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Analysis of Concrete by Using Silico Manganese Slag as a Partial Replacement of Fine and Coarse Aggregate

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ABSTRACT

Presently in India, due to limited modes of practices of utilization, huge amount of iron and Silico manganese slag dumped in yards of each production unit and engaging of important agricultural land and grave pollution to whole environment. This review presents utilization trends of Silico manganese slag and possible potentials for large-scale employment of Silico manganese slag in Indian context. This project aim is to study experimental investigation about the effect of partial replacement of coarse aggregates by Silico manganese slag (SMS), on the 0%, 5%, 10%, 15% & 20% strength and durability properties of concrete, by using the mix design of M30 grade. The optimum percentage of replacement of coarse aggregate by Silico manganese slag is found. This study is carried out to determine the feasibility of using Silico manganese slag as partial replacement for coarse aggregates of M30 grade with different replacement percentages i.e. (0%, 5%, 10%, 15%&20%). In this present study, physical and chemical characteristics of Silico manganese slag are to be analysed and then the research progress of Silico manganese slag with natural aggregate concrete cubes are to be casted by using mix design M30 and are cured for 7 days & 28 days. The mechanical properties of hardened concrete were to be carried out according to IS codes. For mechanical properties of concrete (i.e., Destructive Testing Compressive strength, & Non-Destructive Testing - Rebound hammer) are to be determined and investigated. By comparing the test results, it may be concluded that Silico manganese slag may be used as partial replacement of natural coarse aggregate in concrete.

Keywords : Manganese Slag, Concrete, Compressive strength, Rebound hammer, Compaction factor and Slump cone test.

I. INTRODUCTION

In construction work, there is a high demand for concrete, which is a homogeneous material formed by mixing Cement, Sand, and Aggregate in the presence of water. Cement serves as the binder material, while sand acts as a filler material, occupying the voids between the aggregate. Aggregate, which constitutes more than 70-80% of the total volume in concrete, provides strength to the structure.

The production of aggregate involves crushing stones in stone quarries, which requires significant manpower and mechanical equipment. However, this process generates small dust particles with low density that easily mix with air, leading to adverse environmental impacts and health hazards for workers on-site.

In India, the current practices of utilization result in the accumulation of large amounts of iron and steel slag in production yards, occupying valuable agricultural land and causing grave pollution to the environment. To address these challenges, an alternative solution is to replace the aggregate with silico manganese slag.

Silico manganese slag is a byproduct generated during the production of SiMn alloy, with approximately 1.2 to 1.4 tons of slag generated per ton of alloy produced. By utilizing this abundant source of silico manganese slag, it is possible to create silico manganese slag concrete, which consists of cement, sand, aggregate, and sieved silico manganese slag aggregate.

In this type of concrete, the crushed stone aggregate is partially or fully replaced with silico manganese slag, offering a means to utilize environmental sources and protect the environment. The main objective is to achieve the desired strength by experimenting with different percentages of silico manganese slag in the concrete mixture.

II. LITERATURE REVIEW

Abdulazeez Rotimi (2023), According to existing literature, cement is recognized as the key component in concrete, serving as a binding material. However, it has also been identified as the second-largest industrial source of CO_2 emissions worldwide. This has spurred global efforts to find environmentally friendly alternatives to replace cement and protect the environment partially or fully. To address this concern, an experimental investigation was conducted in this study to assess the compressive and flexural strength of concrete when cement was partially substituted with Ground Granulated Blast Furnace Slag (GGBS). Concrete specimens were prepared with varying percentages of cement replacement, including 0%, 5%, 10%, 20%, 30%, and 40% with steel slag. These specimens were then subjected to analysis. The tests were conducted after 7 and 28 days of curing. The results of this study indicate that at 28 days, there was a decrease of 14% in compressive strength and 10.5% in flexural strength for specimens with 10% cement replacement compared to the control specimens. For specimens with 20% cement replacement, the decrease in compressive and flexural strength was 25.5% and 31% respectively. Nevertheless, it was observed that steel slag has the potential to partially replace cement, particularly when it is crushed into smaller particles that pass-through BS sieve #200.

S. Ganesh, et al. (2018), In this study, the effect of replacement of coarse aggregate by silico manganese slag on mechanical properties and durability properties of concrete was examined. In this study, the mix design considered is M30 grade of concrete. The natural coarse aggregate was replaced by silico manganese slag at different levels: 0%, 25%, 50%, 75%, and 100%. The mixes were designated as SMS 25, SMS 50, SMS 75, and SMS 100 for the respective replacement levels. Additionally, the effect of Fibers on the compressive strength of concrete was investigated. At a 50% replacement level of coarse aggregate with silico manganese slag, the study found that the optimum strength was obtained. Concrete with the replacement of coarse aggregate by silico manganese slag (SMS 50) exhibited similar mechanical properties, including compressive, split tensile, and flexural strength, compared to conventional concrete. Moreover, when the (SMS 50) mix was immersed in acids and alkalinity, it showed very low weight and strength loss, in contrast to the control concrete mix. Furthermore, the addition of Fibers to concrete containing coarse aggregate with steel slag improved their mechanical properties.

V. Subathra Devia, et al. (2014), The investigated effect of partial replacement of coarse and fine aggregates by steel slag (SS) on the various strength and durability properties of concrete, using the mix design of M20 grade, the optimum percentage of replacement of fine and coarse aggregate by steel slag was found. Gradually, as the percentage of replacement increases, the workability of concrete decreases, which is determined using the slump test. Compressive strength, tensile strength, flexural strength, and durability tests such as acid resistance using HCL, H2SO4, and rapid chloride penetration are experimentally investigated. For conventional concrete, the results indicate that the compressive, tensile, and flexural strength improves with the partial replacement of fine and coarse aggregates by steel slag. For both replacements, the deflection in the RCC beams gradually increases as the load on the beam increases, while the mass loss in cubes after immersion in acids is found to be very low. Based on the limits given in ASTM C 1202, the degree of chloride ion penetrability is assessed. The viability of using SS in concrete is established.

Liang Duoqiang, et al. (2011), Manganese slag can be incompletely substituted to cement concrete to lower profitable cost and achieve enhanced mechanical performances. The cement concrete added lower than 30 by manganese slag was not changed significantly, while the ordinary Portland cement added lower than 30 by manganese slag was bettered in mechanical performances.

III. OBJECTIVE

The workability of concrete has been checked with partial replacement of manganese slag as fine aggregate and coarse aggregate.

1. To review the compressive strength of concrete (Destructive test) with partial replacement of course and fine aggregate with manganese metal slag and its powder.
2. To review the compressive strength of concrete (NDT – Rebound hammer test) with partial replacement of course and fine aggregate with manganese metal slag and its powder.
3. To get the optimum percentage of manganese slag and granular slag to induce desired workability.
4. To check results of non-conventional concrete to the traditional concrete
5. To check the relation between 1 day density and compressive strength of concrete.
6. To check the relation between silico manganese slag replacement percentages in concrete mix and the compressive strength by destructive and non-destructive methods.

IV. MATERIAL & METHODOLOGY

Cement: Ordinary Portland cement is the most popular kind of cement used as a basic component in concrete, mortar, plaster, and most specialized grouts throughout the globe. Physical criteria were met by testing the cement in accordance with IS: 8112-1989, and chemical requirements were met by testing it in accordance with IS: 4032-1988.

Fine Aggregate: Sand is a finely split rocky material and mineral particles that make up a natural granular substance. The aggregate exclusively passing 4.75mm sieve and retained on 75 microns sieve is selected. The aggregates were tested for their physical requirements such as fineness modulus, specific gravity and bulk density in accordance with IS: 383-2016.

Coarse Aggregate: Crushed aggregates of less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10mm sieve is selected. The aggregates were tested for their physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 383-2016.

Fig 1: Coarse aggregate, Fine aggregate, and Silicomanganese Slag.

Silico Manganese Slag: SiMn Slag was collected from the Bharveli moil. The SiMn Slag was crushed into small pieces by manually and by using crusher. The required size of SiMn Slag aggregate was separated to use them as partial replacement to the natural fine and coarse aggregate. The SiMn Slag which is lesser than 4.75 mm size was neglected. The crushed SiMn Slag aggregate passing through 16.5mm and 12.5mm sieve and retained on 12.5mm and 10mm sieve are used. SiMn Slag were partially replaced in place of fine and coarse aggregate by 5%, 10%, 15% and 20%.

WATER: Water plays a critical role as an essential ingredient in concrete due to its active participation in chemical reactions with cement.

Mix Proportioning of Concrete Ingredients: All-In aggregate grading for 20mm nominal size aggregate as the requirements given in BIS 383:2016 was used to fix the proportion of aggregate in concrete. Trial and error method was used to fix the proportion of 20mm nominal size aggregate, 10mm nominal size aggregate and natural sand in concrete based on their individual gradations. Based upon this all-in aggregate grading, percentage of 20mm nominal size aggregate, 10mm nominal size aggregate and natural sand was fixed, which was to be used in the calculation of quantities of coarse aggregate and fine aggregate at the time of mix design. IS code 10262:2009 is followed for Mix design of concrete.

Mixing of Ingredients: Hand mixing was done for the preparation and mixing of all concrete mixtures. A hand mixing is a manual process, which used to combine cement, coarse aggregate, fine aggregate, and water to form a homogenous mass. Both, coarse aggregate as well as fine aggregate, were in dry conditions. If the physical properties of the fine and coarse aggregate, such as specific gravity, water absorption, and bulk density, do not meet the required specifications, necessary water corrections may be applied before the mixing operation. These corrections ensure that the water content in the concrete mixture is adjusted appropriately to achieve the desired workability and consistency. All the ingredients, i.e., cement, coarse aggregate, fine aggregate, and water, were weighted with an accuracy of 1.0 gram. Hand mixing was started and firstly, coarse aggregate and fine aggregate were dry mixed thoroughly. After that, cement was added in the mix and it was mixed till a uniform mass was obtained. In the final stages, water was added to the concrete mixture with great care to prevent any loss of water during the mixing process. This careful addition of water helps to maintain the desired water-cement ratio and ensures that the concrete mixture retains its optimal workability and consistency. Preventing water loss during mixing is crucial as it can impact the overall quality and performance of the concrete. The hand mixing was done till we got a concrete mass with uniform colour and consistency. Care was taken during the whole operation to ensure the proper mixing of all ingredients. Workability of all concrete mixtures was checked immediately after the finishing of mixing operation.

Preparation and Casting of Samples: Steel moulds were used to cast all the concrete specimens. All the moulds were cleaned and oiled properly before the mixing of concrete ingredients. They were properly tightened to correct dimensions before casting operations. Care was taken to ensure that there must not be any gap left to prevent the leakage of slurry. Concrete specimens were compacted in two layers using vibrating table. After the casting operations, concrete specimens were left in the casting room for approximately 24 hours, after which they were de-moulded and placed in the curing tank. The specimens were casted to perform compressive strength: Cubical specimens of dimensions 150mm×150mm×150mm were casted for testing destructive and non-destructive compressive strength of concrete.

Mix Design M30:

Mix Designation	Cement (kg/m³)	w/c	Water Content (kg/m³)	Natural Sand (kg/m³)	Coarse Aggregate (20mm + 10mm) (kg/m³)	Silico manganese slag fine (kg/m³)	Silico manganese slag coarse (20mm + 10mm (kg/m³)
CM	430	0.46	211.64	592.74	1140.42	0	0
SMS5	430	0.46	211.22	563.10	1083.40	29.85	57.24
SMS10	430	0.46	210.14	506.79	975.06	56.71	108.75
SMS15	430	0.46	208.55	430.77	828.80	76.56	146.81
SMS20	430	0.46	206.63	344.62	663.04	86.77	166.38

V. RESULT & DISCUSSION

Slump Cone: Workability of all concrete mixes was evaluated as slump in mm as per IS:1199-1959. The slump cone value for CM, SMS5, SMS10, SMS15, and SMS20 are 80, 72, 68, 64, & 59. Which indicates that workability is medium as per IS 456:2000.

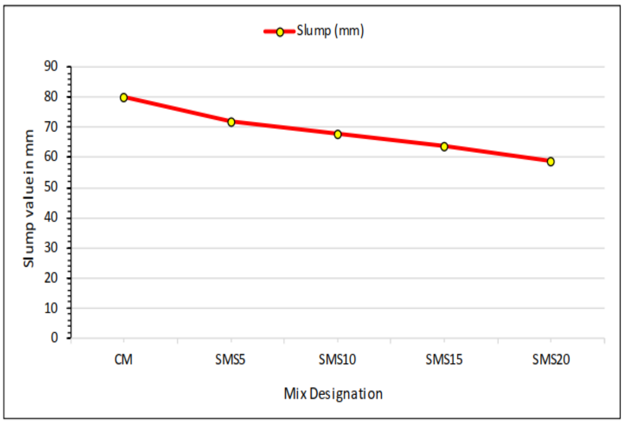

Fig 2: Slump cone graph of Mix design.

Compaction Factor: The method of using compacting factor apparatus for measuring workability of concrete is covered in IS:1199-1959, this code provides the standard procedure for determining the workability of concrete mix in India. Under the following procedure we get compaction factor value for CM, SMS5, SMS10, SMS15, and SMS20 are 0.95, 0.90, 0.89, 0.85, & 0.83. Which indicates that workability is medium as per IS 456:2000.

Density of Concrete: Density of concrete, based upon the 1-day weight of the cubes of 150mm×150mm×150mm at the time of de-molding after 24 hours of casting for CM, SMS5, SMS10, SMS15, and SMS20 are 2411.16, 2433.88, 2467.06, 2478.81, and 2512.10. The relationship between density of concrete mixes with increase in fine and coarse aggregate substitution level is not linear, but it follows cubic variation. The concrete mix that replaces 20% of fine and coarse aggregate has the highest density compared to all other concrete mixes. The control concrete has a density of 2411.16 kg/m3, while the concrete mix with 20% fine and coarse aggregate replacement has a density of 2512.10 kg/m3, representing a 4.2% increase in density.

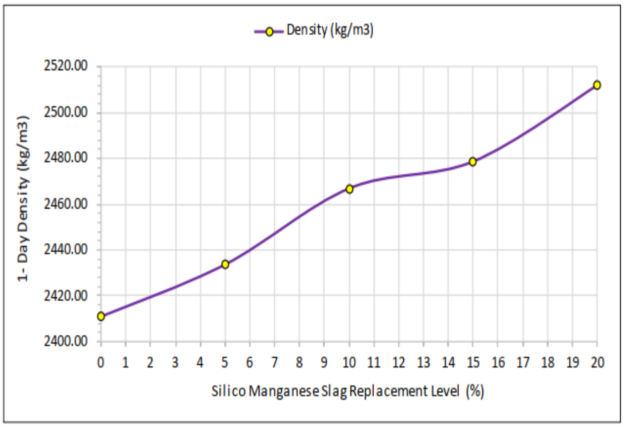

Fig 3: 1 Day-density graph of concrete cubes.

Compressive Strength Test: IS:10262-2009, Guidelines for concrete mix design proportioning [CED 2: Cement and Concrete], The results obtained from the CTM tests to determine the compressive strength. In the 7 days test, the compressive strength for CM, SMS5, SMS10, SMS15, and SMS20 are 29.77, 19.41, 16.08, 15.25, and 17.70, while over time these values increased in all the four SMS mixtures because of the desired curing time of 28 days. In the 28 days test, the compressive strength for CM, SMS5, SMS10, SMS15, and SMS20 are 36.13, 29.99, 23.85, 25.91, and 22.02. The findings revealed that as the replacement level of SMS for fine and coarse aggregate increased, the compressive strength of concrete decreased for all replacement levels. The percentage of strength reduction for SMS replacements at 7 days of 0%, 5%, 10%, 15%, and 20% were approximately 29.77%, 19.41%, 16.08%, 15.25%, and 17.70%, respectively, compared to the strength of the control mix. And at 28 days of 0%, 5%, 10%, 15%, and 20% were approximately 36.13%, 23.99%, 23.85%, 25.91%, and 22.09%, respectively, compared to the strength of the control mix.

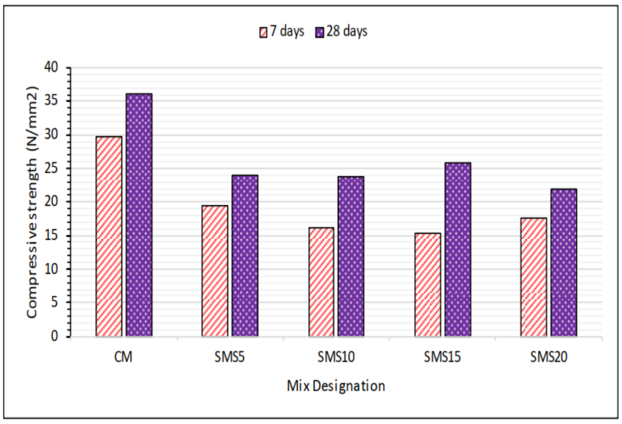

Fig 4: Compressive strength in 7 & 28 Days.

From regression analysis, we observe that compressive strength of concrete mixes decreases with increase to the density of concrete at all ages but generally it happens when the w/c ratio is more in concrete mix. Coefficient of determination, R^2, was calculated at each age and the value of R^2 for the linear variation between 1-day density of concrete and compressive strength of concrete comes out to be 0.5686, and 0.9559 at 7 days, & 28 days.

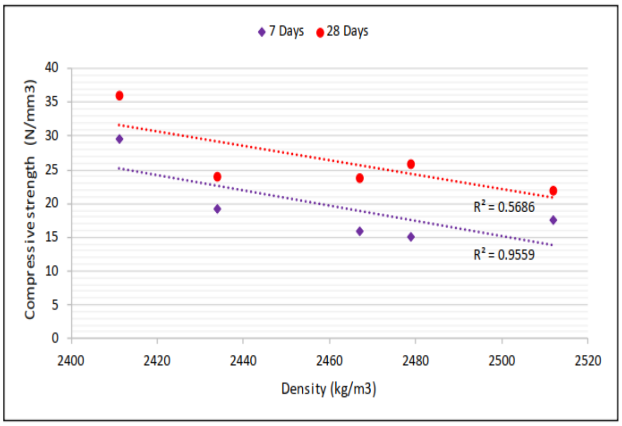

Fig 5: Regression graph between Compressive strength & 1 Day-density.

Rebound Hammer: IS: 13311 (Part 2) –1992, which is an Indian Standard- Methods for non-destructive testing of concrete-methods of test, Part 2: Rebound hammer. The results obtained from the rebound number tests to determine the compressive strength. The values obtained for the control mix at the age of 28 days the control had an approximate value of 36.13 N/mm^2 for simple compressive strength and 25 N/mm^2 for rebound number tests. In the 7 days test, the compressive strength for CM, SMS5, SMS10, SMS15, and SMS20 are 12.9, 11.6, 12.7, 14.1, and 13.2, while over time these values increased in all the four SMS mixtures because of the desired curing time of 28 days. In the 28 days test, the compressive strength for CM, SMS5, SMS10, SMS15, and SMS20 are 25, 12.7, 14.4, 16.3, and 14.5.

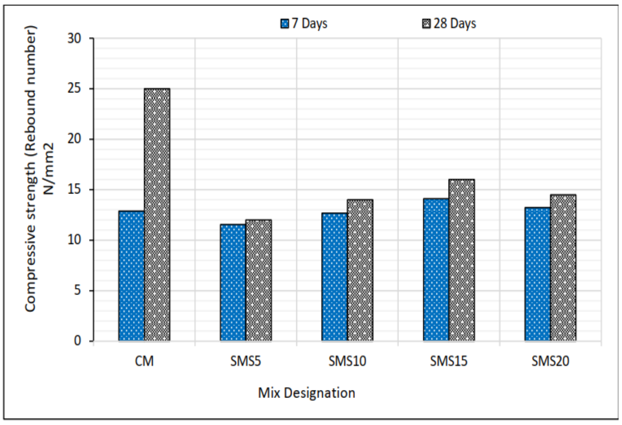

Fig 6: Rebound Hammer Compressive strength in 7 & 28 Days.

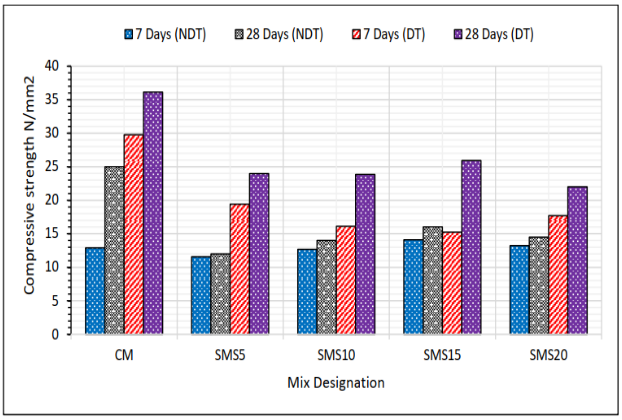

Fig 7: Compressive strength comparison between CTM & Rebound Hammer in 7 & 28 Days.

VI. CONCLUSION

The future scope of using silico manganese slag as a partial replacement of fine and coarse aggregate at different percentages (5%, 10%, 15%, and 20%) holds great promise and potential. As research in this area continues to advance, several key aspects are worth exploring:

- Improved Concrete Mix Design: Further research can focus on optimizing the concrete mix design with different percentages (e.g., 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100%) of silico manganese slag. The goal is to identify the ideal combinations that offer the best compromise between strength, workability, and durability while minimizing any negative effects on concrete performance.
- Performance under Specific Conditions: Investigating the performance of concrete containing silico manganese slag under various environmental conditions (e.g., high temperatures, aggressive chemical environments, and freeze-thaw cycles) is essential. Understanding how this partial replacement affects concrete properties in these scenarios will guide its usage in specific construction applications.
- Long-Term Durability Studies: Long-term durability studies are crucial to assess the aging and performance of concrete containing silico manganese slag. Evaluating the concrete's behaviour over extended periods will help ensure its stability and longevity, making it more viable for infrastructure projects.
- Strength Enhancement Techniques: Research can explore potential additives or treatments that can enhance the strength of concrete when using silico manganese slag as a partial replacement. These techniques could address any strength reduction issues associated with higher slag percentages.

- Sustainable Concrete Practices: The use of silico manganese slag aligns with sustainable concrete practices by reducing the consumption of natural aggregates and utilizing industrial by-products. As sustainability becomes a greater focus in the construction industry, further research and development in this area can lead to wider adoption.
- Standardization and Guidelines: As the use of silico manganese slag in concrete gains traction, there is a need for standardized testing procedures and guidelines to ensure consistency and reliability in concrete mixtures across different projects.

In conclusion, the partial replacement of fine and coarse aggregate with silico manganese slag at various percentages can have both positive and negative impacts on concrete properties. Engineers and researchers must carefully assess the specific requirements of their project, conduct extensive testing, and consider the factors mentioned above to determine the most suitable replacement percentage for optimal concrete performance and cost-effectiveness. Further research and field trials may be necessary to validate the findings and ensure the long-term durability of concrete containing silico manganese slag.

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