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Research Article

Experimental and Analytical Study on Behaviour of Flexural Beams using Blast Furnace Slag

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Abstract

The study presents the experimental and analytical behavior of flexural beams by replacing coarse aggregate with that of blast furnace slag. The basic objective of this study was to identify alternative source of good quality aggregate because the natural stone quarries are depleting very fast due to rapid pace of construction activities in India .The effect of replacing natural coarse aggregate by slag on the compressive strength of cubes, split tensile strength of cylinders and flexural strength of beams are evaluated in this study. Use of slag – a waste industrial by product of iron and steel production provides great opportunity to utilize it as an alternative to normally available aggregate. The test results of concrete were obtained by adding slag to coarse aggregate as a replacement of stone aggregate in various percentages of 0%, 20%, 40%, 60% and 100%. All specimens were cured for 28 days before testing. From the study it has been observed that the blast furnace slag aggregate could be a good replacement of stone aggregate.

Keywords: *Flexural Beams, Blast Furnace Slag, Concrete, Tensile Strength*

1. Introduction

Concrete is an age-old material. It can be used easily in any shape and size of structural member. The main ingredients of concrete are cement, sand and aggregate. So concrete can be considered to be an artificial stone obtained by binding together the particles of relatively inert coarse and fine materials with cement paste. The aggregates are generally cheaper than cement and impart greater volume stability and durability to concrete. The aggregate is used primarily for the purpose of providing bulk to the concrete. The aggregate provides about 70-75% of the body of the concrete and hence its influence is extremely important. The stone aggregate produced by crushing of stone obtained from mountains. The quarrying of stone causes number of environmental problems. Hence to replace these aggregates by slag not only allow the use of waste product but also avoid environmental problem. Slag is a waste produced during manufacturing of pig iron and steel. It consists of oxides of calcium, magnesium, manganese, aluminum, nickel and phosphorous. The major component in the blast furnace slag is SiO_2. The physical properties of slag depend upon change in process of cooling; however, the chemical composition remain unchanged. The slag produced in blast furnace during pig iron manufacturing is called blast furnace slag and slag produced at steel melting plant is known as steel slag.

Large amount of industrial waste produced every year in developing countries. Total world steel production crossed 1200 million metric tons. In India, Slag output obtained during pig iron and steel production is variable and depends on composition of raw materials and type of furnace. For ore feed containing 60 to 65% irons, blast furnace slag production ranges from about 300 to 540 kg per ton of crude iron produced. Lower grade ores yield much higher slag fractions, sometimes as high as one tone of slag per ton of pig iron produced.

2. Blast Furnace Slag

There are various type of slag produced e.g. blast furnace slag, steel slag, copper slag etc. In present study limited upto the use of blast furnace slag are describe. At blast furnace, the slag floating over molten pig iron (hot metal) is poured in slag pot and then forwarded to slag granulating plant or cooling pits. Slag is further divided into three categories on basis of cooling. These are air-cooled slag, granulated slag and expanded slag. In Air-cooled slag formation, the slag is produced by allowing the molten slag to cool under atmospheric conditions in a pit. Under slow cooling conditions, escaping gases leave porous and low-density aggregates with physical properties, making it suitable for many applications. When it formed under controlled cooling, the slag tends to be hard and dense, making it suitable for use in road base and similar applications in construction. Granulated slag is produced by quenching the molten slag by means of high-pressure water jets.

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Quenching prevents crystallization, thus resulting in granular pieces of aggregates. The slag after cooling is crushed and used as road metal and railway ballast. Expanded slag is formed through controlled cooling of molten slag in water with combination of steam and compressed air. However, expanded slag is not produced at any domestic iron and steel plant.

3. Flexural Strength of Beams

Flexural strength or ultimate moment (strength) for reinforced beams is defined as the moment that exists just prior to the failure of the beam. In order to evaluate this moment, we have to examine the strains, stress and forces that exist in the beam.

The load vs deflection curve is drawn for different beams with different percentage ratio of slag. The flexural strength of beams with different quantity of slag are calculated and compared with the beams of control mix. The flexural test is the most popular because it stimulates more realistically the conditions in many practical situations and is simpler to conduct than the tension test. The results allow toughness characterization through one or more method for example absolute energy absorption, dimensionless indices related to energy absorption capacity, equivalent flexural strength as prescribed post cracking deflection although, intended to characterized the material behavior, results from these test are usually effected by the specimen size and geometry. The ACI 544 toughness index constituted the first major effort in recognizing that energy absorption may be important in addition to strength (related to ductility or brittleness.
The ACI 544 toughness index is defined as the ratio of area under the load-deflection curve up to a deflection of 1.9 mm to the area under the same curve up to the first curve deflection. Among the problem with this approach are that the first crack deflection is difficult to determine reliably, and that the choice of the fixed deflection limit of 1.9 mm is arbitrary. Realistically, deflection limits should be based on serviceability requirements. This types of index provide an upper bound value of 1 (for post cracking strain hardening modulus approaching the initial elastic modulus and a lower bound value of 0.25 (for ideally brittle material).
The Japanese concrete institute (JCI) toughness definition T_{JCI}, is computed for a standard size beam as the area under the load deflection curve up to a limiting deflection curve up to a limiting deflection of L/150. The limitation of JCI toughness definition is that the limiting deflection is large and does not reflect a useful level of serviceability for much application. The Belgian, Dutch and German specifications have partially overcome this limitation by requiring energy absorption computation also at smaller deflection limits. Similarly, energy absorption capacity of the standard size plain concrete beam is idealized as P_f ($ð_f$ +l/2000)/2, where Pr and O_f are first crack load and deflection at first crack load respectively. In addition to the energy-based toughness measure T_{JCI}, the Japanese standard recommends the use of an equivalent flexural strength also called flexural toughness factor which is expressed as $T_{JCI}l/ð_{limit}bd^2$ where T_{JCI}= toughness of beam, L= span,ð= limiting deflection, b= width of beam and d= effective depth of beam.

Conclusions

The following conclusion has been made from the present study.

1) The compressive strength of concrete made up op 100% slag aggregate has been increased upto 10% in comparison to conventional concrete having stone aggregate.
2) The split tensile strength of cylinders with 40% slag aggregate has been decreased upto 48% in comparison to conventional concrete and further increase in quantity of slag beyond 40%, the split tensile strength increases about 10%.
3) The maximum value of first crack load has been observed as 72KN with 60% replacement of slag correspondence to 61.67 KN in case of conventional concrete with stone aggregate.
4) The ultimate flexural load was observed maximum with 60% slag aggregate i.e. 190 KN and the ultimate flexural load in case of conventional concrete beam with stone aggregate was observed as 156.8KN.
5) The energy absorption capacity and flexural toughness factor of concrete having 100% slag aggregate has been decreased up to 42% and 45% respectively which shows the brittle behaviors of slag concrete .
6) The moment of resistance of reinforced beam is obtained as 28.22 kn-m experimentally and the moment of resistance is calculated analytically as 20.95 Kn-m

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