# Development of Green Concrete Containing Ternary High Volume SCMs and its In-situ Application

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## Summary

Recently, the use of cement-less concrete containing high volumes of fly ash, and GGBFS instead of purely Portland cement is increasing recently in Korea to reduce energy consumption and the embodied $CO_2$ of structures.

However, as the contents of supplementary cementitious materials (SCMs) increase within the concrete binder, so the early-age compressive strength within 14 days is usually less than normal concrete. In order to improve this early-age compressive strength, a green concrete was developed containing two types of high volume SCMs, such as maximum 70% of GGBFS and fly ash below 40% of total content, to replace cement content using an acceleration chemical admixture.

Adiabatic temperature rise tests were conducted to evaluate the thermal and low-heat properties of green concrete with various cement and SCMs content suitable for mass concrete structures. Recently this green concrete containing only 20% cement and 80% SCMs was applied for the placement of in-situ mass foundations of both buildings and bridges.

**Keywords:** green concrete, compressive strength, supplementary cementitious materials, adiabatic temperature rise, thermal, low-heat.

## 1. Introduction

According to the Korea Cement Association, domestic cement production in 2010 was about 39.3 million tons of Portland cement and burning of cement kilns is very energy intensive [1]. Cement production is one of the major sources of $CO_2$ emissions and was responsible for 2.3% of the total emissions worldwide in 2008 [2]. In order to reduce $CO_2$ and the environmental impact, the amount of cement in the binder should be minimized by employing high-volumes of supplementary cementitious materials (SCMs) such as fly ash (FA) from coal-burning power plant and ground granulated blast furnace slag (GGBFS) from the steel industries. This cement-less concrete called "green concrete" (no relation to its color) is cheap to produce due to its reuse of by-products [3]. The commonly widespread cement replacement levels of FA and GGBFS are known as about 20% and 50%, respectively [4]. At these low-level SCMs replacement, FA and GGBFS could improve the workability, long-term strength, and durability of concrete.

Another reason for using more than one or two SCMs, binary or ternary mix design, is to reduce the temperature rise within large concrete mass structures such as bridge piers and high-rise building foundations. The most direct way of reducing the temperature rise in concrete is by lowering the cement content in the mix design without compromising the strength and durability of structures. Hence, the use of SCMs is an effective and economical method of reducing the temperature rise [5]. This prevents structural cracking from significant tensile stress and severe temperature gradients. Temperature rise prediction made from adiabatic temperature rise curves (recorded from concrete hydration heat) measured by adiabatic calorimetry are widely used in Korea.

A considerable amount of research has been done on low-level SCMs replacement concrete [6]. Most researchers have looked for the optimum amount of SCM in concrete so to maximize strength and have concentrated on the use of binary mixes with fly ash [7]. However, as the cement replacement rates rise up above 60%, so the strength development, especially the early-age compressive strength within 14 days is slower than normal concrete. Also, the accuracy of temperature rise prediction in mass concrete is not good enough due to the lack of adiabatic

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