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Review Article

A brief on high-volume Class F fly ash as cement replacement – A guide for Civil Engineer

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Abstract

Disposal of fly ash (FA) resulting from the combustion of coal-fired electric power stations is one of the major environmental challenges. This challenge continues to increase with increasing the amount of FA and decreasing the capacity of landfill space. Therefore, studies have been carried out to re-use high-volumes of fly ash (HVFA) as cement replacement in building materials. This paper presents an overview of the previous studies carried out on the use of high volume Class F FA as a partial replacement of cement in traditional paste/mortar/concrete mixtures based on Portland cement (PC). Fresh properties, mechanical properties, abrasion resistance, thermal properties, drying shrinkage, porosity, water absorption, sorptivity, chemical resistance, carbonation resistance and electrical resistivity of paste/mortar/concrete mixtures containing HVFA ($\geqslant$45%) as cement replacement have been reviewed. Furthermore, additives used to improve some properties of HVFA system have been reviewed.

Keywords: Class F fly ash; Recycling; Fresh properties; Hardened properties; Additives

Contents

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1. Introduction

World cement demand and production are increasing, the total output of cement in the world may exceed 3 billion tonnes in 2009 (Feiz et al., 2015), whilst in 2012 the total production of cement reached approximately 3.6 billion tonnes (Rashad, 2015). Cement production is highly energy and materials intensive (Rashad and Zeedan, 2011; Rashad, 2013, 2014). In addition, cement plant has been always among industries which generate plenty of CO_2. Beside the emission of CO_2, cement industry launches SO_2 and NO_x which can cause the greenhouse effect and acid rain (Anand et al., 2006; Rashad, 2013). Among the greenhouse gases, CO_2 contributes about 65% of the global warming. The scientific community reported that the global mean temperature is likely to rise by 1.4–5.8 °C over the next 100 years (Rehan and Nehdi, 2005). This is particularly serious in the current context of climate change caused by CO_2 emissions worldwide, causing a rise in sea level and the occurrence of natural disasters and being responsible for future meltdown in the world economy (IPCC, 2007). Alternative binders to PC have been proposed to reduce greenhouse gas emission as blended cements. These blended can reduce CO_2 emissions by approximately 13–22% (Flower and Sanjayan, 2007), although this estimate can vary depending on local conditions at the source of raw materials, binder quantity and amount of PC replacement, type of manufacturing facilities, climate, energy sources and transportation distance.

Recently, huge quantities of FA were found in the world. Manz (1980) reported that the estimated production of coal ash was 278.443 Mt (million tonnes) in 1977, of which approximately 14% was used. Manz (1993) reported that the estimated production of coal ash in 1989 was approximately 562 Mt, of which approximately 16.1% was used, whilst the rest was disposed in landfills. According to the annual survey results published by American Coal Ash Association, for the year 2009, approximately 63 million tonnes of FA was produced, approximately 25 million tonnes from them were used in various applications, whilst approximately 10 million tonnes of them were used in concrete and concrete products, and approximately 2.5 million tonnes were used in blended cements and raw feed for clinker. Ahmaruzzaman (2010) reported that the annual production of coal ash worldwide was estimated around 600 million tonnes, with FA constituting approximately 500 million tonnes at 75–80% of total ash produced. Bakharev (2005) reported that about one billion tonnes of FA was produced annually worldwide in coal-fired steam power plants. Only a small part of this ash is used (20–30%); the rest is land filled-and surface-impounded, with potential risks of air pollution and contamination of