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INITIAL INVESTIGATION OF THE UTILIZATION OF STEEL CHIPS AS A PARTIAL REPLACEMENT OF COARSE AGGREGATES IN CONCRETE

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Abstract: The investigation of recycling different industrial wastes through its utilization in concrete has been lately on the rise. This is due to the fact that some of these wastes have proven to be useful in enhancing the properties of concrete. Previous studies have shown that the utilization of steel chips can be useful when used as a partial replacement of fine aggregates in concrete. This research study focuses on the utilization of steel chips as partial replacement of coarse aggregates. The study investigates the effect of steel chips on the compressive strength of concrete when replacing the coarse aggregates at different percentages. The results show that the compressive strength of concrete can significantly increase with the utilization of steel chips up to 25% replacement of the volume of coarse aggregates in the concrete mix.

1 INTRODUCTION

The continuous availability of Portland cement concrete is very critical to the construction industry. This has led to a dramatic increase in the production of Portland cement (Hanley, 2004). Concrete industry is one of the most demanding and most expanding industries because of urban expansion, rapid population growth, industrialization and the need to improve the standards of living. Unfortunately, Concrete production is consuming copious amounts of raw materials and requires expensive costs in mining for natural resources which lead to increase of greenhouse gas emissions, which impacts the environment negatively. As such, recycling and sustainability have become very critical aspects for the progress of the construction industry. This due to the limitations of natural resources, and the legislation of laws and regulations to protect the environment. Recycling industrial wastes by using them in concrete has several advantages. First, it minimizes the use or the need to process natural resources, such as sand and gravel, which comes with additional cost and energy consumption. Second, recycled industrial waste can be used as a substitute for portions of cement, which minimizes the construction cost and the greenhouse emissions associated with cement production. Incorporating the industrial waste in concrete serves as a legitimate venue of waste disposal provided that they do not possess any side effects on the health of the structure of the inhabitants. Finally, some of the industrial wastes investigated have been proven to enhance some of the properties of concrete. One of the promising industrial wastes that can be of great benefit to the construction industry is steel chips.

Steel chips are by-product of the mechanical cutting of steel cross sections. They vary in sizes and thickness. However, they can be very close to the sizes of the coarse aggregates. They are characterized by having cylindrical shape with smooth surfaces, as shown in Figure 1. Scale and steel chips had already been used multiple times for replacing sand as the fine aggregate in concrete, but never used to replace the coarse aggregate in concrete. Previous studies showed that steel chips and scale could be effective fine aggregate replacement as they enhance the compressive strength of the concrete, and they also could be used in shielding Gamma rays, which makes them very useful in manufacturing radiation shielding concrete mixtures (Alwaeli and Nadziakiewicz 2012).

There are limited ways to recycle steel chips, either by disposal in landfill or by melting. According to a study by Torkar el al. (2010), the melting of steel chips in Arc furnaces could be expensive, non-ecological and not effective. However, the study introduced a new complicated method for recycling steel chips using induction melting furnaces, but also it is very costly.

Figure 1: Steel chips used in this research as partial replacement of coarse aggregates

This research aims to use the steel chips as a raw waste material in concrete as a partial replacement of coarse aggregate. The objective is to determine the optimal replacements percentage that can be used without compromising the compressive strength of the concrete mix.

2 PROBLEM STATEMENT

Steel chips is a by-product that result from steel cutting and manufacturing. The majority of steel manufacturers tend to recycle only a few percentages of these wastes due to the prohibitive cost of re-melting and curing, and also due to the high emission of carbon dioxide gases that results from steel melting furnaces. In stead, these steel chips are dumped in landfills, which in turn affects the environment. A limited number of studies have discussed alternative approaches to reuse steel chips instead dumping into landfills; and even fewer studies discussed its reuse in concrete.

3 OBJECTIVE

This research focuses primarily on reusing steel chips as a partial replacement for the coarse aggregate in the concrete mix. The study focuses on the compressive strength of concrete as a performance measure of the approach. The study aims to assess the performance of the concrete at different percentages replacement of coarse aggregates with steel chips.

4 LITERATURE REVIEW

There have been very limited studies on incorporating steel chips as replacements for fine and coarse aggregate. The literature contained only two studies on the use of steel chips in concrete. The first study was conducted by Debieb and Kenai (2008) when they replaced fine aggregate with steel chips. The results show that the compressive strength of concrete decreased for the mixes that contained steel chips as a replacement of fine aggregates. Alternatively, Alwaeli and Nadziakiewicz (2012) replaced portions of the fine aggregate in concrete with scale and steel chips. In this study, sand was replaced in increments of 25%, 50%, 75%, 100%. The samples were used for testing the compressive strength and gamma radiation shielding. The results showed that the compressive strength of concrete containing steel chips is better than ordinary concrete of up to 25% (Alwaeli & Nadziakiewicz, 2012). At the same time, addition of scale and steel chips enhances the absorption of gamma radiation (Alwaeli & Nadziakiewicz, 2012).

On the other hand, several other studies focused on incorporating other waste materials as a replacement for coarse and fine aggregates in the concrete mix. One study investigated the effect of replacing the coarse aggregate with oil palm shells on the concrete compressive strength. The results showed that the compressive strength was about 41%-51% lower than the regular concrete but was still within the acceptable range for structural lightweight concrete (Basri et al. 1999). A study by Siddique (2003) investigated the effect of replacing the concrete fine aggregates with fly ash-class C. The results show that there is an increase in the compressive strength by increasing the percentage replacement of fly ash-class C in the mix. Aggarwal et al. (2007) studied the effect of the use of bottom ash and waste foundry sand in equal quantities as partial replacement of fine aggregates. The results showed an increase in the compressive, splitting tensile and flexural strength. Batayneh at al. (2007) used ground plastics and crushed glass as a substitute for sand. Crushed glass showed improvement of the compressive strength of concrete up to 20% replacement; however, the plastic was not as effective.

Ismail and Al-Hashmi (2008) conducted a study on the replacement of fine aggregate in concrete with waste iron and the results showed improvement in the compressive strength. In 2009, Ismail and Al-Hashmi replaced fine aggregates in concrete for waste glass. The results demonstrated the tendency of the slump to decrease as the waste glass ratio increased. The compressive strength increased by 4.23% when replacing 20% of fine aggregates with waste glass (Ismail and Al-Hashmi 2009). One study investigated the effects of ceramic industry waste on concrete. The end result for this coarse aggregate replacement showed good workability, and an increase in the compressive and flexural strength of the concrete, as well as the modulus of elasticity (Gobinath et al, 2011). Another study used recycled concrete aggregates as a coarse replacement. The results showed a decline in the quality of the concrete in terms of compressive, flexural strength and splitting tensile strength compared to the control concrete mix. In a different study, waste tire rubber was used in concrete as a coarse aggregate replacement. Although, the rubber chips had negative impacts on the compressive strength of concrete, the study found that the rubber chips' size had a direct impact on the compressive strength. Reducing the size of the rubber chips should result in an increase in its strength. (Huang et al, 2004). As such, many waste materials can ameliorate the properties and durability of concrete when used as replacements of fine and coarse aggregates.

5 METHODOLOGY

A plain concrete mix was used to assess the impact of steel chips on the compressive strength when used as a partial replacement of coarse aggregates. Purposely, the mix did not contain any admixtures or supplementary cementitious materials to exclude the effect of any possible interaction between the steel chips and the additives. Steel chips were used to replace coarse aggregates in concrete by volume at different percentages of 5%, 10%, 15%, 25%, 35% and 50%. Cylinders of 4 x 8 inches were made to test the compressive strength of concrete at 7 and 28 days according to the ASTM standards.

6 EXPERIMENTATION

A simple plain concrete mix with a target compressive strength of 25 MPa was used for comparative analysis and evaluation. The quantities needed for 1m^3 of concrete is given in Table 1. The water/cement ration was used as 0.45 to allow for good workability and easy compaction of the concrete specimens to attain high quality. Steel chips replaced the coarse aggregates at six different percentages (5%, 10%, 15%, 25%, 35% and 50%) by volume, as shown in Table 2. The unit weight of the steel chips used is 4559.81 kg/m^3, which is almost 3 times the unit weight of gravel (1641.08 kg/m^3). The compressive strength was tested at 7 and 28 days, and the results are shown in Figures 1 and 2 respectively.

Table 1: Concrete mix design used

Cement (Kg)	Sand (Kg)	Gravel (Kg)	W/C	Water (liters)
400.00	683.09	1394.25	0.45	180.00

Table 2: Concrete mix proportions for steel chips replacements at different percentages

Cylinder: 4" x 8"	Steel Chips/Gravel Replacement						
	Control	STC2a	STC3a	STC4a	STC5a	STC6a	STC7a
% Replacement	0%	5%	10%	15%	25%	35%	50%
Cement (kg)	4.61	4.61	4.61	4.61	4.61	4.61	4.61
Sand (kg)	7.78	7.78	7.78	7.78	7.78	7.78	7.78
Gravel (kg)	22.15	21.04	19.94	18.83	16.61	14.40	11.08
Water (kg)	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Steel Chips (kg)	0.00	3.31	6.62	9.93	16.55	23.17	33.09

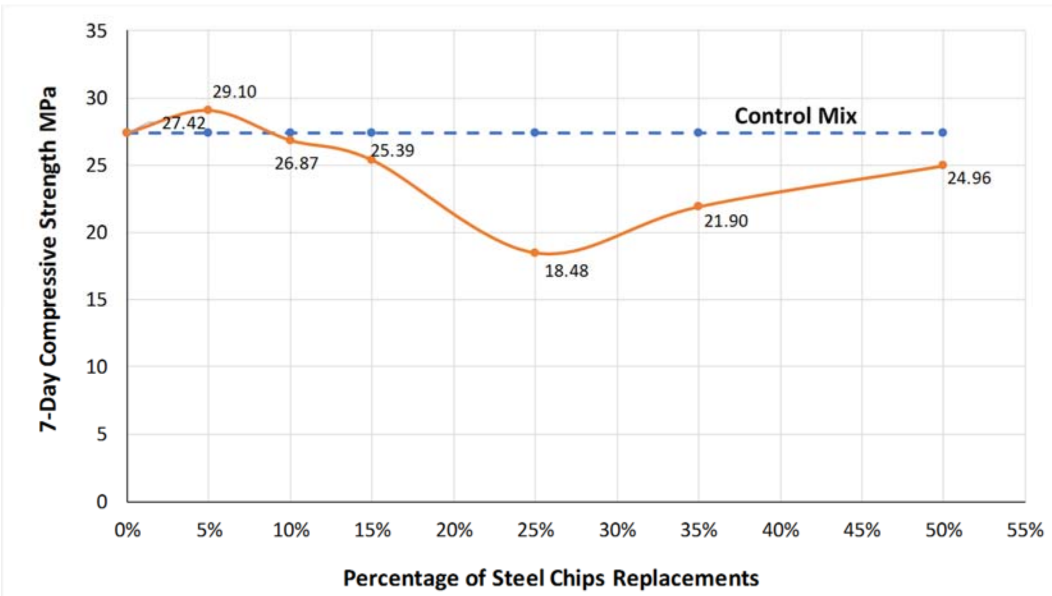

Figure 1: Compressive strength of concrete specimens containing different percentages of steel chips at 7 days

7 FINDINGS AND DISCUSSION

The results show steel chips will not affect the compressive strength of concrete if used as a partial replacement of gravel of up to 15%. However, the compressive strength of concrete can be increased by 18% by replacing 5% of the coarse aggregates with steel chips. These results along with the previous results obtained by Alwaeli and Nadziakiewicz (2012) proves the effectiveness of steel chips in enhancing the concrete compressive strength when used in the mix as a partial replacement of aggregates. However, the results obtained in this study should be further verified as the behavior of the compressive strength of steel-chips concrete does not follow a regular pattern. By investigating the compressive strength curve in Figure 2, it can be noticed that there is a drop in the compressive strength at 15% replacement of coarse aggregates, but it increases again when the replacements of coarse aggregates reach 35% and up. As such, it is recommended to only utilize steel chips as replacement of coarse aggregates in the concrete mix up to 15% until further investigation.

The water/cement ratio (0.45) used in this study was quite high to maintain goof workability; however, it affected the homogeneity of the mix. Since the unit weight of steel chips is almost 3 times the unit weight of gravel, it is expected that the steel chips will sink to the bottom of the concrete members in mixes with high water content. As such, it is recommended to repeat this study using different w/c ratios and investigate the changes in the compressive strength for concrete mixes containing steel chips as a replacement of coarse aggregates.

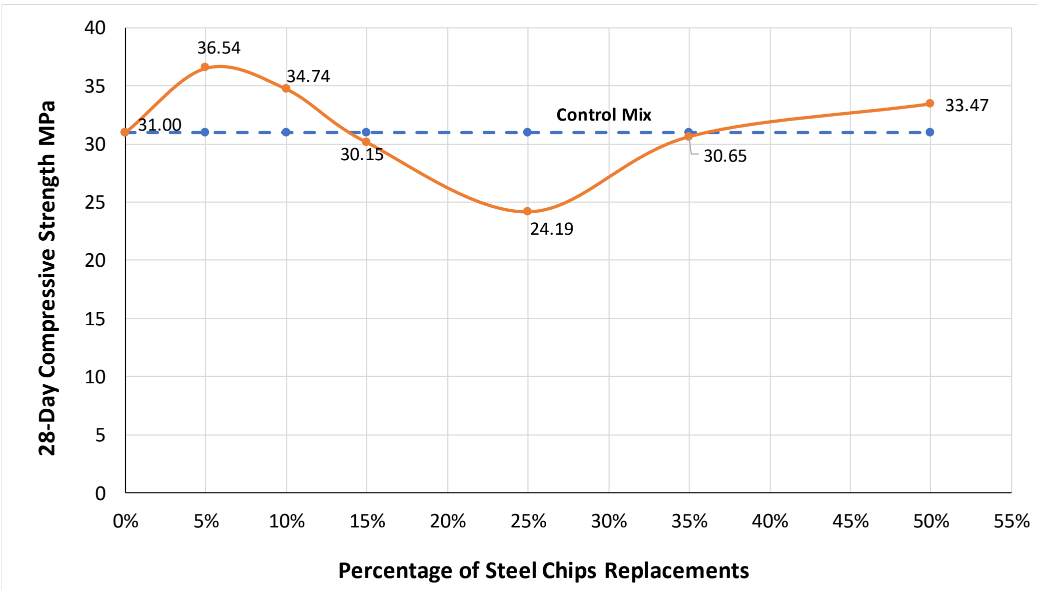

Figure 2: Compressive strength of concrete specimens containing different percentages of steel chips at 28 days

Although steel chips have proven to perform well at convenient percentages, there had been some considerations about the actual usage of the steel chips in the concrete mix that should be mentioned for the sake of clarity and integrity of this research.

- The concrete mixtures with steel chips had significant higher weights than the normal concrete, which could increase the dead loads in the construction members. This could cause limitation for its usage in the construction field. However; steel chips concrete can be efficient if used as heavy weight concrete.

- As a result of its heavy weight, the transportation of the steel chips concrete could be limited and expensive; special trucks have to be designed to carry such type, or if normal concrete truck mixtures are used, then it a smaller amount of concrete per truck can be transported.

- Theoretically, steel chips concrete could be used best as a pavement concrete or sidewalks due to its high durability and high density.

8 CONCLUSION

This research is a promising step forward for sustainability and recycling materials, which will save the environment from depleting its natural resources. Using a raw by-product in concrete without processing is very rare and limited; however, this research showed that steel chips could be a perfect by-product that replaces the coarse gravel in the concrete mix and behaves similarly and even improves the compressive strength of up to 15% if used in small percentages.

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