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A comparative study on the properties of the mortar with the cathode ray tube funnel glass sand at different treatment methods

Hui Zhao *, Chi Sun Poon

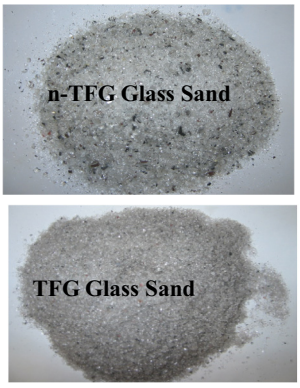
Department of Civil and Structural Engineering, Hong Kong Polytechnic University, Hong Kong, China

HIGHLIGHTS

- Utilizing n-TFG, TFG glass sand increase the fresh, mechanical, durability properties of the mortar.
- n-TFG glass sand series mortar have a better fresh properties than TFG glass sand series mortar.
- The mortars with TFG glass sand have lower mechanical properties than those with n-TFG glass sand.
- The lower drying shrinkage, ASR expansion, the leaching of lead can be found in TFG glass sand mortars.

GRAPHICAL ABSTRACT

With the rapid development of the electronic industry, the management of cathode ray tube (CRT) glass waste has become a major environmental problem. The CRT funnel glass reutilized as the replacement of river sand in the mortar is an environmental friendly management option for the CRT funnel glass waste. In this study, the CRT funnel glass sand of two treatment methods, i.e. untreated with nitric acid (n-TFG), treated with nitric acid (TFG), was used. The properties of the mortars with n-TFG, TFG glass sand were studied and compared. The mortars with TFG glass sand exhibits worse the fresh and mechanical properties than those with n-TFG glass sand. The use of TFG glass sand results in a lower drying shrinkage, alkali-silica reaction (ASR) expansion and leaching content of lead than the n-TFG glass sand series mortars. At the drying shrinkage period of 56 days, the drying shrinkage values of the mortars with TFG glass sand are within the limit of 0.075%. The ASR expansion values of the mortars prepared by TFG glass sand are below permissible limits (0.10%) at 14 days tested age. The lead leaching from the TFG glass sand series mortars comply with the regulatory limits.



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ABSTRACT

With the rapid advances of the electronic industry, the management of the cathode ray tube (CRT) glass waste has become a major environmental problem. In this study, the CRT funnel glass sand untreated with nitric acid (n-TFG) and treated with nitric acid (TFG) were used to replace river sand as fine aggregate for the production of the mortar. The TFG glass sand series mortars exhibit the worse fluidity and fluidity preservation, the shorter setting times, the lower wet density and mechanical properties than those with n-TFG glass sand. The use of TFG glass sand in the mortar also results in the lower drying shrinkage, alkali-silica reaction (ASR) expansion and leaching content of lead than the blended n-TFG glass sand mortars. Moreover, at the drying shrinkage period of 56 days, the drying shrinkage values of the mortars with TFG glass sand are within the limit of 0.075%. The mortars prepared by TFG glass sand

* Corresponding author.
E-mail address: njzhaohui@163.com (H. Zhao).

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Properties
Comparative

have a low ASR expansion, at the tested age of 14 days, which are below permissible limits (0.10%). The lead leaching of the mortars with TFG glass sand comply with the regulatory limits.

1. Introduction

Due to rapid advances in the technology, televisions and computer monitors are replaced by liquid crystal display (LCD), plasma and flat-screen technologies at a fast rate. An appreciable increase in the discarded television and computer monitor amounts has been noted in recent years. It is estimated that about 175,000 t of televisions and computer monitors need to be disposed in the United States each year. By 2050 year, the amounts of the discarded televisions and computer monitors may be six times as much as the current amount. It is reported that, every day, North America generates 163,420 televisions and computer monitors. There are approximately 6 million televisions and computer monitors being used in Hong Kong. If 20 % of televisions and computer monitors are replaced annually, over 490,000 units old televisions and computer monitors are discarded from households every year. The similar situations are also found in the other developed and developing countries [1,2].

The cathode ray tube (CRT) is a key component of televisions and computer monitors, two thirds of the entire weight in the discarded televisions or computer monitors are the CRT, about 85% of them is the CRT glass. In general, the CRT glass can be classified into three parts. The CRT panel glass used as screen is barium-strontium glass with a low content of lead oxide (0–3 wt%), a high content of barium oxide and strontium oxide (12 wt%, 12 wt%). Whereas the CRT neck glass and funnel glass contain high content of lead oxide (30 wt%, 22–25 wt%) and other dangerous elements. Due to high lead content in the CRT funnel glass, the CRT funnel glass has been considered as a hazardous waste. If these CRT funnel glass waste can not properly handled, the lead within the CRT funnel glass can leach from the broken CRT funnel glass cullet, which will contaminate soil and ground water. More important is that these toxic leads can pose serious problem to the public health. The small amounts of lead leaching from the CRT funnel glass cullet can result in a irreversible central nervous system damage for the people, which can induce headaches, behavior problems, reproductive issues and cognitive deficits in children [3,4]. Thus, how to reduce the negative effect of the CRT funnel glass waste on the environment and the public health has become a major concern problem in many countries around the world.

Generally, there are three possible ways to dispose for the discarded CRT funnel glass waste. The first way is to reutilize the discarded CRT funnel glass for new the CRT glass manufacturing. However, this method seems to be impractical in recent years, because the demand for the new CRT glass has dropped significantly. Besides, the CRT funnel glass waste can be reused as a raw materials into another production cycle, i.e. fluxing agent for bricks, glass tiles and other ceramic product [5–8].Although these disposal ways for the CRT funnel glass waste are preferable to landfill. However, the recycling process for the CRT funnel glass waste (include separating, sorting and crushing process to meet the demand by manufacturers) is very complex. These recycling way is only applicable in places, where have enough large space to accommodate the CRT funnel glass waste [9]. Another alternative way to recycle the CRT funnel glass waste is that the abandoned CRT funnel glass was sent to lead smelting for removing lead on the surface of the CRT funnel glass. Using this way to dispose the CRT funnel glass waste, the consumption rate of the CRT funnel glass is lower, the CRT collection facilities have to store a large amount of the CRT waste [10,11]. For these disadvantages of the current ways to dispose the CRT funnel glass waste, the new environmental friendly recycling ways are in demand for the ever-increasing CRT funnel glass waste.

Nowadays, a new way to recycle the CRT funnel glass waste as the replacement of river sand fine aggregate in the mortar has been developed in Hong Kong [12]. A number of previous studies [13,14] have indicated, although the presence of the CRT funnel glass sand in the mortar improves the fluidity, mechanical properties of the mortar, however, the increase in the amount of the CRT funnel glass sand also results in a high alkali-silica reaction (ASR) expansion. Zhao et al. [15] assess the effect of fly ash (FA) and ground granulated blast furnace slag (GGBFS) on the properties of the mortars with the CRT funnel glass sand, the test results show that the mortars with the CRT funnel glass sand have the higher compressive strength, flexural strength, static modulus of elasticity and ASR expansion than that with river sand. Moreover, the leaching values of lead from the n-TFG glass sand-blended mortars are significantly reduced, compared with the original concentration of the leachable lead from the CRT funnel glass sand. Also, at a given replacement level of the CRT funnel glass sand, the FA series mortars have the higher initial slump flow, the lower slump flow loss rate, wet density, mechanical properties, drying shrinkage, ASR expansion and leaching content of lead than the GGBFS series mortars. Ling and Poon [16] study the effect of the CRT funnel glass sand and container glass sand on the properties of the mortar. It can find that, irrespective of glass type, the use of glass cullet in the mortar improves the fluidity, drying shrinkage of the mortar, but reduces the strength. Furthermore, the mechanical properties of the mortars with the CRT funnel glass sand are comparable to those made with the container glass sand. Ling and Poon, Moncea et al. [17,18] also find that the particle size of the CRT funnel glass sand has some effect on the properties of the mortar. Despite the reduction in the particle size of the CRT glass sand leads to a decrease in the fluidity, compressive strength and water absorption of the mortar. However, the use of the finer CRT glass sand particle in the mortar slightly improves the flexural strength and decreases the risk of expansion due to ASR.

Up to now, although there are some extensive literatures about the effect of the types of the mineral admixture and glass sand, the particle size of the CRT funnel glass sand on the properties of the mortar. However, a systematic comparison of the effect of the treatment method of the CRT funnel glass sand on the properties of the mortar is still limited. Therefore, more studies need to carry out in this aspect.

In this study, two types of the CRT funnel glass sand, i.e. untreated with nitric acid (n-TFG) and treated with nitric acid (TFG), were used as the replacement of river sand in the mortar. The mortar samples with n-TFG, TFG glass sand and four replacement levels (0%, 25%, 50%, 75%) were prepared. The fluidity, fluidity preservation, wet density, setting times of the mortar and mechanical properties of the mortar were assessed. Besides, the durability properties of the mortar, i.e. the drying shrinkage, ASR expansion, leaching content of lead from the mortar, were measured. A more comprehensive understanding about the effect of the treatment method of the CRT funnel glass sand on the properties of the mortar was presented.