Structural Materials as a Strategy to Mitigate Global Climate Change

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Summary

Structural engineers can significantly reduce the embodied greenhouse gas emissions of buildings and infrastructure. Replacing cement with complementary cementitious materials, specifically fly ash, offers the greatest potential to reduce CO_2 emissions. In addition to environmental benefits, complementary cementitious materials can improve the performance and durability of structural concrete. However, there is currently an absence of knowledge on whether cement replacement from fly ash is sufficient to address climate change objectives in the short- and long-term.

Determining potential CO_2 reductions requires the analysis of cement demand, fly ash supply, fly ash use in concrete, and the comprehensive analysis of fly ash – a by-product from coal-generated electricity. Current challenges are increasing the use of available fly ash. Reducing CO_2 in the long-term must address several challenges. First, fly ash is shown to decrease in supply compared to future cement demand, thereby reducing the replacement potential. Secondly, the usability of fly ash for concrete applications must be improved to increase utilization. Finally, fly ash supply is dependent on the continued use of CO_2-intensive coal-generated electricity. The results of the research illustrate that cement replacement with fly ash is a strategic means to mitigate CO_2 emissions in the short-term. However, long-term CO_2 reductions for structures will require innovative new materials and design strategies – new challenges for practicing structural engineers in the coming decades.

Keywords: structural engineer; complementary cementitious materials; fly ash; concrete; cement; greenhouse gas; climate change.

1. Introduction

There is "very high confidence" ((Pachauri and Reisinger 2007), pp. 37) that human activities are responsible for increased atmospheric concentrations of greenhouse gases (GHG) leading to climate change (Pachauri and Reisinger 2007). Mitigation of the resulting impacts requires the stabilization of CO_2 concentration at 350 ppm – CO_2-equivalent concentration at 445 ppm (Pachauri and Reisinger 2007)(Bert Metz et al. 2005)(Hansen et al. 2008)(Hansen et al. 2012). This corresponds to a global average temperature increase of 2.0°C above pre-industrial levels, and requires a 85% reduction in global CO_2 emissions by 2050 from the base year 2000 (Pachauri and Reisinger 2007). Attention is focused on CO_2 as it represents a majority of anthropogenic GHG emissions – 77% of total GHG emissions in 2004 (Pachauri and Reisinger 2007). In the climate discussion the building sector has been identified as a major source of end-energy use (IEA 2008), and accordingly CO_2 emissions (B. Metz et al. 2007). Strategies to reduced emissions focus heavily on the operational energy use of buildings (IEA 2008).

There are several structural design strategies to reduce GHG emissions – design for materials, design for recycling, design for efficiency, design for energy, and design for adaptability (Anderson and Silman 2009a). Of these approaches, the use of complementary cementitious materials (CCMs) provides the largest potential reduction in CO_2 emissions (Anderson and Silman 2009b). Emission reductions result from replacing cement in the concrete mix with CCMs (up to 65% cement replacement with fly ash) (Mehta and Manmohan 2006).

https://doi.org/10.2749/222137814814069174
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