Case Studies in Construction Materials 8 (2018) 299–314

Contents lists available at ScienceDirect

Case Studies in Construction Materials

journal homepage: www.elsevier.com/locate/cscm

Case study

Study of mechanical properties and recommendations for the application of waste Bakelite aggregate concrete

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ARTICLE INFO

Keywords:
Waste Bakelite
Aggregate
Concrete
Mortar

ABSTRACT

Bakelite waste from industrial manufacturing may be a hazard to the environment and public health. The utilization of waste Bakelite (WB) to replace natural aggregates (NA), such as natural coarse aggregate (NCA) and natural fine aggregate (NFA), in concrete and mortar is an approach for reducing both waste plastic and natural material. This research examines the utilization of waste Bakelite aggregate (WBA) in concrete and mortar mixtures to form waste Bakelite aggregate concrete (WBAC) and waste Bakelite mortar (WBM). The tests cover the physical and chemical properties of WBA, the mechanical properties of WBAC and WBM (including the extraction of chemical substances from WBA utilization to replace NCA and NFA), and recommendations for the application of replacement. The results indicate that WBA particles of different sizes can replace both fine and coarse natural aggregates. Its weight is less than natural aggregate but the absorption rate is higher. As for recommendations for the application, it was found that replacing 20% of NCA with waste Bakelite coarse aggregate in concrete (WBAC-RNCA) was the most suitable proportion, owing to its mechanical properties and safety for the environment and public health, and because its material cost is acceptable. However, the use of waste Bakelite fine aggregate to replace NFA (WBAC-RNFA) in concrete is not appropriate, because its mechanical properties are not sufficient, and it is considered unsafe for the environment and health. Moreover, WBM is not a suitable material for plastering work, since it may be a hazard to the environment and public health, and its cost is higher than conventional mortar.

1. Introduction

Waste Bakelite is a thermosetting plastic, which is a waste product from the auto industry in Thailand. The waste volume, which is increasing every day, creates a waste management problem. This type of waste is not suitable for re-use. But recycling waste Bakelite as a component in other materials, primarily as a constituent in concrete and mortar, is an effective way to reduce the amount of waste. Many researchers have studied the use of many types of plastic waste as aggregate in concrete or cement mortar [4–10].

Currently, the demand for concrete and mortar in Thailand has a high growth rate and continues to rise, along with the growth of the construction industry. Therefore, the study of the utilization of waste Bakelite (WB) to replace natural aggregate (NA) (including natural coarse aggregate (NCA) and natural fine aggregate (NFA)) in concrete and mortar may lead to more effective means of reducing both plastic waste and the use of natural material. The physical, mechanical and chemical properties of raw Bakelite are

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https://doi.org/10.1016/j.cscm.2018.02.006
Received 25 August 2017; Received in revised form 4 February 2018; Accepted 5 February 2018
Available online 20 February 2018

Table 1
Physical and mechanical properties of Bakelite raw material [1,2].

Item	Property	Product name		Unit
		HEXION	Sumitomo Bakelite Durez	
1	Physical properties			
1.1	Specific gravity	1.42	1.39	g/cm^3
1.2	Water absorption	–	0.60	%
2	Mechanical properties			
2.1	Compressive strength	250	193	MPa
2.2	Tensile strength	50	55	MPa
2.3	Flexural strength	95	69	MPa
2.4	Modulus of elasticity	7500	–	MPa
2.5	Shear strength	–	76	MPa
2.6	Linear shrinkage	–	0.011	cm/cm
3	Thermal resistivity			
3.1	Specific heat capacity	–	1.42	J/g-Celsius
3.2	Thermal conductivity	–	0.402	Watt/m-K

shown in Tables 1, 2 and 3.

2. Materials and methods

2.1. The transformation of waste bakelite into waste bakelite aggregate

The process of transforming waste Bakelite into waste Bakelite aggregate comprises several stages: waste Bakelite size reduction, waste Bakelite aggregate classification by sieve, waste Bakelite fine and coarse aggregate utilization in cement mortar and concrete, and sample testing.

2.1.1. Waste Bakelite size reduction and classification by sieve

The reduction of WB in a hammer mill and classification by sieve follows the procedure used by Usahanunth and Tuprakay [11], the process is illustrated in Fig. 1.

After the size reduction process, the milled aggregates consists of various particle sizes. The U.S. sieve No. 4 (4.75 mm) was used to separate waste Bakelite fine aggregate (WBFA) from the waste Bakelite coarse aggregate (WBCA). The particles that passed through sieve No. 4 were classified as fine aggregate, and those with a grain size larger than 4.75 mm were utilized as coarse aggregate.

2.1.2. Sieve analysis of waste Bakelite aggregate

The sieve test for WBFA and WBCA can be represented by the following gradation curve, shown in Figs. 2 and 3.

2.1.3. Waste Bakelite aggregate utilization in concrete and sample test

The use of WBFA as fine aggregate in cement mortar has been studied by Usahanunth and Tuprakay [11]. In this paper, the follow-up of their study involves an extended study of the use of WBCA and WBFA in concrete.

2.2. Component of materials and mixed design

In this study, the materials for mixing concrete include the following: (1) Portland cement Type 1, conforming to the specification of TIS15-2547 [12]; (2) natural fine aggregate (NFA), which is natural sand and follows ASTM C136 [13], as shown in Fig. 4(b); (3) natural coarse aggregate (NCA), which is crushed stone and follows ASTM C136 [13], as shown in Fig. 5(b); (4) waste Bakelite fine aggregate, conforming to ASTM C136 [13], shown in Fig. 4(a) and used to replace NFA; (5) waste Bakelite coarse aggregate used as

Table 2
Chemical composition of Bakelite [3].

Composition (wt.%)			
Ultimate analysis		Proximate analysis	
Total carbon	53.4	Fixed carbon	31.70
Hydrogen	4.0	Volatiles	47.55
Oxygen	11.6	Moisture	3.01
Sulfur	0.017	Ash	17.74