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EFFECT OF AGGREGATE FRACTION ON CONCRETE STRENGTH

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Abstract: There have been contentions as to whether the coarse aggregate phase or the mortar phase is the primary contributor to the strength of concrete and, consequently, how reducing coarse aggregate fraction would affect the strength. To shed some light on this matter, this study focused on the influence of aggregate fraction on the strength properties of concrete such as compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity. Total aggregate and coarse aggregate fractions were varied while water-cement ratio was kept constant. Test results of total aggregate fraction indicated that the compressive and the spilt tensile strength initially decreased with the addition of total aggregate volume, but gradually increased with further addition of total aggregate volume. The flexural strength and the modulus of elasticity generally increased with the addition of total aggregate volume. Test results of coarse aggregate fraction indicated that the percentage of coarse aggregate did not significantly affect the compressive strength of concrete, especially for water-cement ratio of 0.7. The splitting tensile strength and flexural strength decreased when the percentage of coarse aggregate was reduced. However, the modulus of elasticity increased with further addition of coarse aggregate volume.

Key Words: Aggregate content, compressive strength, tensile strength

1. INTRODUCTION

Although the strength of concrete depends primarily on water-cement ratio (W/C), the properties and volume of aggregate are also the important factors affecting strength. There are also questions as to whether inclusion of coarse aggregate weakens or strengthens the mortar phase of the concrete. In addition, not much is known about the dependence of concrete performance on the percentage of aggregate or about how the aggregate fractions affect the properties of concrete. This study therefore aimed to find various strength properties of concrete using varying values of aggregate content. For this study, the following needs to be clarified:

1. Total aggregate means fine and coarse aggregate. And 100% of total aggregate fraction means the amount of total aggregate as calculated from ACI 211.1-91.
2. Coarse aggregate – 100% of coarse aggregate fraction means the amount of coarse aggregate as calculated from ACI 211.1-91.

Scope of work: The study covers aggregate content from zero to the amount calculated from ACI 211.1-91. Properties investigated were compressive strength, splitting tensile strength, flexural strength and static modulus of elasticity.

2. EXPERIMENTAL PROGRAM

Materials: Ordinary Portland Cement (Type I), 10 mm and 20 mm limestone and clean river sand with fineness modulus of 2.6 were used in this study.

The principal variables involved in this investigation are the proportion of fine and coarse aggregate. This investigation could be divided into two parts as follows:

Part 1: Effect of Total Aggregate Fraction – 46 concrete mixes and 324 specimens were applied in this part. The specimens were under the tests and variations, as follows:

Compressive Strength Test – the specimens were varied with the total aggregate fraction of 0, 25, 50, 75, and 100 percent and water-cement ratio to 0.4, 0.55, and 0.7. Also, the average of 6 specimens was used.

Splitting Tensile Strength, Flexural Strength, and Modulus of Elasticity Test – the specimens were varied with the total aggregate fraction of 0, 33, 66, and 100 percent and water-cement ratio of 0.4 and 0.7. Also, the average of 3 specimens was used.

Part 2: Effect of Coarse Aggregate Fraction (by coarse aggregate addition) – 46 concrete mixes and 324 specimens were applied in this part. The specimens were under the tests and variations, as follows:

Compressive Strength Test – the specimens were varied with the coarse aggregate fraction of 0, 25, 50, 75, and 100 percent and water-cement ratio of 0.4, 0.55, and 0.7. Also, the average of 6 specimens was used.

Splitting Tensile Strength, Flexural Strength, and Modulus of Elasticity Test – the specimens were varied with the coarse aggregate fraction of 0, 33, 66, and 100 percent and water-cement ratio of 0.4 and 0.7. Also, the average of 3 specimens was used.

The specimen sizes for each type of test are as follows:

1. Testing of compressive strength – 75 mm cube
2. Testing of tensile strength – 100 mm diameter by 200 mm long cylinder
3. Testing of modulus of elasticity - 100 mm diameter by 200 mm long cylinder
4. Testing of flexural strength – 75x75x300 mm prism

As a measure to keep water-cement ratio constant between batches of varying aggregate content, the mixes were started with aggregate content of zero. After thorough mixing was achieved, a portion was taken out for specimen casting. A measured portion of the aggregate was then added to the remaining material, followed by further mixing. The procedure was repeated until the aggregate content reached the amount calculated using the procedure outlined in ACI 211.1-91.

3. RESULTS

Total aggregate contents: The results of the effect of total aggregate fraction on the compressive strength, splitting tensile strength, flexural strength and the modulus of elasticity are shown in Figure 1 to 4, respectively. For compressive strength behaviour, in Figure 1, it can be seen that, initially, the compressive strength dropped significantly with the addition of fine and coarse aggregates. With further addition, however, the drop started to bottom out, at about 50% total aggregate. After that the trend was reversed and the strength steadily increased until, at the end, it was slightly higher than the level at the start of the aggregate addition. This trend was irrespective of the aggregate size (10 mm and 13 mm) and the water/cement ratio (0.40, 0.55 and 0.70). It is noted that the splitting tensile strength in Figure 2 showed similar behaviour, although the drop and later the regain in strength was perhaps not as significant as those in found in the compressive strength. With flexural strength and modulus of elasticity, Figure 3 and 4, no initial drops were observed, the strength rises began at the first addition of the aggregates, and continued to do so until the maximum aggregate content was reached. The increases in both the flexural strength and the modulus of elasticity were substantial. Both showed the final strength at over twice the initial strength.

The above behaviour suggested there were two or more mechanisms involved in contribution of the fine and coarse aggregates to the strength properties of concrete, with each mode showed dominance in certain range of aggregate content.

The overall effect however, was that varying total aggregate content significantly affected the compressive and the splitting tensile strength, with the 100 percent total aggregate content giving the highest strength. Furthermore, addition of fine and coarse aggregates substantially increased the flexural strength and the modulus of elasticity. The increases were observed at every level of addition and, at the end, accounted for over 100 percent of the initial strength.

The effects of coarse aggregate content on the strength properties of concrete are shown in Figure 5 – 8. As shown in figure 5 and 8, adding coarse aggregate into the mix had the effect of slightly (about 5 to 10 percent) increasing the compressive strength and the modulus of elasticity. This was true for all water/cement ratios and sizes of aggregate. As for the splitting tensile strength and flexural strength, as shown in Figure 6 and 7, increase in coarse aggregate content appeared to decrease both strength, for mixes with the water/cement ratio of 0.4. The effect was not clear for mixes with water/cement ratio of 0.7, which exhibited small to no change in strength at all.

Overall, the effect of coarse aggregate on the strength properties of concrete appeared to be to cause a small, of the order of 5 to 10 percent, changes in the strength, for mixes with water/cement ratio of 0.4. The effect was not clear for the high water/cement ratio mixes.

4. CONCLUSIONS

From the results of the study, the following conclusions can be made.

1. Total aggregate content had mixed effect on the compressive strength and splitting tensile strength, decreasing the strength at low aggregate content and increasing at the high range. The highest strength were achieved at the 100 percent total aggregate content.
2. Total aggregate content significantly and substantially increased the flexural strength and the modulus of elasticity, by over 100 percent.
3. Addition of coarse aggregate content had little effect on the strength properties of concrete, particularly those with high water/cement ratio.

REFERENCE

ACI Committee 211.1. 1994. Standard Practice for Selecting Proportions of Normal, Heavyweight, and Mass Concrete. ACI 211.1-91 (revised 1994). Amer. Concr. Inst., Detroit. 38 p.

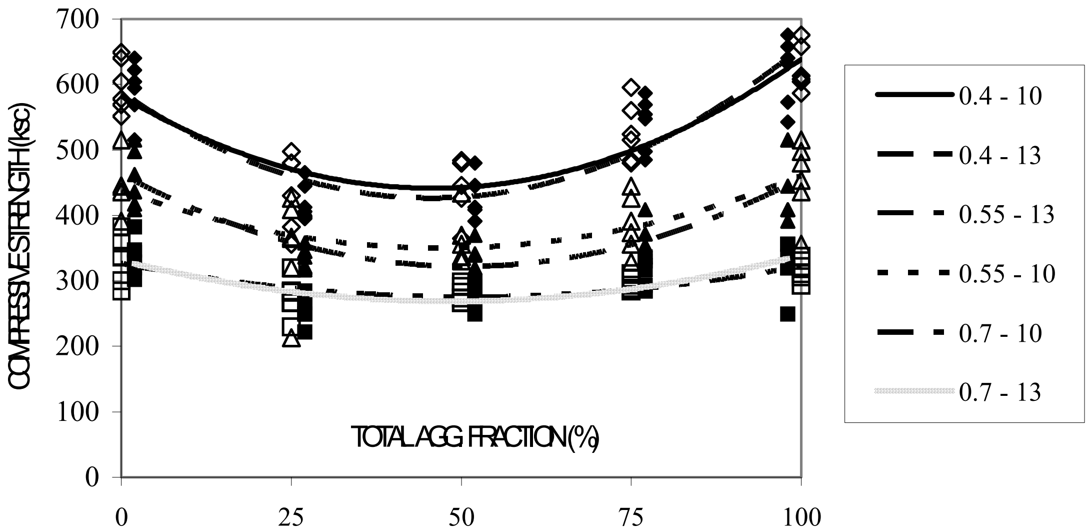

Figure 1. Relationship between compressive strength and total aggregate fraction.

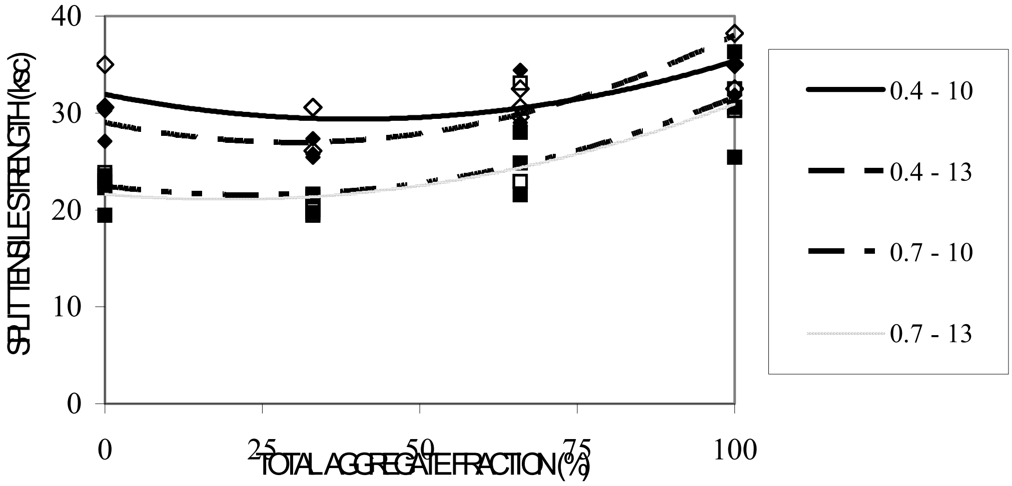

Figure 2. Relationship between split tensile strength and total aggregate fraction.

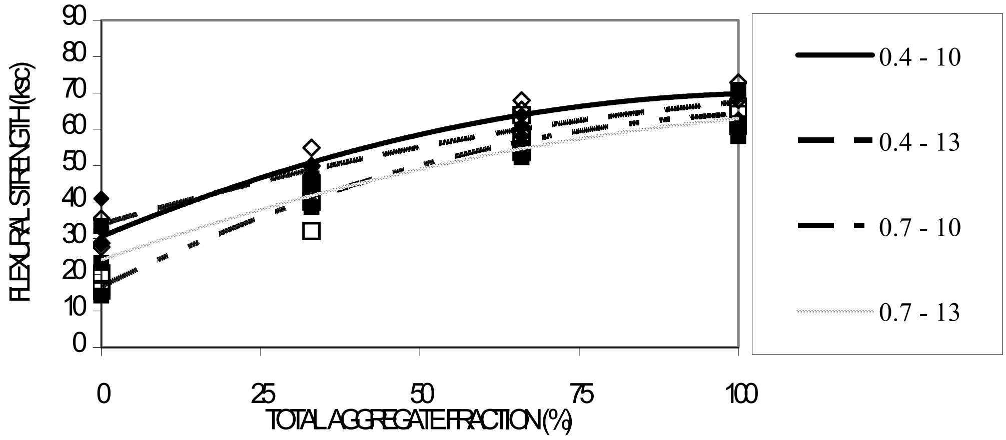

Figure 3. Relationship between flexural strength and total aggregate fraction.

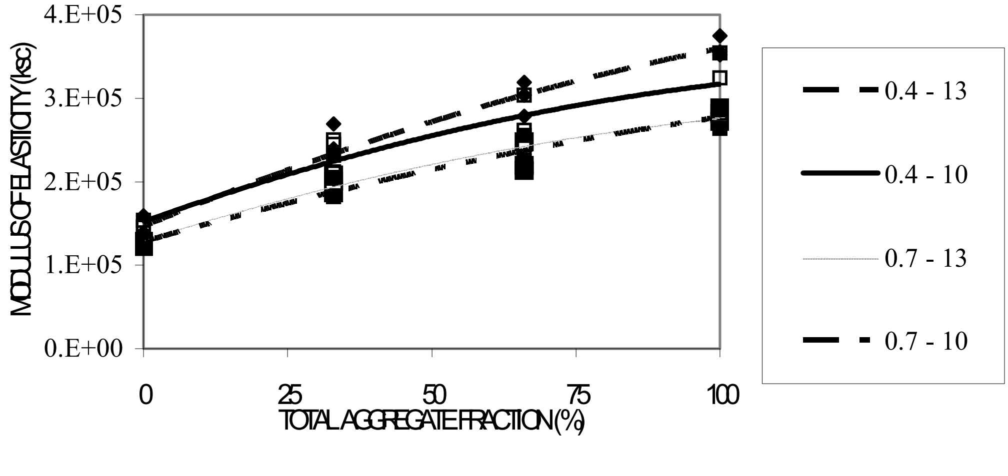

Figure 4. Relationship between modulus of elasticity and total aggregate fraction.

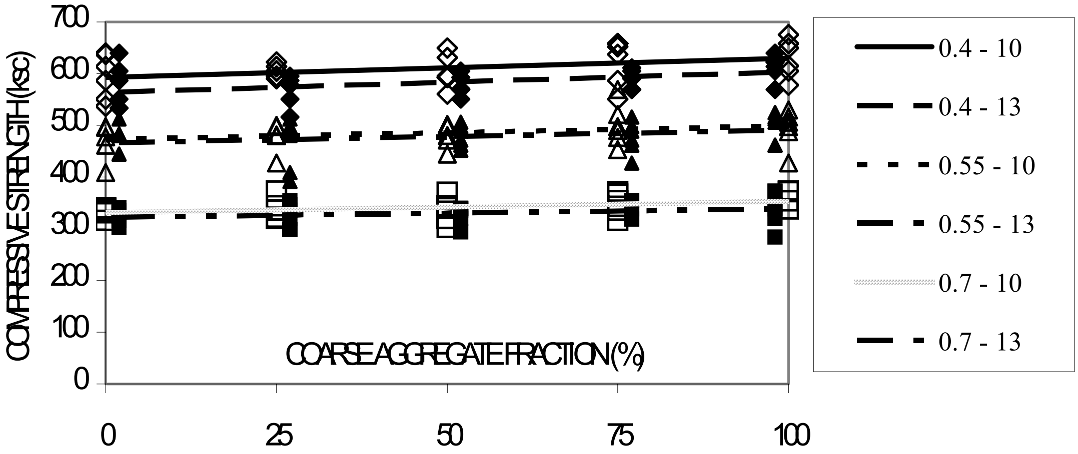

Figure 5. Relationship between compressive strength and coarse aggregate fraction.

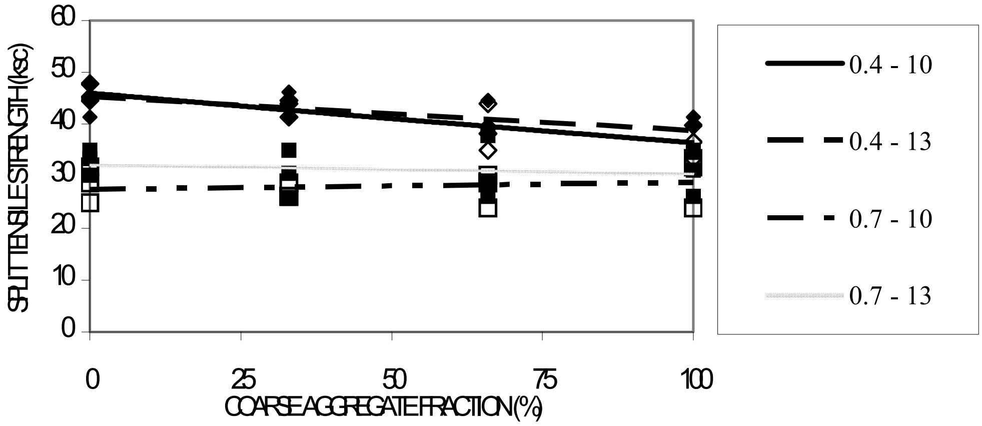

Figure 6. Relationship between splitting tensile strength and coarse aggregate fraction.

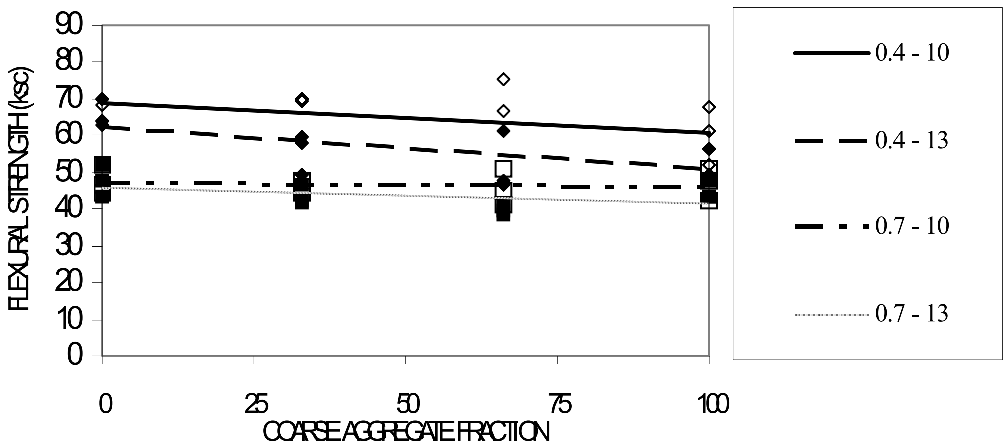

Figure 7. Relationship between flexural strength and coarse aggregate fraction.

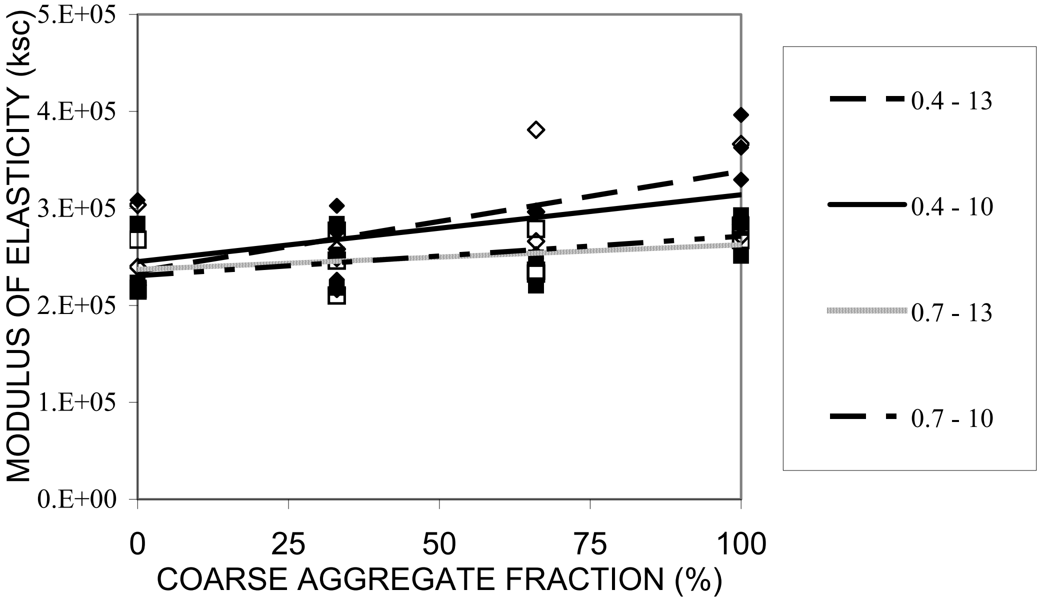

Figure 8. Relationship between modulus of elasticity and coarse aggregate fraction.