

## STUDY TO IMPROVE THE BREAKING STRENGTH OF THE NO-BAKE CHROMITE SAND-FURAN RESIN CORES

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### Abstract

This study was carried out to determine the effects of number of washings, curing time and heat treatment on the breaking strength of no-bake chromite sand-furan resin cores. The Hevi chromite sand produced by a single stage washing of chromite sand was found to exhibit lower breaking strength in service. Forty five samples of no-bake chromite sand mixes were prepared with furan resin at room temperature and 39% humidity from chromite sand washed in single and two stages and cured at 2, 4 and 24 hours. Eighteen of the samples washed in single and two stages were tested for breaking strength without heat treatment, while the 27 obtained from single stage washing sand mix were heated to 900 °C and held at 12, 14 and 16 minutes before cooling. Re-washing gave an appreciable increase in breaking strength only for samples cured for 24 hours. The results obtained showed that highest breaking strength occurred in heat treated and cured samples with the highest occurring at curing period of 24 hours and 900°C with holding time of 16 minutes. For re-washed samples held in room atmosphere, there was a decrease in breaking strength compared to the single stage washed samples. The implication of this work is that Hevi chromite sand has better breaking strength when heat treated at 900°C and held in the temperature for 16 minutes. Evidently, the air cured samples may have been affected by the air humidity.

**Key words:** Chromite sand, Cores, No-bake, Curing, Strength.

### 1. Introduction

Hevi sand is produced from high grade foundry chromite sand that has been specially treated for use as a mould and core media to produce quality castings. It is selectively mined from AMCOL's South African mines which are among the richest and purest chromite deposits in the world. Hevi sand is a unique aggregate prepared for traditionally difficult metal casting applications. Its unique characteristics allow foundry men to produce excellent castings. Its good density provides the mould or core with a high rate of heat transfer and excellent chilling characteristics

often eliminating the need for fabricated or cast metal chills [1].

Natural chromite occurring in chromite sand is a mineral containing oxides of chromium and iron, where these components are present in a certain weight percentage ratio, for instance, 50-80 % chromium oxide and 20-50 % iron oxide [2]. This naturally occurring chrome ore undergoes several intensive cleaning and screening processes to enhance moulding and casting properties and are available in various grades.

Sand casting is one of the major methods used by foundry industry to produce metal castings. In this process, sand or other

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aggregates are bonded together to give shaped cores or moulds using organic or inorganic binders.

Molten metal is then poured into the bonded sand mould and allowed to cool producing metal castings having the shape of the sand mould. Over 70% of all metal castings are produced by sand casting process [1, 3]. Base sands include silica, olivine, chromite, zircon and chamotte [4]. Green sand moulds are made of wet sands that are used to make the mould's shape. Green sand is a mixture of silica, chromite, zircon, olivine, staurolite or graphite. Other additives such as bentonite, water, inert sludge and anthracite are also required. Binders are required to strengthen moulds and cores. They include box, cold box, shell process, no-bake, clay and baking binders such as core oil. The no-bake process is a major technique in use in foundries. In the process, a binder system that will cure at ambient temperature is mixed with foundry sand or other aggregate and allowed to cure at room temperature to produce resin bonded moulds and cores. In practice, a catalyst is added to control the cure speed of the binder system. The cure speed of the no-bake system can be conveniently adjusted by varying the catalyst type and quantity [5]. Binders include clay and water, oil, resin, sodium silicate [6]. No bake moulds are expendable sand moulds similar to typical sand moulds, except they also contain a quick setting liquid resin and catalyst. In using it for moulding, the sand is poured into the flask and held until the resin solidifies at room temperature. The no-bake moulding produces a better surface finish than other types of sand moulds. The metals that are most commonly cast into no-bake moulds are brass, cast iron and aluminum alloys [7, 8].

Furan resins are produced by reactions between phenols and furans. They are used in place of formaldehyde in the conventional production of phenolic resins. No-bake curing

with added esters generally containing up to 25% potassium hydroxide is used as a binder.

The mixture usually consists of washed sand, 1.5% furan resin and 4% amine as catalyst [9, 10].

A work time/strip time (WT/ST) pad is used to determine the rate of the curing of sand mixtures. Work time is the point at which the sand mixture loses its flowability and compaction properties. It is defined as the time from when the furan resin was first added to chromite sand + furan acid catalyst mixture to the time when the WT/ST pad reaches a "B" scale hardness of  $40 \pm 2$  units. Strip time is the point at which the sand mixture is completely cured at the surface of the mould. It is defined as the time from when the furan resin was first added to chromite sand + furan acid catalyst mixture to the time when the WT/ST pad reaches a "B" scale hardness of  $90 \pm 2$  units [11].

The characteristics of moulding sands include refractoriness, chemical inertness, permeability, surface finish, cohesiveness, flowability and collapsibility. The factors that affect the breaking strength of cores include humidity, turbidity, acid demand value and moisture content. In this study, a cost effective method to improve the breaking strength of shapes and cores from foundry mixes consisting of Hevi chromite sand, furan resin and catalyst was investigated.

## 2. Experimental

### 2.1. Materials

About 20 kg of chromite ore sand was obtained from tons of by-products of mining operations across South Africa to produce Hevi chromite sand.

The supply of chromite for chromite sand making has been estimated to constitute less than 3% of the chromite ore mined in South Africa [12].

## 2.2. Methods

### *Chromite sand + furan resin preparation*

About 4 kg of the Hevi chromite sand as-received was weighed into the Kitchen Aid 6 quart mixing bowl. The temperatures of the laboratory room, the chromite sand and the room relative humidity were then taken. Furan catalyst was added into the slight depression made on the chromite sand, and it was covered with the sand. The flab beater was inserted into the mixing bowl, set into position and with the mixing speed placed at no 5 the stirring was done for 60 seconds. The mixing bowl was removed from the mixer and the mixture was fluffed for about four times in 20 seconds to mix the remaining chromite sand on the bottom of the mixing bowl into the mixture obtained. The flab beater was placed in position again and the mixing procedure was repeated for the same 60 seconds. A slight depression was made on the surface of the chromite sand+furan catalyst mixture again and furan resin was added within 60 seconds [7, 9]. The mixture formed was allowed to mix again for another 60 seconds. The fluffing process and mixing was repeated again. The mixer was stopped, the mixing bowl and the sand were removed and prepared sand mixture set aside for tensile specimen preparation.

### *Tensile specimen preparation*

The Work time/Strip time (WT/ST) pad was prepared by making a small square (approximately 10" x 10" x 0.75") of the sand mixture on a flat surface. The 10 gauge core box was filled with the prepared sand mixture from the chromite sand after the first washing (HS1) and the sand rammer was used to pack the sand into the cavity. On completion of the core cavity packing, the excess sand mixture was stricken off with the strike off bar.

The core box was covered with aluminum foil to prevent exposure to the ambient air. The time when the ST was reached was noted and the aluminum foil removed from the core box. The un-covered core box bearing the tensile specimen was allowed to sit for an additional 15 minutes. Afterward, the core box was turned over and the dies removed with the specimen intact and allowed to stay for an additional 15 minutes. Then, the dies were carefully removed from outside of the specimen and the specimen was allowed to stay for 30 minutes more.

The tensile specimens were subjected to the following conditions:

- i. Held 2 hours in air at room temperature (about 23 °C and humidity of 39 %)
- ii. Held 4 hours in air at room temperature (about 23 °C and humidity of 39 %)
- iii. Held 24 hours in dry chamber
- iv. Procedure i to iii was repeated for the Hevi chromite sand re-washed (HS2) with the time taken in steps i to iii referenced to when the strip time was reached
- v. Held in the furnace at 900 °C for 12, 14 and 16 minutes (HS3, HS4 and HS5, respectively)

The samples obtained HS1, HS2, HS3-, HS4 and HS5 were then subjected to tensile test using the Dietert 612-B tensile tester and according to the standard [13]. Each of the series of tests was done in triplicates and the average values calculated.

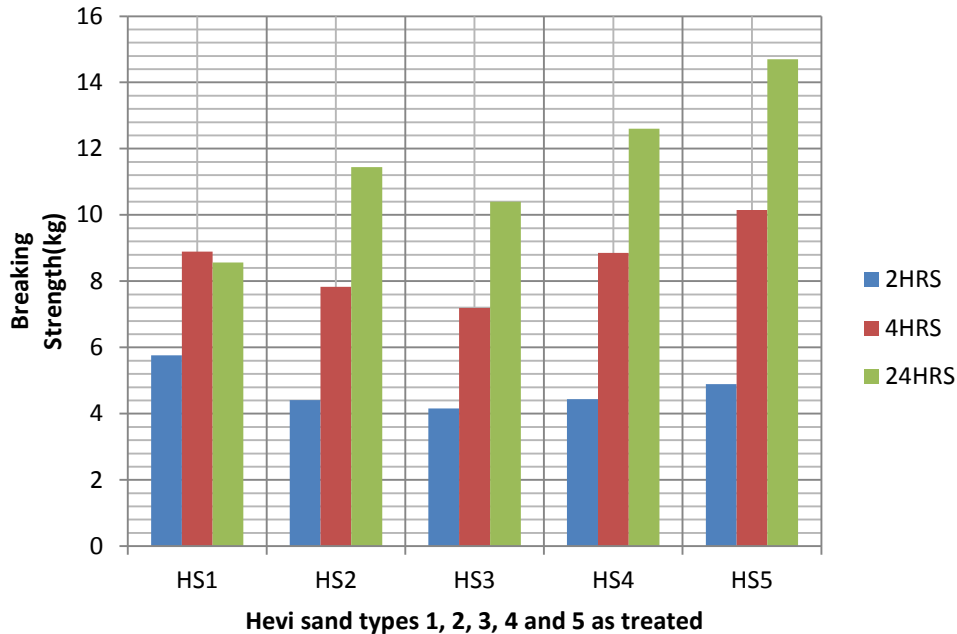
## 3. Results and discussion

In Figure 1, it was observed that at the curing period of 24 hours, there was a general increase in the breaking strength of the specimen from sample HS1 to sample HS5, except for the deviation noted at HS3.

The highest breaking strength of 14.7 kg was obtained for sample HS5 heat treated in the furnace at 900°C for 16 minutes, while the

lowest strength of 8.56 kg was obtained for the chromite sand washed only once and not heat treated. It was further observed that sample HS2 that was obtained from the

chromite sample re-washed for the second time produced good breaking strength of 11.44 kg that was much higher than 8.56 and 10.4 kg for HS1 and HS3, respectively.



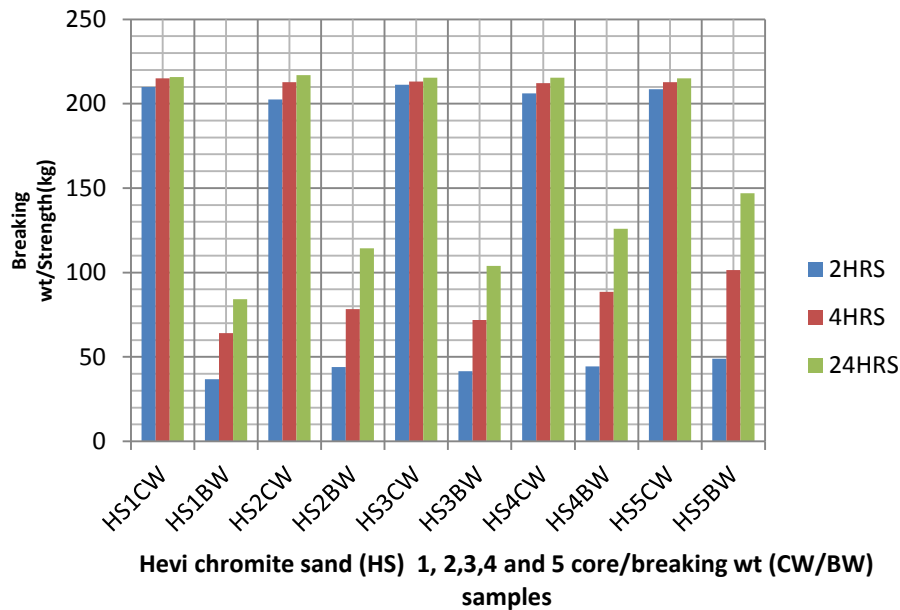
**Figure 1.** Breaking strength of Hevi chromite sand HS1, HS2, HS3, HS4 and HS5 at varying curing periods

For samples HS3, HS4 and HS5, it was observed that the breaking strengths of the samples increased with increasing duration of curing and heat treatment. For samples HS1 and HS2, it was observed that sample HS1 had higher breaking strength than HS2 at 2 and 4 hours curing period, while HS2 strength was only better at 24 hours curing.

The results obtained suggest that re-washing, curing and heat treatment periods are significant process variables in the production of chromite sand moulds and cores. The effect of re-washing was however noted to be less significant at lower curing periods. The results obtained also showed that the improved breaking strengths obtained at increasing time of heat treatment might have resulted from the changes in the micro-

structural features of chromite sand that increases with holding time at high temperature.

Investigations have shown that under certain thermal treatment conditions the spinel structure of the chromite surface disintegrates, whereby the oxide ratio can be seen to change so that the chromite grain surface has a relatively greater amount of iron oxide  $Fe_3O_4$  than chromium oxide  $Cr_2O_3$  [2]. The results also indicated that the improvement in breaking strength obtained on re-washing was much lower than the increase in strength due to heat treatment with holding at 14 and 16 minutes. Figure 2 shows that the sample core weight generally increases with increasing curing duration and that the core weights are not significantly different.



**Figure 2.** Breaking strengths and core weights (X10) of Hevi chromite samples at varying curing periods

#### 4. Conclusions

The breaking strengths of Hevi chromite sand washed and re-washed have been determined. The results obtained showed that breaking strengths increased with increasing curing period and the highest breaking strength was obtained with the samples produced at the highest curing period of 24 hours and heat treated at 900°C at the longest holding period of 16 minutes. It was also found that the second stage washing of the Hevi chromite sand produced no significant improvement in breaking strength, particularly at the lower curing periods.

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