Potential Use of Plasters from GAP Industrial Waste towards an Innovative Green Economy

Emmanuel Emem-Obong Agbenyeku, Edison Muzenda and Innocent Mandla Msibi, Tofu Mbuyiselo, *Member, IAENG*

Abstract**—**A number of durability study on sustainable and ecofriendly platers/mortars produced from the use of glass activated plastic (GAP) industrial waste have been documented. Several tests were conducted on cement plasters formed by the replacement of aggregate with GAP industrial waste in a range of 0-20%. Outcomes of the study revealed approximately 37% decrease in strength properties depending on the percentage replacement of the GAP waste powder. The recorded decrease could play the role of an enhancer towards the durability of the specimen and as such, shows good potential for use.

Keywords**—***Glass Activated Plastic (GAP), Cement, Drying Shrinkage Tests, Industrial Waste*

I. Introduction

IN present times, the prudent utilization of scarce resources, from the use of available by-products and waste materials, as well as decreased consequential environmental impacts, from reduced carbon dioxide emission and reduced aggregate depletion from natural reserves, pinpoints certain actions towards ecofriendly and sustainable building development [1]. Concrete recycling can be a possible solution to environmental challenges by the re-use or transformation of solid waste products from other industrial sectors into possible useful resource in bricks, concrete and plaster manufacture. Such an initiative will go a long way reducing the need to landfill these solid waste materials in South Africa whose landfills are gradually being stretched to limits. As recorded by [2], [3] the transformation of construction and demolition wastes can help maintain an acceptable and most often better concrete quality product. Glass Activated Plastic (GAP) is a simple composite material made of glass fibres spread in a resin, usually polyester, broadly utilized in numerous fields from buildings to furniture as shown in Fig. 1.

Fig. 1. Pictures showing glass activated plastic (GAP) used in various forms

According to [4] GAP processing generates approximately 42,000 tons of industrial waste annually in Western Europe. In countries like South Africa and Italy such waste types are often landfilled due to lack of appropriate and economical technology for re-use or transformation. Also, because of the difficulties of separating the glassy part from the polymeric matrix. A number studies have documented in literature concrete made with recycled glass or produced by polymeric addition/replacement [5-8]. Specifically, concrete made with polyester have been found to be particularly resistant to chemical attacks including thermal cycles and can be utilized in light weight constructions [8]. As such, the potential of utilizing GAP industrial waste in the manufacture of concrete members could be explored. In this light, the study investigated the potential of recycling GAP industrial waste for the production of concrete as a drive towards an innovative green economy. From previous studies by [9], [10] the finest GAP wastes were physically and chemically characterized so as to outline any compatibility issues with cement. In the present study however, cement plasters produced by partly replacing the aggregate volume with selected percentages of GAP industrial waste powder were

Manuscript received March 0, 2016; revised March 0, 2016; submitted for review April 15, 2016.

Emmanuel Emem-Obong Agbenyeku is a research student at the University of Johannesburg, South Africa (phone: +27 11 559 6396; e-mail: kobitha2003@yahoo.com; emmaa@uj.ac.za).

Edison Muzenda is a Professor of Chemical and Petroleum Engineering and Head of Department of Chemical, Materials and Metallurgical Engineering, College of Engineering and Technology, Botswana International University of Science and Technology, Private Mail Bag 16, Palapye, Botswana, as well as visiting Professor at the University of Johannesburg, Department of Chemical Engineering, Faculty of Engineering and the Built Environment, Johannesburg, P.O.Box 17011, 2028, South Africa (phone: +27 11 559 6817; e-mail: emuzenda@uj.ac.za; muzendae@biust.ac.bw).

Innocent Mandla Msibi is Group Executive of Innovation and Impact, Water Research Commission, Pretoria; Research and Innovation Division, University of Johannesburg, South Africa (phone: +27 12 330 0344; e-mail: mandlam@wrc.org.za).

Tofu Mbuyiselo is a research officer at the Process, Energy and Environmental Technology Station (PEETS), University of Johannesburg, South Africa (phone: +27 559 6708; e-mail: mbuyiselot@uj.ac.za).

assessed in terms of certain strength and water absorption property measurements.

II. MATERIALS AND METHODS

A locally produced CEM II Ordinary Portland-Lime (OP-L) blended cement type conforming to the BS EN 197 [11] was used for the study. The Blaine fineness of cement was 0.42 m^2/g and its density was 3.1 kg/m^3. Table I summarizes the chemical composition of cement used in herein.

TABLE I
Summary of chemical constituent of cement used in the study

Chemical Composition	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO
(%)	1.78	32.14	4.13	60.31	1.23
Chemical Composition	TiO_2	SO_3	K_2O	Na_2O	LOI
(%)	0.06	3.17	0.73	0.28	12.35

Physical properties from preliminary test results of the constituent materials are shown in Table II. The fine aggregate used was sharp sand of 7 mm specific maximum size gotten in South Africa conforming to the British Standard Specification [12] and water absorption of 3.0%. Sufficient quantity of GAP powder as industrial waste from a ship harbor in Cape Town, South Africa was initiated in the study with similar chemical and physical characterization reported in works by [9], [10]. An aqueous solution of acrylic-based superplasticizer was added to the mixture up to 30% when needed so as to keep a balanced workability level.

TABLE II
Summarized physical properties of sand initiated in the study

Parameters	Sand
Specific Gravity	2.55
Bulk Density (Kg/m^3)	
Uncompacted	1375
Compacted	1428
Void (%)	10.24
Moisture Content (%)	3.59
Sieve Analysis	
Fineness Modulus (m^2/Kg)	2.53
Coefficient of Uniformity (Cu)	8.05
Coefficient of Gradation (Cg)	1.04

The mix proportion used for this study was 1:3 and the OP-L/GAP substitution was computed by weight with W/C ratio of 0.45. The proportions of OP-L/GAP waste powder in the plaster were 100:0% (as control), 90:10%, 85:15% and 80:20% respectively. The use of GAP waste powder as partial aggregate replacement did not reveal any segregation challenges and the outcomes of the resultant mixtures had closely similar characteristics to traditional ones. Fig. 2 shows the GAP industrial waste powder. For the 15 and 20% replacement rate, the specimens were found to significantly decrease in workability and as such, a 0.5 and 1% dose of superplasticizer was added by weight to the respective mixtures to achieve a balanced workability. For the respective plaster mixtures investigated in accordance with British Mix Design (DOE) method, 100 mm cubic specimens were produced, cured by full submergence in water for 7 days and air dried for 21 days at room temperature. In accordance to the BS 8110 and UNI EN 1015-11, the compressive and flexural strengths of the plaster specimens were determined by observing the strength loss for every increased dose of the GAP industrial waste powder at various curing periods.

Fig. 2. Pictures showing the fine state of glass activated plastic (GAP) industrial waste powder

IV RESULTS AND DISCUSSIONS

The Fig. 3 below shows the flexural strength development with time of the tested plasters with increasing addition of GAP waste as partial aggregate volume replacement. The outcome of the tests revealed that the addition of GAP led to a limited decrease in the flexural strengths of plasters over time, plausibly due to the presence of glass fibres.

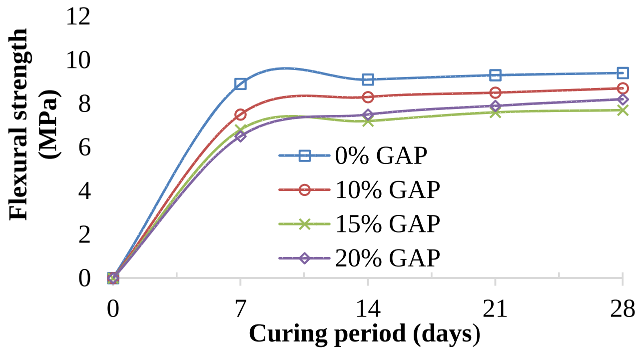

Fig. 3. Flexural strength development over time of tested plasters produced from GAP waste powder

However, aggregate replacement with GAP waste triggered a high decrease in compressive strength of up to 37% as shown in Fig. 4 depending on the percentage replacement. This may be as a result of the lower stiffness of the GAP waste powder compared to sharp sand and the low glass content which was therefore, unable to develop any pozzolanic activity.

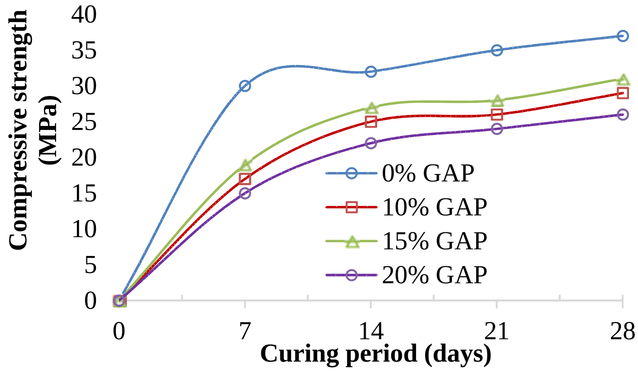

Fig. 4. Compressive strength development over time of tested plasters produced from GAP waste powder

V CONCLUSIONS

Various studies have been documented on durability and ecofriendly platers/mortars produced from the use of glass activated plastic (GAP) industrial waste. However the study herein, reported several tests conducted on cement plasters formed by the replacement of aggregate with GAP industrial waste in a range of 0-20%. Outcomes of the study revealed the following:

- That a decrease in mechanical strength of up to 37% depending on the percentage replacement of the GAP industrial waste powder was recorded in the study.
- That the recorded decrease could most likely play the role of an enhancer towards the durability of the GAP industrial waste plaster specimen.
- The results demonstrated the potential of re-using/recycling an abundantly available industrial by-product, presently destined to landfills in most countries for the production of durable precast members.
- The product of this study may be utilized in cases where no structural complexities are required without compromising standards and as such, contribute to curbing environmental challenges with respect to solid waste disposal.

However, future investigations would be conducted to account for possible environmental contamination that may result from the leaching of toxic substances from the GAP waste plaster.

ACKNOWLEDGMENT

The Authors appreciate the University of Johannesburg where the study was done.

REFERENCES

[1] Malhotra V.M. 2003. Concrete Technology for sustainable development, *Proceedings of the two-Day International Seminar on Sustainable development in Cement and Concrete Industries, Milan, Italy, 17–18 October 2003*.

[2] Hendriks C.F. Janssen G.M.T. 2003. Use of recycled materials in constructions, *Materials and Structures* 36 (11): 604–608.

[3] Damtoft J.S. Glavind M. Munch-Petersen C. 2003. *Proceedings of the two-Day International Seminar on Sustainable development in Cement and Concrete Industries, Milano, Italy, 17–18 October 2003*.

[4] Kelderman H. 2000. Recycling Manager Europe Thermosets, After almost 10 years. *Proceedings of the Ercom Conference of the European Alliance for SMC, Brussels 14 November, 2000.*

[5] Corinaldesi V. Gnappi G. Montenero A. Moriconi G. 2003. Re-use of recycled glass as aggregate for mortar and concrete (in Italian), *Proceedings of the 4th International Congress Added Value and Recycling of Industrial Waste, L'Aquila, Italy, June 24-27, 20.*

[6] Ambrosie J. Pera J. 2003. Durability of glass-fibre cement composites–comparison between normal Portland and Calcium Sulfoaluminate cements, *Oral presentation at Sixth CANMET/ACI International Conference, Thessaloniki, Greece, 1–7 June 2003*.

[7] Quian X. Shen B. Mu B. Li Z. 2003. Enhancement of aging resistance of glass fibre reinforced cement, *Materials and Structures* 36(6): 323–329.

[8] Zhao S. 1995. Microstructure and properties of styrene acrylate polymer cement concrete, *Heron* 40(4): 263–284.

[9] Tittarelli F. Moriconi G. Pauri M.G. Favoni O. 2004. Re-use of GRP industrial waste in new blended cements, *Proceedings of the VII Congresso AIMAT, Ancona, Italy, 29 June-2 July 2004. Published on CD-ROM*.

[10] Tittarelli F. Moriconi G. 2005 Re-Use of GRP Industrial Waste in Cementitious Products, In R.K. Dhir et al. (ed.), *Proceedings of the International Conference on Global construction: ultimate concrete opportunities, Young researcher's forum, Dundee, Scotland, 7 June 2005.* ISBN: 0 7277 3407 5: 153–164. London, Thomas Telford Publishing, United Kingdom.

[11] American Society for Testing and Materials, ASTM 2008. *Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete,* ASTM C 618, 2008.

[12] British Standard Institution, *Cement- Composition, Specifications and Conformity Criteria for Common Cements,* BS EN 197: Part 1, London.