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SEMI LIGHTWEIGHT CONCRETES PRODUCED BY VOLCANIC SLAGS

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ABSTRACT

The properties of the semi-lightweight concretes produced by using volcanic slags as coarse aggregate were investigated. The volcanic slags were brought from the quarry crushed and then classified according to their aggregate sizes of 0-8, 0-16, 0-31.5, 4-8, and 8-16 mm. The concrete series of five different volcanic slag sizes were produced by addition of a specific cement paste in volume fractions of 0.15, 0.30, 0.45 and 0.60. The cubic, cylindrical and prismatic specimens were made from each of the concrete series. The physical and mechanical properties of the concrete series were determined by conducting unit weight, slump, ultrasound velocity, Schmidt hardness, cylindrical and cubic compressive, bending and splitting tensile strength tests. The results indicated that the volcanic slags can be safely used in the production of semi lightweight concrete.

Introduction

The goal here is to enable the concrete to gain new properties by using aggregates with different specifications. That the unit weight of normal concrete is high causes the weight of the construction itself to get near to the load it bears. The fact that the weight of the construction is high makes the earthquake and foundation problems harder and increases the cost. One of the areas of usage which lowers the unit weight and helps the concrete gain a certain degree of strength which has approximately equal the strength of normal concrete required by codes is lightweight concretes. One of the methods of producing lightweight concrete is to use light aggregate instead of normal concrete aggregates. In cases where the use of lightweight aggregate is limited, the production of semi lightweight concrete is under consideration (1,2,3,4).

In this study, the focus was on the properties of semi lightweight concretes produced with volcanic slags. It is desirable that the concrete intended to be used in the walls of pre-fabricated community housing projects should have low unit weight besides their properties of sound and heat insulation. In regions where slags are available in ample amounts, the use of these concretes might be useful in many ways. With the use of lightweight concrete in building, the weight of the construction would be lowered, thus a decrease in steel equipment and in cross sections of RC columns, beams, plates and foundation could be achieved. The air voids formed in the concrete by lightweight aggregates improves thermal insulating property, thus it lowers heat conductivity (4,5,6).

Experimental Studies

In this study (7), to determine the properties of volcanic slags, specimens of semi lightweight concrete were prepared with volcanic slag having five different coarse aggregate sizes. The equipment used, mixtures, specimens produced and the experiments done were given below.

In the production of concrete series, cement type of PC 32.5 was used. The sand used was 0-4 mm in size, specific gravity 2576, unit weight 1600 kg/m^3, fineness modulus 1.90 and water absorption in thirty minutes was 1%.

Microscopic examination of the volcanic slags are composing of sanidine, andesine and quartz phenocrystals and 1% pyroxene crystals in glassy matrix. It was predicted that the voids in the slag occured aftermaths in the matrix during cooling and its name might be hallowy rhyodacite. When it is in a cubic shape with one side measuring 7 cm, it was observed to have a unit weight of 1390 kg/m^3. Its compressive strength was 17 N/mm^2 and its abrasion was found to be 9% with Böhme abrasion device. When it was brought into concrete aggregate, specific gravity of the slag was found to be 1730, unit weight 1330 kg/m^3, water absorption 14%, porosity 0.22.

In preparing the mixtures a composition of mortar phase having 50% sand was taken into consideration; and for the examination of air voids, concretes were prepared with volcanic slag having five volume fractions such as 0.15, 0.30, 0.45 and 0.60. The water-cement ratio was kept constant as 0.40. Concrete series were made in five different aggregate sizes. On the fresh concretes made unit weight and slump tests were carried out, then six cylindrical specimens with dimensions of r = 15 and h = 30 cm, two prismatic specimens with dimensions of 10 × 10 × 50 cm and three cubic specimens with dimension of 20 cm were prepared. Specimens were removed from the moulds after 24 hours and they were kept in the curing tank for 28 days. With tests on hardened concrete unit weight, ultrasound velocity, Schmidt hardness, cylindrical and cubic compressive, splitting and flexural strengths were determined. On the pieces which were broken off the specimens after flexural test, values of 10 × 10 × 10 cm compressive strength were found.

Test Results

After the experiments conducted on series of fresh and hardened concrete, properties for workability and strength were determined. Changes in these properties were examined in relation with the aggregate-volume ratio and the results were given in the figures below.

<u>Evaluation of the Properties of Fresh Concrete</u>. Workability, which is an important concrete property, may change significantly in concretes of volcanic slag. Values obtained from the series by slump test are given in Figure 1. As seen from the figure, grain size and volume ratio affects workability. Especially after the volume ratio 0.45, with the addition of volcanic slag sudden falls in slump values are observed. The concretes that give an average slump of 23 while being at the state of liquid consistency promptly turn into low consistency after this value and their workability becomes more difficult. This situation appears earlier in the series with 4-8 mm aggregate size and the slump which is about 24 at 0.30 slag ratio falls to zero value at 0.45 ratio.

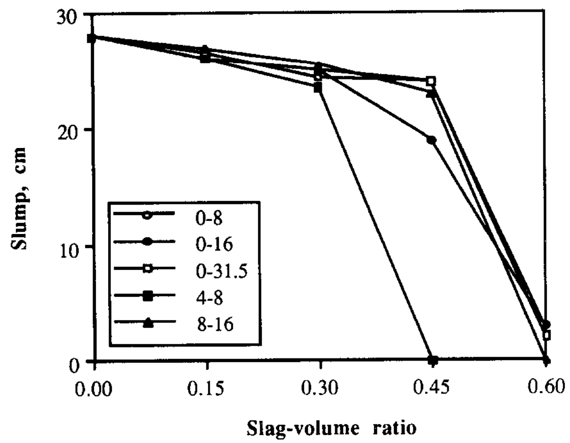

FIG. 1.
Changes in the amount of slump in relation with slag-volume ratio.

Evaluation of the Properties of Hardened Concrete. First ultrasound velocity test were conducted. Then Schmidt hardness tests were done with cubic specimens. The results obtained from these two tests, showed a decrease with the addition of slag, as is the case for all properties. The reason for the decrease in ultrasound velocity is the voids formed by the volcanic slag in the concrete. On the other hand, the reason for the decrease in Schmidt hardness is that the rigidity of the volcanic slag is lower than the cement paste.

Changes in the unit weight depending on the aggregate volume ratio were examined and the results are given in Figure 2. As will be easily seen from the figure, as the aggregate volume ratio increases, unit weight decreases. Using volcanic slags in concretes allows us to decrease the unit weight from about 2400 kg/m^3 down to 1800 kg/m^3. On the other hand, slags having sizes of 8-16 mm allows further decrease in unit weight.

In Figure 3, changes in the cylindrical compressive strengths obtained three specimens in relation with slag-volume ratio were presented. Gradually decreasing compressive strength values were obtained by the addition of slag to the mixture which gives 40 N/mm^2 values when it is in mortar state. It can be seen from the figure that C 16 quality concrete can be obtain from slags of 0.40-0.48, C 20 from slags of 0.34-0.42, C 25 from slags of 0.27-0.35. After seeing that these three different concrete qualities could be obtained with proper volume ratios, research was conducted to find out which of the grain sizes would be more economical. Since it is not used commonly, volcanic slag is a cheap material. So, the series containing the greatest amount of volcanic slag would be the most economical one. As the examination of Figure 3 will show, the series with 0-16 mm grain size is the one with the greatest amount of slag. When taking into consideration the average of the proper limits given above, one can decide that qualities of C 16, 20 and 25 can be obtained with slag ratios of 0.44, 0.38 and 0.31, respectively, and depending on this, volcanic slags can be used in concretes with volume ratios 0.31-0.44. Other

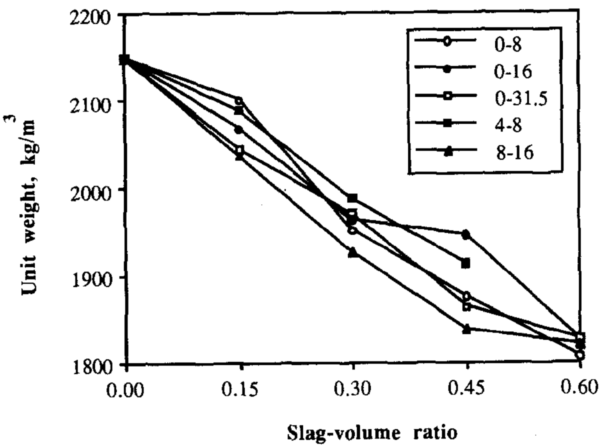

FIG. 2.
Changes in the unit weight in relation with slag-volume ratio.

properties examined in the current study have been evaluated in terms of these regions and the results were presented.

Changes in the cubic compressive strength in relation with slag-volume ratio are given in Figure 4. The results obtained from cubes of 10 (thin dashed lines) and 20 (thick lines) cm in dimension show the specimen size effect in the same concrete series. Cylindrical compressive strengths takes places between these two cube strengths. When it is in the state of mortar, that is, when there is no coarse aggregate in it, it was observed that as we added volcanic slag into

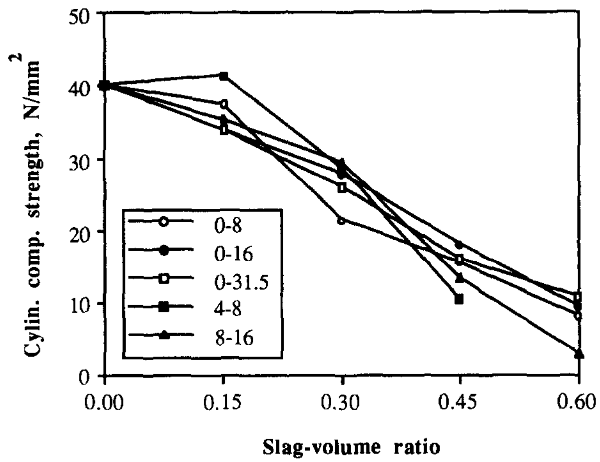

FIG. 3.
Changes in the cylindrical compressive strength in relation with slag-volume ratio.

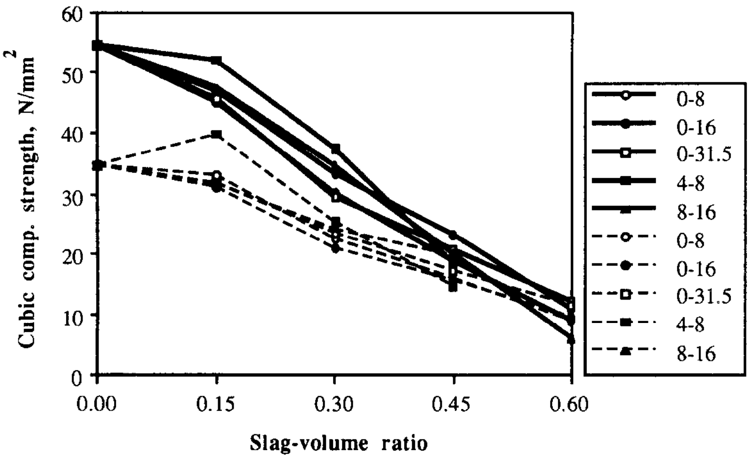

FIG. 4.
Changes in the cubic compressive strength in relation with slag-volume ratio.

the concretes giving 54.5 N/mm^2 cubic compressive strength in 20 cm dimensions, these values fell down to the 6.2 N/mm^2 for 0.45 slag volume ratios. In cube with the dimension of 10 cm, however, the same changes were observed falling from 34.4 N/mm^2 to 6.0 N/mm^2. When cubic and cylindrical compressive strengths were compared, increases were observed in 20 cm cubes. On the other hand, with 10 cm specimens the same concrete gave lower strength values. Smaller sizes of specimens lowers the strength, causing an imbalance in the adherence between the cement mortar and slag.

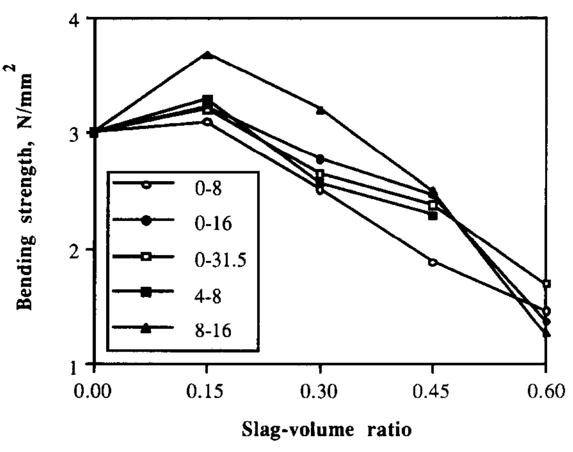

FIG. 5.
Changes in the bending strength in relation with slag-volume ratio.

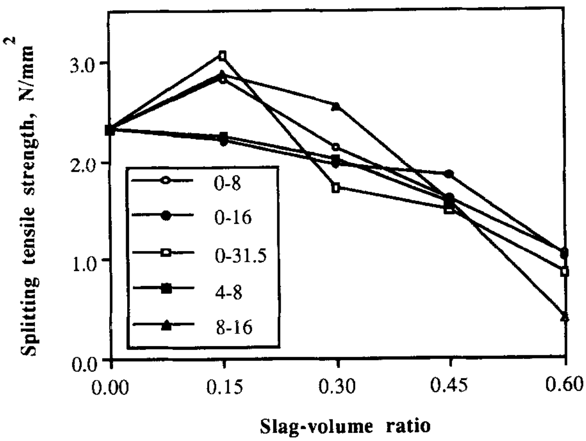

FIG. 6.
Changes in the splitting tensile strength in relation with slag-volume ratio.

Besides knowing compressive strengths of concretes with volcanic slag, desire was shown to find out their bending strengths as well, and the following results were obtained. Changes in the bending strength in relation with slag-volume ratio are given in Figure 5. An increase is seen in bending strength comparing when it is in volume ratio of 0.15. Bending strength, which is 3.0 N/mm^2 when it is in mortar phase, shows a decrease down to 1.25 N/mm^2. Bending strengths given by C 16, 20 and 25 quality concretes in the range of 0.31-0.44 changes between 2.0 and 3.0 N/mm^2, and the best bending strength is obtained in the gap-graded series with 8-16 mm size.

Splitting tensile strengths obtained from three cylindrical specimens, which is one of the important properties of concrete, was also investigated and changes in splitting tensile strengths versus slag-volume ratios were given at Figure 6. As in the bending strength, an increase is seen in splitting tensile strength when it is in the ratio of 0.15. The results obtained here showed parallelism to those obtained with bending strengths above, but for the proper part average splitting tensile strength was found to be around 2.0 N/mm^2. The results of this experiment also showed that the gap-graded series with 8-16 mm grain size had a greater splitting tensile strength.

Conclusions

Addition of volcanic slags into the concrete series causes a decrease in all properties such as workability and strength. Also decreases are seen in unit weight, ultrasound velocity and Schmidt hardness. Evaluation of all the results obtained suggests that semi lightweight concretes could be produced with volcanic slags in C 16, 20 and 25 qualities.

With volcanic slags, concretes with C 16, 20 and 25 quality can be obtained with slag volume ratios of 0.44, 0.38 and 0.31. Unit weights of the concretes obtained with these ratios are about, in average, 1900 kg/m3 and are 20% lighter than normal concretes. It could be appropriate to use 0-16 mm size aggregate in concretes for which compression is important and 8-16 mm size aggregate for concretes for which tensile is important. For the stated limits, bending strengths of the concretes would be around 2.5, splitting tensile strengths 2.0 N/mm^2 and slump value around 23 cm.

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