Construction and Building Materials 107 (2016) 103–108

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Preliminary study on the use of quartz sandstone as a partial replacement of coarse aggregate in concrete based on clay content, morphology and compressive strength of combined gradation

Sanjeev Kumar [a,*], Ramesh Chandra Gupta [a], Sandeep Shrivastava [a], Lazlo Csetenyi [b], Blessen Skariah Thomas [a]

[a] *Malaviya National Institute of Technology, Jaipur 302017, India*
[b] *Concrete Technology Unit, University of Dundee, United Kingdom*

HIGHLIGHTS

- Quartz sandstone (a mine waste) is used in cement concrete as a replacement of natural coarse aggregate.
- M30 grade of concrete was used for the study with water cement ratios of 0.38 and 0.4.
- Clay content analysis and its impact on compressive strength were studied.
- Different blending ratios of coarse aggregates were studied to obtain the best packing and enhanced compressive strength.

ARTICLE INFO

Article history:
Received 15 September 2015
Received in revised form 24 December 2015
Accepted 5 January 2016
Available online 8 January 2016

Keywords:
Chemical composition
Combined gradation
Quartz sandstone
Morphology
Microstructure
Rietveld curve fitting

ABSTRACT

Sandstone is generally composed of grains of quartz and other minerals of fairly uniform size which are often smooth and rounded. These grains are held together by a cementing material which may be siliceous or ferruginous. The toughness of sandstone depends mostly on the nature of this cementing material. While utilising sandstone into concrete, different properties of sandstones has to be studied in detail to know the potential use of sandstone as a part or whole replacement of coarse aggregates. This replacement depends on many factors like mineralogical composition, micro structure, moisture absorption capacity, presence of carbonates and many other parameters. In this study, preliminary tests were analysed for sandstone obtained from Dholpur, eastern most part of Rajasthan state of India. Sandstone waste generation is very much higher in this particular region and it is estimated that Rajasthan alone produces 900 million tons of sandstone waste thus leading to a large dumping of these materials without any particular utilisation. In order to overcome this massive dumping of sandstone wastes and to lessen the use of natural aggregates, a study was carried to find out the effective use of these sandstone wastes in concrete. Tests were done to study the morphology, compressive strength based on combined gradation, clay content percentage and Rietveld curve fitting was done to identify the major constituents in the sandstone aggregate. It was observed that this preliminary study on parent and substitute aggregate was compulsory before replacing the parent aggregate with substitute aggregate. Partial replacement of such aggregates would prevent the usage of natural aggregates which are in the zone of depletion, thus protecting the natural resources and reducing landfilling of mine wastes.

1. Introduction

Aggregates are generally inert granular materials which contribute most towards the strength of overall concrete. Variation in aggregate type affects the strength of the final concrete produced. However sandstone being a sedimentary type of rock might have lesser contribution to concrete strength when compared to natural aggregates. The residual mechanical behaviour of the concrete varies depending on the type of aggregate and thereby it becomes important to understand the chemical and mineralogical characteristics of aggregates before put up into real use of concrete applications. For a high strength concrete, the coarse aggregate type has an apparently contradicting influence on strength and elastic modulus of high strength concrete and they play a vital role on drying shrinkage property [1–4].

* Corresponding author.
E-mail address: sanmfsd@gmail.com (S. Kumar).

http://dx.doi.org/10.1016/j.conbuildmat.2016.01.004

In this regard an attempt has been made to study the primary tests that has to done before utilising quartz sandstone as a partial replacement for coarse aggregates in cement concrete which would contribute towards saving of natural aggregates which are scarce in the surrounding environment.

2. Literature review

Sandstone being a sedimentary material is affected by influence of moisture and moisture is known to decrease the mechanical properties of brittle construction materials. Porosity plays a central role in the compressional behaviour of granites and sandstones [5,6].

Abrasion resistance of the resulting concrete mainly depends upon the properties of the concrete and there is no direct correlation exists between the L.A. abrasion of aggregates and the abrasion resistance of resulting concrete [7].

Van Vliet and Van Mier [8] studied the size effect of strength and fracture energy of concrete and sandstone. It has been recognised for ages that the size effect can have a significant effect on the nominal strength. Thus sandstone of different sizes used in concrete would have a varying effect on its corresponding strength and further implies the importance for proper grading of these aggregates when used in concrete.

Microstructure of concrete is one the important parameters that contribute towards the strength property. Compressive strength of a bio-sandstone could increase if the bottom region of microstructure being dense and less fragile than the top region [9].

Sandstones tend to vary in composition and contribute differently towards the compressive strengths. Clay content in sandstone approximately reduces the compressive strength of concrete to about 40–50% and presence of carbonate in sandstones have a better bonding between cement and aggregate than those containing clay particles [10].

The construction industry is one of the most important economic sectors in most countries, involving a great flux of material and human resources. As the population increases and a proportional increase of the consumption of natural resources and energy occur. Furthermore, it is responsible for a very significant use of natural resources, causing societal concerns inherent to their exhaustion. The incidence of increasing rate of natural resource depletion coupled with the high cost associated with some of the traditionally used aggregates calls for the use of new, abundant and cheap materials [11–13]. Sandstones tend to have low compressive strength than natural aggregates and have a scattered variance on its mechanical properties and are very sensitive to time dependent mechanical deterioration. Sandstones tend to perform well in dry conditions but in wet conditions it is poor when used for unbound forest roads [14,15].

Sandstones were obtained from Dholpur mine wastes, eastern most part of Rajasthan and the aggregates were checked for various properties like apparent specific gravity, water absorption, wear, modulus of rupture and compressive strength. These aggregates were crushed to get the desired grading to make it usable as a replacement for natural coarse aggregate. The fine particles while crushing were removed using a blower and the size of aggregates was maintained uniformly.

3. Material properties and preparation of test samples

The properties of materials and methods of preparations of test specimens are given below.

3.1. Raw materials

Ordinary Portland cement of grade 43, conforming to IS 8112: 1989 [16] was used (specific gravity 3.15, normal consistency 32%, initial setting time 66 min and final setting time 164 min). Natural river sand confirming to zone II as per IS 383: 1970 [17] (void content 34% as per ASTM C 29/C 29M: 2009 [18], specific gravity 2.63, free surface moisture 1% and fineness modulus 2.83). Coarse aggregates, 10 mm size (fineness modulus 6.08) and 20 mm size (fineness modulus 7.22) crushed stone were used as coarse aggregates with an average specific gravity 2.64. Quartz sandstone coarse aggregate, 10 mm size (fineness modulus 6.04) and 25 mm size (fineness modulus 7.24) were used as partial replacement for coarse aggregates with an average specific gravity of 2.45. The particle size distributions of aggregates are shown in Fig. 1 and cement properties in Table 1.

3.2. Preparation of test specimens

To investigate the suitability of quartz sandstone as a substitute for coarse aggregates in concrete, a preliminary study involving compressive strength results for different gradation of combined aggregates were done individually for natural and quartz sandstone aggregates in concrete. M30 concrete grade was designed as per IS 10262:2010 [19] with water cement ratio of 0.38 and 0.4. Based on combined aggregate gradation, compressive strength of concrete containing both the aggregates (natural and quartz sandstone aggregates) are studied individually. In order to maintain a consistent workability for all the mixes, super plasticiser was used to keep C.F above 0.85. Cubes of 100 mm × 100 mm × 100 mm were casted for compressive strength. (7 and 28 days). Indoor temperature was about 25–30 °C during the complete period of casting and compaction factor test was used to determine the workability of fresh concrete. Curing was done in a water tank with a controlled temperature of 25–27 °C. Compressive Strength test was done according to IS specifications.

3.3. Combined gradation of coarse aggregates

Gradation is one of the important parameters for finding out the exact ratio of mixing different size of aggregates together. IS 383:1970 [17] gives the grading limit of coarse aggregates for maximum sizes of aggregates 40, 20 and 16. However the maximum size of aggregate obtained was 25 mm so the values were interpolated to get the exact size of grading for quartz sandstone. The expected value of percentage passing of general aggregate corresponding to size 25 mm are given in Table 2. Percentage passing for combined ratios of natural aggregates in given in Table 3 and for quartz sandstone in Table 4.

4. Laboratory testing program

The testing procedure adopted for finding workability, analysing microstructure, chemical composition by XRD, clay content using methylene blue test are mentioned below.

4.1. Workability of concrete for different proportions of coarse aggregate

Workability of fresh concrete was tested using a compaction factor apparatus as per IS 1199:1959 [20]. Effectiveness of concreting depends on the ease at which concrete can be placed, compacted and finished. Aggregate characteristics affect the water required for a given consistency and sandstone aggregates tend to have higher water absorption than the natural aggregates and water requirement to maintain the same workability is a tedious

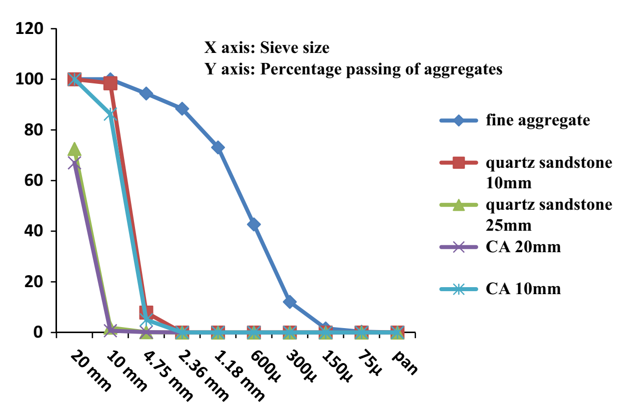

Fig. 1. Particle size distribution of aggregates (natural coarse, natural fine and quartz sandstone coarse).