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Study of the Properties of Concrete by Using Manganese Ore Aggregate

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Abstract

Aggregate is one of the major ingredients of the concrete and the maximum part of strength of the concrete is governed by the aggregate. And thus, partial or total replacement of it can change the physical as well as the chemical properties of the concrete. Nowadays researchers are quite interested in obtaining the more durable and more resistant concrete to the diverse climatic conditions. In this research, aggregate is proportionately replaced with the manganese ore aggregate namely 0%, 25%, 50%, 75%, and 100% for M30 grade of concrete. The concrete having the density greater than 2800 kg/m^3 is term as the high-density concrete. The physical and mechanical properties like the impact test, specific gravity, water absorption, density, compressive strength, flexural strength, split tensile strength tests were done for the both 7- and 28-day cured concrete. When aggregates were fully replaced in the concrete mix with the manganese ore aggregate, a density of 2911 kg/m^3 was obtained from this experiment study. Similarly, based on the experimental tests carried on the conventional concrete, the high-density concrete has more compressive strength, flexural strength, and split tensile strength values.

Keywords: Manganese ore aggregate, high-density concrete, heavyweight concrete, physical and mechanical properties

INTRODUCTION

High-density concrete, also known as heavyweight concrete, has a density ranging from 2800 to 6400 kg/m^3. It is primarily used for radiation shielding, counterweights, and applications requiring high density. Heavyweight concrete is highly effective in shielding against harmful radiation such as X-rays, gamma rays, and neutrons due to its increased unit weight, typically over 2600 kg/m^3. This property enhances its radiation shielding capabilities, with performance improving as the concrete's unit weight increases. Past research has explored various aspects of heavyweight concretes, particularly how their mechanical and shielding properties are affected by different types of aggregates. High-density concrete can be achieved using materials such as barite, steel punches, hematite, steel aggregates, steel shots, and steel treatment waste [1–8].

Gaber [7] discovered that a certain ore could serve as a high-density aggregate for concrete used in coating petroleum pipelines, producing concrete with dry densities ranging from 2804 to 2967 kg/m^3. Ozen et al. [8] found that concrete containing iron ore exhibits significantly higher cylindrical compressive strength compared to other mixtures, and concrete made with a combination of iron ore and steel slag also shows enhanced compressive strength. Ouda [9] performed an experiment and concluded that the barite aggregate has higher specific gravity than magnetite, goethite, and

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serpentine aggregates he also concluded that the concrete made with magnetite fine aggregate showed higher physico-mechanical properties than the corresponding concrete containing barite and goethite. The shielding efficiency against gamma rays was also enhanced [9].

Zhao and colleagues [10] demonstrated that cathode ray tube funnel glass, which is typically considered hazardous, can be effectively treated, processed, and repurposed to produce high-density concrete.

OBJECTIVE

1. To study the behavior of manganese ore aggregate concrete.
2. To evaluate the mechanical properties, tests such as the compressive strength test, flexural strength test, and split-tensile strength test are conducted.

EXPERIMENTAL STUDIES

Materials

For preparing the high-density concrete mix, Ultratech ordinary Portland cement (OPC) 53 grade cement was used. Coarse aggregates and manganese aggregates of size 20 mm were used. Coarse aggregates were available from local quarry and natural sand were used. The manganese aggregates were obtained from Jabalpur, Madhya Pradesh and were used for this experimentation work. Normal aggregate having specific gravity of 2.74 and manganese aggregate having specific gravity of 3.83 were used (Figure 1) [11–13].

Mix Proportion

The concrete mix design for M30 grade was carried out according to Indian Standards specifications. The mix proportion for the 100% replacement of normal aggregate with manganese aggregate was found out to be 1:1.54:3.48. The quantity of materials used for the experiment is presented in Table 1.

Preparation of Specimens

Fresh Concrete Properties

A concrete is said to be fresh concrete in between the time when it is mixed and set. During this period the concrete is mixed, transported, placed and compacted. The properties of concrete in its fresh state are very important because it influence the quality of the hardened concrete (Table 2).

Preparations of Specimens and Curing Conditions

- Cubes of size 150 mm × 150 mm × 150 mm were used
- Beams of size 500 mm × 100 mm × 100 mm were used
- A cylinder of 150 mm diameter and 300 mm height was used.

The number of specimens used for finding out the properties of concrete is given in Table 3.

Figure 1. Manganese ore aggregate.

Table 1. Mix proportion of materials.

Materials	0% Replacement	25% Replacement	50% Replacement	75% Replacement	100% Replacement
Cement (in kg/Cum)	438	438	438	438	438
Water (in kg/Cum)	197	197	197	197	197
Fine aggregate (in kg/Cum)	676	676	676	676	676
Coarse aggregate (in kg/Cum)	1093	820	547	274	0
Manganese aggregate (in kg/Cum)	0	382	764	1146	1528
Water/cement ratio	0.45	0.45	0.45	0.45	0.45

Table 2. Fresh concrete property.

S.N.	Test	Parameter	Minimum Value to Be Obtained
01.	Slump cone test	Consistency	>75 mm according to IS 7320:1974
02.	Density	High-density concrete	>2800 kg/m^3

Table 3. Number of specimens prepared.

Tests	Proportion of Replaced Aggregate				
	Normal Concrete	*MN-25%*	*MN-50%*	*MN-75%*	*MN-100%*
Compressive strength					
7 days	3	3	3	3	3
28 days	3	3	3	3	3
Flexural strength					
7 days	3	3	3	3	3
28 days	3	3	3	3	3
Split tensile strength					
7 days	3	3	3	3	3
28 days	3	3	3	3	3
Total	12	12	12	12	12

TEST RESULTS

Compression Strength Test

The values of the compressive strength test of concrete at the end of the different curing period are presented in Table 4. This shows variations in the strength during the different curing period. From the experiment it is concluded that the 100% replacement of the aggregate results in the higher strength of concrete compared to the normal concrete or conventional concrete (Table 4 and Figure 2).

Density

It is necessary to evaluate the density of the normal concrete as well as the density of manganese aggregate to illustrate whether the replacement of the normal aggregate with the manganese ore aggregate helped to increase the density or not to term it as a high-density concrete. During the experimental analysis it was found out that the density of 100% replacement of aggregate leads to an increase in the density of concrete, that is, 2911 kg/m^3, which is greater than 2600 kg/m^3 (Table 5 and Figure 3).

Density of concrete = (Weight of concrete sample / volume of concrete) × 1000

Table 4. Compression strength test.

Sample Name	Normal Concrete	25% Replacement	50% Replacement	75% Replacement	100% Replacement
Compressive strength (N/mm^2) 7 days	17.54	17.13	18.29	25.38	32.11
Compressive strength (N/mm^2) 28 days	38.59	37.32	41.94	48.30	41.50

Table 5. Comparison of density of concrete.

Sample Name	Normal Concrete	25% Replacement	50% Replacement	75% Replacement	100% Replacement
Density comparison at 28 days	2553	2582	2686	2918	2911

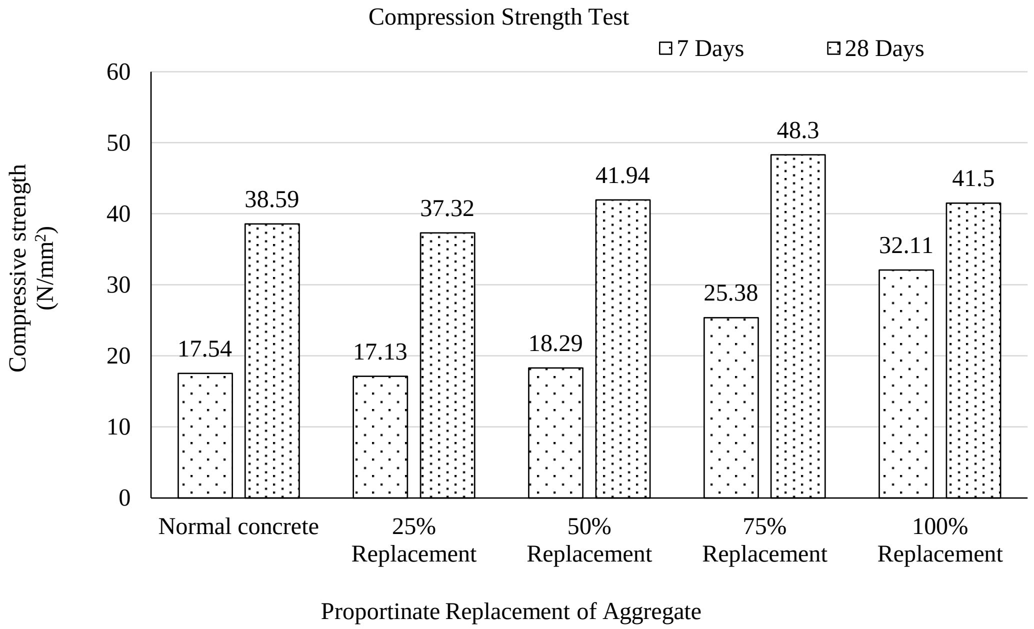

Figure 2. Compression strength test.

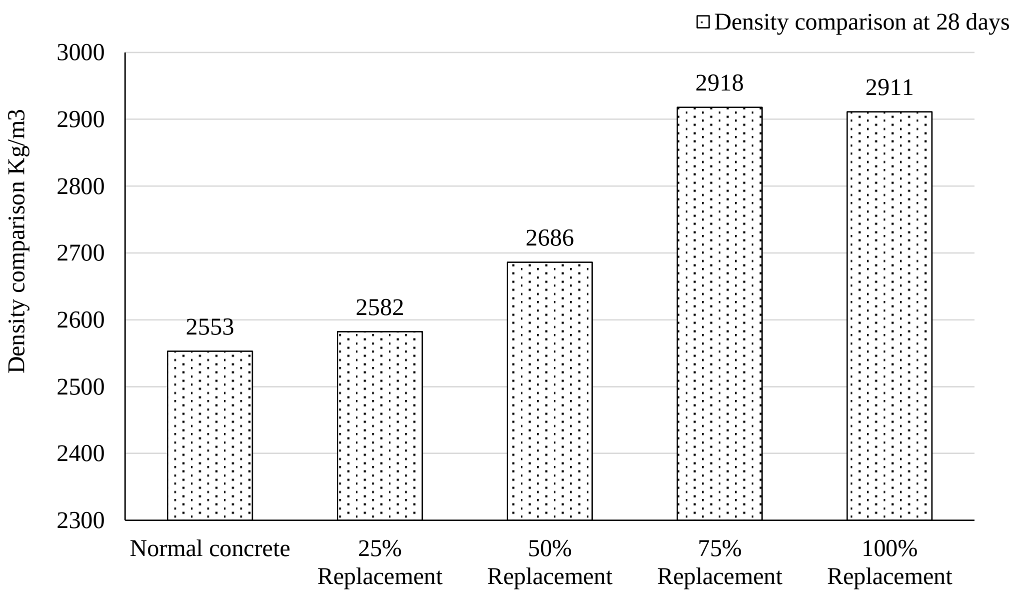

Figure 3. Density comparison at 28 days.

Flexural Strength Test

For this experimental test, beams of concrete of size 500 mm × 100 mm × 100 mm were cast for determining the strength for 7 days and 28 days curing. The beam was subjected to a two-point load to study the behavior (Table 6 and Figure 4).

Split Tensile Strength Test

This test was conducted by placing the cast cylinder of size 150 mm in diameter and 300 mm in length in the universal testing machine and the load was applied until the failure of cylinder along the vertical diameter and throughout the length and breaking the cylinder in two halves (Table 7 and Figure 5).

Table 6. Flexural strength test.

Sample Name	Normal Concrete	25% Replacement	50% Replacement	75% Replacement	100% Replacement
Flexural strength (N/mm^2) 7 days	4.401	4.618	5.213	5.145	5.718
Flexural strength (N/mm^2) 28 days	6.292	6.276	6.642	6.712	6.84

Table 7. Split tensile strength test.

Sample Name	Normal Concrete	25% Replacement	50% Replacement	75% Replacement	100% Replacement
Split tensile strength (N/mm^2) 7 days	2.077	2.185	2.166	2.470	2.583
Split tensile strength (N/mm^2) 28 days	2.986	3.068	3.250	3.687	3.438

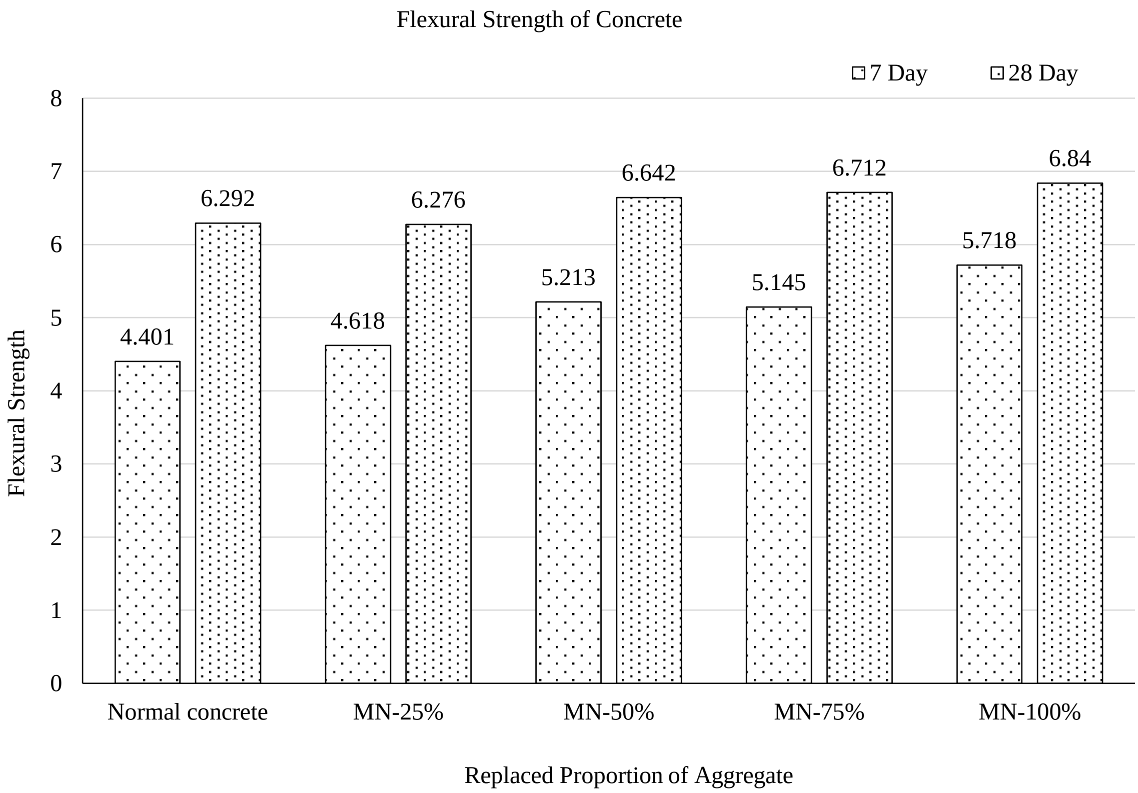

Figure 4. Flexural strength of concrete.

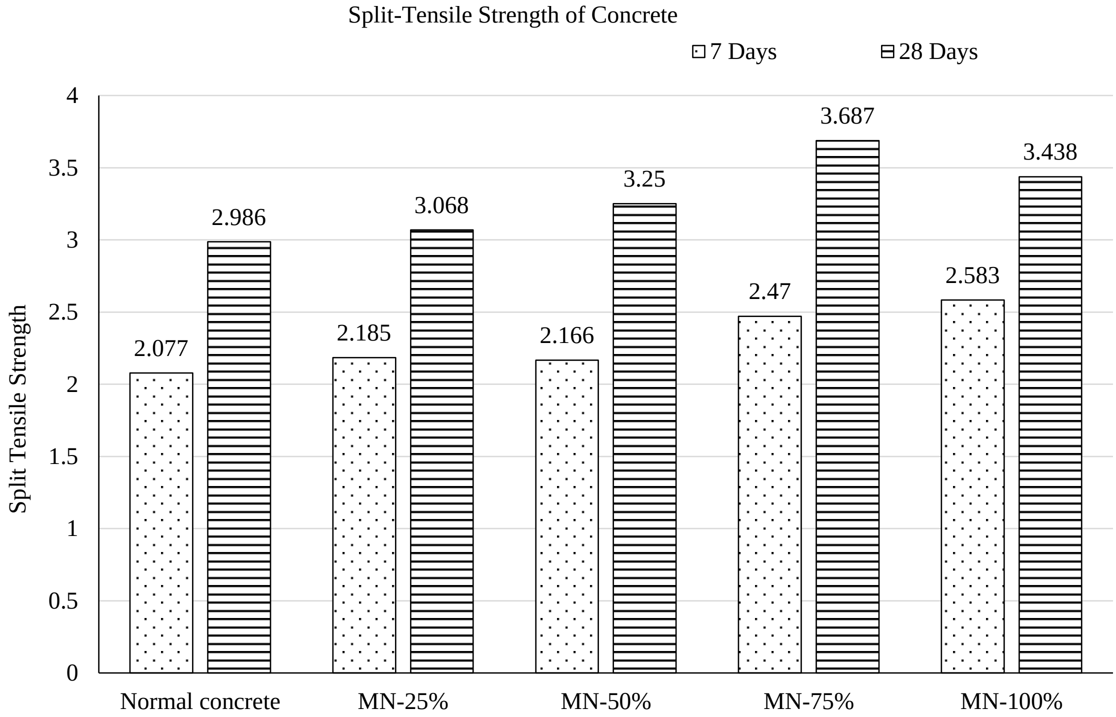

Figure 5. Split tensile strength of concrete.

CONCLUSION

The following conclusions were drawn from the experimental results:

1. Manganese aggregate has a high specific gravity, that is, 3.833.
2. High-density concrete was achieved by replacing 75% and 100% of coarse aggregate with high-density manganese aggregate. The 0% and 50% replacement samples did not satisfy the requirements for high-density concrete (i.e., <2800 kg/m^3).
3. Maximum density of 2911 kg/m^3 was obtained by 100% replacement sample for hardened concrete with 28 days of curing, which is well above normal concrete.
4. High-density concrete made with 75% replacement by manganese aggregate reaches the highest compressive strength values exceeding over M30 requirements at 28 days of curing and was followed by 100% replacement by manganese aggregate which also exceeded the M30 requirements at 28 days of curing.
5. Better results were obtained by the MN100% replacement concrete compared to normal concrete in flexural strength test as well as split tensile strength test.
6. The manganese ore proved to be a suitable high-density aggregate for high-density concrete and its applications.

High Specific Gravity of Manganese Aggregate

The manganese aggregate used in the experiments demonstrated a high specific gravity of 3.833, significantly contributing to the concrete's overall density.

Achievement of High-Density Concrete

Replacing 75% and 100% of the coarse aggregate with manganese aggregate resulted in high-density concrete. Samples with 0% and 50% replacement did not meet the high-density concrete criteria (i.e., density <2800 kg/m^3).

Maximum Density Achieved

A maximum density of 2911 kg/m^3 was recorded for the sample with 100% manganese aggregate replacement after 28 days of curing, indicating a significant increase over typical concrete density.

Superior Compressive Strength

Concrete with a 75% manganese aggregate replacement achieved exceptional compressive strength, surpassing M30 grade standards after 28 days of curing. The 100% replacement sample also surpassed M30 requirements, demonstrating the concrete's strength and durability.

Improved Mechanical Properties

The sample with 100% manganese aggregate replacement outperformed normal concrete in both flexural strength and split-tensile strength tests, indicating enhanced mechanical properties.

Effectiveness of Manganese Ore

Manganese ore proved to be an effective high-density aggregate for concrete, making it suitable for applications requiring enhanced density and mechanical properties.

Practical Applications

The success of manganese aggregate in high-density concrete suggests its potential use in various applications, such as radiation shielding, counterweights, and ballasts.

Environmental and Economic Benefits

Using manganese ore as an aggregate may provide environmental and economic advantages by reducing reliance on traditional aggregates and utilizing a material that might otherwise be discarded, promoting sustainable construction practices.

Long-Term Durability

High-density concrete with manganese aggregate is expected to exhibit superior long-term durability due to its enhanced mechanical properties and resistance to radiation, making it suitable for structures requiring extended service life and minimal maintenance.

In summary, the experimental results demonstrate that manganese aggregate is effective in producing high-density concrete with superior mechanical and durability properties, suitable for a wide range of specialized applications.

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