

Using Optimizing Aggregate Packing for Replacement of Coarse Aggregate with Industrial Waste Slag in Concrete

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ABSTRACT: Concrete is the third largest material consumed by human beings after food and water as per WHO. Concrete plays a vital role in the design and construction of the nation's infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. These are obtained from natural rocks and river beds, thus degrading them slowly. This issue of environmental degradation, and need for aggregates demands for the usage of any other alternative source. Thus the concept of replacement of coarse aggregate with steel slag seems to be promising. This study presents an evaluation of steel slag aggregate concrete in comparison with the conventional natural aggregate concrete. Hardened concrete consist of more than 70% aggregate. Due to the high demand in building construction and the increase of the amount of disposed waste material, suppliers and researchers are exploring the use of alternative materials which could preserve natural sources and save the environment. In this study, steel slag was used as an aggregate replacement in conventional concrete mixes. Steel slag which is mainly consists of calcium carbonate is produced as a by-product during the oxidation process in steel industry. Steel slag was selected due to its characteristics, which are almost similar to conventional aggregates and the fact that it is easily obtainable as a by-product of the steel industry. As a result, utilization of steel slag will save natural resources and clean environment. Furthermore, particle packing analysis is made to optimize the gradation of coarse aggregate which would decrease the cement requirement and increase the density of packing which would result in its improved performance in terms of strength and other parameters.

KEYWORDS: steel slag, aggregate, concrete, industrial waste slag

I. INTRODUCTION

Concrete is unique among major construction materials because it is designed specifically for particular civil engineering projects. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues those together [1]. Almost three quarters of the volume of concrete is composed of aggregates. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete. Natural aggregates are obtained from natural rocks. They are inert, filler materials and depending upon their size they can be separated into coarse aggregates and fine aggregates. The coarse aggregate fraction is that retained on 4.75 mm (No 4) sieve, while the fine aggregates fraction is that passing the same sieve. According to some estimates after the year 2010, the global concrete industry will require annually 8 to 12 billion metric tons of natural aggregates (U.S.G.S and nationalatlas.gov, accessed Nov 2008). Therefore the use of alternative sources for natural aggregates is becoming increasingly important. There is a growing interest in using waste materials as alternative aggregate materials and significant research is made on the use of many different materials as aggregate substitutes such as coal ash, blast furnace slag, and steel slag aggregate. This type of use of a waste material can solve problems of lack of aggregate in various construction sites and reduce environmental problems related to aggregate mining and waste disposal. The use of waste aggregates can also reduce the cost of the concrete production [2] [3]. As the aggregates can significantly control the properties of concrete, the properties of the aggregates have a great importance [4]. The durability of steel slag cement concrete is better than the others. Therefore the main objective

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of this research is to find combined aggregate gradations, using Steel slag aggregate, which will significantly reduce the amount of cement required by 10% to 15% without compromising concrete properties. To achieve this objective, several optimization techniques were being applied to typical M 40 design. These techniques include: (i) introducing an intermediate aggregate with particle sizes mostly between 2.36mm to 9.5mm, which is intended to fill the gap between the traditional binary combination of coarse and fine aggregates; (ii) applying theoretical particle packing models, such as the Theoretical Packing Model by Dewar and the Modified Toufar Model by Goltermann, Johansen and Palbol; and (iii) applying particle density method for standardizing aggregate gradations. With this study's findings, recommendations for improving the specification with respect to aggregate grading requirements will be addressed.

II. MATERIALS USED

The materials used for making Steel slag aggregate concrete specimens are Cement-OPC grade 53, Coarse aggregate - Natural aggregate & Steel slag (figure-1), Fine aggregate - Sand and Water. The raw materials used within the different mixes originate from the same source. No special treatments were given to the constituents of the concrete. The materials were used directly as obtained from shop. The aggregates were used in a dry state. No long time stacking of materials was done. The materials for making concrete were obtained from the shops just prior to starting of each trial set. The properties of the materials used were tested for the purpose of design mix (table-1).

S.no	Material	Specific gravity
1.	Cement	3.15
2.	Natural coarse aggregate	2.75
3.	Steel slag	3.42
4.	Fine aggregate	2.65



Figure-1: steel slag

III. EXPERIMENTAL INVESTIGATIONS

It will be worth to recall at this stages the relationship between aggregate and paste, which are the essential ingredients of concrete. Workability of mass is provided by the lubricating effect of the paste and is influenced by the amount of dilution of paste. Since mineral aggregates with rare exceptions, are far stronger than the paste compound. Essentially, the quality and continuity of the paste govern the permeability of concrete, since little water flows through aggregate either under pressure or by capillary. Further the predominant contribution to drying shrinkage of concrete is that of paste. Since the mix proportions of concrete are governed to a considerable extent by paste, it is helpful to consider more closely the structure of the paste. The fresh paste is a suspension, not a solution in water. The more dilute the paste, the greater the spacing between particles, and thus the weaker will be the ultimate paste structure. The other conditions being equal, for workable mixes, the strength of concrete varies as an inverse function of the water required also depend upon the amount of paste, it is important that as little paste as possible should be used and hence the importance of grading. Based on this, the mix proportion and the gradation of the concrete selected were given in the table-2 and table-3 respectively.

Table-2: mix proportion						
Mix	Mix description	FA	CA	Steel slag	cement	Water/cement ratio
1	Control	896	1140		350	0.45
2	Steel slag coarse aggregate	896		1415	350	0.45

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Table-3: Gradation of coarse aggregate				
Mix	Mix description	Aggregate volume fraction		
		CA	IA	FA
1	Control (Binary)	0.685		0.315
1A	Packing density method	20mm	12.5mm	-
		0.431	0.185	
1B	Modified Toufar particle packing model	0.508		0.492
1C	Theory of particle packing model	0.410		0.399
2	Control (Binary)	0.736		0.264
2A	Packing density method	20mm	12.5mm	-
		0.42	0.18	
2B	Modified Toufar particle packing model	0.445		0.327
2C	Theory of particle packing model	0.559		0.224

Concrete was manufactured based on the mix proportions tabulated in tables 2 and 3. Conventional method of concrete batching and mixing was done. The moulds were first prepared for concrete filling by coating them with mould release. The weighing of the ingredients viz., Cement, fine aggregates, coarse aggregates were made just prior the beginning of producing concrete. This came under recommendation in order to avoid any disproportioning of the ingredients, an outcome that would deem the concrete mix design to differ if the contents were mistakenly added. The coarse aggregate and the fine sand were first mixed together for about 3 minutes. Water was then added to the dry materials and the mixing continued for further about 4 minutes or until an adequately combined mixture was formed. The fresh concrete was then cast into the mould immediately after mixing without any delay. Each layer was given strong manual rodding. Each layer received nearly 25 manual strokes. Thus the moulds were well compacted and the top surface is finished. Three specimens were casted for each set of test. The casted specimens were left undisturbed in the laboratory along with the mould for 24 hrs. The specimens were released from the moulds the next day of casting and were put to curing in the curing tank. The specimens used in this study were in of size: (i) compressive strength – 150mm cube moulds & 150mm dia. x 300mm cylindrical moulds, (ii) split tensile strength test - 150mm dia x 300mm cylindrical moulds and (iii) flexural strength test – 100mm x 100mm x 500mm prism moulds.

IV. RESULTS AND DISCUSSION

Required numbers of standard specimens were tested at both 7 and 28 days. Initially cubical and cylindrical specimens were put to compressive strength test in order to get optimum number of proportions. This was not unusual as compressive strength has fundamental importance in the design of concrete mixtures. No much variation was found with compressive strength results of cubes and cylinder specimens. Particle density method for conventional coarse aggregate gave 6% higher compressive strength than the control mix. Modified Toufar particle packing model for conventional coarse aggregate gave 7% higher compressive strength than the control mix and Theory of Particle packing model for conventional coarse aggregate gave 5% lower compressive strength than the control mix. Particle density method for steel slag coarse aggregate gave 16% higher compressive strength than the control mix. Modified Toufar particle packing model for steel slag coarse aggregate gave 18% higher compressive strength than the control mix and Theory of Particle packing model for steel slag coarse aggregate gave 10% higher compressive strength than the control mix. Comparing Conventional coarse aggregate and steel slag aggregate concrete, steel slag coarse aggregate concrete gave 8% lower compressive strength than Conventional coarse aggregate concrete. Particle density method for steel slag coarse aggregate gave 0.6% higher compressive strength than the conventional coarse aggregate concrete. Modified Toufar particle packing model for steel slag coarse aggregate gave 0.9% higher compressive strength than the conventional coarse aggregate concrete and Theory of Particle packing model for steel slag coarse aggregate gave 6% higher compressive strength than the conventional coarse aggregate concrete. And it was found that A and B type mix were yielding higher strengths both in conventional and steel slag coarse aggregate concrete. Table-4 indicates that as similar to that of the cubical specimens, cylindrical specimens also showed a positive increase in compressive strength of steel slag aggregate specimens than that of conventional aggregate specimens. No much variation was found with compressive strength results of cubes and cylinder specimens. Figure-2 and 3 shows the

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compressive strength of various mix ratios of 7 days and 28 days. From the results, it was ended up continuing further course of work with mix 1A, 1B, 2A & 2B.

- 1A - Packing Density Method (conventional aggregate)
- 1B - Modified Toufar Particle Packing Model (conventional aggregate)
- 2A - Packing Density Method (Steel slag aggregate)
- 2B - Modified Toufar Particle Packing Model (Steel slag aggregate)

Further flexural strength test, split tensile strength test was restricted to these 4 mixes. The tests were continued with suitable specimens.

Table-4: Compressive strength of the concrete				
Mix	Compressive strength (MPa)			
	Cube specimens		Cylindrical specimens	
	7 days	28 days	7 days	28 days
1	34	39.64	34	39.64
1A	34	42	36	42
1B	35.24	42.36	36.23	42.36
1C	31.36	37.64	31.36	37.64
2	28.24	36.34	33	36.34
2A	36	42.24	38.64	43.24
2B	36.24	43	36.24	42
2C	33.54	39.8	33.54	38

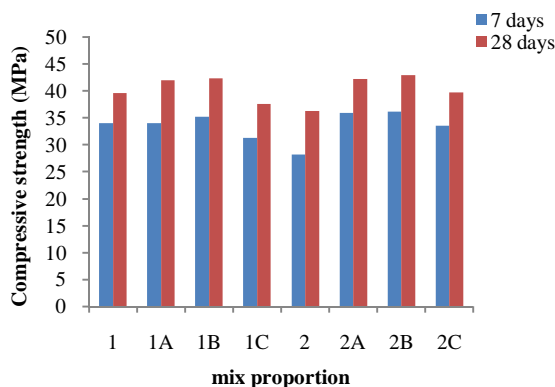


Fig-2: compressive strength of cube specimens

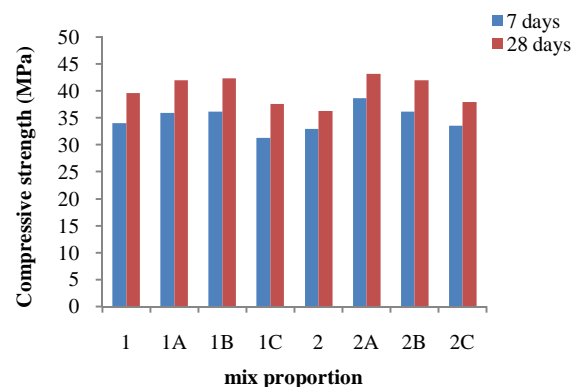


Fig-3: compressive strength of cylindrical specimens

From the table-5 it was identified that the Modified Toufar particle packing model for conventional coarse aggregate concrete gave 20% higher split tensile strength than that of control coarse aggregate concrete. Modified Toufar particle packing model for steel slag coarse aggregate concrete gave 40% higher split tensile strength than that of control steel slag coarse aggregate concrete. Modified Toufar particle packing model found to give higher split tensile strength. It gave 28% higher split tensile strength compared to that of conventional coarse aggregate concrete. Figure-4 shows the split tensile strength of various mix ratios of 28 days.

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Table-5: split tensile strength of concrete at 28 days	
Mix	Split tensile strength (MPa)
1A	1.20
1B	1.44
2A	1.32
2B	1.85

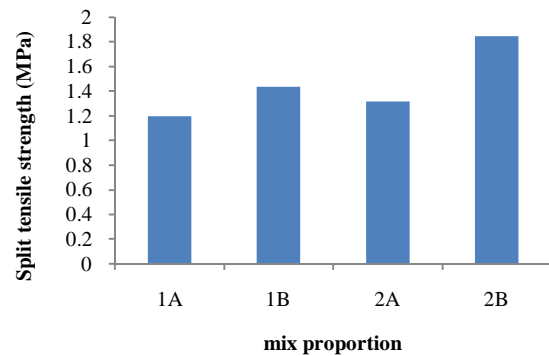


fig-4: Split tensile strength at 28 days (MPa)

Table-6: flexural strength of concrete at 28 days	
Mix	Flexural strength (MPa)
1A	7
1B	8.4
2A	9.2
2B	10.4

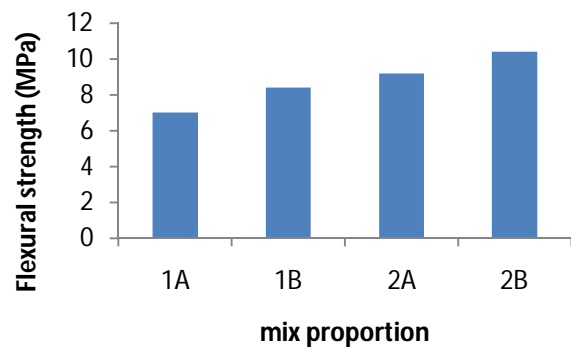


fig-5: flexural strength of concrete at 28 days

Modified Toufar particle packing model for conventional coarse aggregate concrete gave 20% higher flexural strength than that of control coarse aggregate concrete. Modified Toufar particle packing model for steel slag coarse aggregate concrete gave 13% higher flexural strength than that of control steel slag coarse aggregate concrete. Modified Toufar particle packing model found to give higher flexural strength. It gave 34% higher flexural strength compared to that of conventional coarse aggregate concrete. From the results of compressive strength, split tensile strength and flexural strength test, it is clear that Modified Toufar Particle packing method of steel slag coarse aggregate concrete gave the highest strength compared to other concrete specimens. It was also found that steel slag aggregate specimens gave better strength values compared to all other conventional concrete specimens. The entire test results stated above was obtained as average value of three test specimens under each mixes considered. Casting and testing of specimens were with due care confined to a possible extent with the standards.

V. CONCLUSION

From this work it was found that 100% replacement of conventional aggregate with steel slag aggregate was not found to yield better strength, when conventional aggregate ratio was given. With modified aggregate sizes and ratio, based on aggregate packing analysis, better strength results was obtained both in the cases of conventional and steel slag aggregates. Both conventional and steel slag aggregate gave almost similar strength in the laboratory, from which it was concluded that, Steel slag aggregate can be used invariably replacing conventional aggregate in concrete by which it can prove itself economical with no reduction in strength. The optimum mix proportion recommended for M40 grade concrete shall be FA (545.29 kg); CA (0); steel slag (1521.37kg); cement (425.78kg) and water cement ratio is 0.45 using packing density method and modified Toufar particle packing module.

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REFERENCES

- [1] Mindess, S., Young, J. F., and Darwin, D., Concrete, Prentice Hall, Pearson Education, Inc. United States of America, 2003
- [2] Kalyoncu, R.S., "Slag Iron and Steel", US Geological Survey Minerals Yearbook, 2001.
- [3] Farrand, B. and J. Emery., "Recent improvements in quality of steel slag aggregate", Transportation Res., Record, vol.152, pp.137-141, 1995.
- [4] Beshr, H., Almusallam, A.A. and Maslehuddin, M., "Effect of coarse aggregate quality on the mechanical properties of high strength concrete", Construct. Build. Mater. J., vol.17, pp.97-103, 2003.
- [5] Sultan A. Tarawneh, Emhaidy S. Gharaibeh and Falah M. Saraireh, "Effect Of Using Steel Slag Aggregate On Mechanical Properties Of Concrete", American Journal of Applied Sciences, vol.11, no.5, pp.700-706, 2014.
- [6] Khalid Raza, Sharda Sharma, Ritesh Mall and R.D.Patel, "Comparative Strength Analysis Of Concrete By Using Steel Slag As An Alternative To Normal Aggregates (Coarse) In Concrete ", IJCMS ISSN 2347 – 8527, Vol.3, 2014
- [7] Narasimha Raj, Suresh G Patil and B. Bhattacharjee, "Concrete Mix Design By Packing Density Method", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Vol.11, no.2, pp.34-46, 2014.
- [8] Dr.K.Chinnaraju, V.R.Ramkumar, "Study On Concrete Using Steel Slag As Coarse Aggregate Replacement And Eco sand As Fine Aggregate Replacement", IJREAT International Journal of Research in Engineering & Advanced Technology, Vol.1, no.3, 2013.
- [9] Mohammed Nadeem, Arun D. Pofale, "Experimental Investigation Of Using Slag As An Alternative To Normal Aggregates (Coarse And Fine) In Concrete", International Journal Of Civil And Structural Engineering , Vol.3, No.1, 2012.