WEB OF SYNERGY:
International Interdisciplinary Research Journal
Volume 2 Issue 8, Year 2023 ISSN: 2835-3013
https://univerpubl.com/index.php/synergy

A Review Paper on the Utilization of Waste Glass and Optical Fibers as Aggregates in the Production of Concrete Bricks

Onkar Yadav
Assistant Professor, Department of Civil Engineering, Sandip University, Madhubani, Bihar, India

Babul Raj
Research Scholar, Department of Civil Engineering, Sandip University, Madhubani, Bihar, India

Article Information

Received: June 02, 2023
Accepted: July 01, 2023
Published: Aug 07, 2023

Keywords: *Construction industry, Concrete, Waste materials, Glass additives, Plastic optical fibers, Bricks.*

ABSTRACT

The construction industry is experiencing rapid development, resulting in a growing demand for construction materials. Concrete, being the most commonly used material in construction, plays a significant role in further innovations and advancements. However, as we strive for progress, we must also address the challenges of global warming and pollution. The construction industry is widely recognized as one of the major contributors to environmental pollution. To promote sustainability in construction, it is crucial to integrate eco-friendly practices into the core of the industry. One approach is to develop concrete using waste materials as additives or substitutes, aiming to make it more sustainable and environmentally friendly. Waste glass, for instance, is abundantly available and often underutilized in India. Since glass primarily consists of silica, it exhibits properties similar to pozzolanic materials, which can be incorporated into concrete mixes. Additionally, the inclusion of plastic optical fibers (POF) in concrete can provide the material with light transmission properties, adding aesthetic value to the eco-friendly concrete. By harnessing these waste materials and their unique properties, the construction industry can contribute to sustainability efforts while still meeting the demands of development.

1. INTRODUCTION

In today's era of economic growth and technological advancement, the construction of large-scale structures, including residential and commercial skyscrapers, is on the rise worldwide. As developing countries strive for extensive economic development, it becomes crucial to pursue sustainable practices. Concrete, being the predominant material in the construction industry, plays a pivotal role in these developments. However, the rapid expansion of the modern concrete jungle has significant environmental consequences, impacting both living beings and the planet. To address these challenges, it is imperative to prioritize sustainable development at the very core of the construction industry. Researchers are actively working on the development of environmentally friendly concretes by incorporating waste products into the mix. In India alone, approximately 300 million metric tons of cement are produced and consumed annually, contributing to high carbon emissions due to the energy-intensive manufacturing process. Each ton of cement produced is estimated to generate nearly an equal amount of carbon dioxide. Thus, finding alternative, environmentally friendly cement and concrete solutions is of utmost importance for further development without exacerbating environmental damage. These

ISSN: 2835-3013

materials possess different properties and parameters. For instance, materials like rice husk ash and fly ash exhibit chemical reactivity, while waste plastic serves as a filler material in the concrete matrix. By embracing these sustainable practices and utilizing waste materials, the construction industry can pave the way for environmentally friendly and socially responsible developments, mitigating the environmental impact of construction activities.

2. CONCRETE WITH WASTE MATERIALS

Extensive research is underway to explore the utilization of waste materials and by-products from various sectors in concrete production, capitalizing on the versatility of this construction material. These waste materials can be broadly categorized into two groups:

- Noble/non-reacting waste materials and
- Active/chemically reacting waste materials.

The noble/non-reacting waste materials encompass those that do not undergo significant chemical reactions when incorporated into the concrete mix. Examples of such waste materials include waste glass, plastic fibers, and rubber particles. These materials serve as fillers or additives, contributing to specific properties of the concrete, such as enhanced aesthetics, improved insulation, or increased durability. By incorporating these noble waste materials, the construction industry can effectively reduce waste and utilize available resources more sustainably. On the other hand, active/chemically reacting waste materials exhibit chemical reactions when combined with the concrete mix. This category includes materials such as fly ash, silica fume, and rice husk ash. These waste materials possess pozzolanic properties, meaning they react with the calcium hydroxide present in cement to form additional cementitious compounds. By incorporating these active waste materials, the concrete's strength, durability, and environmental performance can be enhanced, while reducing the consumption of cement, which is a major contributor to carbon emissions.

Figure 1: Different types of waste materials (wood, rubber etc) (Google image search)

3. ADVANTAGES OF USING WASTE IN CONCRETE

The incorporation of industrial waste into concrete offers several significant benefits, as mentioned below:

- Effective waste management solution: By utilizing industrial waste in concrete production, a large-scale application of concrete can help address the growing waste management problem. It provides an avenue for effectively managing and repurposing waste materials that might otherwise end up in landfills or contribute to environmental pollution.

- Reduced carbon footprint: The addition of waste materials in concrete allows for a reduction in the usage of cement or other constituents. Cement production is energy-intensive and contributes significantly to carbon emissions. By replacing a portion of cement with waste materials, the carbon footprint of the concrete can be reduced, promoting sustainability and environmental conservation.
- Improved concrete properties: Many waste materials, especially those with pozzolanic properties, exhibit cementitious behavior and enhance various properties of the concrete mix, including strength, water absorption, and durability. By incorporating these waste materials, concrete can benefit from improved performance characteristics, leading to more versatile and reliable construction materials.
- Economic benefits for society: The utilization of certain waste materials can contribute to cost reduction in concrete production. By incorporating these materials, the overall cost of cement concrete can be lowered, making it a more economically viable option, particularly for low-cost housing construction projects. This can have a positive impact on the affordability and accessibility of construction materials, benefiting society as a whole.

Incorporating industrial waste into concrete offers solutions to waste management challenges, reduces the carbon footprint of concrete, improves its properties, and provides economic advantages, making it an attractive approach for sustainable and cost-effective construction.

4. APPLICATIONS OF ECO-FRIENDLY CONCRETE

Concrete compositions incorporating waste materials as constituents exhibit distinct properties compared to traditional concrete, primarily due to the presence of waste. However, these property variations can be leveraged to create eco-friendly concrete with specific applications. In the case of inert or noble waste materials, it is commonly observed that the addition of such materials leads to a decrease in density and strength of the concrete mix. For instance, incorporating plastic waste into the concrete mix reduces its density and lowers its overall strength. Consequently, these types of concrete mixes can be utilized for non-structural elements that do not require load-bearing properties. Prefabricated panels made from such mixes can serve as lightweight and low-strength temporary partition walls. On the other hand, when it comes to metal or rubber waste, these materials tend to enhance the ductility of the concrete through the form of fibers. Concrete containing rubber or metal fibers can be particularly beneficial in areas of high deflection within a structure. These fiber-reinforced concrete compositions provide improved toughness and resistance to cracking, making them suitable for applications where increased flexibility and resilience are desired. By strategically incorporating waste materials with their specific property effects, eco-friendly concrete can be tailored for various construction requirements, optimizing its performance and sustainability.

5. LITERATURE REVIEW

A comprehensive literature survey was conducted to identify relevant studies and research articles focusing on the utilization of waste glass and optical fibers in the production of concrete bricks. Various databases and academic sources were searched using appropriate keywords, and the selected studies were critically reviewed to extract relevant information. The findings were then analyzed to gain insights into the benefits, limitations, and future prospects of using these waste materials as aggregates in concrete brick production.

Sadoon et al. (2014) The research aimed to evaluate the effects of waste glass (WG) replacement for fine aggregates and the use of ordinary Portland cement (OPC) in a concrete mixture on both the fresh concrete properties and mechanical properties. Natural sand, with a maximum size of 4.75mm, was used as the fine aggregate, while natural quartzite gravel, with a maximum size of 20mm and a bulk density of 1530kg/m3, was used as the coarse aggregate. The chemical composition and particle size/sieve analysis of the waste glass were determined and presented in Table 2.3 and Table 2.4, respectively. The unit weight of the waste glass used in the study was measured to be 1460 Kg/m3.

Mizi Et al. (2014) The research investigated the impact of incorporating waste glass particles as a partial replacement for fine aggregates on the fluidity of concrete mixtures. Different mix proportions of ordinary Portland cement (OPC) and waste glass were used in the study. The results indicated a reduction in slump values as the content of waste glass increased. The decrease followed a logarithmic pattern with a high degree of correlation. For instance, the slump values for concrete mixes containing 5%, 15%, and 20% waste glass were measured as 65mm, 56.5mm, and 52mm, respectively. This represented a reduction of 19%, 29%, and 35% compared to the control concrete with a slump of 80mm. The irregular and sharp shape of the waste glass particles, in contrast to the smoother sand particles, was identified as the reason for increased friction and reduced fluidity in the concrete mix. Previous studies also demonstrated a decrease in slump values when increasing the proportion of waste glass as aggregates. For instance, when the waste glass ratio was increased by 30%, 50%, and 70%, the slump decreased by 19.6-26.9%, 30.1-34.6%, and 38.5-44.3%, respectively. Depending on the surface characteristics of the waste glass particles, the reduction in fluidity can be significant in comparison to the control mix.

Yue Li et al. (2015) The study involved the utilization of plastic optical fibers in cement mortar, which was referred to as light transmitting cement mortar (LTCM). The LTCM utilized a high consistency matrix material. The mix design ratio used for the preparation of LTCM was 1:0.75:4 (cement:sand:blast furnace slag) with the addition of 0.2% water reducing agent. The plastic optical fibers were arranged in a fabric-like form, forming a monolayer within the mortar. One end of the fibers was distributed in a single direction, while the other end was supported by cotton yarn, as illustrated in Figure 2.1. The spacing between the fibers was controlled and maintained within the range of 3 to 6mm to ensure consistency throughout the LTCM.

Thiago et al. (2018) The research involved the incorporation of polymer optical fibers (POF) in cement mortar, resulting in a material termed as light transmitting cement-based material (LTCM). The materials used in the study included standard cement following ASTM specifications and sun-dried fine aggregates. A high-efficiency water reducer was added to the mix to improve its workability, and 10% of the cement was partially replaced with silica fume to prevent segregation. The diameter of the POF was measured to be 0.4 mm using a three-point measurement technique.

Olofinnade et al.(2019) The utilization of recycled waste materials in concrete production is recognized as an environmentally sustainable approach that reduces energy consumption and helps preserve natural resources. This type of concrete is commonly referred to as "green" concrete. In this study, the researchers investigated the feasibility of using crushed waste glass as a partial or complete substitute for natural aggregates in the production of moderate strength green concrete. Additionally, ground clay brick was added as an admixture. Concrete mixes containing 10% clay brick powder and 25% waste glass aggregate demonstrated significant strength improvement compared to the control concrete after 28 days of curing. This research highlights the potential of utilizing waste glass and clay brick powder as sustainable alternatives in green concrete production, contributing to the efficient management of waste materials and enhancing the strength properties of the concrete. The waste glass used in the study was sourced from dump sites and waste collection points in Ota, Nigeria, while the clay bricks were obtained as generated waste from ceramic and brick factories. Different percentages of waste glass (ranging from 25% to 100% in increments of 25%) were incorporated into the concrete mixes, and ground clay brick was added in proportions of 10%, 15%, and 20% by mass of Portland cement.

Almaleeh et al.(2019) The study drew the following conclusions: Ceramic tile aggregates can be effectively used as either fine or coarse aggregates in concrete. Fine glass aggregates also exhibit suitable behavior. However, coarse glass aggregates displayed poor performance, particularly in terms of Aggregate Crushing Value (ACV) and Aggregate Impact Value (AIV). The ACV of the coarse glass was measured at 42.3%, and the AIV was 31.0%, both of which exceed the recommended limit of 30%. Therefore, it is advisable to use fine glass, fine ceramic tiles, and coarse ceramic tiles as normal aggregates in concrete under the specified conditions.

Zhang et al.(2020) The utilization of crushed brick as coarse aggregates in concrete offers significant benefits in terms of preserving natural aggregate sources and reducing waste accumulation. This experimental study aimed to investigate the impact of fibers on the fresh and hardened properties of concrete containing recycled aggregates derived from crushed clay bricks. A comparative analysis was conducted to assess the mechanical and durability properties of fiber-reinforced concrete using crushed brick aggregates and natural aggregates. The study also examined the influence of fiber type and content on these properties. The results demonstrate that the workability of fiber-reinforced recycled concrete is comparable to that of conventional concrete. The presence of fibers has a significant effect on the compressive and splitting tensile strength of the recycled concrete. Moreover, the incorporation of fibers, specifically polypropylene (PP) fibers, improves water impermeability. With a fiber content of 0.6 kg/m^3, the water absorption rate of the concrete is nearly halved. However, the inclusion of fibers does not have a substantial impact on gas permeability. Additionally, the introduction of polypropylene fibers contributes to the densification of the microstructure of recycled concrete. Overall, these findings highlight the positive influence of fibers, particularly polypropylene fibers, on the properties of recycled concrete incorporating crushed brick aggregates. The use of fibers can enhance the strength, durability, and water impermeability of the concrete, making it a promising approach for sustainable construction practices.

Mohammad et al.(2020) The investigation of waste plastic and waste glass on plain concrete properties involved designing five trial mixes and conducting various tests, including compression, splitting tensile strength, flexural strength, density, and water absorption. The conclusions drawn from the study indicate that as the amount of waste plastic and waste glass increases, the compressive strength gradually decreases. However, at a 10% replacement ratio, a slight reduction in compressive strength is observed, suggesting that this mixture ratio may be suitable. The splitting tensile strength and flexural strength also decrease with increasing replacement ratio. The density of the concrete samples decreases as the fine and coarse aggregates are replaced with waste plastic and waste glass. Additionally, the water absorption increases with higher proportions of waste plastic and glass. Despite the reductions in certain properties at a 25% replacement ratio, the study concludes that utilizing plastic and glass as aggregates can create environmentally sustainable concrete suitable for structural applications.

Gowtham et al.(2021) The literature survey reveals that the utilization of glass as a construction material offers several benefits. Firstly, it helps minimize the use of natural resources such as gravel and sand, reducing the strain on these limited resources. Additionally, incorporating waste glass in construction can help alleviate the landfill problem associated with glass waste. Moreover, when waste glass is added to concrete with appropriate mix proportions, it improves the compressive strength, flexural strength, tensile strength, and overall durability of the structure. This not only enhances the performance of the construction but also contributes to its sustainability. Another advantage is the potential cost reduction achieved by partially replacing fine and coarse aggregates with waste glass, making the construction process more economical. Overall, using waste glass in construction proves to be an environmentally friendly and sustainable approach.

Zaid et al.(2021) The study examines the effects of incorporating coconut shell aggregate, glass fibers, and silica fume at different percentages on the mechanical properties and durability of waste coconut shell concrete. The findings indicate that the compressive strength of the concrete increases by approximately 20% at 45% coconut shell aggregate, 1.5% glass fiber addition, and 15% silica fume after 28 days. The split tensile strength also improves by 22% at 45% coconut shell substitution, along with glass fiber and silica fume additions. Substituting conventional crushed aggregate with coconut shell results in lighter concrete, reducing the structure's dead load and lowering installation and footing costs. The density of coconut shell concrete shows enhancement up to an optimum level, and the correlation between compressive strength and density confirms its feasibility. The ultrasonic pulse velocity (UPV) test confirms the integrity and homogeneity of coconut shell concrete, while the addition of glass fibers enhances acid resistance. Furthermore, the inclusion of glass fibers and silica fume significantly improves the mechanical strength of the concrete, as observed in both the confinement effect provided by the fibers and the additional formation of C-S-H due to the silica fume. The scanning electron microscope (SEM) analysis reveals improved bonding between the binder matrix and glass fibers, resulting in denser and less porous concrete, thereby enhancing its mechanical properties.

Shakeel et al.(2022) The chemical composition of clear and colored glass powders is similar, making them suitable as pozzolanic materials according to ASTM standards. The optimal glass content in concrete for achieving compressive strength at 28 days is found to be 20%. By incorporating glass as a replacement material, the cost of cement production can be reduced by up to 14% without compromising performance. Furthermore, the use of glass powder in concrete production contributes to environmental sustainability by reducing CO2 emissions and minimizing the production of greenhouse gases and particulate matter. The high surface area of milled waste glass accelerates beneficial pozzolanic reactions by utilizing available alkalis before the formation of potentially harmful ASR gel. However, further research is needed to evaluate the durability and ASR-related aspects of glass-replaced concrete to fully endorse its use in sustainable concrete practices. The utilization of recycled aggregates in concrete offers a promising solution for managing construction and demolition waste.

Najaf et al.(2022) The utilization of microsilica in lightweight concrete (LWC) can enhance its strength; however, excessive use of microsilica can increase the water-to-cement ratio and lead to a decrease in strength. The optimal amount of microsilica is found to be 10% by weight of cement, resulting in a significant 42% improvement in compressive strength of LWC. Waste glass powder can be incorporated in concrete as a partial replacement for fine aggregates, providing environmental benefits and reducing costs. While the addition of glass powder increases concrete strength, excessive usage can make it brittle and negatively impact its properties. The ideal amount of glass powder is determined to be 25% by weight of fine aggregates. Furthermore, when glass powder and microsilica are used together, LWC exhibits exceptional performance with a remarkable 65% increase in strength. The inclusion of fibers in concrete containing glass powder and microsilica further enhances the compressive and flexural strengths. A moderate percentage of fibers generally leads to additional strength improvement; however, excessive fiber content can yield unfavorable outcomes due to their high volume and potential for hardening within the fresh concrete mix. Incorporating 1.5% fibers can result in a 7% increase in compressive strength and a significant 313% increase in flexural strength compared to a concrete specimen containing only glass powder and microsilica.

Kumar et al.(2023) The experimental investigation conducted on bituminous mixes, including Stone Matrix Asphalt (SMA) and Bituminous Concrete (BC), led to the following findings. All three types of fillers used in BC met the necessary specifications, demonstrating their suitability for application. Among the fillers, BC with cement filler exhibited the highest stability, while fly ash and stone dust fillers proved to be viable and cost-effective alternatives. The addition of fibers up to 0.3% improved the stability of BC, although further fiber incorporation did not yield significant stability enhancements compared to SMA. The inclusion of fibers resulted in a decrease in the flow value of BC, but when 0.5% of fibers were added, the flow value increased. SMA displayed superior tensile strength compared to BC, and the introduction of fibers reduced deformation in both types of mixes. Notably, SMA with sisal fiber demonstrated excellent performance for flexible pavement applications, indicating its potential in construction projects.

Abdeltawab et al.(2023) With the increasing concern for sustainable development, it has become crucial to explore alternatives that reduce the consumption of natural resources in various industries. Concrete production, which heavily relies on natural aggregates, significantly impacts the environment due to its large volume. To address this issue, researchers have focused on utilizing recycled materials as substitutes for natural aggregates. This study specifically investigates the use of waste crushed bricks (CB) and crushed recycled concrete (CRC) as partial replacements for fine and coarse aggregates in concrete. Different replacement ratios of 10%, 50%, and 100% by weight were examined for both fine and coarse aggregates. A total of eight concrete mixes, comprising 168 specimens, were subjected to compressive, splitting tensile, and flexural strength tests at 7, 28, and 56 days. The findings demonstrate the feasibility of incorporating CB and CRC in concrete mixes as partial replacements for aggregates. Notably, a 50% replacement ratio of coarse aggregate with crushed concrete resulted in significant improvements of 30%, 25%, and 23% in compressive, tensile, and flexural strengths, respectively. Similarly, a 50% replacement ratio of fine aggregate with crushed bricks led to notable increases of 23%, 28%, and 19% in compressive, tensile, and flexural strengths, respectively. The most effective combination was observed with a 50% replacement ratio of coarse aggregate with crushed concrete, along with a 50% replacement ratio of fine aggregate with crushed bricks, resulting in impressive enhancements of 32%, 28%, and 26% in compressive, tensile, and flexural strengths, respectively.

Kumar et al.(2023) The utilization of manufactured sand in concrete offers several beneficial effects on its performance. In both M40 and M50 grade concretes, when manufactured sand is used, there is a noticeable reduction in water absorption compared to conventional sand concrete. This reduction in water absorption is achieved by employing a lower water-binder ratio, resulting in concrete that is impermeable and more resistant to water penetration. Furthermore, the inclusion of manufactured sand leads to a decrease in chloride ion penetrability, indicating improved durability and lower permeability of the concrete. Another advantage of using manufactured sand is its enhanced resistance to acid and alkaline attacks, resulting in reduced weight loss compared to concrete made with traditional sand. Additionally, concrete mixes incorporating synthetic sand demonstrate improved resistance to impact and abrasion, making them more resilient in challenging conditions. Overall, the incorporation of manufactured sand positively influences various aspects of concrete performance.

6. SUMMARY

The review highlights that the inclusion of waste glass in concrete bricks can improve their thermal insulation, reduce energy consumption, and enhance their aesthetic appeal. Additionally, waste glass exhibits pozzolanic properties, contributing to the strength and durability of the concrete matrix. However, challenges related to alkali-silica reaction (ASR) and the need for appropriate glass particle size distribution need to be addressed. Furthermore, the incorporation of optical fibers in concrete bricks offers unique advantages, including light transmission, enhanced aesthetics, and potential applications in smart infrastructure. However, issues such as fiber dispersion, orientation, and compatibility with the cement matrix require further investigation. The review paper concludes that the utilization of waste glass and optical fibers as aggregates in the production of concrete bricks holds significant potential for sustainable construction practices. The inclusion of these waste materials can address waste management issues, reduce the carbon footprint, and enhance the performance and aesthetics of concrete structures. However, further research is needed to optimize the mixture proportions, address compatibility issues, and evaluate the long-term performance of such concrete bricks. The findings from this review can serve as a basis for future research and development in this field, promoting the adoption of eco-friendly practices in the construction industry.

REFERENCES

1. Sadoon Abdallah, Mizi Fan. *Characteristics of concrete with waste glass as fine aggregate replacement.* International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, Volume-2, Issue-6, June 2014.
2. Mizi Fan. *Characteristics of concrete with waste glass as fine aggregate replacement.* International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, Volume-2, Issue-6, June 2014.
3. Yue Li, Jiaqi Li, Yuhong Wan, Zhiyuan Xu. *Experimental study of light transmitting cement-based material (LTCM),* Construction and Building Materials, 2015 (V 96, page 319-325).
4. Thiago dos S. Henriques, Denise C. Dal Molin, Ângela B. Masuero *Study of the influence of sorted polymeric optical fibers (POFs) in samples of a light-transmitting cement-based material (LTCM),* Construction and Building Materials, 2018 (V 161, page 305-315).
5. Olofinnade, Oluwarotimi & Ede, Anthony & Ndambuki, Julius & Opeyemi, Ayanfe. (2019). REUSE OF GLASS AND CLAY BRICK WASTES AS SUBSTITUTE FOR NATURAL AGGREGATE IN GREEN CONCRETE. Proceedings of International Structural Engineering and Construction. 6. 10.14455/ISEC.res.2019.141.
6. Almaleeh, Abubaker & Shitote, S.M. & Nyomboi, Timothy. (2019). Utilization of Waste Glass and Ceramic Tiles in Concrete as Aggregate. 71. 127 - 144.
7. Kumar, A., Yadav, O. and Shukla, R., 2023. A COMPREHENSIVE REVIEW PAPER ON PARTIAL CEMENT SUBSTITUTION IN CEMENT MORTAR WITH WOOD ASH. *Research in Multidisciplinary Subjects (Volume-1),* p.26.
8. Zhang, Shiping & He, Peiling & Niu, Longlong. (2020). Mechanical properties and permeability of fiber-reinforced concrete with recycled aggregate made from waste clay brick. Journal of Cleaner Production. 268. 121690. 10.1016/j.jclepro.2020.121690.
9. Mohammad, Ilham & Nariman, Nazim & Othman, Kaywan. (2020). Utilization of Waste Plastic and Waste Glass Together as Fine and Coarse Aggregate in Concrete. Eurasian Journal of Science and Engineering. 6. 1-10. 10.23918/eajse.v6i2p1.
10. Gowtham, R & Prabhu, S & Gowtham, M & Ramasubramani, R. (2021). A Review On Utilization Of Waste Glass In Construction Field. IOP Conference Series: Materials Science and Engineering. 1130. 012010. 10.1088/1757-899X/1130/1/012010.
11. Kumar, A., 2023. WEB OF SYNERGY: International Interdisciplinary Research Journal.
12. Zaid, Osama & Ahmad, Jawad & Muhammad, Shahid & Siddique, Muhammad Shahid & Aslam, Fahid & Alabduljabbar, Hisham & Khedher, Khaled. (2021). A step towards sustainable glass fiber reinforced concrete utilizing silica fume and waste coconut shell aggregate. Scientific Reports. 11. 12. 10.1038/s41598-021-92228-6.
13. Kumar, A., Yadav, O. and Kumar, A.N., A REVIEW PAPER ON PRODUCTION OF ENVIRONMENT FRIENDLY CONCRETE BY USING SEWAGE WATER.
14. Shakeel, Zamin & Bhatia, Sakshi & Dar, Nasir. (2022). Utilization of Recycled Glass as Fractional Replacement of Cement and Waste Concrete as an Aggregate in Sustainable Concrete Practice. 10.55524/ijircst.2022.10.3.17.

15. Najaf, Erfan & Abbasi, Hassan & Zahrai, Seyed Mehdi. (2022). Effect of waste glass powder, microsilica and polypropylene fibers on ductility, flexural and impact strengths of lightweight concrete. International Journal of Structural Integrity. 13. 10.1108/IJSI-03-2022-0039.
16. Kumar, A., & Yadav, O. (2023). Concrete Durability Characteristics as a Result of Manufactured Sand. Central Asian Journal of Theoretical and Applied Science, 4(3), 120-127. https://doi.org/10.17605/OSF.IO/8P5HE.
17. (2023). Use of crushed bricks and recycled concrete as replacement for fine and coarse aggregates for sustainable concrete production. Challenge Journal of Concrete Research Letters. 14. 39. 10.20528/cjcrl.2023.02.002.
18. Kumar, N. ., Kumar , P. ., Kumar, A. ., & Kumar, R. . (2023). An Investigation of Asphalt Mixtures Using a Naturally Occurring Fibre. AMERICAN JOURNAL OF SCIENCE AND LEARNING FOR DEVELOPMENT, 2(6), 80–87. Retrieved from http://inter-publishing.com/index.php/AJSLD/article/view/1977.
19. IS 456: 2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standard, New Delhi.
20. Kumar, P. and Alam, M.F., Seismic Analysis of RC Building with Steel Bracing.
21. Kumar, Ajay & Yadav, Onkar & Kumar, Sagar. (2023). AN OVERVIEW ARTICLE ON INCORPORATING HUMAN HAIR AS FIBRE REINFORCEMENT IN CONCRETE. 11. 967-975.
22. IS 10262: 1982, "Recommended Guidelines for Concrete Mix design", Bureau of Indian Standard, New Delhi.
23. IS 383: 1970, "Specification for Coarse aggregate and Fine aggregate from Natural Sources for Concrete", Bureau of Indian Standard, New Delhi.
24. IS 9103: 1999, "Indian Standard Concrete Admixture Specification", Bureau of Indian Standard, New Delhi.
25. IS 9399: 1959, "Specification for Apparatus for Flexural Testing of Concrete", Bureau of Indian Standard, New Delhi.
26. IS 516: 1959, "Flexural Strength of Concrete", Bureau of Indian Standard, New Delhi.