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Strength, Carbon Footprint and Cost Considerations of Mortar Blends with High Volume Ground Granulated Blast Furnace Slag

Chiu Chuen Onn [1,*], Kim Hung Mo [1,*], Mohammed K. H. Radwan [1], Wen Hong Liew [1], Chee Guan Ng [2] and Sumiani Yusoff [2]

[1] Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia; eng.moh.rad@gmail.com (M.K.H.R.); wenhong.wh34@gmail.com (W.H.L.)

[2] Institute of Ocean and Earth Sciences, University of Malaya, IGS Building, No. C308, 50603 Kuala Lumpur, Malaysia; cheeguan.ng@um.edu.my (C.G.N.); sumiani@um.edu.my (S.Y.)

* Correspondence: onnchiuchuen@um.edu.my (C.C.O.); khmo@um.edu.my (K.H.M.)

Received: 27 September 2019; Accepted: 27 November 2019; Published: 16 December 2019

Abstract: Ground granulated blast furnace slag (GGBFS) is a by-product obtained from the iron making process and has suitable properties to be utilized as high volume cement replacement to produce sustainable concrete. This study focuses on investigating the influence of GGBFS replacement level (0%–70%) and water/binder ratio (0.45 and 0.65) on the performance of cement mortar blends. In order to characterize the engineering performance, the compressive strength of the mortar blends was evaluated. Whereas to ascertain the carbon footprint, environmental life cycle assessment was conducted. Besides the compressive strength and carbon footprint, the materials cost for each mortar blends was computed. Based on the compressive strength/carbon footprint ratio analysis, it was found that increased replacement level of GGBFS gave better performance while the cost efficiency analysis shows that suggested GGBFS replacement level of up to 50%. Overall, in considering the strength performance, carbon footprint and materials cost, the recommended GGBFS replacement level for cement blends is 50%. In addition, when the binder content is kept constant, mortar blends with lower water/binder ratio is preferable when considering the same parameters.

Keywords: ground granulated blast furnace slag; sustainability; life cycle assessment; cement replacement; Malaysia

1. Introduction

Among the constituent materials in concrete, cement is the largest contributor to the release and emission of carbon dioxide (CO_2). As much as 4%–6% of the global CO_2 emissions is due to the production of cement. This is due to direct emission from calcination of calcium carbonate as well as indirect emission from combustion of fossil fuel used for calcination, mineral production and transportation [1]. Considering that concrete is one of the most widely used materials worldwide, the CO_2 emission associated with the use of cement is a major environmental concern. Due to this, there have been numerous strategies adopted to reduce such impact, and one of the most commonly used method is through partially substituting cement with supplementary cementitious material (SCM) to produce blended cement [2]. SCM commonly consists of materials with pozzolanic reactivity such as fly ash or self-hydraulic properties such as ground granulated blast furnace slag (GGBFS). It is known that the use of such materials can improve the later age strength and durability properties of concrete when incorporated at the respective optimum amount [3].

GGBFS is manufactured from blast furnace slag, which is a product from the iron-making process. The blast furnace used in making iron operates at temperatures up to 2000 °C which is fed with