University of Belgrade, Technical Faculty in Bor

29th International Conference Ecological Truth & Environmental Research

EcoTER'22

Proceedings

Editor
Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia

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PREFACE

In today's world, the environment has been endangered by the use of outdated technology, fossil fuels and environmental law violations. Therefore, environmental and many other scientists all over the world have been concerned about finding sustainable technology in resolving these issues. That is why environmental research and ecological truth are at the focus of the 29th International Conference Ecological Truth & Environmental Research 2022 (EcoTER'22), which will be held in Sokobanja, Serbia, 21–24 June 2022. On behalf of the Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Conference.

We hope to convey the message of the conference, which is that a transformation of attitudes and behavior would bring the necessary changes. This is also an opportunity for the participants who are experts in this field to exchange their experiences, expertise and ideas, and also to consider the possibilities for their collaborative research.

The 29th International Conference Ecological Truth & Environmental Research 2022 is organized by the University of Belgrade, Technical Faculty in Bor, and co-organized by the University of Banja Luka, Faculty of Technology, the University of Montenegro, Faculty of Metallurgy and Technology – Podgorica, the University of Zagreb, Faculty of Metallurgy – Sisak, the University of Pristina, Faculty of Technical Sciences – Kosovska Mitrovica and the Association of Young Researchers, Bor.

These proceedings include 85 papers from the authors coming from the universities, research institutes and industries in 6 countries: Bulgaria, Italia, Albania, Bosnia and Herzegovina, Montenegro and Serbia.

As a part of this year's conference, the 4th Student section – EcoTERS'22 is being held. We appreciate the contribution of the students and their mentors who have also participated in the Conference.

Financial assistance provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia is gratefully acknowledged by the Organizing Committee of the EcoTER'22 conference.

The support of the Platinum donor and their willingness and ability to cooperate have been of great importance for the success of EcoTER'22. The Organizing Committee would like to extend their appreciation and gratitude to the Platinum donor of the Conference for their donation and support.

We appreciate the effort of all the authors who have contributed to these Proceedings. We would also like to express our gratitude to the members of the scientific and organizing committees, reviewers, speakers, chairpersons and all the Conference participants for their support to EcoTER'22. Sincere thanks go to all the people who have contributed to the successful organization of EcoTER'22.

Prof. Snežana Šerbula,

President of the Organizing Committee

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SUSTAINABLE UTILIZATION OF CATHODE-RAY TUBE WASTE GLASS IN CEMENTITIOUS MATERIALS – A REVIEW

Tatjana Miljojčić[1], Ivana Jelić[1], Marija Šljivić-Ivanović[1], Slavko Dimović[1], Uzahir Ramadani[1]

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Abstract

The advances in the electronic industry have led to a generation of an extensive amount of electrical waste (E-waste) before the end of its proper life span. Excessive usage and production of cathode-ray tubes (CRT), which is the fundamental part of old monitors and screens, has become an immense problem worldwide regarding the environmental issues, since the last few decades thin-film transistors (TFT) and liquid crystal display (LCD) replaced CRTs almost entirely. Consequently, it is of crucial importance to expand and deploy new, renewable methods to manage CRT glass waste. There is an appreciable prospective to use CRT waste glass for new products manufacture, or as an admixture to existing ones, hence the requirement for reusing this kind of waste is favorable. Many investigations have confirmed the positive effect of using grounded CRT waste glass as a fine aggregate. However, this waste is classified as hazardous due to the high lead content. Mixing CRT glass with mortar constructively decreases the amount of cement consumption. Features of this paper relate to a review of recent developments regarding the reuse of CRTs in cementitious materials. Emphasis was placed on their physico-mechanical properties to evaluate the possibility of CRT usage in mortar mixtures.

Keywords: e-waste, recycled aggregate, sustainable development

INTRODUCTION

Concrete is the second most used material worldwide, right after water [1]. Its production implies the utilization of immense amounts of natural aggregates, cement, and water. As a consequence, the pressure on the environment is noticeably growing. In addition to the higher energy efficiency demands, that the sustainable leap brings, there is also the need for overall environmental preservation, and the development of a so-called "circular economy", which implies the efficient use of raw materials [2]. Due to high aggregates consumption, which surpasses 40 billion tons annually [3], questions arise regarding the possible solutions for the replacement of natural raw materials. The extraction of these materials has noticeable and irreversible aftermath on the water supply, ecosystem, soil, wildlife, and the biosphere.

Aggregates that are exploited are categorized as fine or coarse [4]. The most used fine aggregate in mortar mixtures is river sand. One of the issues is the extraction levels of this aggregate that are far beyond the replenishment levels. Consequently, the investigators are searching for alternative solutions in substitute materials to conclude the crisis of sand depletion. It is highly possible to reduce the supply of virgin materials in construction applications through the reuse of recycled aggregates [5]. A supported and more environmentally friendly solution could be the use of substitutes for aggregates such as industrial by-products and waste materials.

Waste glass represents appreciative material that could be efficiently used as an aggregate replacement. Glass is not bio-degradable, it has many different compositions, forms, and appearances, and has versatile applications [6]. Numerous utilization of glass materials are reflected in disproportionate amounts of this kind of wastes annually that later requires a long time to break down naturally. However, glass waste has immense potential for recycling and reuses [7]. Its hardness and low permeability can complement the performance of the latter concrete [5]. There is a great potential for cathode-ray tubes (CRTs) utilization in mortar mixtures since they are made of 85% glass, which is also linked with appropriate waste management and immobilization of hazardous waste disposal [8]. Also, this approach corresponds to better environmental practice: recycling this waste diminishes energy consumption and reduces CO_2 emissions. However, two main concerns arise during the usage of CRT waste glass as a fine aggregate: the leaching of heavy metals and alkali-silica reaction (ASR) representing the disruptive reaction within concrete [9]. The high lead content is stored in the glass, funnel, and panel section, thus this landfilling non-eco-friendly aspect triggered the call for a solution since the presence of lead in CRT glass means that common disposal methods are not the option. Most of the experimental research that integrated CRT glass in mortar mixtures used it as a total or partial substitute for river sand, due to its ability to reduce energy consumption and cost, and generally has a positive environmental impact. Also, CRT glass is high in silica, and it behaves like a pozzolanic material in mortar mixtures [9]. Hence, it could be used as a supplementary cementitious material (SCM) [10].

This paper includes an evaluation of the recent developments regarding the recycling and reuse of CRT glass, as well as the implementation of this waste in mortar mixtures with prominence on their physico-mechanical properties. The following tests were overviewed: consistency, density, water absorption, strengths at static loads, ASR, and lead leaching.

RECYCLING OF CRTs

Technological leaps brought many advantages regarding commodity, usefulness, and luxury in the electronic industry, but on the other hand, e-waste became the fastest-growing problem worldwide that will not cease to slow down any time in the future [8]. Disposal of the immense bulk of old computer monitors and TV screens in landfill sites causes considerable environmental concerns. Convenient recycling of CRT glass has to be accomplished to withdraw possible environmental problems. There are two correct ways to recycle CRT waste glass: closed-loop and open-loop recycling. The first type of recycling method is obsolete since it refers to the recycling of old CRT screens in order to obtain new screens. Since new and improved technologies replaced the need for such screens, this is rarely practiced. The second type of recycling is more exacting, but the technological process is more appropriate since it refers to the employment of CRT waste in order to get new products. Products obtained by this process have greater environmental value and are more cost-efficient [11].

CRT monitor/screen consists of three main parts: funnel glass, front panel glass, and the electron gun. The main constituent of CRTs is silica, but different compounds can be found: barium, strontium, and lead compounds mostly. Recycling of CRTs begins with the separation of the plastic casing, external, and metallic parts. The funnel and panel glass thereafter are separated by laser cutting. Lead content in panel and funnel is different, hence the procedure after separation and recycling for those two differ. Panel glass recycling involves the removal of fluorescent powder, followed by mechanical crushing used to break the glass into smaller particles. After this process, panel glass has a low lead content and it is safe to use it as a fine glass aggregate. Funnel glass has a higher amount of lead, and it has to be immersed in a bath of 5% of HNO_3 solution, for at least 3 h, to extract lead from the surface [12]. After that, it can be mechanically crushed and is ready for usage. It is of great interest to properly recycle CRT glass and thus maximize environmental safety [12].

OVERVIEW OF TEST METHODS AND RESULTS

Consistency

The mortar consistency refers to its property to keep all ingredients together without segregation. Many studies predict better consistency due to the use of CRT glass as a recycled aggregate, mainly in consequence to its low permeability and soft surfaces. In addition, harsh texture and sharp edges may reduce the flow. Methods of CRT glass grounding and its further treatment have a great impact on a slump. Hue and Sun [13] replaced fine aggregate (river sand) with 100% treated and non-treated CRT glass in the production of mortar. CRT glass in mortar mixes was responsible for a detectable increase in slump flow in contrast to a mortar with river sand. It was also reported that utilization of non-treated CRT glass produced higher slump flow than treated CRT glass. In other research, Ling and Poon [14] used different replacement levels of river sand with CRT glass in mortar: 0, 25, 50, 75, and 100%. Due to smooth and imperishable surface of CRT glass, the flow spread diameter expanded. The authors also stated that the consistency of the mortar mixture reduces with the decrease of CRT glass amount.

Density

Many investigations showed that the presence of CRT glass in mortar leads to an increase in density compared to river sand based mortar [15]. In general, higher density is preferred in some applications, such as use for underwater constructions. In the experiment that Zhao and Poon conducted, the river sand was replaced with non-treated and treated CRT glass at replacement levels of 0, 25, 50, and 75% [16]. It was noticed that the substitution of river sand with non-treated CRT glass increases wet density higher than the usage of treated CRT glass.

Water absorption

The replacement of river sand with 100% treated CRT glass significantly decreases water absorption [17]. This outcome was predictable because CRT glass has a lower absorption than the river sand. A decrease in permeability was also observed with an increase in the amount of CRT glass content. Investigators concluded that the smaller particle size of grounded CRT glass led to a further decrease in water absorption [17].

Strengths at static loads

Integration of grounded CRT as a fine aggregate, instead of river sand, leads to higher compressive and flexural strength [13]. After a curing period of 28 days, the compressive strength of CRT mortar was 41% higher than the mortar with river sand, due to the enhancement of particle packing. The higher amount of CRT glass integrated into the mortar, the higher the strength. Similar results were obtained in other studies [18] which showed that non-treated CRT glass improved compressive strength after the curing period. Other investigations [19] notice a decrease in compressive and flexural strength by an increase of CRT glass replacement levels in mortar in the early period of curing. This was probably the result of a feeble bond with the cement paste and lower adhesion, because of the smooth surface of CRTs. However, in the later stages of curing, due to pozzolanic activity, there was less decrease in strength.

ASR

Researchers reported that utilization of CRT waste glass promotes expansion due to ASR [20]. It was noticed that even after 14 days CRT mortar mixtures continued to expand. However, combination with fly ash as SCM led to a decrease in further expansion. It was reported that the presence of fly ash in concrete alleviated the expansion due to pozzolanic activity, i.e. mitigation in alkali content. Zhao *et al*. [21] found similar results, stating that the use of treated CRT glass affected the ASR response within the allowable limit, due to integrated fly ash. Wang *et al*. [20] validated these results, announcing that ASR reaction could be reduced by surface treatment of CRT glass, hence pozzolanic materials are not needed in this case. The conclusion was that ASR could be partially prevented with the use of pozzolanic materials such as metakaolin or fly ash, which leads to denser microstructure, or by CRT glass surface treatment.

Lead leaching

Management of CRT has raised some concerns regarding the lead content which is present in the wasted glass. Removal of the lead could be conducted with acid treatment, which could be expensive and ineffective. Many investigations showed that lead could be adequately immobilized in a mortar matrix since it has been proven that the alkalinity of cement mortar reduces lead leaching. Kim *et al*. [22] reported that lead leaching was almost 0% in the case of a combination of different types of biopolymers. These results were similar to other studies. Romero *et al*. [17] stated that if biopolymer was added into the mixture of mortar with 20% of CRT glass as an aggregate, lead leaching was within the allowable limit. Likewise, there are other methods of lead encapsulation, e.g. the utilization of graphene oxide nanoparticles. Researchers came to the conclusion that usage of 50% of treated CRT glass lead leaching decreases below the limit, while a mixture with 50% of non-treated glass surpasses the acceptable limit. Therefore, it was recommended the utilization of a maximum of 25% non-treated CRT glass to prevent lead leaching above limits. Due to pozzolanic properties, utilization of an additional quantity of fly ash is also advisable [20]. Hence, a number of methods can be done in order to prevent lead leaching: CRT glass amount limitation, fly ash addition, CRT treatment, encapsulation in an alkaline environment, and other techniques.

CONCLUSION

In the light of recent discoveries, utilization of all kinds of industrial by-products and waste has brought a new perspective and insights. Environmental concerns have been raised regarding natural resource depletion. Concrete production implies the utilization of immense amounts of natural aggregates and energy, affecting the overall environment through climate change, pollution, and waste generation.

This review considers the possibility of CRT waste glass utilization in mortar mixtures as a fine aggregate. It has been proven that as a river sand replacement, CRT glass improves some concrete properties. For instance, consistency is enhanced due to the low water absorption and smooth surface. Substitution of river sand by CRTs leads to higher compressive and flexural strength. Also, the risk of ASR can be reduced by using SCMs (metakaolin, fly ash, etc.). Numerous techniques reassure that lead leaching could be successfully controlled by acid treatment, immobilization by mortar mixtures, graphene oxide and biopolymers, limitation in the volume of CRT glass, and SCM addition. The results of reviewed investigations showed that the properties of mortar mixtures containing CRT glass as an aggregate are highly encouraging. However, more investigations are needed to explore all potential benefits.

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