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UTILIZATION OF CHROME ORE CONCENTRATION PLANT TAILINGS AS FINE AGGREGATE IN READY-MIXED CONCRETE

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Abstract

Large amount of the chrome ore concentration plant tailings was discarded during chrome ore mining process. The accumulation of the tailings takes large areas of land for the storage and causes environmental and safety problems. When the annual consumption of the ready mixed concrete per person (approximately 1.5 m^3/person) in Turkey is considered, employment of the tailings in the ready-mixed concrete may be a solution for the recovery of the tailings. In addition, using chrome tailings as a substitution for sand to produce ready-mixed concrete is a possible way to solve the resource problem of sand deficiency. The aim of this study is to investigate the utilization of the tailings taken from a chrome ore concentration plant in Eskisehir, Turkey as fine aggregate in ready-mixed concrete production. For this purpose, the tailings were partially replaced with the fine aggregate by the weight at 0, 10, 20 and 30% proportions by weight in the ready-mixed concrete mixtures. Standard curing is applied until the time of test to the 15x15x15 cm cube specimens taken from the mixtures. The unit weight, compressive strength and ultrasonic pulse velocity values of the cubic specimens were investigated in this study. Performed tests showed that replacing sand to chrome ore tailings has a potential for further investigations.

Keywords: Chrome ore tailings, fine aggregate, ready-mixed concrete, hardened concrete properties

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KROM KONSANTRASYON TESISI POSALARININ INCE AGREGA OLARAK HAZIR BETONDA KULLANIMI

Özet

Krom cevheri madenciliği uygulamaları sırasında büyük miktarlarda krom madeni konsantrasyon tesisi posası açığa çıkmaktadır. Bu posaların birikmesi depolamak için geniş araziler gerektirir ve hem çevresel hem de güvenlik problemlerine neden olur. Türkiye'deki yıllık kişi başı hazır beton tüketimi (yıllık kişi başı yaklaşık 1.5 m^3) göz önünde bulundurulduğunda bu posaların hazır betonda kullanılması bu posaların geri kazanımı için bir çözüm olabilir. Ayrıca, krom madeni posalarını hazır betonda kumun yerine kullanmak kum kaynaklarındaki azalma problemine de bir çözüm olabilecektir. Bu çalışmanın amacı Eskişehir'de bulunan bir krom konsantrasyon tesisinden alınan posanın hazır beton üretiminde ince agrega olarak kullanılabilirliğinin araştırılmasıdır. Bu amaçla alınan posa hazır beton karışımındaki ince agrega yerine ağırlıkça kısmen %0, 10, 20 ve 30 oranlarında yer değiştirilerek kullanılmıştır. Karışımlardan alınan 15x15x15 cm küp numuneleri test gününe kadar standart kürde bekletilmiştir. Küp numunelerin birim ağırlık, basınç dayanımı ve ultrases geçiş hızı değerleri araştırılmıştır. Gerçekleştirilen deneyler krom cevheri posasının kum yerine kullanılması için daha fazla çalışma yapılması için bir potansiyeli olduğunu göstermiştir.

Anahtar Kelimeler: Krom cevheri posası, ince agrega, hazır beton, sertleşmiş beton özellikleri.

1. Introduction

World chromite production was at 3.65 million tons in 1953, it reached 19 million tons in 2009. In the last decade, demand for chromium alloys has increased by about 5% per year and annual chromium ore production increased an average of 4.6% followed the demand, annually [1]. In Turkey, many chrome ore concentration plants have been established since 2000. But efficiency and capacity utilization of the plants are low [2]. If the high production quantity of the chromite to be considered, an important waste and tailings problem originated from the plants occurs in Turkey and all over the world. Chromite is the only mineral that chromium metal one of the natural components of the earth's crust can be produced economically. The chromite is a mineral of the spinel group and crystallizes in the cubic system. The theoretical formula of chromite is $FeCr_2O_4$ but chromite minerals found in nature is symbolized by a formula of $(Mg,Fe)(Cr,Al,Fe)_2O_4$ [3]. The main industrial branches in which chromium is used are metallurgy, refractory and chemical industry. However, the chromium ores extracted from the mines often do not provide the desired product characteristics of these industries. Therefore, it is necessary rendering the chromite ores extracted from the mines to the properties desired by the industries with effective enrichment processes [4]. Chrome ore can be enriched with combing out with hand, sieving and washing to remove the silicate minerals from the ore structure. At later stages, enrichment of the chromite mineral is ensured with shaky tables, magnetic separator, flotation or heavy liquid methods and so, the residual silicate is cleared. All these processes are performed in the chrome ore concentration plants [3]. After the enrichment process is performed, a considerable amount of tailings is released from the plant. These tailings disturb the natural view and cause physical pollution and storage problems. The environmental and storage problems caused by the tailings need to be solved and economic feasibility of the tailings is worth to search for its high amount. For this purpose, an investigation was performed on the possibilities of the recovery of tailings exposed from a chrome ore concentration plant. It is revealed that the tailings can be used after sieving and washing as a lightweight construction material and a part of the tailings can be recovered [5]. An experimental study was performed on the utilization of the serpentine based chromite waste as a ceramic pigment in the colouring agent in wall tile glaze recipes and as a modifier in the floor and porcelain tile glaze recipes. According to the results of the study, the chromite waste can be used for the purposes with any problem [6]. Another study was carried out for re-beneficiation of chrome ore concentration plant tailings. After the washing and sieving processes, the wastes bigger than 0.1 mm size can be used for the production of lightweight construction material as sand. It was emphasised that there are alternative solutions for residual chromium recovery and one of them is the repeating of the concentration process on the tailings [5]. There are a lot of benefits of recycling the wastes for any purpose. As for chrome tailings, usage of the tailings in the concrete can minimize the storage and land problems around the concentration plants. And another advantage is the reduction of the sand consumption and protection of resources. The aim of this study was to recycle the tailings as fine aggregate in ready mixed concrete.

2. Material and Methods

A. Materials

CEM I 42,5 N type cement correspond to TS EN 197-1 and appropriate with ASTM type I was employed in this study. Crushed aggregates used to be in two sizes of 4-11mm and 11-22 mm and sand with a size of 0-4 mm were supplied from Selka ready–mixed concrete plant in Eskisehir. The aggregates used in the mixtures were in concordance with the requirements of TS 706 EN 12620+A1. The top water used as mix water in the mixtures. Chrome tailings were taken from a chrome ore concentration plant in Eskisehir. The concentrated chromium particles from the plant were shown in Figure 1. During the concentration process, there are a lot of tailings occur and disposed of from the plant. The tailings used in this study were the rest of the process.

Figure 1: Concentrated chromium particles.

As seen in Figure 2, the tailings occurred as waste from the chromium production transported to landfill area together with water.

Figure 2: Tailings occurred during the chromium production.

The concentration process was inefficient because the tailings composed of the large amount of ore. So, the tailings accumulated around the concentration plant very rapidly. Dried and stored state of the chrome tailings is shown in Figure 3. Chrome tailings hill causes storage and landfill problems with the environmental and economic disadvantages.

Figure 3 Chrome tailings hill.

Physical and chemical properties of the chrome tailings used in this study were given in Table 1. According to the properties, there was any drawback to use the tailings by sand in the ready mixed concrete.

Table 1: Properties of the chrome tailings

Density, kg/dm^3	Water absorption, %	Fine particulate, % (<0,063 mm)
2,72	1,6	3,6
Organic contaminant	Organic matter	ASR expansion, % (accel. Met.)
<% 0,001	Light yellow	0.01
SO_3, %	Cl, %	S, %
0,02	<0,0005	0,025

B. Methods

There are 4 series of concrete mixtures were prepared in this work. The series were determined according to the chrome tailings content. The mixture proportions of the concrete mixtures were given in Table 2. As seen in the table, the dosage of the cement was determined as 340 kg/m3. Chrome tailings were used in substitution for sand at 0, 10, 20 and 30% proportions. Water-cement ratio was 0,55 in the concrete mixtures. The slump is fixed approximately as 10 cm for all the mixtures. A modified polycarboxylic ether polymers based high range water reducing admixture with specific gravity of 1.09, was used to obtain slump value as 10 cm in concrete mixtures. The amount of admixture employed in the concrete mixtures was adjusted at the time of mixing to obtain the determined slump value.

The concrete mixtures mixed in a pan type mixer and the specimens were moulded and compressed by a vibrating table. Three 15*15*15 cm cube specimens were taken from each mixture for each test.

Table 2: Mixture proportions

Material, kg	Chrome tailings content, %			
	0	10	20	30
Cement	340	340	340	340
Water	187	187	187	187
0-4 mm sand	1100	990	880	770
4-11 mm aggregate	330	330	330	330
11-22 mm aggregate	572	572	572	572
Chrome tailings employed for sand	0	110	220	330

The unit weight, compressive strength, ultrasonic tests were performed on the specimens held in standard curing conditions for 28 days. The unit weight, ultrasonic pulse velocity, compressive strength and dynamic modulus of elasticity values were calculated and the effect of chrome tailings on these values was examined with graphs drawn.

After the pulling out of the concrete specimens from the moulds at 28 days of curing, unit weight values of the specimens were calculated in water-saturated dry surface condition. Each concrete specimen was weighed separately. Then the means of weight values of three specimens were estimated to determine a weight value of each mixture.

Finally, the unit weight value of each concrete mixture was calculated by dividing the mean weight by the specimen volume.

Ultrasonic pulse velocity of any material relates to the elastic properties, compactness and porousness of the material. The ultrasonic pulse velocity values are determined on the specimens at the age of 28 days according to the equation 1.

$$Upv = (S/t) \times 10 \quad (1)$$

Upv is the ultrasonic pulse velocity (km/s), S is the length of the smooth wave path through the sample (cm) (i.e., 15 cm in this work), and t is the passing time of the ultrasonic pulse through S (µs) measured by ultrasonic pulse velocity test machine.

The compressive strength values of the specimens were determined by using the test methods according to TS EN 12390-3 (2010) and ASTM C39/C39M-14a (2012). The compressive strength tests are performed on the concrete specimens at a constant load with a rate of 0.10 MPa/s by using a 3000 kN capacity compression testing machine.

3. Results and Discussion

The changes in the unit weight values of the concretes depending on the chrome tailings content were given in the Figure 5. When the Figure 5 examined, there was a decrease in the range of % 1-2 on the unit weight values of the concretes according to chrome content. The reason for this is that the chrome tailings has largest rain size of 2 mm which was small than the sand (4mm) and the fineness of the tailings was higher than the sand.

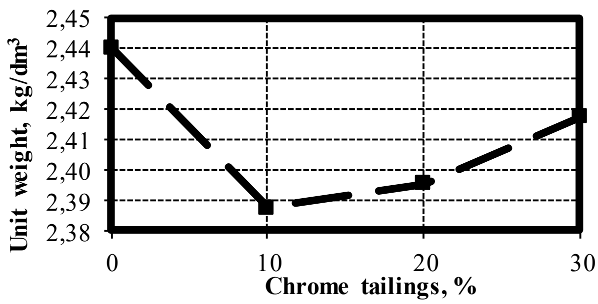

Figure 5: Variation of unit weight according to chrome tailings.

The variation of the compressive strength of the concretes with chrome tailings content was given in Figure 6. As seen in Figure 6, while the compressive strength of the concretes decreased up to 2% with the chrome tailings content until 20% proportion, the compressive strength values increased up to 5% when the proportion of the chrome tailings reached to 30%. Better workability provided by the filler effect of the chrome tailings caused better placing and compacting and so, the compressive strength of the concretes increased.

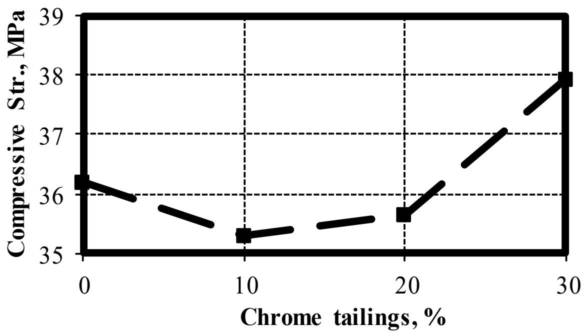

Figure 6: Variation of compressive strength of the specimens.

Ultrasonic pulse velocity values of the concrete specimes made with chrome tailings were given in Figure 7. When the Figure 7 examined, the ultrasonic pulse velocity values of the concretes contain 10% tailings decreased at 4% proportion according to control concrete sharply. In contrast, when the proportion of the chrome tailings reached 30%, the ultrasonic pulse velocity values of the concretes increased up to 6%. The ultrasonic pulse velocity values increased because of increased the occupancy rate of granulometry caused by the fine grain structure of chrome tailings.

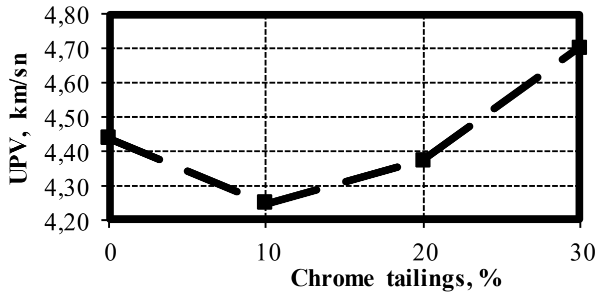

Figure 7: Ultrasonic pulse velocity variation of specimens.

The estimated dynamic modulus of elasticity values of the concretes depending on the unit weight and ultrasonic pulse velocity values were given in Figure 8. As seen in Figure 8, while the dynamic modulus of elasticity values decreased with chrome tailings content up to %10 initially, the values increased up to 11% at higher proportions according to control concrete. The results showed that the dynamic modulus of elasticity behaviour of the concretes was similar with the compressive strength. Filler effect of the chrome tailings and adaptation of the tailings with sand at higher proportions caused this behaviour to occur.

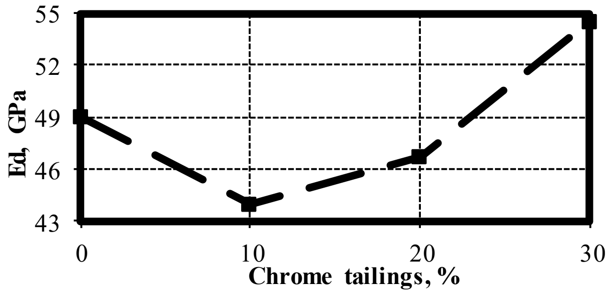

Figure 8: Dynamic elasticity values of the specimens.

4. Conclusion

The following results were obtained in the experimental work:

- Unit weights of concretes decreased with the chrome tailings addition at low rates of 2%.
- The compressive strength of the concretes increased up to 5% with the use of chrome tailings by sand at high proportions as 30%.
- The concretes made with chrome tailings at high proportions have higher ultrasonic pulse velocity up to 6%.
- While the low chrome tailing content decreased the dynamic modulus elasticity of the concretes, high chrome content increased this property.

According to the experimental work done, the usage of the chrome ore concentration plant tailings by fine aggregate in the ready mixed concrete at %30 proportion was recommended with regards to ecological and economic benefits. However, the use of chrome tailings should not be used in low ratios because of the negative effects on the concrete properties. Furthermore, the investigation of the effect of chrome tailings on the durability of concrete may be proposed for further studies.

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