

A Study of the Properties of Bagasse Ash for the Possibility in Making Light Weight Block

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Abstract

This research aimed to investigate the properties of bagasse ash in producing light-weight concrete block. In this work, the bagasse ash from the sugar industries was used as the raw material in the production. It was found that bagasse ash is the pozzolan because it is mixed with many silica and alumina which strengthen the concrete. The researchers designed 13 formula for the mixing ratio among dried bagasse, bagasse ash, and Portland cement. The mechanical properties were then tested. As the experimental results, the compression strength had the significant relationship with three compounds at the level of $P < 0.05$. From the analysis of each formula, a mixture of 2 percent dried bagasse, 65 percent bagasse ash, and 33 percent Portland cement gave the optimal compression strength at 1.4 MPa while the general light concrete block had compression strength of 0.6 MPa with around 30 percent different. However, the formula can be further developed in the future.

Keywords: Compressive Strength; Bagassa ash; Pozzolan; Concrete; Compression

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Introduction

Sugar cane is one of the economic plants for export of Thailand. The popular planting areas are the central, western and north eastern regions. The survey during 2007 - 2008 showed that Thailand produced 73.31 metric tons of sugar cane. Moreover, the trend of sugar cane production increased during 2011 - 2014 as it was used to produce ethanol for adding in the gasohol fuel [1]. Being the main material for producing gasohol, this made the price of sugar cane significantly increased in the last three years. One ton of sugar cane used in sugar production gives around 300 kilograms of bagasse. In 2009, Thailand produced 66.8 metric tons of sugar cane [2]. After the process of sugar production, there remained 20 metric tons of bagasse. From previous researches, it was found that dry bagasse can be used for many purposes such as making plywood, pulp, plastics products and construction materials as discussed in Surin, P. and Buasri, K. [3] who studied the feasibility of production roof tile from bagasse fiber mixed with maize husk fiber. Their study confirmed the possibility in using dry bagasse in producing construction materials with higher strength. Apart from that, bagasse can be used as fuel in electricity production with around 0.70 metric tons of bagasse ash left after the process. Some bagasse ash will be used to produce fertilizer and to fill land. When studying the chemical composition of bagasse ash, it was found that silica which is the chemical compound of pozzolan was the major element. It is used as a compound for producing concrete when pulverized, because the bagasse composes of high silica oxide and alumina oxide of more than 50 percent. It can chemically react with base (calcium hydroxide) and can be soldered with concrete well. This encouraged many researchers to study the properties of bagasse as a mixing ingredient of concrete, and found that the minute bagasse is a good pozzolan. Moreover, Chusilp, N. et al. [4], [5] found that the appropriate ratio of minute bagasse mixture for cement concrete gave 20% higher strength than the concrete that is not mixed with bagasse [4] - [10]. The results also presented that the use of minute bagasse helps to decrease water permeability of concrete and to decrease the expansion of mortar regarding sulfate.

The light-weight block has four main components namely; Portland cement, sand, water and foam. It is a very popular construction material due to its better properties in heat protection, sound protection, light weight, and resistance to pressure, for example when compared to ordinary brick. However, due to the very high cost of light-weight block, people were inspired to find new material as a replacement. From the review of literature, it was found that bagasse ash is good in soldering with cement. It can be used to replace sand and also foam because it is easy to produce and cheaper. Consequently, the researchers have developed the material for producing

light-weight block using bagasse ash and bagasse which are the waste material from agricultural and industrial production process. This study used bagasse ash and bagasse as major materials to test the compressive strength in comparison with TIS. 2601 - 2556. The researchers, then, analyzed to find out the best compound through experiments towards cost reduction and design development for the use in other context.

Research Methodology

This section describes the research methodology used to study the properties of bagasse ash in making lightweight concrete as follows.

- 1) Material: Dry bagasse, Bagasse ash and Portland Cement.
- 2) Design of Experiment using Mixture Design method.
- 3) Product standard testing properties according to the TIS. 2601 - 2556: Compressive Strength.
- 4) Analysis of the best of ingredients that affect the compressive strength and desired properties.

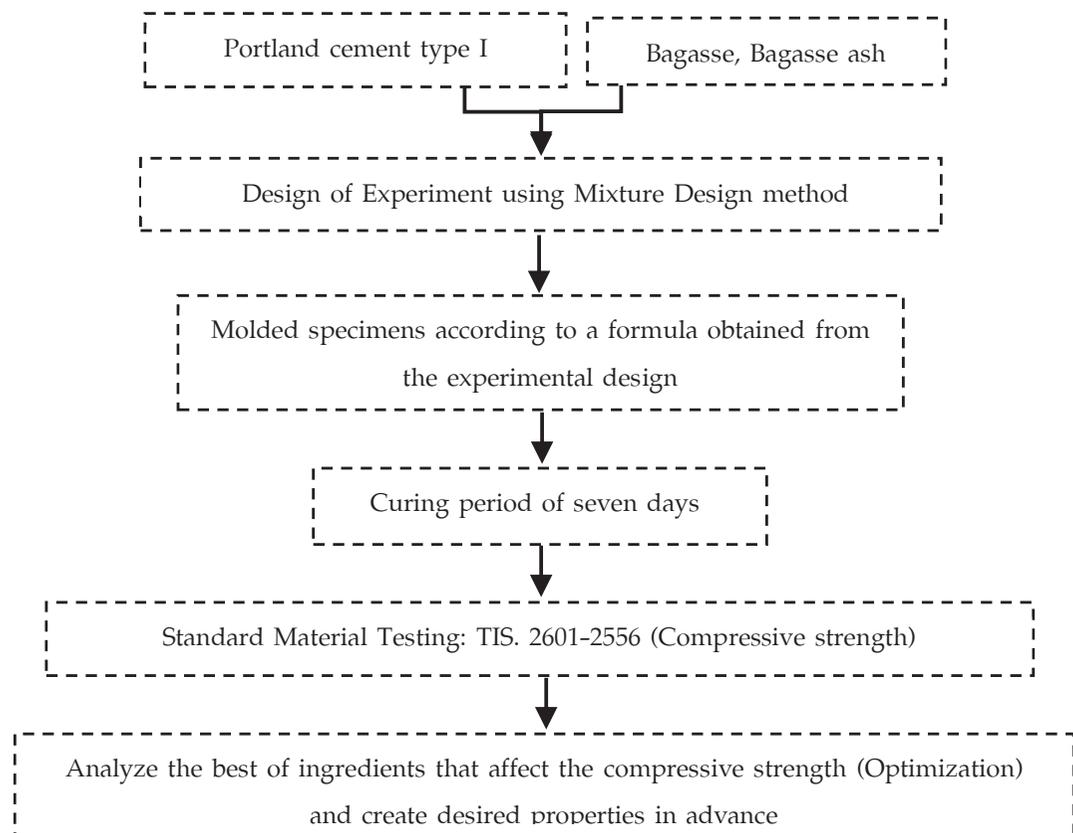


Figure 1 Research methodology diagram

1) Material: Dry bagasse, Bagasse ash and Portland Cement.

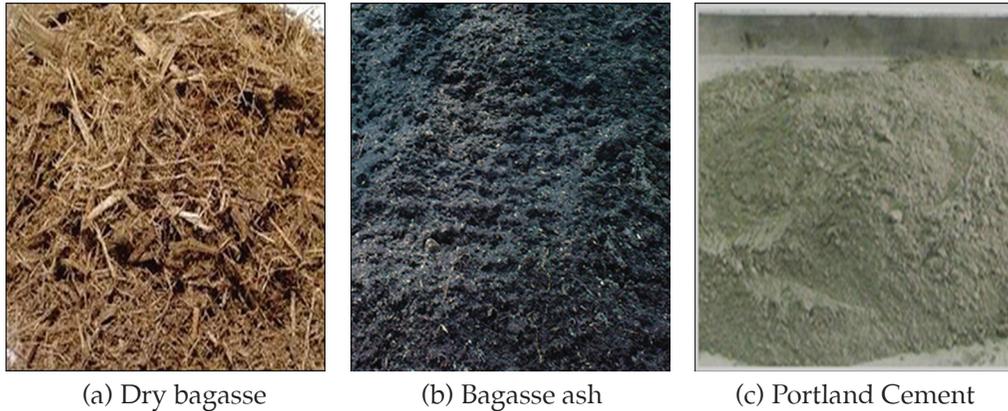


Figure 2 Material testing

2) Design of Experiment using Mixture Design Method

For the experimental design, this research employed Minitab program for the statistical analysis which can predict the results when analyzing problems. The experimental design mixed was used to analyze a mixture of dry bagasse, bagasse ash and Portland cement that affect the strength of the specimen. Then the material ratio of dry bagasse, bagasse ash and Portland cement was determined [11]. This research considered relevant factors such as the strength of the specimen. The design showed 13 recipes from all three ingredients as shown in Table 1 and then three testers were replicated per each ratio sample.

Table 1 Mix proportions of mortar

Ratio	Bagasse ash (%)	Portland Cement (%)	Dry bagasse (%)
1	65.3	31.3	3.3
2	65.3	31.0	4.0
3	67.5	32.3	2.0
4	65.7	31.7	2.7
5	65.0	32.3	2.7
6	65.0	31.7	3.3
7	65.0	33.0	2.0
8	66.3	31.7	2.0
9	65.7	31.0	3.3
10	66.3	31.3	2.3

Table 1 Mix proportions of mortar (cont.)

Ratio	Bagasse ash (%)	Portland Cement (%)	Dry bagasse (%)
11	67.0	31.0	2.0
12	65.3	32.3	2.3
13	66.3	31.0	2.7

- 3) Product standard testing properties according to the TIS. 2601 - 2556: Compressive Strength.

From the design of experiment, a total of 39 pieces of molding samples were made and the specimen was tested for its mechanical properties using TIS. 2601 - 2556 with the test of compressive strength. Finally, a comparison with commercially available lightweight concrete was made.

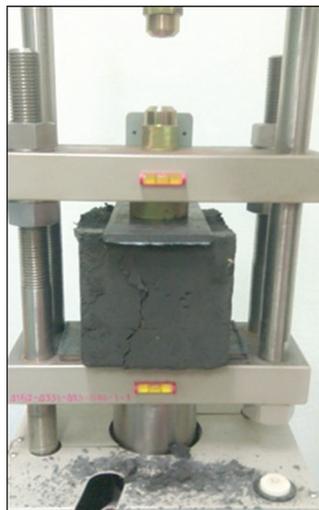


Figure 3 Compression testing machine

- 4) Analyze the best of ingredients that affect the compressive strength and create desired properties in advance.

Research Result

The experimental design was formulated to mix all 13 recipes. Each formula was then combined with all three pieces of the specimen to a total of 39 pieces. All mortars were casted to 150 * 150 * 150 -mm standard molds according to the Industrial Standards TIS. 2601 - 2556 and removed from the molds 24 hours after casting as shown in Figure 4.



Figure 4 The mixing ratio of raw materials made to design the specimen

After curing the specimens for 7 days based on the ACI 308R standard, all the specimens were tested for the mechanical properties by using the testing machine to determine the compressive strength with the results shown in Table 2.

Table 2 Result of compressive strength test with curing period of seven days

Formula	The compressive strength (MPa)			Average (MPa)
	Sample 1	Sample 2	Sample 3	
1	0.78	0.81	0.81	0.80
2	0.65	0.66	0.63	0.65
3	0.99	1.08	1.1	1.06
4	1.1	0.94	1.04	1.03
5	1.09	1.02	1.3	1.14
6	0.82	0.84	0.83	0.83
7	1.5	1.4	1.3	1.40
8	0.97	1.05	0.91	0.98
9	0.73	0.76	0.75	0.75
10	0.71	0.83	0.8	0.78
11	0.86	0.93	0.96	0.92
12	0.86	0.84	0.79	0.83
13	0.92	0.97	0.93	0.94

From Table 2, the 7th formula with a ratio of bagasse ash, Portland cement and dry bagasse as 65 : 33 : 2 gave the highest strength at 1.4 MPa due to higher portion of cement in the mixture (33%). Then, the regression coefficients and variance of the resistance of the compressive strength were estimated as shown in Figure 5 and 6, respectively.

Regression for Mixtures: MPa versus Bagasse ash, Cement, Bagasse

Estimated Regression Coefficients for MPa. (Component proportions)

Term	Coef	SE Coef	T	P	VIF
Bagasse ash	205	71.66	*	*	6878906
Cement	928	294.86	*	*	27090896
Bagasse	-609	483.57	*	*	545051
Bagasse ash*Cement	-2003	656.47	-3.05	0.004	57887206
Bagasse ash*Bagasse	536	656.47	0.82	0.420	431210
Cement*Bagasse	-514	656.47	-0.78	0.439	99810

S = 0.112054 PRESS = 0.526790
 R-Sq = 72.47% R-Sq(pred) = 65.00% R-Sq(adj) = 68.30%

Figure 5 The coefficient of determination (R^2) by Estimated Regression Coefficients (MPa)

Analysis of Variance for MPa. (Component proportions)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	1.09095	1.090948	0.218190	17.38	0.000
Linear	2	0.95209	0.138025	0.069012	5.50	0.009
Quadratic	3	0.13886	0.138860	0.046287	3.69	0.022
Bagasse ash*Cement	1	0.12049	0.116842	0.116842	9.31	0.004
Bagasse ash*Bagasse	1	0.01068	0.008383	0.008383	0.67	0.420
Cement*Bagasse	1	0.00769	0.007694	0.007694	0.61	0.439
Residual Error	33	0.41435	0.414350	0.012556		
Lack-of-Fit	7	0.30328	0.303283	0.043326	10.14	0.000
Pure Error	26	0.11107	0.111067	0.004272		
Total	38	1.50530				

Figure 6 Analysis of Variance ratio (Dry bagasse: Bagasse ash: Portland cement)

The coefficient of determination (R^2) was found by estimating regression coefficients for MPa in Figure 5. The last results of R^2 and adjust R^2 of this experiment were greater than 70%. According to the equation of Haaland [12] and the lack of fit testing in Figure 5, the P -value is smaller than the significance level of $\alpha \leq 0.05$ which means that this model is considered to be sufficient to fit the data. Furthermore, this information could lead to a prediction equation in order to determine the best response.

Then an equation to predict the compressive strength of light weight block using Dry bagasse, Bagasse ash and Portland cement was created as follows:

$$\begin{aligned}
 Y = & 20.5054 (\text{Bagasse ash}) + 92.7930 (\text{Portland}) - 60.8787 (\text{Dry bagasse}) - 20.0258 \\
 & (\text{Bagasse ash} * \text{Portland}) + 5.36397 (\text{Bagasse ash} * \text{Dry bagasse}) - 5.13893 \\
 & (\text{Portland} * \text{Dry bagasse})
 \end{aligned} \tag{1}$$

After that, the best result (Response Optimization) of the mixture of Portland cement, Dry bagasse and Bagasse ash affecting the compressive strength was tested for with the requirement of results of the experiment to have the most features (Maximum) according to Figure 7.

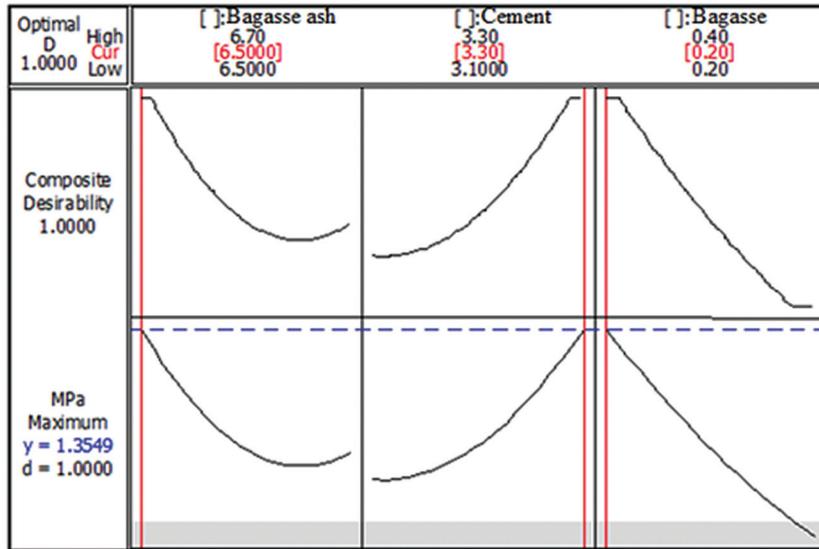


Figure 7 Determination of the Maximum Strength of light weight block

In Figure 7, the maximum compressive strength of lightweight concrete mixed with dry bagasse and bagasse ash was determined. The results from the analysis showed that the highest value at 1.355 MPa was given by the material ratio of 65 : 33 : 2 (Bagasse ash: Portland cement: Bagasse).

After that, the mixture ratio of 65 : 33 : 2 (Bagasse ash: Portland cement: Bagasse) were tested over three replicates and tested for the compressive strength. The test results showed ± 10 percent tolerances.

Results and Discussion

The average compressive strength of light weight block using bagasse and bagasse ash as raw material at 7 days curing was 1.4 MPa with the material ratio of 65 : 33 : 2 (Bagasse ash: Portland cement: Bagasse). The available light weight block in the market must have compressive strength at 2 MPa according to Standard no. TIS. 2601-2556. After comparing with the light weight block sample, this sample test using bagasse and bagasse ash as raw material had 0.6 MPa compressive strength lower than the standard one as shown in table 2 which was about 30 percent lower. However, the compressive

strength of the sample test can be increased with additional periods of curing as in the studies by Ozer, B. and Ozkul, M.H. [13] and make it possible to produce light weight block.

Conclusions

It was found that bagasse ash from sugar cane showed a property of being pozzolan material which can help to increase the strength and can be mixed with cement. Therefore, this research aimed to use bagasse and bagasse ash as raw materials for making lightweight concrete block. The study can be concluded as follows:

1. The average compressive strength of light weight block using bagasse and bagasse ash as raw material at 7 days curing was 1.4 MPa with the material ratio of 65 : 33 : 2 (Bagasse ash: Portland Cement: Bagasse).
2. The equation was created to predict the compressive strength of light weight block using dry bagasse, bagasse ash and Portland cement as follows

$$Y = 20.5054 (\text{Bagasse ash}) + 92.7930 (\text{Portland}) - 60.8787 (\text{Dry bagasse}) - 20.0258 (\text{Bagasse ash} * \text{Portland}) + 5.36397 (\text{Bagasse ash} * \text{Dry bagasse}) - 5.13893 (\text{Portland} * \text{Dry bagasse})$$

In this research, the compressive strength was considered for the possibility of using bagasses ash in making light weight block. However, further study can be conducted with additional properties being investigated including density and volume.

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