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# Incorporating Solid Waste Particles into Concrete Design to Enhance Drainage Infrastructure

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**Abstract.** The inadequate drainage structure can cause water to accumulate on the surface of the pavement, leading to degradation and reduced lifespan of the concrete structure. This study focuses on the incorporation of solid waste particles into the concrete mix to enhance the drainage structure and other concrete structures. Solid waste particles (SWP) are added to the concrete mix to improve the strength and absorption of the concrete, thus increasing the drainage efficiency. This is an economically effective solution since solid waste particles are common and easily accessible. The study investigates the effect of different percentages of solid waste particles (0%, 5%, 10%, and 15%) on the mechanical properties of the concrete mix and its permeability. Compressive strength tests were used to determine the mechanical parameters of the concrete mixtures and water absorption test to describe the porosity and moisture sensitivity of concrete.

## 1.0 Introduction

Urbanization and extreme weather events have increased the need for resilient and sustainable drainage infrastructure. Traditional concrete structures struggle with efficiency, sustainability, and adaptability to changing climate patterns. Researchers and engineers are exploring unconventional approaches to bridge the gap between urban development and environmental responsibility. One such approach is the incorporation of solid waste particles (SWP) into concrete design to enhance drainage infrastructure. This concept aligns with the principles of circular economy and sustainable development, transforming waste materials into valuable resources. This approach offers the potential to revolutionize the construction and maintenance of urban drainage systems by synergizing waste utilization with drainage enhancement. In navigate urbanization, climate change, and sustainable development, it is crucial to find solutions that harmonize progress with responsible resource management. Waste-enhanced concrete represents a novel direction towards more resilient, efficient, and ecologically conscious urban landscapes.

## 2.0 Literature review

In recent years, the field of concrete production has witnessed innovative advancements aimed at achieving sustainable and environmentally friendly construction practices. Researchers have been exploring the incorporation of various waste materials into concrete formulations, resulting in the development of glascrete, rubber-modified concrete, and sulphur rubber concrete.

In 2004, Y. Xi et al. [1] conducted groundbreaking experimental research focused on creating glascrete, a type of concrete that incorporates crushed glass mixtures as a partial replacement for traditional aggregates. This investigation aimed to utilize solid waste materials and repurpose them into a useful construction material. The research highlighted the unique qualities of glascrete, which exhibited potential applications across various construction scenarios. By reusing glass waste, this innovation contributed to waste reduction and resource
conservation.

The utilization of waste tires as a source of rubber particles has gained attention in the construction industry. Blessen Skariah introduced a new application for recycled tires – as a partial replacement for natural aggregates in concrete production [2]. This research demonstrated the feasibility of rubber-modified concrete, which not only offered an eco-friendly approach to disposing of used tires but also showcased the material's potential to enhance the concrete's properties, such as flexibility and impact resistance. Another notable development emerged in the form of sulphur rubber concrete, which combines rubber particles with concrete and employs a sulfur-based binder. This innovative approach offers an alternative to traditional cement-based concrete mixtures. The concept of sulphur rubber concrete gained traction due to its potential benefits, such as reduced carbon emissions associated with cement production. While the exact details of the development weren't provided in the given points, this approach aligns with the broader trend of reducing the environmental impact of concrete production.

Vishnu's [3] research highlighted the multifaceted potential of utilizing waste materials in concrete. This research underscored the efficient incorporation of waste from various sources as additives, fillers, aggregates, and reinforcing fibers. Such integration not only addresses the issue of solid waste management but also contributes to the conservation of natural resources. The adoption of waste materials as construction inputs aligns with the principles of circular economy and sustainable development. In 2015, Lucas Gola's research [4] delved into the autoclave process, which produced waste blocks or rubble as a by product of shaping gray cellular concrete into specific forms. This waste material presented an opportunity for further exploration in terms of reusing it within the construction domain. Investigating ways to incorporate these waste blocks back into the production cycle could lead to resource optimization and reduced waste generation.

Shed light on the limitations of the standard pervious concrete pavement [5]. By identifying areas where the standard approach lacked strength, the research community was prompted to explore methods for enhancing concrete's structural performance. This pursuit aligns with the broader goal of producing concrete that meets not only environmental but also functional and durability requirements. The amalgamation of research efforts aimed at incorporating waste materials into concrete production has given rise to innovative construction materials like glascrete, rubber-modified concrete, and sulphur rubber concrete. These developments not only address waste management concerns but also contribute to more sustainable and eco-friendly construction practices. By harnessing waste materials' potential, researchers are paving the way for a more resource-efficient and resilient construction industry.

Yang [5] concluded in their research that the use of rubberized concrete should be limited to secondary structural components such as culverts, crash barriers, side walks, running tracks and sound absorbers.

Research into new and innovative uses of waste materials are continuously advancing. These research efforts try to match society's need for safe and economic disposal of waste materials. The use of recycled aggregates saves natural resources and dumping spaces and helps to maintain a clean environment. Malek et al in 2007 concentrates on those waste materials, specifically glass waste, plastic sand building construction waste to be used as substitutes for conventional materials, mainly aggregates, in ordinary portland cement concrete (OPC) mixes [6]. Founding in that research stated that the strength of concrete mixes was improved by the partial replacement of fine aggregates with crushed glass aggregates, but the high alkali content of such aggregates would affect the long-term durability and strength, both of which need long-term investigation.

Kishnore and Gupta, in 2020 reviewed about application of domestic and industrial waste materials as aggregate replacement in concrete [7]. Based from their study these wastes as a source can be used as a partial replacement of aggregate of aggregates which ultimately saving the natural resources. They also providing the guidelines for the user to opt these waste materials in the production of concrete. However, more studies are needed to eliminate all the undesirable effects and should be adoptable for long run cases.

**3.0 Objective**

The construction industry has long relied on conventional concrete as a fundamental building material. However, increasing environmental concerns have prompted researchers to explore ways to enhance the sustainability and performance of concrete. This study aims to investigate the potential of incorporating solid waste materials as additives in conventional concrete. The research project is guided by two main objectives:

i. Evaluate the performance of concrete when solid waste is incorporated as additive ingredients. Analyse compressive strength and water absorption, determining the impact of waste materials on concrete's mechanical and absorption characteristics.

ii. The research also aims to determine the optimal ingredient ratio in concrete mix design, balancing waste utilization and structural integrity.

The findings will contribute to sustainable construction practices by exploring the benefits and challenges of incorporating solid waste particle into concrete mixtures.

**4.0 Methodology**

Compressive strength and water absorption tests will be used in the following technique to thoroughly examine the effects of adding solid waste particle on the characteristics of concrete. For the experiment, a total of 36 concrete cubes with dimensions of 10 cm by 10 cm by 10 cm will be used.

I. Preparing Concrete and Materials:

a) Cement: Relevant standards-compliant standard Portland cement shall be utilised.

b) Coarse and Fine Aggregates: Aggregates that meet grading specifications and are readily accessible locally will be used.

c) Solid waste particle (SWP): To partially replace the fine aggregate, varying weight percentages (0%, 5%, 10%, and 15%) of coal bottom ash will be added.

d) Water: Mixing shall be done using potable water that satisfies quality criteria.

Specific proportions will be followed when preparing concrete mixtures. The experiment will be conducted with a constant mix design.

II. Curing and Casting Specimens:

For the experiment, thirty-six cubic specimens with measurements of 10 cm by 10 cm by 10 cm will be cast. Four distinct combinations (consisting of 0%, 5%, 10%, and 15%) of SWP will be made. All the mixtures shall be well combined to guarantee consistency. Following mixing, three layers of the concrete will be poured into the mould and compacted using conventional vibration techniques for each layer.

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After a day, the specimens will be demoulded and cured in a typical laboratory setting. The duration of the cure will be 7 and 28 days in order to assess its immediate and long-term impacts.

III. Test of Compressive Strength:

The compressive strength of the 36 concrete cubes will be tested following the designated curing time. In the compression machine, the cubes will be lined up, and axial stress will be applied steadily until failure. Every cube's compressive strength (measured in MPa) will be noted and averaged for every mix design and curing time.

IV. Test for Water Absorption:

a) The identical set of cubes will be tested for water absorption subsequent to the compressive strength tests.
b) The cubes will be soaked in water for a predetermined amount of time after being dried to a consistent weight.
c) The cubes will be taken out of the immersion period, any extra water drained, and their wet weights measured.
d) The percentage increase in weight due to water absorption will be used to compute the water absorption capacity.

This methodology aims to offer important insights into the viability and advantages of incorporating waste materials into concrete mixtures for improved drainage infrastructure by testing the compressive strength and water absorption of concrete cubes with varying percentages of SWP.

**Table 1**

| Type of materials | Sample | Cement (kg) | Sand (kg) | Aggregate (kg) | Solid waste (kg) |
|---|---|---|---|---|---|
| Previous | 0% (control) | 3.4 | 5.1 | 10.2 | - |
| Addictive solid waste particles | 5% | 3.4 | 5.1 | 10.2 | 0.17 |
| | 10% | 3.4 | 5.1 | 10.2 | 0.34 |
| | 15% | 3.4 | 5.1 | 10.2 | 0.51 |

The mix design provided in the Table 1 outlines the fundamental components of the concrete mix for Grade 25 (G25 or M25) with the inclusion of additives solid waste particle (SWP). The specific quantities of materials, including cement, water, sand and SWP, should be determined based on the desired concrete properties and the type of waste materials being incorporated. This mix design serves as a foundation for conducting experiments and research to evaluate the performance of solid waste concrete in cube moulds with dimensions of 10cm x 10cm x 10cm.

## 5.0 Result and Discussion

The study examines the impact of solid waste percentage on concrete compressive strength after 7 Days (Refer Table 2). The results show a decline in average maximum strength as the solid waste percentage increases, suggesting that lower strength is linked to higher solid waste percentages in the concrete mix. The study also reveals that the solid waste percentage of 15 has the lowest average maximum strength, suggesting a significant negative effect on compressive strength. However, the strength drop is less noticeable at 5% and 10% solid waste percentages. The data also shows similar patterns across various testing techniques. An outlier with a higher maximum strength could be due to an abnormality during testing or a change in the solid waste's composition.

**Table 2.** Maximum Strength (7 days)

| Percentage Solid Waste (%) | Average Maximum Strength (Mpa) | Maximum Strength (MPa) | Maximum Load (kN) |
|---|---|---|---|
| 0 | 35.907 | 37.732 | 377.316 |
| | | 34.590 | 345.899 |
| | | 35.398 | 353.984 |
| 5 | 31.387 | 31.420 | 314.198 |
| | | 31.626 | 316.255 |
| | | 31.116 | 311.156 |
| 10 | 29.845 | 30.609 | 306.091 |
| | | 29.315 | 293.146 |
| | | 29.610 | 296.101 |
| 15 | 26.025 | 25.572 | 255.720 |
| | | 25.263 | 252.625 |
| | | 27.239 | 272.239 |

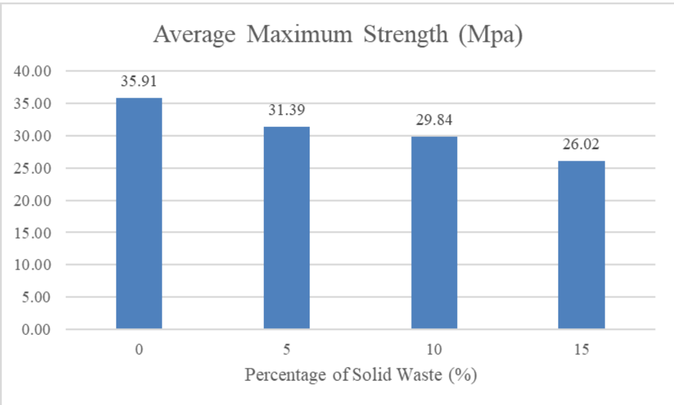


**Figure 1.** Average Strength (7 Days)

In Table 3, results for maximum strength after 28 days was examine. The analysis shows that the maximum average strength of concrete mixes with 5% solid waste is 36.393 MPa, the highest value. The average maximum strength is marginally lower at 0% and 10% solid waste percentages, and at 15% solid waste, the average strength drops to 22.761 MPa. The data suggests that adding a moderate amount of solid waste to concrete can increase its strength but adding more than 15% can significantly decrease it.

**Table 3.** Maximum Strength (28 Days)

| Percentage Solid Waste (%) | Average Maximum Strength (Mpa) | Maximum Strength (MPa) | Maximum Load (kN) |
|---|---|---|---|
| 0 | 33.784 | 32.847 | 328.473 |
| | | 34.264 | 342.64 |
| | | 34.241 | 342.409 |
| 5 | 36.393 | 35.09 | 350.9 |
| | | 38.186 | 381.864 |
| | | 35.902 | 359.022 |
| 10 | 33.175 | 31.961 | 319.612 |
| | | 33.609 | 336.087 |
| | | 33.955 | 339.548 |
| 15 | 22.761 | 21.901 | 219.012 |
| | | 23.083 | 230.826 |
| | | 23.299 | 232.995 |

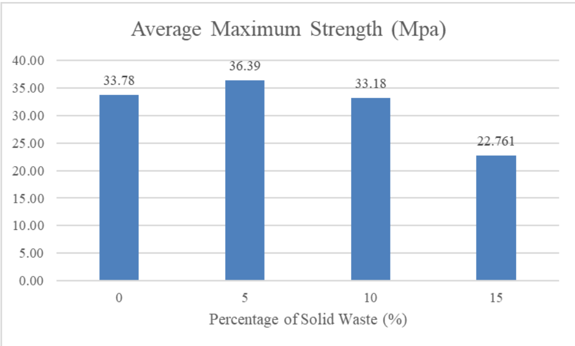


**Figure 2.** Average Strength (28 Days)

Water absorption properties of concrete specimens at different solid waste percentages was tested. The results in Table 4 show that the water absorption percentage changes as the solid waste percentage increases. The average water absorption percentage with 0% solid waste is 2.11%, while it rises to 5.5% with 5% solid waste. The average percentage increases to 3.21% at 10% solid waste, and 0.93% at 15% solid waste. The variability in water absorption measures within each solid waste percentage is due to the intrinsic heterogeneity of materials, testing settings, and sample preparation. The study suggests that increased porosity in the concrete matrix may be due to waste materials, impacting its long-term performance and durability. Further research is needed to understand the connection between waste content and water absorption in concrete.

**Table 4.** Water Absorption

| Solid Waste Percentage (%) | Wet | Dry | Percentage (%) | Average Percentage(%) |
|---|---|---|---|---|
| 0 | 2.29 | 2.24 | 2.23 | 2.11 |
| | 2.315 | 2.27 | 1.98 | |
| 5 | 2.185 | 2.055 | 6.33 | 5.50 |
| | 2.235 | 2.135 | 4.68 | |
| 10 | 2.3 | 2.23 | 3.14 | 3.21 |
| | 2.205 | 2.135 | 3.28 | |
| 15 | 2.135 | 2.12 | 0.71 | 0.93 |
| | 2.2 | 2.175 | 1.15 | |

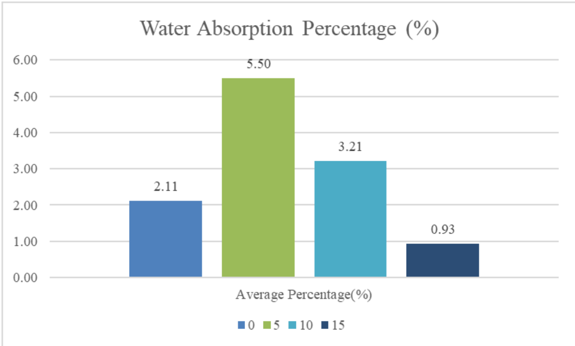


**Figure 3.** Average Water Absorption

## 6.0 Conclusions

The study investigates the impact of adding solid waste materials to concrete mixtures, focusing on compressive strength and water absorption capabilities. Results show that adding waste materials in moderation can improve compressive strength and balance environmental concerns with structural integrity. However, going beyond certain waste content criteria can lead to a loss of strength. The study also highlights the impact of waste on concrete's porosity and moisture sensitivity. The findings suggest the need for strict experimental controls and a customized strategy for each waste material. The findings can help engineers, architects, and legislators make decisions about waste percentages in line with construction regulations and environmental objectives. The research fills the gap between innovative construction practices and sustainable waste management, contributing to resource efficiency and the circular economy.

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