Proceedings of the 5th International Conference on Advanced Science & Engineering ICOASE 2025, University of Zakho and Duhok Polytechnic University, 24th – 25th September 2025

(Special issue for Passer Journal of Basic and Applied Sciences)
Paper No. 03

Mechanical Properties of Concrete with Waste Glass and Waste Ceramic Materials

Naema S. Saleh [1], Lawend K. Askar [1]

[1] Department of Highways and Bridges Engineering, Technical College of Engineering, Duhok Polytechnic University (DPU), Duhok, Duhok 42001, Kurdistan Region, Iraq.
Email: Naema.Sadeeq@dpu.edu.krd and lawend.kamal@dpu.edu.krd

Abstract

Many researchers are currently attempting to make green concrete by substituting waste material. Utilizing hazardous industrial waste in concrete production will improve the environment. In current building construction, the use of sustainable alternatives is growing gradually. Waste glass and ceramic tiles when finely grounded create pozzolanic materials when incorporating into concrete it assesses the mechanical properties of concrete and reducing landfill waste by reusing materials in concrete production. In this study, waste glass was substituted for Portland cement at rates of 5%, 10%, and 15%. Additionally, crushed waste ceramic tiles were substituted for natural fine and coarse aggregates at rates of 10%, 20%, and 30%, respectively. A total of 90 cubes and 90 cylinders were cast. The cubes measured (15 × 15 × 15) cm while, the cylinders had a diameter of 15 cm and a length of 30 cm. The concrete specimens were examined for compressive strength, splitting tensile strength, and ultrasonic pulse velocity at 3, 7, and 28 days. The primary objective was to identify the optimal replacement levels that enhance strength performance and promote sustainability. The findings demonstrated that, in comparison with normal concrete, the adding waste glass with 10% enhancing the mechanical properties of concrete and 20% tile ceramic is ideal percentage for replacing with fine and coarse aggregate.

Keywords: Waste glass, Waste fine ceramic, Waste coarse ceramic.

1 Introduction

Concrete is one of the most extensively used building materials worldwide. The environmental impacts of utilizing concrete as a construction material, encompassing carbon emissions and deforestation for aggregate extraction [1]. On the other hand, the persistent rise in waste produced by industrial and consumer activities necessitates the urgent exploration of sustainable recycling methods to leverage this waste across several sectors, particularly in building.

Therefore, the increasing need for eco-friendly building materials is a great deal of study on the use of waste materials and industrial leftovers in concrete. A successful strategy to minimize environmental impact and encourage circular economy principles is to use industrial and municipal waste as partial substitutes for normal concrete components [2]. Waste glass and waste ceramic materials are one of the most widespread types of solid waste, their physical and chemical properties make them suitable for use in construction materials, especially concrete. Studies demonstrated their potential as partial alternatives to cement and conventional aggregates in the production of concrete but, the results of these studies vary depending on the size of their particles, the replacement ratios, and the treatment method [3, 4]. In addition to helping the environment by reducing landfill disposal, using these waste components in a proper proportion may improve the mechanical performance of concrete. Recent studies have focused on the mechanical properties of mixtures including varying proportions of residual glass and ceramic elements.

1. 1 Overview of Waste Glass as Cement Substitute

One important step in developing cost-effective, energy-efficient, and environmentally friendly infrastructure systems could be substituting some of the cement in concrete with milled (ground) waste glass. Because glass is an amorphous substance with a high silica concentration, it might be categorized as pozzolanic if the particle size is smaller than 75µm. Glass powder with an SiO_2 concentration of more than 72% and a fineness of 600 µm might react with cement alkali to enhance concrete strength and durability (pozzolanic reaction) [5-7]. According to the findings of the tests, silica enhances the connection between cement paste and aggregate. Furthermore, it makes concrete stronger [8, 9].

The findings indicate that certain mechanical `properties can be enhanced at the optimal replacement levels by the pozzolanic activity of finely ground glass and the beneficial attributes of ceramic aggregates [10, 11]. However, higher percentages may result in strength decreases due to changes in the concrete's workability and microstructure [12-14]. Mechanical properties, especially compressive, flexural, and tensile strength, are key indicators of concrete quality. The effect of replacing cement with glass has been studied in numerous studies, which have shown varying results depending on the proportions used. Researchers performed an investigation on concrete incorporating different proportion of recycled glass as cement the study illustrates that high-performance concrete, exhibiting enhanced strength and reduced permeability to chloride and water, can be attained by including 15% glass powder as an additive, which facilitates the pozzolanic reaction instead of only serving as an inert particle for compaction [15].

1. 2 Overview of Waste Ceramic as Aggregate Substitute

Clay is used to make ceramics, which are made by shaping, drying, and then firing the clay. It has been estimated that around 30% of what the ceramics industry produces daily is wasted and it does not easily biodegradable, resulting in its prolonged buildup in landfills, where it occupies significant space and causes substantial negative environmental effects [16]. Ceramic wall tile scraps were discovered to be excellent replacements for both coarse and fine aggregates in concrete [17]. Similarly, at certain replacement ratios, using leftover ceramics as aggregates or powders can provide concrete with competitive or even better mechanical performance, enhancing sustainability and durability [18]. It is also interesting to note that various researchers have reported conflicting behaviour of concrete when using remaining ceramic tile as an aggregate substitute. Utilizing ceramic masonry debris as an additive imparts excellent mechanical strength qualities and economic benefits to concrete [19]. Concrete's compressive, split tensile, and flexural strengths improved when ceramic waste powder was used to replace as little as 30% of the cement. This was found during an assessment of using powdered ceramic waste as a partial cement substitute in concrete that also included polypropylene fibers [20]. The ceramic tile waste is extremely resistant to biological, chemical, and physical degradation processes. These characteristics make ceramic tile waste extremely durable, which is why it is being studied and utilized as a sustainable cement and concrete component [21]. Using recycled ceramic tiles in concrete as alternatives to coarse aggregate changes the properties of both fresh and cured concrete, reducing costs and also solves some of the disposal issues. [22]. It is possible to create lightweight concrete without sacrificing strength by using destroyed ceramic aggregate [23]. waste ceramic possesses physical and chemical properties similar to traditional concrete components, as they contain significant amounts of silica and alumina, generating pozzolanic activity when thoroughly powdered that can enhance concrete properties when utilized as a partial substitute for cement or aggregate [24].

The primary goal of this study is to examine the mechanical characteristics of concrete that contains different amounts of leftover glass and ceramic elements. Some of the goals are to ascertain how varying replacement levels affect tensile, flexural, and compressive strength. also to assess the ideal blend ratio in order to maximize durability and strength. By encouraging waste recycling and lowering environmental burdens related to raw material extraction and cement use, this study contributes to sustainable construction practices, which makes it very relevant overall. By incorporating two significant waste streams into the manufacture of concrete, this paper facilitates the transition to environmentally friendly and circular building materials that comply with international sustainability standards.

2 Materials

In this investigation, the following materials were used to produce concrete:

2. 1 Cement

ASTM C 150 Type I standard specification of Ordinary Portland Cement (OPC) was used in this experiment [25]. It is imported from Turkey and is a product of the Mardin Cement Industry.

2. 2 Fine Aggregate

The naturally occurring clean river sand used as the fine material in this experiment came from the Alkhazer quarry. In order to meet the standards for grading in the construction of concrete specimens, the sieved samples were analyzed in accordance with ASTM C136-06, 2006 [26] and ASTM C33 [27]. Additionally, the relative density and absorption of fine aggregate as specified by ASTM, A., c128-15 [28] were utilized in this investigation. Properties of fine aggregate are listed in **Error! Reference source not found.**.

Table 1: Properties of fine aggregate.

S. N	Property	Value	Unit
1	Max fine aggregate size	4.75	mm
2	Water absorption	0.99	%
3	Moisture content	0.4	%
4	Density dry oven	1453	kg/m3
5	Specific gravity (dry)	2.62	-
6	Specific gravity (SSD)	2.65	-

2. 3 Coarse Aggregate

The coarse aggregate is also obtained from al-khazer area. The coarse aggregate utilized was of a maximum size of 20 mm. It was sufficiently washed to remove every dirt and organic matter that may affect its performance in concrete. Table 2 lists the coarse aggregate's parameters, including its relative density and absorption as defined by ASTM C127-15, A.[29], as well as its sieve analysis in compliance with ASTM C136-06, 2006 [26], ASTM C33 [27].

Table 2: Properties of coarse aggregate.

S. N	Property	Value	Unit
1	Max. coarse aggregate size	19	mm
2	Water absorption	0.8	%
3	Bulk specific gravity (dry)	2.55	-
4	Bulk specific gravity (SSD)	2.63	-
5	Apparent specific gravity	2.69	-
6	Density	1707	Kg/m3

2. 4 Mixing Water

The mixing water that was used in the concrete mixing in the whole process was natural water that is drinkable and has no pronounced taste and an odor that does not increase the concentration of impurities that affect the setting time and concrete strength and it in compliance with ASTM C1602–06 [30].

2. 5 Waste Glass

The waste glass is locally available; in this research it was collected and milled using a mill to get the desired particle size less than sieve #200. The waste glass materials used as a partial replacement for cement due to waste glass powder contain a high percentage of SiO_2. **Error! Reference source not found.** shows waste glass powder.

Figure 1: Glass powder after mild.

2. 6 Waste Ceramic as Fine Aggregate

The ceramic used in this study locally obtained from rehabilitation building works then putted in a modified Los Angeles abrasion test machine for 15 minutes for each 4 kg of ceramic, the result is shown as **Error! Reference source not found.**.

Figure 2: Fine ceramic tiles.

2. 7 Waste Ceramic as Coarse Aggregate

The ceramic used in this study locally obtained from rehabilitation building works. Industrial wastes made of ceramic insulators are typically too large to be fed into a crushing plant. A hammer is used to break them into tiny pieces that are between 100 and 150 mm in size, and a chisel and hammer are used to manually deglaze the surface. To achieve the necessary 25 mm size, these tiny fragments are subsequently fed into a crusher as displayed in **Error! Reference source not found.**.

a b

Figure 3: Coarse ceramic tiles a) Locally obtained waste ceramic, b) Crushing waste ceramic.

3 Methodology

This section describes the method used to look at the mechanical characteristics of concrete composed of waste glass and ceramic. To carry out this study 90 cubes of (15x15x15) cm and 90 cylinders of (15x30) cm were casted. The main variables of the experimental study are replacing glass with different percentages of cement and replacing ceramic with different percentages of the fine and coarse aggregates, which consist of three tests: the concrete compressive strength test, the splitting tensile strength test, and the ultrasonic pulse velocity (UPV) test.

3. 1 Mixing and Casting Sample

The primary mix is 1:2:4 and the water-cement ratio is 0.47. During the addition procedure, the dry mixture of coarse aggregate, fine aggregate, cement, and ceramic was carried out by hand for around 4-5 minutes throughout the process of mixing concrete components. Then for waste glass, cement and leftover glass powder are mixed and added to the concrete components. After that, the water was added and thoroughly combined. Three layers of the concrete mixture were put into the mould, and each layer was manually compacted in compliance with the BS 1881-116:1983 specification, which specifies that a typical square steel rod with a rounded or bullet-shaped end (16 mm in diameter and 60 mm in length) should be used to condense cubes to a density of 36. For splitting tensile strength, cylinders were compressed 25 times using an ASTM C 496 standard tamping rod composed of tiny, round, straight steel (10 mm in diameter x 305 mm long). The materials used are depicted in Figure 4**:** and Table 3 provides a summary of all mixtures design.

Figure 4: materials Preparing for mixing.

Table 3: Sample quantities (Mix proportion)

Samples	Mix	W/C ratio	Samples		Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Waste Glass (kg)	Waste Ceramic (kg)
			cube	cylinder					
Control mix	1:2:4	0.47	9	9	20	40	80	0	0
Waste glass 5%	1:2:4	0.47	9	9	19	40	80	1	0
Waste glass 10%	1:2:4	0.47	9	9	18	40	80	2	0
Waste glass 15%	1:2:4	0.47	9	9	17	40	80	3	0
Waste fine ceramic 10%	1:2:4	0.47	9	9	20	36	80	0	4
Waste fine ceramic 20%	1:2:4	0.47	9	9	20	32	80	0	8
Waste fine ceramic 30%	1:2:4	0.47	9	9	20	28	80	0	12
Waste coarse ceramic 10%	1:2:4	0.47	9	9	20	40	72	0	8
Waste coarse ceramic 20%	1:2:4	0.47	9	9	20	40	64	0	16
Waste coarse ceramic 30%	1:2:4	0.47	9	9	20	40	56	0	24

3. 2 Curing Method

The immersion technique was utilized for curing. To prevent water loss due to evaporation, the samples were covered with nylon sheets for about 24 hours. The molds of the specimens were then removed and put in a water tank (bath) for immersion or continuous wet curing. Furthermore, each sample was submerged in water until it reached the testing age. However, they were healed for three ages, namely three, seven, and twenty-eight days. The casted samples are seen in

Figure **5:** .

Figure 5: Casted samples.

3. 3 Slump Test

The concrete slump test was performed by ASTM C 143. This test is a method of determining the new concrete's properties. The test determines the fresh concrete's workability. The measuring of slump is shown in **Error! Reference source not found.**.

Figure 6: Slump test.

3. 4 The Compressive Strength Test

To determine the compressive strength, 90 cubes measuring (15 × 15 × 15) cm were utilized. For every test, three specimens were used for 3, 7, and 28 days. Concrete cubes were taken out of the molds and left to dry at room temperature for roughly five hours before testing. The compressive strength test was carried out in accordance with BS EN 12390-3:2002 [31]. To test the compressive strength of concrete cubes, a constant loading rate of 2.0 MPs/s was used.

3. 5 The Splitting Tensile Strength Test

Measuring 90 cylinders (15x30) cm with 28 days old were subjected to tensile strength testing. This test was carried out in compliance with ASTM C 496 [32]. Prior to testing, the specimens were placed horizontally on the machine plate, and their surfaces were dried.

3. 6 The Ultrasonic Pulse Velocity Test

The ultrasonic pulse velocity test was conducted in accordance with ASTM C 597–97, 2004. Waving velocity is the test operation, which is contingent upon the elastic properties and density of the material. Consequently, the most favorable outcomes are achieved when the receiving transducer is positioned on the opposing side of the concrete member. This is referred to as direct transmission. In order to guarantee optimal contact between the contact faces of the transducers and the surfaces of the specimens, petroleum jelly was implemented. Then, the average results were calculated.

4 Results and Discussions

4. 1 Compressive Strength

4. 1. 1 Compressive strength of waste glass

The compressive strength findings for all percentages and control mixtures are shown in **Error! Reference source not found.**. Each compressive strength value is the mean of three waste glass specimens; waste glass kept under curing for 3,7 and 28 days. **Error! Reference source not found.** and **Error! Reference source not found.** display the compressive strength of waste glass and control mix for 28 days.

The results showed that the maximum compressive strength was 39.3 MPa for 10%, while the first and third values of compressive strength were 32.4 MPa and 35.7 MPa for 5% and 15%, respectively. According to [33, 34], waste glass increases the setting time since it requires a certain quantity of water, and the proportion of water in the mixture remains constant, therefore waste glass' compressive strength drops after 10%.

Table 4: Compressive strength of control mix and waste glass.

Compressive Strength (Mpa)			
Days	**3**	**7**	**28**
Control mix	10.7	15.6	24.8
Waste glass 5%	14.9	21.1	32.4
Waste glass 10%	20.5	27.5	39.3
Waste glass 15%	16.1	22.4	35.7

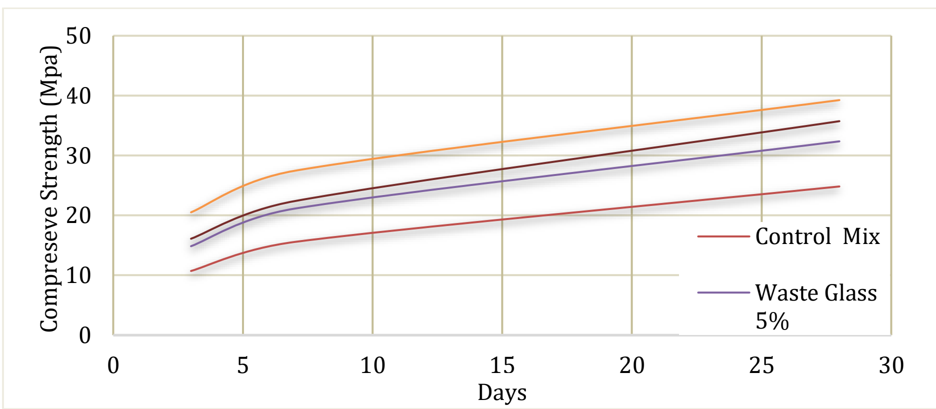

Figure 7: Compressive strength of control mix and waste glass.

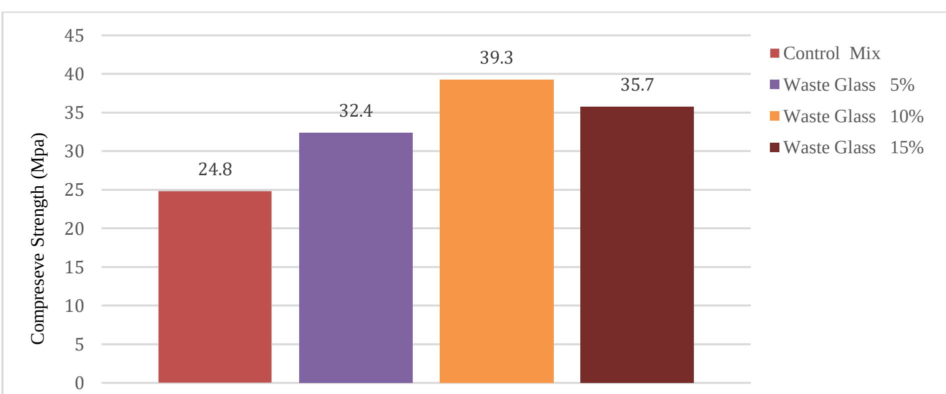

Figure 8: Compressive strength of control mix and waste glass for 28 days.

4. 1. 2 Compressive strength of waste ceramic as fine aggregate

Table 5**:** show the compressive strength findings for all percentages and control mixes. Each compressive strength measurement is the average of three fine ceramic specimens. Three, seven, and twenty-eight days, respectively.

depicts the compressive strength of the control mix and fine ceramic for 28 days.

Table 5: Compressive strength of control mix and fine ceramic.

Compressive Strength (Mpa)			
Days	**3**	**7**	**28**
Control mix	10.7	15.6	24.8
Fine ceramic 10%	11.3	17.0	26.8
Fine ceramic 20%	12.2	17.3	27.7
Fine ceramic 30%	11.4	16.3	26.0

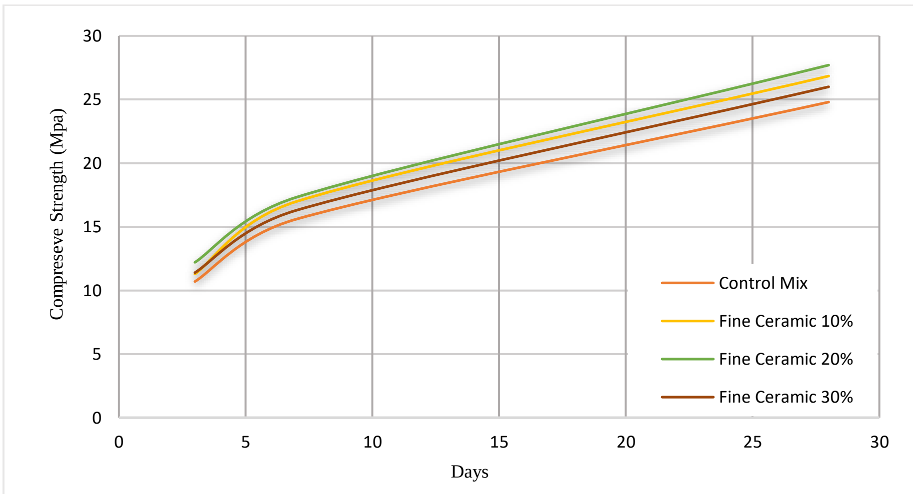

Figure 9: Compressive strength of control mix and fine ceramic.

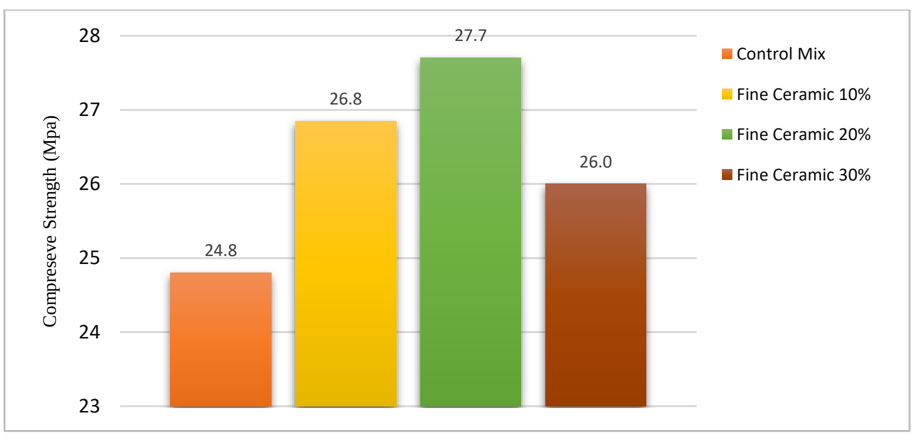

Figure 10: Compressive strength of control mix and fine ceramic for 28 days

After 28 days, the concrete's compressive strength increased by 8% to 11% when 10% and 20% of the natural sand were replaced with fine ceramic tile waste. The 20% fine ceramic blend exhibited the maximum compressive strength, measuring 27.7 MPa. Although the compressive strength decreased to 4.8% with 30% replacement, it was still higher than the control mix.

The data show that continual partial replacement will result in a steady loss of strength. Because ceramic tiles include clay, which reduces concrete's compressive strength. However, the effectiveness of water is the cause for increasing the percentage of ceramic from 10% to 20%, and there has been a percentage of SiO_2 According to Duxson [35]. First, the percentage of water needed for hydration processes is sufficient, and the percentage of voids reduces as the surface area of ceramic increases, causing the concrete's compressive strength to slightly rise. The amount of clay in the concrete and its compressive strength both increase as the percentage of ceramic increases. However, an increase in the ceramic percentage in the mix to 30% indicates a rise in clay and a decrease in concrete's compressive strength due to inadequate water. This results in concrete fractures and a loss of compressive strength.

4. 1. 3 Compressive strength of waste ceramic as coarse aggregate

The compressive strength results for all percentages and control mixes are displayed in **Error! Reference source not found.**. The average of three fine ceramic specimens that were cured for three, seven, or twenty-eight days is used to calculate each compressive strength measurement.

shows the compressive strength of the control mix and coarse ceramic waste tiles after 28 days.

Table 6: Compressive strength of control mix and coarse ceramic

Compressive Strength (Mpa)			
Days	**3**	**7**	**28**
Control mix	10.7	15.6	24.8
Coarse ceramic 10%	10.5	15.3	24.8
Coarse ceramic 20%	10.7	15.4	25.0
Coarse ceramic 30%	10.6	15.4	24.9

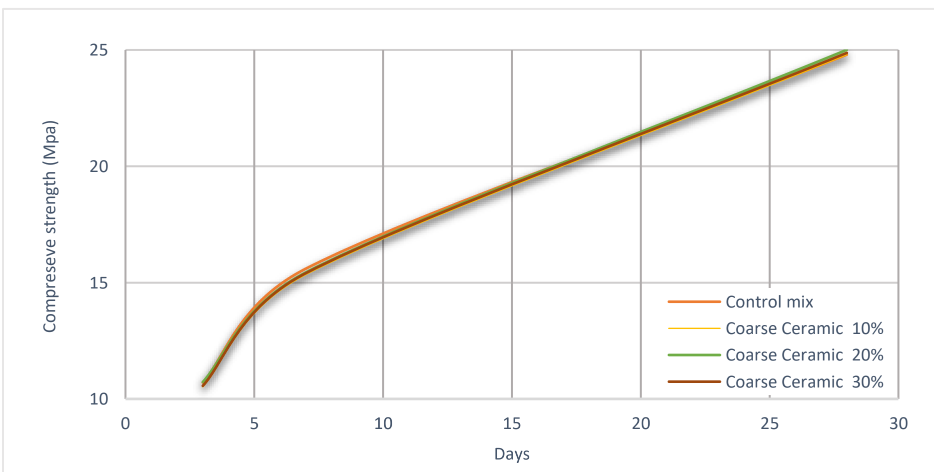

Figure 11: Compressive strength of control mix and coarse ceramic

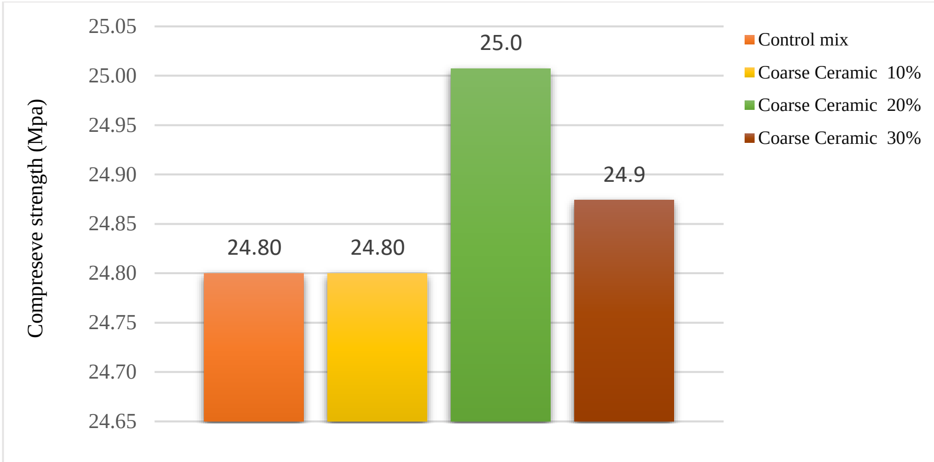

Figure 12: Compressive strength of control mix and coarse ceramic for 28 days

It has been demonstrated from the figures that concrete compressive strength is unaffected by the coarse ceramic waste tiles. However, employing a little amount of coarse ceramic is recommended since increasing the amount of ceramic reduces compressive strength and reduces surface area due to their flaky shape. This indicates that replacing normal coarse aggregate with ceramic waste coarse aggregate in structural works is not recommended for more than 20%. Ceramic waste aggregate's flaky nature and smooth surface texture might have had a role in the strength reduction, which likely resulted in poor matrix bonding qualities. As the curing age increased, the strength values increased as well, indicating that curing influenced concrete strength growth.

4. 2 Splitting Tensile Strength

4. 2. 1 Splitting tensile strength of waste glass

Table 7 demonstrates that the splitting tensile strength of concrete samples using 5% waste glass replaced cement increased 16.67% in comparison to a control combination. The splitting tensile strength increased by 30% with the addition of up to 10% waste glass. There is a 23.3% increase in splitting tensile strength when 15% waste glass is used. Using waste glass in place of cement can strengthen the binding between the aggregate and paste, which may increase tensile strength at the matrix interface. Figures 13 and 14 illustrate the split tensile strength of waste and ordinary glass.

Table 7: Split tensile strength of control mix and waste glass

Splitting Tensile Strength (Mpa)			
Days	**3**	**7**	**28**
Control mix	1.2	1.8	3.0
Waste glass 5%	1.6	2.7	3.5
Waste glass 10%	2.2	3.4	3.9
Waste glass 15%	1.8	3.0	3.7

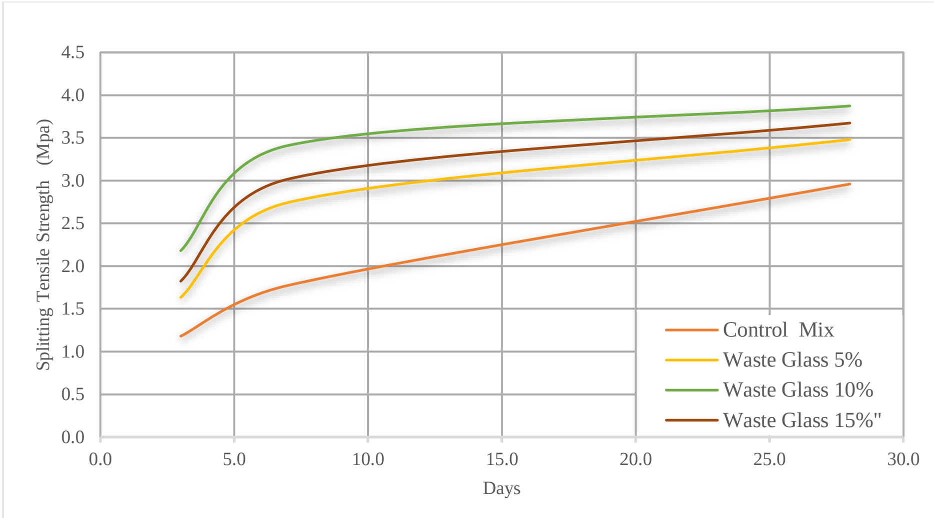

Figure 13: Split tensile strength of normal and waste glass

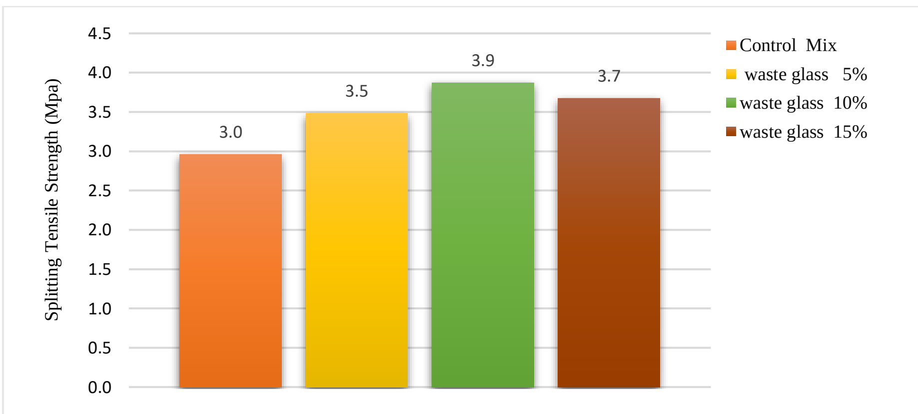

Figure 14: Split Tensile strength of control mix and coarse ceramic for 28 days

4. 2. 2 Splitting tensile strength of waste ceramic as fine aggregate:

As clear in **Error! Reference source not found.** and **Error! Reference source not found.** Adding 10% of fine ceramic increases the tensile strength by 10%, and adding 20% increases it by 16.67%. However, replacing 30% of the fine ceramic results in a split tensile strength increase to 13.3%. The decrease in tensile strength when replacing 30% of fine ceramic is due to the increased clay content in the concrete, which weakens its strength. As the ceramic proportion increases, more clay is present, leading to a decrease in tensile strength due to insufficient water. **Error! Reference source not found.** show the result in 28 days for split tensile strength.

Table 8: Split tensile strength of control mix and fine ceramic

Splitting Tensile Strength (Mpa)			
Days	**3**	**7**	**28**
Control mix	1.2	1.8	3.0
Fine ceramic 10%	1.3	1.9	3.3
Fine ceramic 20%	1.4	2.1	3.5
Fine ceramic 30%	1.3	2.0	3.4

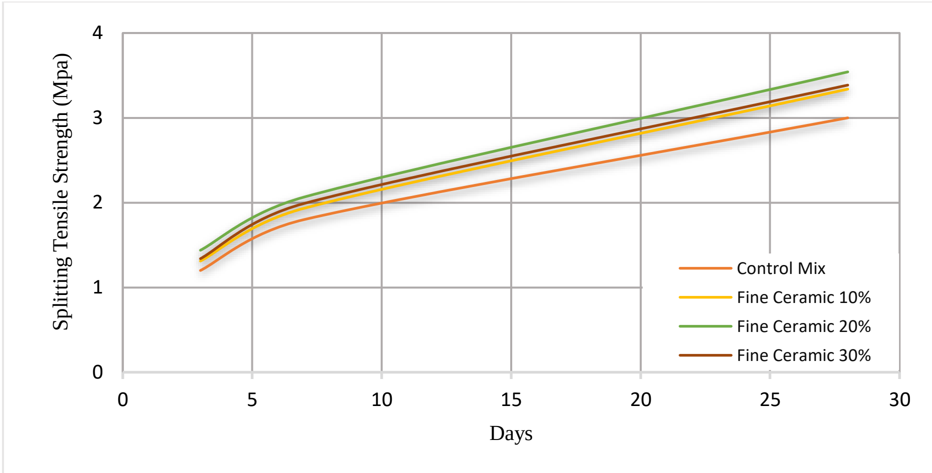

Figure 15: split tensile strength of control mix and fine ceramic

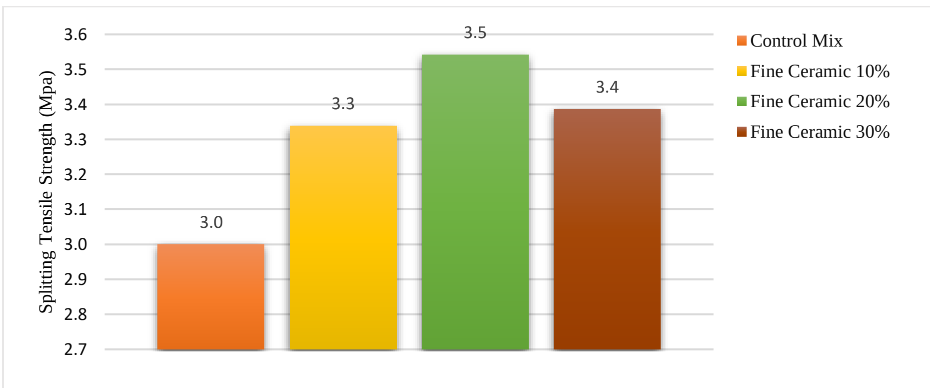

Figure 16: Split tensile strength of control mix and fine ceramic for 28 days

4. 2. 3 Splitting tensile strength of waste ceramic as coarse aggregate:

The split tensile strength of concrete mixtures with ceramic coarse aggregate replacement is show in **Error! Reference source not found.**, **Error! Reference source not found.** and Figure 18. The split tensile strength of concrete with coarse ceramic approximately has no effect on its properties.

Table 9: Split tensile strength of control mix and coarse ceramic

Splitting Tensile Strength (Mpa)			
Days	**3**	**7**	**28**
Control Mix	1.2	1.8	3.0
Coarse Ceramic 10%	1.2	1.8	2.9
Coarse Ceramic 20%	1.3	2.0	3.1
Coarse Ceramic 30%	1.2	1.9	3.0

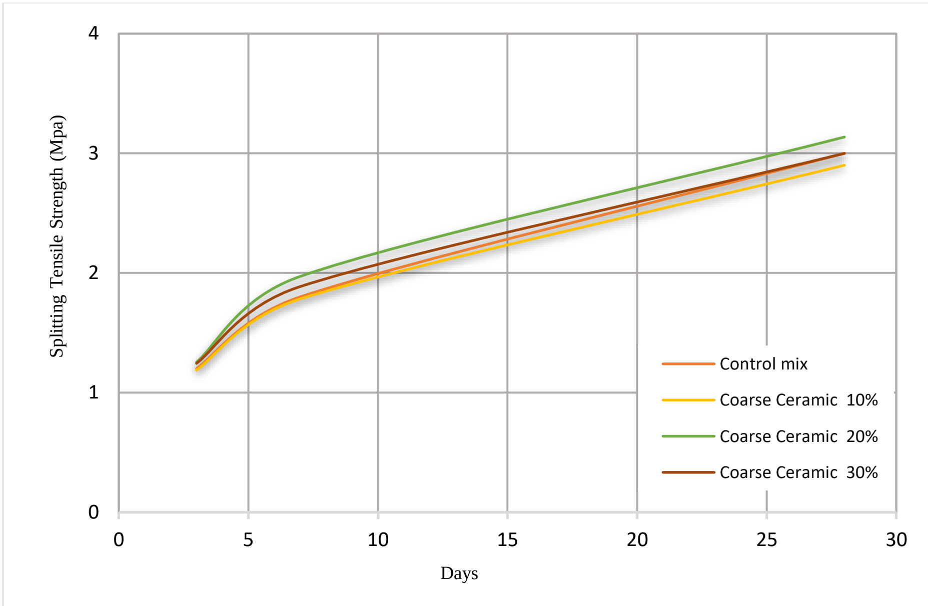

Figure 17: Split tensile strength of control mix and coarse ceramic

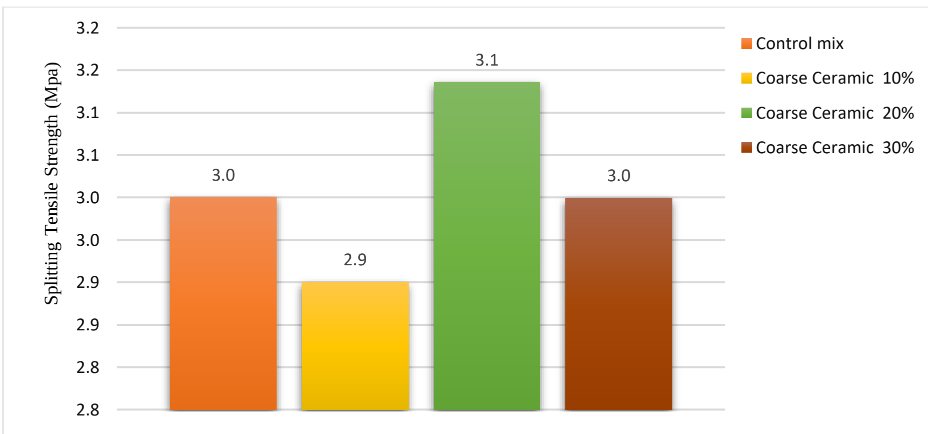

Figure 18: Split tensile strength of control mix and coarse ceramic for 28 days

4. 3 UPV Test

4. 3. 1 UPV test of waste glass

As shown in Figure 19 an increase in waste glass causes UPV to increase. The reason is that waste glass contains SiO2, so when SiO2 increases, the density increases which causes a decrease in voids which makes the UPV increase. The density for control mix was 2400 kg/m^3 and the densities of waste glass were 2410 kg/m^3, 2430 kg/m^3 and 2434 kg/m^3 respectively.

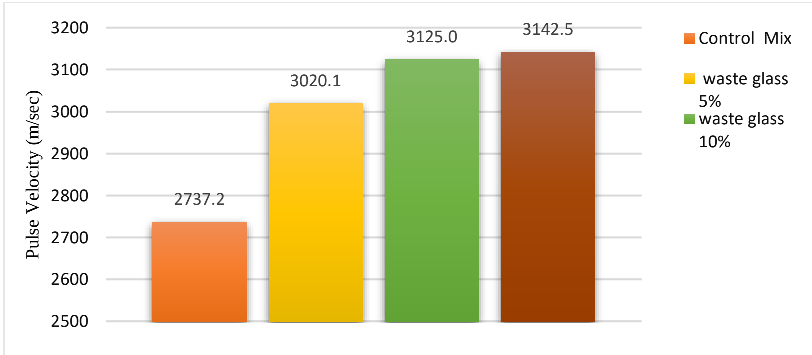

Figure 19: The result UPV of control mix and waste glass

4. 3. 2 UPV test of waste ceramic as fine aggregate

As seen in Figure 20, by increasing the fine ceramic replacement, the UPV increases compared to the control mix but gradually decreases with increasing the fine ceramic replacement. This is because fine ceramic contains clay, which absorbs the water during hydration processes. This crack increases the voids. By increasing the voids, the UPV decreases. However, the reason for the UPV being more than the control at a small percentage is the decreasing of the voids and does not affect the hydration processes.

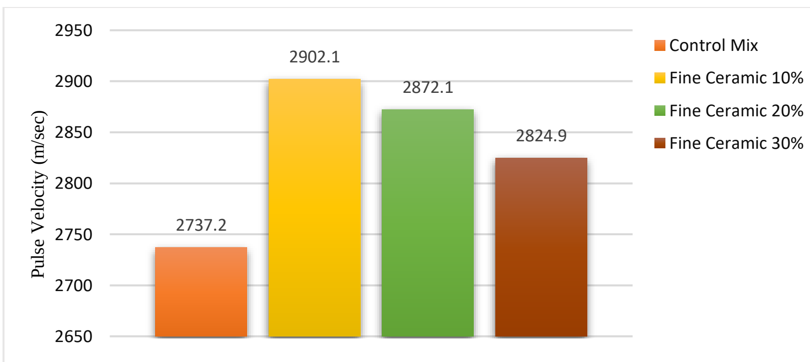

Figure 20: The result UPV of control mix and fine ceramic

4. 3. 3 UPV test of waste ceramic as coarse aggregate

As shown in Figure 21, it has less effect than fine ceramic because the coarse ceramic's granules are larger and non-arranged (flaky shape). However, the reason that the UPV is higher than the control mix is that the coarse ceramic composition is different from the coarse aggregates composition which influence the concrete's performance.

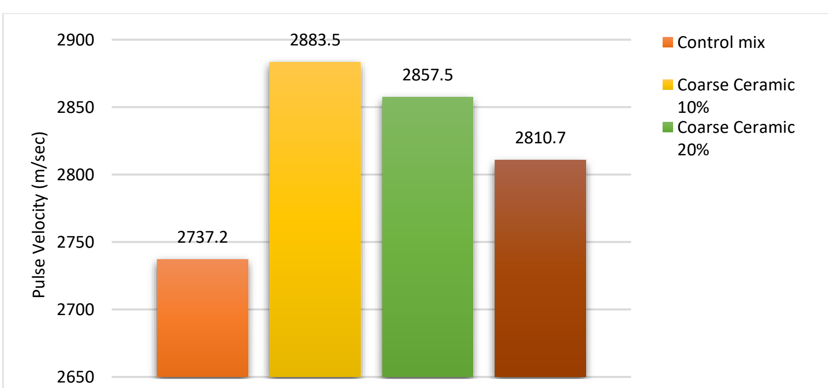

Figure 21: The result UPV of control mix and waste glass

5 Conclusions

5. 1 Waste Glass Conclusions

The results indicate that replacing waste glass (silica powder) with cement enhances the concrete of compressive strength. When glass powder is used in place of cement, the initial and final setting times increase because of high water absorption. The workability of the concrete mixture was considerably reduced when glass powder was added. The ideal percentage of glass powder substitution is 10%, which improves split tensile strength by 30% and compressive strength by 58.46% over a 28 - days period when compared to the control mix. With increasing the fine glass percentage to 15%, the mechanical properties decrease. Conversely, as the proportion of waste glass rises, the UPV rises as well. Concrete's compressive strength is increased by adding SiO2. As the SiO2 concentration gets closer to the critical concentration—where the cement paste reacts optimally with the amount of SiO_2 the compressive strength of SiO2-modified concrete rises. If you add more than that, the concrete may actually become weaker.

5. 2 Fine Ceramic Conclusions

The study found that increasing the ceramic content enhances compressive strength, peaking at 27.7 MPa with a 20% replacement level—an 11.7% improvement over the control mix. However, exceeding this replacement level leads to a decrease in strength, indicating a weakening of the cement and reduced binder cohesion. The ceramic waste fine aggregate concrete has a higher splitting tensile strength than the control mix for all mixes. At 20% replacement, concrete reaches its ideal split tensile strength of 3.5 MPa, which means 3% more than that of control mix concrete. The concrete mix's workability significantly decreased due to the usage of ceramic waste. The fine ceramic particles' pozzolanic activity and filler effect, which increased matrix density and bond strength throughout the interfacial transition zone, were associated with enhancing performance.

5. 3 Coarse Ceramic Conclusions

The ideal split tensile strength of concrete is 3.1 MPa when 20% coarse ceramic waste is used. The splitting tensile strength of ceramic waste coarse aggregate concrete is very close to that of the control mix. The compressive strength of concrete increased gradually as the amount of coarse waste ceramic tile aggregate increased up to a specified limit of 20%, but then decreased by 30%. Concrete achieves its maximum compressive strength of 25 MPa at 20% replacement, which is 1% more than that of ordinary concrete. It is also evident that the mechanical properties of concrete are not significantly harmed by the use of waste course ceramic it serves mainly as an inert filler, not participating in pozzolanic reactions. Although it improves structural cohesion by filling voids, it does not notably enhance concrete strength. Overall, the concrete properties remained acceptable, indicating that ceramic waste could be a viable partial replacement for natural aggregates, promoting environmental and economic benefits.

Finally, using waste glass and waste ceramic tiles in concrete is an effective measure of reducing the costs of concrete and keeping the environment clean along with wastage management and decreasing the use of natural raw materials.

6 Future research is recommended to:

1. Utilize additional waste materials: To combine with glass and ceramic waste to improve durability and mechanical performance.
2. Scaling Up and Field Applications: Evaluate the viability of increasing the usage of these materials in actual building projects and gauge how consistently they perform in field circumstances.
3. Fire and Thermal Resistance: Examine the concrete's ability to withstand heat and fire while adding leftover glass and ceramic elements.
4. Investigation of leftover glass and ceramic components in high-performance concrete, such as fiber-reinforced concrete, high-strength concrete, and self-compacting concrete (SCC).

References

[1] N. Mohamad, K. Muthusamy, R. Embong, A. Kusbiantoro, and M. H. Hashim, "Environmental impact of cement production and Solutions: A review," *Materials Today: Proceedings,* **48**, 741-746, 2022.

[2] L. Chen *et al.*, "Conversion of waste into sustainable construction materials: A review of recent developments and prospects," *Materials Today Sustainability,* **27**, 100930, 2024.

[3] Z. H. Joudah *et al.*, "Effects of Waste Glass Bottle Nanoparticles and High Volume of Waste Ceramic Tiles on Concrete Performance When Exposed to Elevated Temperatures: Experimental and Theoretical Evaluations," *Fire,* **7**(12), 426, 2024.
[4] M. Sabbrojjaman, Y. Liu, and T. Tafsirojjaman, "A comparative review on the utilisation of recycled waste glass, ceramic and rubber as fine aggregate on high performance concrete: Mechanical and durability properties," *Developments in the Built Environment,* **17**, 100371, 2024.
[5] Q. Li, H. Qiao, A. Li, and G. Li, "Performance of waste glass powder as a pozzolanic material in blended cement mortar," *Construction and Building Materials,* **324**, 126531, 2022.
[6] S. Patil and Y. Patilb, "Effect of Varying Glass Powder Size on Performance of Cement Mortar: Microstructural and Compressive Strength Assessment at High Temperatures," 2024.
[7] L. F. Jochem, C. A. Casagrande, L. Onghero, C. Venancio, and P. J. Gleize, "Effect of partial replacement of the cement by glass waste on cementitious pastes," *Construction and Building Materials,* **273**, 121704, 2021.
[8] L. K. ASKAR, I. H. M. ALBARWARY, and M. K. ASKAR, "Use of expanded polystyrene (EPS) beads in silica-fume concrete," *Journal of Duhok University,* **22**(1), 30-38, 2019.
[9] L. K. Askar, B. A. Tayeh, B. A. Bakar, and A. Zeyad, "Properties of ultra-high performance fiber concrete (UHPFC) under different curing regimes," *Int. J. Civ. Eng. Technol. (IJCIET),* **8**(4), 965-974, 2017.
[10] P. Zhang, P. Zhang, J. Wu, Z. Guo, Y. Zhang, and Y. Zheng, "Mechanical Properties and Durability of Sustainable Concrete Manufactured Using Ceramic Waste: A Review," *Journal of Renewable Materials,* **11**(2), 2023.
[11] Y. Chen, X. Xiong, S. Shi, C. Liu, Z. Xu, and Z. Ma, "Effect of glass powder on alkali-silica reaction mitigation for tunnel waste rock slag in concrete," *Journal of Building Engineering,* **98**, 111024, 2024.
[12] Ö. Zeybek *et al.*, "Influence of replacing cement with waste glass on mechanical properties of concrete," *Materials,* **15**(21), 7513, 2022.
[13] H. J. Abd, R. I. Atiyah, and A. M. Hashim, "Effect of Particle Size of Waste Glass on Mechanical Properties of Concrete," *Journal of Madenat Alelem University College,* **11**(2), 58-66, 2019.
[14] J. Ahmad, F. Aslam, R. Martinez-Garcia, J. de-Prado-Gil, S. M. Qaidi, and A. Brahmia, "RETRACTED ARTICLE: Effects of waste glass and waste marble on mechanical and durability performance of concrete," *Scientific reports,* **11**(1), 21525, 2021.
[15] H. Du and K. H. Tan, "Waste glass powder as cement replacement in concrete," *Journal of Advanced Concrete Technology,* **12**(11), 468-477, 2014.
[16] R. J. Daniel and S. Sangeetha, "Experimental study on concrete using waste ceramic as partial replacement of aggregate," *Materials Today: Proceedings,* **45**, 6603-6608, 2021.
[17] E. E. Ambrose, O. R. Ogirigbo, I. E. Ekop, and I. C. Attah, "Compressive Strength, Workability, and Durability Performance of Concrete Incorporating Waste Ceramic Tile as Fine Aggregate," *International Journal of Pavement Research and Technology,* 1-12, 2024.
[18] A. Sharba, "Possibility of using waste glass powder and ceramic tile as an aggregate on the flexural behavior and strength properties," in *R. Abd-Alhameed, R. Zubo, o. Ali (Eds.), 1st international multi-disciplinary conference–sustainable development and smart planning: IMDC-SDSP*, 2020.
[19] Z. Jwaida, A. Dulaimi, and L. F. A. Bernardo, "The Use of Waste Ceramic in Concrete: A Review," *CivilEng,* **5**(2), 482-500, 2024.
[20] K. Velayutham, Sathanandham.T, Vijayan.V, S. Kumar.K, and Manikandan.M, "Strength characteristics on concrete with ceramic waste as a partial replacement of cement," *Journal of Chemical and Pharmaceutical Sciences,* **8**(4), 793-797, 2015.
[21] R. V. Meena, J. K. Jain, H. S. Chouhan, and A. S. Beniwal, "Use of waste ceramics to produce sustainable concrete: A review," *Cleaner Materials,* **4**, 100085, 2022.
[22] K. Manikandan, P. Nanthakumar, M. Balachandar, D. G. Shankar, and G. Vijayakumari, "Partial replacement of aggregate with ceramic tile in concrete," *Materials Today: Proceedings,* 2023.
[23] M. Sekar, "Partial replacement of coarse aggregate by waste ceramic tile in concrete," *International Journal for Research in Applied Science and Engineering Technology,* **5**(3), 473-479, 2017.
[24] H. Kustiawan, S. Boontanon, S. Aroonsrimorakot, and N. Boontanon, "Utilization of Ceramics Sanitaryware Waste (CSW) as an Admixture Material of Cooling Paint Products to Apply in Eco-Friendly Sustainability Infrastructure," in *GMPI Conference Series*, **3**, 10-24, 2024.
[25] A. International, "ASTM C 150-Standard Specification for Portland Cement," ed: ASTM International West Conshohocken, 2012.
[26] C. Astm, "Standard test method for sieve analysis of fine and coarse aggregates," *ASTM C136-06,* 2006.
[27] A. C33, "ASTM C33 standard specifications for concrete aggregates," *ASTM Standard Book,* 2003.
[28] A. Astm, "c128-15 Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate," *American Society for Testing and Materials: West Conshohocken, PA, USA,* 2015.
[29] A. C127-15, "Standard test method for relative density (specific gravity) and absorption of coarse aggregate," ed: American Society for Testing and Materials Philadelphia, PA, USA, 2015.
[30] ASTM, "ASTM C1602–06: Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete," ed: ASTM International West Conshohocken, 2006.

[31] B. Standard, "Testing concrete-Part 116: method for determination of compressive strength of concrete cubes," *BS,* **116**(1983), 36, 1881.
[32] A. C496-90, "Standard test method for splitting tensile strength of cylindrical concrete specimens," *ASTM Stand. B.,* 545-545, 2008.
[33] R.-U.-D. Nassar and P. Soroushian, "Field investigation of concrete incorporating milled waste glass," *The Journal of Solid Waste Technology and Management,* **37**(4), 307-319, 2011.
[34] H. Limantono, J. J. Ekaputri, and T. E. Susanto, "Effect of silica fume and glass powder on high-strength paste," in *Key Engineering Materials*, **673**, Trans Tech Publ, 37-46, 2016.
[35] P. Duxson, J. L. Provis, G. C. Lukey, and J. S. Van Deventer, "The role of inorganic polymer technology in the development of 'green concrete'," *cement and concrete research,* **37**(12), 1590-1597, 2007.