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Case study

Effect of quarry rock dust on the flexural strength of concrete

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ABSTRACT

The effect of quarry dust on the flexural strength of concrete has been experimentally studied and reported in this paper. Concrete used was prepared by replacing 25% and 100% of sand by weight with quarry dust. Also, conventional sand concrete was prepared as reference concrete for comparison. 100 mm cube and 100 × 100 × 500 mm plain beam specimens were prepared using concrete strengths ranging from 25 N/mm^2 to 47 N/mm^2 for the three replacement levels of 0%, 25% and 100% to obtain the compressive and flexural strengths respectively at 28 days. From the results, it was observed that the flexural strength of concrete with 25% and 100% quarry dust were respectively 2% and 4.3% higher compared with concrete with no quarry dust. By carrying out regression analysis, empirical formulas in the form $y = ax^b$ were obtained for concrete with quarry dust. The equations were compared with formulas proposed by ACI, BS, IS codes of practice for estimating the flexural strength using the compressive strength of concrete. It was found that incorporating quarry dust in concrete improves its flexural strength.

1. Introduction

Flexural strength of concrete also called modulus of rupture (MOR) is a measure of the tensile strength of concrete. It is an essential property in structural concrete design because it affects the flexural cracking, shear strength, deflection characteristics and brittleness ratio of concrete. Tensile strength has been conventionally defined as a function of compressive strength. The factors that affect this relationship between the two strengths include: level of strength of concrete, method of testing of concrete in tension, the concrete's moisture content, texture and shape of coarse aggregate and size of specimen [1]. A number of empirical equations have been posited to relate compressive (f_c) and tensile (f_t) strengths. The formulae are of the form $f_t = kf_C^n$ where n and k are constants. For flexural tensile strength the k varies from 0.33 to 0.94 and n from 0.5 to 0.67 [2]. Although, most codes of practice recommend a square root function ($n = ½$) to relate flexural strength with compressive strength, it has been reported that for a wide range of concrete strengths and for high performance concrete, the power function ($n = ⅔$) results in a more accurate prediction of the flexural strength of concrete [3,4]. Generally, the flexural strength is approximately taken as 10–15% of the compressive strength for medium strength concrete [5].

Some of the factors influencing the variability of flexural strength of concrete have been investigated and reported by a number of authors. Amudhavalli [6] and Mathew and Siddique [7] studied the effect of admixtures on the flexural strength of concrete. From their results, they observed that the flexural strength was improved at an optimum silica fume and fly ash content of 10–15% and about 15% respectively. Köksal et al. [8] reported greater flexural strength of concrete containing 1% of steel fibre compared with concrete with 0.5% steel fibre for various silica fume contents. Ahmed et al. [3] showed from an experimental study that the size of a concrete member has significant effect on the flexural strength and consequently proposed an equation incorporating the size effect, $f_t = \frac{0.827}{h^{0.1}} f_C^{2/3}$ (where fc is compressive strength in N/mm^2 and h depth of beam in mm), to predict the flexural strength of concrete.

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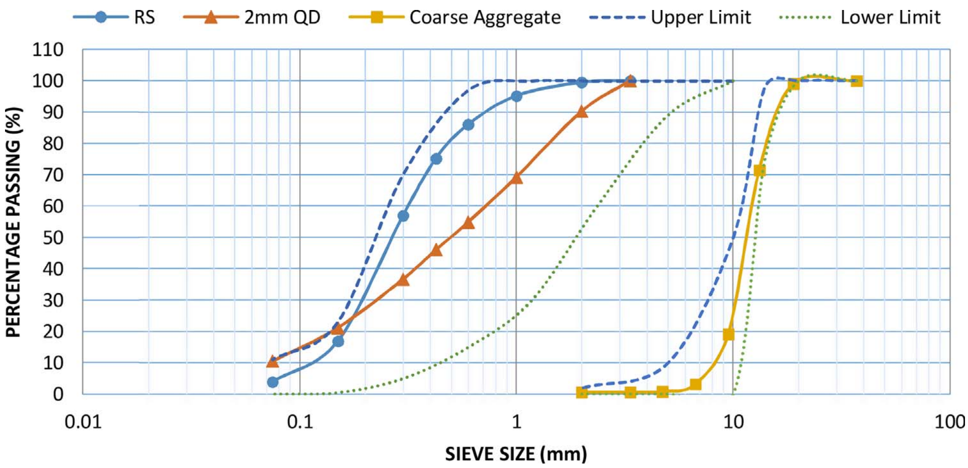

Fig. 1. Grading curves for fine and coarse aggregates.

Previous studies have shown that replacing sand with quarry rock dust produces concrete with about 8–20% increases in strength.

The use of quarry dust as replacement for sand in concrete has been extensively researched in recent years. This stems from the fact that there is growing concern in most parts of the world about the depletion of sand deposits, environmental and socio-economic threats associated with extraction of sand from river banks, coastal areas and farm lands. Quarry rock dust has been found to produce concrete with improved strength, mechanical and durability properties when used as fine aggregate [9–16]. Although quarry dust concrete is reported to have higher flexural strength compared with sand concrete, no studies have been carried out to investigate the correlation between the flexural strength and the compressive strength of concrete containing quarry dust. This paper is, therefore aimed at establishing an appropriate relationship between flexural strength and compressive strength for concrete containing quarry rock dust as fine aggregate.

2. Experimental program

2.1. Materials

Portland limestone cement, river sand and quarry rock dust both of 2 mm maximum size as fine aggregate, and 14 mm crushed rock coarse aggregate were used for the concrete The particle size distribution and the physical properties of the fine and coarse aggregates are shown in Fig. 1 and Table 1 respectively. The fine and coarse aggregates satisfied the BS EN 12620:2002 + A1:2008 [17] specifications.

2.2. Mix proportions and preparation of specimens

Three replacement levels of 0%, 25% and 100% quarry dust were used in the concrete mixes. The 25% is the optimum replacement percentage achieved by carrying out strength studies for 0%, 25%, 50%, 75% and 100% sand replacement levels. The respective 28-day compressive strengths were 24.49, 27.91, 24.64, 21.33 and 19.40 N/mm^2 [18]. The mixes were designed to achieve five different target strengths. The concrete mixes were designed to have a near constant slump in the range of 60–180 mm; and as such, the water-cement ratio varied. The procedure used for the mix design was in accordance with that outlined in “Design of Normal Concrete Mixes” [19]. Table 2 shows the detailed mix proportions.

The cement and aggregates were first mixed together in a concrete mixer. Two-thirds of the required water was first added to the cement-sand-coarse aggregate mixture and mixed thoroughly. The remaining water was added with further mixing to obtain a uniform and homogeneous mix. The mix for each sand replacement level of particular concrete grade was cast in 100 × 100 × 100 mm and 100 × 100 × 500 mm steel moulds and compacted with a tamping rod in three layers. The specimens were de-molded after 24 h and cured by immersion in water for 28 days at a room temperature of 27 °C. The plain beam specimens

Table 1
Physical Properties of Aggregates.

Aggregate	Bulk Density (kg/m^3)	Fines Content (%)	Fineness Modulus	Water Absorption (%)	Moisture Content (%)	Specific Gravity	Crushing Value
River sand	1600	3.89	2.66	6.8	3.56	2.66	–
Quarry dust	1650	10.45	3.54	10.6	0.54	2.64	–
Coarse Agg.	1625	–	–	0.54	0.09	2.71	18.3