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Utilization of trommel sieve waste as an additive in Portland cement production

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Abstract

Large quantities of industrial wastes form in boron industry in Turkey every year. These wastes have dual problems of disposal and health hazards. The wastes such as borax slime, tincal waste, concentration wastes and thromel sieve waste (TSW) contain impurities that accelerate the normal setting and hardening of building materials produced from them. In this study, it was aimed to stabilize TSW produced during manufacture of borax from tincal. The effects of TSW added on the mechanical properties of Portland cement prepared by adding TSW to clinker were investigated. The utilization of TSW in cement industry as an additive was tested and compared with other materials.

Keywords: Boron wastes; Cement; Waste management; Waste stabilization

1. Introduction

Turkey has the largest boron reserve in the world and about 53% of the world's boron ores are in Turkey. The average boron ores production of Turkey is about 1.3 billion tons per year. The most important boron ores in Turkey are colemanite, ulexite and tincal. Products, such as borax, boric acid and sodium perborate are obtained from these ores. But, the trommel sieve waste (TSW) forms in the reactor during the borax production from Tincal. The amount of this waste is about 250,000 tons/year. The TSW contains some insoluble and soluble boron minerals with clay. Boron compounds in this waste discharged to land dissolved by rain water, and pass to soil where they form some complexes with heavy metals such as Pb, Cu, Co, Ni, Cd, etc., so that the potential toxicity of these metals increases, and cause some serious health and environmental problems when the complexes pass to groundwater. Hence, there is a necessity of making use of this waste in large amount to avoid the environmental problems [1].

Cement is a hydraulic binder which is obtained by grinding gypsum, which is added in 3–5% to clinker [2]. Concrete is made by mixing cement, aggregate and water in certain ratios. It is an important building material among the all materials. The superiority of the various mechanical properties of concrete in accordance with the other materials, the production of building elements and their use are important characteristics. However, the high value of unit weight of concrete which is produced with aggregates in normal dimensions, the high heat transfer and the expensiveness of cement are the disadvantages of concrete. It is

Table 1
The chemical analyses of TSW

Parameters	TSW (%)
B_2O_3	6.980
SiO_2	14.270
SO_3	0.540
CaO	17.040
MgO	16.270
Fe_2O_3	0.180
Al_2O_3	1.480
Na_2O	3.840
SrO	1.000
As_2O_3	0.004

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Table 2
The properties of clinker and cement

Parameter	Clinker (%)	Cement (%)
SiO_2	20.710	19.580
CaO	64.200	55.400
MgO	3.470	3.380
Fe_2O_3	3.200	3.000
Al_2O_3	5.940	4.880
SO_3	1.620	3.000
Undissolved solid	0.360	7.620
Heating lost	0.330	3.360

necessary to add various admixtures to the heated clinker to reduce the cost of cement production and to get a product which will have low heat transfer and low unit weight. In addition, it is possible to produce the building materials that have different characteristics with the addition of various admixtures in different ratios. Those admixtures can be either natural or industrial wastes.

The important factors required for obtaining a suitable mixture economically and to get a concrete having optimum characteristics such as selection of the mixing ratios and the properties of materials for concrete. The workability of wet concrete, durability and strength of hardened concrete are the main functional requirements. There are various methods dealing with the calculation of mix proportions and the information about main characteristics of concrete. Whatever methods are used, it is essential that the mix proportions with calculation should be controlled with experimental data and necessary corrections must be realized.

Table 3
Experimental results

	Waste ratio, %	Tensile strength, kg/cm^2			Compressive strength, kg/cm^2		
		2 days	7 days	28 days	2 days	7 days	28 days
TSW	2.5	50	64	77	220	355	434
	5.0	37	56	72	195	325	415
	10.0	34	50	69	175	291	365
	15.0	25	47	60	135	255	340
	25.0	20	35	58	105	190	310
	40.0	–	25	29	–	190	151
	50.0	–	–	25	–	–	125
Heated TSW	2.5	35	50	59	185	265	310
	5.0	29	45	55	150	255	290
	10.0	26	44	53	125	250	285
	15.0	15	35	50	88	229	273
	25.0	10	25	45	55	140	254
	40.0	–	–	34	–	70	170
	50.0	–	–	25	–	–	130
Portland cement		43	56	72	183	279	350
Clinker		52	69	78	221	346	453

The researches show that 50% energy reduction during the clinker grinding, development of strength, decreasing in heating temperature of clinker and high resistance against nuclear radiation are the main characteristics of the concrete produced from cement containing borate [3]. In some studies on the removal of solid boron wastes, the recovery of boron from boron wastes or the stabilization of boron wastes with cement, lime and sand has been studied [3–9]. In addition to TSW and other boron wastes are the important

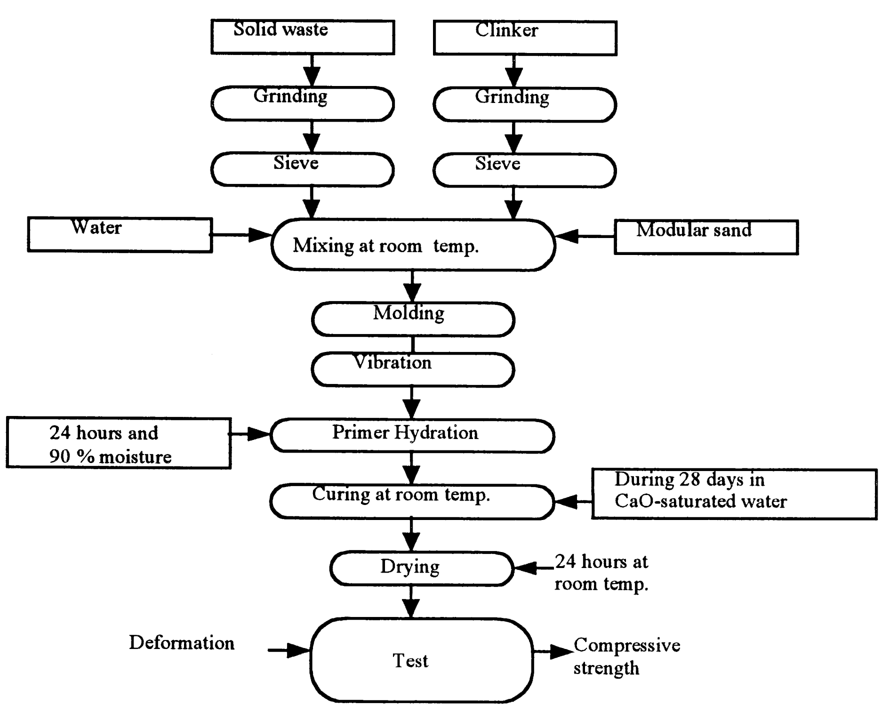

Fig. 1. Flow diagram.

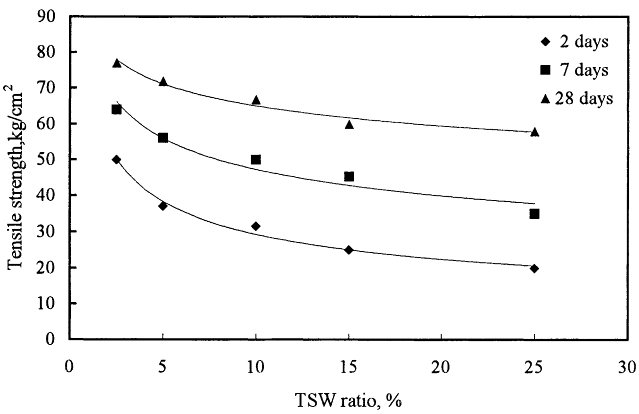

Fig. 2. Tensile strength of concrete with TSW.

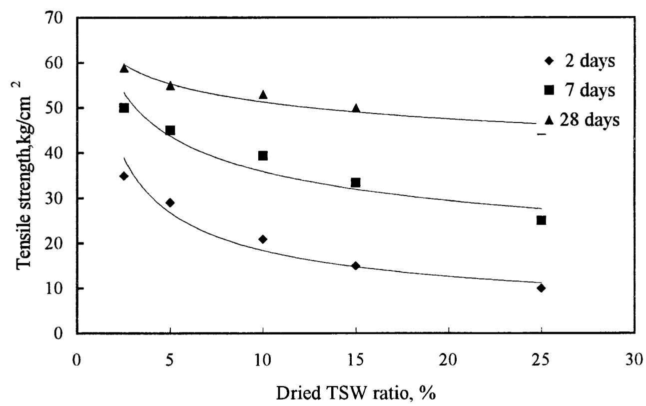

Fig. 4. Tensile strength of concrete with dried (105 °C).

industrial waste generated as by-products from the borax production. There have been reports on the utilization of this waste for making cementitious binders and building products [3,4]. To reduce pollution and disposal of this waste, there is an urgent need to develop useful building materials from them. With this view, investigations were undertaken to produce cementitious binders by blending the TSW with Portland cement as well as by suitably proportioning TSW [5]. In some studies on the removal of solid boron wastes, the recovery of boron from boron wastes or the stabilization of boron wastes with cement, lime and sand has been studied [10,11].

The aim of this research is to investigate the use of TSW as a cement additive in Eti Holding Borax and Acid Factories in Bandırma, Turkey to stabilize this waste.

2. Materials and methods

The materials used in the study were collected from Eti Holding Borax and Acid Factories in Bandırma Turkey. TSW was taken from the outlet of the reactor in which tincal dissolved. This dampy waste was dried in the air and then it was crushed and ground by mechanical ways. The particle sizes of TSW were not taken into account since it has a crushable structure and completely sieved in a 100-mesh sieve. Some physical and chemical features of TSW used in the research are presented in Table 1. Clinker, cement and modular sand, which are provided from Erçimsan-Aşkale

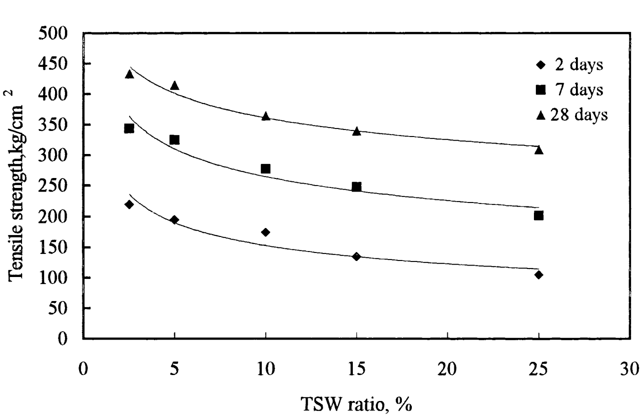

Fig. 3. Compressive strength of concrete with TSW.

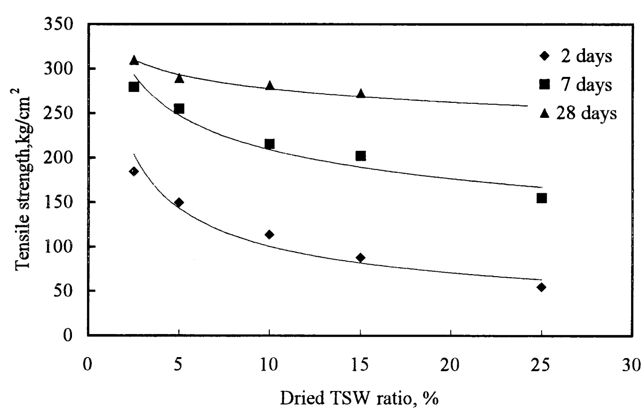

Fig. 5. Compressive strength of concrete with dried (105 °C) TSW.

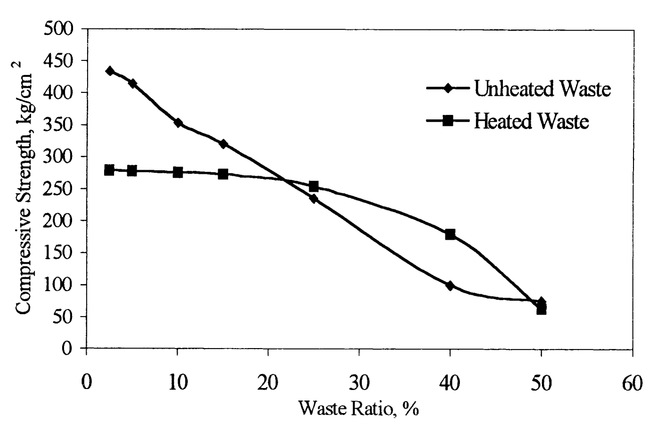

Fig. 6. Compressive strength of concrete with TSW.

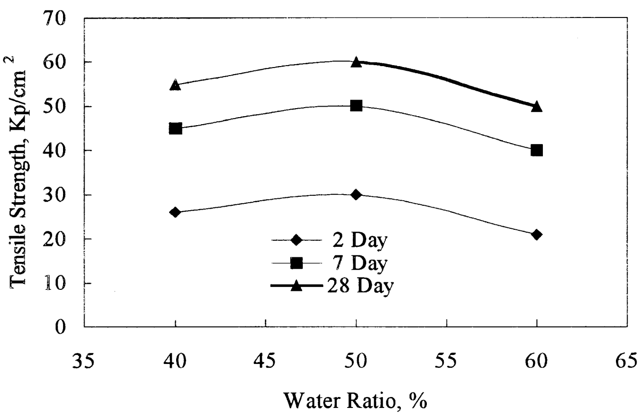

Fig. 7. The effect of water ratio on tensile strength of concrete with TSW.

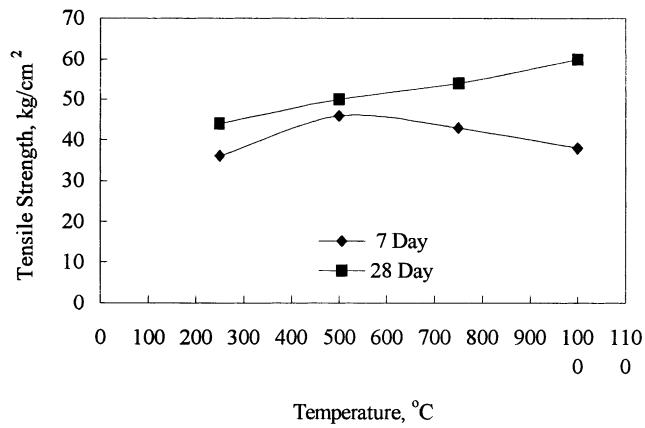

Fig. 9. The effect of heated temperature on tensile strength of concrete with TSW.

Cement Factory in Erzurum, Turkey, were used in the experiments. The properties of the clinker and the cement are given in Table 2.

In the experiments, a three-cell mold (4 × 4 × 12 cm) in dimensions was used. Cement, waste, sand and water were well mixed and the mortar obtained was compressed according to the standards and put into the molds and were vibrated in a mechanical vibrator. After the top surface of the mold was smoothened by a steel plate, the sample was left for the first hydration. In order to reduce the loss of moisture in the samples, the mold was covered with a polyethylene film and kept for 24 h for the first hydration at 20–25 °C and in 90% water saturated air. Then samples remolded were left in lime-saturated water for 28 days and dried in air. The surfaces of the dried samples were smoothened by carburondum and surface areas were measured by a compass weighted by a precision balance. After this procedure, compressive strengths, unit weights and other mechanical properties were tested and recorded. The procedure is shown in Fig. 1 schematically. The compressive strengths were measured in an universal test equipment, which has a maximum capacity of 10000 kg/cm^2 by crushing them with automatic loading machine. Standard methods were employed both in the preparation of the mixtures and the measurements and analysis during the experiments [12–14]. All of these experiments were carried out in Erçimsan-Aşkale Cement Factory in Erzurum, Turkey under real industrial conditions.

3. Results and discussions

The cement samples were obtained by adding separately TSW to the clinker in certain ratios. The compressive strength and tensile strength of the concretes produced by these cements were determined. In the first part of the study, TSW was added to clinker in ratio of 2%, 5%, 5%, 10%, 15%, 20%, 25%, 40% and 50% (w/w). Results obtained in this part of the study are given in Table 3 and Figs. 2–6. It is observed that the cement obtained by adding TSW to clinker had a higher compressive strength and tensile strength than concrete produced with normal Portland cement. The compressive strengths of the concrete produced from pure clinker and Portland cement were 455 and 325 kg/cm^2, respectively, whereas compressive strengths achieved by

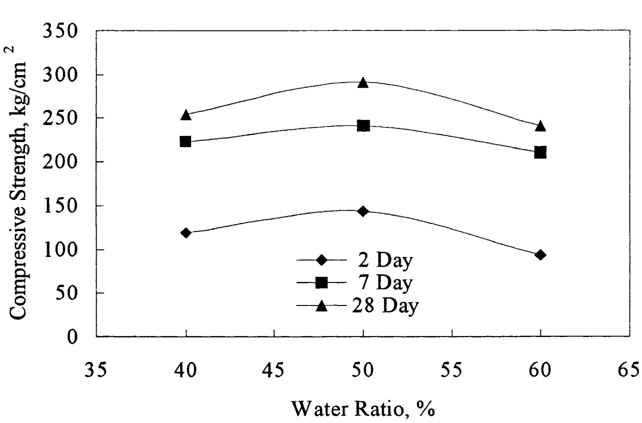

Fig. 8. The effect of water ratio on compressive strength of concrete with TSW.

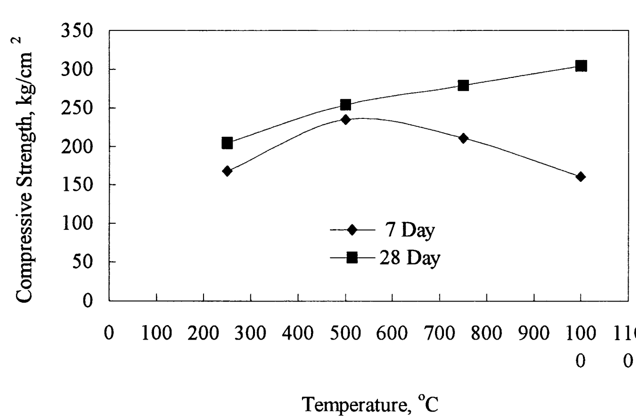

Fig. 10. The effect of heated temperature on compressive strength of concrete with TSW.

addition of 2.5%, 5%, 10%, 15% (w/w) of TSW to the clinker were 434, 415, 365, 340 kg/cm^2, respectively. Additionally, the tensile strength of the concrete produced from pure clinker is 78 kg/cm^2, while being 77 kg/cm^2 for cement produced with 2.5% (w/w) TSW. It has been concluded that the TSW can be added to the clinker to produce Portland cement.

In the second part of the study, the effect of water ratio 40%, 50% and 60% (w/w) on the mechanical properties of cement containing TSW 20% (w/w) ratio were studied. The results given in Figs. 7 and 8 show that an optimum water ratio is 50% (w/w).

In the third part of the study, TSW was heated at 250, 500, 750 and 1000 °C. The waste heated at desired temperature was mixed with clinker at 20% (w/w) ratio. Then, the mechanical properties of concrete produced from heated TSW were determined. Results are given in Figs. 9 and 10. It was seen that the increasing of the temperature caused increasing of mechanical strength.

4. Conclusions

The concrete obtained from the cement with TSW gives the better mechanical strength than that of the others traditional cements. Also, the addition of the TSW to clinker decreases the unit weight of produced concrete. It has been seen that the concrete with TSW decreases the setting time of the concrete. Also, the mechanical strength of the concrete decreases with increasing the TSW ratio. On the other hands, it is known that the obtained cements and concretes are resistive across microbial decomposition because boron compounds are anticeptics [1], and boron compounds also decrease radioactive permeability of the concrete [3]. As a results, it is suggested that TSW can be used as an additive to cement up to 25% by weight.

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