Effect of Shape and Surface Texture of Coarse Aggregates on the Compression Strength of Concrete

SHEAVON E. SANCHEZ
ARISTON G. TRINIDAD
METODIA M. TRINIDAD
VICENTE E. EMPIG

Abstract

The study is conducted to investigate the effects of two types of coarse aggregates, the natural washed and crushed aggregates that vary in shape and surface texture on the compressive strength of concrete. This study also illustrates the variation of the compressive strength of concrete with three types of cement-aggregate ratio, 1:2:3, 1:2:4 and 1:2:5.

Keywords: Shape and Surface Texture of Coarse Aggregates, Sieve Analysis of Fine and Coarse Aggregates, Absorption Test, Curing

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SHEAVON E. SANCHEZ, a BS Civil Engineering Graduate (March, 2005) at MSU-IIT. Iligan City. She is from Pagadian City. ARISTON G. TRINIDAD, a Professor, College of Engineering, MSU-IIT, Iligan City; with a Maters Degree in Structural Engg. & Mechanics (1981) from Asian Institute of Technology, Bangkok, Thailan. METODIA M. TRINIDAD, Associate Professor, College of Engineering, MSU-IIT, Iligan City; with a Maters Degree in Transportation Engineering (1987) from Asian Institute of Technology, Bangkok, Thailand. VICENTE E. EMPIG, Professor, College of Engineering, MSU-IIT, Iligan City; with a Masters Degree in Geotechnical Engineering (1981) from Asian Institute of Technology, Bangkok, Thaniland.

In this study, the water-cement ratio used for the three cement-aggregate ratios is designed to be constant at 0.50. However, the absorption of aggregates that reduces the effective water-cement ratios has not been accounted for. The results of the experiment show that concrete samples with natural washed aggregates have compressive strengths higher than those with crushed aggregates by as much as 33 %. The results also show that the cement-aggregate ratio of 1:2:4 yields the highest compressive strength for both types of coarse aggregates. The results are non-conclusive because of deficiencies in the preparation of concrete specimens.

Introduction

Concrete is a composite material consisting essentially of a binding medium within which the particles or fragments of aggregates are embedded; in Portland cement concrete, the binder is a mixture of Portland cement and water. Hardened concrete, which is the final building material as it is obtained after stiffening, setting and hardening of fresh concrete, possesses the following properties: strength, density, durability, impermeability and thermal properties. In this study, strength or compressive strength of concrete, which is the most important characteristic of hardened concrete, is given primary consideration. High compressive strength is, in most cases, accompanied also by an improvement of the other properties. Therefore, it is considered as a general measure of concrete quality.

Aggregates refer to natural or artificial materials, which are mixed with cement and water to provide bulk in concrete. For aggregates to be suitable in concrete, they should consist of hard, strong and durable particles. They must also comply with certain grading limits. Aggregates should not have large deficiencies or excesses of any size; undersized or oversized particles are limited. The surface characteristics of aggregates are of importance, in particular, the particle shape and surface texture. This is the primary consideration of the study, to determine how the shape and surface texture of the aggregates affect the compressive strength of concrete. Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded, compact aggregate (Herubin and Marotta, 1987).

Cement, the binding medium of concrete, is an adhesive substance that is capable of uniting fragments or masses of solid matter to a compact whole. There are two general types of cement: the organic cement and the inorganic cement. The hydraulic cement, which is a type of inorganic cement, is used in the study. It hardens when mixed with water and the hardened solid is practically insoluble in water. The hardened solid can therefore withstand exposure to water or seawater. The most common type of hydraulic cement, the Portland cement (Type 1) is used in this study. It is produced by pulverizing clinker with a calcium sulphate additive, the former being prepared by igniting a mixture of raw materials, one of which is mainly composed of $CaCO_3$ and the other of aluminium silicate.

In this study, the cement, sand and water are kept constant, while the gravel type varies according to its texture. The gravel types that are used are the natural washed and the crushed aggregates. Natural washed aggregates have smooth, rounded surfaces, while crushed aggregates have rough, angular surfaces.

Objectives of the Study

The objectives of the study are as follows:

a) To evaluate the effect of shape and surface texture of coarse aggregates on the compressive strength of concrete;
b) To determine the effect of cement-aggregate ratio on the compressive strength of concrete.

Methodology

Materials and Equipment, Aggregates, Cement

The coarse aggregates (both natural-washed and crushed) are all taken from a hollow block factory located in Tambo, Iligan City. The natural washed aggregates originally came from a quarry site at Mandulog, Iligan City, while the crushed aggregates are taken from L.T. Gersan Batching Plant located Tambo, Iligan City. One sack (the size of cement sack) each for the two types of aggregates are used for the mixing and casting of concrete samples.

The natural washed aggregates used are mostly rounded, smooth, and greyish and brownish in color. The crushed aggregates, on the other hand, are rough-textured, angular, and greyish in color. Photos of samples of natural washed and crushed aggregates are shown in Figure 1 and 2.

Figure 1. Sample of Crushed Aggregates

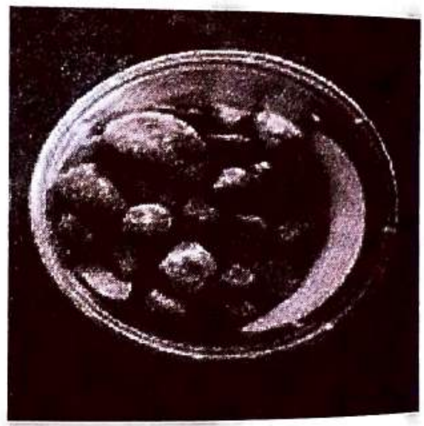

Figure 2. Sample of Natural Washed Aggregates

For the production of concrete samples in this study, two sacks of sand are taken from the same hollow block factory located in Tambo, Iligan City. The sand used is a natural sand with a slight mixture of very fine gravel.A sack of Type 1 Portland cement is used in the study. The water for mixing is taken from MSU-IIT distribution lines supplied by Iligan City Water Works District.

The apparatus and equipment used in this study - the Universal Testing Machine, container for mixing samples, shovel, mason's trowel and the standard stamping rod - mostly come from the MSU-IIT Engineering Material Testing Laboratory. The cylindrical molds are fabricated using a 4-in. diameter PVC pipe. The molds used are not based on ASTM standard which is 6" by 12" since there is not enough available molds of this size in the Soil Mechanics Laboratory at the MSU-

IIT. However, ASTM C31 states that compressive strength specimens shall be cylinders of concrete cast and hardened in an upright position, with a *length equal to twice the diameter*. So, the researcher uses instead a mold with a diameter of 4 in. and a height of 8 in.

Tests Conducted

A series of tests were conducted that are significant to the study. These are: sieve analysis for fine and coarse aggregates, unit weight determination test, absorption test, and compression test.

Mixing and Casting

Mixing of concrete is done in 3 different cement-aggregate proportions: 1:2:3, 1:2:4, and 1:2:5 for each gravel type, natural washed and crushed aggregate. The method used is proportioning by weight. Before the actual mixing is conducted, the aggregates are in their surface-dry condition. The preparation of the aggregates is initiated by weighing them according to the prescribed cement-aggregate ratio. The water-cement ratio is kept constant at 0.5.

Thus, 18 specimens are cast at the Micro-Concrete Roofing (MCR) area at the MSU-IIT. The mixing and casting of concrete for the production of 9 samples using natural washed aggregate is done in one day. The second production of samples using crushed aggregate is done the following day. The process of mixing and casting of concrete is done in accordance with ASTM C31 which is the standard method for making concrete test specimens in the field.

Curing

Since all the desirable properties of concrete are improved by curing, the curing period should be as long as practicable in all cases. In this case, the researcher is only concerned on the 28-day compressive strength of concrete, so the curing period is 28 days. Fortunately, there is no damage observed on each sample during removal from molds. Curing process starts after the samples are taken out of the cylindrical molds. The concrete samples without the molds are soaked in water for 28 days.

At the end of the 28th day, the samples are all taken out of the water and are allowed to dry for testing.

Compression Test

Compression test is conducted on each set of samples at the Materials Testing Laboratory at the MSU-IIT after the 28-day curing period. The samples are removed from the cylindrical molds and are tested using the Universal Testing Machine (UTM) as shown in figure 3 and Figure 4. The maximum load applied on each specimen is recorded and the average compressive strength is computed by dividing the maximum load applied by the cross-sectional area of the cylindrical sample.

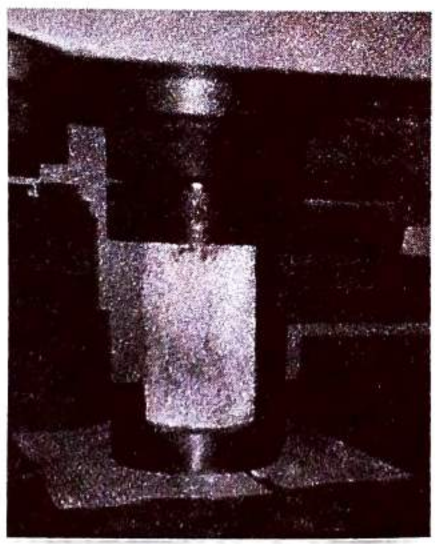

Figure 3. Compression Test of Concrete Sample

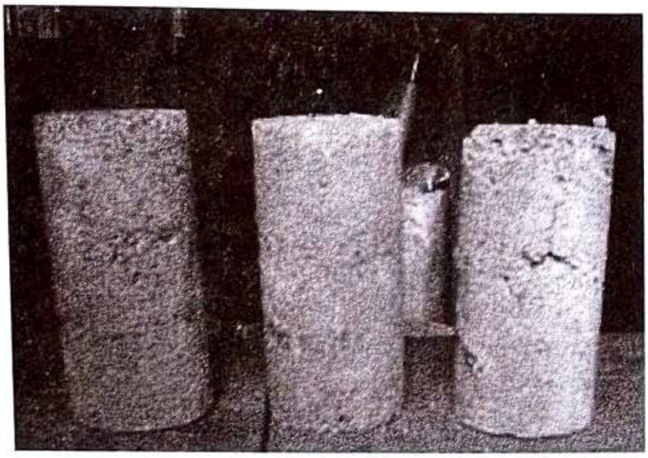

Figure 4. Typical Outcome After Compression Test

Results and Discussions

Compression Test

Figure 5 shows that concrete samples with natural washed aggregates yield higher compressive strength for the 3 different cement-aggregate ratios as compared to the concrete samples with crushed aggregates. This finding is in conflict with generally accepted trend, since crushed aggregates, as cited in the review of related literature, contribute to high strength, therefore concrete samples with crushed aggregates should have also yielded higher compressive strengths than those with natural washed aggregates. The reason for this is attributed mainly to the lower effective water-cement ratio used and the improper preparation of aggregates before mixing. As indicated in the absorption test conducted and also cited in the literature review, crushed aggregates absorb more water than natural washed aggregates. Therefore, the effective amount of water used for the mixture using the crushed aggregates – 777.29 g for 1:2:3, 606.08 g for 1:2:4, and 522.75 g for 1:2:5 - are lower compared to that of the natural washed aggregates – 875.8 g for 1:2:3, 832.96 g for 1:2:4, and 634.5 g for 1:2:5. Thus, the water available for hydration is insufficient or there is not enough water that is available for complete reaction with cement to take place. The number of tamping times is also not exactly 25 as it should have been. The concrete samples after one day were observed to be weak and not properly compacted which is an indication that mix was deficient in cement-sand component.

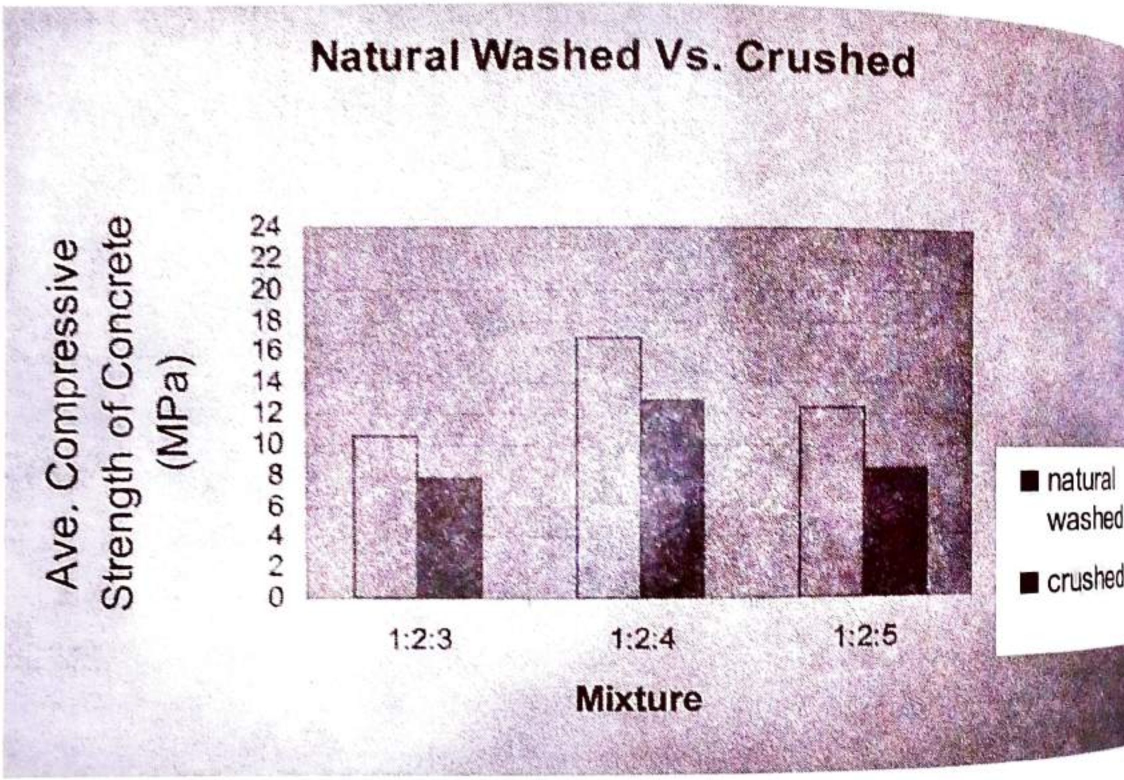

Figure 5. Average Compressive Strength of Concrete (Natural Washed Coarse Aggregates Vs. Crushed Coarse Aggregates)

Statistical Analysis

The structure of hypothesis testing is formulated with the use of the term *null hypothesis*. The *null hypothesis* refers to any hypothesis we wish to test that is designed to be rejected and is denoted by Ho. The rejection of Ho leads to the acceptance of an alternative hypothesis, denoted by Ha. The acceptance of a hypothesis merely implies that the data do not give sufficient evidence to refute it. On the other hand, rejection implies that the sample evidence refutes it.

The P-Value approach has been adopted extensively by users in applied statistics. The approach is designed to give the user an alternative (in terms of probability) to a mere "reject" or "do not reject" conclusion. A P-value is the lowest level (of significance) at which the observed value of the test statistic is significant (Walpole and Myers, 1998). At 5.0% significance level, when the P-Value obtained is less than 0.05, the null hypothesis is rejected and the alternative hypothesis is accepted. When the P-Value is greater than 0.05, the null hypothesis is accepted.

Ho_1: There is no statistically significant difference on the compressive strength of concrete between natural washed and crushed aggregates.

Ha_1: There is a statistically significant difference on the compressive strength of concrete between natural washed and crushed aggregates.

Since the P-Value of the F-tests in Table 3 is 0.2142, which is greater than 0.05, the null hypothesis is therefore accepted. Statistically, there is no significant difference on the compressive strength of concrete between natural washed and crushed aggregates at 0.05 significance level.

Table 3. Anova Table for the Compressive Strength of Concrete Using Crushed and Natural Washed Aggregates

Source	Sum of Squares	D. F.	Mean Square	F - ratio	P - value
Between groups	20.008	1	20.008	2.18	0.2142
Within groups	36.772	4	9.193		
Total (corr.)	56.780	5			

From Table 4, we can see that natural washed aggregates produce higher mean value of compressive strength as compared to crushed aggregates.

Table 4. Summary of Statistics

Sample	Count	Mean	Median	Std deviation
natural	3.0	13.0	12.00	3.00
crushed	3.0	9.7	8.39	2.77

Table 5 on the range tests between the compressive strength of concrete between natural washed and crushed aggregates justifies the null hypothesis from the ANOVA table. The tests signify that statistically, there is no significant difference on the compressive strength of concrete between natural washed and crushed aggregates at 0.05 significance level.

Table 5. Range Tests

Multiple Range Test; Response variable: Col. 1; Method: 95.0 percent LSD			
Col. 2	Count	Mean	Homogeneous Groups
crushed	3	9.70112	X
natural washed	3	13.3533	X
Contrast		Difference	+/- Limits
natural washed – crushed		3.65221	6.87344
* Denotes a statistically significant difference			

Figure 6 compares the means plot of the compressive strength of concrete using natural washed and crushed aggregates. Natural washed aggregates produce higher mean value as compared to crushed aggregates.

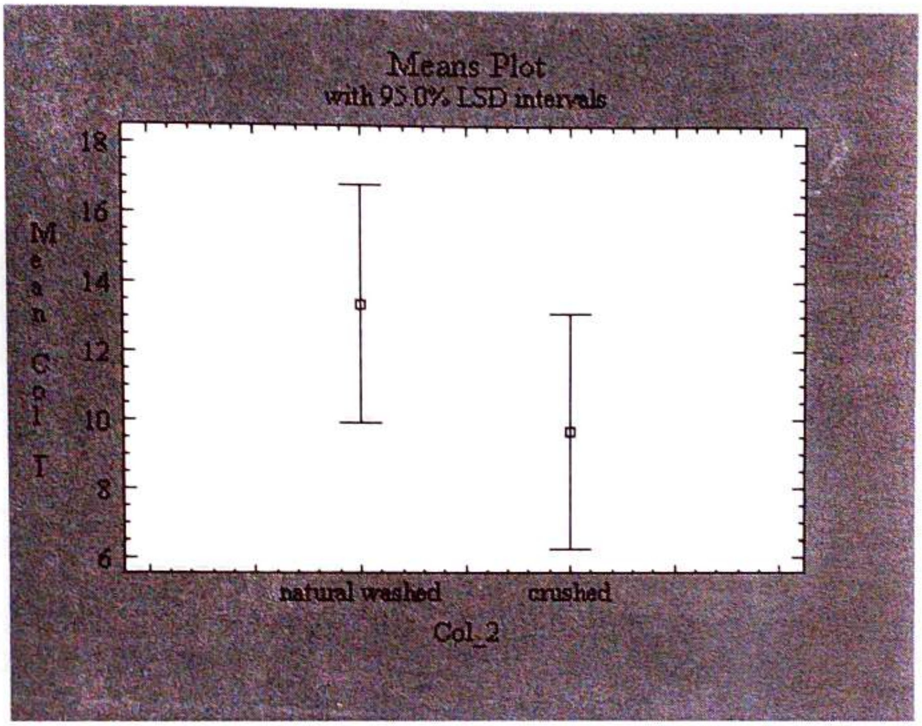

Figure 6. Means Plot for the Compressive Strength of Concrete using Natural Washed Aggregates and Crushed Aggregates

Conclusion

After conducting the compression test for the samples using both the natural washed and crushed coarse aggregates, the researcher arrives at the following conclusions:

1) At 5% significance level, statistically, there is no significant difference on the compressive strength of concrete among the three different cement-aggregate ratios using natural washed coarse aggregates.
2) At 5% significance level, statistically, there is a significant difference on the compressive strength of concrete among the three different cement-aggregate ratios using crushed coarse aggregates.

3) At 5% significance level, statistically, there is no significant difference on the compressive strength of concrete between the use of natural washed and crushed aggregates.
4) For both cement-aggregate proportions, the ratio of 1:2:4 have relatively higher values than the other 2 ratios.
5) There is a variation on the compressive strength of concrete between use of natural washed and crushed aggregates. Natural washed aggregates yield higher compressive strength compared to that of crushed aggregates by as much as 33% as indicated in Appendix C-4.

However, the results are non-conclusive because of the deficiencies in the preparation of the concrete specimens and some errors in the procedure.

Recommendations

The following recommendations are presented for similar studies that may be conducted by other researchers.

1) Adjust the water content to account for absorption of aggregates in order to maintain constant water-cement ratio.
2) To obtain standard results of compressive strength, use the ASTM standard size for concrete cylinder, 6" x 12".
3) Conduct a slump test for each cement aggregate ratio to determine the workability of the concrete samples.
4) Produce 5 samples or more for each proportion to improve reliability of data.
5) Vary the mixtures by adding a certain percentage of natural washed aggregates to the crushed aggregates to see if it affects the compressive strength.
6) Research more on studies related to the effect of the shape and surface texture of coarse aggregates on the compressive strength of concrete.

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