Investigating the effect of light aggregate and curing methods on the properties of cement-slag concretes

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ABSTRACT

One of the optimal methods for producing cement and concrete is to replace part of the cement with cheap additives. These pozzolans help reduce cement consumption, energy, and greenhouse gas emissions. They also improve the mechanical properties and durability of concrete. In this study, 11 mixing designs were made, including a reference and 10 cement-slag concrete designs. Slag powder from the Ahvaz Steel Plant was used instead of 40% cement (by weight). In five designs, scoria lightweight aggregate was used instead of part of the natural aggregate, and in the other five designs, Leca was used. These two types of lightweight aggregate were used with two curing methods with drinking water and laboratory temperature. Standard cubic and prismatic samples were used for the tests. In the mixing design, scoria and Leca lightweight aggregates were replaced by 30%, 40%, 50%, 60% and 70% with natural aggregates (pea and almond). Also, a third-generation modified superplasticizer and a polycarboxylate-based extreme water reducer were used. To determine the rheological, mechanical and durability properties, slump tests, concrete specific gravity, compressive strength, indirect tensile strength, electrical resistance, volumetric water absorption and water penetration depth were performed. The results showed that using 40% steel slag with a combination of scoria and Leca aggregates in concrete production has positive results. At the age of 91 days, the compressive strength of cement-slag concrete should not be less than the same strength as the reference concrete. Therefore, 40% replacement of slag with scoria and Leca aggregates can be considered optimal.

KEYWORDS

Cement- slag concrete, Scoria, Leca, Curing, Natural aggregates

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1. Introduction

Concrete is one of the main materials in the construction of engineering structures [1]. The physical and mechanical properties of concrete, along with the ease of production, have made it the most widely used material in the construction industry. After being formed in a mold, concrete quickly acquires suitable mechanical properties [2]. Mufti et al. [4] studied in an article how 10%, 20%, 30% and 40% of cement can be replaced with scoria powder. This was to control the alkaline silica reactions. They measured the expansion of prismatic mortar. The results showed that with increasing the amount of replacement, the expansion of the specimens decreased. However, only the design containing 40% scoria was able to control the expansion in accordance with the requirements of the code. Naderi and Boni [3]. This study is a continuation of the previous study by Sajedi and Bahraminia [6] and similar studies [4-5] on the effect of slag on the properties of cement-slag concrete. Based on the results of those studies, the use of natural porous materials such as scoria and lico aggregates that absorb and retain water well was selected. The aim of this selection is to achieve concrete with appropriate internal curing. In this study, ten mixing designs with 40% slag from the Ahvaz Steel Plant in powdered form were used as a replacement for part of the cement consumed. Also, 30%, 40%, 50%, 60% and 70% scoria and Leca aggregates were used separately as a replacement for part of the aggregate (pea and almond) in the manufacture of concretes. The samples made from the designs were cured at the ages of 28 and 91 days in two environments of drinking water and laboratory temperature and were subjected to the necessary tests. These tests included slump, specific gravity, compressive strength, indirect tensile strength, electrical resistance, volumetric water absorption, and water penetration depth. The results of these tests were reviewed and analyzed.

2. Materials and Methods

In this study, eleven mixing designs were investigated based on the Iranian Concrete Code (ABA) [7]. Scoria and Leca aggregates were used in proportions of 30%, 40%, 50%, 60% and 70% as a substitute for natural aggregate. Also, 40% of Ahvaz steel slag was used as a substitute for cement. The naming method of the mixing designs is as follows:

S represents slag, 40% is the weight of slag in the designs, Sc represents scoria lightweight aggregate and Le represents Leca aggregate. The number after each letter indicates the percentage of use of those materials as a substitute. For example, S40Sc30 means that the concrete contains 40% slag and 30% scoria aggregate. RC means reference concrete. Details of the final mixing designs of the study are presented in Table1.

Table 1: Details of the research mixture design (kg/m3)

Row	Project name	Project code	Weight of materials							
			Almond sand	Peanut sand	Sand	Leca	Scoria	Water (Lit)	Superplasticizer(Lit)	w/c
1	Reference concrete	RC	33.2	38.3	94.8	0	0	11.62	0.24	0.44
2	Concrete with 40% slag and 30% scoria	S40Sc30	23.7	27.91	94.8	0	19.89	18.2	0.34	0.41
3	Concrete with 40% slag and 40% scoria	S40Sc40	19.3	23.6	94.8	0	28.6	18.2	0.34	0.41
4	Concrete with 40% slag and 50% scoria	S40Sc50	16.1	19.7	94.8	0	35.7	18.2	0.34	0.41
5	Concrete with 40% slag and 60% scoria	S40Sc60	12.8	15.8	94.8	0	42.9	18.4	0.37	0.42
6	Concrete with 40% slag and 70% scoria	S40Sc70	9.65	11.8	94.8	0	50.05	18.4	0.37	0.42
7	Concrete with 40% slag and 30% Leca	S40Le30	28	29.2	94.8	21.8	0	18.2	0.32	0.41
8	Concrete with	S40Le40	24	25.1	94.8	29	0	18.2	0.35	0.41

	40% slag and 40% Leca									
9	Concrete with 40% slag and 50% Leca	S40Le50	20	20.9	94.8	36.3	0	18.2	0.35	0.41
10	Concrete with 40% slag and 60% Leca	S40Le60	16	16.8	94.8	43.6	0	18.4	0.39	0.42
11	Concrete with 40% slag and 70% Leca	S40Le70	12	12.5	94.8	50.8	0	18.4	0.39	0.42
*The steel slag used in this mixing plan is 17.6 kg/m^3; The cement used18.4, 0.39, 0.42, this mixing plan is 26.4 kg/m^3.										

3- Analysis of compressive strength results

According to the results of Figure 1, It was predictable that using slag from the Ahvaz Steel Plant as a partial replacement for cement and using scoria and Leca as a partial replacement for aggregates would reduce mechanical properties. A point that is common to all samples is that the main effect of slag is evident at older ages. An examination of the results shows that using 30% and 40% scoria and Leca aggregates at the age of 91 days increases the strength compared to the reference sample. Although the increase of 6% seems insignificant, it indicates a positive effect of steel slag with scoria and Leca aggregates on compressive strength up to the age of 91 days. The possible reason for this small increase is the further progress of cement and slag hydration reactions over time. One of the reasons for the late effect of slag is the high iron oxide content in it, which is more than 43%. In Figure 9, the compressive strength results at 28 and 91 days are shown only for samples cured in drinking water and laboratory temperature. The effect of scoria and Leca aggregates with 40% Ahvaz steel slag in the early days of setting was lower than that of the reference concrete. However, over time, the strength of the samples approached that of the reference concrete and the samples containing 30% and 40% scoria and Leca aggregate showed higher strength than the reference sample. The results of this study can be compared with the study of Momeni and Qovidel [8], which showed that samples containing Leca aggregate performed better in mechanical tests.

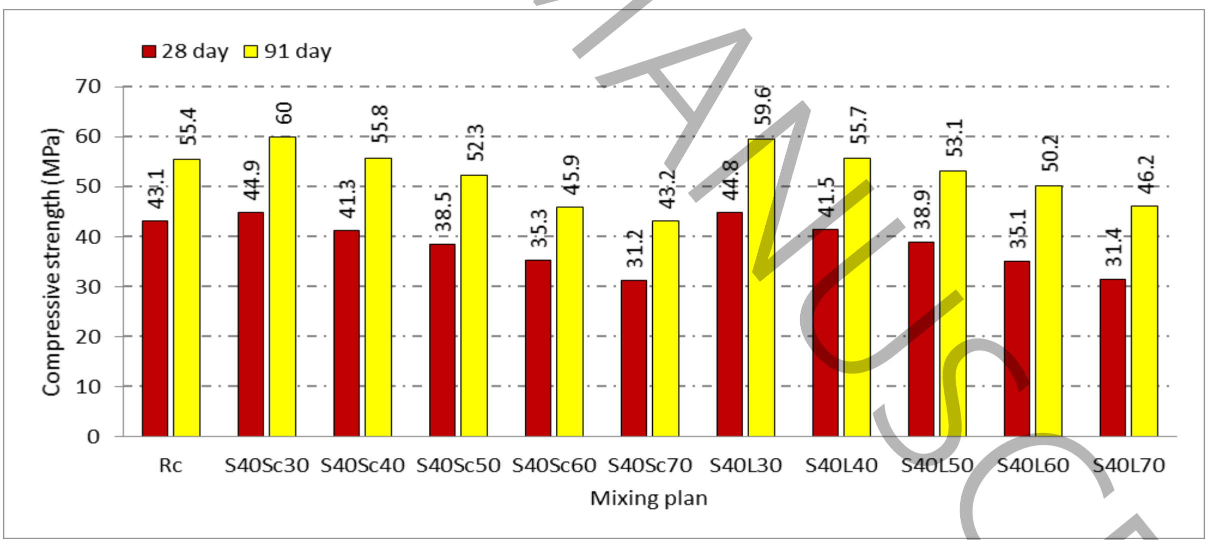

Figure 1: Compressive strength results of samples treated with drinking water

4- Summary and Conclusions

This study is a continuation of the study by Sajedi and Bahraminia [20], which investigated the effect of slag from Ahvaz Steel Plant on the properties of cement-slag concretes. In this study, 40% slag from Ahvaz Steel Company was considered as the optimal composition.

The aim is to develop environmentally friendly concretes. These concretes were made using slag pozzolan produced in Ahvaz Steel Company and natural scoria and Leca aggregates. Various mechanical properties and durability tests were performed on concrete samples at the ages of 28 and 91 days. The key results of the study are as follows:

• Samples containing 30% and 40% scoria aggregates cured in drinking water showed the highest compressive strength at the age of 91 days. This indicates the positive effect of proper curing and selection of the optimal percentage of replacement on the hydration process and strength development.

• Finally, simultaneous replacement of 40% scoria aggregate and 40% Leca aggregate instead of 40% Ahvaz steel slag resulted in a suitable and significant improvement in mechanical properties at the age of 91 days. This combination is proposed as the final optimal design from the perspective of concrete strength performance and durability in this study.

5. References

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