Performance Evaluation of Cement Concrete by Partially Replacing Coarse Aggregates with Sandstone Found in the Vicinity of Jabalpur Region

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***Abstract* - Previous studies shown the importance of aggregate packing and grading to enhance the performance of concrete. Changes in aggregate proportions and their influence on concrete properties such as strength and modulus of elasticity was studied by several researchers. Similarly, when sandstone used in concrete, compressive strength of resulting concrete might vary, and it is being accepted as the most important mechanical property of structural concrete.**
Thus, the objective of the present work is "To find out the possible use of sandstones as coarse aggregates obtained from Mahakoshal region, in cement concrete and also find out some of the properties of such concrete in fresh and hardened states."

***Index Terms* - sandstones, coarse aggregates, concrete etc.**

I.INTRODUCTION

With an enormous increase in waste generation, construction sector has become one of important cause for environmental degradation. With increased innovations, urbanizations and industrialization in different fields, a huge amount of recyclable materials go as a waste without being utilized. The idea of replacing raw materials such as fine and coarse aggregates with waste products has been encouraged by the construction industry to promote sustainability (Thomas et al., 2013, 2015; Abdul and Hossein, 2016). The accumulation of stone wastes has also been increasing throughout the year and the land requirements to dump these wastes becomes a significant burden for civil and environmental engineers.

International natural stone production is plenty and many European and Asian countries have indulged in stone quarrying like India. These lands generate an enormous amount of quarry wastes which is being dumped without any particular utilization. Reduction of raw material generation and reduction of waste utilization being the two key parameters in reducing material throughput. At the same time, waste prevention, recycle and reuse reduces the need for virgin materials and also reduces the associated environmental impacts (Gazi et al., 2012; Van Ewijk et al., 2016).

Aggregates

The term 'aggregate' covers a variety of materials used in the construction industry. Aggregates can be defined as 'particles of rock, manufactured or recycled material which, when brought together in a bound or unbound condition, form part or whole of an engineering or built structure'. The vast majority of aggregates used in construction work are for roads or concrete structures, where they are used unbound in the lower layers of road pavements, bitumen bound in the upper road layers or bound by cement in concrete. Other applications for aggregates include mortar sand, railway ballast, and filter media. Each end use requires aggregate with specific properties in terms of particle size distribution (grading), shape and surface texture, strength, and resistance to degradation.

1.1 Aggregate Type

The 'aggregate type' depends on the type of resource it is won from and the processing that the material undergoes to make the aggregate product. Aggregate type should be described as follows (adapted from Fookes et al., 2001):

1. Whether natural or artificial.
2. If natural, whether crushed rock, gravel, or sand.
3. If a gravel or sand, whether uncrushed, partly crushed, or crushed.

4. If a gravel or sand, whether land won or marine.
5. If recycled, this should be stated

1.2 Sandstone
Sandstones are a sedimentary type of rock which is composed of rock grains and silt- sized particles. They are of different types based on the geological property, elemental framework and most of the sandstones has quartz and feldspar due to the abundance of them in earth's crust. Being a widespread aggregate resource, sandstones are widely used in concrete construction around the world. The geological properties of sedimentary rocks are fairly diverse such as quartzite, arkose, subarkose and greywacke aggregate that may produce a range of hardened concrete properties. Therefore, it is important that the aggregate can be easily characterized to obtain predictable concrete properties. The factors influencing the strength of concrete are the amount and type of cement, w/c ratio, aggregate type and grading, workability of fresh concrete, mineral admixtures used, chemical additives, curing conditions and time, etc.

II-LITERATURE REVIEW

Mohmmad Arif et al; 2018 deals with the durability properties of concrete containing sandstone slurry as a filler material. A significant quantity of sandstone slurry gets deposited, and their disposal problem becomes acuter. In order to utilize these wastes and to practice a sustainable construction, the ultimate solution is to use these types of sandstone slurry in concrete. Since durability plays an enormous role in maintaining the infrastructure for years,
Ali Ergün 2011 describes the procedures and results of a laboratory investigation of mechanical properties carried out on the concrete specimens containing diatomite and WMP as partial replacement of cement in concrete. The laboratory work essentially consists of characterization of the raw and waste materials, preparation of concrete specimens with diatomite and WPM in different ratios by weight as replacement for cement and a super plasticizing admixture to reduce water demand and compression and flexural tests of the specimens.
Sandstones vary in composition and consequently when used in concrete as aggregate may cause different concrete strengths. However, there are few data about correlating the effects of different sandstone aggregates. In the work carried out by M. Yılmaz and A. Tugˇrul highlighted some mechanical aspects concerning the use of different sandstones as concrete aggregate. The sandstone samples were first tested to determine their petrographic characteristics and aggregate properties.
Sanjeev Kumar et al; 2016 presents the results of experimental research to examine the suitability of quartz sandstone as a substitute for natural coarse aggregates in cement concrete. The quartz sandstone wastes were used in definite percentages and replaced for coarse aggregates from 0% to 100% at every 20% interval. The article presents with tests such as pull off strength, carbonation, sulphate attack, porosity and extended results of compressive strength, flexural strength.

III-RESEARCH METHODOLOGY

With an enormous increase in waste generation, construction sector has become one of important cause for environmental degradation. With increased innovations, urbanizations and industrialization in different fields, a huge amount of recyclable materials go as a waste without being utilized. The idea of replacing raw materials such as fine and coarse aggregates with waste products has been encouraged by the construction industry to promote sustainability. The accumulation of stone wastes has also been increasing throughout the year and the land requirements to dump these wastes becomes a significant burden for civil and environmental engineers.

3.1 Material properties and sample preparation
Cement: Ordinary Portland cement grade 43 as per BIS: 8112-1989 as used in this experimental study. Normal Consistency of this cement is 26%. Initial setting time is 120 min and final setting time is 260 min (4 h 20 min).
Quartz sandstone: Quartz sandstone is used as a filler material. Quartz sandstone coarse aggregates of sizes 10 mm size with a fineness modulus of 6.12 and 20mm size with a fineness modulus of 7.11 were used as the partial replacement for coarse aggregates with an average specific gravity of 2.45. The fineness modulus is an index number which represents the mean size of the particles. 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 2.60.

The quartz sandstone was obtained from PVS Infra-resources Pvt. Limited, Damoh. The property of the sandstone has been given:

Table 3.1 Properties of quartz sandstone waste obtained from PVS Infra-resources Pvt. Limited, Damoh

Properties of quartz sandstone waste obtained from PVS Infra-resources Pvt. Limited, Damoh			
Technical Information		Value	Standard
Water Absorption (% by weight)		1.89	IS2386(P:3) 1963
Specific Gravity, (g/cc)		2.6	IS2386(P:3) 1963
Moisture Content (%)		0.32	SOP-KTRC-WI-Mech-285
Soundness	(a) Sodium Sulphate (%)	2.33	IS 2386(P:5) 1963
	(b) Magnesium Sulphate (%)	2.46	

Figure 3.1 Quartz Sandstone used for the study

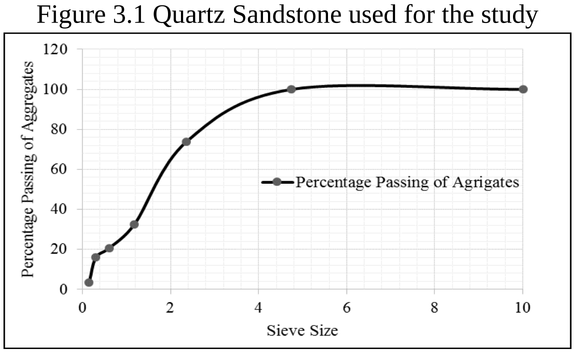

Figure 3.2 Sieve Analysis of Coarse and Fine Aggregates

Preparation of test specimens

The mix design is designed in agreement with the Indian Standard Codes. The design concrete is of M40 grade as per the design standard of IS 10262:2010 with water cement ratio of 0.35, 0.4 and 0.45. 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 sandstone aggregates in concrete. The slump maintained in between 30-60mm for the water cement ratio considered for the design mix. Based on combined aggregate gradation, compressive strength of concrete containing both the aggregates (natural and quartz sandstone aggregates) are studied individually.

3.2 Testing of Materials

3.2.1 Fresh and hardened concrete properties

Average of two specimens were taken into account for each of test carried out. The load acting on the concrete specimens were increased gradually at the rate of 140 kg/sq cm/minute for compressive strength test. With the continuous increase in loading, the maximum load at which the concrete specimens failed was noted.

Figure 3.5 Specimens for Analysis

Figure 3.6 Curing of Specimens for Analysis

Figure 3.7 Crushing strength test of Specimens

3.2.2 Flexural Strength tests

A prismatic beam of concrete is supported on a steel roller bearing near each end is loaded through similar steel bearings placed at the third points on the top surface (2-point loading). Test details are described in BS EN 12390-5. Normative Annex A describes a method whereby the load is applied through a single roller at centre span (centre-point loading).

For two-point loading a constant bending moment is produced in the zone between the upper roller bearings. This induces a symmetrical triangular stress distribution along vertical sections (assuming elasticity) from compression above the neutral axis at mid-height to tension below the neutral axis.

Figure 3.8 (a) and (b) Flexural strength test of Specimens

3.2.3 Test for Water Absorption

ASTM C 642 (2006) standard specification was used for the testing. Three concrete samples of 100mm size were oven dried at 100°C and kept at room temperature for a day before the initial weights were tabulated. Concrete samples were kept in water for 48 h with 50 mm maintained as the free board. The specimens were uncrated, wiped with a clean fabric before the weight was catalogued. The water absorption values of concrete having different replacement levels of quartz sandstones were evaluated in comparison to that control concrete made solely from conventional coarse aggregates.

3.2.4 Durability

Environmental forces such as weathering, chemical attack, heat, freezing and thawing try to destroy concrete. The period of existence of concrete without getting adversely affected by these forces is known as durability. Generally dense and strong concretes have better durability. The cube crushing strength alone is not a reliable guide to the durability. Concrete should have an adequate cement content and should have low water cement ratio.

IV-RESULT ANALYSIS

4.1 General

When sandstones are incorporated into concrete, several property changes occur due to its porosity, presence of clay and carbonate. The following results have been carried out after the analysis.

4.2 Results for various tests

4.2.1 Fresh and hardened concrete Properties

The density of fresh and hardened concrete with increase in level of sandstone replacement is given in Table 4.1-4.3 for water cement ratio 0.35, 0.4 and 0.45 respectively along with mixture proportions.

Table 4.1 Mixture proportions and properties of fresh concrete for the water-cement ratio of 0.35

Mixture proportions and properties of fresh concrete for the water-cement ratio of 0.35							
Ingredients (in kg/m3)	Percentage replacement of total aggregate by sandstone						
	0	5	10	15	20	25	30
Cement	537	537	537	537	537	537	537
Water	201	201	201	201	201	201	201
Fine Aggregate (kg/m3)	922	922	922	922	922	922	922
Coarse Aggregate (kg/m3)	822	780.9	739.8	698.7	657.6	616.5	575.4
Quartz Sandstone Aggregate	0	41.1	82.2	123.3	164.4	205.5	246.6
Admixture	1	1.05	1.1	1.15	1.15	1.1	1.2
Compaction Factor	0.9	0.9	0.89	0.89	0.88	0.87	0.87
Density	3300	3225	3210	3195	3180	3170	3150

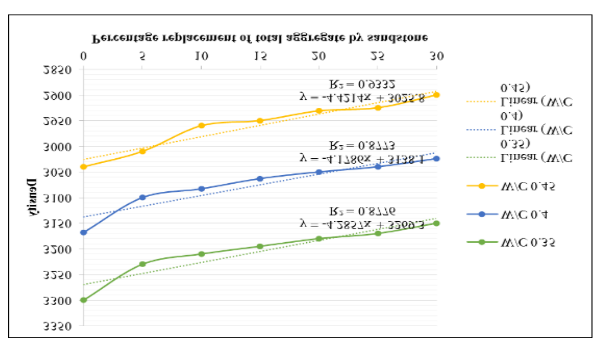

Figure 4.1 Variation of Density for various percentage replacement of total aggregate by sandstone

Workability and density of fresh concrete containing increased dosages of quartz sandstone aggregates were compared with the control concrete containing only the conventional aggregates. It can be observed from the figure 4.1 that the density of fresh concrete decreases as the level of replacement increases due to the lesser specific gravity of sandstone aggregates and greater void spaces when compared to conventional coarse aggregates. Also in the hardened concrete as the sandstone replacement increases density decreases. Since the density is a function of specific gravity and the specific gravity of sandstone is less than that of natural aggregate, the density of hardened concrete decreased as the level of sandstone increases.

V-Conclusion & Future Scope

Experiments were conducted to study potential use of quartz sandstone as partial replacement of coarse aggregates in concrete. Quartz sandstones were added as coarse aggregates from 0% to 30% in the multiples of 5%. M40 grade of concrete is designed as per IS: 10262–2010, with water/cement ratio for 0.35, 0.40 and 0.45.

The following conclusions drawn from the experimental study are as follows:

- Density of fresh concrete decreases as the level of replacement increases due to the lesser specific gravity of sandstone aggregates and greater void spaces when compared to conventional coarse aggregates.
- In the hardened concrete as the sandstone replacement increases density decreases.

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