Binder Replacement in Casting Process of Rice Mill Cylinder by Pozzolan Material

Thitikan Boonkang, Nalin Pianthong, Tawanchai Pothom, Sukangkana Lee, Suapong Bangpan

Abstract— This research has objective to apply pozzolan material used as a binder material replacement coordinate with original binder material in rice mill cylinder casting. In present, the original binder is magnesium oxide cement which imported from abroad with an average value of 80 million baht per year. This research has selected pozzolan materials were rice husk ash, bagasse ash and metakaolin use in the experimental and replace total as 40% : magnesium oxide cement as 60% by design experiment with Minitab on mixture design function which has 10 formulation for compressive strength and tensile strength. It found formulation suitable was rice huck ash : bagasse ash : metakaolin as 15 : 25 : 60. When use this formulation to cast rice mill cylinder and test rice milling, it found average good rice percent : 80.12 and average wear rate : 4.43 g/hr. The original binder has average good rice percent : 76.02 and average wear rate : 7.02 g/hr.

***Index Terms*— pozzolan, binder material, rice mill cylinder, casting**

I. Introduction

In the past until present, rice milling machine has agriculture base machinery that important for Thai agriculturist. The agriculturist brought small rice milling machine which capacity as 1-2 ton/day to use increasing in the present because it has convenient and fastness for rice mill rice in family. Normally, small rice milling machine has different follow with locality. It separated two types were vertical axle and horizontal axle. The agriculturist used generally as horizontal axis which driven by electric motors because it was low price and easy purchased locally**.** However, rice quality depends on several factors such as grain shape, size, moisture and process of shelling and polishing [1]. The process of rice polishing is an important step and the quality of milled rice has broken rice percentage will be more or less depends on the quality of rice polishing

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cylinder [2]. Normally, the rice polishing cylinder has two composite materials were abrasive material and binder material [3]. The abrasive material has emery grain and silicon carbide. The binder material has magnesium oxide cement and magnesium chloride.

The casting process of rice mill cylinder was brought the shaft which made from cast iron to crack coating materials that worn out and casted by magnesium oxide cement and abrasive materials in a ratio of 1 to 5 by weight and mixed with magnesium chloride salt water has the degree of salinity as 30 degrees. After mixed everything, brought the mixture which has toughness to cast with cast iron core wrapped with a thickness of about 1 inch. Then dry out about 1 day, lathed it into surface allow to size that required. When lathing was finished, it can be used. However, the casting process must be careful was mixed magnesium oxide cement and magnesium chloride salt water has suitable toughness. This process uses skill and experience [4]. Because the rice mill cylinder has been too hard, it affects to broken rice. On the contrary, if rice mill cylinder has too soft. It affects to wear and short life time. The rice mill cylinder has ruined and poor quality. It can not be used again. Therefore, the study and development of binder materials has important to improve the casting process.

In present, the magnesium oxide cement is imported from abroad about 3,311 tons/year which valued average 80 million baht per year [5]. So, to decrease this material from abroad. It has idea to apply pozzolan materials in domestic which is a waste of the agricultural such as rice husk ash, bagasse ash and metakaolin mix with magnesium oxide cement to reduce production cost and to improve casting process [6]. Research of Jittima Pasaraae [7] about the study of rice husk ash mixed with lime in the block paving. It found rice husk ash which is burned at 650 ° C for 1 hour and passed through sieve 325 that the amount does not exceed 34 percent to mix with lime. So, it can make block paving. For bagasse ash, research of Phongsathorn Likitpiboon [8] studied the development of bagasse ash as pozzolan material which brought it which passed through sieve 325.Result of experiment was bagasse ash to replace portland cement type 1 about 10-40 percent. The research of metakaolin was Jaroenwut Panyanusornkit [9] about morta cement improvement for repair work. It found kaolin which was burned at 800 ° C for 6 hours to replace cement about 10-40 percent. The suitable replace was between 20-30 percent. Therefore, the application to bring pozzolan material in domestic for replacement cement imported from abroad. It is alternative to reduce production cost and increase value of pozzolan material.

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II. Research Method

A. Design of Experiment

In the experiment has separated 2 methods as below

1)The study which suitable proportion of pozzolan material by response two important sections were compressive strength and tensile strength. Then, it used suitable proportion of pozzolan material to cast rice mill cylinder.

2)Comparison testing of rice mill efficiency between original binder and binder which has pozzolan material by response two important sections were good rice percent and wear rate.

The factors which studied were rice husk ash, bagasse ash and metakaolin to set as x_1, x_2 and x_3. When evaluated by Minitab Release 14.00 Program in Mixture Design function for design of experiment that shown in TABLE I.

B. Scope of Research

1) The study of replacement binder from pozzolan material and tested the efficiency of rice milling between original binder and binder which has pozzolan.
2) This research has used mixture design from design of experimental by Simplex Centroid function [10-11] that shown in Fig.1 to investigate suitable proportion of pozzolan material.
3) Control factors were pozzolan material such as rice husk ash, bagasse ash and metakaolin which passed through sieve 325 and replace total as 40% : magnesium oxide cement as 60% [7-9].
4) The formulation to cast specimen and rice mill cylinder have proportion of abrasive material : binder material as 5:1 and tested rice milling efficiency with horizontal axle rice mill machine which popular in the localcity.
5) Rice for testing was Jasmine Rice 105 allow by industrial standard 888-2532 and rice must check moisture and cleaned to remove scrap that included. The rice milling for analysis factors to use rice in rate as 20 kg per one treatment.
6) Using Minitab Release 14.00 Program for evaluation and design of experiment by Mixture Design function to analysis and response surface method to investigate suitable proportion of pozzolan material.

TABLE I: PRORROTION OF POZZOLAN MATERIAL BY DESIGN OF EXPERIMENTAL

No.	Proportion of Pozzolan (%)			Composite Material	
	x_1	x_2	x_3	magnesium oxide cement (gram)	Abrasive Material (gram)
1	100	0	0	60	500
2	0	100	0	60	500
3	0	0	100	60	500
4	0.50	0.50	0	60	500
5	50	0	50	60	500
6	0	50	50	60	500
7	33.33	33.33	33.33	60	500
8	66.67	16.67	16.67	60	500
9	16.67	66.67	16.67	60	500
10	16.67	16.67	66.67	60	500

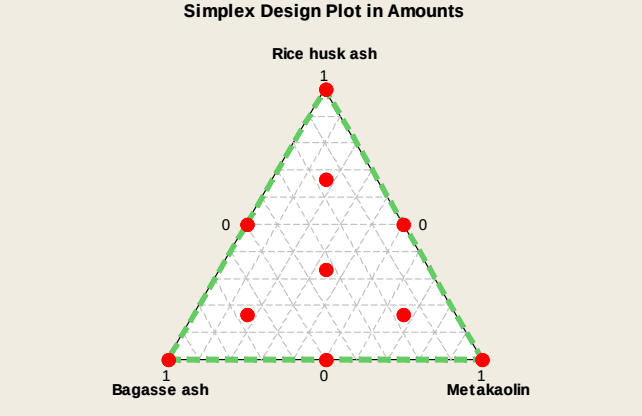

Fig. 1. Design of experiment as simplex centroid

III. Result and Discussion

A. Testing Result about Compressive Strength and Tensile Strength

When brought the testing results of compressive strength and tensile strength to evaluate in MINITAB Release 14.00 for the experimental design with Mixture Design function. It found the the mixture with pozzolan materials has significant to compressive strength because P value is less than $\alpha = 0.05$. In addition, it found R-Sq = 82.61% and R-Sq (adj) = 78.997% that shown in TABLE II. In general, this value 70 percent more than [13-14]. The value obtained from this study was reliable and can be used. In terms of tensile strength, It found the the mixture with pozzolan materials has significant to tensile strength because P value is less than $\alpha = 0.05$. In addition, it found R-Sq = 74.89% and R-Sq (adj) = 69.66% that shown in TABLE III. In

TABLE II: ESTIMATE REGRESSION COEFFICIENTS FOR TEST COMPRESSIVE STRENGTH OF POZZOLAN MATERIAL

Term	Coef	SE Coef	T	P	VIF
Rice husk ash	15.31	0.8315	*	*	1.964
Bagasse ash	16.02	0.8315	*	*	1.964
Metakaolin	18.14	0.8315	*	*	1.964
Rice ash * Bagasse	20.80	3.8322	5.43	0.000	1.982
Rice husk ash * Metakaolin	29.92	3.8322	7.81	0.000	1.982
Bagasse ash * Metakaolin	14.54	3.8322	3.89	0.001	1.982

S = 1.49327 PRESS = 75.9689
R-Sq = 82.61% R-Sq(pred) = 75.32% R-Sq(adj) = 78.99%

TABLE III: ESTIMATE REGRESSION COEFFICIENTS FOR TEST TENSILE STRENGTH OF POZZOLAN MATERIAL

Term	Coef	SE Coef	T	P	VIF
Rice husk ash	3.020	0.1507	*	*	1.964
Bagasse ash	2.785	0.1507	*	*	1.964
Metakaolin	3.188	0.1507	*	*	1.964
Rice ash * Bagasse	2.090	0.6947	3.01	0.000	1.982
Rice husk ash * Metakaolin	3.758	0.6947	5.41	0.000	1.982
Bagasse ash * Metakaolin	3.262	0.6947	4.69	0.000	1.982

S = 0.270707 PRESS = 3.05786
R-Sq = 74.89% R-Sq(pred) = 56.34% R-Sq(adj) = 69.66%

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general, this value 70 percent more than. The value obtained from this study was reliable and can be used.

Minitab Release 14.00 program has Response Optimizer function to find suitable value of the factors which has the best value of experiment. The researcher has chosen to use desirability function to determine the suitable factor. In this step must be to set the scope of the responses were lower level, target, upper level, weight of response and the importance of response. In this research used weight and significance of response was 1 due to focus the response near reach target and it must be within certain limits. When analyzed the data by Response Optimizer was suitable value. The scope of response in terms of compression strength and tensile strength to set up the target as average compressive strength and tensile strength of original binder in the present [3]. The compressive strength average as 23 MPa with the lower level as 20 MPa and upper level as 26 MPa. The tensile strength average as 4 MPa with the lower level as 3 MPa and upper level as 5 MPa. When evaluated by Minitab Release 14.00 program in Response Optimizer function. It found compressive strength response of mixture that shown in Fig.2 and tensile strength response of mixture that shown in Fig.3. It found both conditions were similar and evaluated two conditions will have suitable proportion of pozzolan materials.

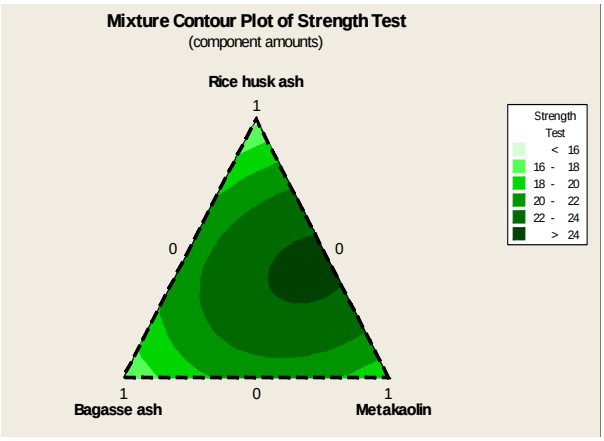

Fig. 2. Response mixture of compressive strength testing

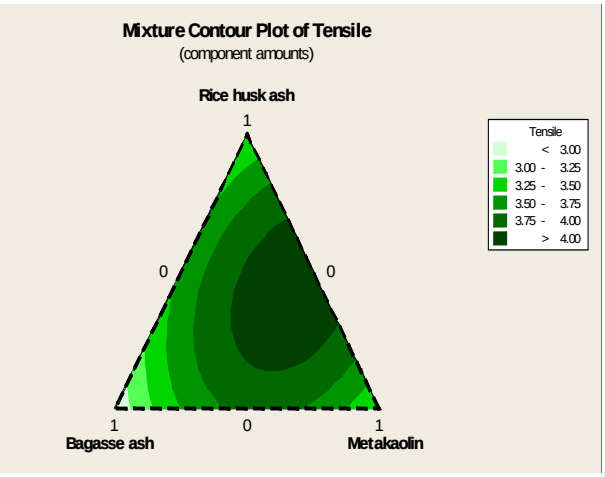

Fig. 3. Response mixture of tensile strength testing

After evaluated two conditions that shown in Fig.4, it found the suitable proportion of pozzolan materials were rice husk ash (0.15423) : bagasse ash (0.24776) : metakaolin (0.59801) or estimated ratio as 15: 25: 60. This formulation responsed the compressive strength results as 22.8880 MPa and the satisfaction as 0.96266. In terms of tensile strength response results as 4.0000 MPa and the satisfaction as 1. The total satisfaction as 0.98115 which nearly reaches 1 was set and can be used.

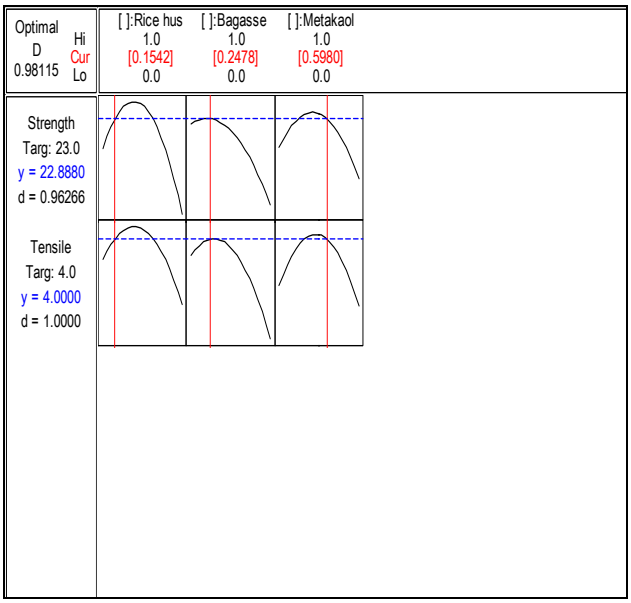

Fig. 4. Response and desirability of compressive strength and tensile strength

B. Testing Result of Rice Milling Efficiency

The comparison testing of rice milling efficiency was compared between new rice mill cylinder which has pozzolan binder and old rice mill cylinder which none pozzolan material binder. For new rice mill cylinder used suitable proportion of pozzolan materials were rice husk ash: bagasse ash : metakaolin in the ratio 15: 25: 60 have total quantity as 40% (280 g) mixed with magnesium oxide cement in the ratio as 60% (420 g). So, the total quantity binder as 700 g to mix with abrasive materials were emery No.14,16 and silicon carbide which total quantity 3,500 g. The ratio of abrasive material with binder material was 5: 1 by weight. To pour magnesium chloride has 30 degrees salinity as 700 ml into the mixture and mixed with all ingredients together [3] for rice mill cylinder casting 3 pieces. For old rice mill cylinder used all magnesium oxide cement mix with abrasive materials were emery No.14,16 and silicon carbide which have total quantity 3,500 g for rice mill cylinder casting 3 pieces also. Efficiency testing was evaluated from good rice percent and wear rate of rice mill cylinder.

When evaluated by Minitab Release 14.00 from One-way ANOVA function showed that type of binder has significant to wear rate because P value was less than $\alpha = 0.05$ and found R-Sq = 89.64% R-Sq (adj) = 88.26% that shown in TABLE IV. In general, this value 70 percent more than [13-14] . The value obtained from this study was reliable and can be used. It found wear rate of new rice mill cylinder has average wear rate as 4.439 g / hour which less than old rice mill cylinder has average wear rate of 7.022 g / hour. In addition, it found type of binder has significant to good rice percent because P value was less than $\alpha = 0.05$ and found R-Sq = 72.02% R-Sq(adj) = 70.28% that shown in TABLE V. It found average good rice percent of new rice

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TABLE IV: EVALUATION FACTORS OF BINDER TYPE AND WEAR RATE

Source	DF	SS	MS	F	P
Binder Material	2	29.15	14.575	64.88	0.000
Error	15	3.37	0.225		
Total	17	32.52			

S = 0.4740 R-SQ = 89.64% R-SQ(ADJ) = 88.26%

TABLE V: EVALUATION FACTORS OF BINDER TYPE AND GOOD RICE PERCENT

Source	DF	SS	MS	F	P
Binder Material	1	68.91	68.91	41.19	0.000
Error	16	26.77	1.67		
Total	17	95.68			

S = 1.293 R-Sq = 72.02% R-Sq(adj) = 70.28%

mill cylinder 80.12% which more than old rice mill cylinder has average good rice percent as 76.02%.

C. Economic Analysis

From work efficiency evaluation between new rice mill cylinder which has pozzolan binder and old rice mill cylinder which none pozzolan material binder, It found old rice mill cylinder has paddy milling time average 20 kg per 60 minute and new rice mill cylinder has paddy milling time average 20 kg per 65 minute. So, it found work efficiency was similar. When compared rice milling efficiency, it found old rice mill cylinder has average good rice percent as 76.02% and average wear rate as 7.02 g/hour. For new rice mill cylinder has average good rice percent as 80.12% and average wear rate as 4.43 g/hour. So, it found new rice mill cylinder has good rice percent increasing and wear rate decreasing that shown in TABLE VI. The production costs of rice mill cylinder have material from abroad as bellow [14] : Emery abrasive material as 60 baht/kg and Silicon Carbide abrasive material as 70 baht/kg, magnesium oxide cement as 75 baht/kg and magnesium chloride saline as 50 baht/kg. The new binder costs have magnesium oxide cement(60%) as 45 baht/kg and pozzolan material(40%) as 5 baht/kg. The price of axis rice mill cylinder in domestic as 700 baht.

TABLE VI: COMPARISON THE COST OF TWO BINDER MATERIALS AND RESULT OF RICE MILLING

Detail	Original Binder	Pozzolan Material Binder
Cost (baht)	1,090	1065
Rice (kg/day)	120	130
Rice from paddy 1 kg milling (gram)	600	650
Good rice percent	76.02	80.12
Wear rate (gram/hour)	7.02	4.43
Time (minute)	60	65
Wage (person per day)	250	250

IV. CONCLUSION

In the experimental, suitable proportion of pozzolan materials were rice husk ash, bagasse and metakaolin in the ratio 15 : 25 : 60 which total as 40 percent mixed with magnesium oxide cement which original binder in the ratio as 60 percent. When used this formulation to cast rice mill cylinder and tested rice milling. The rice mill cylinder which mixture of pozzolan materials has the amount of rice increased as 10 percent, average good rice percent increased as 4.1 percent and average wear rate decreased as 36.89 percent that affects life time increasing. Although, production costs per unit have decreased not so much. But, pozzolan material application as binder replacement has affects to the amount of rice, good rice percent increasing and wear rate decreasing. When considering the overall, the support to use pozzolan material is a mixture. It will reduce the import of raw materials up to 40 percent or about 30 million per year. The development of rice mill cylinder in the future should bring abrasive material in domestic to test with pozzolan material binder. It will help to reduce production costs and affects to the decreasing of import raw materials from abroad.

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