SCORIA SAND REPLACEMENT IN STRUCTURAL CONCRETE

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ABSTRACT

Scoria is found abundantly in Ethiopia. The use of scoria so far has been limited to highway construction as a base course, as mortal aggregate in masnory construction and for the production of hollow concrete blocks. However, scoria, which can replace sand and crushed stone aggregates, has not been used in reinforced concrete constructions. This may be attributed to lack of sufficient technical data necessary for structural design.

The availability of scoria in large quantities, where sand is scarce and crushed stone is expensive, can have a significant reduction in cost in concrete construction. If the proper strength parameters are identified and construction procedures of grain grading and concrete mixes are established a cheap local building material could be introduced to the building industry.

The purpose of this paper is to present an experimental investigation on the strength of scoria concrete by replacing the normal siliceous sand (fine) aggregates by scoria. The experimental results of concrete strength in compression strength and tensile strength are presented.

INTRODUCTION

Scoria is a volcanic cinder which generally has a porous nature and rough surface and whose colour ranges from red to black. Scoria is formed as a result of a cooled and solidified lava in which large volume of gasses have been formed. This mode of formation occurs as a result of a loose spongy structure of the solidified lava. Scoria is abundantly distributed in Ethiopia, especially in the Great Rift Valley which crosses the north-eastern part of the country as shown in Fig. 1.

The use of scoria in Ethiopia so far has been limited as a base course in road construction and as the main aggregate in the manufacture of masonry blocks used in building construction. The extensive use of this abundant material in the building industry is a subject that deserves a serious consideration. In regards to the use of pumice in lightweight concrete for structural use, extensive work has been carried out and at present design datas are included in most of the codes. The study on the properties of lightweight aggregate concrete made with pumice and scoria found in Ethiopia was first made by Mikyas [1] in 1970. Since then, to the knowledge of the authors, no further work has been carried out on scoria concrete for structural use. Scoria is not as light as pumice; consequently, concrete made from scoria may not be classified within the category of lightweight concrete.

The use of scoria concerte for structural use calls for a reliable design data. With this in mind, this preliminary investigation was undertaken to find the possibility and feasibility of replacing the fine sand aggregates used in normal concrete by natural scoria, and also to compare the performance of these concretes. However, extensive experimental investigation must be carried out prior to presenting representative design data for use by engineers who are familiar with standardized design procedures.

This somewhat limited study was planned to furnish insight into some of the observations made on the experimental investigation. Since only a single site of scoria, a single type of natural sand, and a single normal weight gravel were used, the data reported may not be applied to all scoria concretes. However, the observations should provide information on some of the little understood aspects of this property of concrete. This calls for further experimental investigation on the subject. It is planned to proceed with this investigation on a comprehensive scale to obtain a more complete

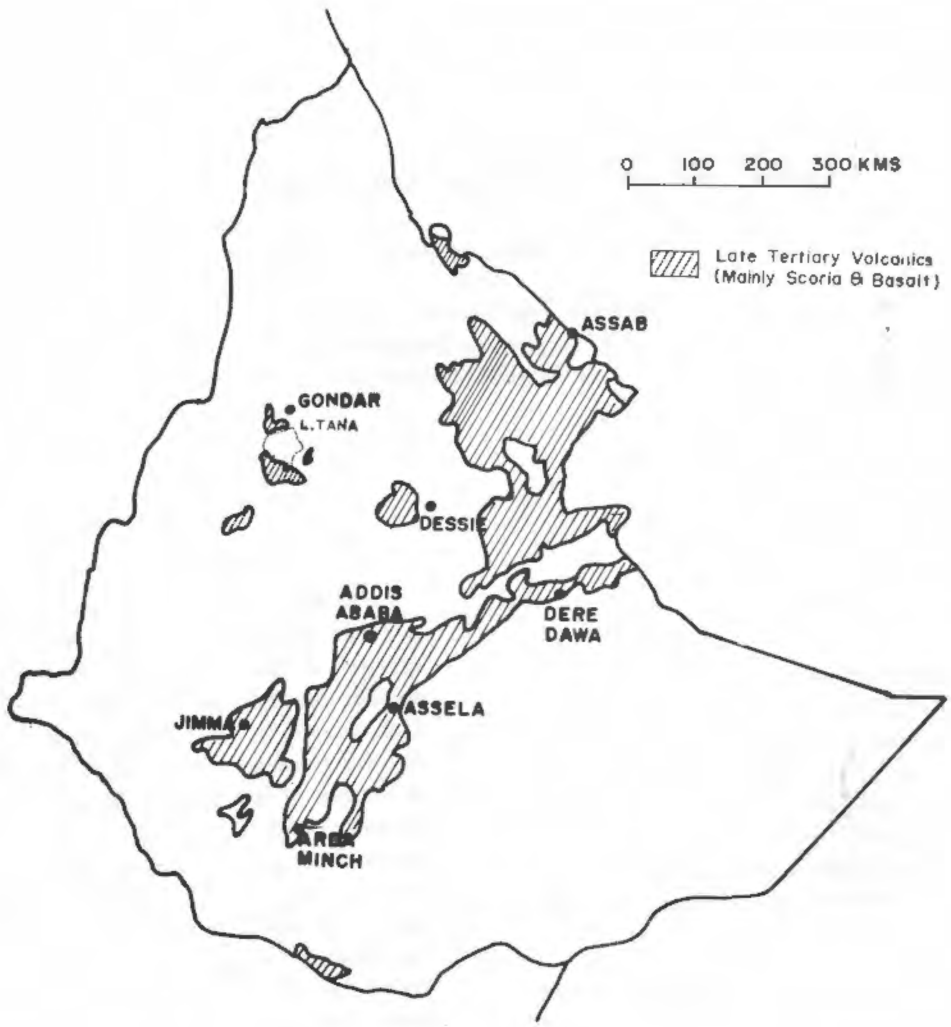

Fig. 1 Distribution of Scoria in Ethiopia

data on concrete for structural use made of scoria fine and course aggregates.

MATERIALS AND TESTING PROGRAMMES

The experimental investigation on the materials was carried out in the Civil Engineering Laboratory of Addis Ababa University.

Cement

The cement used in all mixes was Portland-Pozzolana cement from Addis Ababa Cement Factory. Physical and chemical tests were not conducted on the cement, but the standard data may be obtained from the Factory.

Aggregates

Three types of aggregates have been nsed, namely, normal crushed basalt aggregate, normai silicon sand, and scoria. These aggregates have undergone sieve analysis prior to their use to check whether or not they would comply with the ASTM recommendations [2].

The gradation of two different sized crushed coarse aggregates as they were brought to the laboratory are shown in Fig. 2. For the coarse basaltic aggregate the maximum size taken was 1 in (25 mm) and ranges down to No. 4 (6 mm) size. As shown in Fig. 2, the sieve analysis indicated that these coarse aggregates were graded outside the range recommended by ASTM. To comply with the recommendation, the aggregates were blended until the average of the recommended range was obtained. The result of the blended aggregate used is also shown in Fig. 2.

The normal sand aggregate used was found to satisfy the ASTM requirement for fine aggregates. The result of the sieve analysis is shown in Fig. 3.

The scoria aggregate was brought from a quarry

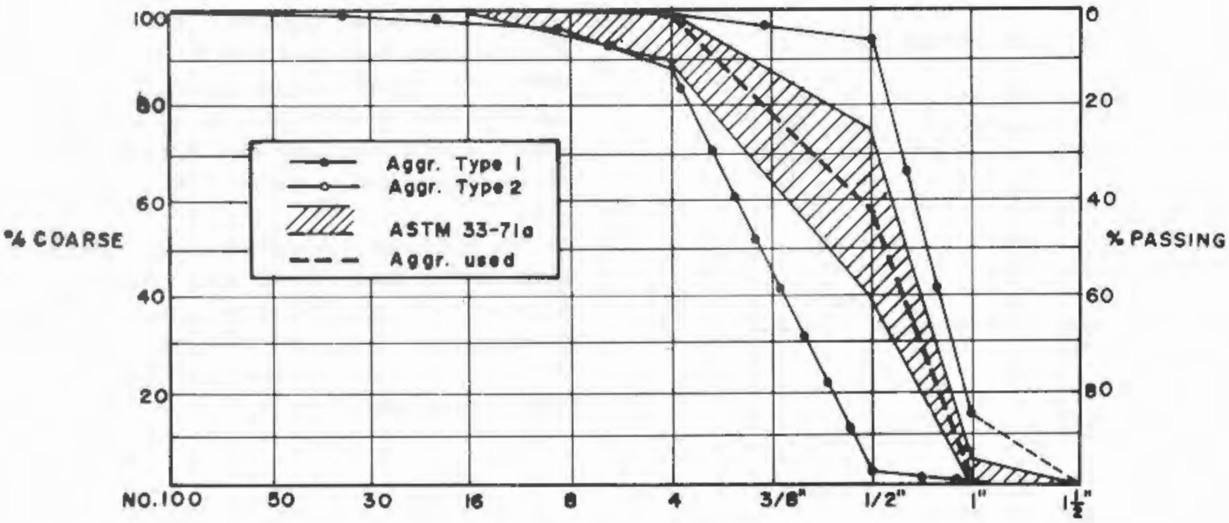

Fig. 2 Grain Distribution of Blended Coarse Aggregates

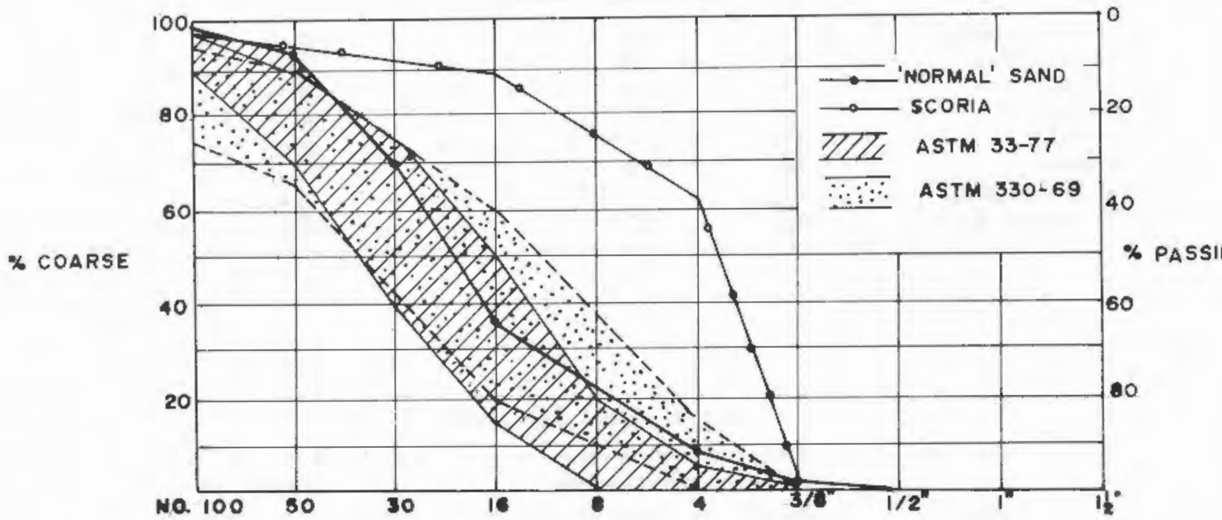

Fig. 3 Grain Distribution of Normal and Scoria Sand

near Kaliti, about 15 km south of Addis Ababa. The particular batch of scoria brought to the laboratory was too coarse to be used as a fine aggregate; thus some degree of screening was carried out and the resulting sieve analysis is shown in Fig. 3.

Mix Preparations

Initially it was intended to carry out the mixing operation by determining the specific gravity and moisture content of the various ingredients such that a more accurate yield would be obtained. But the precise determination of these properties was found to be time consuming and it was felt that such an accurate procedure was not necessary for this preliminary investigation. It was deemed sufficient to adopt the mixing operation through ratio-by-weight of the three ingredients: coarse aggregate, fine aggregate and cement. The amount of mixing water to be used was such that it should produce a mix plastic consistency of 40 to 80 mm slump. When the required slump size was attained, the mix was put into moulds and mechanical vibration was used to consolidate the specimen. Each specimen was cured at room temperature (20°C) and a relative humidity of 100% for a period of seven days or twenty eight days depend on the type of thest to be carried out.

Five different types of mixes were used for compressive and tensile strength tests. The compositions of these mixes vary essentially in the content of normal sand and scoria. The designations of the mixes used in this investigation and the corresponding proportions are given in Table 1.

Table 1. Mix Nomenclature

Mix	Sand (%)	Scoria (%)
I	100	0
II	75	25
III	50	50
IV	25	75
V	0	100

TEST RESULTS

The specimens prepared for testing were 200 × 200 mm cubes and 150 × 300 mm cylinders which were consolidated by internal vibration. The placing of the concrete and the proportioning procedures were in accordance with AC13A-59 [3]. The mix proportions used are given in Table 2.

The compressive strength values were obtained from compression tests on 200 mm cubes. The 7 day and 28 day compressive strengths of the cubes were obtained by testing three specimens from each type of mix. The results are given in Tables 3 and 4 respectively and are compared graphically in Fig. 4.

Table 2. Concrete Mixes

Description	Mix I	Mix II	Mix III	Mix IV	Mix V
Coarse aggregate (Kg)	40	40	40	40	40
Normal sand (kg)	40	30	20	10	0
Scoria (kg)	0	10	20	30	40
Cement (kg)	20	20	20	20	20
Water (litre)	13.0	14.5	15.0	16.0	17.0
Slump (mm)	64	90	55	70	40
Vibration time (min)	2.0	1.0	2.5	2.0	1.0
Cement content (kg/m^3)	462	418	418	400	400

Table 3: 7-day Test Results

Mix	Specimen No.	Compressive Strength Force (Kg)	Compressive Strength Stress (Kg/cm^2)	Splitting Strength Force (Kg)	Splitting Strength Stress (Kg/cm^2)
I	101	57200	143	7900	11
	102	56400	141	7600	11
	103	52600	132	8600	12
II	201	53350	133	9000	13
	202	53000	133	8750	12
	203	53700	134	9000	13
III	301	52400	131	8800	12
	302	49400	124	7100	10
	303	49200	123	8250	12
IV	401	40500	101	5250	7
	402	40500	101	6000	8
	403	37800	95	5250	8
V	501	42900	107	6800	10
	502	42000	105	7000	10
	503	41000	103	7000	10

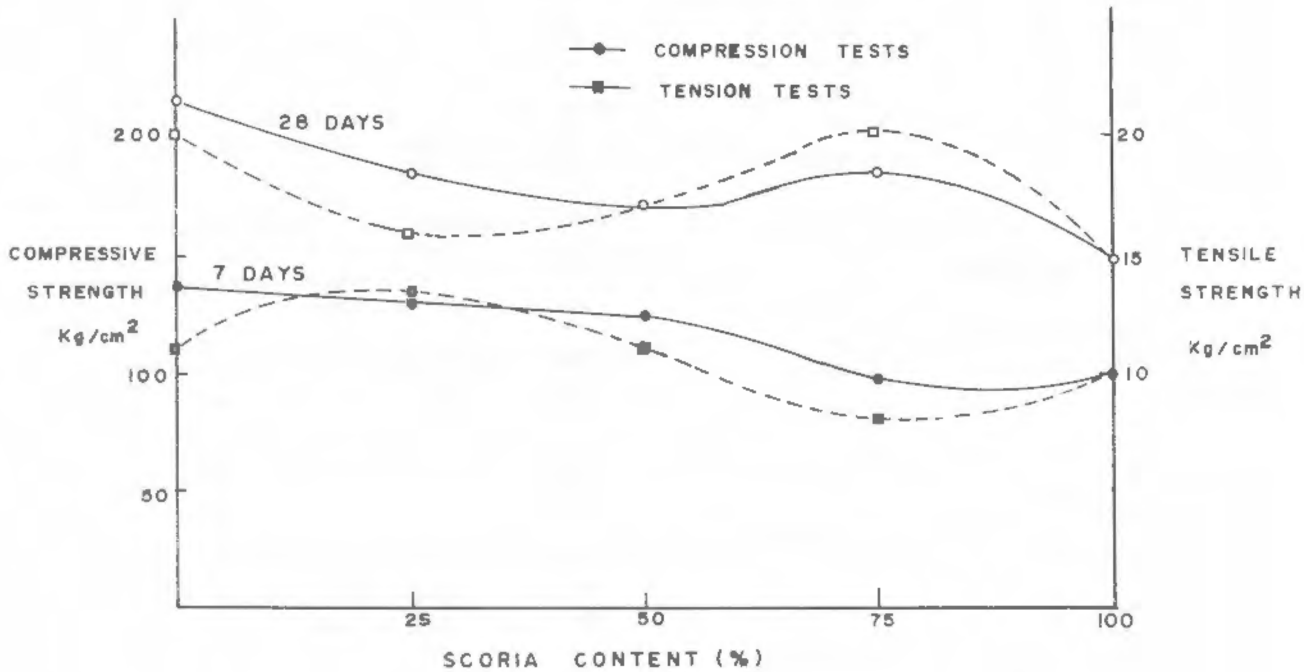

Fig. 4 Effect of Cement on Split-Tensile Strength

Table 4: 28-day Test Results

Mix	Specimen No.	Compressive Strength Force (Kg)	Compressive Strength Stress (Kg/cm^2)	Splitting Strength Force (Kg)	Splitting Strength Stress (Kg/cm^2)
I	111	90000	225	13700	19
	112	77000	193	14500	21
	113	91000	228	–	–
II	211	76000	190	12000	17
	212	7000	175	10300	15
	213	76100	190	–	–
III	311	60500	151	11500	16
	312	71400	179	13000	18
	313	73200	183	–	–
IV	411	76800	192	14000	20
	412	71100	178	14000	20
	413	74200	186	–	–
V	511	58500	146	9000	13
	512	58500	146	11000	16
	513	58100	145	–	–

To obtain the tensile strength values the splitting tensile strength test (ASTM C496-71) has been adopted. In this test a concrete cylinder is placed on its side in the testing machine and subjected to a diametral compression. Such loading induces a fairly uniform tensile stress normal to the loaded diameter causing the specimen to fail by splitting along the diameter. The results obtained from the 7-day and 28-day tests are given in Tables 3 and 4 respectively and are compared graphically in Fig. 4.

CONCLUSION

Based on the test results obtained from the 7-day and 28-day concrete specimens, the following conclusions may be made:

1. There is a variation in compressive strength as the ratio of the scoria to sand content is changed. There is a general trend in reduction of compression strength as the proportion of scoria is increased.

2. There is only a small variation in splitting tensile strength for different ratios of scoria content. Some improvement in tensile strength was observed as the scoria content is increased. At this stage it is not yet possible to determine to optimum mixes to obtain higher tensile strength.

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