Weight Reduction Study Of Polycrete-An Asbestos-Free Building Material Product

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ABSTRACT: Motivated by the dual need of developing alternative non-carcinogenic building material products from local raw materials and the need for sustainable solid waste management of polyethylene packaged water sachets waste in Nigeria, an asbestos-free composite material, *polycrete*, viable for use as ceiling and partitioning boards in buildings was recently developed by the author. The technical viability of forming a durable composite material from polyethylene fibers (shredded/granulated polyethylene sachets- poly-fibers), and cement in durable economic mix ratio of 1:4 by volume (i.e. one part of cement with 4 parts of fiber) was established with test specimens cast in plastic moulds as presented at RETAV Conference 2009, at Obafemi Awolowo University, Ile-Ife, Nigeria. In order to meet workability requirements (for easy penetration of nails), some amount of paper was also added to introduce some ductility to the mix. Building on the success of initial trials with model specimens, prototype ceiling boards, 600mm x 600mm in size are now being investigated for production. Replicating the mix ratios as established for the model specimens in the prototype production, final product weight of 4.4kg per piece was achieved. It was considered desirable to reduce the weight per product to about 3.5kg so as to be comparable with lighter ceiling products made from gypsum (Plaster of Paris - POP). Various combination weights of Portland cement, poly-fibers, waste paper, and water were varied with the objective of producing a 600mm x 600mm prototype with a product weight not exceeding 3.5kg. This paper presents results of the trials and establishes a minimum weight of 2.5kg Portland cement, 0.5kg poly-fiber, 0.1kg paper and 2.25kg of water to produce a 600mm x 600mm by 5.0mm thick ceiling board with a product weight of 3.35kg. Production process was replicated several times with durable prototypes being formed each time. A comparable asbestos-cement ceiling sheet (produced by Nigerite - 1.2m x 1.2m x 3.5mm thick in dimension - four times the surface area of polycrete product) weighs 8.0kg. In addition to the asbestos-free attribute of polycrete, other obvious advantage of Polycrete Decorative Ceiling board over the Nigerite product is the artistic pattern design embossed on it, making it aesthetically more pleasing to home owners than the plain version of Nigerite product.

Keywords: polyethylene fibers, polycrete, asbestos-free, building materials, composite materials, mix ratio

1 Introduction

The technical viability of forming a durable composite building material product, **polycrete**, by mixing shredded polyethylene fibers and cement in economic mix ratio of 1:4 by volume was established by the author and presented at the November 2009 RETAV Conference of Obafemi Awolowo University. In order to account for possible production imperfections and to accommodate larger body stresses in the prototypes, an economic durable mix ratio of 1:3 by volume was recommended for production of prototypes. [1] Building on the success of initial trials with model specimens, prototype ceiling boards, 600mm x 600mm in size are now being investigated for production. Replication of the mix ratios as established for the model specimens in the prototype, produced final product weight of 4.4kg per piece. It was considered desirable to reduce the weight per product to about 3.5kg so as to be comparable with competing technologies of ceiling products made from gypsum (Plaster of Paris-POP) and asbestos-cement. Various combination weights of Portland cement, poly-fibers, waste paper, and water were varied with the objective of producing a 600mm x 600mm prototype with a product weight not exceeding 3.5kg.

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This paper presents results of the trials and establishes a minimum weight of 2.5kg cement, 0.5kg polyfiber, 0.1kg paper and 2.25kg of water to produce a 600mm x 600mm by 5.0mm thick ceiling board with a product weight of 3.35kg. Production was replicated several times with durable prototypes being formed each time. A comparable asbestos-cement ceiling sheet produced by Nigerite , 1.2m x 1.2m x 3.5mm thick in dimension (four times the surface area of polycrete product) weighs 8.0kg. In addition to the asbestos-free attribute of polycrete, other obvious advantage of polycrete ceiling board over the Nigerite product is the various architectural patterned designs that comes with it, making it artistically more pleasing to home owners than the plain version of Nigerite product.

2 Materials and Methods

Materials used in this study include:

i. Packaged Water Polyethylene Sachets Waste
ii. A Hammer Mill for shredding/granulating waste polyethylene
iii. Portland Cement
iv. 600mm x 600mm Patterned Moulds
v. Water, trowel, Straight Edge and Range
vi. Weighing Balance

a. Hammer Mill Design Features

In the initial model trials of this product development, it was observed that the fibrous type of poly-fiber bonded better than the granulated type due to more interlocking potential possessed by the former. [1] The ability to produce more of the fibrous type of poly-fibers was therefore identified as a major focus of the previous study [1]. Thus, the author collaborated with other researchers at the Department of Mechanical Engineering , Obafemi Awolowo University [2] so as to apply mathematical modeling techniques to determine the best machine components (such as, type of hammers, screen aperture size and shape, shaft speed etc.) to produce the right type of hammer mill for production of the fibrous poly-fibers.

Certain design features of a hammer mill (Fig. 1) influence the type of poly-fiber particles that are produced. Thus the aperture size and shape of the screen slots were varied (i.e. round holes versus slits) to determine the shape that produces more of thread-like particles rather than granules. The larger the size of the slots, the faster ground materials are output. The longer materials stay in the grinding chamber, the greater the tendency for the polyethylene materials to melt thus forming more of granules rather than the fibrous type. An optimal size/shape of screen slots which produced the desired type of poly-fibers was thus obtained and used for the shredding process.

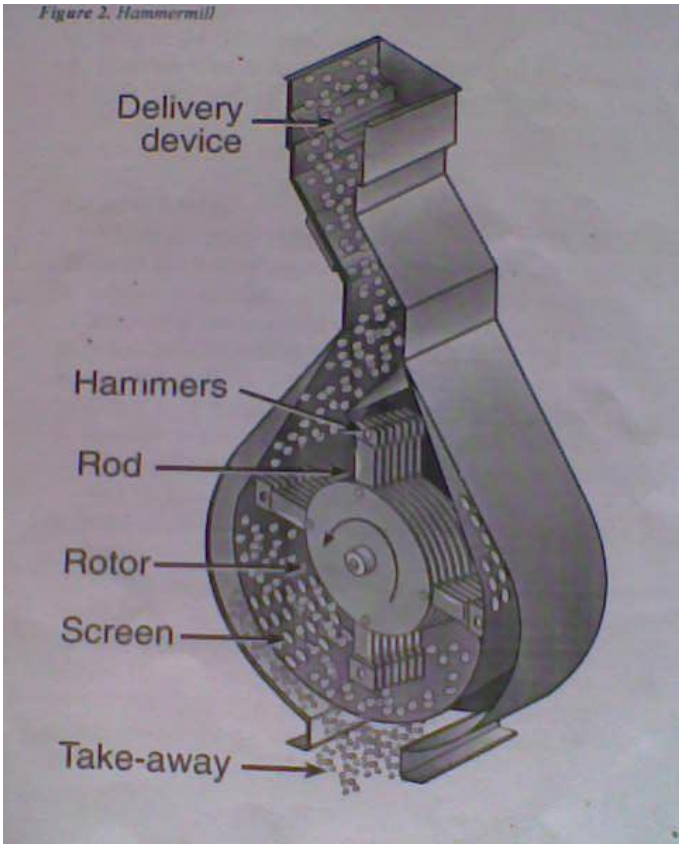

Fig.1 Main Components of Hammer Mill [2]

(Plate1a)

(Plate1b)

(Plate1c)

(Plate 1d)

Plate 1: Processing stages in the casting of polycrete model specimens and prototype: 1a- produced strands; 1b-cement and strands before mixing; 1c-forming of polycrete model specimen and 1d- two polycrete boards with one Nigerite cieling sheet.

3 Results and Discussion

Referring to Table I, the results of this study have shown:

i. The technical viability of producing lighter weight polycrete ceiling board prototypes of 600mm x 600mm size.
ii. Component material weights for Portland cement, poly-fiber, waste paper and water were varied to produce different weights and thicknesses of products. Using 3.5kg to 2.75kg cement content yielded products ranging from 10.00mm to 7.0mm thickness with product weights of 4.4 to 3.4kg. The formed products were stable but considered too bulky for ceiling board applications. They may become relevant in partitioning board applications.
iii. On account of the high "surface area-to-weight ratio" of paper, it was considered desirable to add some paper to the mix to enhance the ductility/workability of product.
iv. Cement content of 2.5kg, 0.5kg of poly-fiber, 0.1kg of paper and 2.25kg of water produced a stable prototype of 3.35kg (after 5 days of air-drying) with a moderate thickness of 5.0mm which compares favorably with competing technologies of asbestos-cement and gypsum ceiling products. A high Water-Cement (W/C) ratio of 0.9 was necessary to allow easy flow of mix into deeper parts of mould.
v. 600mm x 600mm x 5.0mm polycrete ceiling boards has moderate weight of 3.35kg and a unit weight of 1860.0kg/m^3 compared with 1587.0kg/m^3 for Nigerite asbestos-cement sheet and 2,400.0kg/m^3 for standard 1:2:4 concrete respectively.
vi. In addition to the desirable asbestos-free attribute of polycrete, other obvious advantage of polycrete ceiling boards over the Nigerite product is the various architectural patterned designs embossed on it, making it artistically more pleasing to home owners than the plain version of Nigerite product.

Table I: Summary of Prototype Production Trials

Product Components	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Portland Cement (kg)	3.5	3.0	3.0	3.0	3.0	2.75	**2.5**	2.25
Poly-fiber (kg)	1.0	0.6	0.6	0.5	0.5	0.5	**0.5**	0.5
Paper (kg)	0	0.18	0.15	0.15	0.1	0.1	**0.1**	0.1
Water (kg)	4.0	3.75	3.0	3.0	2.62	2.25	**2.25**	2.25
Product Weight w_p (kg)	4.4	3.95	3.95	3.7	3.7	3.4	**3.35**	2.95
Product Thickness t_p (mm)	10.0	9.0	8.0	7.0	7.0	6.0	**5.0**	4.5
Product Quality	O.K.;But too bulky	O.K.;But too bulky	O.K.;But too bulky	O.K.	O.K.	O.K.	**O.K.**	**Not O.K. – Broke up into pieces; inadequate Bonding**

4 Conclusion

The results of this study have shown that a durable engineered composite material - **polycrete** can be formed by mixing shredded polyethylene fibers with cement and paper in specific optimized proportions as determined in this study. Polycrete has a good promise of replacing asbestos-cement products in ceiling boards and partitioning wall applications in building construction. A 600mm x 600mm x 0.5mm polycrete ceiling board is produced with 2.5kg cement, 0.5kg of poly-fiber, 0.1kg of paper and 2.25kg of water. The polycrete board with an area of 0.36m^2 has a product weight of 3.35kg compared with an asbestos-cement sheet of 1.44m^2 area and weight of 8.0kg. In addition to the asbestos-free attribute of polycrete, other

obvious advantage of Polycrete Decorative Ceiling Boards over the Nigerite product is the various architectural patterned designs embossed on it, making it artistically more pleasing to home owners than the plain version of Nigerite product.

5 References

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