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# A RESEARCH ON THE PHYSICAL FEATURES OF CONCRETES WITH FERRO-CHROMIUM SLAG

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## Abstract

In this study, waste ferrochromium slag is used instead of using natural aggregate, and low density concrete is produced. For this purpose, slag aggregate is mixed with 10%, 30%, 50% and 70% cement to produce samples. The tests applied to the samples show that an increase in slag in the mix decreases thermal conductivity, specific heat capacity and comprehensive and tensile strength while porosity and water absorption capacity increases. If slag aggregated concrete is used for the structural member of a building, *i*) factory waste ferro chromium slag will be utilized and contributed to economy. *ii*) The use of slag in building concrete, bricks, briquettes and panel walls will lower the heating expenses and facilitate energy saving.

**Key Words:** Ferro chromium slag, porous materials, lightweight aggregates, building material, concrete.

## 1. Introduction

In this study, waste-form porotic ferro chromium slag is used instead of classic aggregate for producing low density concrete. Slag is produced in Elazig Eti Chromium Factory during mixing proper percentages of chromite, quartzite, coke and heating in arch furnaces to produce ferro chromium melt. Slag accumulates on melt's surface and after separation, it is accumulated in the slag storage. From each gross ton of ferro chromium, 1.6 ton of slag is produced and slag storage accumulation for a year surpasses 150.000 tones. Ferrochromium slag, which is considered an important industrial waste hasn't got a utilization field yet. Its physical appearance normally looks like light brown, granulated fine aggregate while being fairly lighter and porotic than normal sand or gravel material. $SiO_2$ and $Al_2O_3$, the main components in building materials are richly found in slag. For this reason, it carries concrete aggregate features (Yıldırım, 1987).

There are no significant studies that are bound by specifications and standard that renders ferro chromium as aggregate. Some of the similar studies closely relating the subject are summarized below:

Babu et al, investigated the mechanical properties of light concretes produced using fly ash (50%) with expanded polystyrene (from 0 to 66.5%) instead of regular aggregate (Babu et al, 2005). Kaya and Kar tested thermo-mechanical properties of the concretes with EPS + tragacanth resin (Kaya & Kar, 2016) and EPS + apricot resin (Kaya & Kar, 2017). Devecioglu and Bicer, (2016) investigated thermal and mechanical properties of concretes by using expanded clay aggregates instead of sand in concrete. Demirel, studied thermal conductivity in sample with cement + EPS and pumice (Demirel, 2013). Rim at al (1999), determined thermal and mechanical properties of lightweight concrete with mixture of cement + clay and wood pellet (10% - 30%) composites. Benazzouk et al [8], investigated mechanical and thermal properties by using partial (30, 40, 50%) rubber particle instead of sand in concrete. Bicer and Celik, studied thermal and mechanical properties of concretes by using pumice aggregates and pine tree resin in concrete (Bicer & Celik 2020).

In this study, in the context of ferro chromium slag being considered as a building material; thermal conductivity, heating capacity, pressure and pulling strength, water absorption and drying up rates are determined scientifically for slag mix with cement in specific percentages. The results for ferro chromium slag are then compared with similar building materials and utilization in buildings is studied. Ferro chromium slag concretes are more advantageous than concrete (C 25), granite, lime stone, sand stone, marble and common brick materials in terms of density and thermal conductivity.

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## 2. Materials and Methods

### 2.1. Materials

*Ferro-Chromium Slag:*
The slag sample's chemical compounds which were taken from Elazig Eti-Krom Factory are listed in Table 1. Its loose specific bulk density is specified as 0.88 g/cm$^3$ and dense specific bulk density is specified as 1.0 g/cm$^3$. Its true density is 1.6 g/cm$^3$ (Fig 1).

Fig. 1**.** View of ferro-chromium slag aggregate

*Cement***:**
CEM IV/B (P) 32.5 R pozzolanic cement (KPÇ 325) was added as a binder to ferro chromium slag aggregate. The cement's density value was estimated as 3.1 g/cm$^3$ and its thermal conductivity value was 0.751 W/mK and its chemical components are given in Table 1.

Table 1. Chemical composition of the cement and ferro-chromium slag used (%)

| component / Material | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $Cr_2O_3$ | MgO | CaO | $SO_3$ | Undefined |
|---|---|---|---|---|---|---|---|---|
| Ferro-Chromium slag | 29.50 | 31.10 | 0.90 | 3.70 | 31.80 | 0.80 | - | |
| Cement | 18.65 | 6.15 | 3.25 | - | 2.34 | 56.4 | 5.91 | 6.75 |

### 2.2. Preparation of samples

KPÇ 325 cement which is used as a binding agent for ferro chromium slag is mixed with slag by 10, 30, 50 and 70 percent by weight, then, textured to mortar consistency with water and for the heating test and mechanic tests, it is poured on the 150x60x20 mm and 70x70x70 mm metal molds respectively.
Prepared samples are projected to 28 days of drying in 20 ºC room temperature and stored until measuring phase

### 2.3. Methods

#### 2.3.1. Thermal tests

The thermal conductivities, specific heats and thermal diffusivity of specimens were detected by *Isomet 2104* portable heat transfer analyzer, which makes measurements by using the hot wire method according to Norm (DIN) 51046. Measurements were made on different parts of the specimens three times and the averages of these measurements were used in the study. Its range and sensitivity were 0.02-6.00 W/mK with ± 5 % precision respectively and volumetric heat capacity in the range of $4.0 \times 10^4$ J/m$^3$ K and $4.0 \times 10^6$ J/m$^3$ K with 15% precision. The temperature was between 26°C and 28°C during measurement.

### 2.3.2. Mechanical tests

The mechanical strength tests on the samples are undertaken according to the *ASTM C 109-80* standard (ASTM 1985). Compressive strength test was applied on sample blocks. Tensile strength values calculated by Eq. (1) according to the *TS 500* standard (TSE 500, 2000).

$$f_{ctk} = 0{,}35.\sqrt{fck} \tag{1}$$

Where, $f_{ck}$: compressive strength (N/mm$^2$) and $f_{ctk}$: tensile strength (N/mm$^2$).

### 2.3.3. Water absorption (WAP) and drying ratio (DR) tests

This test aimed to find out the presence of a dry volume, allowing expansion of ice crystals, when the building materials froze by coming in direct contact with water. The material acquired strength against freezing due to this characteristic. The critical amount of moisture is 30% of the total dry volume, below which the material does not deform on freezing. The experiments were performed according to the *BS 812-109* standard (BS 812-109, 1990). The water absorption values and drying ratio values were calculated by Eq. (2) and Eq. (3). They are presented in Fig 5, Fig 6 and Fig 7.

$$\mathrm{WAP} = \frac{W\mathrm{d} - \mathrm{Wk}}{\mathrm{Wk}}\,.100 \tag{2}$$

$$\mathrm{DR} = \frac{W\mathrm{d} - \mathrm{Wk}}{\mathrm{Wd}}\,.100 \tag{3}$$

## 3. Results and Discussion

Samples prepared for low density concrete production show that slag does not start a chemical reaction with cement paste and, because of porotic and textured surface of slag grains, improvement in adherence is detected. In conclusions of tests about the prepared samples;

Thermal conductivity coefficient of concretes, produced by means of using slag aggregate is lower than the standard concrete, and that it is reduced down to 25.78% where the slag amount is increased from 10% to 70% (Fig 2).

If the values for similar building materials were compared, slag aggregated cements' thermal conductivity is lower than all of them (Table 3). For this reason, the slag bears the potential to be utilized in building elements where thermal insulation is critical. As can be seen in Figure 3, the more the slag amount is, the lower the heat capacities are. Its thermal capacity values are higher, compared to a number of other building materials. It can be said that the aforementioned advantages of slag aggregated concretes in terms of thermal properties are due to their porous structure (Table 4).

For compressive strengths, the strength values decrease where the slag percentage increases, as shown in Figure 4. Increasing the slag ratio from 10% to 70%, the compressive strength values decrease by 80.38%. However, standard concrete can be produced with an addition of up to 30% slag, in compliance with the strength values issued in TS 500. Moreover, it can also be recognized as an alternative method for concrete production by means of being mixed with standard concrete aggregate, thus ensuring that the weight is decreased to a certain extent in building elements, where weight is considered as a disadvantage.

Water absorption ratios of concrete blocks, comprising various ratios of slag are under 30%, which is the critical threshold, as shown in Figure 5. Therefore, it can be understood that ferro chromium slag aggregated concretes can be used in humid environments. Time-based water absorption behaviors can be seen Figure 6. Taking a glance on the drying behaviors in Figure 7, it can be seen that the samples leastwise do bear the ability to breathe.

Table 2**.** Mixing ratio of samples

| | |
|---|---|
| Sample 1 | 10% ferro-Chromium slag + cement |
| Sample 2 | 30% ferro-Chromium slag + cement |
| Sample 3 | 50% ferro-Chromium slag + cement |
| Sample 4 | 70% ferro-Chromium slag + cement |

Table 3. The physical properties of some building materials [13]

| Materials | Density ($kg/m^3$) | Thermal conductivity (W/mK) | Specific heat capacity Cp(J/kgK) | Thermal diffusivity $a.10^{-7}(m^2/s)$ | Compre. strength ($N/mm^2$) | Tensile strength ($N/mm^2$) |
|---|---|---|---|---|---|---|
| Concrete (C25) | 2307 | 1.4 | 979 | 6.19 | 30 | 1.7 |
| Granite | 2643 | 1.73 | 816 | 13.15 | 120 | 7.5 |
| Limestone | 2483 | 1.16 | 908 | 5.68 | 35 | 3.0 |
| Sandstone | 2163 | 1.63 | 712 | 10.58 | 80 | 6 |
| Marble | 2603 | 2.77 | 808 | 3.4 | 50 | 5.0 |
| Common brick | 837 | 0.692 | 837 | 5.16 | 16 | 1.4 |
| **Sample 1** | **1750** | **0.772** | **1320** | **3.38** | **25.9** | **1.78** |
| **Sample 2** | **1658** | **0.717** | **1234** | **3.74** | **17.1** | **1.48** |
| **Sample 3** | **1598** | **0.669** | **1150** | **3.60** | **9.2** | **1.06** |
| **Sample 4** | **1500** | **0.573** | **1060** | **3.67** | **5.08** | **0.79** |

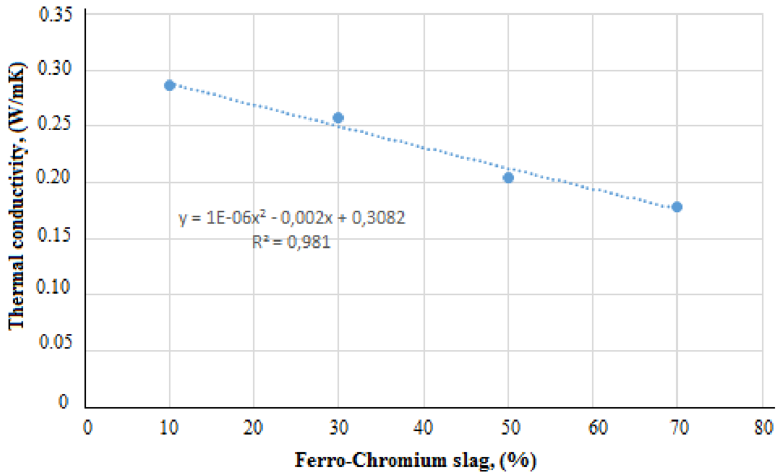


Fig. 2. Thermal conductivity variations according to slag

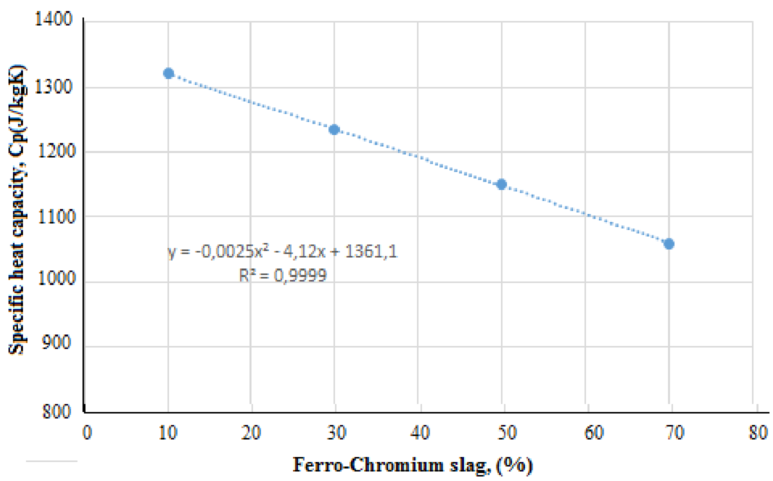


Fig. 3. Specific heat capacity variations versus slag

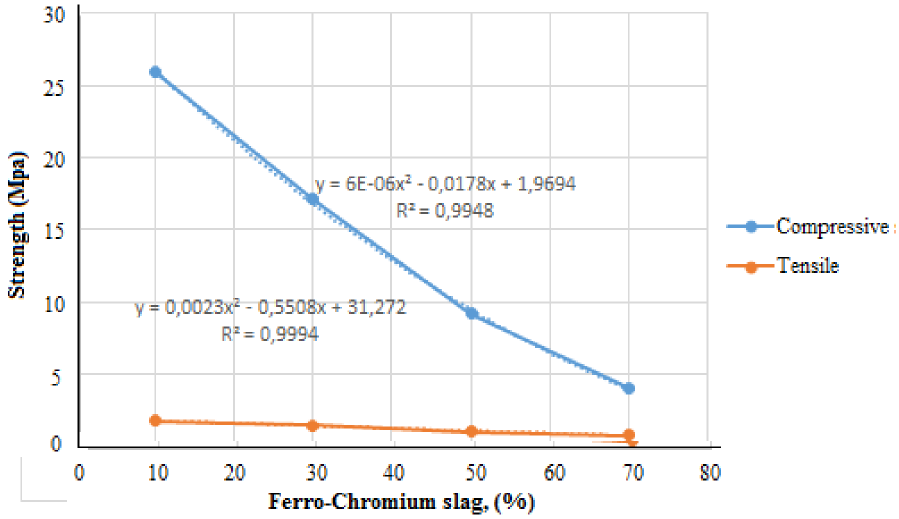


Fig. 4. Strengths variations versus slag

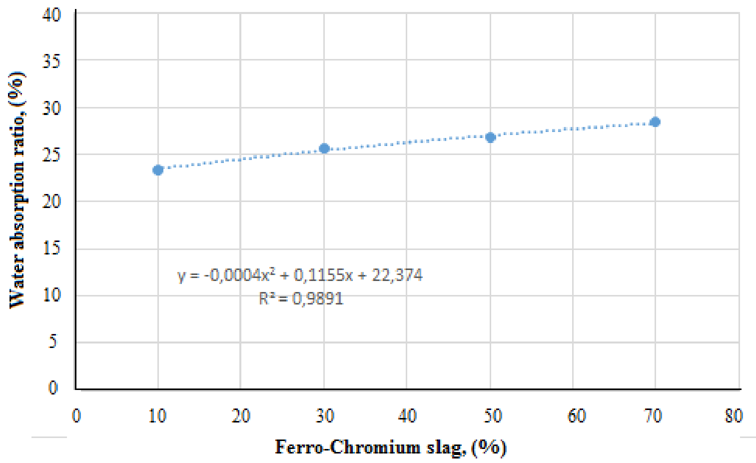


Fig. 5. Water absorption ratio variations according to slag

Table 4. Some physical features of similar studies.

| Material | Density ($g/cm^3$) | Thermal conductivity (W/mK) | Compressive Strength (MPa) | References |
|---|---|---|---|---|
| Cement + fly ash + EPS + sand | 1.150 | - | 3.5 | [2] |
| Cement + fly ash + EPS + sand | 1.350 | - | 12.0 | |
| EPS (80%) + cement (20%) + tragacanth (1%) | 0.536 | 0.050 | 0.89 | [3] |
| EPS (20%) + cement (80%) + tragacanth (1%) | 1.232 | 0.320 | 10.85 | |
| EPS (80%) + cement (20%) + apricot resin (1%) | 0.553 | 0.060 | 1.50 | [4] |
| EPS (20%) + cement (80%) + apricot resin (1%) | 1.291 | 0.322 | 13.05 | |
| Cement + exp clay (5%) + tragacanth (1%) | 1.183 | 0.213 | 5.46 | [5] |
| Cement + exp clay (10%) + tragacanth (1%) | 1.056 | 0.189 | 2.07 | |
| Cement + exp clay (20%) + tragacanth (1%) | 0.867 | 0.182 | 1.48 | |
| EPS + pumice blocks | 0.578-0.600 | 0.130 | 1.77 ($N/mm^2$) | [6] |
| Cement + clay + wood pellet (10%) | 1.010 | 0.220 | 2.67 | [7] |
| Cement + clay + wood pellet (20%) | 0.870 | 0.160 | 2.35 | |
| Cement + clay + wood pellet (30%) | 0.700 | 0.140 | 1.35 | |
| Cement and rubber particle (30%) | 1.473 | 0.625 | 23.30 | [8] |
| Cement and rubber particle (40%) | 1.300 | 0.516 | 16.00 | |
| Cement and rubber particle (50%) | 1.150 | 0.470 | 10.50 | |
| Cement + pumice (20%)+pine tree resin (1%) | 1.580 | 0.390 | 20.58 | [9] |
| Cement + pumice (20%)+pine tree resin (1%) | 1.492 | 0.338 | 14.68 | |
| Cement + pumice (20%)+pine tree resin (1%) | 1.401 | 0.280 | 10.59 | |
| Cement + pumice (20%)+pine tree resin (1%) | 1.298 | 0.248 | 5.36 | |
| Sample 1: (10% ferro-Chromium slag + cement) | **1.750** | **0.772** | **25.9** | Present |
| Sample 2: (30% ferro-Chromium slag + cement) | **1.658** | **0.717** | **17.1** | |
| Sample 3: (50% ferro-Chromium slag + cement) | **1.598** | **0.669** | **9.2** | |
| Sample 4: (70% ferro-Chromium slag + cement) | **1.500** | **0.573** | **2.08** | |

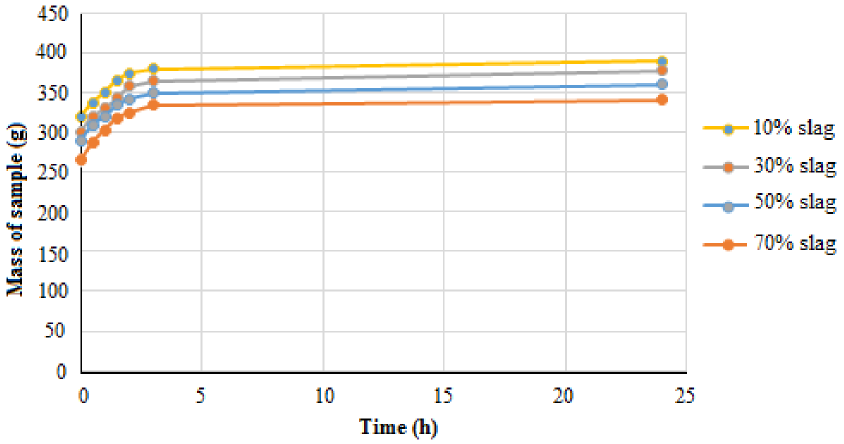


Fig. 6. Mass change of samples in water absorption tests

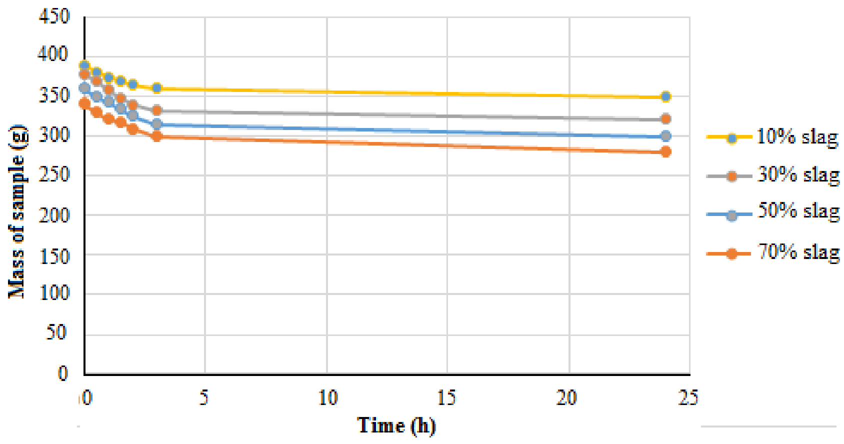


Fig. 7. Mass change of samples in the drying test

## 4. Conclusions

Conclusions of studies on concretes produced by ferro chromium instead of natural aggregates are summed up below;

✓ It is possible to produce concrete that has low density or has insulation qualities when using ferro chromium slag instead of natural aggregate in production. In the event of utilization of this waste material, environmental pollution will be lowered and a positive contribution to economy will be made.

✓ If ferro chromium slag is used as a partition element in the form of brick, briquette or concrete, it will lighten the building weight (density:1.500 g/cm$^3$) and reduce heating costs with its light weight and 0.573 W/mK thermal conductivity coefficient.

✓ Using ferro chromium in abundance within concrete leads to a detrimental effect in endurance, but it might, on the other hand, be viable to use ferro chromium scarcely in concrete production.

✓ It is found that Ferro chromium slag proves to facilitate heating properties and heat insulation of concrete positively,

As a result, the ferro-chromium slag aggregate with cement offers can be potential construction and insulation materials and simultaneously solve the environmental problem by recycling solid waste.

## Kaynaklar

1. **Yıldırım M.M. (1987).** Metallurjik katı atıklardan yaralanabilme olanakları, T.M.M.O.B, Metallurji Müh. Odası, 49, 12-15.
2. **Babu D.S, Babu K.G &Wee TH. (2005).** Properties of lightweight expanded polystyrene aggregate concretes containing fly ash. Cement and Concrete Research, 35, 1218-1223.
3. **Kaya A. & Kar F. (2016).** Properties of concrete containing waste expanded polystyrene and natural resin, Construction and Building Materials, 105, 572-578.
4. **Bicer A. & Kar F. (2017).** The effects of apricot resin addition to the light weight concrete with expanded polystyrene, Journal of Adhesion Science and technology, 31(21), 2335-2348.
5. **Devecioglu A.G. & Bicer Y. (2016).** The effects of tragacanth addition on the thermal and mechanical properties of light weight concretes mixed with expanded clay. Period. Polytech. Civil Eng., 60(1), 45-50, 2016.
6. **Demirel B. (2013).** Optimization of the composite brick composed of expanded polystyrene and pumice blocks. Construction and Building Materials, 40, 306-313.
7. **Al Rim K., Ledhem, A. & Douzane, O. (1999).** Dheilly, RM. Queneudec, M.. Influence of the proportion of wood on the thermal and mechanical performances of clay-cement-wood composites. Cement and Concrete

Composites, 21, 269-276.
8. **Benazzouk A., Douzane O., Mezreb K., Laidoudi B. & Queneudec M. (2008).** Thermal conductivity of cement composites containing rubber waste particles, Experimental study and modelling. Construction and Building Materials, 22, 573-579.
9**. Bicer A. & Celik N. (2020).** Influence of pine tree resin on thermos-mechanical properties of pumice-cement composites, Cement and Concrete Composites, 112.
10. **ASTM C. (1985).** Standard specification for fly ash and raw or calcined natural pozzolan for use as mineral admixture in Portland cement concrete, ASTM, Philadelphia, ASTM C; 618-685
11. **TS 500, (2000).** Turkish Standard, Ankara.
12**. BS 812-109, (1990)**. Testing aggregates-part 109: methods for determination of moisture content, *British Standards Institution* 1990**.**
13. **Toksoy M. (1988).** Thermal conductivity coefficients of industrial materials, Journal of Engineers and Machinery, 347, 12-15.