10th International Congress on Civil Engineering, 5-7 May 2015
University of Tabriz, Tabriz, Iran

Effects of Using Nano-Silica Particles, Fly Ash and Waste Water Sludge on Properties of Cement Mortar

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Abstract

Wastewater sludge has been widely applied to cementitious materials. In this paper, the influence of nano-SiO_2, wastewater sludge and fly ash addition as cement replacement has been studied. In all cases, two sludge contents of 0 and 7.5 percent by weight of cement were introduced to the mortar mixes. Moreover, 0 and 1 percent of nano-SiO_2 was added to the mixture. The fly ash replacement level of 20% by weight of the cementitious material was used for all the mortar mixes. This high level of replacement was selected such that the effect of the fly ash replacement could be detected. The water-binding ratio of 0.54 was assigned to the mix. Tests were carried out on mortar specimens cured at 7, 14 and 28 days. From the results of compressive strength, setting time, SEM and XRD tests can be concluded that adding nano-SiO_2 and fly ash to environmentally friendly cement mortar containing sewage sludge can improve it properties.

Keywords: Nano-SiO2, Wastewater sludge, Fly Ash, Cement mortar, Sustainable development.

1. INTRODUCTION

In modern society, much sludge including industrial sludge (tannery sludge, sludge from the paper industry, electroplating sludge, etc.) and domestic sludge is produced every day. Sludge must be treated or stabilized to be safe for use or dispose. Worldwide, wastewater sludge is disposed by different methods. The most common methods of sludge disposal are agricultural use, landfilling and incineration. In many countries wastewater sludge is used in agriculture in the form of composts. However, in some areas, the sludge produced does not just contain a large percentage of organic material but also environmentally toxic heavy metals, which makes it unsuitable for agricultural purposes. Landfills option can be used carefully due to high costs and risk materials in sludge which may contaminate surface and ground water. Use of the incineration method to dispose sludge reduces only sludge volume. The remaining ash would still needed to be disposed in a land fill. The incineration process requires large capital investment and expensive safeguards against pollution [1, 2]. Most of the treatment processes, however, are either too expensive or not practically available at this stage. Therefore, the reuse of sludge containing heavy metal may be a better alternative than that of treatment processes [3].

On the other hand, Portland cement production consumes massive amounts of raw materials (limestone, clay, etc.), and large amounts of energy (850 kcal/kg of clinker) and increases the emissions of greenhouse gases (around 0.85 kg of CO_2/kg of cement) so there is a great interest in replacing cement by a new material to reach sustainable development. One of these new materials is dry sludge (as a replacement material to cement) [1, 3].

As demonstrated in previous work and confirmed by this study, the addition of sludge reduces the mechanical strength of mortar, and this makes sludge an unsuitable additive for short-term high-strength concrete and for reinforced and pre-stressed concrete [1, 4].

In this new century, the technology of nano-structured material is developing at an astonishing speed and will be applied extensively with many materials. Due to an ultrafine size, nano-particles show unique physical and chemical properties different from those of the conventional materials. Previous works indicate that the SiO_2 in nano scale behave not only as a filler to improve the microstructure, but also as an activator to promote pozzolanic reactions. Nano-SiO_2 can react with calcium hydroxide ($Ca(OH)_2$) crystals, which are arrayed in the interfacial transition zone between hardened cement paste and aggregates, and produce C–S–H