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A SUSTAINABLE WASTE MANAGEMENT APPROACH: RECYCLING CERAMIC MATERIALS AND STEEL SLAG TO PARTIALLY REPLACE OF FINE AGGREGATE IN M20 CONCRETE

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ABSTRACT

Recycling can be a great solution to our current world. A large quantity of ceramic materials and steels changes into wastage during production and processing. Wastages from ceramic materials are also produced by transporting and fixing system due to its brittle nature. Therefore, using these wastes in concrete production could be an effective measure in maintaining the environment and improving the properties of concrete. In this paper, steel slag powder and ceramic tiles were introduced in concrete mixes. Ceramic industry and steel slag waste problem can be reduced by using these wastes in place of fine aggregate which maintain the balance of nature and avoid environmental problems. This paper examined the possibility of using ceramic tiles and steel slag wastes in concrete. Hence, the crushed waste ceramic tiles mix with steel slag were used in concrete as a replacement of natural fine aggregates with 0%, 7.5%, 15%, 22.5%, 30%, 37.5%, 45% and 52.5% of substitution under 1:1.5:3 ratio. Both compressive and split strength test were conducted in order to find out the most economic as well as maximum strength. The optimum value of wastes to be used within the concrete mix was determined as 15% under the ratio in case of compressive strength and split strength test for M20 concrete.
Key words: ceramic materials, steel slag, fine aggregate, waste management, recycling

INTRODUCTION

Huge number of natural aggregates, sand and water are being consumed in concrete production. Consequently, to minimize these, research have concentrated on the use of waste materials as potential alternatives in the construction industry, especially in concrete construction. In fact, utilization of waste materials in concrete construction is one of the prime research interests to reach the goal of achieving sustainable construction (Horvath, 2004). Fine aggregate is an important ingredient in concrete production. Due to the high expense of natural sand used as a fine aggregate and the growing emphasis on sustainable construction, the construction industry must look for alternative resources (Murari, et al., 2015). Steel slag and ceramic material is very common industrial waste. Steel slag, the by-product of steel and iron production is generated in large quantities daily and ceramic material waste from Ceramic industry (Teo, et al., 2020).Aggregates impart about 70% to 75% of volume to concrete. In this aspect, consumption of waste tiles or broken tiles as fine aggregates in concrete manufacturing can be a new scientific sobriety in the field of sustainable concrete. Due to its relationship to the composition of hardened cement paste and ability to improve concrete quality, concrete strength has gained more prominence (Tam, et al., 2018).

It is believed that the water cement ratio and degree of compaction have a significant impact on concrete strength at a particular age under specific curing circumstances. When blast furnace slag aggregate completely replaces the natural aggregate in concrete, the density is reduced. When a final product must have a reduced self-weight, this is advantageous(Valcuende, et al., 2015).Steel slag is produced during the oxidation of steel pellets in an electric arc furnace; it makes up a portion of 15–20% of iron output depending on the composition of the steel and on the steel production process. A part of 15-20% of the iron generated in an electric arc furnace comes from the oxidation of steel pellets;

this is known as steel slag depends on the steel composition and the steel manufacturing method (Furlani, et al., 2010).

Slag is frequently seen as granulated solids with huge clusters, coarse and extremely fine particles. These goods are regarded as troublesome and dangerous for the manufacturing facilities and the environment. Previously, unregulated sand extracted from rivers caused serious environmental concerns. As a result, different recycled materials were required as concrete aggregates, serving as a partial replacement for natural counter parts(Devi & and Gnanavel, 2014). Recycling technologies to use steel slag as construction material have received increasing attention, used steel slag to produce Portland cement with iron slag and limestone and confirmed that the compressive strength of concrete was above standard values for type I Portland cement(Qasrawi, et al., 2009).

In this paper, it aims to study experimentally, the effect of partial replacement of fine aggregates by ceramic materials and steel slag, on the various strength properties of concrete, by using the mix design of M20 grade. A preliminary investigation is undertaken to determine the impact of steel slag and ceramic materials replacing some of the fine aggregate on the strength characteristics of concrete. The core view of this paper is to analyze the compressive strength and tensile strength behavior of concrete mixes as a substitution of fine aggregate and propose a mix design guideline for concrete mixes using Ceramic Tiles and Steel Slag as supplementary sandy material. From an environmental standpoint, the substitute materials used in concrete are disposed of safely(Bommisetty, et al., 2019).The durability of using waste ceramic and steel slag in concrete has not been extensively studied. To study the effects of steel slag and ceramic material wastes on the strength qualities of concrete, this work substitutes steel slag and ceramic wastes for a portion of the fine aggregate.

OBJECTIVE

The objective of this paper has mentioned below:

1. To recycle ceramic materials and steel slag to partially replace of fine aggregate in M20 concrete

METHODOLOGY

Replace Percentage: Before performing (CT+SS) sand cement mortar solidification, a mixing composition was formed based on cylinder size that used in this experiment (8-inch height * 4-inch diameter) and the dry volume is 150.80 in^3. The ratio that has been followed here is 1:1.5:3. In mixing composition, ceramic tiles and steel slag powder used as the substitute of sand (0%, 7.5%,15%,22.5%,30%,37.5%,45%,52.5%) with the range of 7.5% per composition.

Figure 1 Mixing of concrete ingredients

Figure 2 Filling the cylinder sampler with concrete for test

Flow Chart

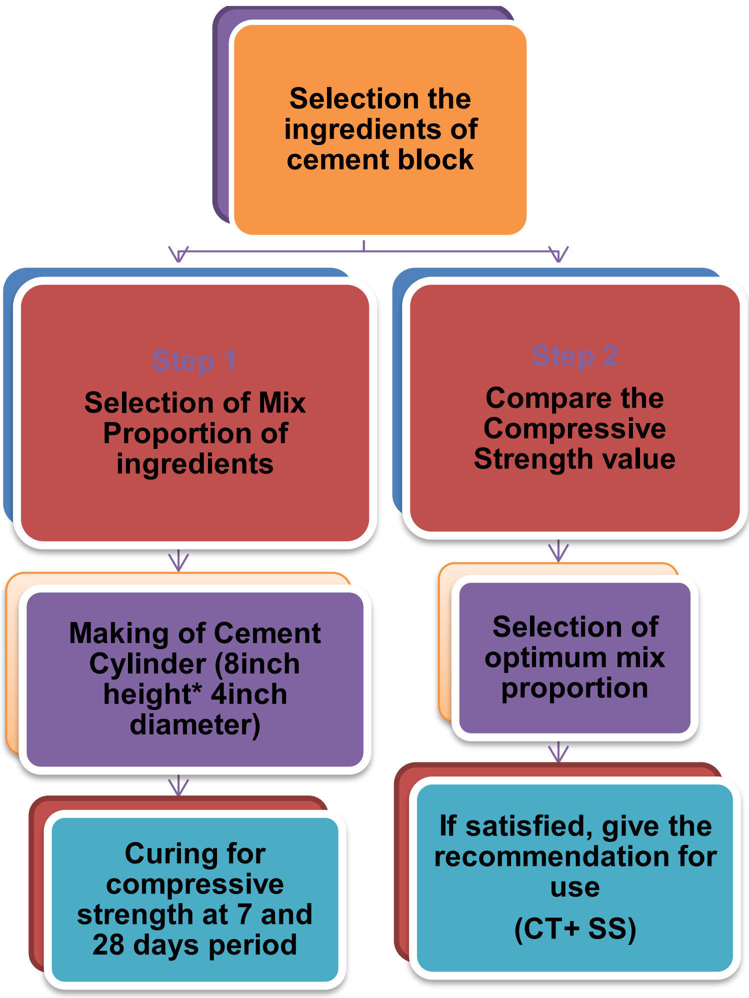

Figure 3 Evaluation of compressive strength behavior of (CT+SS) - Sand, based cement mortar

Compressive Strength: It is possible to describe concrete's compressive strength as its ability to bear loads before breaking. The compressive strength test, one of many that were conducted on the concrete, is the most crucial since it provides information on the properties of the concrete(Khoury, 1992).

Split Strength: A technique that involves employing a cylinder with a split along the vertical diameter to gauge the tensile strength of concrete. The tensile strength of concrete may be tested indirectly using this technique. Tensile strength is one of the fundamental and crucial characteristics of concrete. The design of concrete structural components necessitates an understanding of its value(Gurusideswar, et al., 2020).

Figure 4 Test setup for compression test of cylinders

Figure 5 Test setup for splitting tensile strength of cylinders

Concrete: Concrete is a composite building material made up of cement (most often Portland cement) and other cement materials such ceramic tiles and slag cement, aggregate, water, and chemical admixtures. Concrete's strength, durability, and other features are determined by the properties of its components, the amount of the mix, the manner of compaction, and other controls throughout the placement, compaction, and curing processes(Habert, et al., 2020).

Steel slag: Steel slag is a byproduct of steel production that is generated during the separation of molten steel from impurities in steel-making furnaces. The slag forms as a molten liquid melt and is a complex solution of silicates and oxides that hardens upon cooling. Steel slag was collected from an established steel factory which is located at the capital city of Bangladesh. There are many steel manufacturing industries are available in Bangladesh. The industry name is Shohag Khan Steel Industries Company, Narayanganj, and Dhaka, Bangladesh (Figure 6).

Ceramic tiles: Ceramic tiles are made from a combination of clays and other raw elements from nature, such sand, quartz, and water. Ceramic Tiles was collected from a Mendibag garbage tiles industry which is located at the Sylhet City in Bangladesh. The Tiles which were selected in this research work mostly floor tiles (Figure 7).

Figure 6 Steel Slag

Figure 7 Ceramic tiles

M20 concrete: M20- M stands for Design Mix (M = mix), and 20 is the compressive strength of concrete after 28 days of curing when we test the specimens (cubes), 1:1.5:3 mix ratio (cement, sand, and aggregate) (Krishna, 2017). The highest strength obtained by the concrete M20 after 28 days of curing is 22.09 MPa (3203.8836 psi) (Piplewar, et al., 2013). Also 28 days of curing the concrete M20 results in a maximum Split Tensile strength development of 3.12 MPa (452.5177 psi) (Dashrath, et al., 2014).

RESULT AND DISCUSSION

The compressive strength and split strength of concrete cylinders were tested at 7 days & 28 days curing under 1:1.5:3, sometimes it is so important to analyze the value of compressive strength and tensile strength of concrete (0%) with respect to other individual mixing proportion. The following bar charts have presented the comparison between (0%) compressive strength of concrete versus (7.50%, 15%, 22.50%, 30%, 37.50%, 45%, and 52.50%) modified (CT+SS) sand and following results have shown the comparison as well as results of tests.

Compressive Strength of Modified (CT+SS) Sand under 1:1.5:3 ratio: In figure 8 and figure 9, the value of compressive strength of concrete has increased gradually up to the percentage of replacement of 15%, then it gradually decreased (22.50%, 30%, 37.50%, 45%, and 52.50%) for modified (CT+SS) sand for 7- and 28-days curing, 15% has illustrated the maximum compressive strength which was 2164.454 psi for 7 days and 4293.354 psi for 28 days. For 0% (CT+SS) the compressive strength was found 3649.351 psi at 28 days and 1967.787 psi at 7 days.

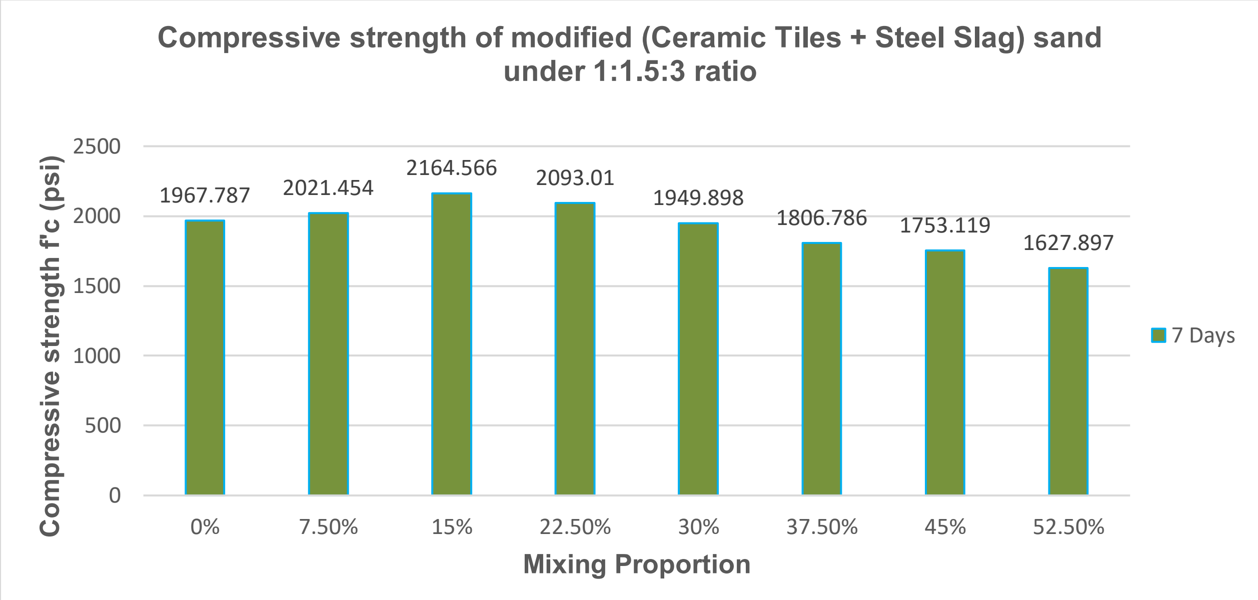

Figure 8 Compressive strength of modified (Ceramic Tiles + Steel Slag) sand under 1:1.5:3 ratio 7 days

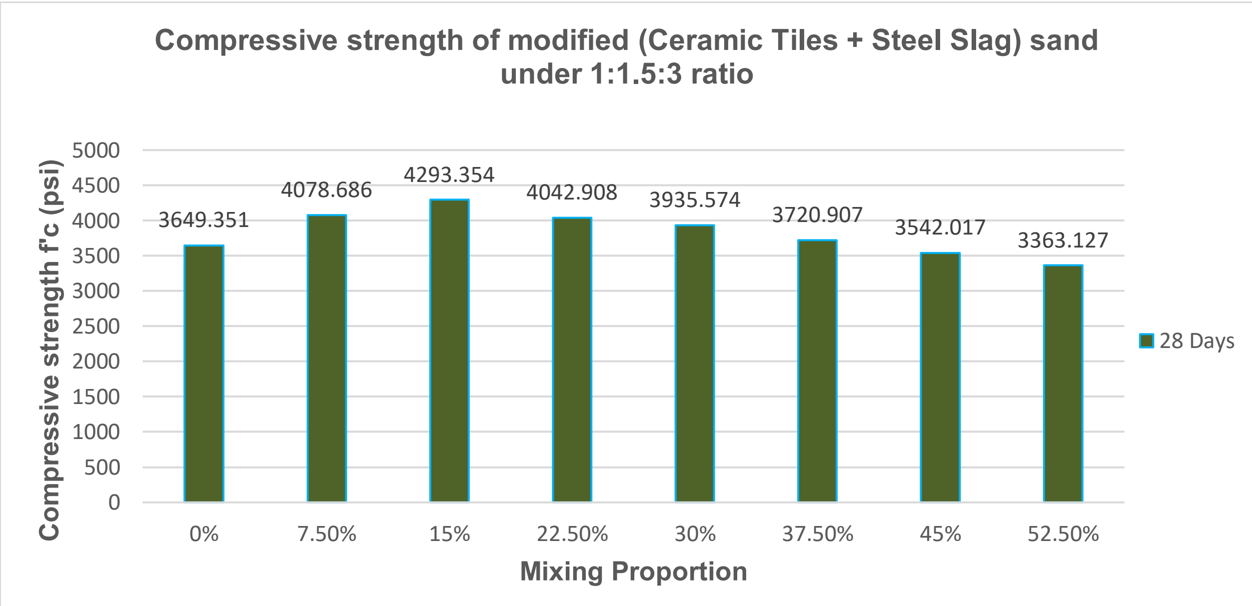

Figure 9 Compressive strength of modified (Ceramic Tiles + Steel Slag) sand under 1:1.5:3 ratio 28 days

Split Tensile Strength of Modified (CT+SS) Sand under 1:1.5:3ratio: Figure 10 and 11has shown the value of split tensile strength of concrete. The value of split tensile strength of concrete has increased gradually up to the percentage of replacement of 15%, then it steadily reduced (22.50%, 30%, 37.50%, 45%, and 52.50%) for reformed (CT+SS) sand for 7- and 28-days curing.

The figures have explained that, 15% has proved the maximum split tensile strength which was 281.3936 psi for 7 days and 558.136 psi for 28 days curing. For 0% (CT+SS) the split tensile strength was found 474.4156 psi at 28 days and 255.8123 psi at 7 days curing.

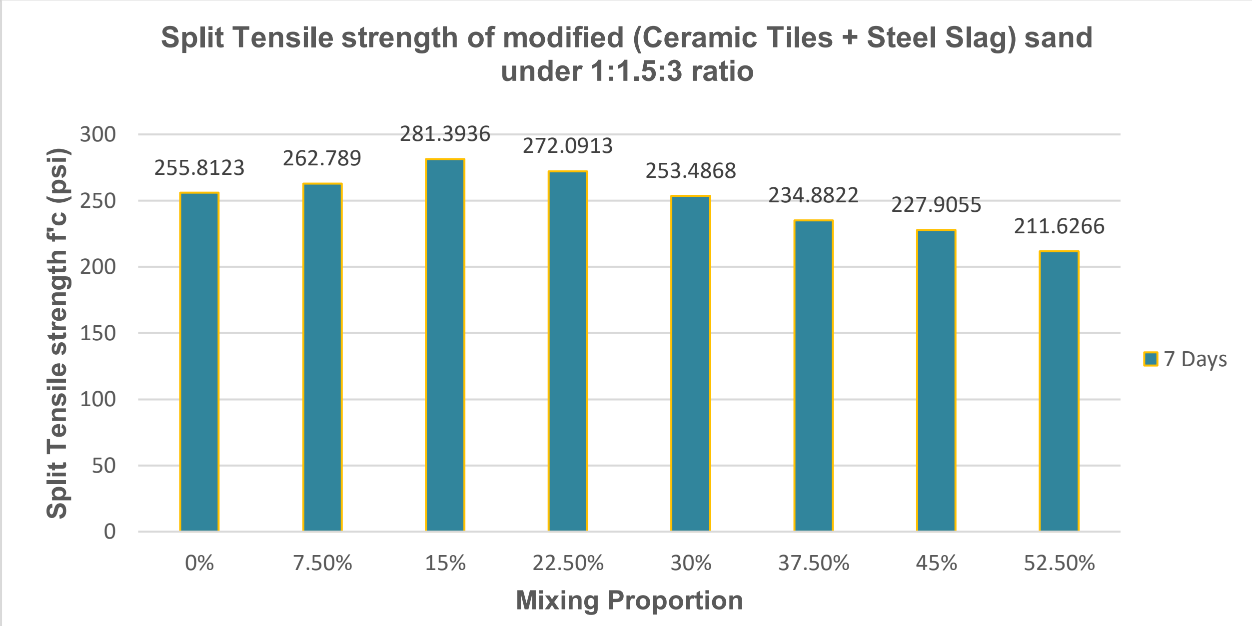

Figure 10 Split Tensile strength of modified (Ceramic Tiles + Steel Slag) sand under 1:1.5:3 ratio 7 days

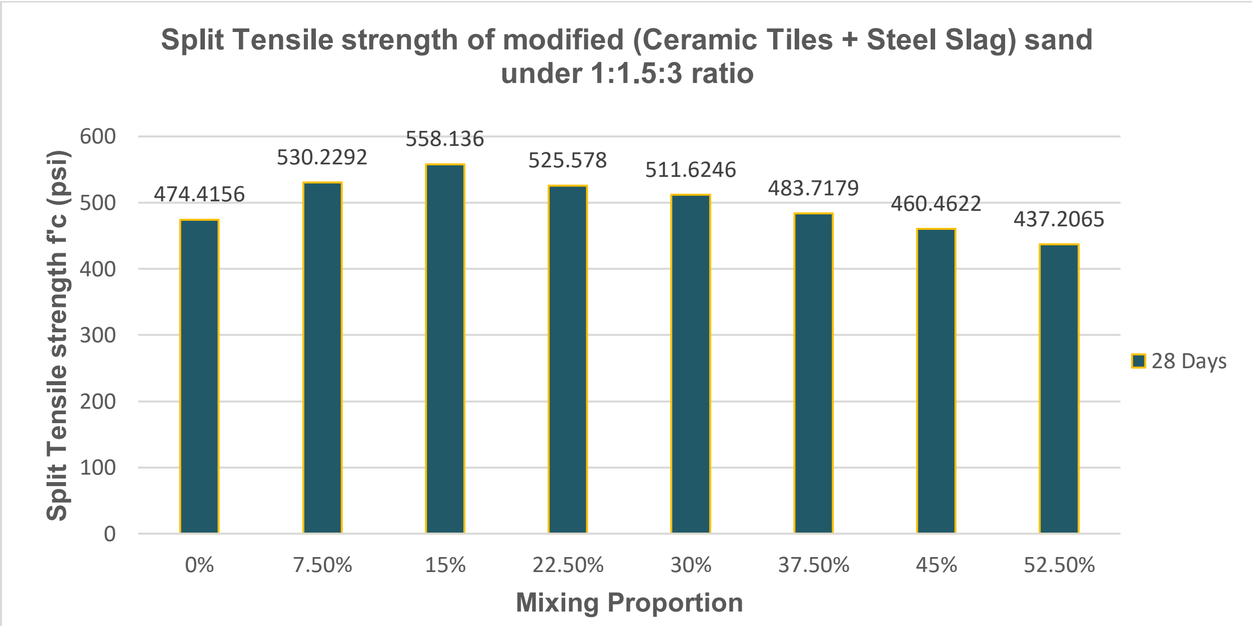

Figure 11 Split Tensile strength of modified (Ceramic Tiles + Steel Slag) sand under 1:1.5:3 ratio 28days

The comparison of compressive strength of modified mix concrete (Ceramic Tiles + Steel Slag) in 28 days and M20 standard value has described by figure 12. Modified mix concrete has shown the greater compressive strength in every sample of mixing proportion than the standard value of M20.

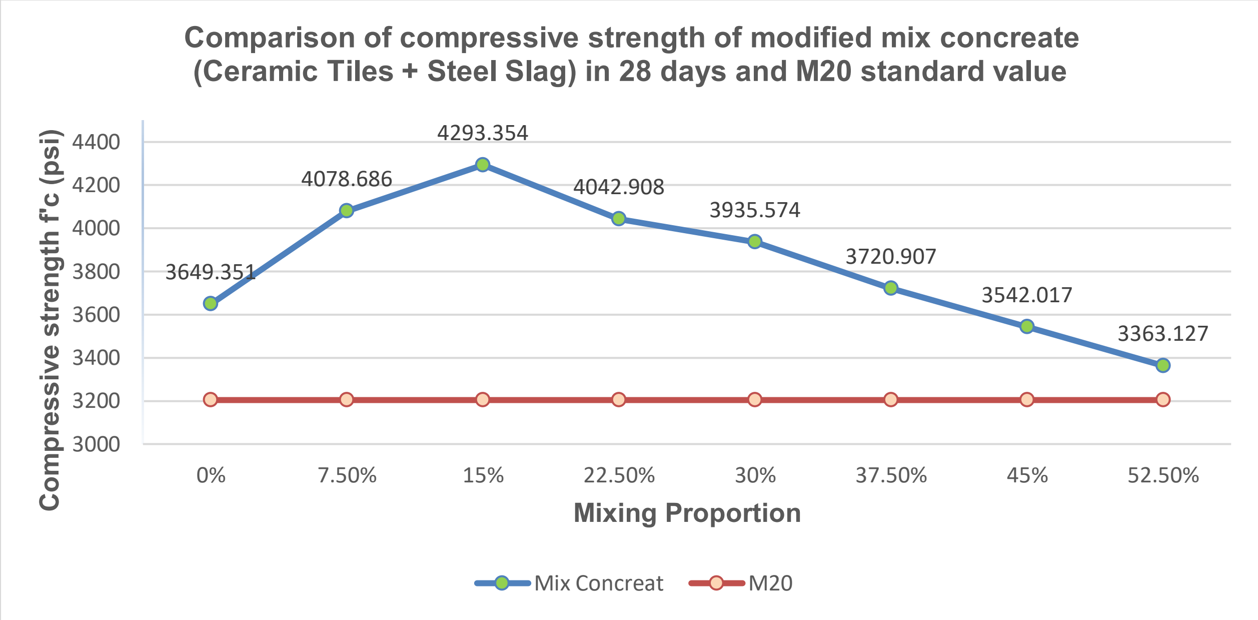

Figure 12 Comparison of compressive strength of modified mix concrete (Ceramic Tiles + Steel Slag) in 28 days and M20 standard value

15% of mixing proportion has shown the optimum compressive strength of concrete value which is more than 4000 psi. Minimum tested compressive strength of modified concrete of 52.5% proportion showed greater strength than standard value of M20.

Figure 13 appeared with the comparison of split tensile strength of modified mix concrete (Ceramic Tiles + Steel Slag) in 28 days and M20 standard value. Modified mix concrete proportion in every sample of mixing confirmed a greater split tensile strength than the standard value of M20 except 52.5%.

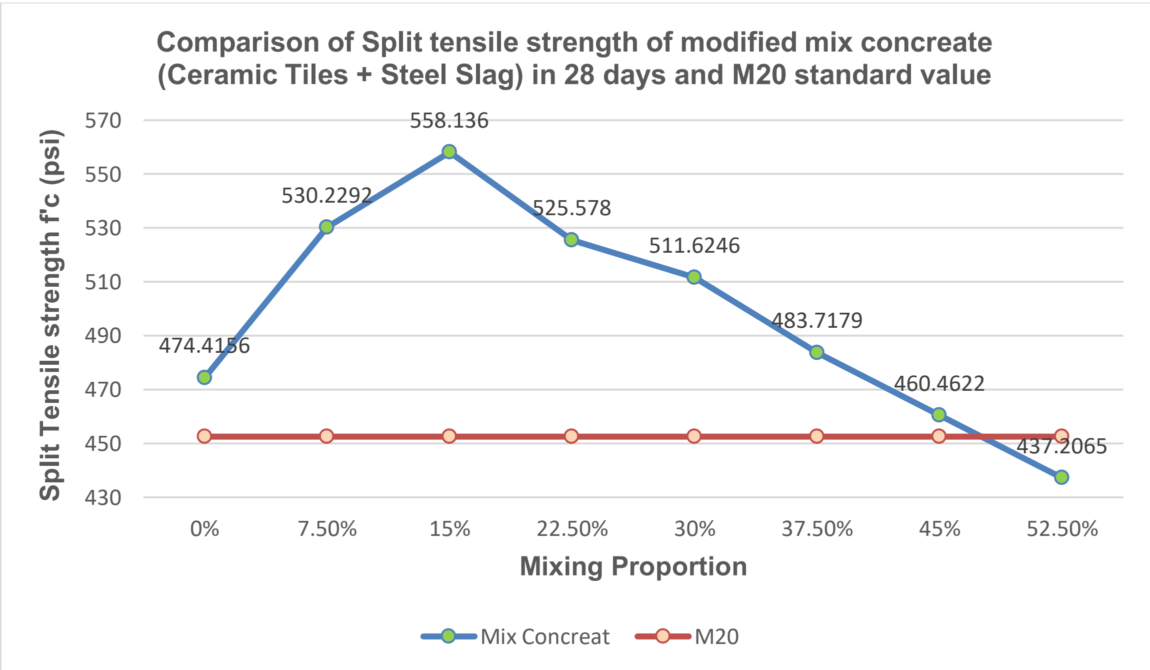

Figure 13 Comparison of split tensile strength of modified mix concrete (Ceramic Tiles + Steel Slag) in 28 days and M20 standard value

In figure 13, 15% of mixing proportion has shown the optimum split tensile strength of concrete value which was more than 500 psi. Minimum split tensile strength of modified concrete of 45% proportion showed greater strength than standard value of M20. The lowest value 437.2065 psi was found for 52.5% proportions which was less than M20 standard value.

CONCLUSION

In this study, a series of trials were observed to find out optimum composition of (ceramic tiles + steel slag) as a substitution of sand. The ratio of cement: sand: aggregates was 1:1.5:3 and compared with M20 standard value. The followings were the main findings of this study:

- The modified mix concrete exposed optimum compressive and split tensile strength in 15% of mixing proportion. Further changes reduced both strengths beyond that point.
- Up to 52.5% of the mixing proportion displayed greater compressive strength than standard value of M20.
- For split tensile strength up to 45% of the mixing proportion confirmed greater strength than standard value of M20.

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