# Use of Steel Mill Slag in Concrete as Fine Aggregates

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## Abstract

Waste materials and some industrial by-products are hazardous to environment and health of living beings. But many of these waste materials can be recycled or reused. Some of these can be used in concrete as a construction material, that can reduce land filling expenses and protect the environment from injurious effects. In this study, natural fine aggregates were replaced with steel mill scale, which is produced as a waste material in steel industries. A detailed experimental study was carried out to determine the effect of replacement of fine aggregates in high strength concrete with steel waste. Three grades of fine aggregates and steel waste were used for attaining optimum packing density. Compressive strength test was conducted on specimens with varying steel waste content. Flow and dry density tests were also performed on these mixes. It was observed that an increase in the percentage of steel scale waste increased the flow as well as the dry density of the concrete mixtures. The compressive strength of concrete mixtures also increased due to steel scale waste content up to a certain percentage.

**Keywords:** Steel scale waste, recycling, packing density, compressive strength test.

## 1. INTRODUCTION:

The increase in population, development of industries and escalation of consumerism have produced a rapid growth in the production of waste materials. Some of the waste materials can be reused or recycled or can be used as a raw material in different productions, whenever it is possible. Iron and steel industries are the main producer of steel scale waste (SSW) [Furlani and Maschio]. Steel mill scale is produced in all steel industries but only small fraction is used in Pakistan. Previously, in Pakistan, mill scale was also exported to China, but now huge amount of this waste material is being dumped as a landfill. Land-filling is not a suitable solution because some of the portion of this metallic waste leaches into the groundwater, thus deteriorating the environment. On the other hand, natural resources are depleting day by day due to the development of construction industry. Therefore, we need to look for an alternative of the natural materials in concrete.

Limited researches have been conducted on the use of steel mill scale in concrete. Pradip et al. (1990) determined the effects of steel mill scale in the production of cement mortar. Al-Otaibi (2008) used the SSW as aggregate replacement, where the effect of SSW on concrete was observed by replacing it in percentages of 0%, 20%, 40%, 50%, 70% and 100%. Compressive strength tests were conducted at 3,7 and 28 days. It was seen that compressive strength increased with up to 40% replacement. Moreover, reduction in drying shrinkage was observed. Another study determined by Pereira et al. (2011) concluded that greater water content is required in order to maintain the workability of the mix. It was seen that concrete mix having water/cement ratio of 0.55 and 0.65 resulted in high water consumption and greater compressive strength.

The significance of this study is to use steel mill scale as replacement of sand, providing an environment friendly solution for waste management. It will help prevent natural resources from further depletion.

The objective of this study is to evaluate the effects of partial as well as full replacement of natural fine aggregates with steel mill scale waste on the mechanical properties of high strength concrete (HSC). Combination of different grades of SSW and fine aggregates which gave the highest packing density are used for preparing concrete mixtures. Flow, hardened density and compressive strength of the concrete samples are tested.

## 2. METHODOLOGY:

Steel mill scale filler was collected and separated into different grades. The optimum packing density of steel mill scale was determined and a suitable mix design was developed for the optimum mix. Compressive strength test, hardened density test and flow table tests were conducted according to ASTM specifications.

## 3. MATERIAL PROPERTIES:

Commercially available Fauji brand ordinary Portland cement (OPC Type-I) was used. Silica fume and quartz powder were added as 25% and 40% of OPC to prepare HSC. Locally available sand was used as a fine aggregate. SSW of different grades was prepared by sieving (similar to fine aggregates). Fine aggregates/SSW were divided into three different grades i.e., Grade I (2-1.18mm), Grade II (1.18-0.6mm) and Grade III (0.6-0.075mm). Particle density (PD) of various combinations of these grades were checked and the combination with the highest packing density (PD) was used in the mix composition. Super-plasticizer was used to increase workability of the concrete.

Figure 1: Determination of packing density using vibrating table

### 3.1 Mix compositions:

It was observed that G1G3 combination of fine aggregates resulted in the highest PD for both sand and SSW. Based on the PD results, G1 (50%) and G3 (50%) of sand/SSW were used for final HSC mix. First mix was prepared with 100% sand (0.5 G1 & 0.5 G3). Then sand was replaced with SSW (0.5 G1 and 0.5 G3) by 20%, 40%, 60%, 80% and 100%. w/c ratio of 0.22 was used for all mixtures. Flow of all concrete mixes was tested as per ASTM C-1437. Concrete specimens (2”x2”) of all mixes were cast and cured as per standard specification. After curing, dry density of concrete specimens was checked and later on samples were subjected to compressive strength test.

Figure 2: Samples of HSC before compressive strength testing

## 4. RESULTS AND DISCUSSION:

### 4.1 Flow table test:

Figure 3 shows the comparison of flow of HSC made with various combinations. It was observed that flow increased with the increase in SSW content in the HSC due to the reason that SSW absorbs less water as compared to sand. Mixture with 100% sand exhibited flow of 195mm and it increased up to 235mm for the mix in which sand was totally replaced by SSW (S0 SSW100). Mixtures with the varying replacement percentages have the flow in between 195mm and 235mm

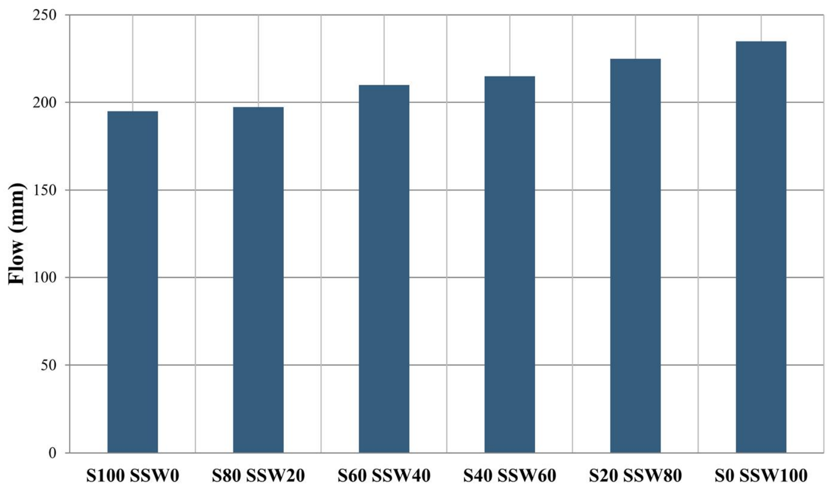

Figure 3: Flow of various HSC mixtures waste

### 4.2 Dry density test:

The dry density test was performed as per ASTM C138 after 28 days of curing. Figure 4 shows that the increase of SSW content increased the dry density of the HSC, due to higher specific gravity of SSW as compared to the natural fine aggregates. The control specimen exhibited a dry density of 2427 kg/m$^3$ and the mixture with 100% SSW showed around 17.5% increase in dry density as compared to the control specimen. Therefore, SSW increased the weight of the concrete.

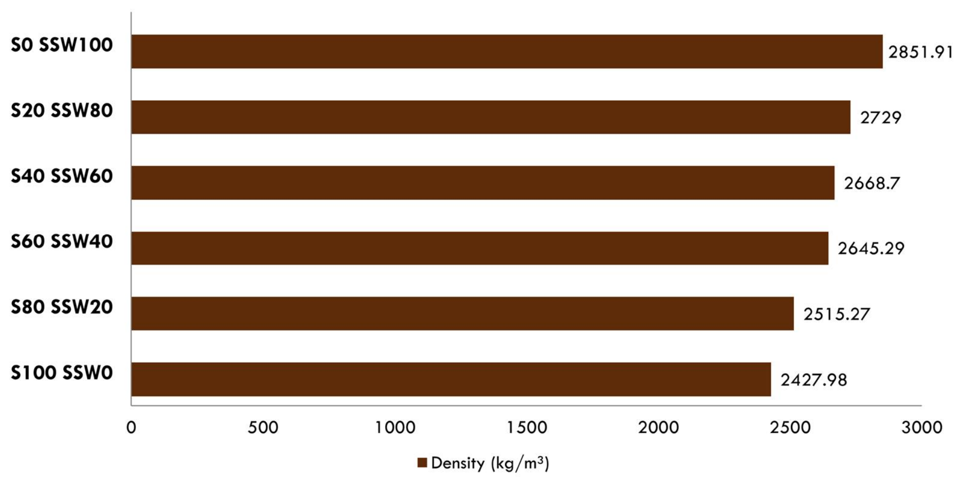

Figure 4: Dry densities of various HSC mixtures at 28 days

### 4.3 Compressive strength test:

Figure 5 compares the 28 days compressive strength of control mixture (S100SSW0) and mixtures containing SSW as a fine aggregate in different proportion. It was observed that the compressive strength increased with the addition of SSW up to 40% replacement, which was the optimum level. S60SSW40 experienced 27% increase in the compressive as compared to the control mix. After 40% replacement level, although the compressive strength started decreasing, still the mixture prepared with 100% sand replaced with SSW (S0SSW100) exhibited 1.8% higher strength than the control mix. The higher compressive strength in the case of steel slag mixtures can be attributed to higher density of these mixtures.

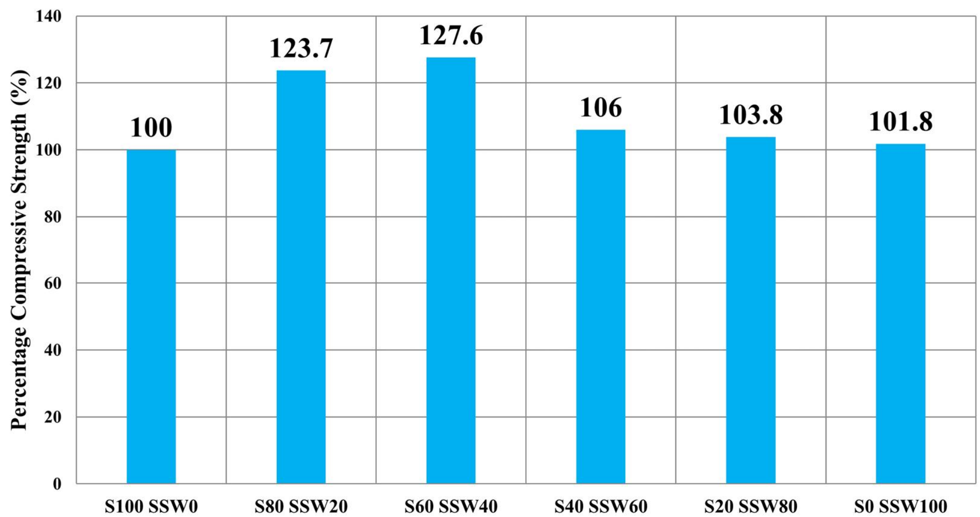


Figure 5: Percentage compressive strength of concrete mixtures

**5. CONCLUSIONS:**

Following conclusions can be withdrawn from this study:

- Due to different sizes of fine aggregates, varying packing densities were observed.
- Flow of concrete mixture increased as percentage of steel scale waste increased.
- With the addition of SSW content in mixture, increase in dry density was observed.
- Optimum compressive strength was observed at 40% replacement of sand with SSW.
- 100% replacement of sand with SSW exhibited comparable compressive strength with the control mix.

**6. FUTURE RECOMENDATIONS:**

Any future work in the same direction should also consider deriving stress-strain plot for the compression test on concrete cylinders.

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