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Effect of Various Types of Fillers on Mechanical Properties of Concrete

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ABSTRACT: *An experimental study on the effect of inclusion of three different types of fillers on mechanical properties of concrete is carried out. This paper presents the results of laboratory tests of 72 concrete cylindrical specimens of 10 cm diameter and 20 cm length with inclusion of* V_f*=10% of steel fillers, cast iron fillers and stone powder fillers in the concrete mix. Permeability, Compressive strength and splitting tensile strength are investigated by comparing the density of different types of concrete. Test results demonstrated that the stone powder fillers significantly improve mechanical properties of concrete while the cast iron fillers decline.*

KEYWORDS*:* Filler, Compressive Strength, Splitting Tensile Strength, Modulus of Elasticity, Density

INTRODUCTION

Preventing early concrete cracking to protect concrete against water penetration and so, delaying deterioration of concrete, has always been an important issue in concrete structures. Mechanical properties of concrete define this behavior and these mechanical properties are controlled by different factors such as concrete mix design and casting and curing procedure. The ACI manual of concrete practice specifies procedures for measuring, mixing, transporting and placing concrete. But the type and quantity of concrete aggregates have the most important role to determine concrete mechanical properties.

LITERATURE REVIEW

The effect of various types of aggregates on compressive strength and density of concrete are previously studied by many other researchers but there is lack of information about the various types of fillers and their effects on the mechanical properties of concrete. The type and grading of aggregates on the mechanical properties of concrete is very important especially in high performance concrete (Giaccio et al., 1992, Cetin et al., 1998, Aitcin et al., 1990). Zhou et al. (1995) concluded that the difference of strength for different types of concrete, made of various aggregates, could be as high as 40 MPa for the same water-binder ratio of 0.25. Light metallic aggregates are physically stronger and more resistant against wearing and impact than the conventional aggregates. The investigation by Oluokun

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and Malak (1999) showed that the inclusion of Ilmenite and Hematite coarse aggregates into concrete mix appeared to significantly increase the compressive strength, enhance the stress-strain behavior, and result in the production of tougher and more ductile concrete with a compressive strength of about 36 MPa. The research work reported here examined the effect of addition of steel, cast iron and stone powder fillers on the mechanical properties of concrete. One control mix proportions for concrete, of conventional fine aggregates, with fixed volumes, were designed. Also, an explanation for the observed metallic aggregate's density effect on the concrete is proposed.

METHODOLOGY

Raw materials

Cement: The ordinary port land cement, Type II, was used.
Aggregates: River sand with a fineness modulus of 2.6 was used as the fine aggregate. Crushed stone with maximum size of 20 mm was used as coarse aggregate.
Metallic aggregate: Steel filler, cast iron filler and stone powder filler were passed from sieve No.100 (150 µm). Steel filler and cast iron filler, manufactured locally were used, with specific gravity of 7800 (Kg/m^3) and 7200 (Kg/m^3), respectively. The steel used in this paper were produced with combination of iron and chrome alley.

Mixture of Concrete

Mixture of concrete are chosen with a water-to-cement ratio of 0.4, and 10% of sand's weight filler content. This amount of filler is needed to modify the sand's standard curve. The fillers were then equaled by volume. It should be noted that the unit weight of concrete increases with the metallic filler aggregate content.

Table 1. Concrete mix design

Cement (Kg/m^3)	Gravel (Kg/m^3)	Sand (Kg/m^3)	W/C
432	944	1243	0.4

Casting, Curing and Testing of Specimens

Cylindrical 10 cm × 20 cm specimens were used in the experiments. These cylindrical specimens were poured and compacted in three steps using vibrating table. The specimens were then kept in a 20℃ curing room having 98% relative humidity for 24 hours after which they were preserved for 27 days in lime-saturated water. Absolute volume method was used in the calculation of the concrete mixture.

Testing Specimens

In this study, during the experiment, the physical and mechanical properties of concrete were investigated. Three types of specimens were made from the above mentioned mixture. The 10 cm × 20 cm cylinders were primarily tested for compressive strength and tensile strength. As reported in Table 2, considerable decrease in the 28-day splitting tensile strength and compressive strength observed by inclusion of cast iron. Unit weights of produced concrete with steel, cast iron and

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stone powder, were 2610(Kg/m3), 2595(Kg/m3), and 2460(Kg/m3), respectively. Slumps were not high enough without the use of plasticizer.

Experimental results

The ASTM code procedure, was used for testing mechanical properties, such as compressive strength (ASTM C39 / C39M - 09a), splitting tensile strength (ASTM C496 / C496M - 04e1) and modulus of elasticity (ASTM C469 - 02e1). The test results are summarized in Table 2.

Table 2. Average test results

Series	Compressive strength (MPa)	Splitting tensile strength (MPa)	Modulus of elasticity (MPa)	Unit weight (Kg/m^3)
Steel	31.2	3.1	26200	2610
Cast iron	23.7	2.7	22900	2595
Stone powder	35.9	3.3	28100	2460

Compressive Strength

The compressive strength of different types of fillers are presented in Figure 1. The results show that with inclusion of steel filler and cast iron filler, concrete's strength decreases significantly despite their aggregates' high strength and high density. An inclusion of V_f=10% of metallic aggregates decreased the compressive strength by 29% than of the regular concrete while inclusion of stone powder filler increased the concrete's strength.

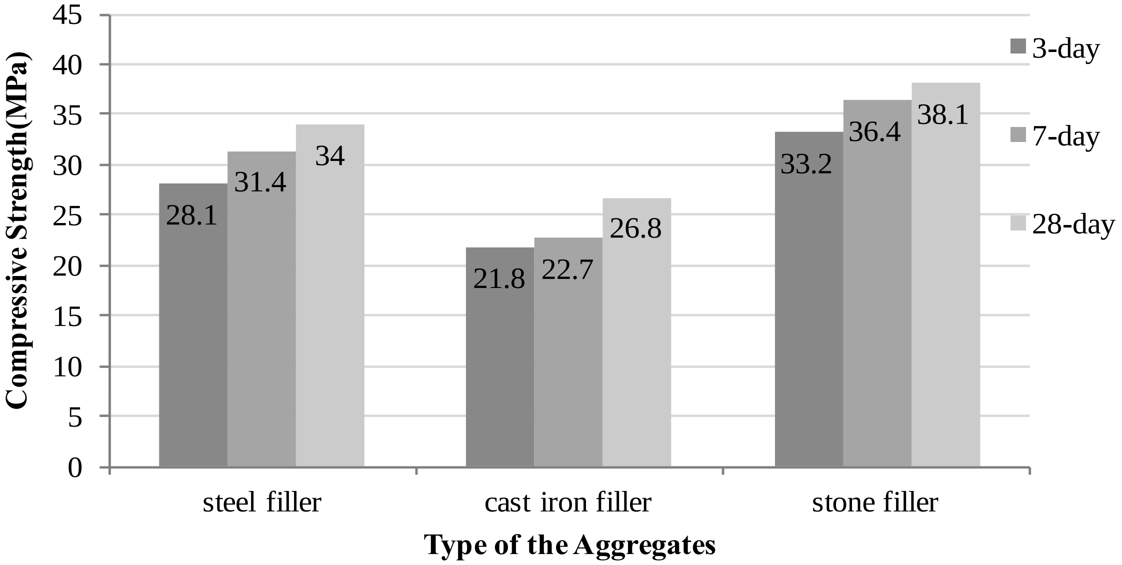

Figure 1. Concrete Compressive strength vs. type of the aggregates

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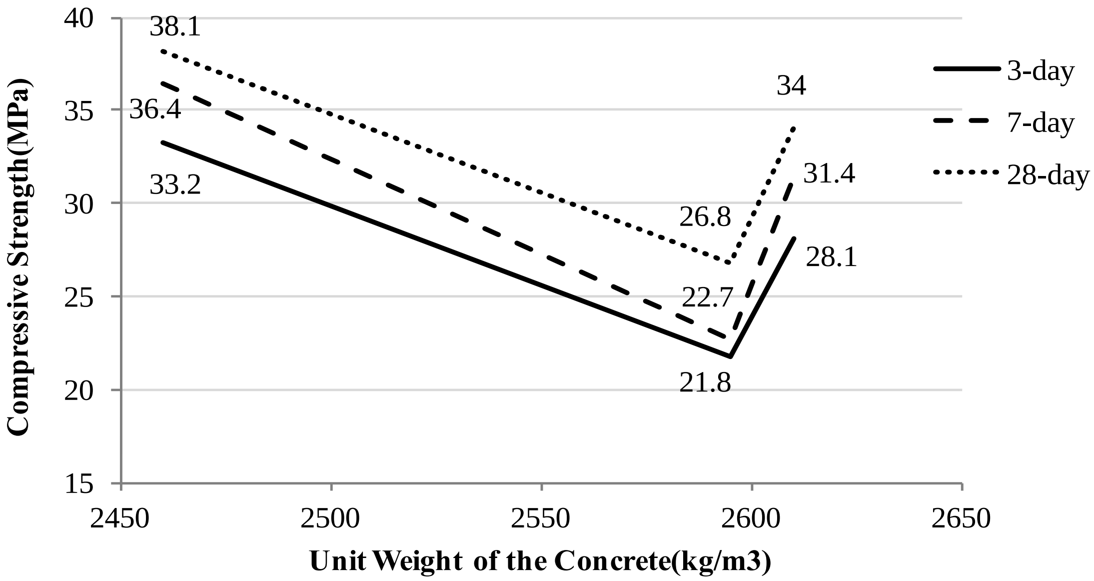

Figure 2. Compressive strength of concrete vs. unit weight of the concrete

Figure 2 shows that compressive strength of concrete in the ages of 3, 7 and 28 days generally decreases as density increases. The increase in density is not because of concrete becoming denser but is because of using heavier aggregates.

Splitting Tensile Strength

The splitting tensile strength tests on cylindrical specimens with different fine aggregate inclusions was used to determine the tensile strength of concrete. Test results reported in Figure 3, show considerable decrease in the 28-day tensile strength by the addition of metallic fillers.

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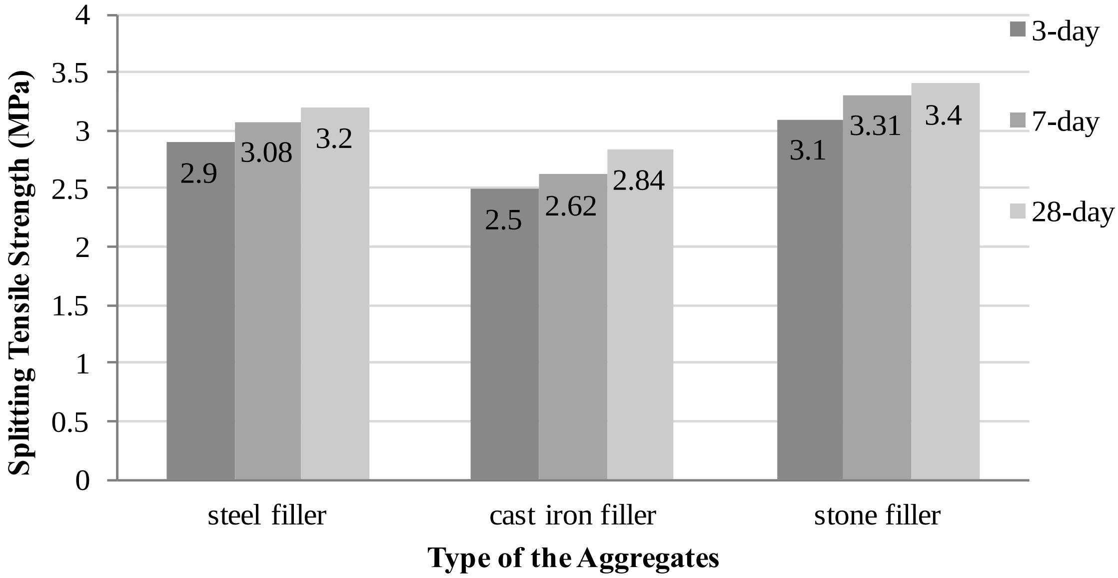

Figure 3. Splitting tensile strength of concrete vs. type of the aggregates

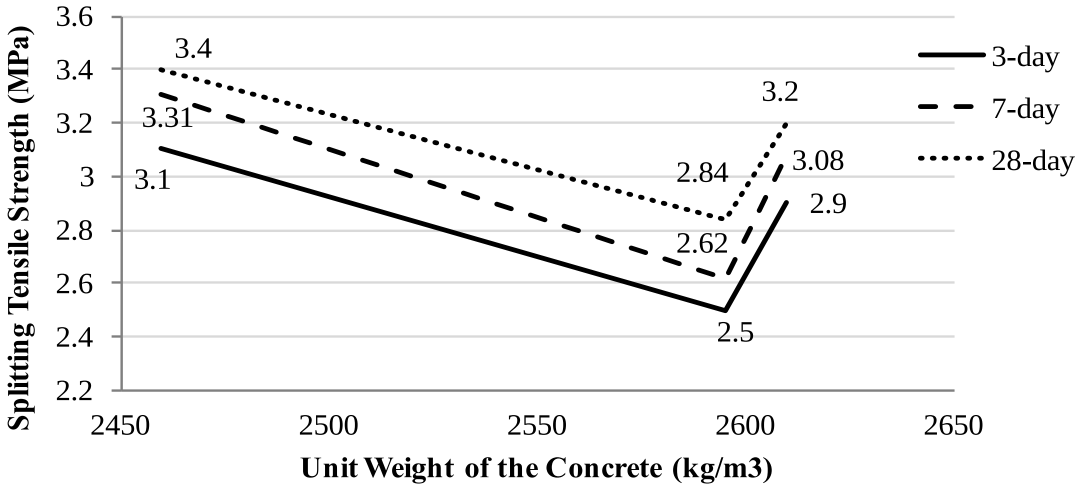

Figure 4. Splitting tensile strength for concrete vs. unit weight

As it is shown in Figure 4, splitting tensile strength of cast iron-concrete, is less than others. Although stone powder-concrete has the least density among these three types, addition of stone powder fine aggregates led to the highest concrete tensile strength. An inclusion of V_f=10% cast iron fine aggregate, reduced tensile strength to 16% than the regular concrete.

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Modulus of elasticity

E modulus values were calculated from ultrasonic duration values. The modulus of elasticity at age of 3, 7 and 28 days, were obtained in this study. The curing condition of specimens is the same as the condition for determining compressive strength. Experimental results showed that the modulus of elasticity of concrete produced with fine metallic aggregates is less than regular concrete. According to the test results shown in Figure 5, the inclusion of V_f=10% of fine metallic aggregate reduces the modulus of elasticity of concrete to approximately 18% that of regular concrete.

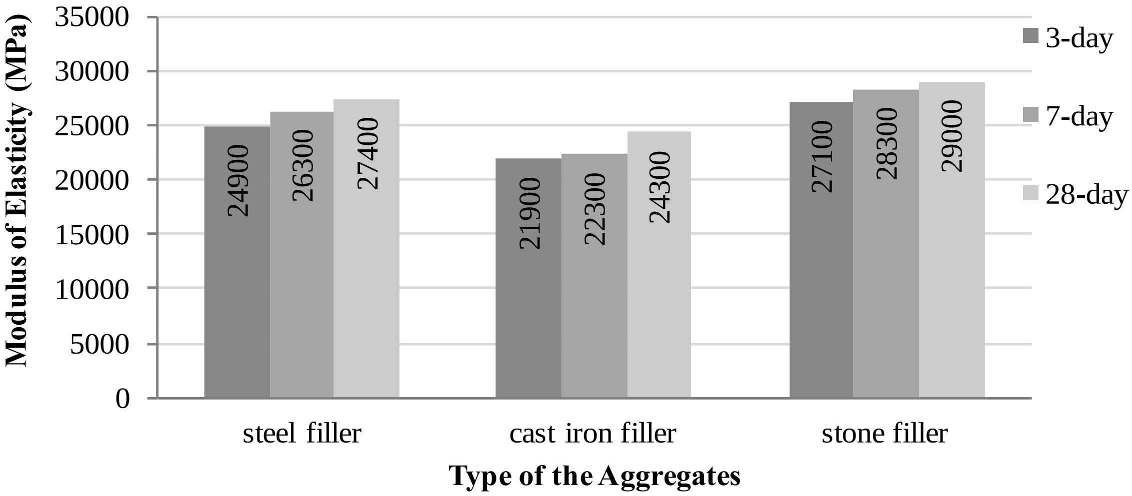

Figure 5. Modulus of elasticity of concrete vs. type of the aggregates

Figure 6 shows that, although the stone powder-concrete has the lowest density, it is more rigid than others.

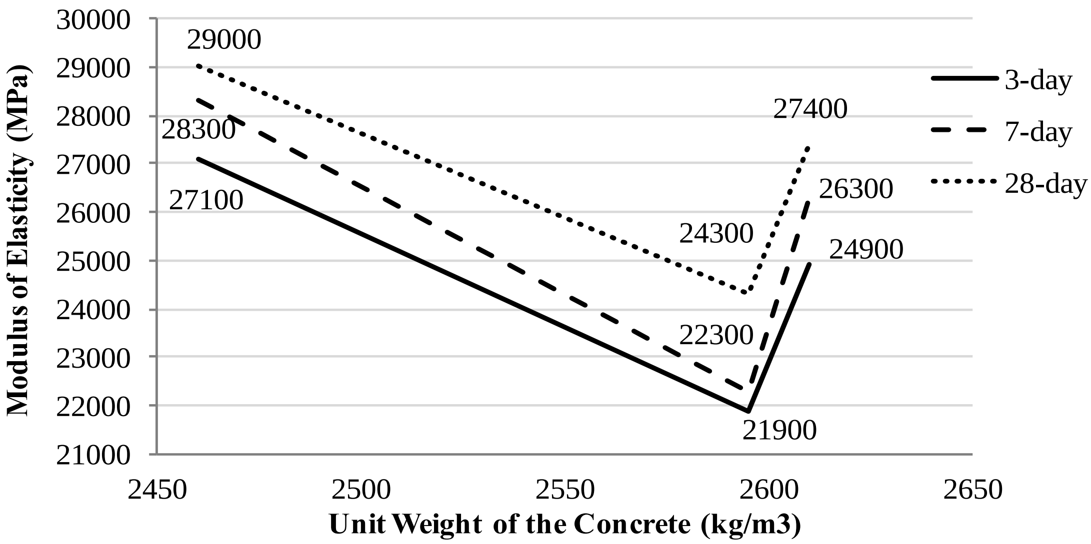

Figure 6. Modulus of elasticity of concrete vs. unit weight

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4.4. Permeability

The inclusion of heavyweight fine aggregates into concrete does not decrease the permeability of the concrete to water despite their aggregates' higher strength and higher density. The water permeability of concrete for different types of fillers is shown in Fig. 4. In fact, an inclusion of V_f=10% of fine metallic aggregates significantly increases the water permeability of concrete comparing the regular concrete.

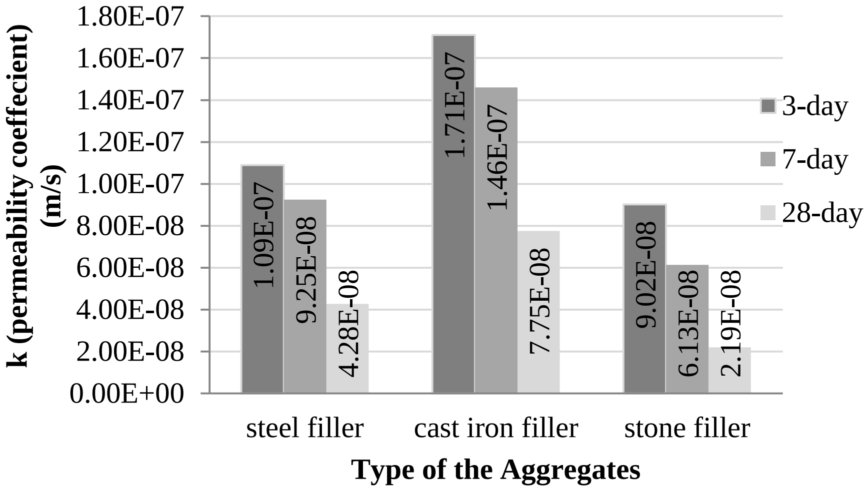

Figure 7. Permeability of concrete vs. type of the aggregates

The permeability coefficient used here, *k*, is based on Darcy's law for a falling water head and is expressed as:

$$\frac{dQ}{dt} = -\frac{A'\,dh}{dt} = k\,\frac{h}{L} - \frac{dh}{h} = k\,\frac{hA}{A'L}\,dt \qquad \text{Eq. 1}$$

with integration from h_0 to h_1:

$$k = \frac{A'}{At}\,ln\frac{h_0}{h_1} \qquad \text{Eq. 2}$$

Where:
k = Permeability coefficient (m/s)
A' = Cross sectional area of pipette (m^2)
A = Cross sectional area of the concrete specimen (m^2)
t = time (sec)
h_0 and h_1 = Initial and final water heads (m)
L = Thickness of concrete sample (m)
Q = Volume of water flow (m^3)
As shown in Figure 8, increase in density of concrete does not decrease the water permeability of concrete since increase in density in this study is because of using heavyweight materials.

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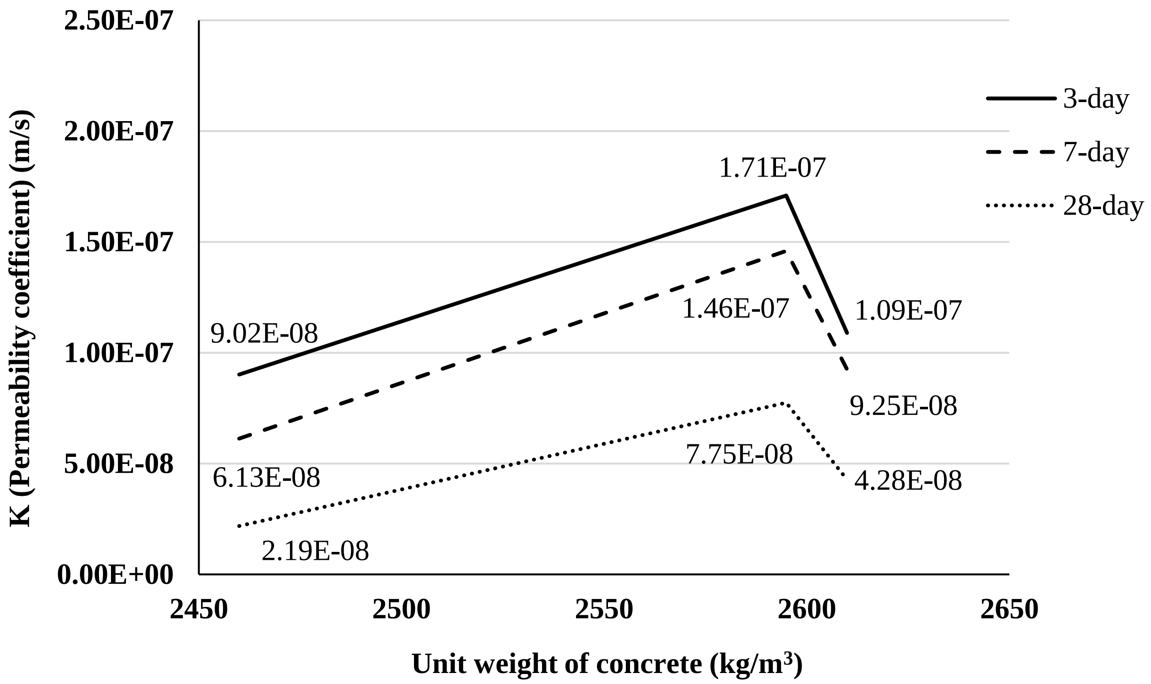

Figure 8. Permeability of concrete vs. unit weight

DISCUSSION AND CONCLUSION

This work is aimed to investigate the effect of inclusion of special fine metallic aggregates in the concrete mix. The following conclusion can be drawn from the experimental results of this study:

1. Cast iron filler decreases all of the mechanical properties of concrete studied in this work. This reduction is probably the result of carbonic compounds of cast iron filler, since the compressive strength of pure carbon is much less than iron or other aggregates, therefore it seems that the decrease in the mechanical properties is caused by carbon breaking sooner than other materials. It conspicuously showed that using fine aggregates with higher unit weight does not help to improve the compressive strength, splitting tensile strength and E modulus of the concrete.

2. Among these three types of fine aggregates in this study, concrete including V_f=10% stone powder fine aggregate has higher compressive strength, splitting tensile strength and E modulus of elasticity and less water permeability coefficient than others, which implies a higher cracking resistance and more suitable for shielding structures.

3. Since the inclusion of steel filler and cast iron into the concrete ease the water penetration through the concrete by corrosion of metallic fine aggregates of concrete surface, it accelerates concrete deterioration. Thus, the metallic fine aggregates would not be recommended to be used in the structures exposed to water.

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FUTURE STUDIES

It is recommended to study the effect of inclusion of other types of fillers in concrete mix on mechanical properties and permeability of concrete, for example non-metallic fillers like synthetic fillers.
Also, the effect of fire in the concrete specimens with metallic fine aggregates should be studied.

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