World Applied Sciences Journal 8 (2): 206-209, 2010
ISSN 1818-4952

Comparative Study on Compressive Strength of Medium Grade Cement Concrete Using Various Types of Coarse Aggregates

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Abstract: Concrete is an artificial stone manufactured from a mixture of binding material and inert material (fine and coarse aggregates). In this study, three types of coarse aggregates; stone chips (crushed stones), stone shingles (uncrushed stones) and *khoa* (crushed bricks) were used to assess the strength of concrete at different water-cement ratio and mix design ratio. The relative performance of the mentioned types of coarse aggregates was focused for medium grade concrete. From laboratory experiments, it was revealed that the gained strength of stone shingles and stone chips were 20% and 13% higher than that of *khoa* accordingly. The maximum compressive strength was found as 42.8 MPa at w/c ratio of 0.45 for stone shingles and 41.2 MPa as well as 36.8 MPa at w/c ratio of 0.50 for crushed stone and *khoa* respectively after 28 days. In addition, *khoa* showed extra water requirement criteria of 10% over stone shingles. The mix design ratios of stone shingles nearly satisfied the standard mix design ratios compared to the chips of stone and brick. The analysis of the concrete mix design according to its property might not provide that strength which could be achieved by the standard concrete mix. Therefore, from the study, it can be concluded that stone shingles are appropriate for better performance in terms of strength and economy over uncrushed stones and similarly stone chips are suitable over *khoa* only when all relevant parameters for the strength of medium grade cement concrete are same except aggregate type, w/c and mix design ratio. Admittedly, *khoa* from good bricks can satisfy the least requirement of concrete compressive strength.

Key words: Compressive strength · Medium grade cement concrete · Water-cement ratio · Crushed brick · Crushed stone · Uncrushed stone

INTRODUCTION

Concrete is one of the most important construction materials comparatively economical, easy to make, offering continuity and solidity and fast to bind with other materials. It is made by the mixture of cement, fine aggregate (sand), coarse aggregate (crushed or uncrushed stones) and water in the proper proportions. Concrete is used more than any other man-made material in the world [1]. As of 2006, about 7.5 km^3 of concrete are made each year-more than one cubic meter for every person on Earth [2]. The product will not be concrete unless all of these four components are present. The keys to good quality concrete are the raw materials required to make concrete and the mix design as specified in the project specifications. The strength of concrete mainly depends on w/c, slump, the type and quality of cement, mixing time, mix ratio, the grading and physical properties of aggregates, the degree of consolidation of wet concrete and the efficiency of curing, the age of the concrete and so on. Shortly, the factors involved in concrete strength development are of two categories: materialistic and managerial. The present study focuses the relative strength performance of various types of coarse aggregates.

Three types of coarse aggregates are used in Bangladesh: stone shingles (40 mm-downgraded natural uncrushed stones), stone chips (40 mm-downgraded crushed stones) and *khoa* (40 mm-downgraded crushed bricks of grade A [3]. Stone shingles are cheaper than stone chips and *khoa* are cheaper than shingles in the local market. A study on the relative strength performance of stone shingles to stone chips for low-grade concrete (cube strength at 28th day up to 15 MPa) was conducted

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before [4]. It revealed that 6~11% higher strength was attained for uncrushed aggregates than crushed when cement content and slump were kept constant. Another study [5] on medium grade concrete (concrete having cube compressive strength of 6~50 MPa at 28th day) also showed that uncrushed aggregates provided more strength (22% after 28 days) than crushed aggregates. No study is available on the strength performance of *khoa*.

The objective of the study was to assess the compressive strength of concrete according to their mix design ratio for various types of locally available coarse aggregates as stone shingles, stone chips and *khoa* and water-cement ratios (w/c) while other parameters were kept constant. It was also under the study that either *khoa* was capable to surpass the least required compressive strength for residential buildings or not. The study ensured that standard concrete mix design provided the desired strength.

MATERIALS AND METHODS

Properties of Cement: Commercially purchased ordinary Portland cement was used in the experiments. Properties of the cement were determined first. Normal consistency and setting times were determined by using Vicat apparatus and test methods conform to the standard requirements of specification C187 and C191 [6] respectively. The compressive strength of the cement mortars was measured and test method conforms to the standard requirements of specification C109 [6]. A 200mm sieve was used for fineness test. The properties of cement found from laboratory tests are shown in Table 1. The cement used for the laboratory experiment ensured satisfactory properties (according to ASTM C150) as a binding material for concrete.

Table 1: Properties of cement used in the laboratory experiment

Cement Properties	Values: Experimented	Values: Standard[1]
Normal Consistency	28.5%	22~30%
Fineness	91.2%	minimum 90%
Initial Setting Time	64 min.	≥45 min
Final Setting Time	167 min.	≤375 min
Compressive Strength (28 days)	33.5 MPa	27.6 MPa

[1](Aziz, 1995; Hossain and Seraj, 1985)

Table 2: Properties of aggregates used in the laboratory experiment

Aggregates	Specific gravity	Absorption	Fineness Modulus
Stone shingles	2.76	0.34%	-
Stone chips	2.75	0.32%	-
Khoa	2.35	0.30%	-
Sand	2.70	2.46%	2.54

Properties of Aggregates: Locally available coarse and fine aggregates were used in the study. Standard test method ASTM C136 [6] was used for sieve analysis of fine and coarse aggregates. For coarse aggregates, the sieve analyses were performed through standard sieve sizes of 50, 37.5, 20, 14, 10, 5 and 2.36 mm by a mechanical sieve shaker for 15 minutes. On the other hand, standard sieve sizes of 4.75, 2.36, 1.18, 0.6, 0.3, 0.15 and 0.075 mm were used to analyze the fineness of sand. The sieve analyses results are shown in Figure 1. Specific gravity and absorption of coarse aggregates was determined according to Standard test method ASTM C127 [6] whereas for fine aggregates, Standard test method ASTM C128 [6] was used. The properties of aggregates used in the laboratory experiment are shown in Table 2. The percentage of specification ensured the sand grade as of zone-1 [7]. The percentages of passing through sieves were obtained as per the standard specification percentage for coarse aggregates.

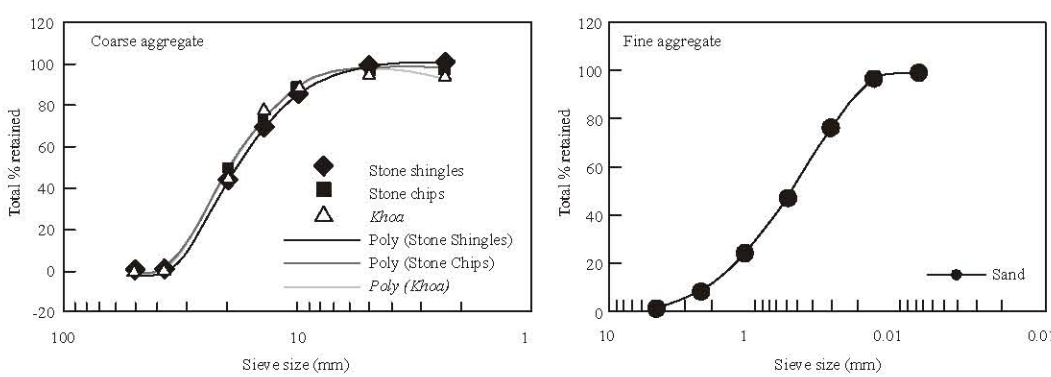

Fig. 1: Sieve analyses of coarse and fine aggregates used in laboratory experiment with 2nd order polynomial trend-line

Table 3: Slump for various mix design

Coarse aggregate	w/c	Mix ratio	Slump (mm)
Stone shingles	0.40	1: 1.88: 3.56	38.1
	0.45	1: 2.31: 3.93	38.9
	0.50	1: 2.61: 4.44	38.1
Stone chips	0.40	1: 1.39: 2.63	38.1
	0.45	1: 1.72: 2.93	38.6
	0.50	1: 1.95: 3.33	38.1
Khoa	0.40	1: 1.28: 2.43	38.6
	0.45	1: 1.59: 2.70	38.1
	0.50	1: 1.81: 3.08	38.6

Slump for Different Mix Designs: Slump tests were conducted for various w/c and mix designs. Standard test method ASTM C143 [6] was used for the test. Mix design ratios, as shown in Table 3, were followed as cement to sand to coarse aggregate. The 40mm downgraded coarse aggregate, ordinary Portland cement and zone-1 graded sand [3] were used for slump test. Slump was measured by the following relation

Slump in mm = 305-height in mm after the subsidence

The values of slump for all w/c and mix design ratios were in between 38.1~38.9 mm, as shown in Table 3, expressed low workability [8]. As the standard mix design ratio of cement to sand to coarse aggregate is 1:2:4, for three types of w/c, stone shingles maintained the mix design ratio satisfactorily. The mix design ratios were calculated by simplified concrete mix design [8].

Cube Test for Concrete: Concrete cubes were made in standard cubic moulds [6] as predefined mix design ratios and w/c. Mechanical vibrator was used to compact and fill the voids. Segregation was avoided carefully while vibrator used. After hardening, the concrete cubes were separated from the mould and kept in water for curing. The compressive strengths at 3, 7, 14 and 28 days were checked. At each checking day 5 specimens of each type were constructed. Method of testing conformed to the standard requirements of specification BS1881 [6].

RESULTS AND DISCUSSION

From laboratory experiments, it was revealed that stone shingles gained 20% higher strength than that of *khoa* and stone chips gained 13% higher strength than that of *khoa* at 28th day. Though stone chips and *khoa* had sharp irregular shape rather than stone

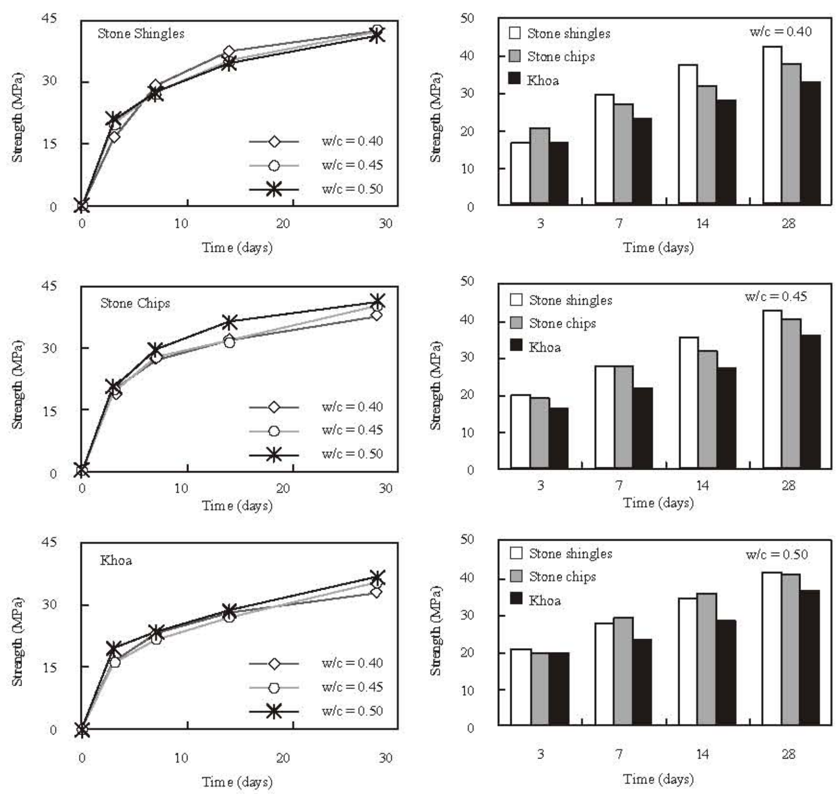

Fig. 2: Comparative strength performance of concrete with different aggregates and w/c ratio

shingles, they showed lower strengths in the study. The reason behind that was mainly the usage of designed concrete mix instead of standard mix, which directly related to the strength of concrete. The maximum compressive strength for stone shingles was found at w/c of 0.45 as 42.8 MPa after 28 days. The highest compressive strength of stone chips was found as 41.2 MPa when the w/c was 0.50. The highest compressive strength of *khoa* was found as 36.8 Mpa which contented the 28th day design strength for structurally reinforced concrete work (www.maturitycentral.com) at w/c of 0.50. As per prediction, in Figure 2, *khoa* showed lower compressive strength for all conditions than that of stone shingles and stone chips. Due to lower specific gravity of *khoa*, lower concrete density was achieved and lower density indicated lower strength. *Khoa* showed more strength, in every checking day, at w/c ratio of 0.50 compared to the strengths found at w/c ratios of 0.40 and 0.45. As w/c of 0.40 indicates low workability, stone shingles showed higher strength than others. The compressive strengths of stone chips and *khoa* at w/c of 0.40 showed lower strength at all checking times possibly due to bad workmanship. However, the trend-line of strength for stone chips and *khoa* showed similarity at all w/c. Compare to stone chips and *khoa*, stone shingles nearly satisfied the standard mix design ratios. The extra water requirement can be defined as the amount of water needed for obtaining same workability or slump on design mix and 10% of the extra water requirement was found for stone chips than that of stone shingles [5]. As *khoa* had lower specific gravity and absorption percentage compared to other aggregates used in this study, the requirement of water is higher than that of other used aggregates to obtain same workability. This study also revealed that, for stone shingles, 10% less water was required than for *khoa*. The comparative strength performance at various aggregate types and w/c is shown in Figure 2. In the bar charts of Figure 2, the compressive strength of concrete made of stone chips appeared significantly higher, at 3rd day while w/c was 0.40. After one and two week, the concrete made with stone chips also showed the maximum strength with respect to others at those days.

CONCLUSION

From the Study it Can Be Concluded That:

- Stone shingles are appropriate for medium grade concrete for better performance in terms of strength and economy over crushed stones according to their own mix design ratios.
- The maximum compressive strengths for stone shingles, stone chips and *khoa* were found at w/c of 0.45, 0.50 and 0.50 respectively after 28 days.
- Although *khoa* shows lowest strength among all types of studied coarse aggregates, *khoa* from good bricks can satisfy the least requirement of concrete compressive strength for construction of residential buildings. Moreover, *khoa* is available everywhere in Bangladesh and economical.
- Lower specific gravity provided lower compressive strength.
- Stone shingles require less water than other types of coarse aggregates.

ACKNOWLEDGEMENT

This study was financially supported from the research budget of the Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology, Sylhet, Bangladesh.

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