HBRC Journal (2015) 11, 1–6

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

Mechanical properties of Self-Consolidating Concrete incorporating Cement Kiln Dust

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Received 3 December 2013; accepted 25 February 2014

KEYWORDS

Self-Consolidating Concrete;
Flow-ability;
Cement Kiln Dust;
Shrinkage

Abstract Self-Consolidating Concrete (SCC) has been widely used in both practical and laboratory applications. Selection of its components and their ratios depends, mainly, on the target mechanical and physical properties recommended by the project consultant. Partial replacement of cement in SCC with cheap available industrial by-product could produce environmentally durable concrete with similar properties of normal concrete. In the current research, SCC was produced by blending Cement Kiln Dust (CKD) with cement in different ratios. Four mixes incorporating cement kiln dust with partial cement replacement of 10%, 20%, 30%, and 40% were produced and compared with a control mix of Normally Vibrated Concrete (NVC). Superplasticizer was used to increase the flow-ability of SCC mixes. The fresh and hardened mechanical properties of all mixes were determined and evaluated. Moreover, time-dependent behavior was investigated for all mixes in terms of drying shrinkage test. The shrinkage strain was measured for all specimens for a period of 120 days. Based on the experimental results, it was found that SCC mixture containing 20% cement replacement of CKD exhibited the highest mechanical strength compared to other SCC mixes and NVC mix as well. It was observed that the volumetric changes of specimens were directly proportional to the increase of the cement replacement ratio.

Introduction

Self-Consolidating Concrete (SCC) has superior advantages over Normally Vibrated Concrete (NVC) due to its ability to flow under its own weight without compaction, its ability to obtain homogeneity without segregation of aggregates, and its ability to be placed in a variety of molds with sharp edges. Hajime and Masahiro [1] mentioned that the main source of concrete durability is providing adequate compaction by skilled workers which have been reduced with time. The solution to overcome this shortage and to achieve durable concrete is to employ SCC which can be consolidated into every corner

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Peer review under responsibility of Housing and Building National Research Center.

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http://dx.doi.org/10.1016/j.hbrcj.2014.02.007

of the formwork, purely by means of its own weight and without the need of any compaction. This technique could then be very useful for casting of massive sections for durable hydraulic structures as well as lining of canals and dams, where the mechanical compaction could entail large efforts and costs.

Three methods are mainly used to produce SCC; namely "Powder-Type SCC" by increasing the powder content, "Admixture-Type SCC" using Viscosity-Modifying Agent (VMA), and "Combined-Type SCC" by increasing powder content in combination with using VMA at the same time. In comparison to NVC, all three types work with an increased amount of superplasticizer. The selection of a specific SCC mix proportion depends on structural conditions, constructional conditions, available materials, restrictions in concrete production plant, etc.

Cheap environmental by-products were used by many researchers to produce SCC mixes. Gao et al. [2] studied the influence of adding fly ash and small percentage of clay on the shrinkage behavior and cracking tendency of SCC. Dehwah [3] studied the effect of using quarry dust powder, silica fume and fly ash on the properties of SCC mix. The mechanical properties as well as economic aspects were compared for each case. Kraus et al. [4] studied the economical savings from adding foundry silica-dust in the manufacturing of SCC. It was observed that as the foundry silica dust content increased, the demand for VMA decreased while the demand for high-range water-reducing admixture increased. Amr [5] studied the effect of using different mineral admixtures such as silica fume, fly ash, blast furnace slag, limestone powder, Cement Kiln Dust and rice husk ash as a partial replacement of cement with 10% only. Adam [6] studied the effect of different sand to aggregate ratios (s/a) on the properties of different SCC types. The study concluded that using s/a of 40% may be regarded as the optimum choice for producing SCC with an acceptable behavior at Egypt using locally available construction materials. Adam [7] concluded that Admixture-Type SCC proved to be an optimal choice for its ease in selecting its mix proportions, reasonable properties and low production cost compared to other types of SCC.

Usually shrinkage and creep properties of SCC are of big concern to researchers, particularly in arid and/or semi-arid regions. Thus, not only the mechanical properties might affect the selection of SCC mix proportions but also the shrinkage behavior. The shrinkage of concrete involves a combination of several shrinkage components, that is, plastic shrinkage, autogenous shrinkage, drying shrinkage, thermal shrinkage, and carbonation shrinkage. Kamal and Wu [8] mentioned that proper evaluation of shrinkage is very critical for the design of prestressed structural members made of SCC. They additionally added that SCC has higher binder content and lower coarse aggregate volume. These factors could increase the risk of thermal, autogenous, and drying shrinkage, leading to cracking and reduction in serviceability.

In the current research, Cement Kiln Dust (CKD) has been added as a partial replacement of cement by weight with 10%, 20%, 30% and 40% of the total binder content (cement + CKD). Superplasticizer was used to increase the flow-ability of SCC mixes. The mechanical properties of NVC were put into glance with SCC mixes blended with CKD. Moreover, the overall shrinkage strain values were measured for prismatic specimens over 300 mm gauge length along testing period of 120 days.

Experimental program

Materials

The used fine and coarse aggregates in the current study were provided from locally available sources in Egypt. Natural sand with a fineness modulus of 2.34 and specific gravity of 2.64 was used as a fine aggregate. Whereas, Natural gravel, with a nominal maximum size of 20 mm and specific gravity of 2.50, was used as coarse aggregate. The grain size distribution of fine and coarse aggregates compared to upper and lower limits of Egyptian code of practice [9] is shown in Figs. 1 and 2, respectively. CKD was used as a partial replacement of cement. Ordinary Portland cement Type-I was used as a binder material. The chemical composition of CKD and cement is presented in

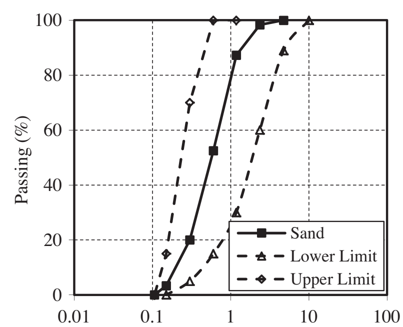

Fig. 1 Grain size distribution of fine aggregate.

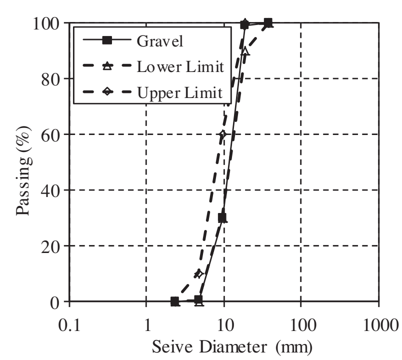

Fig. 2 Grain size distribution of coarse aggregate.

Table 1 Chemical Composition of CKD and Cement.

Chemical compound	% of total weight	
	CKD	Cement
Silicon dioxide, SiO_2	13.50	23.00
Iron oxide, Fe_2O_3	2.50	1.70
Aluminum oxide, Al_2O_3	3.70	6.40
Calcium oxide, CaO	40.20	67.00
Magnesium oxide, MgO	1.14	4.10
Loss in ignition (LOI)	5.70	1.70