A Study Bakelite Plastics Waste from Industrial Process in Concrete Products as Aggregate

Seree Tuprakay
Faculty of Engineering, Ramkhamhaeng University, Huamark, Bangkapi, Bangkok, Thailand 10240
Email: aj.seree.t@gmail.com

Nopagon Usahanunth and Sirawan Ruangchuay Tuprakay
Faculty of Engineering, Ramkhamhaeng University, Bangkapi, Bangkok, Thailand 10240
Faculty of Science and Technology, Suan Dusit University, Bangplad, Bangkok, Thailand 10700
Email: konthai98@yahoo.com, sirawanr@gmail.com

***Abstract*—Bakelite is prohibited to dispose for direct land filling and open burning because of the unsafe disposal and emission reasons. The purposes of this research are characterization of BPW and using BPW as aggregates in concrete products. The physical characteristics of BPW, the bulk specific gravity was 1.30-1.40 g/cm^3. Chemical composition of BPW, total carbon, hydrogen, oxygen and sulfur was 53.4, 4.0, 11.6 and 0.017%, respectively. Composition of ash of Bakelite, CaO, SiO_2 and SO_3 was 94.53, 5.14 and 0.33%, respectively. pH value of BPW and fine Bakelite plastics waste (FBPW) was 8.10 and 12.00, respectively. Water absorption capacity of BPW and FBPW was 0% and 25%, respectively. After grinding, BPW become FBPW. The water absorption of FBPW was 25%. Using BPW as aggregates in concrete products by preparing and testing mortar samples with 0%, 20%, 40%, 80% and 100% replacement percentage at each curing age 7, 14 and 28 days. Based on a testing standard of American Society for Testing Material (ASTM). The specimen test results showed that the compressive strength and density of Bakelite plastics waste Mortar (BPWM) was lower than Conventional Mortar (CM). The compressive strength decreased with increasing of replacement percentage and it increased with curing time.**

***Index Terms*—Bakelite plastic waste, concrete products, aggregate**

I. Introduction

The global demand for plastics had grown significantly over [1], with the worldwide consumption approaching ~100 million tons per year [2], Ref. [3] explained that Bakelite or polyoxybenzylmethylenglycolanhydride was developed in 1907 by Belgian chemist, Leo Baekeland. In 1993, it was designated a National Historic Chemical Landmark by the American Chemical Society in recognition of its significance as the world's first synthetic plastic. Many researcher study about properties of Bakelite [4]-[14]. It is a thermoset phenol formaldehyde resin commonly used for parts of automobiles, electric insulators components, telephone casings and heat resistant properties in kitchenware, and is formed from an elimination reaction of phenol with formaldehyde [3]. These products are suitable for their durability [15]. Calcium carbonate ($CaCO_3$) is found in the polymer as a filler material, and limited published research exists on the recycling of thermosets. It cannot be remelted to form a new product, and are landfilled or incinerated, both of which lead to environmental problems [1, 16]. Toxic effects of Bakelite are due to the presence of phenol as well as methyl and ethyl alcohols. The influence of Bakelite on water quality can be seen in an increase in oxidisability and in the appearance of phenol in the water. Hence disposal of Bakelite should be avoided to prevent water pollution [3].

Cross-linked polymers are formed when long chains are linked in one gigantic. Addition and condensation polymers can exist with a cross-linked network, depending on the monomers used in the synthesis. Familiar examples of cross-linked polymers are Bakelite, rubber, and casting (boat) resin [17]. Bakelite waste is used for many process to disposal and recycling [3, 18, 19]

II. Materials

A. Portland Cement Type 1

Cement powder used for mixing in concrete. This material is available in the local market and this cement produced conforming to the specification of TIS15-2532 [20].

B. Natural Fine Aggregate (NFA)

The Natural Sand used as fine aggregate complied to ASTM C136 [21] which dry bulk specific gravity is 1,602 kg/m^3 [22] as shown in Fig. 1.

C. Water

Water quality which can be used to mix in mortar mixture shall comply with ASTM C1602 [23].

Manuscript received July 5, 2017; revised November 11, 2017.

doi: 10.18178/ijscer.6.4.263-267

Figure 1. Natural fine aggregate.

D. Bakelite plastics Waste (BPW)

BPW (Fig. 2) was highly functional plastic products centering on phenol resin products. It used in various automobile-related products due to the outstanding properties achieved by its strong network bridge structure, such as high heat resistance and good chemical resistance. After grinding BPW was size reduction as fine Bakelite plastics waste (FBPW) (Fig. 3)

Figure 2. BPW from automotive components manufacturing.

Figure 3. FBPW.

III. Procedure and Eauipment

The type I Portland cement was used as the main binder in the experiment and was mixed with water and aggregates by mixer. According to ASTM C 192, aggregate and approximately 70% of total mixing water were added to the wetted mixer. Then start the mixer, cement was added simultaneously. The remaining mixing water was gradually added to ensure the uniform blending. However the total mixing time was not lower than 10 minutes. After mixing, it was used to consolidate the concrete into the 5x5x5 cm^3 cubic mold (Fig. 4) and was taken to analyze compressive strength at appropriate time by compressive strength test machine (Fig. 5) according to the ASTM C109. After 24 hours, all of the specimens were demolded and cured in the moisture room until the time of testing.

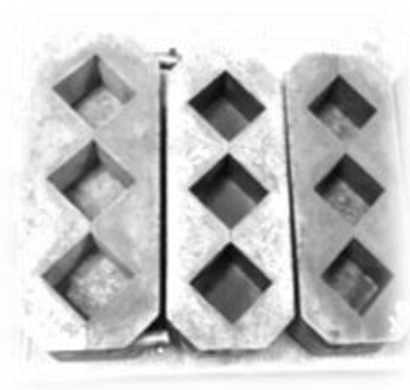

Figure 4. Cubic Molds.

Compressive strength is the most important commonly concerned property of hardened concrete, because other properties such as bonding or durability are related to the compressive strength.

Figure 5. Compressive strength test machine.

IV. Result

A. The Characteristics of BPW

1) Physical characteristics of BPW

1.1) Bulk Specific Gravity

Bulk Specific Gravity can be used to preliminarily evaluate chemical compositions, noncombustible material, voids and fineness of the material. Moreover, it is significant in designing the mix proportion and unit weight of concrete. In Table I, a comparison of bulk specific gravities of BPW, Portland cement, sand and crushed stone are tabulated.

TABLE I. BULK SPECIFIC GRAVITIES OF MATERIAL

Material	Bulk specific gravity
BPW	1.30-1.40
Portland cement	3.12-3.15
Sand	2.65
Crushed stone	2.70

1.2) Particle Size Distribution

BPW was grinded with hammer mill cutting machine. This milling machine mesh size used 5 mm and 10 mm for waste Bakelite size reduction. The particle size of BPW at various grinding time was shown in Fig. 6.

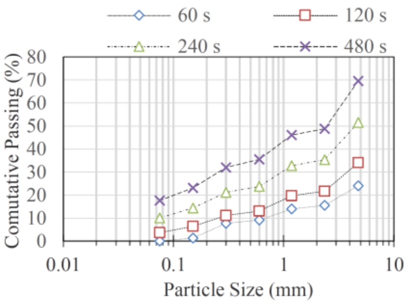

Figure 6. Particle size of BPW.

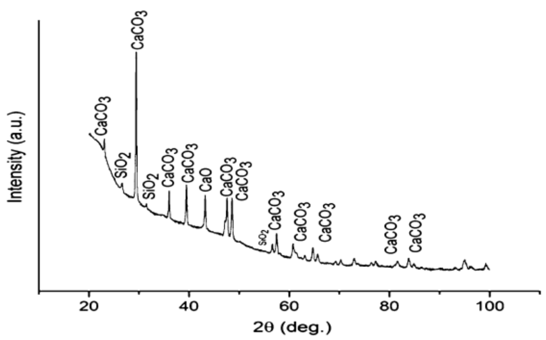

Figure 7. X-ray diffraction pattern of BPW. [18]

2) Chemical characteristics of BPW

2.1) Chemical composition

Chemical composition of material can be used to predict the behavior of the material in the environment as well as in its applications. The Chemical composition of BPW was characterized by XRD showed mainly calcium carbonate with a small amount of silica impurity (Fig. 7). Chemical analysis of BPW is also given in Table II and III.

Total carbon, hydrogen, oxygen and sulfur of BPW was 53.4, 4.0, 11.6 and 0.017%, respectively. Composition of ash of BPW, CaO, SiO_2 and SO_3 was 94.53, 5.14 and 0.33%, respectively.

TABLE II. CHEMICAL COMPOSITION OF BPW [18]

Ultimate analysis	**Composition (wt. %)**	**Proximate analysis**	**Composition (wt. %)**
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

TABLE III. CHEMICAL COMPOSITION OF ASH OF BPW [18]

Compound	**CaO**	**SiO_2**	**SO_3**
wt.%	94.53	5.14	0.33

2.2) pH

pH value of BPW and FBPW was 8.10 and 12.00, respectively. The pH of material is an indication of how its leachate would behave in the real environmental as well as in the leaching test. Normally, high pH which contributes to high alkalinity would make it pass the regulatory LP-NO.6 test. Because most regulated metals remain insoluble at high pH solution.

2.3) Water Absorption Capacity

The results showed that water absorption capacity of BPW and FBPW was 0% and 25% , respectively. Water Absorption capacity of material is defined as the ability of an oven-dried material of absorb moisture in a 100% relative humidity environment. It may be sued as an indication of how much the material would take up water in the mix.

TABLE IV. COMPRESSIVE STRENGTH AND RELATIVE COMPRESSIVE STRENGTH AT DIFFERENCE PERCENT REPLACEMENTS AT 7-DAY CURING TIME

Percent replacement	Compressive strength (MPa)	Relative compressive strength (%)
0	5.33	100.00
20	3.73	69.98
40	1.27	23.83
60	0.40	7.50
80	0.00	0.00
100	0.00	0.00

TABLE V. COMPRESSIVE STRENGTH AND RELATIVE COMPRESSIVE STRENGTH AT DIFFERENCE PERCENT REPLACEMENTS AT 14-DAY CURING TIME

Percent replacement	Compressive strength (MPa)	Relative compressive strength (%)
0	9.13	100.00
20	4.46	48.85
40	1.86	20.37
60	1.53	16.76
80	0.46	5.04
100	0.00	0.00

TABLE VI. COMPRESSIVE STRENGTH AND RELATIVE COMPRESSIVE STRENGTH AT DIFFERENCE PERCENT REPLACEMENTS AT 28-DAY CURING TIME

Percent replacement	Compressive strength (MPa)	Relative compressive strength (%)
0	7.60	100.00
20	3.53	46.45
40	1.33	17.50
60	0.33	4.34
80	0.00	0.00
100	0.00	0.00

B. Utilization of BPW as Aggregates in Concrete Products

1) Effect of replacement percentage

The experiments using fine BPW as fine aggregates in concrete products by preparing and testing mortar samples with 0%, 20%, 40%, 80% and 100% replacement percentage. The results are shown in Table II IV V and VI for 7-day, 14-day and 28-day curing, respectively. The mortar specimens at 80 and 100% replacement were unable to remain as cubes. In all cases of the specimens, the compressive strength was dependent on the amount of fine BPW in the binder system. It was observed that when fine BPW substituted aggregates, compressive strength lower than the controls were obtained. The compressive strength and relative compressive strength decreased as the percentage of fine BPW in the mix was increased.

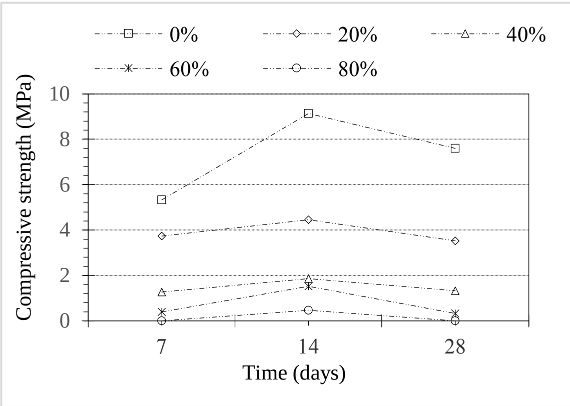

Figure 8. Compressive strength at difference curing time

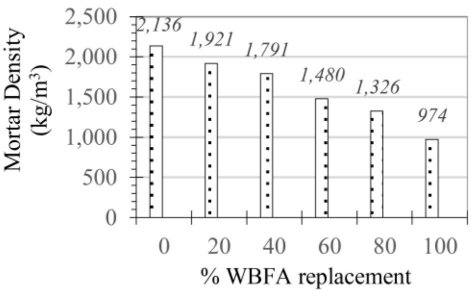

Figure 9. Density of Bakelite waste mortar at 28 days.

2) Effect of curing time

Fig. 8 shows the change in compressive strength with age at various replacement percentage. It is observed that, for all specimens, the compressive strength increased with curing time, but sample specimens notable increased the compressive strength of concrete compared to control concrete at all age (up to 28 days). The 28-days, density of Bakelite waste mortar was lower than conventional mortar which equal to 2,136 kg/m^3 as shown in Fig. 9 Density of Bakelite waste mortar decreased with increasing in replacement percentage of fine BPW. The minimum density of specimen (100 % replacement) is 974 kg/m^3 that is 54.41% lower than conventional mortar.

V. CONCUSION

1) The bulk specific gravity of BPW was 1.30-1.40 g/cm^3. Chemical composition of BPW, total carbon, hydrogen, oxygen and sulfur was 53.4, 4.0, 11.6 and 0.017%, respectively. Composition of ash of Bakelite, CaO, SiO_2 and SO_3 was 94.53, 5.14 and 0.33%, respectively. The pH value of BPW and fine BPW was 8.10 and 12.00, respectively. Water absorption capacity of BPW and FBPW was 0% and 25%, respectively.

2) The compressive strength and density of Bakelite plastics waste Mortar (BPWM) was lower than Conventional Mortar (CM).

3) The compressive strength of BPWM decreased with increasing of replacement percentage

4) The compressive strength of BPWM increased with curing time.

For further studies beyond this work, should to feasibility study to develop concrete product such as concrete block, curbs, concrete pipe and paving block on focus of economic, leaching test and social impact.

ACKNOWLEDGMENT

This research was funded by the Research and Development Institute, and Faculty of Engineering, Ramkhamhaeng University, Thailand. The authors are grateful to Mr. Pravin Rungrueng N.Y.C. Industry Co., LTD. for Bakelite waste support, and for advice from Assist. Prof. Dr.Waranon Kongsong, Assist. Prof. Dr. Suppachai Sinthaworn, Dr. Sathian Charoenrien, Finally, the authors would like to thank the four students; Junyong Nualsaard, Kotchakorn Thongsukha, Pawanrat Wancha-am and Naruemon Wongphanit from Environment Engineering Department, Ramkhamhaeng University for all off their fully support in sample preparing, test equipment and laboratory facilities.

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Dr. Seree Tuprakay was born in Nakorn Si Thamarat Province, Thailand, on 21 October 1972. Graduated in Doctoral of Engineering (D.Eng. Environmental Engineering) from Kasetsart University, Bangkok, Thailand, date of graduation is 21 November 2005.
He works at Faculty of Engineering, Ramkhamhaeng University, Huamark, Bangkapi, Bangkok, Thailand.

Mr. Nopagon Usahanunth was born in Phrae Province, Thailand, on 25 October 1964. Graduated in Master Degree of Business Administration from Burapha University, Chonburi, Thailand, date of graduation is 2004. He is Ph.D. candidate at Inspection and Engineering law, Faculty of Engineering, Ramkhamhaeng University, Huamark, Bangkapi, Bangkok, Thailand.

Dr. Sirawan Ruangchuay Tuprakay was born in Yala Province Thailand, on 5 June 1973. Graduated in Doctor of philosophy (Ph.D. Environmental Management) from Chulalongkorn University, Bangkok, Thailand, date of graduation is August 2007.
She works at Faculty of Science and Technology, Suan Dusit University, Bangplad, Bangkok, Thailand.