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Utilization of Turkish Chromite Tailings in the Manufacturing of Building Bricks

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This paper concerns with the building bricks made with chromite tailings material which mainly consists of SiO_2 and MgO. In chromite mining large amounts of clay containing tailings have to be discarded. The chromite tailings in mineral processing do not only cause economical loss but also bring about serious environmental problems. In order to solve this problem, the possibility of using chromite tailings in red brick manufacturing was investigated. Physical properties of the bricks made with the tailings were similar with the control bricks. The compressive strength increased up to 405 kg/cm^2 with an addition of 20% tailings in comparison with reference bricks having 380 kg/cm^2 on compressive strength.

Key Words: Chromite, Tailings, Waste, Reuse, Red bricks.

INTRODUCTION

Until recently clay was the essential material necessary to produce a majority of ceramic bodies, playing the role of binder. It renders the mass plastic and enables forming of products. However, the application of clay as a component of ceramic bodies causes some disadvantages. It requires a vast amount of water which must be subsequently removed by drying and the most important thing is the exploration of clays, still expensive, whereas the resources of the better varieties are limited. All these circumstances make us look for new unconventional ceramic raw material and technological processes. Such raw material may be the waste products, produced in great quantities by power, mining and other industries, which pollute the natural environment and may be utilized to a great extent by the ceramics industry. The idea of using solid waste as aggregates or admixtures for building materials is not new[1, 2]. Recycling and reuse of industrial, urban and agricultural waste materials may be a feasible alternative solution for waste disposal[3, 4]. Bauxite 'red mud' as a raw component was used up to 20% by weight in clay mixtures for ceramic bodies' production and the results indicate excellent perspectives[5]. Fly ash is another well known waste material to manufacture red-brown bricks[6, 7]. In addition, molten slag[8], dredged harbour sediments[9] and boron wastes[10] were used for brick production.

World chromite production was about 12.2 million tonnes in 1996 and Turkey has produced about 2 million tonnes alone[11]. The total concentration of fine chromite tailings of Turkey is around 3 million tonnes with a grade of 12–20% Cr_2O_3. Therefore, many investigators have been working to benefit from these fine tailings[12]. Generally fine chromite tailings consist of ultrabasic minerals. Ophiolite is accepted. Their general names are dunite (90% > olivine), peridotite (90% > olivine), serpentine, etc.[13].

Bricks contain a rough ceramic class of clay (SiO_2, Al_2O_3, H_2O and other dispersed oxide compounds). These are produced at high temperatures and used as a construction material. After the clay passes through some preparation stages it is modified to a rigid and undeformed material. In addition, it is not influenced by external conditions except some special situations; because of this, clay must be fired or pressed to obtain these physical properties. Production of bricks for different uses can be accomplished by adding additional minerals[14].

EXPERIMENTAL

The aim of this study is the production of the optimum quality bricks with the help of the determination of physical and chemical properties of Aladag-Adana (Turkey) fine chromite tailings (Tables 1 and 2).

TABLE-1
CHEMICAL COMPOSITION OF THE ALADAĞ-ADANA CHROMITE TAILINGS

Oxides	Wt. (%)
SiO_2	29.95
Al_2O_3	4.84
MgO	32.30
CaO	3.66
Cr_2O_3	8.75
Fe_2O_3	6.56
Loss of ignition	13.94
Total	100.00

TABLE-2
SIZE DISTRIBUTION OF THE TAILINGS

Size (mm)	Wt. (%)	Cr_2O_3 (%)
–1.000 + 0.600	24.53	7.79
–0.600 + 0.425	18.94	6.98
–0.425 + 0.300	12.39	5.87
–0.300 + 0.212	8.94	5.07
–0.212 + 0.106	19.90	6.43
–0.106 – 0.063	7.24	19.70
–0.063 + 0.038	3.18	26.85
–0.038	4.88	17.66
Total	100.00	8.75

The representative sample, in quantity about 250 kg containing 8.75% Cr_2O_3, was taken from a tailings stock pile. It was treated for physical properties, chemical composition and brick manufacturing. The sample material to make use of brick was under 1 mm. Operation of a full scale production brick on the bench scale was carried out at Alganlar Brick Plant, Adana. The brick machine was manufactured by Karl Handle and Söhne Mühlacker (Germany) which had 0.05 m^3/h capacity. An appropriate mix of water (17–20%), moist clay and chromite tailings was kneaded for 30 min and then the mixture was formed to test size of brick (37 × 140 × 27 mm) under vacuum. Bricks were produced at six levels of the tailings content by dry weight: 40, 30, 20, 10 and 5% and control (0%) and marked 10 cm with scale for finding total shrinkage. They were dried at room temperature for 7 days then fired at the furnaces of the brick plant for 7 d as the temperatures ranged from 850 to 950°C. Average ten bricks for each level were tested according to ASTM C67-92a[15], TS 705[16], TS 4563[17] standard tests or modified versions. The quality of bricks was determined on the basis of compressive strength, colour, appearance, total shrinkage, density, water adsorption, frost resistance, harmful magnesia and firing weight lost.

RESULTS AND DISCUSSION

No property change was observed in bricks made with the tailings when compared with the control bricks. The colour of the tailings added bricks was light brown. Smoothness was found similar to all bricks. A value of 10 cm was marked on the green bricks, then the bricks were fired and their length was measured again. The difference between the two values gave the total shrinkage. The results (Fig. 1)

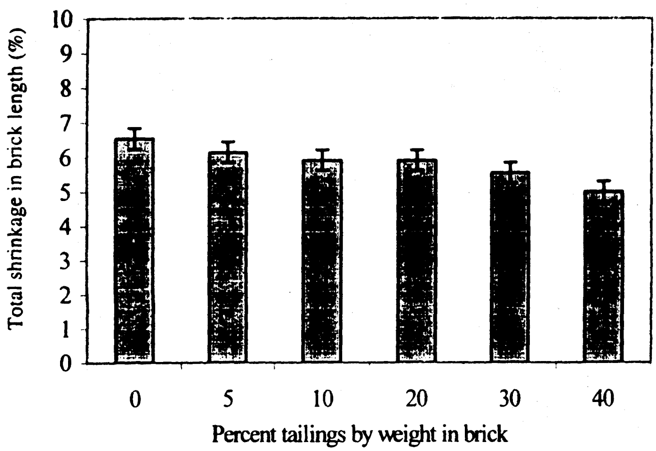

Fig. 1. Per cent shrinkage in brick after firing for varying levels of chromite tailings

showed that an addition of the tailings from 0 to 40% by weight to clay decreased the total shrinkage from 6.54 to 5.02%, respectively. Cold water absorption of the bricks is presented in Fig. 2 which shows that the cold water absorption increased with increasing tailings content in brick. Density of the bricks (Fig. 3) rose up from 1.76 to 1.81 g/cm^3 with increasing the tailings content from 0 to 40% by weight in bricks respectively.

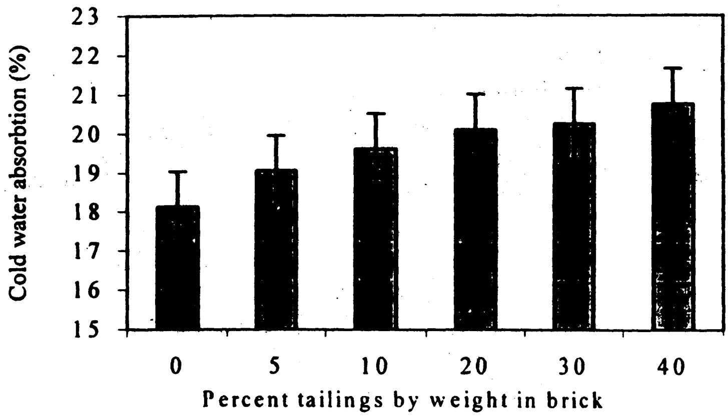

Fig. 2. Per cent of cold water absorption in brick containing varying levels of chromite tailings

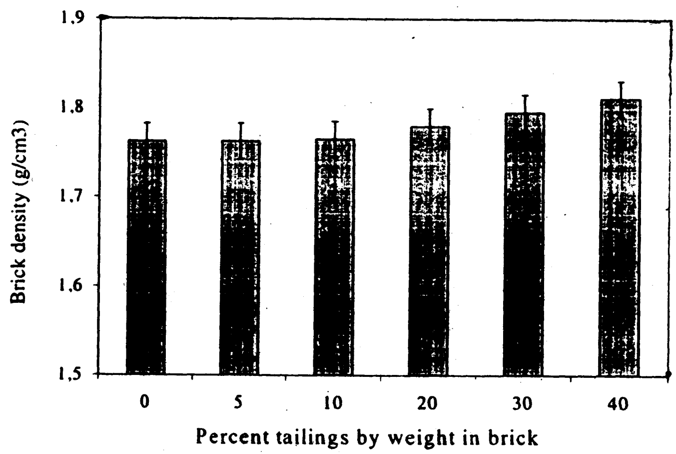

Fig. 3. Density of brick containing varying levels of chromite tailings

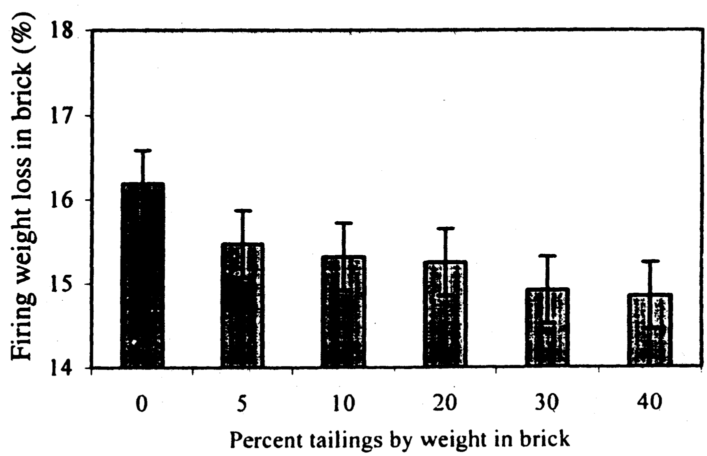

Fig. 4. Per cent firing weight loss in brick containing varying levels of chromite tailings

Change in brick weight after firing is presented in Fig. 4. Increasing tailings content resulted in decreasing firing weight. Fig. 5 indicates that compressive strength of 20% tailings added bricks gave optimum result. If the tailings ratio is

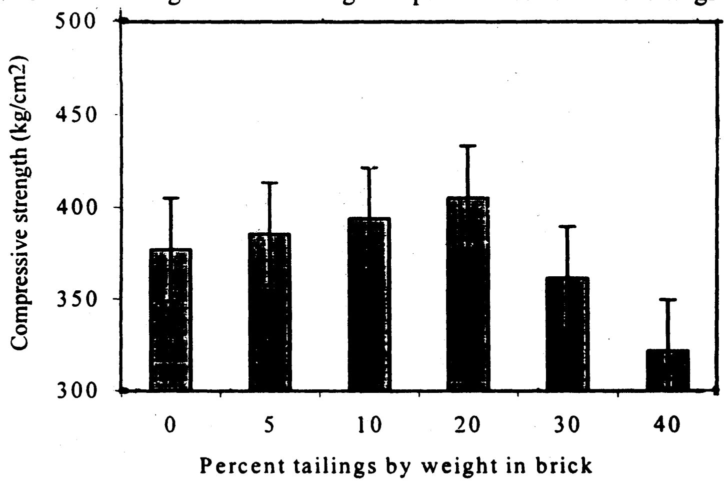

Fig. 5. Compressive strength of brick containing varying levels of chromite tailings

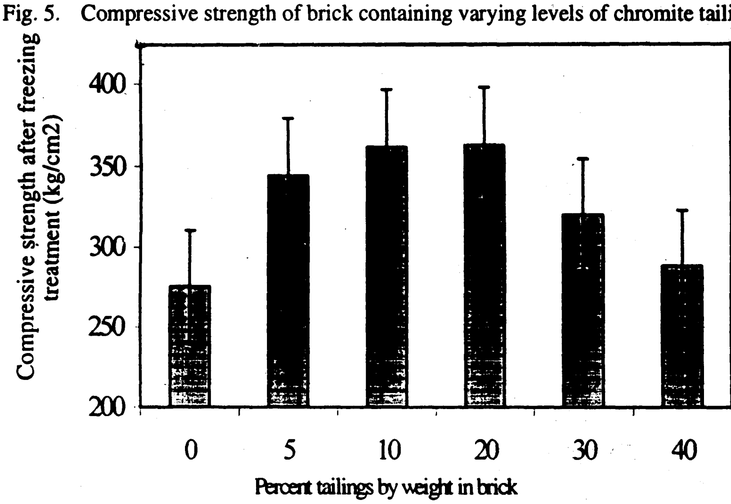

Fig. 6. Compressive strength of brick of chromite tailings after freezing test.

higher than 20% the results of compressive strength tests indicate a decrease. Fig. 6 shows the freezing test results. It is observed that the control bricks were dispersed partially although the tailings added bricks resisted the freezing test. A decrease in brick strength after magnesia treatment is shown in Fig. 7 but the values were in the standard. A laboratory leaching test has been used to predict the time-dependent leaching behaviour of chromite tailings added bricks[18]. This was a repetitive shaking test using distilled water as a model leachate to simulate rain-water and also HCl since it is commonly used in leaching studies, since at acid concentrations greater than 0.01 M, the protonation and dissolution of most metal oxides as the corresponding aquo ions are thermodynamically favoured. For leaching test, 1 g of ground brick samples made of 20% tailings were leached

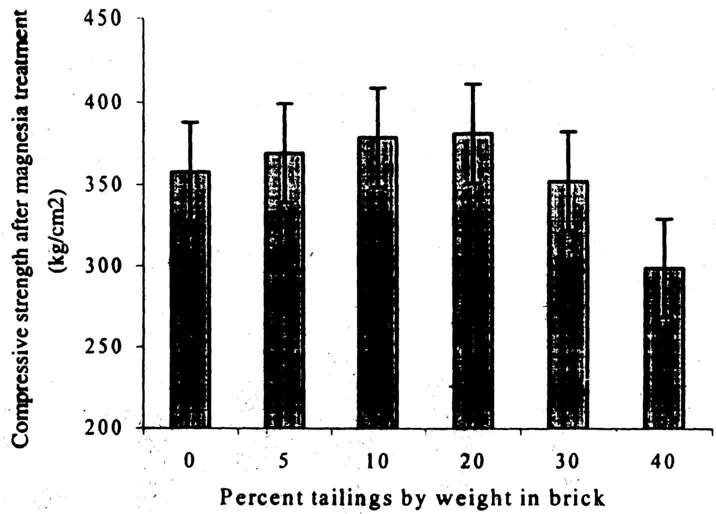

Fig. 7. Compressive strength of brick of chromite tailings after magnesia treatment

with distilled water and 0.1 M HCl for 1, 24, 168, 336 and 720 h. The solutions were then filtered through Whatman No. 1 filter paper. The suspensions were stored in polyethylene bottles. After the 30-day leaching period, all the samples were analyzed for Cu, Ni, Cr, Zn, Pb and Cd by flame atomic absorption spectroscopy with a Perkin-Elmer Model 306 spectrometer. None of the trace elements analyzed was water-soluble and data from the leaching tests in Table-3 indicate that Cu, Ni, Cr and Zn were detected in leachates by atomic absorption analysis.

TABLE-3
LEACHING PROFILES OF TRACE ELEMENTS IN BRICK

Leaching period (h)	Element (mg/L)			
	Cu	Ni	Cr	Zn
1	0.03	0.75	0.07	0.08
24	0.03	1.75	0.05	0.06
168	0.02	2.25	0.51	0.06
336	0.01	3.20	0.82	0.12
720	0.02	4.00	0.90	0.20

Pb and Cd were not detected.

Conclusions

Bench-scale tests showed that a brick, met with the TS 4563, can be produced from chromite tailings (with average 20% direct replacement of clay) in brick. Fine chromite tailings are considered as a waste material and have no commercial worth expect for some applications. This is a practical method for utilizing chromite tailings in bricks which would reduce problems of disposal, in terms of tonnage and overall costs in Turkish brick market.

The authors are aware of no industry standards for bricks with regard to leaching of metals. Overall, results were inconclusive, which may have been due in part to the limited number of data points. It should be noted that brick making clay, like many earthen raw materials, contains trace metal impurities. Thus, addition of tailings may not have added to metal loading of the brick.

The brick company has started to use the tailings in plant scale trial in April 2001. Preliminary results showed that the plant-sized bricks met the TS 4563 and developeded some cracks during the drying stage. The clay minerals in tailings may be the cause for this. Currently detailed mineralogical, economic and also blending studies continue and the overall operation results have not been obtained yet.

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