International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-06, Issue-01, Apr 2020

Potential Use of Waste Cathode Ray Tube (CRT) Glass as Fine Aggregate in Concrete for Sustainable Built Environment: A Review

[1*] Shimol Philip, [2] Deepika S., [3] Robin David, [4] Farsana Shahul, [5]Reeja P. Soman, [6]Neethu Elsa Anil

[1, 4, 5] M. Tech Student, Department of CE, Saintgits College of Engineering, APJ Abdul Kalam Technological University, Kerala, India.

[2] M. Tech Student, Department of ECE, TKM College of Engineering, APJ Abdul Kalam Technological University, Kerala, India.

[3]Assistant Professor, Department of ME, VAST TC, APJ Abdul Kalam Technological University, Kerala, India.

*Corresponding Author, Email: shimolphilip16@gmail.com

Abstract: Electrical and electronic waste (E-waste) has become a great matter of concern all around the world. Due to the fast growth in kinescope technology, Cathode Ray Tubes (CRTs) are being replaced by lighter and thinner panels with flat displays, namely – Light Emitting Diodes (LEDs), Plasma Display Panels (PDPs) and Liquid Crystal Displays (LCDs). The environmental hazards caused by CRTs waste generation have become an extensive dilemma around the globe. Lead is contained in sufficient amounts in the waste CRTs, which causes serious hazards to human health and the environment. The increasing demand for concrete and natural resources due to swift urbanization has made it crucial to replace the natural aggregates in concrete either as a partial replacement or total replacement, without affecting the concrete performance. CRT waste glasses are abundant in silica, have low water absorption property and adequate intrinsic strength. These characteristics of CRT waste glass make it apt for usage as pozzolan or sand in construction materials. They can be partially or totally replaced for natural sand as fine aggregate in concrete. This review work extends an in-depth summary of literature detailing the reuse of CRT glass waste as a fine aggregate replacement in concrete. The properties such as water performance, thermal property, strength and durability of CRT glass waste-based concrete and their method of manufacturing have also been studied in this paper. Furthermore, a comparative performance analysis of CRT glass waste concrete with other E-waste incorporated concrete has also been included in this paper. The current work shall contribute to enhancement towards sustainability and economic development of CRT glass waste incorporated concrete in the construction industry. Thus, the issues related to CRT glass waste such as contamination of soil, environment and water bodies, health issues caused to living beings and simultaneously, the degradation of natural restricted aggregate resources could be reduced considerably by several folds.

Keywords — Electrical and Electronic waste, Cathode Ray Tubes, Light Emitting Diodes, Plasma Display Panels, Liquid Crystal Displays.

I. Introduction

Electronic Waste (E-waste) has become a menace to the environment for the past few years. Cathode Ray Tubes (CRTs) are the most prevalent among E-wastes. Due to the fast replacement of CRTs with Liquid Crystal Displays (LCDs) and Light Emitting Diodes (LEDs),considerable proportion of waste CRT glass is been send to the landfill nowadays[1].CRT is considered to be a threatening glass waste and the issues associated with it causes hindrance to

 DOI : 10.35291/2454-9150.2020.0298

easy recycling of the glass[2]. Since CRT waste is not biodegradable, its disposal causes serious environmental hazards. The problem posed by CRT glass wastes has turned out to be a serious environmental challenge around the globe. Hence, effective measures need to be taken for proper reuse of this glass waste. CRT monitors are made up of various formulations of glass in the neck, funnel and panel sections. All of these are hazardous as they have high concentrations of heavy metals like selenium, barium and lead [3]. Figure 1ilustrates the different components of CRT glass waste.

In general, waste CRTs is recycled based on open-loop and closed loop recycling systems [4]. Presently, due to the decreasing demand of CRT in the market, the recycled CRT waste volume for traditional closed-loop recycling system has decreased to a large extent. Since open-loop techniques have several defects, the technology is unfavourable to the application and popularization. Lead is extracted from CRT waste using the hydrometallurgical technology, but this technique causes environmental pollution, has low efficiency and produces waste liquids in large amount. The lead so extracted is mostly in the ionic form and needs further processing like electrolytic deposition. Another technique of extracting lead from waste CRT is the pyro metallurgical technology, which consumes energy and produces a lot of wastewater and soot that is hazardous to the environment. Using CRT waste for production of glass-ceramics, foam and as a substitute material or raw material also consumes a lot of energy and brings lead in CRT waste to the final product. Hence, many studies are been done for treating CRT waste in an economical, efficient and environmental-friendly way. It is been found that it is feasible to utilize CRT waste for concrete, cement mortar and other construction materials, due to its low energy consumption, easiness and reduced impact on environment.

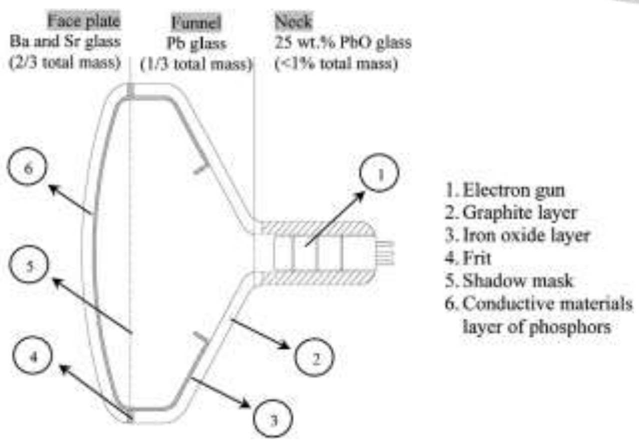

Fig. 1 Schematic illustrating CRT glass waste components

Concrete comprises of fine and coarse aggregates (such as sand and gravels) that bond together chemically by Portland cement. One of the substantial consumers of sand, rock and gravel (natural resources) is the concrete industry. Using large amount of natural resources in production of concrete leads to nature exploitation and imbalance of environment, which is the major constraint for sustainable development. Hence, nowadays, most of the countries anticipate decreasing the use of natural resources [5]. Due to this, the potential utilization of waste materials in the production of concrete is rising in the recent years.

Chemically, E-waste consisting of CRT is wealthy in silica, which showcases pozzolanic behaviour and makes it a potential replacement for fine, natural, river sand in the production of concrete. The environmental impact could be reduced by utilizing glass that is rich in silica, in construction materials [1]. Glass can be used in various forms in concrete production; for example, it can be used as replacement of cement in form of powder [5]. It can also be used partially to replace fine and coarse aggregate in concrete production. This study examines the possibility of using CRT waste glass as fine aggregate replacement in concrete manufacturing. The manuscript is an endeavour to evaluate the characteristics of the concrete thus developed, for its strength, durability, thermal and water absorption properties. The large demand and low supply/availability of these natural resources in the construction industry can be overcome by the use of CRT waste glass as fine aggregates. It is an innovative initiative towards production of cost effective and sustainable green concrete. This great move could lead to a greener environment and also sort out the issues caused due to mining of natural fine aggregates.

II. Application Of Crt Glass Wastes In Concrete

The endeavours to consider the utilization of CRT glass wastes as a constituent in concrete have been made before by numerous researchers. The use of waste CRT glass in the production of green concrete can be an effective way of disposing of this abundant waste, preserving the degradation of natural aggregates and enhancing the properties of the concrete produced. From an extensive review of the literature, it is clear that researchers have used different amounts of CRT glass waste as a substitute for fine aggregate in concrete production. Distinctive tests evaluated various properties of the developed concrete following the different accessibility standards. The following section addresses properties of waste CRT glass incorporated concrete.

III. STRENGTH PROPERTIES OF CRT GLASS WASTE CONCRETE

Many researchers have studied the strength characteristics of CRT glass waste incorporated green concrete. Strength properties of CRT glass waste-based concrete reported by researchers are presented in Table 1.

 DOI : 10.35291/2454-9150.2020.0298

Researchers have attempted different target compressive strengths ranging from 17.1 MPa to 63.9 MPa using different cement types, coarse aggregate types, super plasticizers, replacement levels of fine aggregate and water-cement ratio. In actual practice, the compressive strength of concrete can vary from 17 MPa for residential concrete to 28 MPa and higher in commercial structures.

3.1 Compressive Strength

The strength of hardened concrete measured by the compression test is the compressive strength of concrete. The compression strength of concrete is a measure of the ability of the concrete to resist loads that tend to compress it. This is measured in compression testing system by crushing cylindrical concrete specimens. All other mechanical parameters such as splitting tensile strength, modulus of rupture and modulus of elasticity directly depend on the compressive strength of the concrete. Compressive strength depends on particle strength of aggregate, the strength of the matrix, cement content and W/C ratio. The compressive strength values of CRT glass waste incorporated concrete after 28 days of curing analyzed by various researchers are summarized in Table 1.

From Table 1, it is evident that in every experiment, the compressive strength decreased by increasing the percentage of aggregate replacement by CRT glass waste. Ling and Poon [6] worked on the production of a heavyweight concrete using barite as coarse aggregate and treated CRT glass waste as fine aggregate. A water-cement ratio of 0.42 was adopted for the study. 25%, 50%, 75% and 100% of fine aggregate replaced with an equal volume of treated CRT glass waste. There was a decline in the compressive strength values with the addition of treated CRT glass waste. At the 28th day, the compressive strength of the control mix (barite as coarse aggregate and crushed fine stone as fine aggregate) was 42.1 MPa. But the percentage increase in CRT glass waste decreases the compressive strength value and it reduced to 35.1 MPa when the crushed fine stone was fully replaced by CRT glass waste. Similar observations have been presented by Liua et al. [7], Liub et al. [8], Zoua et al. [9], Liuc et al. [10], Dai et al. [11], Yang et al. [12], Zoub et al. [13], Ding et al. [14], Liud et al. [15].

Table 1 Strength properties of concrete using CRT glass waste as fine aggregate replacement.

Author (year)	W/C ratio	Mix proportions/ (% replacement)	Compressive strength (MPa)	Split tensile strength (MPa)	Flexural strength (MPa)
Sua-Iam and Gritsada (2012)	0.38	CRT-20% and lime stone- 0%	28.3	-	-
		CRT- 20% and lime stone- 5%	47.2	-	-
		CRT- 20% and lime stone- 10%	34.3	-	-
		CRT- 20% and lime stone- 15%	30.9	-	-
		CRT- 40% and lime stone- 0%	25.8	-	-
		CRT-40% and lime stone-5%	35.2	-	-
		CRT-40% and lime stone-10%	39.5	-	-
		CRT- 40% and lime stone-15%	33.5		
Ling and Poon (2012)	0.42	CRT- 25%,	40	2.4	-
		CRT- 50%,	37.5	2.3	-
		CRT- 75%,	37	1.9	-
		CRT- 100%	36	1..7	-
Romero et al. (2013)		CRT- 10	28.5	-	-
		CRT- 20	32.3	-	-
		CRT- 30	30.8	-	-
Liu[a] et al. (2016)	0.40	CRT- 20%	55	-	-
		CRT- 40%	54	-	-
		CRT- 60%	49	-	-
		CRT- 80%	47	-	-
		CRT- 100%	45	-	-
Walczak et al. (2015)	-	CRT- 0%	17.1	-	3.8
		CRT- 100%	19.8	-	4.4
		CRT-80% and fly ash-20%	22.9	-	4.9
Liu[b] et al. (2019)	0.18	CRT- 25%	170	-	38
		CRT- 50%	165	-	37
		CRT- 75%	154	-	34
		CRT- 100%	148	-	32
Zou[a] et al. (2018)	0.6	CRT- 30%	34.28	-	-
		CRT- 60%	33.55	-	-
		CRT- 100%	30.49	-	-
Liu[c] et al. (2019)	0.45	CRT- 20%	39.1	4.3	-
		CRT- 40%	36	4.3	-
		CRT- 60%	34.8	4.2	-

 DOI : 10.35291/2454-9150.2020.0298

		CRT- 80% CRT- 100%	34.7 33.1	4.1 3.9	- -
Dai et al. (2019)	0.4	CRT- 5% CRT- 10% CRT- 15%	38 36 34		4.11 4.00 3.76
Benabed et al. (2020)	0.4	5 MK and CRT- 0% 5 MK and CRT- 20% 5 MK and CRT- 30% 5 MK and CRT- 30% 5 MK and CRT- 40% 5 MK and CRT- 50%	63.9 61 60.1 60 59.3 58	- - - - - -	- - - - - -
Yang et al. (2018)	0.35 0.45 0.55	CRT- 50% CRT- 100% CRT- 50% CRT- 100% CRT- 50% CRT- 100%	29.5 27.1 23.5 19.7 21.6 19.6	- - - - - -	5.3 4.7 3.9 3.7 3.8 3.3
Zou[b] et al. (2018)	-	CRT- 20% CRT- 40% CRT- 60% CRT- 80% CRT- 100%	35.9 34.8 33 34 33.7	- - - - -	6.2 6 5.1 5.3 5.2
Ding et al. (2019)	-	CRT- 25% CRT- 50% CRT- 75% CRT- 100%	32 31.3 29.8 25.2	3.3 3 2.9 2.4	- - - - -
Liu[d] et al. (2019)	-	CRT- 20% CRT- 40% CRT- 60%	38.8 37 33.3	- - -	- - -

Liu[a] et al. [7] developed an anti-radioactive concrete by effectively utilizing CRT funnel glass waste by partially replacing fine aggregate. Sand in the control mix was replaced in the ranges of 20%, 40%, 60%, 80% and 100% and tests were conducted. The optimum percentage of replacement was considered as 40%.

Liu[b] et al. [8] introduced an innovative cementitious material known as ultra-high-performance concrete (UHPC). UHPC was used to recycle CRT waste without lead extraction. The aggregate was replaced at a range of 25%, 50%, 75% and 100%. At the 28th day, the compressive strength value reached 147.9 MPa for 100% replacement of fine aggregate with CRT.

Zou[a] et al. [9] investigated the varying trends of compressive strength of concrete, dipped in 5% and 10% of Na_2SO_4 solution, by replacing 0%, 30%, 60% and 100% of natural sand by CRT glass waste. The compressive strength value showed a general trend of a boost in value up to peak range and then decreased. This variation mainly depends on the continuous salt crystallization and generation of gypsum. 30% of CRT (treated with 5% of Na_2SO_4 solution) glass waste replacement showed satisfactory results.

A similar observation of a reduction in compressive strength with the increased addition of CRT glass waste was found by Liu[c] et al. [10]. The maximum compressive strength value of 39.1 MPa was observed with a 20% replacement of fine aggregate by CRT waste. Dai et al. [11] replaced 5%-15% fine aggregate with CRT. A maximum compressive strength value of 38 MPa was obtained for 5% replacement. Yang et al. [12] conducted the study based on three water-cement ratios (35, 45 and 55) and 50% and 100% of fine aggregate were replaced with CRT. The maximum strength value was observed at 50% replacement of fine aggregate and at a water-cement ratio of 35. A similar reduction in compressive strength with the increase in replacement ratio of fine aggregate with CRT was found out by Zou[b] et al. [13]. Fine aggregate was replaced in the range of 20%, 40%, 60%, 80% and 100%. Ding et al. [14] found that 25% replacement of fine aggregate with CRT shows the maximum compressive strength value of 31.3 MPa at the 28th day.

Liu[d] et al. [15] investigated about the suitability of replacement of high-density magnetite sand by CRT glass waste and obtained a similar trend of reduction in compressive strength with replacement. Like [2], 40% replacement gave the maximum compressive strength value at the 28th day. According to these studies, the smooth surface of the CRT glass waste particles negatively affected the bonding between the cement paste and glass waste particles and thus a reduction in compressive strength value with the increased amount of waste replacement. Also, the high porosity of the CRT glass waste imparted negative impacts on the strength values.

From previous studies, it can be seen that incorporation of CRT alone shows a reduction in compressive strength with more replacement of fine aggregate by CRT. But there are some studies that monitored the effectiveness of using some

 DOI : 10.35291/2454-9150.2020.0298

other materials along with CRT as fine aggregate. Sua-Iam and Gritsada [16] developed self-compacting concrete (SCC) by partially incorporating Cathode Ray Tube (CRT) and limestone powder in place of fine aggregate. 20% or 40% of CRT glass waste by weight of fine aggregate was added. Limestone powder was added at the rate of 5, 10, or 15% to suppress viscosity effects and thereby to increase the workability of the concrete mix. The compressive strength value of control mix was more than that of concrete incorporated with 20% of CRT glass waste. But a slight increase was observed with the addition of 5% of limestone powder. But the further increase of both CRT and limestone powder leads to a reduction in the value of compressive strength. Therefore, CRT and limestone powder to be incorporated in concrete was optimized as 20% and 5% respectively.

Similarly, Benabed et al. [17] investigated the feasibility of partial replacement of CRT glass waste as fine aggregate and partial replacement metakaolin as the cement in concrete. The compressive strength value gets reduced with the addition of CRT. But a concrete mix with 5% metakaolin (MK) and 0% of CRT shows the maximum strength value. Although the presence of MK increases the strength value, the further addition of CRT decreases the compressive strength value. Also, 5% and 10% of MK incorporation gave improved values. But beyond 10%, there was a reduction in the strength value.

Walczak et al. [2] investigated the feasibility of using CRT funnel glass waste and fluidized fly ash in concrete by partially and fully replacing river sand. Three mixes were studied that is a mix without incorporating CRT and fly ash, mix fully replaced with CRT alone and final mix incorporating 80% of CRT and 20% of fluidized fly ash. The compressive strength value of the final mix was more than that of the other two mixes. The increased value was observed due to the improved pozzolanic activity of fluidized fly ash and high reactivity of CRT funnel glass waste than river sand.

Romero et al. [18] worked on cylindrical concrete specimens cast with different contents of the crushed CRT glass waste (10%, 20% and 30%). Here fine aggregate was replaced by CRT alone. But the test results showed a boost in compressive strength value as replacement of fine aggregate increases from 10% to 20%. It is attributed due to the usage of limestone as coarse aggregate in concrete. But further replacement resulted in a decline in compressive strength value.

For normal field applications, the compressive strength can vary from 10-60 MPa. Concrete made by using CRT glass waste as fine aggregate shows compressive strength value more than 30 MPa in almost all studies. Therefore CRT glass waste can be effectively utilized in concrete by partially replacing fine aggregates.

3.2 Splitting Tensile Strength

In general, the contribution of concrete tensile strength to the design of reinforced concrete is neglected. However, in the case of lightweight concrete members, its low tensile strength can cause considerable tensile cracking at very low loading capacity. Split tensile strength of values of CRT glass waste incorporated analyzed by various researchers are summarized in Table 1.

Similar to that of the trend of compressive strength, split tensile strength decreases with increasing the fine aggregate replacement by CRT. Ling and Poon [6] investigated the split tensile strength of heavyweight concrete made with barite as coarse aggregate and CRT glass waste as the fine aggregate. The test result showed a general trend of the gradual decrease in split tensile strength with the incorporation of CRT glass waste. Since the CRT glass waste substitution rate increased from 0 to 25%, 50%, 75% and 100, the tensile strength decreased on average by 4.6%, 6.8%, .5 18.5% and 25.7%. Similar observations were done by Liu[c] et al. [10], Ding et al. [14].

Liu[c] et al. [10] found a similar trend of reduction in split tensile strength with the increase in replacement ratio of CRT glass waste. The maximum value of split tensile strength was observed with 20% replacement. Reduction in split tensile strength with the replacement of fine aggregate by CRT was observed by Ding et al. [14]. The maximum value was obtained at 25% replacement of fine aggregate. This is supported by the fact that adhesion between aggregates and cement paste plays an increasingly important role in affecting the tensile properties of concrete specimens.

3.3 Flexural Strength

As stated in the variation of compressive strength and split tensile strength, flexural strength shows a similar trend of decline in its value with more CRT addition. Liu[b] et al. [8] established that the flexural strength value of ultra-high-performance concrete (UHPC) shows a trend of reduction with the addition of CRT glass waste. The test result shows a flexural strength value of 32.7MPa on the 28th day of testing. Similar results were obtained by Dai et al. [11], Yang et al. [12],and Zou[b] et al. [13].

According to Dai et al. [11], the 5% replacement of CRT aggregates gives a flexural strength value of 4.11 MPa. Beyond 5% replacement, the strength values get reduced. Yang et al. [12] also observed a common trend of reduction in flexural strength with the addition of CRT in concrete as fine aggregate. Maximum strength value was observed at 50% of fine aggregate. Zou[b] et al. [13] confirmed that flexural strength shows a similar trend as that of other

 DOI : 10.35291/2454-9150.2020.0298

authors for 20%, 40%, 60%, 80% and 100% of fine aggregate replacement with CRT. From the above reviewed literatures, high porosity of CRT glass waste and the weak bond between cement paste and CRT glass waste are observed as the reason behind such a variation in flexural strength.

Walczak et al. [2] stated that the incorporation of CRT funnel glass waste and fluidized fly ash in concrete by partially and fully replacing fine aggregate reported a different result. The tests result shows a trend of increase in flexural strength value with the incorporation of both fly ash and electronic waste. The mix with 80% CRT and 20% fly ash as fine aggregates reported a flexural strength value of 4.9 MPa at the 28th day of curing. The reason behind this variation is due to the improved pozzolanic activity of fluidized fly ash and high reactivity of CRT funnel glass waste than river sand.

IV. Durability Properties Of CRT Glass Waste Concrete

The durability of the OPC-concrete can be defined as the tendency to withstand one or more of the weather conditions, such as disintegration and decompositions, chemical attack, abrasion or other processes that are destroyed by the retention of engineering properties. This means that the durable OPC-concrete will maintain its unique original quality, shape and serviceability with respect to the environment.

4.1 Chloride Attack

Chloride attack is the most important criterion for determining the durability of concrete because it is primarily responsible for the corrosion of reinforcement. Surprisingly, the corrosion of reinforcement is alone responsible for more than 40% of the failure of the structure. According to the initial specifications of the Bureau of Indian Standards, the chloride content of cement should not exceed 0.05%, although this limit is now allowed to extend to 0.1%.

Zou[a] et al. [9] concluded that the resistance to chloride ion penetration of concrete immersed in 8% of sodium chloride solution enhanced with CRT glass waste addition. Yang et al. [12] observed that the chloride ion penetration resistance was improved with the CRT addition in concrete. CRT addition resulted in a concrete mixture with compact nature and therefore large penetration resistance. Benabed et al. [17] monitored that the partial incorporation of MR with CRT in concrete improved the resistance against chloride attack. It was attributed due to the fineness of MR with which it could fill the pores in concrete and resulted in a compacted structure of the hardened concrete.

From the reviewed literature, it is evident that the resistance to chloride attack has been greatly improved by using CRT glass waste in concrete in a proper amount.

4.2 Water Absorption and Permeability

The permeability of concrete plays a crucial role in its durability, as it controls the rate of moisture absorption. As the permeability increases, the durability decreases or in other words, more durable concrete exhibit less permeability. The permeability of the concrete depends mainly on the microstructure's attributes such as porosity, sorptivity, saturated water absorption etc. The saturated water absorption attribute of concrete is a measure of porosity or volume of pores in the hardened concrete where the water resides in a saturated state.

According to Liu[b] et al. [8] the rate of water absorption capacity of ultra-high-performance concrete (UHPC) made by replacing fine aggregate with CRT glass waste was increased. The water absorption capacity after 24 hours increases from 1.74% to 2.40% with the addition of CRT wastes. This variation was observed due to the usage of coarse CRT glass waste instead of small sized particles.

Zou[a] et al. [9], Liu[c] et al. [10], and Yang et al. [12] carried out their works by incorporating small sized CRT glass waste particles in concrete. According to them, water absorption capacity gets reduced with the increased replacement of fine aggregate by CRT glass waste, because small sized particles of CRT lead to a decrease in the water absorption value. According to Yang et al. [12], the water absorption capacity increases with an increase in water-cement ratio.

4.3 Porosity

Porosity of concrete (ie, volumetric proportion of voids) has been widely measured in concrete for the prediction of properties of concrete. Concrete is a naturally porous material. This is caused by the excessive use of water for hydration purposes to make the concrete mix sufficiently workable and the difficulty of extracting all the air from the concrete during compaction.

Sua-Iam and Gritsada [16] measured the porosity of a concrete mix made by replacing fine aggregate with CRT glass waste and limestone powder. The fine particle size distribution of both CRT and limestone powder resulted in a concrete mix with comparatively large density and less porosity. Similarly, Benabed et al. [17] found that the incorporation of both CRT and MR leads to a reduction in the porosity of the concrete than that of a control concrete mix. The optimum value of porosity was observed at 10% MK and 50% CRT glass waste. Study of permeability parameters also confirmed that the porosity of concrete incorporating CRT glass waste is somewhat lower than that of conventional concrete. It can be concluded that the

 DOI : 10.35291/2454-9150.2020.0298

durability of E-waste concrete is at the acceptable level, though it is slightly lower than that of conventional concrete.

V. Thermal Properties Of Crt Glass Waste Concrete

Buildings barely monitor the indoor climate conditions to a comfortable level without mechanical air conditioning, but the use of thermal insulator in roofs and walls is the only technique to reduce the rising demand for air conditioning. Thermal properties influencing the temperature rise and distribution of a concrete structural member includes thermal conductivity, thermal diffusivity, specific heat and mass loss. Thermal conductivity is the ability of a material to conduct heat. The average value of thermal conductivity in normal strength concrete ranges from 1.4 to 3.6w/m°c at room temperature.

The thermal insulation property of concrete containing CRT glass waste aggregates is beneficial from an energy point of view. The thermal conductivity of CRT glass waste incorporated concrete found in literature published by various authors [19, 20] is lower than that of conventional concrete. This means that CRT glass waste concrete has better thermal insulation properties than conventional concrete. Thus, it can be concluded that concrete incorporating CRT glass waste aggregates can keep the room cooler than the outside temperature.

VI. Conclusion

This article explored the possibility of using CRT glass wastes as fine aggregates for the production of a variety of green concretes for building and infrastructure industries. This was attained by gathering the advantages and disadvantages identified by various researchers in their respective efforts related to the use of CRT glass wastes in concrete. This review explicitly analysed the attributes such as compressive strength, split tensile strength, flexural strength, thermal insulation capacities, chloride attack and permeability of concrete, all of which were found to be within acceptable levels of sustainable construction. Following important conclusions have been drawn from these studies:

- Limited research work has reported on the better use of CRT glass waste in concrete. Therefore, a thorough study on the engineering properties of CRT glass waste-based concrete can help to achieve their effective utilization in concrete.
- Test on compressive, split tensile and flexural strength of concrete incorporating CRT glass waste as fine aggregate shows a trend of decline in their values with CRT addition. But addition of limestone, metakaolin and fly ash initially shows an increase in strength with more CRT incorporation.
- Even though all the percentage replacement satisfies the requirement of all strength values for field application, most of the reviewed journals take 20%-40% as the optimum replacement by considering other properties of concrete.
- Durability properties also get enhanced with CRT incorporation. When compared with control mix of concrete, the porosity came down with CRT addition.
- Replacement of fine aggregate significantly decreased the thermal conductivity when compared with the control concrete. The inherently low thermal conductivity of CRT glass aggregate is responsible for the reduction in overall thermal conductivity of the concrete.

This concept is not merely used for a good reason to address its waste management problems, but also helps to protect the environment and reduce the deterioration of concrete aggregates from natural sources. Therefore, the development of CRT glass waste based eco-efficient green concrete is highly essential to preserve soil, water sources (groundwater, surface and drinking water), environment from contamination and for the well-being of humankind and the natural world. This can be contemplated as an approach of extracting ‘‘the finest from the wastes” which is in fact the need of the time to protect the Mother Earth.

References

[1]Yao, Z., Ling, T., Sarker, P., Su, W., Liu, J., Wu, W., & Tang, J. (2018). Recycling difficult-to-treat e-waste cathode-ray-tube glass as construction and building materials: A critical review. Renewable and Sustainable Energy Reviews, 81, 595-604.

[2]Paweł Walczak, Jan Małolepszy, Manuela Reben, and Karol Rzepa (2015). "Mechanical Properties of Concrete Mortar Based on Mixture of CRT Glass Cullet and Fluidized Fly Ash" Procedia Engineering, vol. 108, 2015. doi:10.1016/j.proeng.2015.06.170.

[3]Méar, François & Yot, Pascal & Cambon, Martine & Ribes, Michel. (2006). The characterization of waste cathode-ray tube glass. Waste management (New York, N.Y.). 26. 1468-76. 10.1016/j.wasman.2005.11.017.

[4]Qi, Yaping & Xiao, Xiang & Lu, Yan & Shu, Jianchen & Wang, Jianbo & Chen, Mengjun. (2018). Cathode ray tubes glass recycling: A review. Science of The Total Environment. 650. 10.1016/j.scitotenv.2018.09.383.

[5]Jamil, Md & Kaish, A. B. M & Ibrahim, K. & Zain, M.. (2018). Incorporation of CRT waste glass as coarse aggregate in steel fiber reinforced concrete. AIP Conference Proceedings. 2020. 020040. 10.1063/1.5062666.

 DOI : 10.35291/2454-9150.2020.0298

[6] Ling, Tung-Chai and Chi Sun Poon (2012) “Feasible use of recycled CRT funnel glass as heavyweight fine aggregate in barite concrete.”.

[7] Tian, Ying & Liu, Wen & Cui, Su & Sun, Shi & Wang, Yi & Li, Jin & Fu, Yue & Wang, Jian. (2016). Recycled CRT Funnel Glass as Coarse Aggregate and Fine Aggregate in the Radiation Protection Concrete. Materials Science Forum. 847. 437-444. 10.4028/www.scientific.net/MSF.847.437.

[8] Liu T, Wei H, Zou D, Zhou A, Jian H, Utilization of waste cathode ray tube funnel glass for ultra-high performance concrete, Journal of Cleaner Production (2019).

[9] Liu, Tiejun & Qin, Shanshan & Zou, Dujian & Song, Wen. (2018). Experimental investigation on the durability performances of concrete using cathode ray tube glass as fine aggregate under chloride ion penetration or sulfate attack. Construction and Building Materials. 163. 634-642. 10.1016/j.conbuildmat.2017.12.135.

[10] Song, Wen & Zou, Dujian & Liu, Tiejun & Teng, Jun & Li, Lei. (2019). Effects of recycled CRT glass fine aggregate size and content on mechanical and damping properties of concrete. Construction and Building Materials. 202. 332-340. 10.1016/j.conbuildmat.2019.01.033.

[11] Wang, Jiaqing & Guo, Shuaicheng & Dai, Qingli & Si, Ruizhe & ma, Yunxiang. (2019). Evaluation of Cathode ray tube (CRT) glass concrete with/without surface treatment. Journal of Cleaner Production. 226. 10.1016/j.jclepro.2019.03.300.

[12] Kim, Il Sun & Choi, So Yeong & Yang, Eun Ik (2018). Evaluation of durability of concrete substituted heavyweight waste glass as fine aggregate. Construction and Building Materials 184 (2018) 269–277

[13] Liu, Tiejun & Song, Wen & Zou, Dujian & Li, Lei (2018). Dynamic mechanical analysis of cement mortar prepared with recycled cathode ray tube (CRT) glass as fine aggregate. Journal of Cleaner Production 174 (2018) 1436e1443

[14] Liu, Hualiang & Shi, Jianjun & Qu, Huiqiong & Ding, Dexin (2019). An investigation on physical, mechanical, leaching and radiation shielding behaviors of barite concrete containing recycled cathode ray tube funnel glass aggregate. Construction and Building Materials 201 (2019) 818–827

[15] LIU, Hua-liang & SHI, Jian-jun & QU, Hui-qiong & DING, De-xin (2019). Feasibility of using recycled CRT funnel glass as partial replacement of high density magnetite sand in radiation shielding concrete. Trans. Nonferrous Met. Soc. China 29(2019) 831−839

[16] Sua-Iam, Gritsada. (2012). Use of Limestone Powder to Improve the Properties of Self-Compacting Concrete Produced Using Cathode Ray Tube Waste as Fine Aggregate. Applied Mechanics and Materials. 193-194. 472-476. 10.4028/www.scientific.net/AMM.193-194.472.

[17] Ouldkhaoua, Younes & Benabed, Benchaa & Abousnina, Rajab & Kadri, El-Hadj, Khatib ,Jamal (2020). Effect of using metakaolin as supplementary cementitious material and recycled CRT funnel glass as fine aggregate on the durability of green self-compacting concrete. Construction and Building Materials 235 2020) 117802

[18] Romero, Diego & James, Jacqueline & Mora, Rodrigo & Hays, Carol. (2013). Study on the mechanical and environmental properties of concrete containing cathode ray tube glass aggregate. Waste management (New York, N.Y.). 33. 10.1016/j.wasman.2013.03.018.

[19] Chung, S. Y., Abd Elrahman, M., Sikora, P., Rucinska, T., Horszczaruk, E., & Stephan, D. (2017). Evaluation of the Effects of Crushed and Expanded Waste Glass Aggregates on the Material Properties of Lightweight Concrete Using Image-Based Approaches. *Materials (Basel, Switzerland)*, *10*(12), 1354.

[20] Krishnamoorthy R.R., Zujip J.A. Thermal conductivity and microstructure of concrete using recycle glass as a fine aggregate replacement. Int. J. Adv. Res. Technol. 2013;3:463–471.

 DOI : 10.35291/2454-9150.2020.0298