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Physical Properties of Cathode Ray Tube (CRT) Used as Aggregate for Road Pavement Application

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ABSTRACT

The amount of electronic waste (e-waste) generated globally has been increasing steadily, including in Malaysia. Utilizing the e-waste as alternative recycled materials can help to conserve natural resources as well as reduce the demand for natural resources. Furthermore, recycled materials can be used in countries with limited aggregate resources. The present study aims to compare the physical properties CRT glass e-waste used as partial replacement for natural aggregates in road pavements. The study method for laboratory work were carried out in accordance with the American Society for Testing and Materials (ASTM) specifications. Three physical tests were carried out to determine the strength of the sample, i.e. Los Angeles abrasion test, specific gravity test and water absorption test. Result shows that CRT glass has a high value of 59.50% for the Los Angeles abrasion test, which exceed the specified requirement of 50%. The value for water absorption test shows that the CRT glass sample was able to achieve the specified requirement. The result for specific gravity test shows that the natural aggregates have a value higher than that of the CRT glass sample. Aggregates with higher specific gravity are generally stronger than those with lower specific gravity. Studies have to be carried out to identify the feasibility of using CRT e-waste glass as an alternative recycled material in the construction of road pavements.

Keywords: Electronic waste (e-waste); CRT glass; natural aggregates; road pavements

INTRODUCTION

Production of waste occurs throughout the world, and the amount of waste produced in all countries continue to increase. In Malaysia, this include the production of electronic waste. The rapid economic growth and urbanization in Malaysia has resulted in higher amounts of electronic waste being produced each year. The environmental threats posed by these electronic wastes has given rise to social and environmental management problems (Askari et al. 2014; Shumon et al. 2014; Suja et al. 2014). While Ahmad et al. (2017), Soleimanbeigi and Edil (2015) and Hamim & Yusoff (2013) explain that the use of waste materials not only solves the environmental problems but also saves the cost.

Electronic waste comprises waste components from various types of appliances, such as computers, monitors, televisions, printers, refrigerators and components containing batteries. These components are discarded by users when the equipment is damaged or has become obsolete and are no longer able to provide the most advanced capabilities (Cucchiella et al. 2015; Tanskanen 2013; Osman et al. 2016). Cathode ray tubes (CRTs) are the main components of monitors, and make up about 85% of the weight of televisions and computer monitors. There is an urgent need to examine and address the issues surrounding electronic waste disposal management. One approach in the management of electronic waste is to reuse the materials as alternative materials in other fields. This will conserve and reduce the demand for natural resources. CRTs contain lead (Pb), which is a hazardous material and the disposal of which poses problems (Singh et al. 2016; Yao et al. 2018; Yu-Gong et al. 2016).

It is estimated that 175,000 tonnes of television and computer monitors are disposed annually in the United States. Some studies predict that, by 2050, the amount of the discarded CRT waste will increase six-fold (Zhao et al. 2013; Zhao & Poon 2017). The current practice of shifting from using CRT TVs and old computer monitors to utilizing LCD (liquid crystal displays), LED (light emitting diode) panels, and PDP (plasma display panes) have also contributed to the increase in CRTs in the coming years in developed countries as well as developing countries (Singh et al. 2016; Yao et al. 2018). CRT waste has a promising potential for use as a replacement for natural aggregates in engineering works. Several studies have shown that physical properties, such as size, shape and percentage used as substitution, has a strong influence on the mortar and concrete produced using CRT waste (Zhao et al. 2013b; Poon 2013; Romero et al. 2013; Zhao et al. 2013a). From the study also shows that, CRT glass residue has a smooth surface and angular grain shape (Ling & Poon 2014; Romero et al. 2013).

Some studies have shown the effectiveness of using electronic waste due to its good properties as aggregate replacement material in concrete mixes. The silica in cathode tubes has pozolanic properties which makes it suitable for use as a substitute for river sand in concrete mixes (Yao et al. 2018; Singh et al. 2016b). The use of pozolanic can lower cost. In addition, the presence of this pozolanic material enhance concrete properties by increasing the bond between the materials in the concrete mixes (Karim et al. 2014; Garg & Jain 2014). While Ling & Poon (2012) pointed out that CRT can be used as 100% fine aggregate replacement in the production of concrete mixtures and concrete blocks.

This study focuses on comparing physical properties in terms of the strength of glass electronic waste when using CRTs, (Figure 1) as a partial replacement for natural aggregates in construction of road pavements. The laboratory work adopted in the study is based on the specifications set by the American Society for Testing and Materials (ASTM).

FIGURE 1. Glass CRT sample

METHODOLOGY

MATERIAL

The aggregates used to prepare the specimens in this study are various types of granite (natural aggregate) and CRT glass (recycled waste). The aggregates and CRT glass were sieved to separate the samples according to the sizes specified by ASTM standards.The natural aggregate used in this study was purchased from Kajang Rock (M) Sdn Bhd, Selangor while the CRT glass was obtained from Nippon Electric Glass (NEGM) in Shah Alam. The CRT supplied by NEGM has undergone several preparation processes. All components of the CRT glass were first separated using laser cutting methods. The funnel part of the CRT glass components were processed by crushing and grading the glasses to obtain angular glass particles. In the present study the CRT glass supplied by NEGM was used as coarse aggregate. Figure 2 show the processes for preparing CRT glass.

FIGURE 3(a). Apparatus for Los Angeles Abrasion Test

Three physical tests were carried out to determine the strength of the samples, i.e., Los Angeles abrasion (Figure 3(a)), specific gravity and water absorption tests (Figure 3(b)).

LOS ANGELES ABRASION

The Los Angeles abrasion test was carried out according to ASTM C 131. The Los Angeles abrasion test is carried out to evaluate the abrasion, shifting and cracking as well as any combination of the three characteristics in a steel drum. Different sizes of 5000 grams of the samples were put in the drum along with specific number of steel balls. The drum was rotated up to 500 times at a speed of 33 rpm. The aggregates were removed from the machine and sieved using a 1.70 mm sieve.

The Los Angeles value was calculated using the following equation:

$$\text{Los Angeles value} = \frac{m_T - m_w}{m_T} \times 100$$

where,

m_T = total mass of the washed and dried material before abrasion (g)

m_W = mass of material retained on the 1.70 mm sieve after abrasion, washing, drying and re-sieving (g)

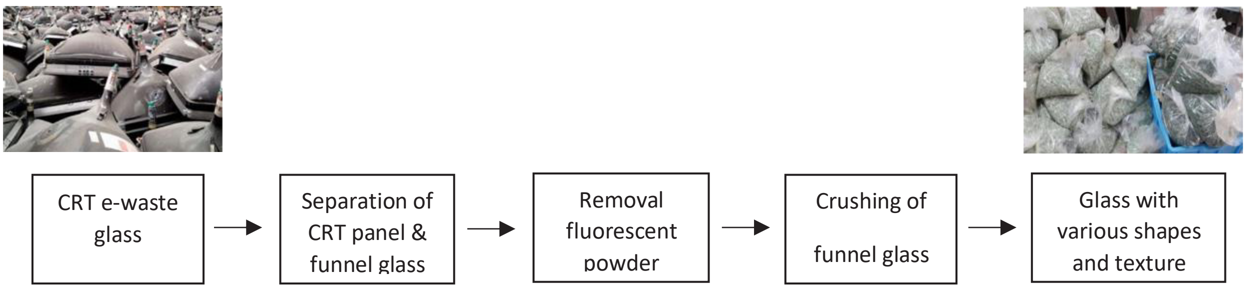

FIGURE 2. Processes of preparation CRT glass

FIGURE 3(b). Apparatus for Specific Gravity & Water Absorption Test

SPECIFIC GRAVITY & WATER ABSORPTION

Specific gravity and water absorption tests for coarse aggregates were carried out in accordance with ASTM C127 "Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate".

The specific gravity of aggregates is determined to identify the strength or quality of a material. Specific gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Aggregates with low specific gravity are generally weaker than those with higher specific gravity.

Specific gravity was calculated using the following equation:

$$\text{Specific gravity, } s_g = \frac{m_3}{m_3 - (m_1 - m_2)}$$

where,
m_1 = mass of saturated aggregate suspended in water with basket (g)
m_2 = mass of basket suspended in water (g)
m_3 = mass of the saturated surface dry fine aggregate (g)

Water absorption is defined as an increase in the mass of aggregates due to water penetration into the pores of the particles during a specific period of time, but not including water adhering to the outside surface of the particles; it is expressed as a percentage of dry mass.

Water absorption was calculated using the following equation:

$$W_a(\%) = \frac{m_2 - m_1}{m_1} \times 100$$

where,
W_a = water absorption of the aggregate (%)
m_1 = dry mass of the aggregate (g)
m_2 = mass of saturated surface of dry fine aggregate (g)

TABLE 1. Comparison of the physical properties of CRT and natural aggregates

Test	Result		Specification Requirement (%)
	CRT	Aggregate	
Los Angeles Abrasion (%)	59.50	34.12	< 50.00
Water Absorption (%)	0.24	0.49	< 2.00
Specific Gravity	2.54	2.68	N.A

RESULTS AND DISCUSSION

Table 1 shows a comparison of the physical strength of CRT and natural aggregates. Each test result is discussed in detail in the following section.

LOS ANGELES ABRASION

Figure 4 shows the result of Los Angeles abrasion test. Figure 4 shows that CRT glass has a high value which exceed the specification limit. The Los Angeles abrasion value for CRT glass is 59.50% in comparison to the allowed standard value of less than 50% (Figure 4). This value is 9.5% higher than the permissible standard requirement. This indicates an unsatisfactory strength in measuring the crushing of CRT materials that will be used as partial replacement. However, the mix containing both CRT glass and natural aggregates has a lower value. Using CRT glass as coarse and fine-grained aggregates gives an optimum value of up to 40% (based on volume percentage) and therefore is suitable for use in the production of concrete mixtures (Tian et al. 2016).

Study by Arulrajah et al. (2014) shows that through a blends of fine recycled glass with other recycled materials it provides the value of LA abrasion loss allowed for pavement base use.

WATER ABSORPTION

Figure 5 shows the result for water absorption.The CRT glass and natural aggregates samples used in the test meet the standard requirements. The values of the water absorption for CRT galss and natural aggregates are 0.24% and 0.49%, respectively, compared to the standard requirement of less than 2%. The water absorption value for the natural aggregates is 51% higher than that for the CRT glass. Ramero et al. (2013) pointed out that a high water absorption of aggregate indicates a high porosity of the aggregate sample. Study by Abdul Mulok et al. (2018) shows that high rate of water absorption will be reduction in mechanical properties of sample.

SPECIFIC GRAVITY

Figure 6 shows the results of specific gravity test. The value for natural aggregates is higher than that for the CRT glass. The specific gravity of CRT glass and natural aggregates are 2.54 and 2.68, respectively. The specific gravity for natural

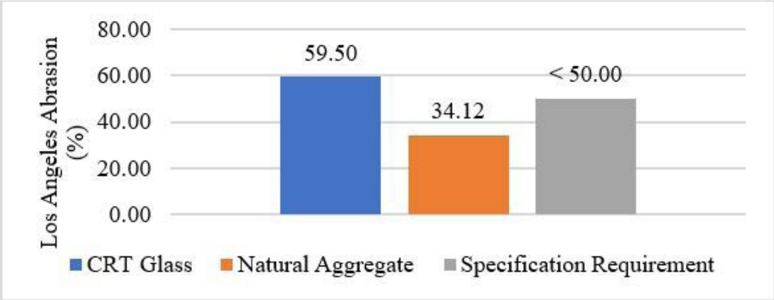

FIGURE 4. Result Los Angeles Abrasion Value

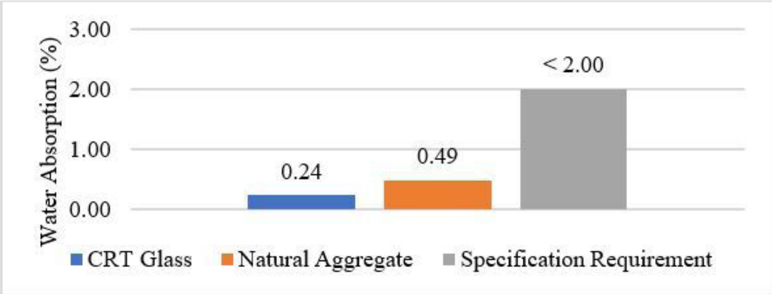

FIGURE 5. Result Water Absorption

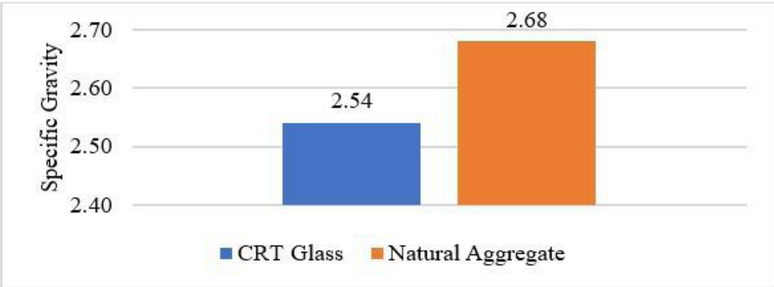

FIGURE 6. Result Specific Gravity

aggregates is 5% higher than the value for CRT glass. Aggregate samples with high specific gravity values are usually stronger (Romero et al. 2013; Chavan 2013).

CONCLUSION

CRT has a promising potential for use as soil coating in construction of roads. Further studies have to be carried out to identify the potential uses of recycled CRT glass as an alternative material in construction of road layers. Recycled residual CRT glass could be used in combination with other materials as an alternative for natural aggregates. Determination of physical and engineering properties of electronic waste is carried out based on whether the materials will be used as a stabilizer for pavement layers, fossil works, slope surface works or road reclamation.

DECLARATION OF COMPETING INTEREST

None.

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