American Concrete Institute
Always advancing

ACI PRC-231.1-25
TechNote

Managing and Increasing Early-Age Strength of Low-Clinker Concrete Mixtures—TechNote

Keywords: calcined clays; early-age strength; global warming potential (GWP); low-clinker concrete; silica fume; slag cement; supplementary cementitious materials (SCMs).

Introduction

Various roadmaps have been developed by the cement and concrete industry that highlight the need for a significant reduction of carbon dioxide (CO_2) emissions associated with concrete production. One strategy to reduce emissions is to reduce the clinker content in concrete. This can be accomplished by optimizing aggregate gradations or chemical admixtures to reduce total cement content used or use cementitious materials that have a low percent of clinker in them. However, low-clinker (content) concretes may, or may be perceived to, suffer from lower early-age strengths, which have limited their application in practice. This TechNote discusses low-clinker concrete, primarily obtained through the use of supplementary cementitious materials (SCMs), and provides practical advice concerning the strength of these mixtures at early ages (from setting to 7 days).

Question

Low-clinker concretes are increasingly being used in practice. What methods can be used to overcome and manage low early-age strengths of some low-clinker concretes?

Response

As the concrete industry works on progressively reducing its carbon footprint, the adoption of low-clinker concrete has been indicated as the most efficient near-term solution to achieve lower CO_2 emissions (Global Cement and Concrete Association 2022). Low-clinker concrete is generally produced by replacing clinker with fillers or SCMs, although clinker content can also be reduced by optimizing the paste volume fraction. This document focuses on the subset of low-clinker concrete mixtures with high volumes, typically higher than 45%, of clinker replaced by SCMs. In this document, unless otherwise mentioned, clinker refers to portland-cement clinker. SCMs contribute to later-age strength and durability; however, these materials are often slower to react, resulting in slower early-age strength development. While this may be acceptable for certain applications, in other applications, some alterations may be needed for these mixtures. Measures can be taken to increase strength, especially at early ages. Methods to improve early-age strength development include reducing water-cementitious materials ratio (*w*/*cm*), refining particle packing, incorporating accelerators and seeding materials, using highly reactive cements and SCMs, and heat curing. Construction practices may need to be reviewed to determine exactly what strength is needed by what time. Approaches that better define strength-gain expectations as well as using techniques such as the maturity method or matched curing to better predict when strength is achieved can be vital for maintaining construction schedules.

Discussion

Low-clinker-content concrete—Concrete production is responsible for approximately 8% of global human-made carbon dioxide emissions because of the large quantities produced and consumed annually (Olivier et al. 2016). Production of portland cement is responsible for most concrete material-related emissions, with aggregates responsible for less than 3% emissions (Anderson and Moncaster 2020). The manufacturing process for 1 metric ton of ASTM C150/C150M Type I cement in North America typically emits approximately 919 kg CO_{2eq} (ACA 2021). The emissions are largely due to the energy needed to heat the raw materials to up to 2732°F (1500°C) and due to decomposition of CO_2 from limestone in the raw materials. A small portion of the emissions are due to grinding and transportation operations (ACA 2021). The release of CO_2 from the limestone during manufacture cannot be avoided without switching raw material sources, which is, at present, difficult to do at a large scale.

Low-clinker concrete is generally obtained by replacing a portion of the portland cement with SCMs. The emissions associated with production of SCMs are not zero, typically ranging from 27 kg CO_{2eq}/ton for some fly ashes to 372 kg CO_{2eq}/ton for