# SOME PROPERTIES OF MORTARS CONTAINING CHROMIUM-STEEL WASTE CHIPS

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***Abstract:*** *Especially in recent times, many studies have been performed on cementitious mortar materials to have different properties. Some of these studies include the production of different building materials to reduce the harmful effects of devices emitting electromagnetic and radioactive waves used at industrial scale. For this purpose, in this work, chromium steel shavings in metallic character obtained during metal machining processes, were used in cementitious mortar mixes by replacing with limestone fine aggregate in a certain ratio. These mixes were tested to examine their physical and mechanical properties. The findings were compared with those of control specimens. With the inclusion of chromium steel chips, bulk density, apparent porosity, water absorption and capillarity of the mortars increased while flexural and compressive strength decreased.*

**Keywords**: Cementitious mortar, Chromium steel chips

## *1. Introduction*

The use of recycled wastes in cementitious material manufacturing has attracted worldwide interest due to increasing disposal costs and environmental concerns. Disposal waste from solid metal technology is a global environmental problem and there are a lot of research works, trying to solve this problem [1]. Steel chips or shavings are formed during the machining operations that are performed on cast or formed steel products. These operations include milling, drilling, etc. The steel chips or shavings formed as a waste material could replace sand or aggregate in the cementitious mortars. In the study of Furlani et al. [2] steel scale wastes were utilized in the production of mortars by replacing sand in 5-40 % range. It was reported that the obtained mortars presented good compressive strength and low water absorption, however, higher apparent density [2]. Alwaeli et al. [3] used steel chips and shavings from the iron and steel industry in the production of concrete. They replaced sand in the concrete with steel shavings in 25 – 100 % range. Their aim was to enhance compressive strength and gamma radiation absorption property of the concrete. They reported that the concrete containing steel shavings presented better compressive strength in addition to gamma ray attenuation properties, as compared to the conventional concrete [3]. In the study of Ismail [4], flexural strength of the concretes was also reported to increase slightly with the addition of waste iron aggregate into the concrete instead of sand.

Some of the recent studies on building materials focus on the reduction of the harmful effects of devices emitting electromagnetic and radioactive waves. These materials contain metals in the form of wire, etc. The present study aims to produce mortars containing metal chips, by utilizing waste chromium steel chips obtained from metal machining operations. Therefore, in addition to utilization of cheap starting materials, elimination of waste products through a useful process has been aimed. For this purpose, in this work, chromium steel shavings in metallic character obtained during machining processes were used in cementitious mortar mixes by replacing 10 vol. % with limestone aggregate. The mechanical properties of the cementitious mortar mixes were assessed along with some other properties. Further characterization of the obtained mortars is in progress.

## *2. Experimental Procedure*

CEM I 42.5R complying with TS EN 197-1with a specific gravity of 3.06 was used as cement. The mixtures had a w/c ratio of 0.60 and aggregate/cement ratio of 4.7. Limestone aggregate was replaced with waste chromium-steel chips by a ratio of 10% in volume. Table 1exhibits some properties of limestone aggregate and waste chromium-nickel chips. Figure 1 illustrates the aggregates used in the specimens.

***Table. 1.*** *Some properties of limestone and waste chromium-steel chips as aggregates*

| **Sand** | **Specific gravity (g/cm$^3$)** | **Rodded unit weight (g/cm$^3$)** | **Loose unit weight (g/cm$^3$)** | **Rodded porosity (%)** | **Loose porosity (%)** |
|---|---|---|---|---|---|
| **Limestone** | 2,71 | 1746 | 1611 | 35,43 | 40,42 |
| **Chromium-Steel** | 7,83 | 1291 | 1000 | 83,48 | 87,20 |

***Figure. 1.*** *Images of limestone (upper) and waste chromium-steel chips (lower) used in mixes as aggregates.*

The specimens were cast into steel moulds and maintained for 24 h. The hardened specimens were then demoulded and kept under lime-saturated water at 20 ± 2 $^{o}$C until the age of testing. The 24-

hour sorptivity was determined by the measurement of the capillary rise absorption rate. The bulk density, water absorption and porosity values were obtained by testing prism specimens according to ASTM C 642. The flexural and compressive strength of hardened specimens were determined in accordance with TS EN 1015-11.

## *3. Results and Discussion*

Although the specific weight of chromium nickel in Table 1 is higher, the effect of this specific weight is not reflected on the unit weights of the mortars. This is because the gradation of the limestone aggregate is more consistent and appropriate than the chromium steel particle size distribution. This fact can be understood from the unit weights of the aggregates and the amount of voids between aggregate particles. The unit weights of chrome steel aggregates are lower because of intergranular voids.

It is seen that the intergranular voids mentioned above are one of the reasons causing the drops in the strengths in Table 2. According to the 7 and 28-day results, the increase in unit weight, the decrease in the apparent porosity and in the capillary voids were greater for control samples. This can be attributed to the fact that the control samples with less voids have more cement paste volume and thus more CSH gel resulting from hydration. This kind of behavior was also observed in some other investigations [5-7]. In addition, similar reductions in water absorption rates are due to the fact that the water absorption of chromium steel aggregates are negligible when compared to the limestone aggregates. Taking the strengths into consideration, the flexural strength development was higher in the control samples, while the compressive strength development was lower in the same control samples than the chromium steel aggregate samples. This may be due to the hydrated gels forming a more packed structure. The amount of void in the samples is a parameter that is more effective in flexural strength than the compressive strength. Also, under compressive stresses, voids and other defects tend to close.

***Table. 2.*** *Physical and mechanical properties of the specimens*

| **Properties** | **Control** | | **Chromium** | |
|---|---|---|---|---|
| | **7-day** | **28-day** | **7-day** | **28-day** |
| **SSD bulk density (g/dm$^3$)** | 2.32 | 2.36 | 2.50 | 2.52 |
| **OD bulk density (g/dm$^3$)** | 2.16 | 2.21 | 2.31 | 2.34 |
| **Apparent bulk density (g/cm$^3$)** | 2.55 | 2.60 | 2.86 | 2.87 |
| **Apparent porosity (%)** | 15.30 | 14.97 | 19.31 | 18.52 |
| **Water Absorption (%)** | 7.07 | 6.78 | 8.36 | 7.92 |
| **Capillarity (cm/s$^{1/2}$)** | 0.001961 | 0.000714 | 0.002547 | 0.001029 |
| **Flexural strength (MPa)** | 6.91 | 8.78 | 6.14 | 7.77 |
| **Compressive strength (MPa)** | 43.79 | 50.99 | 31.12 | 38.49 |

Images of the structures of the plain mortar and of the mortar containing chromium steel chips are presented in Fig. 2 (a) and 2 (b,c), respectively. It can be seen that the plain mortar is composed of cementitious mix and fine limestone aggregates. The sizes of these aggregates were smaller than 3 millimeters, as seen in Fig. 2 (a).

The black shaving-like thin strips are chromium steel chips in the structures given in Fig. 2 (b) and (c). It can be seen that the lengths of the chromium steel chips were in 1-2 mm range and their widths were smaller than 1 mm. Structural examination of the samples that contain chromium steel chips reveal that the chips were homogenously distributed in the structure of the mortars.

A high magnification image of the mortar that contained chromium steel chips is given in Fig. 2 (c). It was seen that there were no voids or porosity between the cementittious mix and chromium steel chips. The interface seemed clean and it can be inferred that the bonding between the cementitious mix and the chromium steel chips is good.

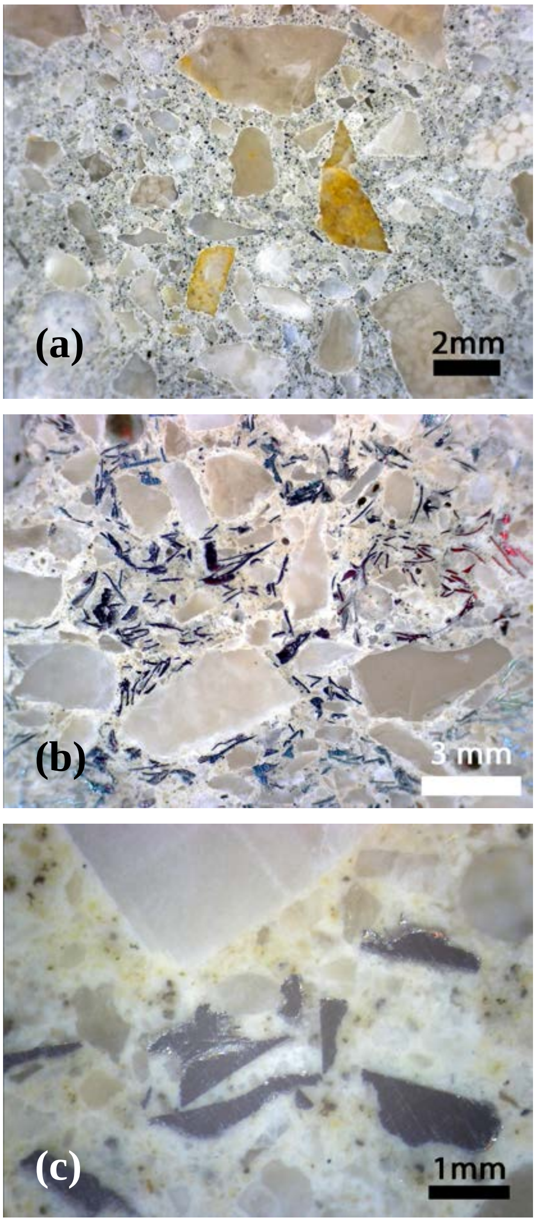

***Figure. 2.*** *Images showing the structures of (a) plain mortar, (b) mortar containing chromium-steel chips and (c) mortar containing chromium-steel chips (higher magnification image)*

Compressive stress-strain plots of the plain mortars and mortars containing chromium steel chips are presented in Fig. 3 (a) and (b), respectively. In general, replacement of fine aggregate with chromium steel chips resulted in a slight decrease in the compressive strengths of the mortars. This can be attributed to the lower strength of the chromium steel chips as compared to the limestone aggregates. This finding is in agreement with the literature, where ferrous alloy chips are added into different mortars [2-4].

Strain at maximum stress was seen to increase with the replacement of fine aggregate with chromium steel chips. This may be a result of the higher ductility of the chromium steel chips.

In addition, the elastic modulus of the mortar which contained chromium steel chips was seen to be lower. This is most probably due to the lower elastic modulus of the chromium steel chips, as compared to limestone aggregates. This results in lower rigidity but higher elastic strain of the mortars.

When the areas under the stress-strain curves are considered, it can be suggested that the mortar containing chromium steel chips has higher toughness than the plain mortar.

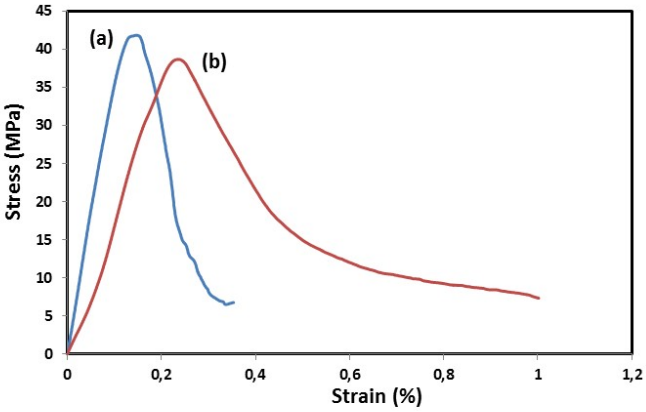

***Figure. 3.*** *Compressive stress – strain plots of (a) plain mortar and (b) mortar containing chromium-steel shavings.*

## *4. Conclusion*

Cementitious mortar mixes were produced by replacing limestone fine aggregate with chromium steel chips at 10 vol. % ratio. Obtained mortars presented higher bulk density, apparent porosity, water absorption and capillarity, toughness, and lower flexural and compressive strength. Produced mortar will be further characterized as a candidate material for electromagnetic or radiation shielding purposes.

## **References**

[1] V. Sasnauskas, A. Augonis, D. Vaičiukynienė, Conference: IBAUSIL 19 Internationale Baustofftagung 16-18 September 2015, Weimar, Bundesrepublik Deutschland, Volume: 2.

[2] E. Furlani, S. Maschio, Case Studies in Construction Materials, 4 (2016) 93–101

[3] M. Alwaeli, J. Nadziakiewicz, Construction and Building Materials, 28 (2012) 157–163

[4] Z. Z. Ismail, E. A. Al-Hashmi, Waste Management, 28 (2008) 2048–2053

[5] N.U. Kockal, F. Turker, Construction and Building Materials, 21 (2007) 634-645

[6] N.U. Kockal, Indian Journal of Engineering and Material Sciences, 22 (2015) 203-214

[7] N.U. Kockal, IJST Transactions of Civil Engineering, 37 (2013) 67-76