Enhancing the Mechanical Characteristics of the Traditional Concrete with the Steel Scrap

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Abstract. The mechanical performance of concrete with varying proportions of steel scraps as a composite additive is investigated in this work. A M50 grade concrete admixture with a 0.35 water-to-binder ratio was prepared for this study. The appropriate quantity of superplasticizer was included as the mineral admixture. Steel scraps are obtained as waste from local machining workshops and then included in various proportions, including 0.25, 0.5, 1.0, and 2.0 percentages. The cubical mortar specimens were being employed to determine the compressive characteristics of mortar structure with and without steel scrap, whilst the cylinder-formed specimens and beam shaped samples were being utilized to determine the indirect tensile strength and flexural strength of concrete mixture. All experiments with different percentages of steel scrap were conducted on the 3 replicates, and the mean value is provided in this paper. After 28 days, the cement without steel scrap seemed to have a mean compression, flexural, and tensile strengths of 46.3 MPa, 5.52 MPa, and 4.23 MPa, which were improved to 51.7 MPa, 6.16 MPa, and 4.58 MPa with the inclusion of 1.0% steel scrap. The proposed investigation will contribute to reducing cement use, hence reducing cement industry's adverse ecological impacts.

Keywords: steel scrap; mechanical properties; concrete mixture; reinforcement; enhancement.

1. Introduction

Fibre like substances in cementitious material has been employed ever since 1920s and 1930s, while asbestos were commonly employed, although this was progressively faded away due to safety concerns [1, 2]. Because of the harmful effects of asbestos material on the human body, numerous alternative fibres have really been created for the utilization in cement. Mortar is a structural material characterized by high compressive characteristics in comparison to its tensile behaviour that is around
10% of compressive performance [3, 4]. Additionally, mortar is a fragile material with a small breakdown stress. Nowadays, there is indeed a tendency toward incorporating fibre reinforcement into cementitious materials in order to enhance its material characteristics and endurance. Nevertheless, prior to utilizing any fibre, it is necessary to understand its efficiency in order to accomplish the preferred outcome [5, 6, 7]. To completely appreciate the effectiveness, it is vital to understand the several aspects associated with the fibre, such as its thickness, width, and the manufacturing technology used to manufacture it. Numerous scholars have investigated the influence of geometrical and fibre elements on the behaviour of concrete [8, 9, 10]. A prior study demonstrated the usefulness of polypropylene fibre in preventing masonry spalling. Nonetheless, when the structural properties of concrete develop, fibreglass was shown to be beneficial in reducing shrinkage fractures. Numerous studies have also demonstrated that Polyester fiber has beneficial compression strength, while others found no effect. Similarly, other researchers observed that polypropylene fibre had no effect on flexural strength, while others reported both positives and negatives [11, 12]. Steel fibers is commonly used in the construction industry, including pavements, concrete tiles, and tunnel linings. Numerous researches have reported on the increased post-crack behaviour of concrete with steel fibre. However, relatively few researches exist that demonstrate the effect of fibre reinforcement on mineral admixture concrete and the subsequent development of a simulation analysis for determining the proportion of fibre reinforcement [13, 14]. As a consequence, this study examined the effect of fibre reinforcement on cementitious materials with mineral admixtures and developed a link among the proportion of fibers and toughness and setting period.

Steel scrap reinforced mortar is a sort of mortar that is created by incorporating irregular and distinct steel scraps into traditional concrete to enhance its mechanical, structural, and longevity qualities. To make reinforcement in concrete, many types of synthetic and accessible materials mixed into the cementitious mixture [15, 16]. Additionally, filaments can be oriented in a certain manner or arbitrarily, depending on their functional use [17, 18]. Steel scrap reinforcement in mortar has qualities that are dependent on the dimension of the steel scraps, such as diameter, alignment, and dispersion within the cementitious mixture [19, 20]. The inclusion of steel scraps improves the physical parameters of steel scrap reinforced formwork, including tensile strength, compression and flexural strength, fracture toughness, and modulus of rupture [21, 22]. Additionally, the inclusion of steel slag to normal concrete increases its resilience. Additionally, it strengthens concrete's flexural and tensile properties. Additionally, it is noted that pinched or looped tip steel scraps are more efficient than other methods of steel scraps due to their strong anchoring in the cement structure [27, 28]. Additionally, steel scrap reinforced masonry (SSRC) inhibits the formation of fractures and their spread in cementitious structure [29, 30].

This research is primarily concerned with determining the effect of steel scrap reinforcing in M50 grade of concrete at various scrap content levels, including 0.25 percent, 0.5 percent, 1.0 percent, and 2.0 percent after 28 days curing period, which is not properly dealt in the previous works. Throughout the research, the mechanical properties (compression, tensile, and flexural strengths) have been studied, and the obtained results have been critically reviewed.
2. Materials and methods

2.1. Preparation

![Steel scraps, Finer aggregates, Coarser aggregates](image)

Figure 1. (a) Steel scraps (b) Finer aggregates (c) Coarser aggregates utilized in the work.

In this research examination, mortar of M50 grade was used. Five distinct steel scrap doses (0%, 0.25%, 0.5%, 1.0%, and 2.0%) were employed in this research. The average size of steel scrap used in the work is 10 mm length. With a moisture-to-binder proportion of 0.35, a predetermined mix of cement, finer and coarser aggregates were developed [31, 32]. The finer aggregate used for this experiment had a modulus of fineness of 2.28 and a relative density of 2.57. The coarser aggregates utilized had a large limit of 17 mm and a relative density of 2.68. The materials used in the cementitious mixture are given in Figure 1.

To investigate the effect of steel scrap on structural qualities, an adequate amount of superplasticizer was used as the admixtures with the mortar. Table 1 show the cementitious ingredients and Table 2 give the characteristics of the steel scraps used in the present experimentation.

| Constituent | Coarse aggregate | Fine aggregate | Cement | W/C ratio | Steel fiber mass density (kg/m\(^3\)) |
|-------------|------------------|----------------|--------|-----------|-------------------------------------|
|             | 1152             | 648            | 341    | 0.35      | 0% to 2.0%                           |

Table 2. Characteristics of the steel scraps.

| Characteristics | Description                  |
|-----------------|------------------------------|
| Shape           | Irregular cylinder           |
| Dimension       | 0.4 mm thick and 30 mm long (Approx.) |
| Density         | 8000 kg/m\(^3\)             |
| Relative density| 8.0                         |
| Elastic modulus | 200 GPa                     |

2.2. Testing method

The compression strength testing was done with 15 cm side cube samples cast to the specified standards. Cementitious samples were produced using standard concrete and steel scraps at varying ratios, including 0.25, 0.5, 1.0, and 2.0 percentages [8]. Mortar cubical samples were produced, demolded, and allowed to cure over 28-days of curing age. Every fraction was represented by three specimens. Following curing, the cube samples were subjected to compression testing. Split tensile strength tests were done on cylinder shaped samples with a 15 cm cross section and a length of 30 cm, as specified. Mortar examples had been produced using standard concrete and steel scraps at varied
percentages. The concrete cylinder samples were made, demolded, and allowed to cure during a 28-day curing time [3, 8]. Every proportion was represented by three samples. Following the curing age, the concrete cylinder samples had been evaluated in the same manner as described previously. Flexural strength was determined applying conventional formulae on a beam with size of 10 cm square cross section and 50 cm length.

3. Results and discussion
After some 28-day curing age, the concrete cubical samples had been evaluated in a compression test. For every proportion of steel scrap, three cube samples were produced. Figure 2 depicts the mean compression strength of mortar for different proportion of steel scraps. The compression strength of the concretes were determined as 46.3 MPa, 47.4 MPa, 49.2 MPa, 51.7 MPa, and 48.6 MPa, respectively for the addition 0%, 0.25%, 0.5%, 1.0%, and 2.0% of steel scraps, respectively with the concrete. Compression strength tests revealed that adding steel scraps to cementitious materials increased its compressive strength until it reached 1.0 percent, at which point it was started diminished. The optimal steel scrap dose was determined to be 1.0 percent by content. When steel scrap was added at a rate of 1.0 percent to M50 concrete grades, the compression strength rose by 11.67% after 28 days of curing, comparing to normal concrete.

![Figure 2. Compression strength of the mortar with diversified fraction of steel scraps.](image)

Figure 3 illustrates the split tensile property of the mortar for diversified proportion of steel scraps. The split tensile characteristics of the concretes were determined as 5.52 MPa, 5.67 MPa, 5.86 MPa, 6.16 MPa, and 5.89 MPa, respectively for the addition 0%, 0.25%, 0.5%, 1.0%, and 2.0% of steel scraps, respectively with the concrete after curing them for 28 days. Similar to the compression characteristics, the tensile strength also started declined after adding 1.0% of steel scraps. The maximum increment by 11.5% was achieved with the 1.0% steel scraps in mortar.
Figure 3. Split tensile strength of the mortar with diversified fraction of steel scraps.

Figure 4. Flexural strength of the mortar with diversified fraction of steel scraps.

Figure 4 shows the disparity of flexural strength with different fraction of steel scrap in the mortar. The split tensile characteristics of the concretes were determined as 4.23 MPa, 4.31 MPa, 4.42 MPa, 4.58 MPa, and 4.44 MPa, respectively for the addition 0%, 0.25%, 0.5%, 1.0%, and 2.0% of steel scraps, respectively with the concrete. The steel scrap of 1.0% with the concrete once again seems to be superior for improving flexural characteristic of the mortar for the curing time of 28 days. The increment of 8.27% in flexural strength was achieved with the aid of 1.0% steel scrap in the mortar.
As a whole, the steel scraps of 1.0% with the conventional concrete served better in improving the mechanical characteristics of the mortar.

4. Conclusion

The conventional concrete was studied for its mechanical characteristics after incorporating varied fraction (0%, 0.25%, 0.5%, 1.0%, and 2.0%) of steel scraps in concrete. The compression, split tensile, and flexural characteristics were taken for the investigation. The steel scrap composition of 1.0% was identified as the ideal composition; further improving the proportion of the steel scrap deprived the properties of the mortar. The cement without steel scrap seemed to have a mean compression, flexural, and tensile strengths of 46.3 MPa, 5.52 MPa, and 4.23 MPa, respectively, which had been amended to 51.7 MPa, 6.16 MPa, and 4.58 MPa with the inclusion of 1.0% steel scrap. The enhancement in compression strength, split tensile as well as flexural strengths of the traditional cementitious mixture was 11.67%, 11.5% and 8.27%, respectively. Consequently, the addition of metal scrap can effectively minimize the use of cement in the cementitious mixture.

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