UTILISATION OF LD SLAG AS AGGREGATE IN CONSTRUCTION INDUSTRY

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ABSTRACT. This paper aims to study the mechanical behaviour of concrete after replacing the natural aggregates with Linz-Donawitz (LD) slag aggregates. Both the natural fine and coarse aggregates were replaced with LD slag aggregates up to 100% at an interval of 20%, respectively. The mechanical properties of the concrete incorporating LD slag in the mix has been compared with reference concrete for finding the suitability of LD slag as aggregates. Standard concrete specimenssuch as cube, cylinder and prism were cast, cured andtested on 28 days of maturity for their compressive strength, split tensile strength & flexural strength, respectively. Thetest results show that the concrete incorporating LD slag aggregates possess higher strength than that of the reference concrete. These findings indicate that the LD slag can be considered as a potential replacement material for natural aggregates in construction industry.

INTRODUCTION

The rapid increase in population of the world and improvement in the financial status of the people led to the demand for new and better housing facilities day by day. Similarly, the need for better services and recreational facilities along with demands for basic facilities such as schools, hospitals, sewage system and water supply etc. has also increased. This increase in demand has made the construction sector leading in terms of the total material consumed [1]. Concrete and steel are the two most used construction materials with a total production of more than 25 billion tons and 1.69 billion tonnes per year [2-3]. This leads to two of the biggest environmental problems faced by the researchers today. Increase in concrete production has resulted in excessive use of limited natural resources and huge amount of slag production during manufacture of steel. The steel slag disposal is a huge problem as it needs a large area of land and which can adversely influence the ecosystem of dumping zones too [4]. To cope with these problems, this study was done to check for the feasibility of using LD slag aggregates as a replacement material for natural aggregates in concrete.

As defined by ASTM, steel slag is a non-metallic product consisting primarily of calcium silicates and ferrites combined with fused oxides of iron, aluminium, manganese, calcium, and magnesium. It is a by-product of steel making produced during separation of the molten steel from impurities in steel-making furnaces. When a basic oxygen furnace (BOF) is used, 75 to 150 kg of steel slag is produced per metric ton of steel; with an electric arc furnace (EAF), 65 to 80 kg of steel slag is created per metric ton of steel [6].The Instant chilled steel slag possesses good physical and mechanical properties and is stable enough to be used as aggregate in concrete [7]. Samir I. Abu-Eishah et al. [8] studied the performance of concrete mixtures made with electric arc furnace (EAF) steel slag aggregate produced in the Arabian Gulf region and found out that the EAF steel slag produced high-strength concrete compared to similar conventional concrete mixtures. Perviz Ahmedzade & Burak Sengoz [9] observed that steel slag used as a coarse aggregate improve the mechanical properties of asphalt mixtures. Ibrahim M. Asi [10] concluded that replacing upto 75% of limestone coarse aggregate by SSA improved the mechanical properties of the asphalt concrete mixes. H. Beshr [11] compared the strength of concretes containing different types of coarse aggregate and concluded that steel slag aggregate concrete is stronger than that of crushed limestone aggregate concrete. The durability of slag concrete is acceptable, though slightly lower than that of conventional concrete. When the mix proportions are adequate, both the mechanical strength and the durability of slag concrete are satisfactory, although in less care mixes durability is likely to be impaired [12]. The durability characteristics of steel slag cement concretes were better than those of crushed limestone aggregate concrete [13]. Being one of the biggest manufacturers of steel in India, TATA Steel Ltd. produces approximately 1 million tonnes of steel slag every year [5].

MATERIAL PROPERTIES

Cement

In this study, Portland slag cement (PSC) of Lafarge brand Conforming to IS 455-1989 has been used as binder.

Table 1 Physical properties of Portland Slag Cement

S.No.	PARTICULAR OF TESTS		RESULTS
1	Consistency		31%
2	Fineness		4%
3	Specific gravity		2.95
4	Setting time	Initial	108 minutes
		Final	258 minutes
5	Soundness(by apparatus)	Le-Chatelier	1mm (expansion)
6	Compressive strength	3 days	17.8 N/mm^2
		7 days	24.85 N/mm^2
		28 days	36.75 N/mm^2

Natural Aggregates

Locally available sand (NFA) collected from River Kharkhai has been used in the research work. The natural coarse aggregate (NCA) used were non-flaky, non-elongated and angular in shape. Thelimestone aggregates passing through 20 mm sieve & retaining on 10 mm sieve and passing from 10 mm sieve & retaining on 4.75 mm sieve were graded in a ratio 70:30 before using in concrete.

LD slag aggregates

LD slag is the byproduct of steel industry which is produced when ladle furnaces are used during the production of steel. LD Slag used has been supplied by TATA Steel Ltd. Jamshedpur. The slag produced from the furnace is allowed to cool and then crushed into aggregates of required sizes. All the LD slag aggregates are weathered for at least 6 months before being used in concrete. The physical properties of the materials used in this work are shown in tables below. The LD Slag used was provided in two different sizes, LD coarse aggregate (LDCA) varying between 4.75mm to 20 mm and LD fine aggregate (LDFA) below 4.75mm in size. The LDCA provided were non-flaky, non-elongated and had a smooth surface texture.

Table 2 Physical properties of NFA and LDFA [18-19]

S. No.	PARTICULAR OF TESTS	NFA	LDFA
1	Fineness modulus	2.83, Zone –II	1.93, Zone-III
2	Specific gravity	2.59	2.73
3	Free moisture	0.20%	3.9 %
4	Water absorption	0.80%	6.5 %
5	Bulk density Compacted	1610 Kg/m^3	1920 Kg/m^3
	Loose	1560 Kg/m^3	1787 Kg/m^3
6	Bulking of sand	Maximum bulking of natural sand is 23.1 % at 3% moisture	Maximum bulking of LD Slag is 15.70 % at 10 %moisture

Table 3 Physical properties of NCA and LDCA

S. No.	PARTICULAR OF TESTS		NCA	LDCA
1	Fineness modulus		6.60	6.94
2	Specific gravity		2.83	2.92
3	Free moisture		0.10%	0.60 %
4	Water absorption		0.35%	0.85 %
5	Bulk Density	Compacted	1782 Kg/m^3	2109 Kg/m^3
		Loose	1606 Kg/m^3	1948 Kg/m^3
6	Crushing Strength		17.6 %	13.35%
7	Impact Value		16.4 %	13.06%

EXPERIMENTAL PROGRAM

Conventional concrete of grade M25 was designed, cast and tested on 28 days of maturity. The concrete mix was prepared to obtain a slump value of 60-100 mm. Concrete cubes of size 150 mm × 150 mm × 150 mm, cylinders of size 150 mm × 300 mm and prisms of size 100 mm × 100 mm × 500 mm were cast and cured under water at a temperature of (25±2)$^{\circ}$C and then tested for their compressive strength, split tensile strength and flexural strength respectively at the age of 28 days. The specimens were cast using normal fine and coarse aggregates as referral concrete and then replacing the fine and coarse aggregates with LD slag aggregates in specified intervals of various percentages. An average of 6 cube, cylinder and prism specimens were cast for each concrete mix and tested at its' maturity to get the testresults. A total of 216 cubes, 108 cylinders and 108 beams were cast, cured and tested to study the fundamental strength behaviour of LD slag aggregate concrete.

RESULT AND DISCUSSION

The concrete specimens were tested for their compressive, split-tensile and flexural strengths to study the variation in the fundamental behaviour of the concrete when natural aggregates are replaced by the LD slag aggregates. Also the workability of various concrete mixes were measured and compared in order to study the effect of LD slag aggregates on concrete in fresh state.

Workability

Workability is the most important parameter for any green concrete as it determines the ease with which the concrete can be poured, compacted and finished. In this study, the workability of the concrete was found out using slump cone test method. It was observed that the workability of the concrete mixes reduced significantly with the increase in LDFA in the concrete, this may be due to the increased surface area of LDFA which has more fine particles in it. Also, the water absorption of LDFA is much greater than that of NFA, which may influence the workability adversely. With the increase in LDCA content in concrete also, a slight decrease in workability of was observed. To keep the overall cost of concrete low, the LDCA was used directly without treating them physically, mechanically or chemically.

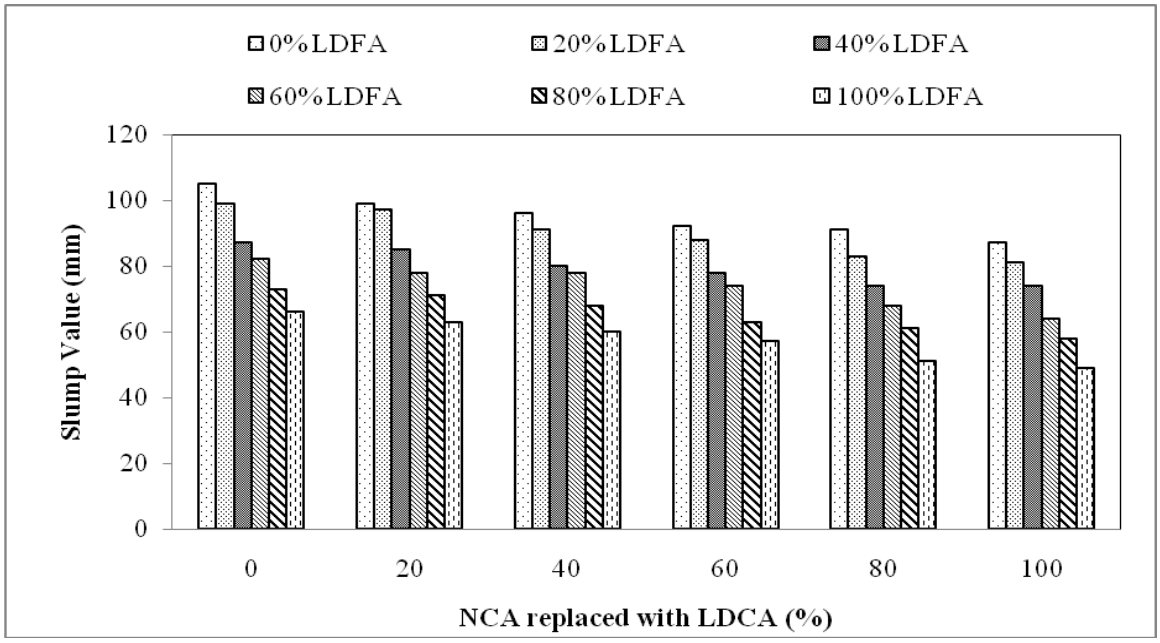

Figure 1 Workability vs aggregates replacement

Compressive Strength

The compressive strength is the most fundamental property of the concrete as itdecides the characteristic strength of concrete. Partial replacement of NFA & NCA with LDFA & LDCA has a positive impact on the compressive strength of the concrete. But when the NFA and NCA are fully replaced with LD slag aggregates, the compressive strength of the concrete reduced significantly. The increase in strength can be attributed to good physical and mechanical properties of LDFA & LDCA respectively.

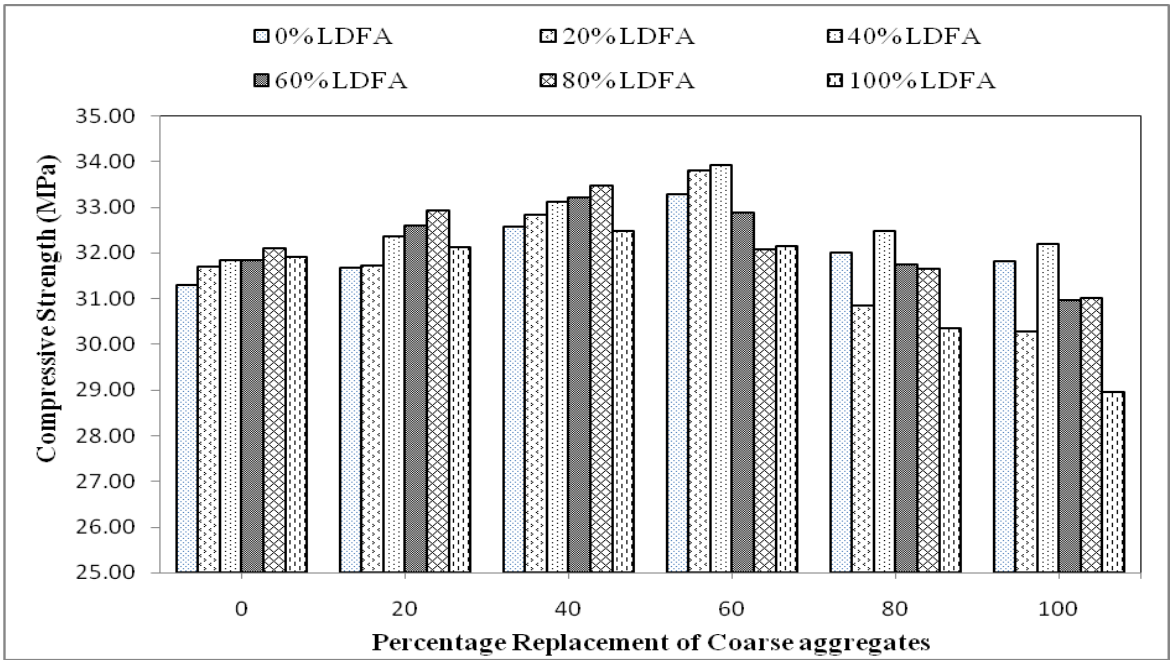

Figure 2 Compressive Strength vs aggregates replacement

Split tensile strength

The split tensile strength of concrete was carried out by indirect test method. The tensile strength corresponds to the strength of concrete in tension. As concrete is weak in tension, it is imperative to study the effect of LD slag aggregates on its' tensile strength. The test results indicate that the tensile strength of the concrete increases with the increase in slag content. Hence, it can be inferred that the partial replacement of natural aggregates with LD slag aggregates results in better tensile strength.

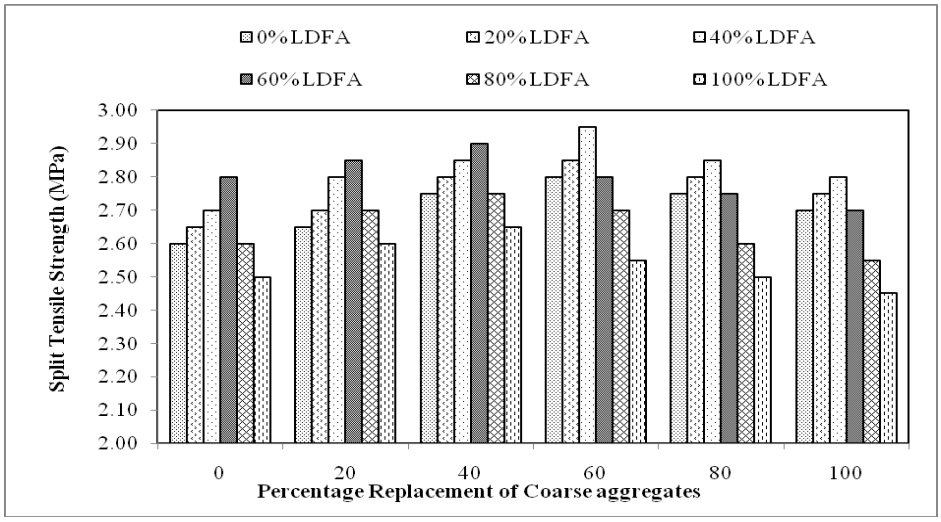

Figure 3 Split tensile strength vs aggregates replacement

Flexural strength

The flexural strength test of concrete was performed by two point load method. The results reveal almost the similar trend as in the case of compressive strength and split tensile strength tests. The flexural strength of the concrete was improved with increase in percentage replacement of NFA and NCA by LDFA and LDCA respectively. The flexural strength of concrete with 100% LD slag aggregates is much lower than that of the normal concrete containing 100% natural aggregate.

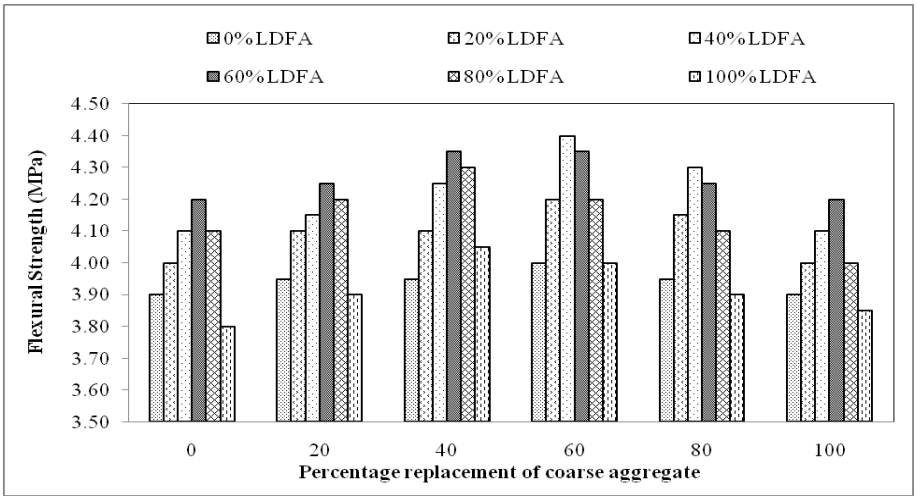

Figure 4 Flexural Strength vs aggregates replacement

CONCLUSION

- The workability of concrete decreases significantly with the increase in percentage replacement of NFA with LDFA.
- Increase in percentage replacement of NCA with LDCA influence the workability of concrete marginally.
- The maximum compressive strength, split tensile strength and flexural strength of concrete with 40% LDFA and 60% LDCA.
- The compressive strength of the concrete made with full replacement of natural aggregates with LD slag aggregates is well comparable to that of referral concrete.
- The split tensile strength and flexural strength of concrete with 100% LD slag aggregate is lower than that of the reference concrete.

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