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Experimental Study on the Use of Aluminium Dross and Ground Granulated Blast Furnace Slag in Making Eco-Friendly Concrete

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ABSTRACT: Concrete, made from cement, aggregates, and water, is still a key material used in construction around the world. However, making cement is a big contributor to global CO₂ emissions because it requires a lot of energy. As people become more worried about the environment, researchers are looking for ways to make concrete more sustainable without losing its strength. The construction industry is now under pressure to use circular economy ideas and find better ways to use waste to reduce its impact on the environment. This review looks at Aluminium Dross, which is a harmful byproduct from making aluminium, and Ground Granulated Blast Furnace Slag (GGBS) as possible substitutes for cement in eco-friendly concrete. Normally, Aluminium Dross needs expensive ways to get rid of it, but it has special qualities that make it useful for construction. Studies show that it has pozzolanic and filler properties, which can help make concrete stronger and last longer. The chemical makeup of Aluminium Dross includes alumina and silica, which help it act like cement.

Research shows that using the right amount of Aluminium Dross can keep or even improve concrete's performance while solving waste issues. Using Aluminium Dross helps reduce cement use and the carbon emissions linked to it. It also turns waste into a useful building material, helping both the environment and waste management. Plus, it can make concrete production more cost-effective by lowering the cost of raw materials. GGBS has similar properties to cement, so it can be used as a replacement. In this study, the effect of GGBS on fresh and hardened concrete was tested by using different percentages of GGBS in place of cement. We also looked at how Aluminium Dross (5%, 10%, and 15%) affects concrete. If the ideal mix of Aluminium Dross is found, then more cement can be replaced with mineral additives like GGBS (5%, 10%, 15%, 20%, and 25%). From these mixtures, the best combination of Aluminium Dross and GGBS was found to give the strongest concrete. The results showed that using 10% Aluminium Dross and 20% GGBS gives the best strength.

KEYWORDS: Aluminium Dross, GGBS, Green Concrete, Sustainable Construction, Partial Cement Replacement, Industrial Waste Utilisation, Workability, Compressive Strength, Flexural Strength.

I. INTRODUCTION

Many materials are available in the global market, and research is being done on alternative materials to replace fine aggregate and cement, though on a smaller scale. Based on existing studies and experiments, this research uses aluminium dross and GGBS as substitutes for cement. Aluminium dross is a leftover material that forms during the smelting, casting, and recycling of aluminium and its alloys in primary smelters, foundries, and recycling plants. The properties of these materials can vary depending on their source. The design properties and behaviour of cement and sand can be quickly assessed from existing literature for use in preliminary design. However, there is not enough information on mechanical by-products, and there is no clear evidence that they have similar design properties to cement and sand. It is important to provide this valuable information to designers because sustainable construction is becoming more important. Meeting this need is the main purpose of this study. Therefore, there is a need to use other supplementary materials that not only provide the required strength and durability but also protect concrete from high temperatures and water damage. Due to the high cost of disposing of aluminium dross and GGBS in landfills, using these by-products in concrete is an effective way to manage waste. Optimal use of aluminium dross and GGBS not only saves a large amount of cement but also reduces pollution.

Aluminium dross and GGBS are by-products that occur during the production of aluminium and iron respectively. These materials can be effectively used in concrete production as alternatives to sand and cement. This can also improve the physical and chemical properties of concrete, such as compressive strength, tensile strength, and flexural strength. Similarly, GGBS is a by-product from the iron-making industry. As industrialization and urbanization continue to grow, the production of iron is increasing, and the number of industrial by-products is also rising. Using these by-products in concrete as a partial replacement for OPC can be very beneficial in creating high-quality concrete. Aluminium dross is a product obtained from the manufacturing process of aluminium. A lot of energy is used to extract more aluminium from the dross, so if the dross is processed and used as a service engineering material, the energy can be saved.

The current study looks into how using aluminium dross as a partial substitute for cement at different levels (from 0% to 15%) and GGBS as a partial substitute for fine aggregates at a constant 5% level affects the mechanical and durability properties of concrete. Mechanical properties refer to the ability of concrete to resist forces once it has gained the necessary strength to support the load it was designed for. Durability means how well concrete can withstand harmful chemical reactions, weathering, wear, and other forms of damage, while still maintaining its shape, quality, and functionality over time. When exposed to harsh environmental conditions, durable concrete can retain its original structure and performance as intended for its intended lifespan. Concrete that is properly made, tested, and arranged can function with minimal or no need for maintenance, avoiding extra costs for regular upkeep to prolong the life of structures. Concrete made with great care and skilled craftsmanship may not need repairs or renovations for a long time, but still requires regular maintenance after ensuring that all related installations—like plumbing, sanitation, and electrical systems—are properly done following best practices.

II. LITERATURE SURVEY

The objective of literature review is to collect published information from numerous study publications. We choose valuable data for research investigations using data analysis.

1. Budda Damodhara Reddy et al. [2024] Disposal and recycling of dross is a global issue. The majority of aluminium-based dross is buried in landfills, which can lead to the leaching of harmful metal ions into shallow groundwater, causing serious pollution problems. Also, when aluminium dross comes into contact with groundwater, it releases dangerous gases such as ammonia, phosphine, methane, hydrogen, and hydrogen sulfide. Aluminium-based dross is considered a hazardous waste material that comes from the aluminium smelting process. The environmental impact of aluminium dross has been a growing concern for researchers. There are ongoing efforts to find useful ways to utilize this hazardous waste through engineering applications. In this study, aluminium dross is mixed into concrete as a partial replacement for cement, under various conditions.
2. Sancheng Qing et al. [2024] looked at how toxic substances in phosphogypsum (PG) and aluminium dross (AD) stop them from being used widely in construction. Their study focused on using AD and PG as additives in cement to lower environmental harm and cut down on waste going to landfills. Different tests were done to see how AD behaves at various heat levels. The study checked several things, including how strong the mix was, how much phosphorus and fluorine dissolved, the heat given off during mixing, and how much the mix expanded. They found that AD heated to 900°C helped remove nitrogen better while still keeping the cement's hydration qualities. Heating AD at 900°C also made it easier for gypsum and calcium silicate to dissolve, which helped create more ettringite (AFt), calcium silicate hydrates (C-SH), and calcium aluminate hydrates (C-A-H). The best mix was 14% heated aluminium dross (HAD), 6% PG, and 80% Portland cement (PC), which gave a compressive strength of 25.87 MPa. This research offers a new way to use both PG and AD together, helping make cement production more sustainable by using industrial waste.
3. Muñoz-Vélez, M.F. et al. [2023] conducted a study to look into the possibility of setting up an industrial plant that can turn aluminium dross into raw materials suitable for cement. They looked at the technical aspects of washing and grinding processes. Using X-ray diffraction, they found that washing reduced the amount of AlN, a compound that releases ammonia when it gets wet, by 88%. Impact milling was found to be the most effective method for grinding. An economic analysis, using cash flow models, showed that selling the product for at least USD 0.12 per kilogram would result in a 9.7% return over five years. The findings show potential for both the metallurgical and construction industries to make low-carbon products from recycled aluminium dross. The

research also helps regulators and policymakers in developing rules and encouraging measures to support companies in adopting sustainable practices.

4. Aadil Hameed [2023] This study replaced cement with different amounts of Aluminium waste powder (AWP), from 2.5% up to 10%, to create practical mortar mixes. Samples that were 50 mm in size were kept moist for 3, 7, and 28 days to check how well they flowed, their density, and how strong they were. The same amount of water compared to cement was used in all mixes. The results showed that as more AWP was added, the mortar became less able to flow. When the samples were kept wet, they became less dense and less strong as the AWP content increased. The strength tests showed that using up to 2.5% AWP kept the strength at a good level, but using 10% AWP greatly reduced the strength. The mix with 2.5% AWP had the highest strength after 28 days of curing.

III. METHODOLOGY

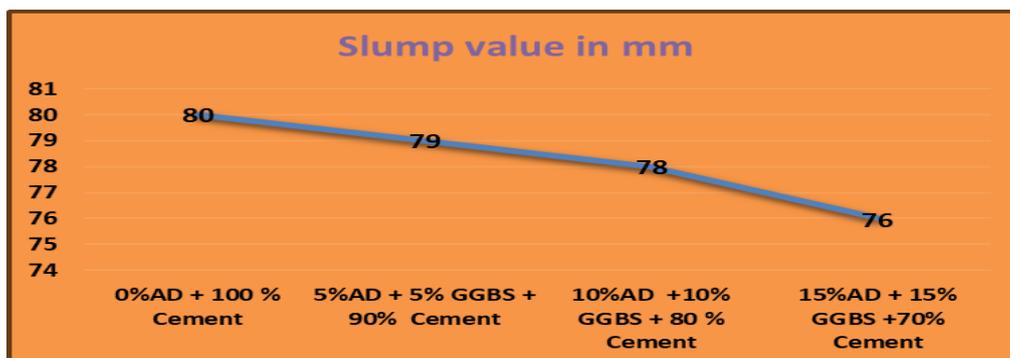
The physical properties of ingredients are assessed as per relevant Indian standards.

- ✓ M30 grade concrete mix is designed as per Is 10262:2019 by considering the properties of ingredients.
- ✓ Concrete mix design is prepared by replacing at the intervals of 0, 5, 10 & 15 % of cement by partially replacing the Aluminum dross & 5, 10, 15, 20 & 25% GGBS.
- ✓ Workability of all the mixes is assessed by conducting slump test
- ✓ Compressive strength, split tensile strength & flexural strength of concrete mixes are assessed at 7, 14 & 28 days.

IV. EXPERIMENTAL RESULTS

TABLE NO 1: MIX PROPORTION OF M30

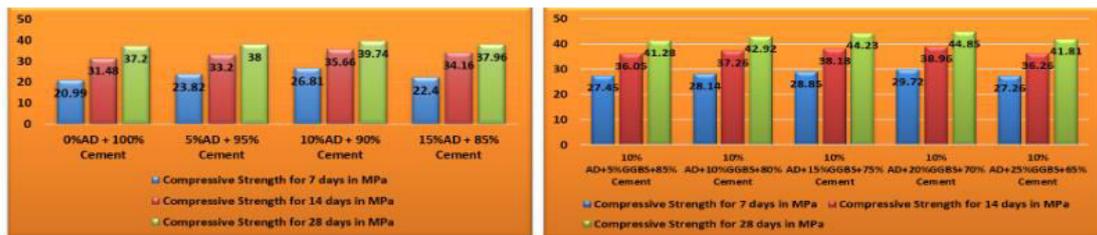
Grade	M30
Proportion	1: 2.25: 3.68
W/C ratio	0.45
Cement	330 Kg/m ³
Fine Aggregate	742 Kg/m ³
Coarse Aggregate	1215 Kg/m ³
Water	149 Kg/m ³
Chemical admixture	3.30 Kg/m ³



GRAPH NO 1 SLUMP CONE VALUES

TABLE NO 2 TEST RESULTS OF COMPRESSIVE STRENGTH AT 7 DAYS, 14 DAYS & 28 DAYS

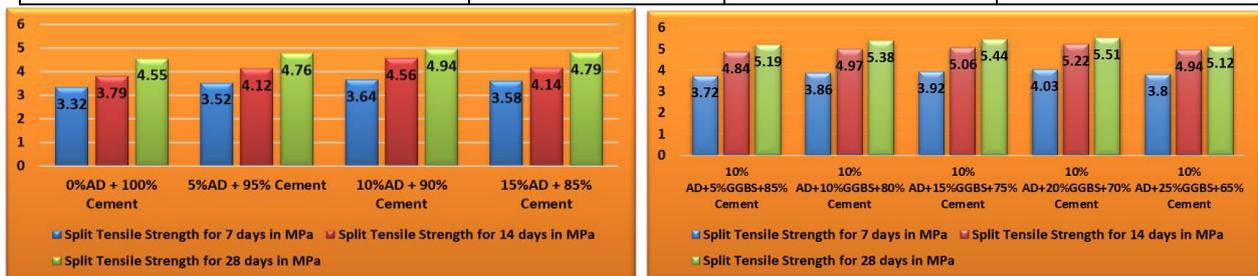
Mix % Replacement	Compressive Strength for 7 days in MPa	Compressive Strength for 14 days in MPa	Compressive Strength for 28 days in MPa
0%AD + 100% Cement	20.99	31.48	37.20
5%AD + 95% Cement	23.82	33.20	38.00
10%AD + 90% Cement	26.81	35.66	39.74
15%AD + 85% Cement	22.4	34.16	37.96
10% AD+5%GGBS+85% Cement	27.45	36.05	41.28
10% AD+10%GGBS+80% Cement	28.14	37.26	42.92
10% AD+15%GGBS+75% Cement	28.85	38.18	44.23
10% AD+20%GGBS+70% Cement	29.72	38.96	44.85
10% AD+25%GGBS+65% Cement	27.26	36.26	41.81



GRAPH 2 Development of Compressive strength &Relation between optimum Aluminium dross (10%)+ %GGBS replacement and Compressive strength

TABLE NO 3 TEST RESULTS OF SPLIT TENSILE STRENGTH AT 7 DAYS, 14 DAYS & 28 DAYS:

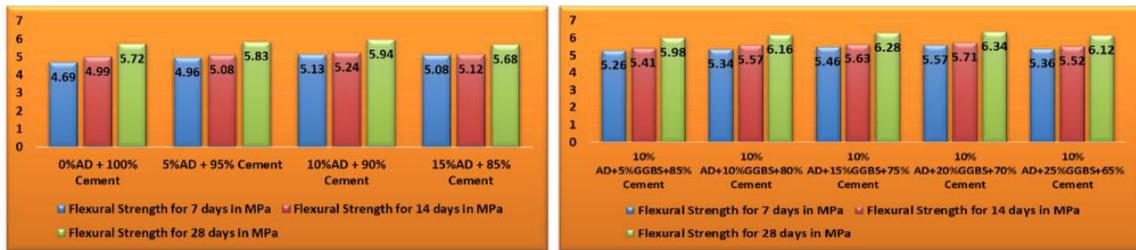
Mix % Replacement	Split Tensile Strength for 7 days in MPa	Split Tensile Strength for 14 days in MPa	Split Tensile Strength for 28 days in MPa
0%AD + 100% Cement	3.32	3.79	4.55
5%AD + 95% Cement	3.52	4.12	4.76
10%AD + 90% Cement	3.64	4.56	4.94
15%AD + 85% Cement	3.58	4.14	4.79
10% AD+5%GGBS+85% Cement	3.72	4.84	5.19
10% AD+10%GGBS+80% Cement	3.86	4.97	5.38
10% AD+15%GGBS+75% Cement	3.92	5.06	5.44
10% AD+20%GGBS+70% Cement	4.03	5.22	5.51
10% AD+25%GGBS+65% Cement	3.80	4.94	5.12



GRAPH 3 Development of Compressive strength &Relation between optimum Aluminium dross (10%) + %GGBS replacement and Split Tensile strength

TABLE NO 4 TEST RESULTS OF FLEXURAL STRENGTH AT 7 DAYS, 14 DAYS & 28 DAYS:

Mix % Replacement	Flexural Strength for 7 days in MPa	Flexural Strength for 14 days in MPa	Flexural Strength for 28 days in MPa
0%AD + 100% Cement	4.69	4.99	5.72
5%AD + 95% Cement	4.96	5.08	5.83
10%AD + 90% Cement	5.13	5.24	5.94
15%AD + 85% Cement	5.08	5.12	5.68
10% AD+5%GGBS+85% Cement	5.26	5.41	5.98
10% AD+10%GGBS+80% Cement	5.34	5.57	6.16
10% AD+15%GGBS+75% Cement	5.46	5.63	6.28
10% AD+20%GGBS+70% Cement	5.57	5.71	6.34
10% AD+25%GGBS+65% Cement	5.36	5.52	6.12



GRAPH 4 Development of Compressive strength & Relation between optimum Aluminium dross (10%) + %GGBS replacement and Flexural strength

V. CONCLUSIONS

Based on the above research, the following analysis was conducted on the synthetic Aluminium dross and GGBS with mineral additives as partial replacement of cement.

1. Its operation is low according to the Aluminum dross ratio in the transition.
2. The results showed that the maximum percentage of Aluminum dross replacing cement was formed when the Aluminum dross content was **10%**.
3. The highest concrete properties were obtained with the concrete mixture containing **10%** Aluminum dross and **20%** GGBS compared to other mixtures.
4. The test results showed that the strength of the concrete combined with Aluminum dross and GGBS was increased better than that of the Aluminum dross concrete mixture.
5. It is seen that when 10% Aluminum dross is used, the compressive strength increases by **6.83%**, the tensile strength increases by **8.57%** and the flexural strength increases by **3.85%** compared to traditional concrete.
6. Compared to ordinary concrete, using 10% Aluminum dross and 20% GGBS can increase the compressive strength by **20.56 %**, the tensile strength by **21.09%** and the flexural strength by **10.84%**.

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