mixture, Journal of Engineering Science & Technology. Vol. 33.
- IQS 5/1984 portland cement. Central organization for standardization and quality control. Iraq (in Arabic).
- IQS 45/1980 aggregates from natural sources for concrete and building construction. Central organization for standardization and quality control. Iraq (in Arabic).
- Ismail, Z., and al-Hashmi, E. A., 2009. Recycling of glass waste as a partial replacement for fine aggregate in concrete. Journal Elsevier Vol.29.
- Khoso, S.,2017. Utilization of glass waste as partial replacement of fine, Engineering Science and Technology International Research Journal, 1(1), pp. 59–63.
- Liaqat, m., shah, m. L., and Baig, M. A., 2018. Effect of glass waste as partial replacement for coarse aggregate in concrete, International Journal of Technical Innovation in Modern Engineering & Science, Vol. 4.
- Pappu, A., Saxena, M., Asolekar, SR., 2007. Solid Wastes Generation in India and their Recycling Potential in Building Materials, Building and Environment, 42: 2311-2320
- Rahim, N. L., Che Amat, R., Ibrahim, N. M., Salehuddin, S., Mohammed, S. A., and Abdul Rahim, M., 2015. Utilization of recycled glass waste as partial replacement of fine aggregate in concrete production, Materials Science Forum Vol. 803
- Villar-cociña, E., Morales, E.V., Santos, S.F., Savastano, H. Jr., Frías, M., 2011. Pozzolanic behavior of bamboo leaf ash: characterization and determination of the kinetic parameters cement and concrete composites, Journal Elsevier Vol. 33.
- Warnphen, H., Supakata, N., and Kanokkantapong, V., 2019. The reuse of glass waste as aggregate replacement for producing concrete bricks as an alternative for glass waste management on Koh Xichang. Engineering Journal, volume 23 issue 5.