From Refuse to Resource: E-Plastic as Building Material

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Abstract

The pursuit of the sustainable development goal of responsible consumption and production requires innovative multi-disciplinary approaches. These goals are achieved in the present work with the use of granulated plastic made from waste electronic and electrical equipment (WEEE) panels as a substitute for sand in the production of concrete mixtures. The optimal amount of plastic added, curing time, and water-cement ratio were determined experimentally. Data show that a theoretical compressive strength of 17.68 MPa was achieved using a water-cement ratio of 0.45, 6% sand replacement and 19 days curing time. While this strength is already suitable for general construction purposes, this represents a 13.54-percent deterioration compared with conventional concrete. Thus, enhancement was done with the addition of arrowroot powder as organic admixture which improved the compressive strength to a level comparable to conventional concrete. These results reveal that E-plastics are technically viable process inputs in the production of building materials and provide a sustainable strategy for responsible consumption and production.

Keywords: E-Plastic, WEEE, RSM, arrowroot

1. Introduction

A staggering amount of waste electrical and electronic equipment (WEEE or E-waste) is generated annually owing to technological adoption and the increasingly short lifespan of most electronic devices. Current estimates place this amount at 50M tons (Sthiannopkao & Wong, 2013) of which only a fraction is recycled. Among the various components of WEEE, E-plastics has become one of the fastest rising streams since it represents 5% of the total material composition (Sua-iam & Makul, 2013). It is of particular concern because it is known to contain carcinogenic substances (Manikandan & Senthamilkumar, 2015).

Traditional techniques have been used to dispose E-wastes such as recycling, incineration, acid bathing, and landfilling (Luhar & Luhar, 2019). An emerging and worthwhile alternative is its use in manufacturing green concrete since it reduces landfilling needs, mitigates CO_2 emission, cuts material cost, and reduces consequential hazards and other environmental issues (Prasanna & Rao, 2014).

Studies have used various types of E-plastic in concrete production (Damal & Londhe, 2015; Nadhim, Navya & Pranay, 2016; Kumar & Baskar, 2015). The amount of E-plastic added was also varied since the compressive strength of concrete deteriorated beyond certain values (Akram, Sasidhar & Pasha, 2015).

On this note, this study was conducted to determine the optimum amount of E-plastic that can be incorporated into concrete with consideration of water-cement ratio and curing time. Furthermore, this study explores the use of a locally-available root crop as organic admixture to mitigate the negative effect of E-plastic on concrete strength. This way, E-plastic as refuse material is converted into a valuable resource as process input in the production of building materials.

2. Materials and Methods

2.1 Materials

Ordinary Portland cement (OPC) and crushed coarse aggregates were used to produce concrete mixtures. The E-plastic as aggregate was prepared by grinding and sieving to pass 4.75 mm and retained at 0.425 mm. Mature arrowroot (*Maranta arundinacea*) from Quezon Province, Philippines was processed at ambient conditions to starch powder using procedure provided by Starch International.

2.2 Methods

All concrete mixtures were produced to conform with ASTM C192 for Class A concrete according to a central composite design (CCD) with three independent variables (Table 1) with alpha of 2. Twenty experimental runs were conducted for optimization. The mixtures were shaped using 4"x8" cylindrical molds and compressive strength was determined using Universal Testing Machine in accordance ASTM C93 standards.

Table 1. Experimental conditions

Factor	Experimental Level	
	-1	+1
Sand replacement (%)	4	8
Curing time (days)	13	25
Water-Cement ratio	0.375	0.525

Response surface methodology (RSM) was used for model development and optimization. Experimental results were analyzed using Design Expert (StatEase). Meanwhile, the effect of organic admixture was determined in terms of the amount of arrowroot powder added, from 1-2.5% of cement used.

3. Results and Discussion

3.1 Optimization and verification

The experimental results suggested a significant quadratic model for the system (R^2 = 0.9013) with curing time, water-cement ratio, and the square of curing time as significant factors. It was determined that a compressive strength of 17.68 MPa was attainable at 6% E-plastic replacement rate, water-cement ratio of 0.45, and 19 curing days. Concrete of this strength is suitable for general construction purposes. To verify the model, additional experimental runs were conducted and the actual compressive strength of 17.618 MPa attained was 99.65% in agreement with the theoretical value.

3.2 Arrowroot as organic admixture

A concrete mixture with no E-plastic was made at similar water-cement ratio and curing days. Testing showed that the sample had a higher compressive strength of 20.45 MPa, implying that the addition of E-plastic decreased concrete strength. To mitigate the reduction in strength, arrowroot was added as organic admixture at different amounts. The results are shown in Figure1 below.

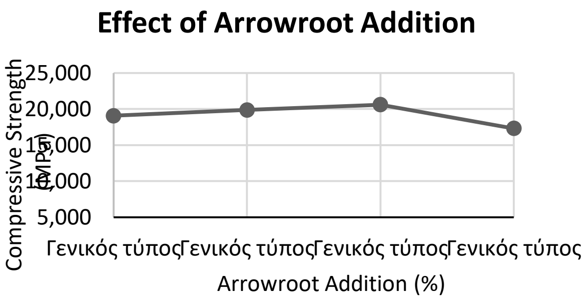

Figure 1. Effect of arrowroot addition on concrete strength.

From the results, it can be observed that the amount of added arrowroot affected the compressive strength of concrete. Furthermore, it can be seen that the optimal amount of arrowroot was 2%.A comparison of the strengths of three concrete mixtures tested at similar conditions is given in Figure 2 below.

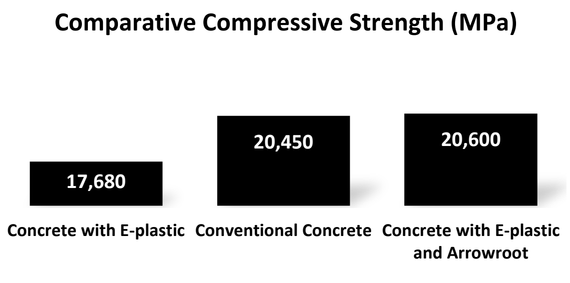

Figure 2. Comparative compressive strengths for three concrete mixtures.

As can be seen from the figure, the lowest compressive strength was observed for concrete mix with E-plastic, confirming that replacement of the traditional aggregates with this material negatively impacts concrete strength. The values show that the replacement of aggregates with E-plastic reduced the compressive strength of concrete by 13.54 %. However, with the addition of arrowroot the compressive strength increased by 16.52 %, to levels comparable with conventional concrete.

4. Conclusion

This study has shown that E-plastic can be used to produce concrete mixtures applicable as building material. Furthermore, the addition of arrowroot as organic admixture is able to mitigate the negative effect of E-plastics on concrete strength. Based on the findings, it can be concluded that E-plastics can be converted from being an E-waste refuse into a valuable resource suitable as process input in the production of building materials.

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