International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

Structural Performance of Reinforced Concrete Beams Containing Waste Glass

Hawra Mohamed Ali M. Taher[*]

[*]*Department of civil Engineering, College of Engineering, University of Karbala, Karbala, Iraq.*

Corresponding Email: [*]hawra.m@uokerbala.edu.iq

Received: 01 March 2023 **Accepted:** 17 May 2023 **Published:** 26 June 2023

Abstract:** As more towns and factories have been built over the course of the last several years, there has been a concomitant increase in the amount of waste glass that has been produced. The vast majority of glass that is considered waste is thrown in landfills, and only a small part of this glass may really be recycled. Because of the significant costs involved in cleaning and color sorting. The fact that glass does not decompose in landfills means that this type of waste disposal is not considered to be good for the environment. Recent research has revealed that recycled glass can be successfully utilized in concrete in as an aggregate, or as a replacement for cement. Both of these applications have been demonstrated to have positive results. The utilization of fine and coarse aggregates served to highlight this point. Glass has the ability to have a nature that is cementitious. This is due to the fact that glass is an amorphous substance and contains relatively significant amounts of silicon and calcium. In addition, glass is made up of calcium and silicon in proportions that are nearly identical to one another. Glass that has been treated to a finer particle size than waste glass, which has been processed to a coarser particle size, does not contribute to the alkali-silica reaction (ASR) since the waste glass has been processed to a coarser particle size. The use of pozzolanic reaction products as a substitute for cement that can be used in limited amounts will, in addition to improving the characteristics of concrete through the pozzolanic reaction, contribute to a greener environment. This is due to the fact that one ton of portland cement output resulted in the production of about one metric ton of carbon dioxide, which contributes to issues relating to global warming. In other words, one ton of portland cement output caused the production of approximately one ton of carbon dioxide. The most recent advancements in the structural behavior of reinforced concrete beams and the present status of recycling operations for waste glass are both investigated in depth during the course of this research paper's investigation. In addition, the article details the actions that need to be done in order to successfully employ waste glass in place of aggregate and cement. These products will not only help to recycle previously used glass, but they will also make the environment that surrounds us greener.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

Keywords: Recycling, Waste Glasses, Beam, Flexure, Shear.

1. INTRODUCTION

Globally, industrialisation and urbanization are responsible for the annual production of several million tons of waste glass. The most common places that waste glass can be found are in receptacles for waste, window screens and window glasses, tube lights and bulbs, electronic devices, pharmaceutical bottles, and liquor bottles. Certain industries, such as those that create containers, are only able to recycle a tiny fraction of the material because the process of cleaning and sorting is so complicated and expensive. This limits the amount of material that can be recycled. Because the rate of glass recycling is lower than the rate at which other categories of solid waste are recycled, the recovery and reuse of glass is considered to be a very critical environmental concern in many countries [1]. The majority of the waste glass is thrown away in landfills because the contaminants that it contains are difficult to eliminate, the cost of transporting the waste glass to manufacturing plants is prohibitively expensive, and mixed color waste streams are difficult to sort into viable raw glass stocks [2]. Due to the inert nature of glass, which prevents it from dissolving, the wastes that are being produced now will continue to damage the environment for hundreds or maybe thousands of years after they have been produced. The disposal of waste glass does not provide an option that is useful to the environment and does not have an effect that is beneficial to society because waste glass does not disintegrate quickly on its own. The exploitation of waste glass in the construction sector is among the most appealing of the available possibilities. This is due to the fact that it is possible to make use of a substantial number of the resources that were previously mentioned. The cement used in normal concrete is generally considered to be one of the most crucial components of the mixture [3]. Cement is produced at a pace of approximately 2.35 billion tons per year, which is equivalent to nearly 1 cubic meter of cement for each and every person living on the earth. During the production of cement, there is a little but significant amount of carbon dioxide that is released into the atmosphere. This amount accounts for somewhere in the range of five to ten percent of the total amount of CO_2 that is produced all over the world. About a ton of carbon dioxide is released into the atmosphere for every ton of Portland cement that is manufactured, which contributes to the production of greenhouse gases. The primary cause of the production of greenhouse gases is the expansion of holes in the ozone layer, which in turn contributes to the progression of global warming [4].

The amount of carbon dioxide contained in the atmosphere has increased by around 30 percent over the course of the past two centuries due to human activity. It is anticipated that a decrease of 5.2% in the overall amount of CO_2 that is released into the atmosphere will result from a reduction of 10% in the CO_2 emissions that are produced by industries that produce cement. Utilized glass shards can be used as an alternative to cement in the construction of concrete buildings and structures, which can be helpful for the aforementioned reasons. When one ton of glass is recycled, more than one ton of natural resources are preserved. Additionally, Six tons of recycled container glass equals one ton of saved carbon dioxide emissions. The expenses associated with creating concrete would decrease, and our company would have a more positive relationship with the natural environment. These not only contribute to the

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

recycling of previously used glasses, but they also make the space around them cleaner and more eco-friendly [5]. Reusing waste glass in concrete and the building industry has been the subject of a number of studies and inquiries as a potential means of reducing the amount of mixed-color waste recycled glass that ends up in landfills, as well as to establish a solid ground for the development of a comprehensive understanding and additional research. The purpose of these studies and investigations is to investigate the viability of reusing waste glass in concrete and the construction industry as a way to lessen the volume of mixed-color waste recycled glass that is the costly cost of disposing of glass waste has brought attention to the prospect of utilizing glass as an aggregate in concrete, which has sparked the curiosity of researchers. This is because concrete is a material that can be broken up into smaller pieces. When waste glass is used as an aggregate in concrete, the structure of the concrete undergoes noticeable changes, one of which is a reduction in the strength of the link between the aggregate and the cement paste. These shifts are a result of the altered structure of the concrete, which can be traced back to the source of the problem. These alterations are brought about by the utilization of discarded glass [6]. When compared to the usage of a natural aggregate, which can also be considered an aggregate, it is anticipated that the interlocking shear strength between the aggregate and the cement paste will be reduced when using glass as an aggregate. Glass can be considered an aggregate. However, the Alkali-Silica Reaction is recognized as a fundamental barrier that prevents the use of recycled glass in concrete. This reaction takes place when alkali is mixed with silica. Because of this reaction, recycled glass cannot be utilized in the production of concrete. In the 1940s, Stanton was the one who produced the very first discovery concerning the ASR. The ASR process results in the formation of an alkali-silicate gel as the outcome of the reaction. Because the ASR gel is capable of absorbing water, it has the tendency to swell up and become more expansive when exposed to it [7]. As a result of this property, the ASR gel: As a result of this, ASR gel has the potential to inflict serious damage on the microstructure of concrete as a consequence of the internal stresses that are generated as a result of the volume fluctuations. This is because of the fact that the volume of the gel changes throughout the curing process. Even though the adverse effects of ASR might not become apparent for a number of years, and even though the condition is regarded as a problem with a long-term outlook, it is nevertheless always regarded as a potential concern. This is the case even though the effects of ASR might not become apparent until after a number of years. In addition, glass is a byproduct of the fusing process that is not an organic substance. It is produced when molten glass is allowed to cool to a solid state without going through the process of crystallization. The percentage of silica found in typical glass products is shockingly high [8]. Due to its amorphous structure as well as the relatively high quantities of silicon and calcium it contains, ground glass has the potential to take on a pozzolanic or even cementitious quality when it is ground to a fine powder. This quality can be achieved by grinding the glass to a very fine powder. Because of the steady accumulation of waste glass, a relatively recent practice has emerged in which extremely finely ground glass is used as a pozzolanic material. This practice was spurred on by the accumulation of waste glass. Because of the continual accumulation of waste glass and the problems that it generates for the environment, this is a method that has been endorsed as a result of the fact that it is a problem [9].

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

Using Waste Glass in Concrete as an Ingredient

In a number of distinct methods, recycled glass can fulfill the role of a partial replacement for one or more of the constituents that are responsible for the formation of concrete. A significant number of scholars investigated the viability of using recycled glass as a substitute for either fine or coarse aggregate. Other researchers took advantage of the pozzolanic qualities that glass powder possesses in order to partially replace cement in their research [10]. This was done by using the powder. In light of the conclusions of a literature review concerning the numerous applications of waste glass in concrete, "discarded glass" will be the new term of choice going forward.

Using Waste Glass as Course Aggregate

Pieces of recycled glass are often included into the production of concrete, where they serve as an alternative to coarse aggregate in some applications. He made the startling discovery that the material was deteriorating in both its workability and its compressive strength. According to the findings of some other researchers, the incorporation of coarse glass aggregate into concrete did not have a substantial impact on the material's workability, but it did result in a slight reduction in the material's strength. These researchers used recycled glass cullet in place of coarse aggregate used in the majority of concrete mixes [11]. They found that the presence of glass aggregates generated expansions in concrete or mortar as well as internal stresses owing to ASR. These effects were brought about by the aforementioned phenomenon. Because of these occurrences, the material's durability diminished, and it also developed fractures and became more permeable as a result of the increase in its permeability. In addition, pieces of shattered glass, sometimes known as cullet, were incorporated into concrete as aggregate. When the coarse aggregate glass concentration was more than 0.4, there was a reduction in the weight of a single unit of concrete. In addition, the coarse glass did not influence the mix's capacity to be worked with in any way. After performing an analysis, he arrived at the following conclusion: the optimal content percentage of glass coarse aggregate to be used as a partial replacement of natural coarse aggregate to be used with a w/c ratio of 0.4 was approximately 0.265, with 28-day compressive strength approximately 385kg/cm2; this was the conclusion he reached after performing an analysis. He performed a numerical analysis and came to the conclusion that the optimal content percentage of glass coarse aggregate to be used as a partial replacement of natural coarse aggregate In addition, he arrived at the conclusion that there was an insignificant impact on the pull-out strength of the concrete, a marked improvement in its flexural-strength, and a slight reduction in its splitting-strength. He came to these conclusions after observing the effects of the change in the concrete [12].

Using Wastes Glass as Fine Aggregate

It was investigated whether or not ground waste glass might be utilized as a fine aggregate, and both the immediate and long-term effects of such an application on the characteristics of fresh and cured concrete were investigated. The physical properties of the crushed glass aggregate that is obtained from the waste glasses make it suitable for use as a fine aggregate in the production of concrete. This aggregate can be obtained by crushing the waste glasses. These characteristics include the appropriate shape, size, gradation, and specific gravity of the material. It is probable that the angular grain shape of the broken glass will have an effect on

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

the workability of the concrete; yet this shape proved highly useful for the development of the concrete's strength. The compressive, flexural, and splitting tensile strengths of the material were slightly diminished as a result of the use of fine glass as a partial replacement for natural sand. Nevertheless, this drop did not constitute a statistically significant trend. Porosity and water absorption of concrete prepared with varied percentages of glass aggregate each revealed a slight increase when compared to the control mix. This increase was not significant, however [13].

Waste Glass Powder as Partial Substitution of Cement

Due of the extremely strong pozzolanic reactivity of glass powders, these particles can successfully serve as a viable replacement for cement in many applications. The pozzolanic reactivity of the substance increases in proportion to the fineness of the material. In the event that the aggregates are alkali-reactive, the presence of alkalis in the glass powder may cause an alkali silica reaction. [Case in point:] Finely ground glasses have a reduced ASR expansion, which is another advantage of using these glasses. Because of this, adding ground glass powder to cement will result in a significant increase in the material's strength and longevity, in addition to assisting in the preservation of natural resources and contributing to the upkeep of an environmentally friendly atmosphere [14].

Flexural behavior of reinforced concrete beam incorporating waste glass

The effect of substituting WG powder for cement at the percentages of 0% (reference), 10% (suggested), and 15% is investigated. The structural behavior of RC beams packed with WG powder was studied in a similar fashion. Researchers in this study utilized nines beams with dimensions of 150 mm in width, 150 mm in depth, and 900 mm in span length. When analyzing the flexural behavior, two more factors were considered in addition to the effect of the glass powder. To name a few: the effect of longitudinal steel reinforcement on rebar (2x8 mm, = 0.0049; 2x12 mm, = 0.013785), and the effect of transverse reinforcement spacing (stirrups; 65 and 170 mm). Beams made with WG powder have better flexural performance and resistance than the standard reference beams. The natural fine aggregate has been replaced with recycled glass in a number of different amounts, as the subject of this investigation found out. The composition of the control samples consists solely of natural sand and coarse aggregate. These samples are manufactured out of ordinary Portland cement concrete (OPCC) of grade 30, which is the standard. The recycled glass concretes have a composition of 70% natural fine aggregate and 30% crushed glass with a size of 300 microns. Additionally, there are recycled glass concretes that have a composition of 70% fine aggregate, 15% crushed glass with a size of 300 microns, and 15% crushed glass with a size greater than 300 microns [15]. The comparable strengths of 47, 61, and 55 MPa are shared by all three. The flexural test results show that recycled glass concrete is not as strong as conventional concrete. Measurements of the flexural strength of concrete including recycled glass showed values of 91% and 84% of the theoretical value, respectively. However, the control specimen's flexural strength is 10% higher than the theoretically predicted value. Although recycled-glass-containing concrete had a higher compressive strength than the control concrete, the flexural test showed that it was not as functional as reinforced concrete. However, after replacing 30% of the fine sand with recycled glass powder, the recycled glass concrete still has a hardness index that is on par with

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

the control samples. This demonstrates the recycled glass concrete's resilience thanks to its ductile character. By comparing the results of flexural tests conducted on reinforced recycled glass concrete and control concrete, it is clear that both combinations fail at significantly lower stresses in the former. When compared to the standard concrete, this is the case. The theoretical value (considered to be 100%) is 111% higher than the maximum load achieved by the control concrete. When compared to the projected value, the failure rates of concrete made using C30RG30% and C30RG15%15% are 91% and 84%, respectively. But even with the 30% replacement of fine sand with recycled broken glass, the hardness index of recycled glass concrete is just as high as that of the control samples. As a result, it appears that recycled glass concrete has a ductile behavior, which is an advantage [16].

Shear behavior of reinforced concrete beam incorporating waste glass

Shear behavior of reinforced concrete beams subjected to bending loads was studied with and without waste glass powder included into the beams. Analyses were conducted to determine the relationship between the load and the beam's vertical displacement, the strain in the beam, the crack's pattern and its progression, the load's relationship to the cracks, and the failure's underlying cause. Two primary goals were accomplished through the partial replacement of cement with waste glass powder: Two benefits may be seen here: (a) a financial one, in the form of a decrease in the price of supplemental materials; and (b) an environmental one, in the form of a resolution to some of the solid waste problems that waste generates, as well as a decrease in energy consumption [17]. The economy and the environment would benefit if these goals were accomplished. Due in large part to the accomplishment of these two milestones, the project's intended outcomes were realized. As part of the experimentation, nine beams measuring 150 mm x 150 mm x 900 mm will be analyzed. The design goal for these beams is to fail under shear loads. Both 0.02267 (216mm) and 0.013785 (212mm) of steel reinforcement, 0%, 10%, and 15% of glass powder as a partial replacement of cement, and 65 and 170 mm of space between the stirrups were tested. Glass powder was successfully tested as a cement additive. During the course of the study, investigators utilized ground-up glass in several of the experiments in place of or in addition to cement. The ultimate load of the test beams that included the glass powder was higher than that of the control beam, demonstrating that the addition of the glass powder increased the beam's strength capacity. Through further testing, it was discovered that the strength of the beam could be improved. The hypothesis was put through its paces, and the findings were examined. The reported load at failure increased by 39% for the 10% replacements and 23% for the 15% replacements when compared to the figures for the control beam. When the longitudinal steel reinforcement was raised from 2 by 12 millimeters to 2 by 16 millimeters, the composite material changed from being somewhat flexible to being more brittle. Because of this, the maximum load increased but the vertical displacement decreased. This has not altered as the percentage of recycled glass powder has remained the same. By reducing the distance between the stirrups from 170 mm to 65 mm, we were able to safely reduce the maximum load. Because the reduced weight allowed for greater vertical movement, there was a commensurate increase in vertical displacement. When compared to control beams, those that incorporate waste glass powder (particularly at 15%) have less vertical displacement. The usage of recycled glass powder results in brittle beams. No reasonable person would ever want the outcome you've described. It is recommended that

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

fiber-reinforced waste glass powder be utilized to make the most of waste glass powder's property of boosting the final strength of the beam. The beam was able to demonstrate this quality when the maximum load before failure grew. We suggest substituting fibers for portion of the powdered glass to mitigate the addition's brittle failure quality. The strength of the finished beam can be increased by using powdered scrap glass. The aforementioned applications could benefit from this. It is recommended that you use waste glass powder that already contains fibers in order to make the most of the features of waste glass powder and maintain all the benefits that come with utilizing waste glass powder [18].

2. CONCLUSION

The following inferences and findings are drawn from the work of previous researchers:

1. When compared to conventional concrete of the same weight-to-volume ratio, the compressive strength of concrete mixes containing glass-wastes as partial substitutes of aggregate (either fine or coarse) has been demonstrated to be lower. This holds true whether the glass-waste in question is large or small.
2. As an alternative to using natural aggregate, you can use glass waste to make concrete with the same slump as regular concrete.
3. Using glass wastes as a partial aggregate replacement in concrete led to growth that was linked to ASR (either fine or coarse).
4. That glass powder with a particle size of less than 75 m has a pozzolanic property and can be used to substitute cement in specific applications. The glass powder in question possesses pozzolanic properties.
5. Glass wastes mixed with cement to partially replace the cement in the mixture have been discovered to produce concretes with improved low permeability and higher resistance against the invasion of moisture. As a corollary, increasing the glass powder content also improves ASR.
6. Adding glass powder to concrete improves its mechanical properties and its resistance to wear and tear, according to the research presented in this article.
7. The ultimate load and ductility of the beam members strengthened with waste glass powder were higher than those of the HSC specimens treated with silica fume.
8. The flexural test performed on recycled glass concrete reveals that both combination types fail under lower load conditions compared to the control concrete. The control concrete is capable of carrying 111% more weight than the amount that is considered theoretically possible. In spite of this, recycled glass concrete that replaces 30% of the fine sand with recycled broken glass displays ductile behavior. This may be demonstrated through the utilization of a toughness index that is comparable to that of the control samples. When compared to the control beam, the higher ultimate load at failure observed for beams that incorporated glass powder indicates that the shear strength capacity of the beam was improved when glass powder was employed. When compared to the control beam, the reported load at failure rose by 39% and 23%, respectively, due to the 10% and 15% replacements.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

3. REFERENCES

1. Morizet, Y., Hamon, J., La, C., Jolivet, V., Suzuki-Muresan, T., & Paris, M. (2021). Immobilization of 129 I in nuclear waste glass matrixes synthesized under high-pressure conditions: an experimental study. Journal of Materials Chemistry A, 9(42), 23902-23915.
2. Dawood, Mustafa B., and Hawra Mohamed Ali M. Taher. "Various methods for retrofitting prestressed concrete members: A critical review." Periodicals of Engineering and Natural Sciences (PEN) 9.2 (2021): 657-666.
3. Khazaalah, T. H., Shahrim Mustafa, I., Al-Ghamdi, H., Abdul Rahman, A., Sayyed, M. I., Almuqrin, A. H., ... & Mohd Shariff, H. (2022). The Effect of WO3-Doped Soda Lime Silica SLS Waste Glass to Develop Lead-Free Glass as a Shielding Material against Radiation. Sustainability, 14(4), 2413.
4. El-Nemr, K. F., Ali, M. A., & Gad, Y. H. (2022). Manifestation of the silicate filler additives and electron beam irradiation on properties of SBR/devulcanized waste tire rubber composites for floor tiles applications. Polymer Composites, 43(1), 366-377.
5. El-Nemr, K. F., Ali, M. A., & Gad, Y. H. (2022). Manifestation of the silicate filler additives and electron beam irradiation on properties of SBR/devulcanized waste tire rubber composites for floor tiles applications. Polymer Composites, 43(1), 366-377.
6. Taher, S. M., Saadullah, S. T., Haido, J. H., & Tayeh, B. A. (2021). Behavior of geopolymer concrete deep beams containing waste aggregate of glass and limestone as a partial replacement of natural sand. Case Studies in Construction Materials, 15, e00744.
7. Manikandan, P., & Vasugi, V. (2021). A critical review of waste glass powder as an aluminosilicate source material for sustainable geopolymer concrete production. Silicon, 13(10), 3649-3663.
8. Ahmad, J., Martínez-García, R., de-Prado-Gil, J., Irshad, K., El-Shorbagy, M. A., Fediuk, R., & Vatin, N. I. (2022). Concrete with Partial Substitution of Waste Glass and Recycled Concrete Aggregate. Materials, 15(2), 430.
9. Rajendran, R., Sathishkumar, A., Perumal, K., Pannirselvam, N., Lingeshwaran, N., & Madavarapu, S. B. (2021). An experiment on concrete replacing binding material as waste glass powder. Materials Today: Proceedings, 47, 5447-5450.
10. Kumar, A., Mishra, R. K., Khader, S. A., Yadav, A. K., Jha, S. N., Bhattacharya, D., ... & Tomar, B. S. (2021). Electron beam irradiation induced changes in local structure of simulated waste bearing sodium borosilicate glasses. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 486, 85-93.
11. CHIHEB, D., & BELAOURA, M. (2022). Effect of Recycled Waste Glass Addition as a Partial Replacement for Fine Aggregate on Resistance to Freeze-thaw Of High Performance Concrete. Jordan Journal of Civil Engineering, 16(2).
12. Atoyebi, O. D., & Sadiq, O. M. (2018). Experimental data on flexural strength of reinforced concrete elements with waste glass particles as partial replacement for fine aggregate. Data in brief, 18, 846-859.
13. Orouji, M., Zahrai, S. M., & Najaf, E. (2021, October). Effect of glass powder & polypropylene fibers on compressive and flexural strengths, toughness and ductility of concrete: An environmental approach. In Structures (Vol. 33, pp. 4616-4628). Elsevier.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 03, No. 04, June-July 2023
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise.34.28.36

14. Orouji, M., Zahrai, S. M., & Najaf, E. (2021, October). Effect of glass powder & polypropylene fibers on compressive and flexural strengths, toughness and ductility of concrete: An environmental approach. In Structures (Vol. 33, pp. 4616-4628). Elsevier.
15. Hama, S. M., Mahmoud, A. S., & Yassen, M. M. (2019, August). Flexural behavior of reinforced concrete beam incorporating waste glass powder. In Structures (Vol. 20, pp. 510-518). Elsevier.
16. Sun, J., Wang, Y., Yao, X., Ren, Z., Zhang, G., Zhang, C., & Wang, X. (2021). Machine-learning-aided prediction of flexural strength and ASR expansion for waste glass cementitious composite. Applied Sciences, 11(15), 6686.
17. Yassen, M. M., Hama, S. M., & Mahmoud, A. S. (2022). Shear behavior of reinforced concrete beams incorporating waste glass powder as partial replacement of cement. European Journal of Environmental and Civil Engineering, 1-16.
18. Taher, S. M., Saadullah, S. T., Haido, J. H., & Tayeh, B. A. (2021). Behavior of geopolymer concrete deep beams containing waste aggregate of glass and limestone as a partial replacement of natural sand. Case Studies in Construction Materials, 15, e00744.