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STRENGTH PROPERTIES OF HIGH VOLUME SLAG CEMENT CONCRETE

SASAN PARNIANI
(MA081371)

A project report submitted in partial fulfillment of the
Requirements for the award of the degree of
Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
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November, 2010

I declare that this project report entitled *"strength properties of high volume slag cement concrete"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved mother and father

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ABSTRAK

Sangga relau bagas terkenal sebagai salah satu bahan dalam proses penghasilan konkrit. Pada tahun 1905, sangga relau bagas berbutir telah mula digunakan untuk menghasilkan campuran simen di Amerika Syarikat. Pada masa kini, telah dipertimbangkan untuk digunakan sebagai unsur atau bahan pengikat yang dicampur bersama dengan simen Portland dalam proses penghasilan konkrit. Kajian ini dilakukan bertujuan untuk mengkaji ciri kekuatan sangga relau bagas dalam konkrit. Kerja-kerja makmal telah dilaksanakan berdasarkan tiga aspek kekuatan konkrit yang mengandungi simen sangga relau bagas. Bagi langkah pertama, konkrit dengan peratusan kandungan sangga relau bagas penggantian telah disediakan dan diuji bagi mengenalpasti kapasiti optimum sangga relau bagas berbutir dalam konkrit untuk mencapai kekuatan tertinggi. Untuk mencapai objektif ini, sampel-sampel berbentuk kubus (dimensi: 100m x 100mm x 100mm) telah disediakan dan diuji bagi mengenalpasti pecahan terbaik kandungan sangga relau bagas yang diperlukan untuk mencapai kapasiti kekuatan mampatan maksima. Sampel-sampel berbentuk prisma (dimensi: 100mm x 100mm x 500mm) juga disediakan dan diuji untuk mengenalpasti kekuatan lentur bagi konkrit simen sangga. Bagi langkah kedua, dua rasuk konkrit bertetulang rasuk telah disediakan dan diuji untuk mengenalpasti serta membandingkan ketinggian isipadu simen sangga relau bagas dengan konkrit biasa berdasarkan sifat kelenturan untuk konkrit dari jenis ini. Akhir sekali, kesan-kesan dari penyembuhan keadaan disiasat dan kehilangan kekuatan simen sangga relau bagas apabila terdedah kepada penyembuhan yang lemah diperiksa. Keputusan ujian menunjukkan bahawa 40% sangga relau bagas penggantion menghasilkan kekuatan mampatan yang terbaik bagi konkrit pada usia 28 hari. Walau bagaimanapun, kesan daripada kekuatan lentur konkrit sangga relau bagas adalah berbeza. Selain itu, adalah dipelajari bahawa flexibility rasuk berkurang dengan peningkatan penggantian ketinggian isipadu sangga relau bagas dalam rasuk konkrit bertetulang. Daripada keputusan-keputusan ujian tersebut, didapati bahawa kehilangan kekuatan dalam konkrit sangga relau bagas berbutir adalah lebih tinggi jika dibandingkan dengan konkrit biasa dalam keadaan penyembuhan yang lemah.

ABSTRACT

The use of blast-furnace slag as constitute of concrete is well known. The use of ground granulated blast-furnace (GGBFS) slag for producing blended cement commenced in 1905 in United States. Recent consideration has been given to use of GGBFS as separate cementitious material mixed along with Portland cement in production of concrete. This study was conducted to investigate strength properties GGBF slag in concrete. Laboratory work was done in three aspects of slag cement concrete strength. At first step different percentages of replacement slag in concrete was done and tested to determine the optimum strength volume o GGBFS in concrete. To accomplish this objective, cube samples (100mmx100mmx100mm) was prepared and tested to evaluate the best proportion of slag to reach maximum compressive strength. Also prism samples (100mmx100mmx500mm) were tested to determine flexural strength of slag cement concrete. At second step, two reinforced concrete beams were cast and tested for evaluating and comparing high volume slag cement with plain concrete in according to flexural behavior of this type of concrete. Finally the effect of curing condition investigated. And strength loss of slag cement concrete in expose to poor curing was examined. The test results conclude that 40% replacement of slag has best compressive strength in concrete at 28 days .but effect of flexural strength of GGBFS concrete was different. Furthermore it shows that ductility and flexibility of beam decrease with substitute of high volume slag in reinforced beam. Eventually results indicate that strength loss in GGBF slag concrete is more than normal concrete in poor curing conditions.

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CHAPTER 1

INTRODUCTION

Slag cement, or ground granulated blast-furnace slag (GGBFS), has been used in concrete projects more than a century in worldwide. Earlier usage of slag cements explains that long-term performance is improved in several ways. Based on these recent experiences researchers have found that main effects of improved durability are in life cycle costs and reduce maintenance costs. Consuming slag cement to substitute a portion of portland cement in a concrete mixture is a useful technique to make concrete better and more consistent. Main effects of slag cement usage are:

- Easier finish ability
- Higher compressive and flexural strengths
- Lower permeability
- Improved resistance to aggressive chemicals
- More consistent plastic and hardened properties

When iron is manufactured using a blast furnace, the furnace is continuously charged from the top with oxides, fluxing material, and fuel. Two products—slag and iron—gather in the bottom of the hearth. Molten slag floats on above the molten iron; both are tapped distinctly. The molten iron is transferred to the steel producing facility, while the molten slag is changed to a granulator. This process, known as granulation, is the rapid cooling with water of the molten slag into a raw material called granules.Rapid cooling prevents the development of crystals and forms glassy, non-metallic, silicates and alumina silicates of calcium. These granules are dried and then ground to a suitable fineness, the result of which is slag cement. The granules can also be jointed as an ingredient in the manufacture of blended Portland cement. GGBFS cement has exactly the same chemical ingredients as ordinary Portland cement, only in slightly differing proportions. Thus it can replace Portland cement by up to 85% in making ready-mixed concrete. nowadays, slag cement is used to produce blended cement that complies with ASTM C 595 (1992).Slag cement can be used as a constituent in hydraulic cement produced under ASTM C 1157(1992).

ASTM C 989, first adopted in 1982, provides for three strength grades of GGBF slag, depending on their related mortar strengths when mixed with an equal mass of portland cement. The classifications are Grades 120, 100, and 80, based on the slag-activity index expressed as:

SAI = slag-activity index, percent = (SP/P x 100)

SP = average compressive strength of slag-reference cement mortar cubes, psi

P = average compressive strength of reference cement mortar cubes, psi

Classification is in accordance with Table 1.1 (adapted from ASTM C 989) as follows:The slag-activity index test is influenced by the Portland cement used; ASTM C 989 specifies total alkalies and 28- day compressive strengths for the reference cement. The precision of this test is such that the coefficient of variation is 4.1 percent for single laboratory testing and 5.7 percent for multilaboratory testing.

In addition to requirements on strength performance, the specification limits the residue on a 45-mm (No. 325) sieve to 20 percent and the air content of a mortar containing only GGBF slag to a maximum of 12 percent.

The specification also includes two chemical requirements: one limiting the sulfide sulfur (S) to a maximum of 2.5 percent and the other limiting the sulfate content (reported as SO_3) to a maximum of 4.0 percent.

Canadian standards CSA A363 and CSA A23.5 differentiate between GGBF slags that react hydraulically with water and those that require activators to develop their cementitious properties quickly.

Blended cements, in which the GGBF slags are combined with portland cement, are covered by ASTM C 595. Three types of such cements are addressed: 1) slag-modified Portland cement [Type I (SM)], in which the GGBF slag constituent is less than 25 percent of the total mass; 2) Portland blast-furnace slag cement (Type IS), which contains 25 to 70 percent GGBF slag; and 3) slag cement (Type S), containing 70 percent or more GGBF slag. While the specifications permit the GGBF slag and the other ingredients to be ground either together or separately and blended, most portland blastfurnace slag cements have been interground. Such cements have been used worldwide for almost 100 years, and have excellent service records (Lea 1971).

Table 1.1—Slag-activity index standards for various Grades as prescribed in ASTM C 989

Grade	Slag-activity index, minimum percent	
	Average of last five consecutive samples	Any individual sample
	7-day index	
80	------	-----
100	75	70
120	95	90
	28-day index	
80	75	70
100	95	90
120	115	110

1.1 Background

First usage of slag was at 1700s, when the material was mixed with lime to make mortars. The first U.S. production was in 1896. Until the 1950s, granulated slag was used in the manufacture of blended portland cements, or as raw feedstock to make cement clinker. However, the 1950s saw slag cement become available in other countries as a separate product. The first granulation facility in the U.S. to make a separate slag cement product was Sparrows Point, Maryland, in the early 1980s. Recently the supplying and adding of slag to concrete increase rapidly in compare with before.

Same as Portland cement slag cement is hydraulic material and tend to react with water to form cementitious material (calcium-silicate hydrate or CSH). Like pozzolans, slag cement consumes by-product calcium hydroxide from the hydration of portland cement to form additional CSH. The resulting cement paste is stronger and denser, thus improving the concrete.

The beneficial influence of slag cement in concrete depends on many factors such as proportion of replacement and curing conditions, but in general use of GGBFS in concrete has the following advantages:

- Slag increases the amount of C-S-H gel in concrete thereby increasing density and reducing permeability.

- GGBFS raise ability of concrete against sulphate attacks by diluting the total amount of C_3A in concrete.

- Usage of slag cement will reduce the potential of ASR in system by decreasing pore size and total alkalis in concrete.

- Slag reduces temperature of hydration therefore decline thermal stress in concrete.
- GGBFS may increase the compressive and flexural strength of concrete in long time (after 28 days) if it is cured in specific conditions.

- Slag cement can help the environment because the emission of CO_2 in this type of concrete is about half of the OPC concrete

1.2 Problem statement

Durability and strength are the most important objects in concrete mix design ,cement is well know as a important factor to produce concrete, which means it is essential to use cementitius material in any construction activities. Recently most of the countries are faced to lack of cement. The industrial and agricultural material has been developed to produce new cementitious material instead of cement .providing and developing of these materials is not really sufficient enough to make use in concrete. Therefore, full profitable utilization can be achived by further development and adjustment for the material that have been studied.

1.3 Objective

- To study the effects of slag cement replacement on the compressive strength of concrete.
- To determine the effects of slag cement replacement on the flexural strength of concrete.
- To evaluate slag cement concrete in different curing conditions.
- To assess cracking behaviour and deflection of slag cement reinforced concrete beam

1.4 Scope of study

The scope of study is established to achieve the objectives, and this study will be mainly concentrated on experimental works. Experiments regarding to the compressive and flexural strength tests to suit with study period, will be done in different percentages of slag and different curing conditions