The 2018 Structures Congress (Structures18)
Songdo Convensia, Incheon, Korea, August 27 - 31, 2018

Assessment of compressive strength of cement mortar with waste LCD glass powder from the early age strength

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Abstract

The sustainable development principle of replacing natural resources with renewable material is an important research topic. In this study, waste LCD (liquid crystal display) glass powder was used to replace cement (0%, 10%, 20% and 30%) through a volumetric method using three water-binder ratios (0.47, 0.59, and 0.71) to make cement mortar. The compressive strength was tested at the ages of 7, 28, 56 and 91 days. The test results show that the compressive strength increases with age but decreases as the water-binder ratio increases. The compressive strength slightly decreases with an increase in the replacement of LCD glass powder at a curing age of 7 days. However, at a curing age of 91 days, the compressive strength is slightly greater than that for the control group (glass powder is 0%). When the water-binder ratios are 0.47, 0.59 and 0.71, the compressive strength of the various replacements increases by 1.38-1.61 times, 1.56-1.80 times and 1.45-2.20 times, respectively, during the aging process from day 7 to day 91. Furthermore, a prediction model of the compressive strength of a cement mortar with waste LCD glass powder was deduced in this study. According to the comparison between the prediction analysis values and test results, the MAPE (mean absolute percentage error) values of the compressive strength are between 2.79% and 5.29%, and less than 10%. Thus, the analytical model established in this study has a good forecasting accuracy. Therefore, the proposed model can be used as a reliable tool for assessing the design strength of cement mortar from early age test results.

Keywords: Cement mortar, LCD glass powder, prediction model.

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1. Introduction

*Note: Copied from the manuscript submitted to "Computers and Concrete, An International Journal" for the purpose of presentation at ACEM18/Structures18.

Advances in optoelectronics technology, software, and other high-tech industries have made Taiwan a "green silicon island" in the global high-tech manufacturing and service industries. However, these developments have also generated a considerable amount of industrial waste, which could lead to environmental damage if handled incorrectly. Recycling industrial waste has the potential to generate enormous economic benefits and reduce the dependency on national resources (Cheng, 2002). Rapid industrial development and an increasing standard of living have increased the production of waste glass, of which only a small amount is reused or recycled (Mohamad, 2006). Liquid crystal products, such as LCD screens and mobile phone panels have become increasingly popular in recent years. As the world's leading manufacturer, Taiwan's TFT-LCD panel production accounts for approximately 39.2% of the total world output. Waste materials generated from manufacturing account for approximately 12,000 tons of LCD waste glass per year (Cheng, 2002; Fang, 2006; Wang, 2009).

The major materials of liquid crystal displays include glass (85-87%), polymer membranes (12.7-14%), and liquid crystals (0.12-0.14%) (Chang, 2005; Roland *et al.*, 2004). The main chemical constituents of waste LCD glass are SiO_2, Na_2O, and a small amount of an indium-tin-oxide conducting film. The conducting film coated on the LCD to reduce the resistance of the substrate's surface enhances light transmittance and conductivity. Thus, the treatment of waste LCD glass by landfill, incineration, and composting is inappropriate (Lin, 2007). Thus, how to reuse or recycle LCD glass waste is an important issue for Taiwan because the glass contains a large amount of silicon and calcium and is classified as a Portland material. In addition, its properties such as the unit weight, compressive strength, elasticity modulus, thermal expansion coefficient and heat transfer coefficient are notably close to concrete. Accordingly, previous studies (Topcu and Canbaz, 2004; Wang *et al*., 2007; Wang and Huang, 2010) indicate that adding crushed waste glass to concrete as a fine aggregate can reduce the concrete air content and unit weight, more efficiently pack the concrete pores, provide better durability, surface resistance, resistance to acid, salt and alkali ions, chlorine iontophoresis, and better performance of the concrete ultrasonic pulse velocity. Islam *et al*. (2017) presented that the manufacturing of cement (key ingredient used to produce concrete) is a major source of greenhouse gas emissions; thus, the use of supplementary cementitious materials (SCMs) to offset a portion of the cement in concrete is a promising method for reducing the environmental impact from the industry. Therefore, waste glass recycling can reduce the material costs, and the effect on the environment and CO_2 emission, which are the preferred outcomes for sustainable environmental protection.

Sakale *et al*. (2016) reported that glass is an amorphous material with high silica content and thus is potentially pozzolanic when the particle size is less than 75 μm. Therefore, glass powder (GP) can be used as an alternative supplementary cementing material in concrete (Omran and Tagnit-Hamou, 2016). A significant increase in the properties and durability of concrete was reported, when glass with fine particles was used as a cement replacement (Carsana *et al*., 2014; Schwarz *et al*., 2008; Matos and Sousa-Coutinho, 2012). The application of waste glass as a finely ground mineral additive (FGMA) in cement is another possibility for recycling (Bashar and Ghassan, 2008). A major concern regarding the use of glass in concrete is the chemical reaction that occurs between the silica-rich glass particles and the alkali ions in the pores of concrete (alkali-silica reaction). This reaction is detrimental to the stability of concrete unless appropriate precautions are taken to minimize its effect. Preventative action includes the incorporation of suitable pozzolanic materials such as fly ash, ground blast furnace slag, or met kaolin in the