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Strength, abrasion and permeability studies on cement concrete containing quartz sandstone coarse aggregates

Sanjeev Kumar *, Ramesh Chandra Gupta, Sandeep Shrivastava

Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur, India

HIGHLIGHTS

- Quartz sandstone (mine waste) is used in cement concrete as a replacement of conventional coarse aggregates.
- M30 grade of concrete was used for the study with varying water cement ratios of 0.35, 0.4 and 0.45.
- Strength, abrasion, absorption and permeability studies were carried out.

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ABSTRACT

Sandstones being a sedimentary type of rock are composed of sand-sized mineral grains, rock fragments and pieces of fossils which are held together by mineral cement. They differ from other igneous rocks in possessing a framework of grains that touches each other but not in continuous contact. Quartz being a mineral which is highly resistant to both physical and chemical weathering are also found in sandstones. Being found in sandstones, they can be used as partial replacement of aggregate in cement concrete without a substantial decrease in strength properties. In countries like India, sandstone waste generation is very high and it is estimated that Rajasthan alone produces 900 million tonnes of sandstone waste thus leading to a large dumping of these materials without any essential utilisation. 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. M30 grade of concrete was designed as per IS 10262: 2010, with water cement ratio of 0.4. However to find the scattering of strength plots, water cement ratios of 0.35 and 0.45 were also adopted for the study. Control mix consists of 0% quartz sandstone and substitution of coarse aggregates was done for 0–100%, in the multiples of 20%. Tests were done to determine the compressive strength, flexural strength, abrasion resistance, permeability and sorptivity in concrete samples. It was observed that the quartz sandstones might be utilised as a partial replacement of coarse aggregates up to 40% without considerable decrease in its preferred strength.

1. Introduction

Concrete is widely used as a construction material in modern society. With the growth in urbanisation and industrialisation, the demand for concrete is increasing. Therefore, raw materials and natural resources are required in large quantities for concrete production worldwide. At the same time, a considerable amount of industrial waste, agricultural waste and other types of solid material disposal are creating environmental issues [1]. So it becomes necessary to find an alternative source for raw materials and to lessen the wastes being dumped.

While utilising aggregate of different sizes, proper grading and its effect on strength should be studied to find out the exact ratio in which they can be mixed. Aggregates in RCC shows an obvious size effect on many properties of concrete. The aggregate size however may cause aggregate segregation, concrete internal defect or other issues [2]. Thus sandstone of different sizes used in concrete would have a varying effect on its corresponding strength and further it is important to grade these aggregates when used in concrete [3].

Sandstone being a sedimentary material is affected by the influence of moisture and moisture is known to decrease the

Abbreviations: RCC, reinforced cement concrete; CA, coarse aggregate; FA, fine aggregate; SEM, scanning electron microscopy; DMG, Department of Mines and Geology; CDOD, centre for development of stones; CF, compaction factor.

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

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mechanical properties of brittle construction materials. Since the conditions for the transport processes involved in concrete's degradation mechanism strongly depend on its pore structure it is important to study, in particular, the porosity, capillarity and the permeability of the microstructure of concrete [4,5].

Addition to strength, abrasion resistance is also used as an index to measure the quality of concrete. Aggregate type, surface finish of concrete and type of curing has a strong influence on abrasion resistance. Abrasion resistance of the resulting concrete mainly depends on upon the properties of the concrete and there is no direct correlation exists between the Los Angeles abrasion of aggregates and the abrasion resistance of resulting concrete [6].

The microstructure of concrete is also one the important parameters that contribute towards the strength property. It is generally agreed that the interfacial transition zone (ITZ) is one of the most important factors for performance of cement-based materials which can be viewed by SEM observations [7].

Elemental composition and type of sandstone might vary and they contribute differently towards the compressive strengths. Clay content in sandstone approximately reduces the compressive strength of concrete to about 40–50% and the presence of carbonate in sandstones have a better bonding between cement and aggregate than those containing clay particles [8]. Sandstones tend to have lesser compressive strength than conventional aggregates and have a distributed plots on mechanical properties and are very sensitive to time-dependent mechanical deterioration. Sandstones perform well in dry condition but in a wet condition it is poor specifically for less cemented sandstone types [9,10].

The demand for aggregates for concrete production has escalated with the increase in large-scale infrastructure and construction projects in many countries. This has led to increased focus on identification of alternatives to natural aggregates with the intention of conserving the natural aggregates for future and to maintain ecological balance [11].

According to DMG Rajasthan, the quantum of stone wastes generated has increased to a greater extent and the sandstone wastes alone accounts to 25% of the mined-out reserves [Table 1]. To utilise them in cement concrete, sandstones wastes were obtained from Dholpur mines in Rajasthan and the aggregates were checked for various properties like apparent specific gravity, water absorption, wear, modulus of rupture and compressive strength [Table 2]. 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 was removed using a blower and the size of aggregates, was maintained uniformly.

2. Raw materials and preparation of test specimens

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

Ordinary Portland cement of grade 43, conforming to IS 8112: 1989 [12] 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 [13] (void content 34% as per ASTM C 29/C 29 M: 2009 [14], specific

Table 1
The output of mined out sandstone reserves in Rajasthan, India.

	Sandstone Waste Generated (in thousand tonnes)							
Year	1 Mined out Reserves	2 Mine waste @ 25% of Mine Production (3)	3 Sandstone Production as per DMG, Rajasthan (As Blocks or Khandas)	4 Dressing Waste (Lumps – 15% of Block Waste)	5 Processing Waste + Polishing Waste (Powdered – 25% of Block weight)	6 Dressing Waste + Polishing + Processing waste	7 Total Waste	8 Finished Goods by Weight (1–7)
2001	8233	2058	6175	926	1544	2470	4528	3705
2002	7636	1909	5727	859	1432	2291	4200	3436
2003	9783	2446	7338	1101	1834	2935	5381	4403
2004	11176	2794	8382	1257	2096	3353	6147	5029
2005	9359	2340	7019	1053	1755	2808	5147	4211
2006	10,409	2602	7807	1171	1952	3123	5725	4684
2007	11,594	2898	8695	1304	2174	3478	6376	5217
2008	13,956	3489	10,467	1570	2617	4187	7676	6280
2009	18,462	4616	13,847	2077	3462	5539	10,154	8308
2010	15,632	3908	11,724	1759	2931	4690	8598	7034
2011	18,840	4710	14,130	2120	3533	5653	10,363	8477
2012	21,841	5460	16,381	2457	4095	6652	12,112	9729
2013–2014	43,351	10,838	32,513	4877	8128	13,005	23,843	19,508
Total	200,272	50,068	150,205	22,531	37,553	60,184	110,250	90,021

As per data provided by CDOS, Rajasthan, India.

Table 2
Properties of quartz sandstone waste obtained from Dholpur mines.

Technical Information	Sample condition		Value	Standard
Water Absorption (% by weight)	–		1.36	IS 2386-(Part III)-1963
Specific Gravity, (g/cc)	–		2.43	IS 2386-(Part III)-1963
Modulus of rupture (MPa)	Dry	Parallel to rift	16	ASTM C-99
		Perpendicular to rift	9	
	Wet	Parallel to rift	13	
		Perpendicular to rift	8	
Compressive Strength (MPa)	Dry	Parallel to rift	115	ASTM C-170
		Perpendicular to rift	108	
	Wet	Parallel to rift	106	
		Perpendicular to rift	91	
Abrasion (mm)	Average wear		1.89	IS 1237