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"Research Note"

UTILIZATION OF CRUSHED TILE AS AGGREGATE IN CONCRETE*

İ. B. TOPÇU** AND M. CANBAZ

Dept. of Civil Engineering, Eskişehir Osmangazi University, 26480, Eskişehir, Turkey
E-mail: ilkerbt@ogu.edu.tr

Abstract– Crushed tile is an industrial waste that causes environmental pollution. Therefore the possible utilization of this material would reduce environmental pollution. The utilization of crushed tile as a coarse aggregate in concrete would have a positive effect on the economy. In concrete production, Portland cement, river sand, 4-32 mm in size crushed stone and crushed tile as coarse aggregates in the replacement ratio of 0, 50 and 100 % were used. Mechanical and physical tests were conducted on specimens. The strength and unit weight of crushed tile aggregate concrete were decreased compared to the control concrete. Absorption and capillarity coefficients were increased compared to the control concrete.

Keywords– Recycling, crushed tile, physical properties, mechanical properties

1. INTRODUCTION

The amount of tile waste on earth is enough for use as an aggregate in concrete. Tile is produced from natural materials sintered at high temperatures. There are no harmful chemicals in tile. Waste tiles cause only the apparition of pollution. However some parts of tiles are used in cotto as flooring and also flooring in tennis courts, walkways, cycling paths and gardens as a ground material. Therefore waste tiles are stored in factory fields because of their economical value. Nevertheless, each year approximately 250,000 tons of tiles are worn out, while 100 million tiles are used for repairs. These waste materials can be recycled to save money. Crushed tile aggregate, CTA, is a material especially proposed for the buildings constructed in hot climates. The unit weight of concrete is decreased with use of the CTA compared to the control concrete. In previous investigations CTA was examined and no noteworthy negative effects on the strength of the concrete were found. The weakest bonds were between CTA and mortar, therefore failure occurred in this surface. The strength of concrete was increased with the addition of minerals and chemical waste. The use of CTA decreases costs and it also supports environmental health [1]. The other investigation examined the utilization of rubble as an aggregate in concrete. According to this investigation an increase in the stone ratio of rubble decreased the mechanical strength of concrete [2]. The use of crushed concrete as an aggregate caused drying shrinkage, decreased resistance to abrasion and changed water absorption [3]. The elasticity modulus of concrete produced with CTA rubble was 70 % of the elasticity modulus of the control concrete [4]. Both the compressive and tensile strengths of the CTA added concrete were higher, but the drying shrinkage was lower. The inclination of the curve in the ascending part of the strain deformation diagrams was smaller and also deformation was higher compared to the normal concrete due to compressive strength [5]. It was observed that CTA was 33 % lighter in

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**Corresponding author

weight. Besides, porosity and resistance to abrasion of CTA were smaller. The 28-day relative compressive strength, tensile strength and flexural strength of CTA concrete were 0.93, 1.02 and 1.15, respectively [6]. In this study, CTA was replaced by crushed stone to produce concrete specimens. Thereafter, the strength of the concrete was examined by conducting mechanical and physical tests.

2. EXPERIMENTAL STUDY

a) Materials

Cement (C): CEM I 42.5 R Portland cement, the product of the Eskişehir Cement Factory was used. The specifications of cement are shown in Table 1.

Water (W): Tap water was used as mixing water. Sulfate content, hardness and pH of water were 5.8 mg/lt, 3.9 mg/lt and 6.3, respectively.

Aggregate: Eskişehir-Osmaniye sand (S) and Söğüt Zemzemiye crushed stones (CS) were used. Maximum aggregate size was 31.5 mm.

Table 1. Properties of CEM I 42.5 R Portland cement used in tests

Chemical Analysis, %	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	LOI
	20.96	5.58	3.69	63.97	1.69	2.84	1.15

Physical Properties	Specific Gravity	Fineness, cm^2/gr	Compressive Strength, MPa	2 days	7 days	28 days
	3.15	3315		21.9	38.3	45.1

Crushed tile aggregate (CTA): CTA was obtained from the waste depot of the Kılıçoğlu Tile Factory and CTA was crushed 4-16 mm and 16-31.5 mm sizes. The unit weight, specific weight and water absorption of crushed tiles were 925 kg/m^3, 1904 kg/m^3, 11.56 % respectively. Abrasion amounts were 21 % and 82 % respectively for the Los Angeles abrasion tests at 100 and 500 cycles. The abrasion of crushed tile was quite high. The maximum amount of abrasion was 50 % at 500 cycles.

Table 2. Mixture proportions of concrete containing CTA

kg/m^3	K300	K300	I300	K300	I300	K350	K350	I350	K350	I350	K400	K400	I400	K400	I400
	0	50		100		0	50		100		0	50		100	
S	739	739	739	739	739	721	721	721	721	721	705	705	705	705	705
CS I	581	581	291	581	0	568	568	284	568	0	555	555	278	555	0
CTA I	0	0	222	0	443	0	0	217	0	434	0	0	212	0	424
CS II	581	291	581	0	581	568	284	568	0	568	555	278	555	0	555
CTA II	0	222	0	443	0	0	217	0	434	0	0	212	0	424	0
W	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190
C	300	300	300	300	300	350	350	350	350	350	400	400	400	400	400

b) Production of specimens and experiments

The mixture proportions were determined by the absolute water method. Three different cement contents were used in concrete 300 kg/m^3, 350 kg/m^3 and 400 kg/m^3. The volume and weight of the materials in the mixture is given in Table 2. 0-4 mm aggregate was coded as S, 4-16 mm aggregate was coded as CS-CTA I, and 16-32 mm aggregate was also coded as CS-CTA II. CEM I 42.5R cement, river sand, crushed stones 4-16 and 16-32 mm in size, and CTA in the replacement ratio of 0, 50 and 100 % of which two of the crushed stones types were used in the experimental study. Concrete specimens were cast in cylinder and cube molds. Concrete specimens were cured under standard cure conditions (21±1 ºC in lime saturated water). Ultrasonic pulse velocity, compressive strength, and splitting tensile strength tests were conducted at the end of the 28th day. The capillarity, 24-hour water absorptions, freeze-thaw effect and abrasions of CTA concrete were examined [7-10].

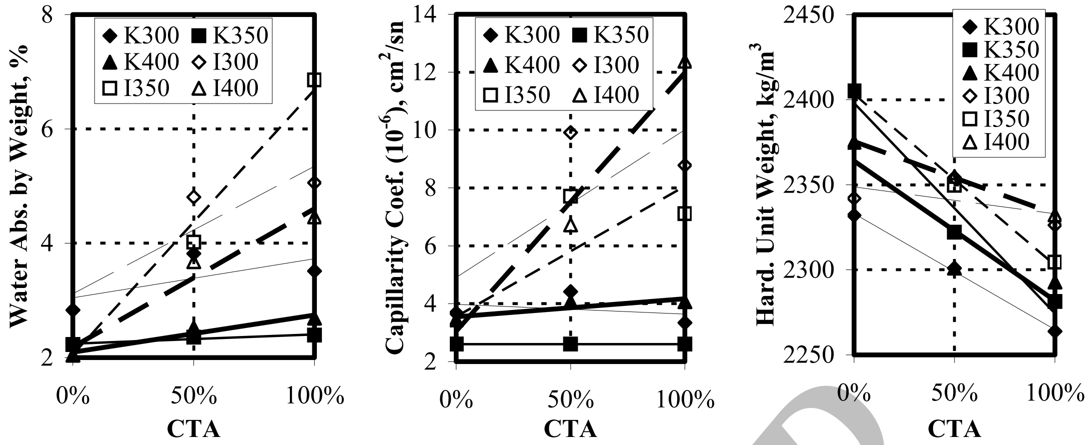

Fig. 1. Water absorption, capillarity coefficients and unit weight of concrete containing CTA

3. RESULTS AND DISCUSSION

Ultrasonic pulse velocities, compressive strength, and splitting tensile strength were conducted at the end of the 28th day. The hardened unit weight, ultrasound velocity, dynamic modulus of elasticity, splitting tensile strength and compressive strength were then calculated. The capillarity, water absorptions, freeze-thaw effect and abrasions of CTA concrete were determined. The results of water absorption tests are given in Fig. 1. The water absorption ratios of the concrete specimens by weight are obtained between 2.04-6.86 % in Fig. 1. The use of CTA increased the water absorption ratio of concrete, especially for concrete produced with 4-16 mm CTA, which increased 200 %. The water absorption of CTA was greater than the water absorption of crushed stone. This situation caused an increase in the water absorption of concrete. The capillarity coefficients of concrete specimens are given in Fig. 1. They have varied between 2.6×10^{-6}-12.38×10^{-6} cm^2/s. The increase in the ratio of (32-16 mm) CTA did not change the capillarity coefficient, but (16-4 mm) CTA changed capillarity coefficient at the ratio of 250 %. The increase in the amount of CTA, and also the rough structure of the CTA caused workability problems and pores in concrete. Then hardened unit weight of concrete is given in Fig. 2. The unit weight of concrete specimens varies between 2405 and 2263 kg/m^3. The increase in the CTA ratio caused a 4 % decrease in the hardened unit weight, as the specific weight of CTA was lower than specific weight of the crushed stone.

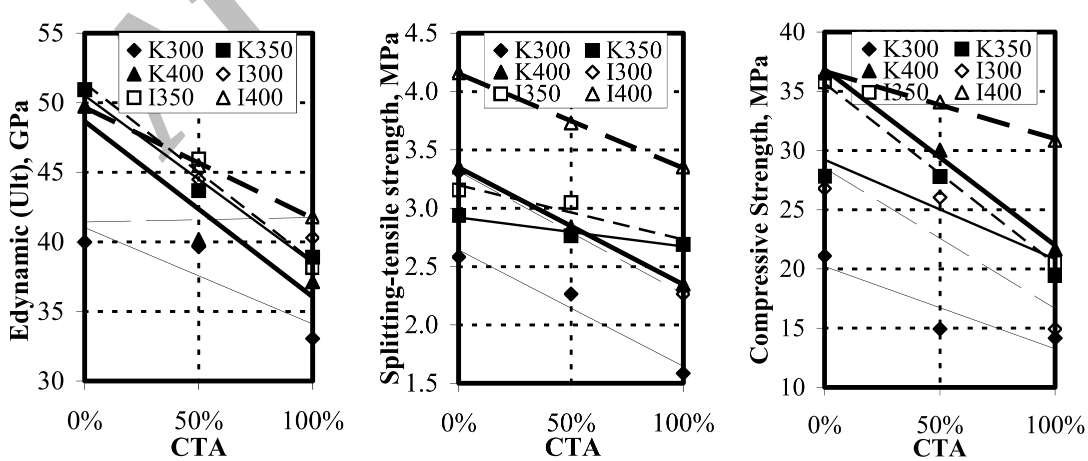

Fig. 2. Dynamic modulus of elasticity, splitting-tensile and compressive of CTA concrete.

Dynamic elasticity modulus related to ultrasonic pulse velocity and unit weight is given in Fig. 2. Elasticity modulus has varied between 33.06-50.93 GPa. The increase in the replacement ratio of CTA caused a 25 % decrease in the elasticity modulus. The rough structure of CTA caused an increase in the porosity ratio of the concrete. Splitting tensile strengths of concrete have varied between 1.58-4.16 MPa and are given in Fig. 2. The use of CTA caused a 40% decrease in the splitting tensile strength of the concrete. The coarse and rough structure of the CTA formed more pores in the cross sections of the concrete and the application of strength in these cross sections might have lower splitting tensile strengths. Compressive strengths of concretes are given in Fig. 2. Compressive strengths have varied between 36.56-11.42 MPa. Compressive strength was decreased 43 % due to the utilization of CTA in concrete. The reason was that CTA increased the amount of pores in concrete and the strength of CTA was lower than that of crushed stone. The σ-ε toughness diagrams of concrete specimens are given in Fig. 3. Toughness decreased 40 % with the use of CTA at a dosage of 350-400, and increased with the use of (32-16 mm) CTA at a dosage of 300. Maximum toughness was seen at 400 dosages concrete. Low compressive strength of CTA also lowered the toughness of concrete. Abrasion and freeze thaw tests were conducted on the 7x7x7 cm concrete specimens with the replacement of CTA at the ratios of 0-50-100 % as sand. Experimental results of abrasion and freeze thaw tests were given in Fig. 3. As seen from Fig. 3, the weight loss of concrete with CTA after freeze-thaw tests were increased 0.4 % to1.4 % by increasing the CTA ratio. CTA reduce the weight losses of mortars after freeze-thaw tests. If Fig. 3 is considered the abrasion of concrete, with CTA. It was 6-23 $cm^3/50\ cm^2$. At the end of the abrasion test, abrasion increased by increasing the CTA ratio. Low hardness and the weak chemical bond of CTA increase abrasion and the freeze-thaw resistance of concrete.

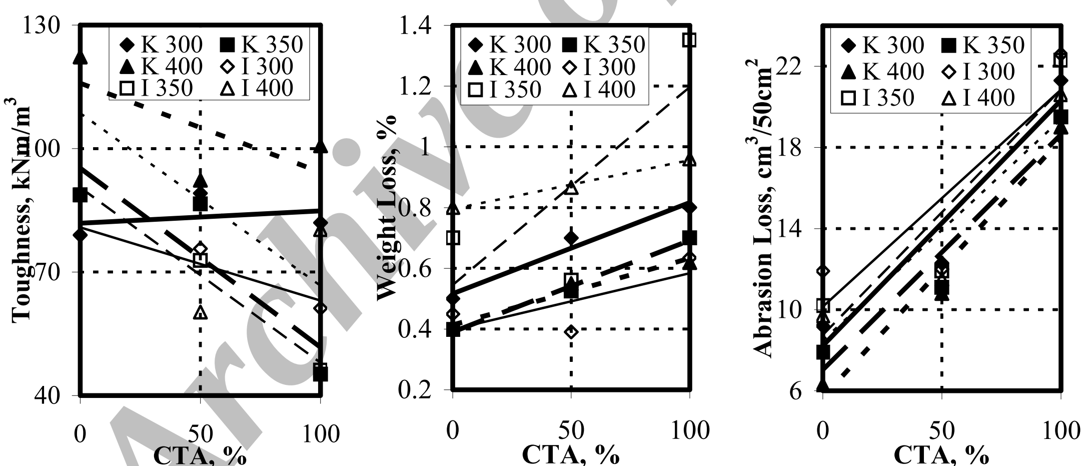

Fig. 3. Toughness, weight loss after freeze-thaw effect and abrasion loss of CTA concrete

4. CONCLUSIONS AND SUGGESTIONS

Waste tiles are the main problem of tile factories. The aim of this investigation was the utilization of waste tiles in concrete as a coarse aggregate. The unit weight of CTA concrete has decreased 4 % according to experimental results. The use of CTA caused a 40 % loss in compressive and splitting tensile strengths. CTA has negatively affected abrasion and freeze-thaw durability. According to these results, 100 % replacement of CTA as a coarse aggregate is not appropriate. The use of CTA in concrete has positive effects on the environment and obtaining lower costs. CTA has to be recycled for economy. For this aim, crushed tile has to be investigated for being recycled. CTA can replace oxides to color concrete, especially for flooring and walls. Pozzolanic reactivity of fine granulated tile can be investigated. Architectural and insulation use of crushed tiles can also be examined.

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