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Use of local discarded materials in concrete

Ramzi Taha *, Nasser Al-Nuaimi, Abdulazeez Kilayli, Abdelhamid Ben Salem

Department of Civil and Architectural Engineering, Qatar University, Doha, Qatar

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Abstract

Steel slag, a by-product of steel manufacturing, is generated in large quantities in Qatar. In fact, it is estimated that more than 400,000 tons of steel slag are generated annually in the country. Gravel, resulting from washing sand, is also produced at more than 500,000 tons/year in Qatar. Both materials are not efficiently used in the country and most of its aggregate (gabbro) needs are imported from neighboring countries. This paper presents the results obtained on the use of steel slag, gravel and gabbro in concrete. A total of nine concrete mixtures were prepared. One concrete mixture that contained 100% gabbro aggregate was considered as the control mix. Four concrete blends containing 100%, 75%, 50%, and 25% steel slag (by weight) were prepared as partial replacements of gabbro aggregates. Another four concrete mixtures containing 100%, 75%, 50%, and 25% gravel (by weight) were cast as partial replacements of gabbro aggregates. All samples were cured in a water tank for 7, 28 and 90 days and then subjected to compressive, flexural and splitting tensile strength tests. All concrete mixtures prepared easily met the 28-day compressive strength design requirement of 28 MPa. Best results were obtained for concrete prepared using 100% steel slag aggregates. Concrete cast using 100% gravel yielded lower strength results than the control mixture (100% gabbro). However, there was an increase in strength values with an increase in gabbro content in gravel/gabbro mixtures. Additional work is necessary to establish long-term performance, especially concerning what is reported in the literature about the expansive characteristics of steel slag aggregates when used in concrete. It should be noted that concrete cured for 90 days in the water tank did not exhibit any reversal in strength.

Keywords: Slag; Gabbro; Concrete; Waste; Recycling

1. Introduction

Steel slag, a by-product of steel manufacturing, is generated in large quantities in Qatar. In fact, it is estimated that more than 400,000 tons of steel slag are generated annually in the country. Gravel, resulting from washing sand, is also produced at more than 500,000 tons/year in Qatar. Such materials are not efficiently utilized in Qatar. However, the country suffers from the availability of good aggregates that could be utilized in road, parking, buildings and other construction. Also, as a result of infrastructural renewal in Qatar there will be a great demand for aggregates and other construction materials over the next ten years. It is estimated that more than 15 million tons of aggregates are imported each year to Qatar from Oman, the United Arab Emirates and Saudi Arabia, thereby, increasing construction costs and probably causing unnecessary project delays. Thus, our environmental responsibilities and potential economic benefits that might be realized dictate that we utilize steel slag, gravel and other discarded materials in the construction sector.

* Corresponding author. Address: Department of Civil and Architectural Engineering, Qatar University, P.O. Box 2713, Doha, Qatar. Tel.: +974 4403 4118.
E-mail address: ramzitaha@qu.edu.qa (R. Taha).
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Many countries including the United States of America, Britain, Australia, India and others routinely use steel slag in road bases and subbases, asphalt concrete paving, and other applications. A wide spread use of steel slag is not prevalent in Qatar yet. Research was thus needed to promote and investigate, where possible, the recycling of steel slag and gravel deposits (generated as a result of sand washing) in concrete mixtures.

This paper will present the results obtained from a research project on the use of steel slag, gravel and gabbro (imported aggregates) in concrete.

2. Literature review

Several research studies (Maselehuddin and Khan, 1999; Maseluhddin et al., 2003; Bosela et al., 2008; Patel, 2008) were conducted on the use of steel slag aggregates in concrete. Control mixtures were prepared using natural aggregates such as limestone and crushed gravel. Trial concrete mixes were also cast using different percentages of steel slag aggregates as substitutes for coarse natural aggregates. Fresh and hardened concrete were subjected to mechanical and durability tests. All laboratory results indicate that concrete prepared using steel slag aggregates produced equal or better performance than that of concrete cast using coarse natural aggregates.

However, there were no serious attempts to investigate the performance of fresh steel slag aggregate against aged aggregates in concrete. Also, data regarding long-term concrete performance are limited and inconclusive, especially concerning the expansive characteristic of steel slag aggregate. Much research work remains to be done in this regard.

On another note, granulated blast furnace slag has been extensively studied for use in cement and concrete. This slag is accepted for use in the construction industry. Several research studies (Dongxue et al., 1997; Altun and Yilamz, 2002; Shi and Hu, 2003; Baby, 2012; Kounrounis et al., 2007) investigated also the use of steel slag in composite cements. Concerns were raised concerning the low content of reactive calcium silicate compounds and the potential for expansion due to the high content of free calcium and magnesium oxides.

Kounrounis et al. (2007) investigated composite cements containing up to 45% w/w steel slag. The steel slag fraction used was in the range of 0–5 mm. A wide range of tests were conducted on cement pastes and mortars, including initial and final setting times, standard consistency, flow of normal mortar, autoclave expansion and compressive strength. The authors conclude that “slag can be used in the production of composite cements of the strength classes 42.5 and 32.5 of EN 197-1. In addition, the slag cements present satisfactory physical properties. The steel slag slows down the hydration of the blended cements, due to the morphology of the contained C_2S and its low content in calcium silicates”.

Shi and Hu (2003) indicated that steel slag has the potential to be used as a cementing product. However, he recommended that other materials to be combined with the steel slag to consume the free calcium in order to eliminate the propensity for expansion.

3. Research objective and scope of work

The main objective of this paper is to present the research results obtained on the use of steel slag, gravel and gabbro in concrete mixtures.

The emphasis of the work in the initial phase of this study was on the feasibility of utilizing steel slag and gravel aggregates in concrete, as a total or partial replacement of gabbro aggregate, used in construction in the State of Qatar by studying the properties of fresh and hardened concrete. Tests were conducted on concrete samples made of different aggregates to determine their acceptability for use in concrete. The different mixes were tested to determine compressive strength, splitting tensile strength, flexural strength, air content, and bulk density.

A total of nine concrete mixes were cast in the Department of Civil Engineering Laboratories at Qatar University. One concrete mix containing 100% gabbro aggregate was considered the control mix. Four concrete mixes containing 100%, 75%, 50%, and 25% steel slag (by weight) were prepared as partial replacements of gabbro aggregates. Another four concrete mixes containing 100%, 75%, 50%, and 25% gravel (by weight) were cast as partial replacements of gabbro aggregates.

4. Materials’ collection and mix proportioning

4.1. Cement

Cement used in this research work was Ordinary Portland Cement (OPC) produced by Qatar National Cement Company (QNCC). To minimize the storage time and other problems of bagged cement storage at the distribution sale market point, the cement was directly purchased from the QNCC through a special request. This brand of cement is the most widely available and used by the construction industry in the State of Qatar, as QNCC is the largest cement producer in Qatar.

4.2. Sand

Fine sand used in the research was washed sand known in Qatar as government wash sand, which was brought from the government sand washing plant. This sand was used in all concrete mixes prepared in the laboratories. The sand was tested in accordance with ASTM C33 to meet the specification requirements of concrete mixtures. Sieve analysis results for the sand are shown in Fig. 1 along with the upper and lower ASTM limits for each sieve size.