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Recycling of Steel Scraps as a Strength Enhancement Material in Concrete

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ABSTRACT. *Cement industry is very energy consumptive and produces CO2 and also generates greenhouse gases which are the major cause of global warming. The production of cement and the use of concrete are both rising daily. So, to protect environment, alternate materials are required. Construction industry have several constructional byproducts and wastes as a variant of traditionally used products. In the process of production and working with steel, steel chips are formed as a waste material. The best way to reduce environmental pollution and improve waste recycling is to partially replace concrete with steel chips. Due to these factors and the abundance of material, steel chips were used as a partial cement replacement at 0.5%, 1%, 1.5%, and 2% by the volume of cement. The properties such as compressive strength, split tensile strength, flexural beam strength, and modulus of elasticity are checked after 7, 14 and 28 days. Comparing these qualities to those of control molds showed that by raising the percentage of steel chips in the concrete up to 1.5%, mechanical characteristics are improved; however, when percentage is increased to 2%, mechanical properties are also affected.*

Keywords: Steel waste, Cement Pollution, Recycling waste, Mechanical Properties.

1. INTRODUCTION

The amount of garbage created has expanded due to global development, rapid economic development, and industrial growth, and this volume is often not managed properly. Furthermore, most garbage contains highly hazardous chemicals that are incredibly detrimental to the environment and humans. Traditionally, industries have handled trash by simply releasing waste into the atmosphere without treatment. This exercise significantly increased pollutants and harmed the environment [1]. Around 4 billion tons of Ordinary Portland Cement (OPC) are produced yearly, with output increasing at a 9% annual pace [2]. The emissions from 1 ton of OPC production are almost 1 kg SO_2, 2 kg NO_x, and 10 kg dust [3]. The cement industry annually emits around 1.5 billion tons of greenhouse emissions worldwide. It accounts for 7-8% of total greenhouse gas emissions [4]. Twenty years ago, the manufacture of OPC had a very high carbon intensity; each ton of OPC generated about 810 kg of CO_2 emissions [5]. Manufacturing cement has a high environmental impact and takes a lot of energy and raw materials. Numerous strategies have been proposed to reduce greenhouse gas emissions, save energy, and reduce the amount of raw materials used in producing OPC. Manufacturing steel scrap cement, and concrete are one of the most incredible possibilities [6]. Metal chips are tiny particles of various metals that are the remnants or waste following machine or similar material removal techniques. They are also known as chips, turnings, filings, or shavings [7]. There are only a few methods for recycling steel chips, including melting and disposal in landfills. The process of melting steel in furnaces is inefficient, polluting, and extremely expensive [6]. Potentially, this waste might replace some of the cement in concrete. Construction materials harm Earth's ecosystems because 50% of all materials used for construction are extracted from Earth [7]. The cement industry is the third largest energy consumer in the whole world, consisting of 7% of all industrial energy use [8]. Since industrial lathes produce a lot of steel waste (3–4 kg per lathe per day), there will be better environmental management of lathe steel waste [7]. Recycling offers a way to reduce that trash and put it to good use.

Study shows, the impact of steel chips on the compressive strength of concrete, which noticeably increases when used as a 25% substitute for the number of coarse particles in any concrete mix. Results show that replacing 5% of the coarse aggregates with steel chips will increase 8% [2]. Additionally, lathe waste concrete beams demonstrate less deformation and fracture propagation than standard beams [8]. The results of the fiber-reinforced concrete show that the porosity of these mixtures increased compared to the base mixture and that the fiber addition did not affect the initial or final setting times [9, 10]. Concrete that has been reinforced with lathe trash performs better than standard concrete [11]. The ability of crack control in the elastic zone is responsible mainly for the increased cracking load of high-strength concrete beams when PET fiber is added to the concrete [3]. The compressive strength rises when lathe waste is added to regular concrete at percentages of 3%, 6%, and 9% by weight of fine aggregate [12]. Additionally, steel fiber increases concrete strength linearly as the proportion of steel fiber is raised, as well as compressive strength, flexural strength, and split tensile strength [13]. Abbas Hadi from the test showed that [7] the mechanical properties of concrete, including compressive strength, split-tensile strength, bending strength, and modulus of elasticity increases by 10.2%, bending strength by 45%, split tensile strength by 30%, and modulus of elasticity increases by 250% [14, 15]. In other instances, the densities rise when the amount of fibers increases. The density rises from 1395.20 kg/m3 for 0% to 1425.57 kg/m3 at 3% fiber content and 28 days [16].

The purpose of the research was to contribute in the field of construction industry utilizing the various industrial wastes to protect the environment and obtain more durable concrete. Different approaches to deal with mentioned issues are also discussed. Usage of steel chips in concrete is one of best way to counter the issues, as we can deal with both issues at the same time. According to the literature, steel chips showed outstanding results when used to substitute coarse and fine aggregate in concrete. In this study, we replaced 0.5, 1, 1.5, and 2% of cement with steel chips. The main purpose of this study is:

- Improving the mechanical properties of concrete.
- Minimizing the usage of cement and finding a best partial replacement for it.
- Recycling the waste from steel industry.

2. METHODOLOGY

2.1 Mix Design

To determine the impact of steel chips on the properties of concrete, steel chips are employed as a partial replacement for cement in a plain concrete mix of (1:1.5:3) weight given in Table 1, 3000 psi cylindrical strength. Using a standard mixer and a water-to-cement ratio of 0.50, concrete samples were made by ASTM C192M. Table 3 lists the concrete mix proportions. We did not add any admixtures to avoid any potential interference between the steel chips and the admixtures. Concrete is made with steel chips, which substitute cement in weight-based ratios of 0.5, 1.0, 1.5, and 2.0 %.

Table -1: Mix-Proportion of Concrete

Type	Component	Mix Design (1:1.5:3 ratio)	
	3 Cubes, 3 Cylinders, 1 Beam	Weight (kg)	Properties
Control	Cement	16.36	Normal setting time 30 min
	Water	8.18	Normal tap water
	Fine agg:	24.5	Finess modules: 2.6
	Course agg:	49.09	Finess modules: 3.1
	w/c ratio	0.5	In Consideration of workability
Steel chips	0.5%	0.118	-
	1%	0.236	-
	1.5%	0.354	-
	2%	0.472	-

2.2 Casting of Samples

After the concrete was well mixed, it was cast into various molds (cubes, cylinders, and prisms), with multiple samples being formed for different mix proportions. The number of cast samples is provided in the table; they were demolded and immersed entirely in clean water for curing after almost 24 hours. The concrete specimens were then allowed to cure for 7, 14, and 28 days. Before testing, samples were removed and allowed to dry outside for a day. According to ASTM standards, a total of 27 cubes, 20 cylinders, and 4 beams were cast to test the mechanical properties of concrete at 7, 14, and 28 days.

2.3 Curing of Samples

During curing, the cylinders, cubes and beams are stored at a normal temperature and in an environment that prevents moisture loss for up to 28 Days. Different samples were taken out at 7 days, 14 days and then at 28 days for testing. Curing was done according to ASTM C31.

3. EXPERIMENTAL WORK

The various properties of concrete were investigated in connection to scrap steel chips. The results showed that it outperformed regular concrete regarding workability and compressive strength. Samples were examined after 7, 14, and 28 days. The figure of material and during testing are shown in Figure 1.

Fig -1: Material and Testing

4. EXPERIMENTAL RESULTS

The control 28 days cylindrical compressive strength is 20.89 MPa, while by adding 0.5% of steel chips it hiked to 23.53 MPa. Also, for 1% it became 28.89 MPa, and 37.20 MPa, 20.79 MPa for 1.5% and 2% respectively. It can be observed that at 1.5% the strength is max and is about 78% increase in strength. All other tests showed similar results and on average 40-50% increase was noted at 1.5% replacement.

Table -2: Compression Testing Results for 28 Days (MPa)

Compressive Strength (MPa)						
Steel Chips Ratio %		Control	0.50%	1%	1.50%	2.00%
Cylinders		20.89	23.53	25.34	30.33	22.59
Cubes	1	15.49	26.22	28.89	37.20	20.79
	2		24.19	30.00	36.25	20.19
	Average	15.49	25.20	29.45	36.72	20.49

Concrete's strength characteristics are improved by the bridging action of discontinuous fibers [17]. As a result, the addition of steel fiber enhances the compressive strength, split tensile strength, flexural beam strength from 0–1.5% replacement. The main strength material in concrete is cement, so by removing more than 1.5% cement affects the strength adversely. We can see in the Table 2; the strength decreases at 2% replacement. Bridging action increases the strength up to 1.5% replacement of steel chips, as it is shown in figure 2.

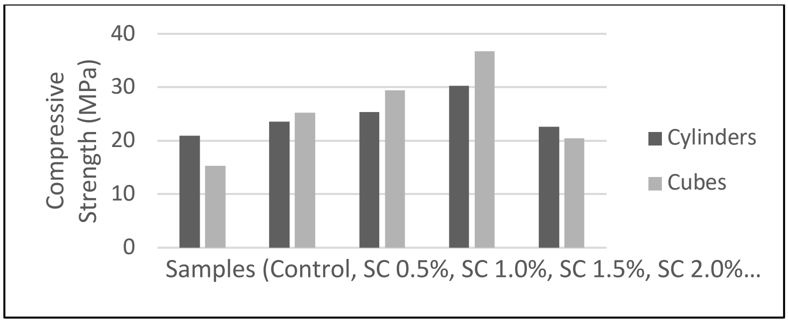

Chart -1: Graph Comparing Compressive Strength with Different Steel Chips Ratio (28 Days)

3. CONCLUSIONS

Cement utilization is rising steadily due to the booming building industry. The cement industry is a significant source of pollution and a drain on the environment. Steel industry waste, on the other hand, contributes to landfills. Environmental pollution is a problem in both businesses. These issues may be alleviated by using steel chips to replace cement in specific applications. In addition, the material has superior mechanical characteristics. The best way to ensure concrete maintains its mechanical attributes while preserving the environment is to include steel chips in the mix.

According to our result, the strength of concrete shows rises when steel chips are added. A 10-15% rise is noted at 0.5% SC, 20-25% at 1% SC, and 40-50% at 1.5% SC. Also, the rise in strength for cubes was even higher than this. For every cubic meter of concrete, usage of cement can be decreased by 1.5% or almost 5-6kg. On the other hand, 5-6kg of steel waste will be recycled. The price difference of materials between control specimen and 1.5% replacement is about 220PKR or 1USD per cubic meter. It is recommended to use steel chips as a partial replacement of cement over all other replacements due to their vast availability, high strength. Using this technique on a commercial scale will help both financially and will also be a step toward sustainable construction and a clean environment.

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