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UTILIZATION OF WASTE MATERIALS IN THE CONSTRUCTION OF RIGID PAVEMENT

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Abstract - *The project aims to find suitable waste materials from various industries and the environment to replace cement and aggregate in highway construction. Global studies have highlighted the negative impacts of waste materials on the environment and human health, emphasizing the need for substitutes with similar properties to cement. Using waste materials in construction reduces the reliance on cement, cutting costs and minimizing harmful effects. Proper design and material selection are crucial in incorporating waste materials into pavement construction to ensure longevity and durability. Construction practices like placement, compaction, and curing also play a significant role in the durability of concrete pavements. The focus of the project is on utilizing plastic waste and Electric Arc Furnace Slag (EAFS) as replacements for coarse aggregate and cement, respectively. Tests were conducted to determine standard values and ranges for these materials, establishing a relationship between different proportions of plastic aggregate and EAFS and compressive strength values. Substituting 20% of cement with EAFS resulted in a 4.58MPa increase in compressive strength at 7 days, with the highest value recorded for unmodified concrete at 28 days. The difference in compressive strength values decreased with higher percentages of coarse aggregate substitution. The optimal value was found at 2.5% replacement of coarse aggregate with plastic aggregate for 7 and 14 days, while the highest value was observed at 5% replacement for 28 days.*

Key Words: Waste Material, Pavement, Rigid Pavement, Improvement, strengthening of the pavement.

1.INTRODUCTION

Employing cutting-edge technologies in the production of eco-friendly construction materials, such as self-compacting concrete derived from a variety of industrial byproducts, represents a proactive approach to environmental conservation while ensuring the fabrication of long-lasting construction materials. Concrete, a predominant building material, consists mainly of sand, aggregates, and cement. By substituting cement with pozzolanic materials like fly ash, silica fume, rice husk ash, metakaolin, and Electric Arc Furnace Slag (EAFS), and utilizing crushed granulated blast furnace slag to reduce production costs, the structural integrity and strength of concrete are maintained. However, the extensive extraction of concrete ingredients from the Earth's crust each year leads to environmental strain through resource depletion. Recent technological progress underscores the importance of using industrial and organic waste materials as alternative resources for manufacturing a variety of valuable products. Common solid wastes such as plastic waste, EAFS, rice husk, and discarded construction materials can be repurposed through strategies involving partial cement replacement to meet the growing demand for cement and concrete. Plastic waste, in particular, poses challenges due to its slow decomposition rate and extended lifespan. Improper disposal of plastic waste contributes to environmental deterioration and economic burdens, resulting in contamination of the food chain, loss of biodiversity, energy inefficiencies, and financial repercussions. Additionally, the presence of EAFS in industrial settings presents health risks to workers and creates unfavorable working conditions. To tackle these issues, the integration of plastic waste and EAFS into rigid pavement construction emerges as a promising solution to reduce waste accumulation in the vicinity. By incorporating these materials into pavement construction, not only is waste effectively managed, but also environmentally friendly and efficient practices are promoted. The inclusion of plastic waste and EAFS in concrete offers numerous benefits, making it a sustainable and viable choice for infrastructure development.

2.SLAG

Blast Furnace (BF) slag and Steel-Making (SM) slag are the two main types of slags produced in the steel industry. Electric Arc Furnace Slag (EAFS) is a type of Steel-Making slag that is extracted through the refinement of discarded steel scrap in an electric arc furnace. EAFS is characterized by its high concentration of free calcium and iron oxides. This slag is obtained during the steelmaking process, which involves melting liquid steel and then undergoing acid refining. The material has a rocky texture and can be easily crushed, making it suitable for use as concrete aggregate. Utilizing EAFS not only provides a partial solution to environmental challenges but also helps improve the microstructure of concrete. This improvement is often difficult to achieve with just pure Portland cement. The use of EAFS that has passed through a 90-micron sieve is visually demonstrated in the project's representation. By incorporating EAFS into concrete production, the project aims to showcase the benefits of using this slag as a sustainable alternative in construction materials.

Figure-1: EAFS Passing 90µ Sieve.

3.COMPARISON BETWEEN PREVIOUS RESEARCH AND LABORATORY DATA FOR 7 DAYS COMPRESSIVE STRENGTH OF EAFS

Upon thorough analysis of various research studies and laboratory experiments, it was determined that the highest compressive strength can be achieved by substituting 30% of cement with EAFS during testing in a controlled environment. Surprisingly, a different study proposes that the most effective replacement value is actually 20%. It is worth noting that there was a significant decrease of 6.4 MPa in compressive strength when using a 20% replacement of cement with EAFS, compared to the findings of the previous research. These results underscore the critical importance of carefully selecting the appropriate percentage of cement replacement to achieve the best possible compressive strength outcomes. It is evident that further investigation and experimentation are necessary to fully understand the optimal conditions for enhancing compressive strength in construction materials.

There are multiple factors that can lead to differences in the results observed, such as variations in the composition of slag, variations in the conditions under which the curing process takes place, and differences in the methodologies used for testing. It is also important to note that the size, shape, and treatment of the samples being tested can have an impact on the values obtained for compressive strength. Moreover, even subtle differences in the calibration of equipment and the techniques used by operators can introduce variability into the results obtained. Despite the challenges that come with comparing data from different sources, it is crucial to emphasize the significance of maintaining rigor and standardization in experimental procedures. Looking ahead, it will be essential to work towards aligning methodologies and establishing common standards for testing the properties of Electric Arc Furnace Slag (EAFS) in order to facilitate meaningful comparisons and enhance our knowledge of this versatile material. By engaging in collaborative efforts and adopting transparent reporting practices, we can overcome these obstacles and cultivate greater confidence in the characterization of EAFS properties, ultimately enabling more informed decision-making in engineering applications.

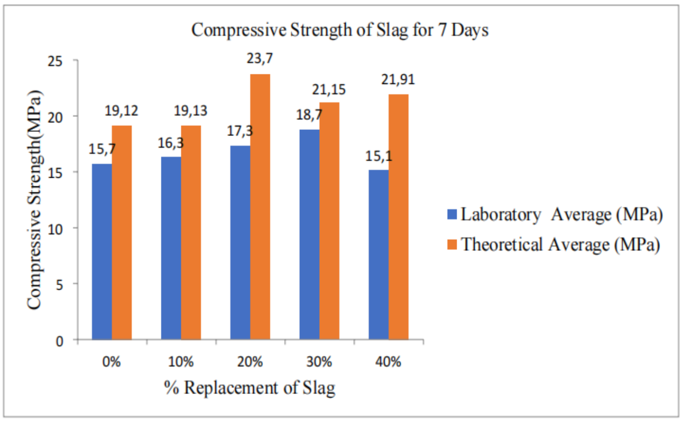

Figure-2: Graph of Slag for Compressive Strength 7 Days vs. % Replacement of EAFS.

4.COMPRESSIVE STRENGTH TEST OF EAFS FOR 14 DAYS

The compressive strength test for Electric Arc Furnace Slag (EAFS) at the 14-day mark is a crucial step in assessing the quality and performance of this material. To conduct this test, representative samples of EAFS are carefully collected and then shaped into cylindrical specimens following specific standard dimensions. These samples are then placed in a controlled environment for a curing period of 14 days to allow for proper strength development. Once the curing period is complete, the specimens are removed from the molds with precision, and their dimensions are measured accurately to ensure consistency. Subsequently, the specimens are subjected to compressive force in a universal testing machine, where the force is applied at a constant rate until failure occurs. The maximum load at which failure happens is recorded for each specimen, and the compressive strength is calculated by dividing this maximum load by the cross-sectional area of the specimen.

After conducting the test on multiple samples, the average compressive strength of the EAFS at the 14-day mark is determined and reported, along with any noteworthy observations or findings. It is essential to adhere to relevant standards and guidelines during the testing process to ensure the accuracy and reliability of the results obtained. Notably, the test results showed that the maximum compressive strength was achieved with a 30% replacement of EAFS, indicating the potential benefits of using this material in certain applications.

Table-1: Compressive Strength estimation when slag is used for 14 days

Replaced Slag (in%)	S - 1	S - 2	S - 3	Laboratory Average
	(MPa)			
0%	30.1	28.5	29.4	29.3
10%	28.2	30.1	28.7	29.0
20%	31.2	32.1	29.4	30.9
30%	32.5	33.2	33.4	33.3
40%	24.5	29.3	28.5	27.4

5.COMPARISON BETWEEN PREVIOUS RESEARCH AND LABORATORY DATA FOR 28 DAYS COMPRESSIVE STRENGTH OF EAFS

During the laboratory testing, it was observed that substituting 30% of cement with slag yielded the highest compressive strength value after 28 days. This discovery contrasts with the findings of a previous research paper, which indicated that unmodified concrete had the highest value. However, the laboratory testing showed an increase in compressive strength compared to the earlier study. In particular, there was a significant 9 MPa increase in compressive strength when 30% of EAFS was substituted for cement during laboratory testing, in comparison to the results of the previous paper. These results imply that incorporating slag as a partial replacement for cement could enhance compressive strength values and warrant further investigation in future research endeavors.

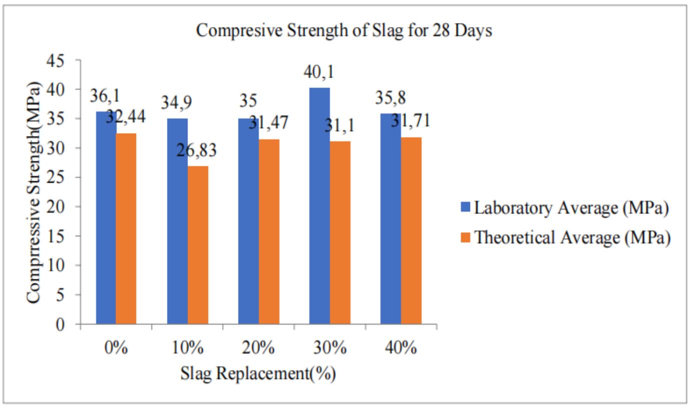

Figure-3: Graph of Compressive Strength vs. % Slag replacement for 28 Days.

6.FLEXURAL STRENGTH TEST OF EAFS FOR 7 DAYS

The flexural strength test of Electric Arc Furnace Slag (EAFS) at 7 days is a crucial evaluation of the material's ability to resist bending forces. To conduct this test, carefully prepared representative samples of EAFS are shaped into either cylindrical or rectangular forms, following specified standards. These samples then undergo a meticulous curing process under controlled conditions for a duration of 7 days, which helps in promoting hydration and strength development within the material. After the curing period is completed, the samples are allowed to adjust to room temperature before the actual testing takes place.

During the testing process, a specialized flexural strength testing machine is utilized, calibrated according to either ASTM guidelines or other relevant standards. The samples are positioned on supports within the testing machine, and a load is applied gradually and consistently until the samples reach their breaking point. The maximum load endured by each sample, as well as the corresponding amount of deflection at the point of failure, are both carefully recorded for analysis.

Following the testing phase, the flexural strength of each sample is determined using specific formulas that consider key parameters such as the maximum load applied, the span length, and the dimensions of the sample. These calculated flexural strength values are then documented along with details regarding the preparation of the samples, the conditions under which they were cured, and the specific parameters of the testing process. These results play a vital role in assessing the performance of EAFS and in determining its suitability for different applications.

It is essential to strictly adhere to established testing protocols and standards to ensure the accuracy and reliability of the results obtained from the flexural strength test of EAFS. By following these guidelines, researchers and engineers can make informed decisions regarding the use of EAFS in various construction and industrial settings.

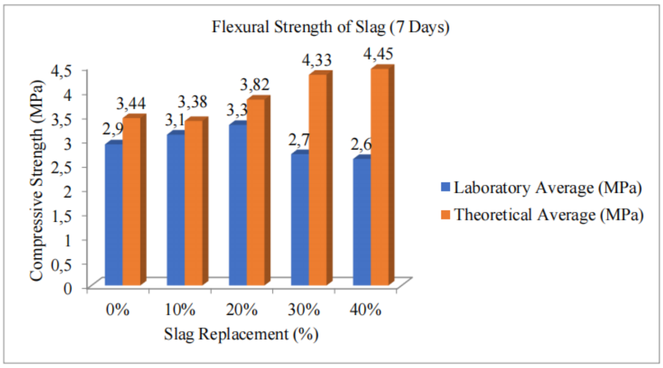

Figure-4: Graph of Slag for Flexural Strength 7 Days.

7.COMPARISON BETWEEN PREVIOUS RESEARCH AND LABORATORY DATA FOR 7 DAYS FLEXURAL STRENGTH OF EAFS

When it comes to concrete, the flexural strength is highly dependent on the proportions used. Interestingly, laboratory data shows that theoretical strengths tend to be higher than what is actually observed in practice. There are a number of factors that could contribute to this discrepancy, including the use of different additives and an increase in the water-cement ratio. Additionally, the quality of cement used can also impact flexural strength outcomes. Overall, it's important to carefully consider all of these variables when working with concrete in order to achieve optimal results.

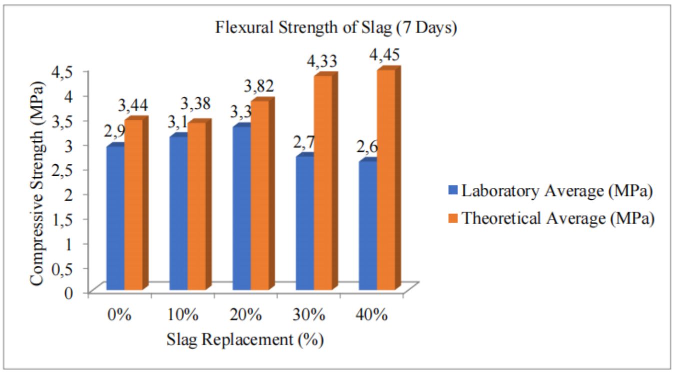

Figure-5: Graph of Slag for Flexural Strength 7 Days.

8. FLEXURAL STRENGTH TEST OF EAFS FOR 28 DAYS

During laboratory testing and research paper analysis, it was discovered that the most effective value for flexural strength after 28 days was achieved through the use of slag as a replacement for cement. Specifically, a 20% replacement of cement with slag in laboratory testing proved to be optimal, while a 30% replacement was found to be most effective in the research paper. These findings suggest that incorporating slag into cement mixtures may have significant benefits in terms of improving flexural strength.

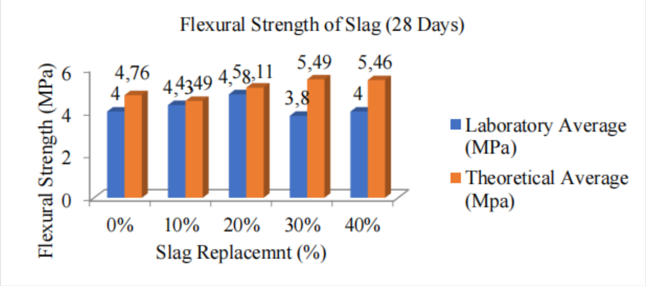

Figure-6: Graph of Slag for Flexural Strength 28 Days

9.COMPARISON BETWEEN PREVIOUS RESEARCH AND LABORATORY DATA FOR 7 DAYS SPLIT TENSILE STRENGTH OF EAFS

After conducting laboratory testing for 7 days, it was discovered that the most ideal tensile strength values were achieved through the use of slag replacements of either 10% or 40%. Interestingly, previous research had only identified the optimal value as being associated with a 40% slag replacement. This finding highlights the importance of continued exploration and experimentation within this field, as new information and insights may lead to even more effective solutions in the future

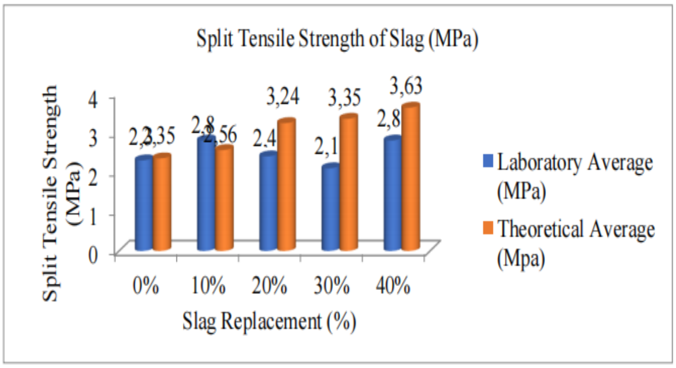

Figure-7: Graph of Slag for Tensile Strength 7 Days vs. % Replacement of EAFS.

10.CONCLUSION

The study involved replacing EAFS with cement and coarse aggregate with plastic waste in varying ratios. Compressive strength increased up to 30% replacement of cement by EAFS for 7 days in laboratory testing. The maximum compressive strength was observed at 30% replacement of cement by EAFS for 28 days. However, increasing the percentage of slag replacement led to a decrease in compressive strength for 28 days. In terms of flexural strength, the optimal value for concrete (M40) was found at 20% replacement of cement in the lab for 7, 14, and 28 days. Contrarily, the research paper indicated that the best replacement was at 40%. Tensile strength testing revealed that the optimal value was discovered for 10% and 40% slag replacement for 7 days in the lab, but the research report identified the ideal value only for 40% slag replacement. The characteristics of steel slag aggregate likely influenced the strength increase.

The compressive strength of plastic replaced aggregate was found to be optimal at 2.5% replacement in laboratory testing, contrasting with the research paper's finding of maximum strength at 5% replacement of coarse aggregate.

For flexure strength, the best value at 7 days was observed at 2.5% replacement of coarse aggregate with plastic waste in both laboratory and research paper settings. There was a

17.14% increase in flexure strength at 5% replacement compared to unmodified concrete, showing a linear relationship between flexure strength and percentage replacement of coarse aggregate with plastic waste up to 5%.

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