Report on High-Volume Fly Ash Concrete for Structural Applications

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This report presents technical information to support the use of high-volume fly ash concrete for structural applications. The advantages and limitations of high-volume fly ash concrete are discussed, and the characteristics of the fresh and hardened materials and the durability of the material to various aggressive environments are covered. Field applications are presented along with sustainability features.

Keywords: alkali-silica reaction; compressive strength; corrosion of reinforcement; cracking; deicing salts; fly ash; heat of hydration; mixture proportions; modulus of elasticity; shrinkage; sulfate attack; sustainability; tensile strength.

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CHAPTER 1—GENERAL

1.1—Introduction

High-volume fly ash (HVFA) concrete is a sustainable construction material when proportioned properly and used in appropriate construction applications. This report summarizes published data on the composition and properties of the material, such as workability, strength, and durability. The report affirms the viability of HVFA concrete for structural applications and discusses construction issues.

HVFA concrete is defined as having a large replacement by mass of portland cement with fly ash. Malhotra (1986) defined HVFA concrete as concrete containing 50 percent or more fly ash by mass of total cementitious materials, and Ramme and Tharaniyil (2000) defined it as concrete with 37 percent or more fly ash by mass as total cementitious materials.

Naik and Ramme (1985) tested HVFA concrete using ASTM C618 Class C fly ash mixtures and having water-cementitious material ratios (*w*/*cm*) ranging from 0.42 to 0.57, without the use of high-range water-reducing admixtures. In 1986, however, a significant research program was initiated to explore the possibility of HVFA concrete attaining compressive strengths of 7250 psi (50 MPa) or higher for structural applications (Malhotra 1986). This research used concrete mixtures containing ASTM C618 Class F fly ash, 0.30 *w*/*cm*, and high-range water-reducing admixtures. The results of this work showed the potential of HVFA concrete as a sustainable material with workability, strength, and durability exceeding that of conventional portland-cement concrete having similar cementitious content. Summaries of the results on HVFA concrete using Class F fly ash are given by Malhotra (1992, 2002), Bilodeau and Malhotra (2000), and Malhotra and Mehta (2012).

Low-strength HVFA concrete mixtures are not covered herein. In this document, HVFA concretes that have minimum specified compressive strengths of 2500 psi (17 MPa) are discussed.

1.2—Significance

This report provides background information and technical data to support the use of HVFA concrete for structural applications. From a sustainability standpoint, HVFA concrete not only significantly reduces consumption of portland cement, but also results in a concrete of superior quality in many aspects when compared with that of conventional concrete in regard to workability, strength, and durability. In addition, this technology is currently available for wide-scale implementation and is backed by more than 25 years of field usage and test results.

1.3—Historical background

In 1937, Davis et al. (1937) experimented with concretes containing fly ash of up to 50 percent replacement by mass of portland cement. They concluded that the use of HVFA in mass concrete has definite advantages, such as lower temperature rise due to heat of hydration and less risk due to thermal cracking. These findings were applied in the first significant use of fly ash in concrete for Hungry Horse Dam in Montana, which was built from 1948-1952. In those early years, concretes using high levels of fly ash were limited to mass concrete structures. The incentive was to reduce the adiabatic temperature rise resulting from heat of hydration of portland cement. Compressive strengths were generally low at early ages with strengths increasing from 1450 to 2900 psi (10 to 20 MPa) at 90 days.

In the late 1970s, the use of fly ash at 60 to 70 percent by mass of cementitious material was found to significantly improve the performance of roller-compacted concrete (Dunstan 1983). The Upper Stillwater Dam in Utah was constructed using this material in early 1980. During a full-scale trial test of roller-compacted concrete in 1978, a slipformed vertical facing element was constructed using concrete containing approximately 40 percent fly ash by mass (Dunstan 1983). Subsequently, the first major placement of concrete containing over 50 percent fly ash replacement by mass of portland cement was in 1981, where the concrete was consolidated by immersion vibration for the construction of access roads at the Didcot Power Station in Oxfordshire, UK (Dunstan 1983). Success in this project led to use of the material in other applications between 1982 and 1984: foundation and retaining walls for an oil tank storage area (51 percent fly ash by mass), marine slipway (52 percent), sewage treatment works (54 percent), and concrete viaducts (35 to 65 percent). Five of these structures were evaluated by visual examination and testing of cores approximately 10 years after construction, and were found to be in excellent condition (Dunstan et al. 1992).