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Manufacture of artificial aggregate using alkaline solution

Fabricarea agregatelor artificiale folosind soluție alcalină

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ABSTRACT
The construction industry's continuous quest for sustainable practices has led to the exploration of alternative construction materials that minimizeenvironmental impact while maintaining structural integrity. Aggregate constitutes the major part of any concrete construction. Conventional aggregates are obtained directly from nature. The major problem associated with conventional aggregates is the depletion of resources. The project work describes the utilization of industrial slag which is dumped as landfill. Slag, a by-productof various industrial processes, have emerged as promising candidates for use as construction aggregates in concrete. This study explores the feasibility of replacing traditional coarseaggregates with slag. This project aims to investigate the performance and feasibility of incorporating different types of slags, including Copper Slag (CS), and Steel Slag (GGBS), as raw material and alkaline solution as binding material in the manufacture of coarse aggregate. Through laboratory testing, mechanical properties analysis, and environmental assessments, the study seeks to provide valuable insights into the development of eco-friendly and high-performance coarse aggregate for the production of concrete. The results of the manufactured aggregate shows that the properties tested are nearer to the aggregate properties suggested by Indian standards (IS 456- 2000, IS 383, and IS 9103-1999). The study also focuses on the effect of curing temperature to enhance the properties of the manufactured aggregates in the Phase-II of the project.

Keywords: Conventional Aggregate, Copper slag, Ground granulated blast furnace slag (GGBS), Geopolymer, Pelletization

1. INTRODUCTION

The construction industry's continuous quest for sustainable practices has led to the exploration of alternative construction materials that minimize environmental impact while maintaining structuralintegrity. Aggregate constitutes the major part of any

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concrete construction. They include fine aggregates which passes through IS 4.75mm sieve,coarse aggregates which retain on IS 4.75mm sieveand 'all in aggregates 'which constitutes all of the major fractions. Conventional aggregates are obtained directly from nature. The major problem associated with conventional aggregates is the depletion of resources. The harm caused to the environment is tremendous. So, the requirement of proper substitution for conventional aggregate is a matter of immediate importance. Slags, a byproduct of various industrial processes, have emerged as promising candidates for use as construction aggregates in concrete. The utilizationof industrial byproducts as raw materials for coarseaggregates aligns with the principles of the circular economy, turning waste into a valuable resource. This approach not only reduces the environmental impact of aggregate production but also minimizesthe need for extensive quarrying, therebyconserving natural resources and mitigating habitatdisruption. This introduction sets the stage for an exploration of the various industrial byproducts, production processes, engineering properties, and environmental implications associated with the innovative endeavor to create sustainable coarse aggregates. This study explores the feasibility of replacing traditional coarse aggregates with slag. This project aims to investigate the performance and feasibility of incorporating different types of slags, including Copper Slag (CS), and Steel Slag (GGBS), as raw materials in the manufacture of coarse aggregate. This progressive initiative seeks to address environmental concerns associated with traditional aggregate extraction while simultaneously offering a valuable solution for managing industrial waste.

2. OBJECTIVE

- To Prepare Light Weight Aggregate Using alkaline solution as binding material
- To vary the molarity and curing temperature from 50°C to 70°C and studying the properties as per Indian standards
- To study the mechanical properties of concretemanufactured using artificial aggregate
- To study the durability properties (Sulphateattack) of concrete manufactured usingartificial aggregate

3. SCOPE

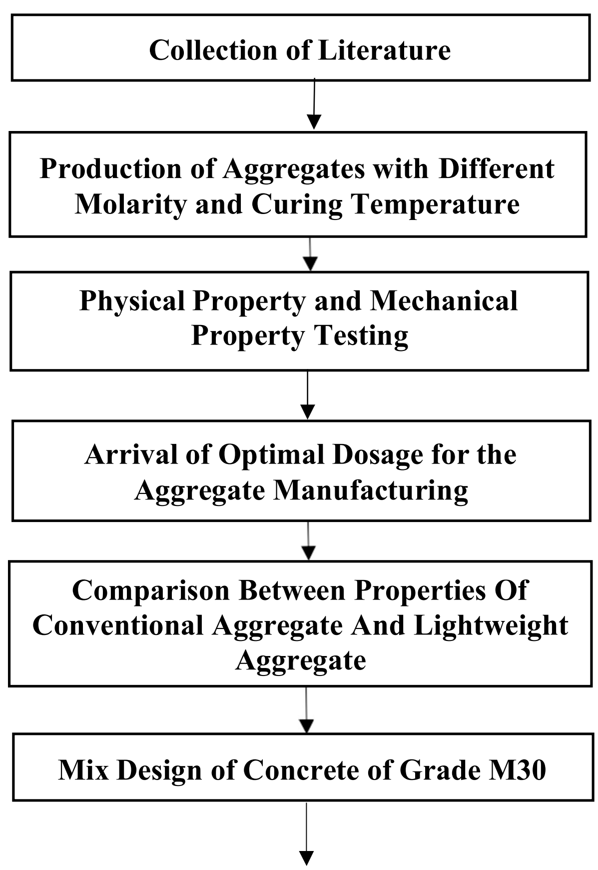
- The scope of this project involves reducing theenvironmental impact due to traditional aggregate extraction.
- The scope involves creating awareness and fostering market acceptance of sustainable coarse aggregates.
- The scope extends to fostering innovation and collaboration across industries.
- Researchers, engineers, and stakeholders collaborate to optimize production processes, develop new technologies, and share best practices, contributing to the continuous improvement of sustainable aggregate production.

- The project considers the market feasibility of sustainable coarse aggregates. This involves evaluating the economic viability, cost- effectiveness, and market acceptance of these alternative materials. Stakeholder engagement and communication strategies are essential components to promote awareness and acceptance within the construction industry.

4. SIGNIFICANCE

- **Waste management**: Utilization of the industrial slag which are dumped as landfill
- **Lower carbon emission:** Method of production of aggregate reduces greenhousegas emission
- **Sustainability:** Substitution of natural aggregate with LWA manufactured from wastematerials to reduce the dependency on nonrenewable resource usage.
- **Cost effectiveness:** The project considers the market feasibility of sustainable coarse aggregates. This involves evaluating the economic viability, cost-effectiveness, andmarket acceptance of these alternative materials.

5. METHODOLOGY



Testing for Mechanical and Durability of Properties of Concrete

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Report

6. MATERIALS

6.1 SLAG

6.1.1 Copper Slag

Copper slag is a byproduct of the copper smelting process, composed mainly of iron, silica, and otherminerals. It can be recycled to recover valuable metals like copper and iron, and is often used as a partial replacement for sand in concrete or as agranular material in road construction due to its density and strength. While it offers economic and environmental benefits by reducing waste and promoting recycling, proper management is essential to mitigate potential risks associated withheavy metal leaching. Its abrasive nature also makes it suitable for sandblasting applications.

COMPONENT	PERCENTAGE (%)
SiO2	35 to 45
Fe	30 to 40
CaO	8 to 16
Al_2O_3	5 to 15
MgO	1 to 6
S	1 to 5
Cu	less than 1

Advantages And Applications

Copper slag is a valuable resource in construction, reducing waste and environmental impact. It enhances concrete and asphalt's strength and durability, making it ideal for sandblasting and surface preparation. It's also used in land reclamation, glass manufacturing, soil stabilization, and cement production, contributing to sustainability and resource efficiency.

6.1.2 Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of the iron and steel manufacturing process, created by rapidly cooling molten slag from a blast furnace. This results in a glassy, granulated material that is then finely ground into a powder. GGBS offers numerous benefits, including high resistance to chemical attack, low permeability, and enhanced durability, making it anexcellent alternative to traditional Portland cement in concrete mixes. By partially replacing cement with GGBS, construction projects can significantly reduce their carbon footprint, as GGBS production generally emits fewer greenhouse gases. It is widely used in various applications, including ready-mix concrete and precast products, particularly in environments requiring increased durability, such as marine structures. Overall, GGBS promotes sustainability in construction while improving the performance of concrete.

COMPONENT	PERCENTAGE (%)
SiO2	35 to 45
CaO	35 to 45
Al_2O_3	10 to 15
MgO	5 to 15

Application and Advantages

The use of GGBS not only provides a sustainable approach to managing industrial by-products but also contributes to the advancement of environmentally friendly construction materials with high performance. GGBS demonstrates pozzolanic properties, allowing it to react withcalcium hydroxide in the presence of water to create additional cementitious compounds.

Incorporating GGBS into concrete reduces the reliance on energy-intensive Portland cement production, thereby contributing to a decrease in carbon dioxide emissions associated with cement manufacturing. Additionally, the utilization of GGBS offers an environmentally friendly solutionfor handling blast furnace slag, transforming an industrial by-product into a valuable construction material. This reduces the problem of pollution caused by dumping slag in landfills. GGBS is a versatile and sustainable material with valuable properties that enhance the performance of concrete and other construction materials. Its adoption contributes to both environmentalsustainability and efficient use of industrial byproducts in the construction industry.

6.2 ALKALINE SOLUTIONS

6.2.1 Sodium Hydroxide Solution

Sodium hydroxide (NaOH) solution is a colorless, odorless, and highly alkaline liquid that is more dense than water. A colorless liquid that is more dense than water. A strong base that feels slippery and has a high pH. Used in many products, including soaps, drain cleaners, and cement mixes.Can cause severe burns to the skin and serious tissue damage if it gets into the eyes or is inhaled. Should be stored in a cool, dry, well-ventilated location separate from organic and oxidizing materials, acids, and metal powders.

6.2.2 Sodium Silicate Solution

Sodium silicate solution, also known as water glass, is a colorless, transparent, and non- flammable aqueous solution of sodium silicate.

Composition

Sodium silicate is a chemical compound with the formula NaSiO, and its chemical formula varies depending on the ratio of sodium oxide (Na2O) and silicon dioxide (SiO2).

Uses

Used in adhesives for bonding paper, glass, porcelain, leather, textiles, and stoneware. Used in refractory cements and construction. Used in food and beverage processing. Injected into the soil to stabilize it and increase its strength and stiffness. Sodium silicate solution is a strong irritant to skin,eyes, and mucous membranes. It may be toxic by ingestion. When handling sodium silicate solution, you should wear protective gloves, clothing, eye protection, face protection, and hearing protection.Store sodium silicate solution locked up at +15°C to +25°C.

7. TRIAL MIX DESIGN

- 3 coarse aggregate mixes were made with different Molarities were prepared.

S.No	MIX	MOLARITY	ALKALINE\ ASH RATIO
1	MIX 1	8 M	2.5 : 1
2	MIX 2	10M	2.5 : 1
3	MIX 3	12 M	2.5 : 1

7.4 PREPARATION OF COARSEAGGREGATE

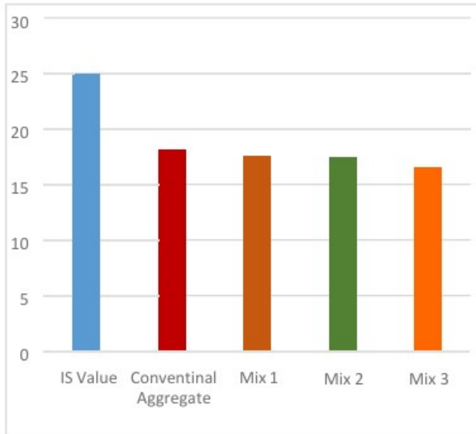
- Pelletization is a process that turns material fines into pellets or granules to make themeasier to handle.
- It's used in many industries to process materials that are difficult to handle, such as powders and fines. In the context of aggregates, pelletization is used to create artificial lightweight aggregates.
- GGBS and Copper Slag serves as primary materials with copper slag adding density and GGBS contributing to the binding properties
- For the production of coarse aggregate initiallythese materials dry mixed in the pelletizer machine for 5 to 10 minutes.
- The speed and angle of the pelletizer can be changed accordingly.
- In that dry mix geopolymer solution (NaoH + Na2sio3) is added in the pelletizer gradually while the pelletizer is still rotating for the formation of pellets.
- The production of our lightweight aggregate is carried out in a disc pelletizer.
- These aggregates are produced in a disc type pelletizer machine which has 100mm depth and 500mm diameter with speed and angle variation from 1 to 65rpm and 0-90° respectively.
- After 45 to 55 minutes the formed pellets are carefully collected and spreaded in a sheet at room temperature 25° C and left to dry for 12 hours.
- These aggregates are then heated / immersed inwater.
- Then all the physical and mechanical tests are carried out for the prepared aggregates.

8. TESTING OF AGGREGATES

8.1 FLAKINESS INDEX TEST

- The Flakiness index test was conducted andthe following observations were noted.

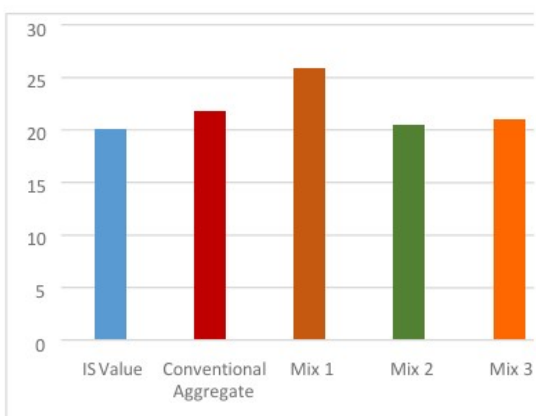
S.NO	MIX	FLAKINESS INDEX
1	MIX 1	17.5
2	MIX 2	17.4
3	MIX 3	16.5
4	CONVENTIONAL AGGREGATE	18.1



8.2 ELONGATION INDEX TEST

- The Elongation Index test was conducted andthe following observations were noted.

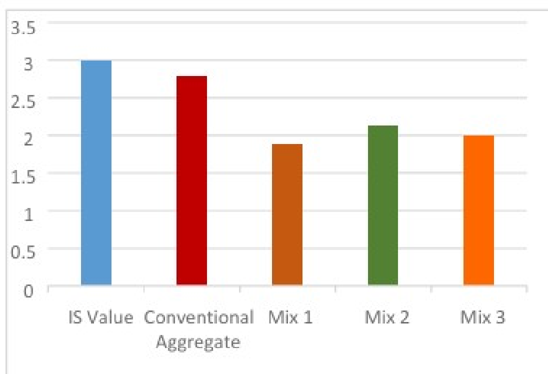
S.NO	MIX	ELONGATION INDEX
1	MIX 1	25.8
2	MIX 2	20.4
3	MIX 3	20.9
4	CONVENTIONAL AGGREGATE	21.81



8.3 SPECIFIC GRAVITY TEST

 The Specific Gravity test was conducted andthe following observations were noted.

S.NO	MIX	SPECIFIC GRAVITY
1	MIX 1	2.26
2	MIX 2	2.51
3	MIX 3	1.73
4	CONVENTIONAL AGGREGATE	2.8



8.4 WATER ABSORPTION TEST

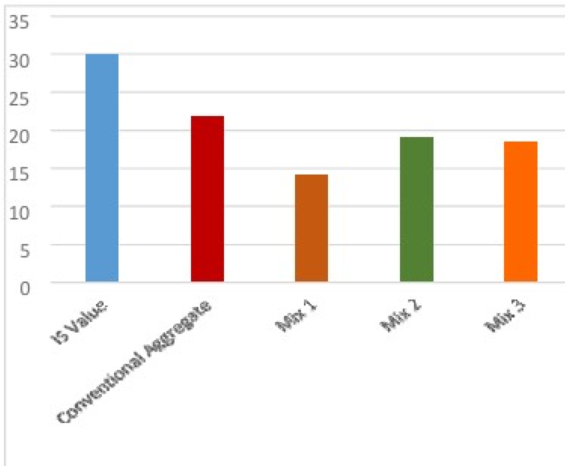
 The test was conducted and the following observations were noted.

S.NO	MIX	WATER ABSORPTION
1	MIX 1(8M mix)	9.1
2	MIX 2(10M mix)	8.8
3	MIX 3(12M mix)	8.4
4	CONVENTIONAL AGGREGATE	5.58

This makes them suitable for high-strength lightweight concrete applications, particularly where weight reduction is critical without compromising strength (e.g., high-rise buildings orlong-span bridges). However, lightweight aggregates may not always have the same load- bearing capacity as conventional aggregates in specific structural contexts.

8.5 CRUSHING TEST

S.NO	MIX	CRUSHING VALUE
1	MIX 1(8M mix)	**14.2**
2	MIX 2(10M mix)	**19**
3	MIX 3(12M mix)	**18.46**



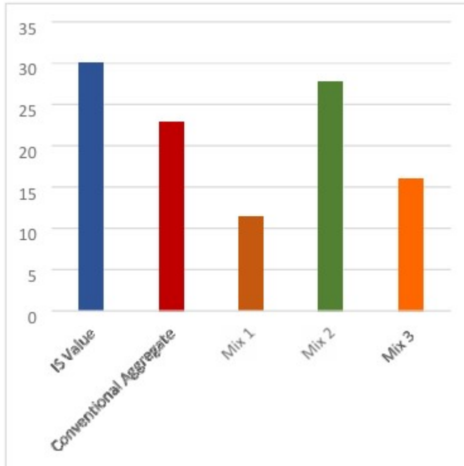
The crushing value is an important property of aggregates, representing their resistance to crushing under a gradually applied compressive load. It helps assess the quality and suitability of aggregates for use in construction, especially in high-load-bearing applications. Comparison ofCrushing Value for Conventional and Lightweight Aggregates. Conventional Coarse Aggregatetypically consists of materials like crushed granite,basalt, or natural gravel.

Crushing values generally range between 20% and 30% for good quality aggregates used in road construction, as specified by IS 383:2016. Lower crushing values (e.g., below 20%) indicate higher strength and better suitability for construction.

Lightweight aggregates with crushing values between 14% and 19% have higher resistance to crushing than many conventional coarseaggregates.

8.6 IMPACT TEST

S.NO	MIX	IMPACT VALUE
1	MIX 1(8M mix)	**11.4**
2	MIX 2(10M mix)	**27.8**
3	MIX 3(12M mix)	**16**



The impact value of an aggregate is a measure of its toughness and ability to resist impact forces, which is critical for determining its suitability in road construction and other load-bearing applications. Comparing the impact value of conventional coarse aggregates (like natural stones or crushed rocks) with lightweight aggregates Typical impact values: usually range from 10 to 30%. Conventional Aggregates: Typically higher values (e.g., 25- 30%) indicate good toughness for heavy-duty applications.

Lightweight Aggregates (9–11%): Lower values indicate higher resistance to impact, which is surprising for lightweight materials.

Lower impact values in lightweight aggregates could be attributed to uniform pore distribution andstrong bonding in geopolymer aggregates.

Discussion need to be made whether low impact values make lightweight aggregates suitable for specific applications (e.g., non-load-bearing structures, lightweight concretes, or precast panels). The use of lightweight aggregates with low impact values can reduce structural dead load while maintaining adequate durability.

Potential challenges in high-impact zones or heavily loaded pavements.

Lightweight aggregates with impact values of 9–11 are comparable or better than many conventional aggregates.

Study need to be done on relationship between impact value and other properties, such as compressive strength, durability, and density.

This comparison could emphasize that lightweightaggregates, especially those geopolymer-based, are not just alternatives but potential upgrades for specific applications. Their low impact values, while seemingly advantageous, need to be studied further to ensure they meet all practicalrequirements in construction.

9. SUMMARY AND CONCLUSION

In this study material properties such as flakiness index, elongation index, specific gravity, water absorption value, crushing value, impact value was found with tests as per the IS 2386:1963. The materials used in this project are copper slag, ground granulated blast furnace slag, Geopolymer. Three Coarse aggregate mixes with copper slag, ground granulated blast furnace slag, and different Molarities (8M, 10 M, 12M) of geopolymer solutions were prepared. The dry materials were weighed separately and mixed together in the pelletizer equipment. The coarse aggregate mixes were prepared with GGBS (80%), copper slag (20%). The procedures for the tests were studied carefully and the tests were conducted for both conventional aggregates and three mixes with different Molarities of geopolymer. Test were conducted for manufactured aggregates prepared using different proportions of alkaline Solution such as 8M, 10M and 12M. The 8M Mix is observed to provide better impact and crushing strength compared to 10M and 12M mixes. The tests conducted were flakiness index test, elongation index test, specific gravity test, water absorption test, crushing value test, and impact value test. The results of tests were then comparedwith Indian standard as per IS 2386:1963. It is observed that the alkali aggregate irrespective of molarity satisfies the Indian Standards specification. The aggregate will be test for the influence of different curing temperature and the properties of concrete will be tested in the phase IIof the project.

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