International Journal of Research and Review
Volume 11; Issue: 10; October 2024
Website: www.ijrrjournal.com
Research Paper E-ISSN: 2349-9788; P-ISSN: 2454-2237

Influence of Glass Granular Class on the Compressive Strength of Glass-Sand Mortar

Djidoula TAKO[1], Koudzo ASSAGBAVI[1,2], Marceline NKWENKEU[3], Kossi Eli Benoît MITEKOR[1], Yawovi M. X. Dany AYITE[4]

[1]Institut de Formation Technique Supérieure (IFTS), Lomé, TOGO.
[2] Laboratoire d'Energétique et de Mécanique Appliquée (LEMA), Ecole Polytechnique d'Abomey-Calavi, Université d'Abomey-Calavi, Cotonou, Bénin.
[3]Ecole Africaine des Métiers de l'Architecture et de l'Urbanisme, Lomé, TOGO.
[4]Laboratoire de Recherche en Sciences de l'Ingénieur (LARSI), Ecole Polytechnique de Lomé, Université de Lomé, Lomé, TOGO.

Corresponding Author: Djidoula TAKO

DOI : https://doi.org/10.52403/ijrr.20241048

ABSTRACT

This study examines the effect of glass particle size and color on the compressive strength of mortars made from glass, sand, and cement. A range of water-to-cement (W/C) ratios was applied, and tests were conducted to measure density and compressive strength at both 2 and 7 days. The glass, available in green, brown, and white, was introduced as both fine and coarse particles.
The findings reveal that incorporating glass significantly enhances compressive strength compared to traditional mortars without glass, regardless of its color. Brown glass, especially in its coarse form, exhibited the best mechanical performance. With a W/C ratio of 0.48, mortars containing coarse brown glass particles reached a peak compressive strength of 34.78 MPa, showing a relative increase of 134.52% compared to mortars without glass. Fine brown glass particles also demonstrated strong compressive strength, though lower than the coarse ones.
The density analysis showed a positive correlation between density and compressive strength, suggesting that denser mortars perform better mechanically. The superior performance of coarse glass particles is likely due to their optimal granular distribution, which enhances the bonding between cement and glass particles, leading to greater overall strength.

Keywords: Compressive strength – Particle size – Recycled glass – Mortar – Density

INTRODUCTION

The management and recycling of glass waste remain a significant challenge for municipalities worldwide [1]. In 1994, the United States produced approximately 9.2 million metric tons of post-consumer glass, with 80% coming from packaging materials [2]. For example, New York City collects over 100,000 tons of glass annually, with processing costs reaching up to $45 per ton [3]. Although recycling glass into new products reduces energy consumption and the demand for raw materials, not all used glass can be recycled due to the presence of impurities, economic constraints, and mixed color compositions.
In Togo, the management of glass waste poses significant challenges. In major cities such as Lomé, glass waste accumulates without the benefit of a proper recycling infrastructure. This accumulation not only results in environmental concerns but also imposes additional financial burdens on municipalities regarding waste collection

and disposal. Furthermore, due to limited resources and competing priorities, the efficiency of glass recycling in Togo has yet to reach the levels observed in certain developed regions.

Given these constraints, the incorporation of recycled materials in construction presents a notably promising alternative. The construction industry has the capacity to integrate large volumes of materials with diverse quality levels, sourced from various locations. Notably, the use of recycled glass as an aggregate in cement-based concrete or as a partial substitute for cement has received considerable interest in recent decades [4-15].

Glass, being an amorphous material rich in silicon and calcium, demonstrates pozzolanic and potentially cementitious properties when finely ground. The addition of ground glass to concrete not only enhances its overall value but also allows for the recovery of the energy expended in the glass manufacturing process [11, 15-18].

Nevertheless, incorporating recycled glass as an aggregate in concrete presents several challenges. Studies conducted in the 1960s revealed that concrete containing glass aggregates frequently exhibited cracking [19-20]. In response, a wealth of subsequent research has focused on elucidating and mitigating this issue, examining the properties of concrete mixtures with different proportions and types of ground glass [4, 7-10, 21-22].

In this context, this study aims to investigate the effect of glass granularity on the compressive strength of glass-sand mortars. Collected glass was sorted by color (green, brown, white) and classified into two granular categories: fine and coarse. The physical properties of the constituent materials (sand, glass and cement) were thoroughly analyzed to formulate various mortar mixtures, adjusting the water content while keeping the amounts of cement and the proportions of sand and glass constant. The goal of this research is to deepen our understanding of the underlying mechanisms and to determine the optimal conditions for incorporating recycled glass into cement-based mortars.

MATERIALS & METHODS

The experimental program was designed to investigate the influence of glass granularity and color on the compressive strength of glass-sand mortars.

To accomplish the defined objectives, the following methodology was implemented:

- Characterization of materials.
- Fabrication and characterization of glass-sand-cement specimens to examine the influence of granular classification on the physical and mechanical properties of the mortars.

The cement employed in this study is CPJ 35, produced by CIMTOGO and widely available in hardware stores throughout Lomé. The sand, sourced from Dalavé, located approximately 27 km north of Lomé, is characterized as silty. The recycled glass used for this research was obtained from the glass processing site operated by the NGO “Environnement Propre”. At the site, the glass was sorted both by color (white, brown, and green) and by particle size (coarse and fine crushed glass).

MATERIAL CHARACTERISTICS

SAND

To classify the sand, tests were conducted in accordance with the NF P11-300 standard [23], including:

- The humus test,
- The fineness modulus,
- Density,
- Water content,
- Sand equivalent, and
- Particle size analysis.

Table 1 provides the test results for humus content, fineness modulus, density, water content, and sand equivalent.

Table 1: Results of humus test, fineness modulus, density, water content, sand equivalence

Humus test	Fineness modulus	Density		Water content (%)	Sand equivalence (%)
		Absolute density	Apparent density		
Light yellow coloration	2.12	2.48	1.53	2.02	79.6

The light yellow coloration observed during the humus test confirms the absence of organic matter in the sand. The sand equivalent test indicates that the sand is clean, containing a low percentage of clay fines, making it well-suited for producing high-quality concrete. With a fineness modulus of 2.12, this sand falls into the fine sand category, which enhances its workability.

The chemical composition of the sand samples was analyzed using scanning electron microscopy (SEM) coupled with energy-dispersive X-ray spectroscopy (EDS), enabling precise local elemental analysis [25]. For this study, a Cambridge Instruments S260 SEM was employed to determine the elemental composition of the sand. The chemical analysis (Figure 1) revealed that the sand consists predominantly of silica and oxygen, confirming its classification as silty sand.

Figure 2 presents the particle size distribution curve of the sand, analyzed in accordance with the NF EN ISO 17892-4 standard [24]. The findings reveal that the sand displays a continuous particle size distribution spanning from the 0.063 mm sieve to the 4 mm sieve.

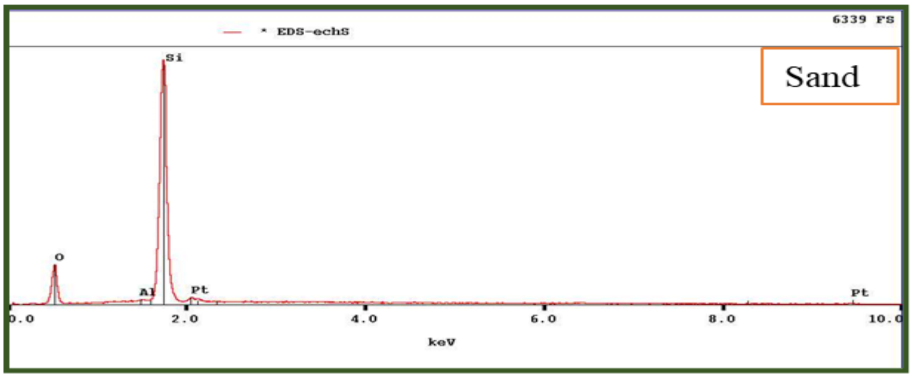


Figure 1: Results of the chemical analysis of the sand

GLASS

The classification tests performed on the glass predominantly focus on density [26] and particle size analysis. The results of the density tests are summarized in Table 2.

Analysis of Table 2 indicates that the absolute density of most glass types is relatively consistent, averaging approximately 2.5 g/cm³. Notably, exceptions include fine brown glass, which has a density of 2.4 g/cm³, and coarse white glass, which measures 2.6 g/cm³.

Table 2: Density test results

Type of glass		Density	
		Absolute density	Apparent density
Green	Fine	2.5	1.51
	Coarse	2.5	1.56
Brown	Fine	2.4	1.48
	Coarse	2.5	1.58
White	Fine	2.5	1.50
	Coarse	2.6	1.60

The apparent density shows significant variability, reflecting differences in compaction and porosity among the glass samples. Generally, fine particles exhibit lower apparent densities compared to their coarse counterparts of the same type. For example, fine green glass has an apparent density of 1.51 g/cm³, whereas coarse green glass measures 1.56 g/cm³.

Among the samples, fine brown glass displays the lowest apparent density at 1.48 g/cm³, indicating a higher volume of voids or a distinct compaction structure. Conversely, coarse white glass exhibits the highest apparent density at 1.60 g/cm³, suggesting enhanced compaction.

The results of the particle size analysis conducted on the various glass samples used in the experiments are depicted in Figure 1.

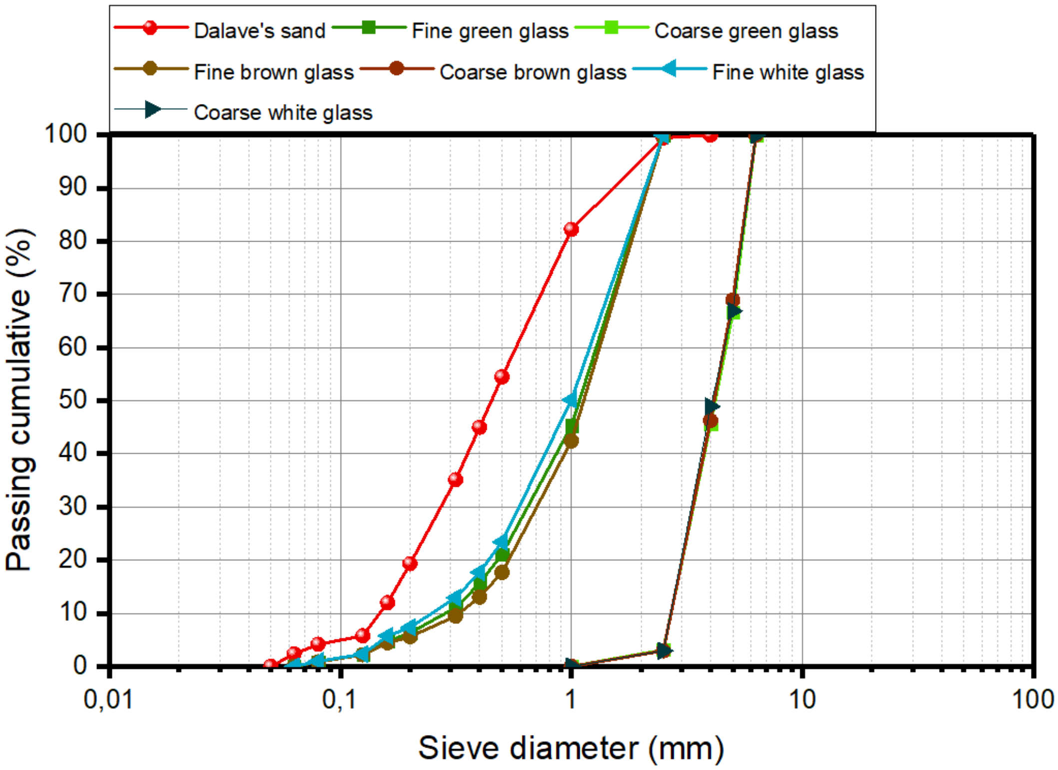


Figure 2: Results of the particle size analysis conducted on the different materials

The comparison of the particle size distributions among the fine glasses reveals the following characteristics:

- Green Glass: Exhibits a well-balanced distribution, characterized by a substantial proportion of medium-sized particles and a minimal presence of very fine particles.
- Brown Glass: Composed primarily of coarser particles, displaying a lower level of fineness relative to both green and white glass.
- White Glass: Presents a finer distribution, with a significant proportion of particles passing through smaller sieves, indicating a higher concentration of fine particles.

These granulometric analyses indicate that white glass is the finest, brown glass is the coarsest, while green glass occupies an intermediate position in terms of particle size.

The comparison of particle size distributions among the coarse glasses reveals several key observations:

- Green Glass: Displays a balanced particle size distribution, with a rapid decrease in the number of particles passing through finer sieves.
- Brown Glass: Shows a granulometric profile similar to that of green glass,

although with slight differences in the proportions of particles that pass through the sieves.

- White Glass: Exhibits a distinct distribution, featuring a higher proportion of particles passing through the 4 mm sieve compared to both green and brown glasses.

These granulometric findings suggest that the coarse crushed glasses - green, brown, and white - exhibit comparable particle size distributions, with slight variations in the proportions of particles that pass through intermediate sieve sizes.

The chemical analysis produced results displayed in Figures 3 to 5. Overall, the glass samples primarily consist of silicon (Si) and calcium (Ca). Additionally, trace amounts of platinum (Pt), oxygen (O), potassium (K), magnesium (Mg), aluminum (Al), iron (Fe), and sodium (Na) were detected. Notably, the brown and white glasses demonstrate a higher calcium content compared to the green glass. However, the analytical equipment used did not provide precise measurements of the exact percentages of the chemical composition for each glass type.

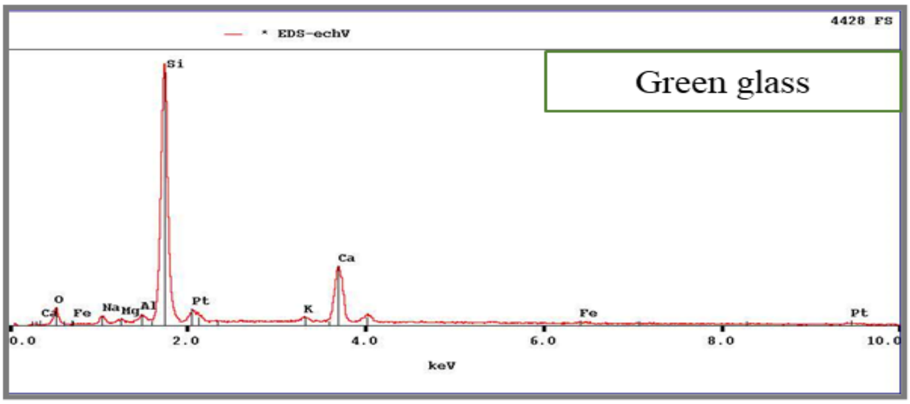


Figure 1: Results of the chemical analysis of green glass

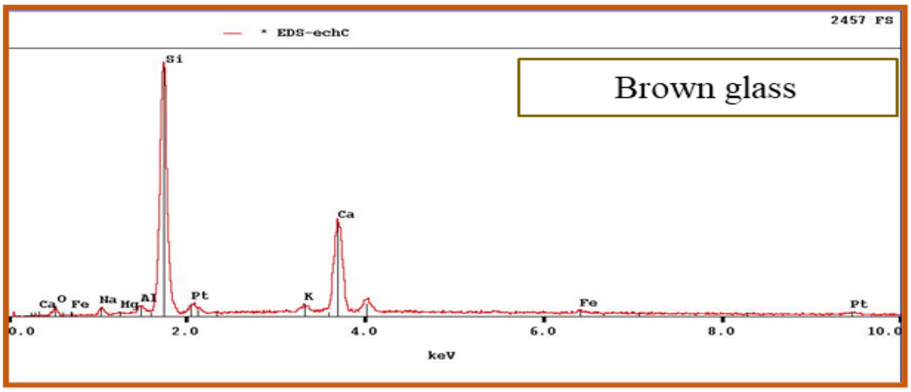


Figure 2: Results of the chemical analysis of brown glass

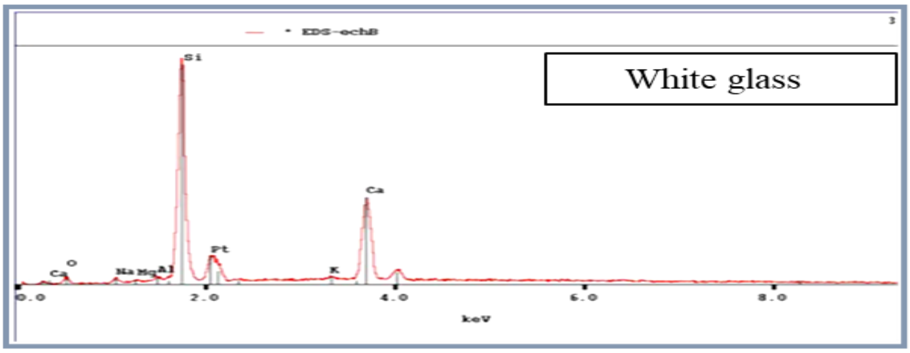


Figure 3: Results of the chemical analysis of white glass

FORMULATION AND COMPOSITION OF GLASS-SAND-CEMENT MORTAR

The mortar formulation is developed by adjusting the water content for each particle size class, while maintaining constant values for the amount of cement, sand, and glass percentages. A fixed quantity of 450 g of cement is used, with a glass-to-sand ratio of 0.43 [28].

The water content variation depends on the size of the crushed glass particles. For fine particles, adjustments are made in 5 g increments, whereas for coarse particles, the water content is varied in 10 g increments. The reference water quantity is set at 215 g, and this baseline is gradually decreased to establish different water-to-cement (W/C) ratios in the mortar, according to the specified increments.

Each type of glass is categorized into two particle size ranges, and for each size range, five (5) specific water-to-cement (W/C) ratios are determined. Table 3 provides a summary of the glass-sand-cement mortar composition.

Table 3: Composition of Glass-Sand-Cement Mortar

Cement (g)		450				
Sand (g)		945				
Glass (g)		405				
Coarse elements)	Water (g)	215	205	195	185	175
	W/C ratio	0.48	0.46	0.43	0.41	0.39
Fine elements)	Water (g)	215	210	205	200	192
	W/C Ratio	0.48	0.47	0.46	0.44	0.43

The mortar used in this study was prepared following the guidelines of the NF EN 196-1 standard [27], which outlines the process for sample preparation and curing. The mix consists of crushed glass, sand, cement, and water, with varying water-to-cement (W/C) ratios for each test series.

For each W/C ratio, six specimens, each measuring 4x4x16 cm³, were produced. The mortar was cast into metal molds and left to cure for 24 hours in a humid chamber at a temperature of 20°C ± 2°C to ensure initial setting. Afterward, the specimens were removed from the molds and submerged in a water bath, where they were stored until the day of testing, ensuring a stable curing environment.

The compressive strength tests were performed in two phases: three specimens were tested after 2 days of curing, and the other three after 7 days. The results for each curing period represent the average of measurements taken from six half-specimens.

Additionally, density and water absorption tests were conducted to complement the compressive strength analysis.

RESULTS, ANALYSIS AND DISCUSSION

This section focuses on presenting and discussing the results of the density, water absorption, and compressive strength tests, conducted in accordance with EN 772-1 standards.

DENSITY TESTS

Tables 4 and 5 summarize the average density results obtained from the experiments.

Table 4: Average results of density tests on fine-grained glass

Glass Type (Fine Element)	W/C ratio	Density					
		before immersion (CV)		At 2 days (CV)		At 7 days (CV)	
Green	0.48	2.18	(0.37%)	2.21	(0.43%)	2.24	(0.31%)
	0.47	2.19	(1.31%)	2.20	(0.03%)	2.24	(1.13%)
	0.46	2.17	(0.98%)	2.20	(0.31%)	2.22	(0.92%)
	0.44	2.12	(1.37%)	2.14	(0.51%)	2.18	(1.22%)
	0.43	2.08	(0.75%)	2.11	(0.77%)	2.14	(0.55%)

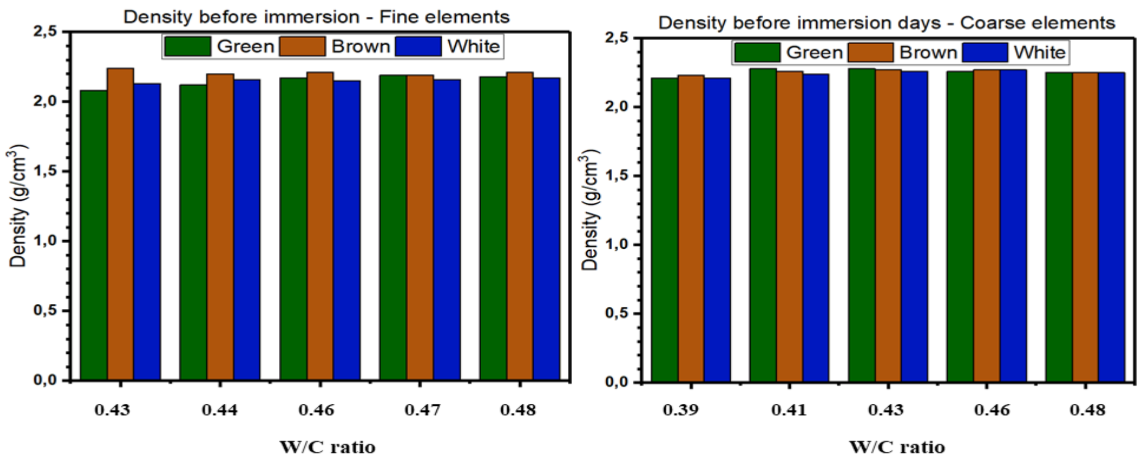
Brown	0.48	2.21	(0.68%)	2.22	(0.02%)	2.25	(0.64%)
	0.47	2.19	(0.63%)	2.22	(0.04%)	2.23	(0.56%)
	0.46	2.21	(1.78%)	2.23	(0.04%)	2.25	(1.72%)
	0.44	2.20	(0.63%)	2.23	(0.02%)	2.24	(0.65%)
	0.43	2.24	(0.66%)	2.26	(0.06%)	2.27	(0.61%)
White	0.48	2.17	(0.64%)	2.18	(0.08%)	2.20	(0.60%)
	0.47	2.16	(0.51%)	2.17	(0.09%)	2.19	(0.42%)
	0.46	2.15	(0.90%)	2.17	(0.20%)	2.19	(0.86%)
	0.44	2.16	(0.27%)	2.18	(0.41%)	2.20	(0.27%)
	0.43	2.13	(0.83%)	2.14	(1.28%)	2.16	(0.79%)

$$\text{CV} = \text{ Coefficient of variation } = \frac{\text{Standard deviation}}{\text{Average}}$$

Table 5 : Average results of density tests on coarse-grained glass

Glass Type (Coarse Element)	**W/C ratio**	**Density**					
		before immersion (CV)		**At 2 days (CV)**		**At 7 days (CV)**	
Green	0.48	2.25	(0.26%)	2.28	(0.39%)	2.30	(0.24%)
	0.46	2.26	(0.82%)	2.30	(0.36%)	2.31	(0.77%)
	0.43	2.28	(0.34%)	2.31	(0.42%)	2.32	(0.20%)
	0.41	2.28	(0.31%)	2.31	(0.30%)	2.32	(0.37%)
	0.39	2.21	(0.64%)	2.23	(0.44%)	2.24	(0.60%))
Brown	0.48	2.25	(0.25%)	2.27	(1.80%)	2.30	(0.27%)
	0.46	2.27	(0.52%)	2.30	(0.14%)	2.31	(0.48%)
	0.43	2.27	(0.28%)	2.30	(0.61%)	2.31	(0.20%)
	0.41	2.26	(0.46%)	2.30	(0.93%)	2.31	(0.41%)
	0.39	2.23	(1.34%)	2.26	(1.39%)	2.28	(1.28%)
White	0.48	2.25	(0.20%)	2.28	(0.29%)	2.29	(0.19%)
	0.46	2.27	(0.35%)	2.30	(0.42%)	2.31	(0.34%)
	0.43	2.26	(0.68%)	2.30	(0.34%)	2.31	(0.74%)
	0.41	2.24	(0.31%)	2.27	(0.23%)	2.28	(0.25%)
	0.39	2.21	(0.48%)	2.24	(0.33%)	2.25	(0.49%)

Based on the data from Tables 4 and 5, the graphs in Figure 6 were plotted. Each graph illustrates the variations in density of the samples at different water/cement (W/C) ratios, enabling a detailed comparison of the effects of glass particle size on the mortar density. The density differences between fine and coarse particles are also highlighted, providing a comprehensive overview of the properties of glass-based mortars.



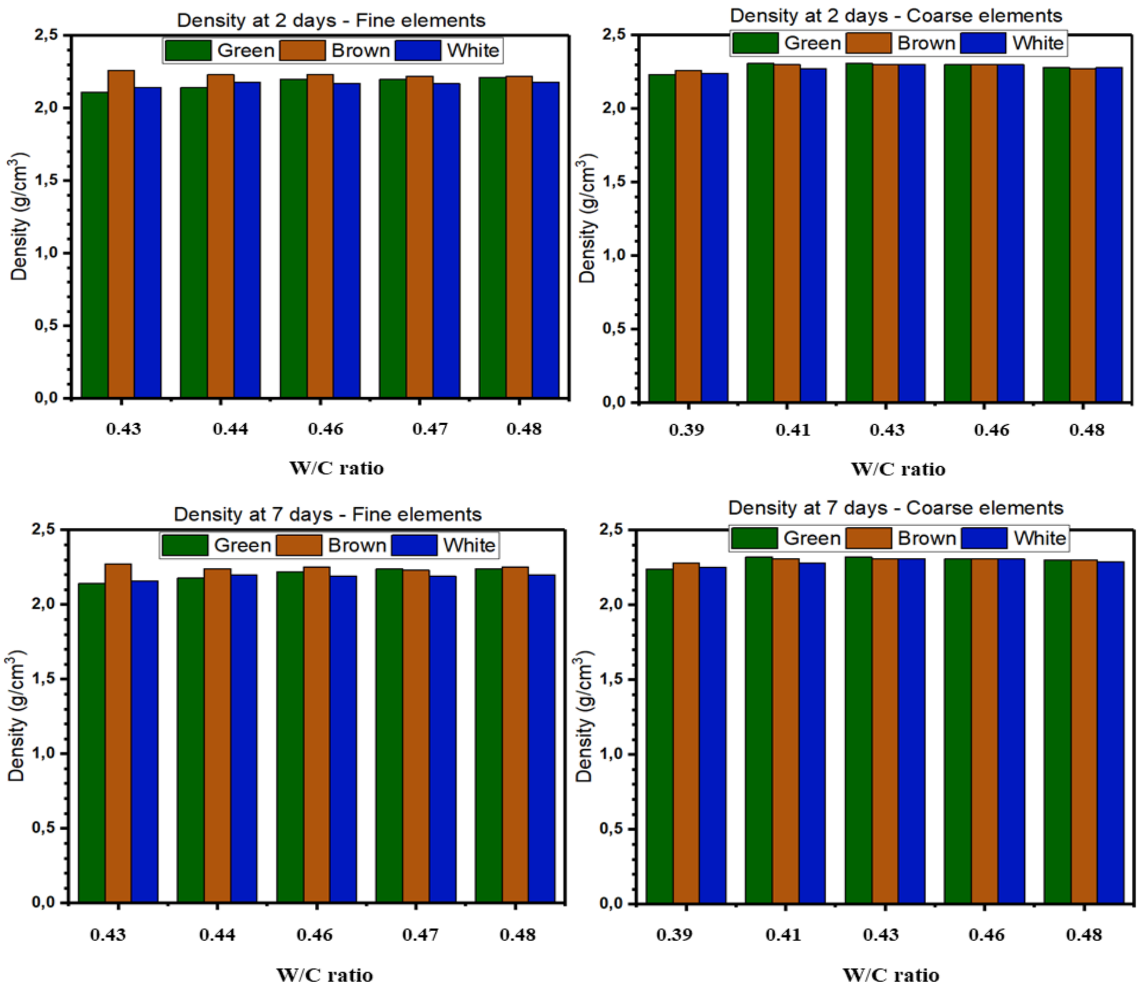


Figure 4: Results of density test

The density of green glass exhibits a progressive increase over time, signifying effective compaction in the mixtures across both particle size classifications. The coefficients of variation (CV) are consistently low, demonstrating high reproducibility and uniformity among the samples. In comparison, brown glass shows slightly elevated densities, indicating enhanced integration within the mortar matrix, particularly pronounced for fine particles. The CV values remain low, affirming the reliability of the measurements. In contrast, white glass presents slightly lower initial densities but displays a comparable and steady rise after both two and seven days.

ABSORPTION OF MORTARS

Table 6 displays the absorption rates of the mortars as a function of age and the water-to-cement ratio (W/C).

Table 6: Absorption Rates of Mortars

Absorption rate for mortar with fine-grained glass elements				Absorption rate for mortar with coarse-grained glass elements			
W/C	**From 1 to 2 days**	**From 1 to 7 days**	**From 2 to 7 days**	**W/C**	**From 1 to 2 days**	**From 1 to 7 days**	**From 2 to 7 days**
0.48	1.38	2.75	1.37	0.48	1.33	2.22	0.89
0.47	0.46	2.28	1.82	0.46	1.77	2.21	0.44
0.46	1.38	2.30	0.92	0.43	1.32	1.75	0.43
0.44	0.94	2.83	1.89	0.41	1.32	1.75	0.43
0.43	1.44	2.88	1.44	0.39	0.90	1.36	0.46

The data presented in Table 6 reveal that, within the same granular class, the water absorption rate at 7 days exceeds that at 2 days, irrespective of the water/cement (W/C) ratio. This observation indicates a continuous, gradual absorption of water by the material over time.
Notably, the increase in water absorption (D) between the 2-day and 7-day marks is generally more pronounced in mortars composed of fine aggregates than in those with coarse aggregates. This trend suggests that coarse aggregate mortars may reach saturation more rapidly due to their structural characteristics, which facilitate quicker initial water uptake.

COMPRESSIVE STRENGTH

Tables 7 and 8 display the average results of the compressive strength tests conducted on sand-glass-cement mortar specimens at 2 and 7 days of curing.

Table 7: Average results of compression tests on sand-glass-cement mortar specimens at 2 days

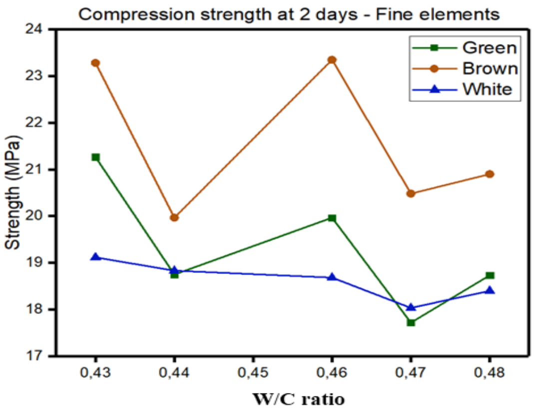
Compressive strength at 2 days							
Fine elements				Coarse elements			
W/C Ratio	**Green**	**Brown**	**White**	**W/C Ratio**	**Green**	**Brown**	**White**
0.48	18.73	20.90	18.40	0.48	20.90	20.22	21.20
0.47	17.72	20.48	18.03	0.46	23.72	23.03	23.79
0.46	19.97	23.35	18.68	0.43	27.60	26.25	31.12
0.44	18.75	19.97	18.83	0.41	27.00	26.73	26.85
0.43	21.27	23.28	19.12	0.39	27.48	25.32	27.02

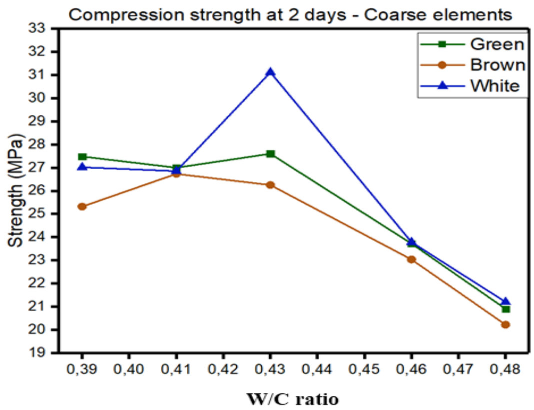
Table 8: Average results of compression tests on sand-glass-cement mortar specimens at 7 days

Compressive strength at 7 days							
	Fine elements				**Coarse elements**		
W/C Ratio	**Green**	**Brown**	**White**	**W/C Ratio**	**Green**	**Brown**	**White**
0.48	26.25	27.50	27.68	0.48	34.78	30.90	31.82
0.47	27.25	28.50	27.98	0.46	34.63	34.35	33.30
0.46	26.90	28.17	27.08	0.43	36.57	35.45	35.50
0.44	24.02	27.40	26.92	0.41	35.62	34.80	33.42
0.43	24.85	27.90	27.38	0.39	35.85	35.42	36.47

To effectively illustrate the data from the tables and provide deeper insights into the relationships between density and compressive strength for the different glass types, Figures 7 and 8 present the following:

- **Figure 7** illustrates how compressive strength varies with the water/cement (W/C) ratio for each glass type (green, brown, white), categorized by fine and coarse aggregates at both 2 and 7 days.
- **Figure 8** demonstrates the relationship between density and compressive strength for each type of glass (green, brown, white), again distinguishing between fine and coarse aggregates at 2 and 7 days.





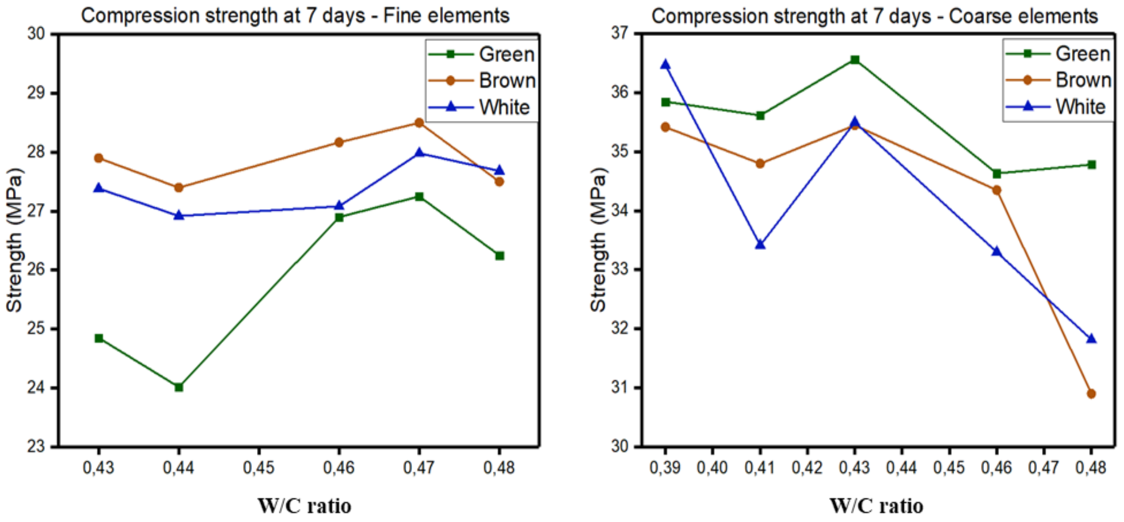


Figure 5: Results of compression tests

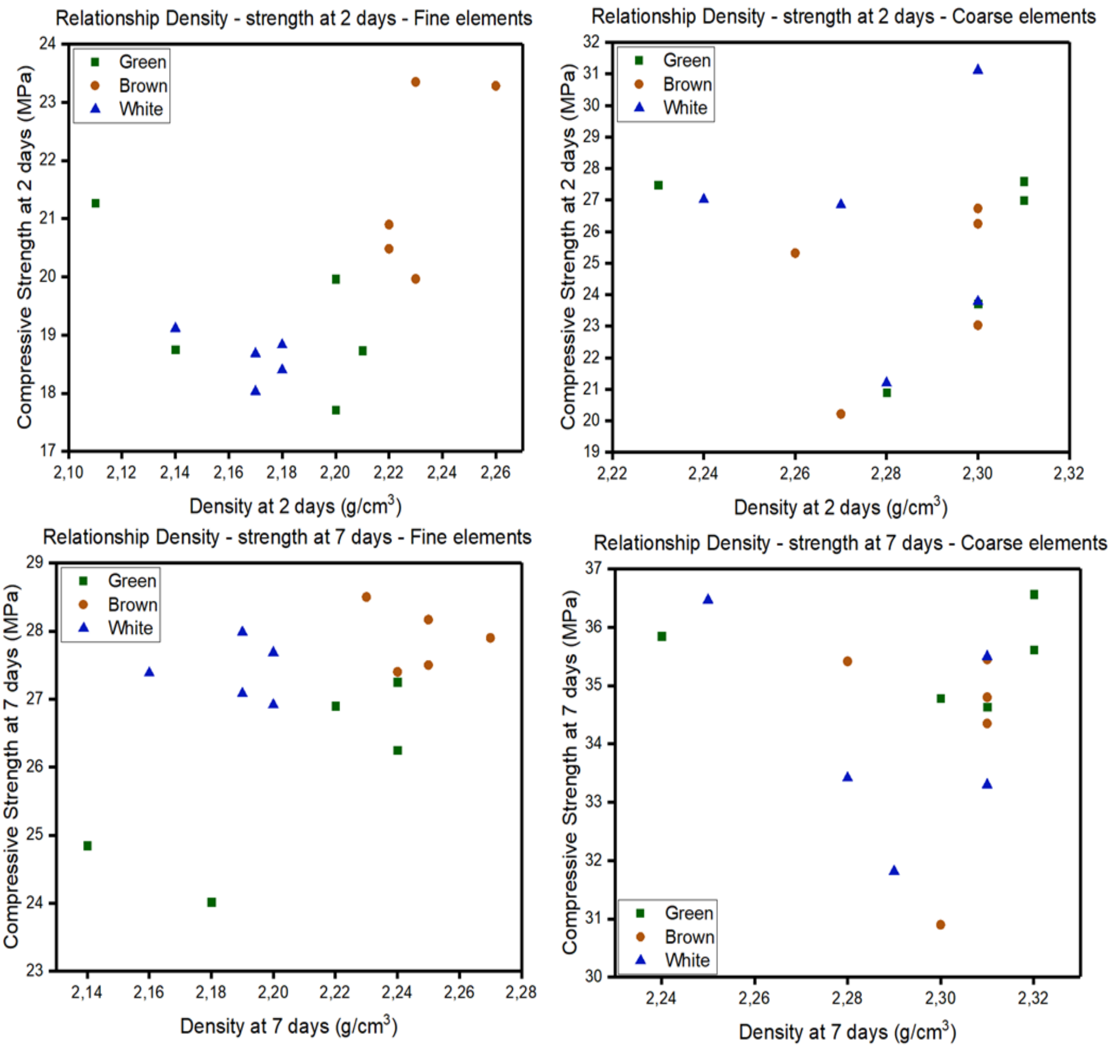


Figure 6: Relationship density-strength

Specimens incorporating fine glass particles display considerable variability in compressive strength based on the color of the glass. For example, brown glass achieves a maximum compressive strength of 28.50 MPa at 7 days with a water/cement (W/C) ratio of 0.48. In comparison, green and white glass reach maximum strengths of 27.25 MPa and 27.98 MPa, respectively, at the same age. This observation suggests that the finer particle size of brown glass is more favorable for enhancing compressive strength compared to the other colors.

Conversely, samples containing coarse glass particles generally exhibit higher compressive strengths than those with fine particles. For instance, white glass with a W/C ratio of 0.39 attains a maximum strength of 36.47 MPa at 7 days, while brown and green glasses demonstrate maximum strengths of 35.45 MPa and 36.57 MPa, respectively. This indicates that coarse glass particles provide superior mechanical performance, irrespective of the glass color.

The results demonstrate that coarse glass particles achieve significantly higher compressive strengths than fine particles at both 2 days and 7 days. For example, with a water/cement (W/C) ratio of 0.43, the compressive strength of coarse green glass increases from 27.6 MPa at 2 days to 36.57 MPa at 7 days. In contrast, fine glass particles only show an increase in strength from 21.27 MPa to 24.85 MPa during the same time frame.

From these analyses, we can infer the following conclusions:

- Mortars incorporating coarse aggregates generally demonstrate a more uniform particle distribution, which enhances compaction and minimizes voids within the matrix. This leads to a denser structure and, consequently, increased compressive strength. In contrast, fine aggregates may not interlock as effectively, resulting in greater void content and slightly reduced strength.
- Coarse aggregates provide a larger surface area in contact with the cement paste, thereby improving adhesion and mechanical bonding. This enhanced interconnection contributes to the superior compressive strength observed in samples containing coarse glass particles.
- The glass color, combined with particle size, significantly influences the mechanical properties of the mortar. Notably, brown glass exhibits better performance across both aggregate classes, likely due to its unique chemical composition. However, the positive impact of coarse particle size is consistent across all glass colors, highlighting the critical role of particle size in achieving higher compressive strength.
- The water-to-cement (W/C) ratio has a significant effect on compressive strength, as indicated by the observed variations in results for each aggregate class. Lower W/C ratios are associated with higher strength, which is consistent with established concrete formulation principles.

Based on the results obtained, an analysis was performed to investigate the relationship between density and compressive strength in mortars incorporating glass of different colors. The findings are summarized as follows:

- Green Glass Mortars: Mortars containing green glass display a clear trend where higher densities are associated with increased compressive strengths. The fine aggregates achieve a maximum compressive strength of 21.27 MPa at a density of 2.18 g/cm³, while the coarse aggregates reach up to 27.6 MPa at a density of 2.28 g/cm³.
- Brown Glass Mortars: Among the three glass colors, brown glass mortars exhibit the highest compressive strengths, particularly for fine aggregates. The fine aggregates attain a maximum strength of 28.5 MPa at a density of 2.27 g/cm³, while the coarse aggregates yield a strength of 35.45 MPa at a density of 2.30 g/cm³. A strong positive correlation between density and compressive strength is observed for brown glass.

- White Glass Mortars: Mortars containing white glass also show a positive correlation between density and compressive strength, though the compressive strengths are slightly lower than those of brown glass. Fine aggregates achieve a maximum strength of 27.983 MPa at a density of 2.27 g/cm³, whereas coarse aggregates reach 36.467 MPa at a density of 2.31 g/cm³.

Drawing on the research conducted by AYITE et al. [28] regarding glass-sand formulations, Table 9 has been compiled.

Table 9: Comparative table of mechanical strength (MPa) at seven (7) days of mortar

W/C ratio	Without Glass (MPa) [28]	With Fine glass elements (MPa)			With Coarse glass elements (MPa)		
		Min	Mean	Max	Min	Mean	Max
0.48	14.83	26.25	27.14	27.68	30.90	30.94	34.78
0.46	14.74	26.90	27.38	28.17	33.30	32.30	34.63
0.43	12.56	24.85	26.71	27.90	35.45	33.13	36.57

From Table 9, it is clear that mortars incorporating glass exhibit significantly higher mechanical strength compared to those without glass. This trend is consistent across all tested water/cement (W/C) ratios (0.48, 0.46, and 0.43).

For example, at a W/C ratio of 0.48, the maximum compressive strength of the mortar without glass is 14.83 MPa, whereas the compressive strength of mortars containing coarse glass aggregates reaches up to 34.78 MPa, representing a relative increase of 134.52%.

This analysis indicates that the inclusion of glass, regardless of its color, may contribute to a pozzolanic reaction, which enhances the formation of calcium silicate hydrate (C-S-H) [1], [11] in the mortar matrix. This, in turn, significantly boosts the compressive strength.

CONCLUSION

This study offers a comprehensive analysis of the influence of glass particle size and color on the compressive strength of glass-sand mortars. The findings reveal that while the color of the glass has a minimal effect on mechanical strength, particle size plays a pivotal role in enhancing the mortar's mechanical performance. Mortars containing coarse glass particles demonstrate significantly higher compressive strengths compared to those with fine particles, underscoring the critical importance of particle size in optimizing the mechanical properties.

These results underline the potential of recycled glass as a sustainable and high-performance construction material, presenting a viable alternative for the construction industry. Furthermore, the observed variations in density based on particle size align with strength trends, indicating a strong positive correlation between density and compressive strength. These insights provide a solid basis for the practical application of recycled glass mortars and advocate for their broader use in future construction projects.

From this analysis, several potential research directions arise:

- **Optimization of Particle Size Distribution**: A more thorough investigation into optimizing the distribution of particle sizes, by incorporating a well-balanced mix of fine and coarse particles, could further enhance the compressive strength of glass-based mortars. This approach has the potential to minimize voids and increase overall mortar density, leading to improved mechanical performance.
- **Microstructural Investigations**: In-depth microstructural studies could offer valuable insights into how particle size distribution impacts the formation of cement hydrates and the phase distribution within the mortar matrix. Gaining a better understanding of these

interactions is crucial for refining mortar formulations and maximizing the performance of glass-incorporating mortars.

Declaration by Authors

Acknowledgement: None
Source of Funding: None
Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. C. Shi and K. Zheng. A review on the use of waste glasses in the production of cement and concrete. Resour. Conserv. Recycl. 2007; 52(2) : 234–247 doi: 10.1016/j.resconrec.2007.01.013.
2. W. H. Chesner, R. J. Collins, and M. H. MacKay. User Guidelines for Waste and By-product Materials in Pavement Construction. US Dep. Transp. 1997; no. Federal Highway Administration, Publication No. FHWA-RD-97-148.
3. W. Chesner. Waste glass and sludge for use in asphalt pavement. Inyang H, Bergeson K, Ed. Util. Waste Mater. Civ. Eng. Constr. 1992; no. New York: American Society of Civil Engineering, pp. 296–307.
4. C. Meyer, S. Baxter, and W. Jin. Alkali-aggregate reaction in concrete with waste glass as aggregate. Proc. 4th Mater. Eng. Conf. 1996; no. Materials for the New Millennium. Reston, Va: ASCE; 1996., pp. 1388–97.
5. C. Meyer and S. Baxter. Use of Recycled Glass for Concrete Masonry Blocks Final Report 97-15. Albany, New York: New York State Energy Research and Development Authority. 1997.
6. C. Meyer and S. Baxter. Use of recycled glass and fly ash for precast concrete. Rep. NYSERDA 98-18 to New York State Energy Res. Dev. Authority. 1998; no. Dept. of Civil Engrg. and Engrg. Mech., Columbia University, New York.
7. C. Pollery, S. Cramer, and R. De La Cruz. Potential for using waste glass in portland cement concrete. J. Mater. Civ. Eng. 1998; 10(4):210–9.
8. Z. Bazant, G. Zi, and C. Meyer. Fracture mechanics of ASR in concretes with waste glass particles of different sizes. J Eng Mech 2000. 1998; pp. 126:226–32.
9. E. Byars, B. Morales-Hernandez, and H. Zhu. Waste glass as concrete aggregate and pozzolan. Concrete. 2004; 38(1):41–4.
10. I. B. Topcu and M. Canbaz. Properties of concrete containing waste glass. Cem. Concr. Res. 2004*;* 34, pp. 267–74.
11. T. Dyer and R. Dhir. Chemical reactions of glass cullet used as cement component. J. Mater. Civ. Eng. 2001; 13(6): 412–7.
12. R. Dhir, T. Dyer, A. Tano, and Y. Cui. Towards maximizing the value and sustainable use of glass. Concrete. 2004; 38(1):38–40.
13. A. Shayan and X. A. Value-added utilisation of waste glass in concrete. Cem. Concr. Res. *2004;* 34:81–9.
14. C. Shi, Y. Wu, Y. Shao, and C. Riefler. Alkali-aggregate reaction of concrete containing ground glass powder. Proc. 12th Int. Conf. AAR Concr. 2004:789–95.
15. A. Shayan and A. Xu. Performance of powder as pozzolanic materials in concrete: A filed trail on concrete slabs. Cem. Concr. Res. 2006; 36:457–68.
16. Y. Xie, Z, Xi. Use of recycled glass as a raw material in the manufacture of portland cement. Mater. Struct. 2002;35:510–5.
17. C. Shi, Y. Wu, C. Riefler, and H. Wang. Characteristics and pozzolanic reactivity of glass powders. Cem. Concr. Res. 2005;35:987–93.
18. G. W. McLellan and E. B. Shand, Glass Engineering Handbook. McGraw-Hill, Inc, 1984.
19. R. Pike, D. Hubbard, and E. Newman. Binary silicate glasses in the study of alkali-aggregate reaction. High Res. Board Bull. 1960;275:39–44.
20. C. D. Johnston. Waste glass as coarse aggregate for concrete. J .Test Eval. 1974;2(5):344–50.
21. Z. Bazant, W. Jin, and C. Meyer. Microfracturing caused by alkali-silica reaction of waste glass in concrete. Mihashi H, Rokugo K, Ed. Proc. 3rd Int. Conf. Fram. Fract. Mech. Concr. Struct. 1998;3 (Germany, no. Freigburg):1687–94.
22. C. Chen, R. Huang, J. Wu, and C. Yang. Waste E-glass Particles used in cementitious mixtures. Cem. Concr. Res.2006;36: 449–56.
23. AFNOR – NFP 11-300. Classification des matériaux utilisables dans la construction des remblais et des couches de forme d’infrastructures routières. 1992.

24. N. E. I. 17892-4. Geotechnical investigation and testing - Laboratory testing of soil - Part 4 : Determination of particle size distribution.
25. NF EN ISO 14719. Analyse chimique de matériaux réfractaires, du verre et d'émaux - Dosage Fe2+ et Fe3+ par la méthode spectrophotométrique en utilisant la 1,10 phénanthroline. 2012.
26. NF EN ISO 17892-2 Reconnaissance et essais géotechniques - Essais de laboratoire sur les sols - Partie 2 : détermination de la masse volumique d'un sol fin. 2014.
27. NF EN 196-1. Méthodes d'essais des ciments - Partie 1 : détermination des résistances. *2016*.
28. Y. M. X. D. AYITE, D.A. HOUNSI, I. PACHOUKOVA, K. BEDJA. Valorization of glass from waste in Togo : Study of the formulation of a glass-sand mortar. Research Journal of Engineering Sciences. 2017; 6(11): 1-6.

How to cite this article: Djidoula TAKO, Koudzo ASSAGBAVI, Marceline NKWENKEU, Kossi Eli Benoît MITEKOR, Yawovi M. X. Dany AYITE. Influence of glass granular class on the compressive strength of glass-sand mortar. *International Journal of Research and Review*. 2024; 11(10): 536-549. DOI: *https://doi.org/10.52403/ijrr.20241048*

******