การพัฒนาดินเหนียวเผาจากภาคตะวันออกเฉียงเหนือเป็นส่วนผสมวัสดุประสานในกระบวนการขึ้นลูกหินขัดข้าว

Development of Calcined Clay from Northeast used as Binder in Casting Process of Rice Polishing Cylinder

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อประยุกต์ดินเหนียวเผาจากภาคตะวันออกเฉียงเหนือเป็นส่วนผสมวัสดุประสานในการขึ้นรูปลูกหินขัดข้าว ทดแทนวัสดุประสานเดิมซึ่งเป็นปูนแคลซิเนดแมกนีไซด์ที่นำเข้าจากต่างประเทศและช่วยลดต้นทุนการผลิต ในงานวิจัยนี้ได้เลือกดินเหนียวจาก 3 แหล่ง คือ นครราชสีมา บุรีรัมย์ และอุบลราชธานี มาผสมร่วมกับเถ้าแกลบเพื่อเพิ่มความแข็ง โดยออกแบบการทดลองและประมวลผลด้วยโปรแกรม MINITAB Release 14 ในการทดสอบแรงอัดและแรงดึง พบว่า อัตราส่วนของดินเหนียวเผา : เถ้าแกลบ ที่เหมาะสม จากทั้ง 3 แหล่ง คือ 83 : 17, 75 : 25 และ 78 : 28 ตามลำดับ เมื่อนำสูตรดังกล่าว ไปขึ้นรูปลูกหินขัดข้าวและทดสอบการสีข้าว พบว่า ลูกหินดินเหนียวเผานครราชสีมามีร้อยละข้าวหักต่ำสุด รองลงมาลูกหินดินเหนียวเผาบุรีรัมย์และลูกหินดินเหนียวเผาอุบลราชธานี กล่าวคือ มีร้อยละข้าวหักเฉลี่ย 31.48, 32.41 และ 38.91 ตามลำดับ โดยมีนัยสำคัญที่ระดับ α=0.05 ในขณะที่ อัตราการสีกหรอเฉลี่ยนั้น พบว่า ลูกหินดินเหนียวเผานครราชสีมามีอัตราการสีกหรอเฉลี่ยต่ำสุด รองลงมาลูกหินดินเหนียวเผาอุบลราชธานีและลูกหินดินเหนียวเผาบุรีรัมย์ มีอัตราการสีกหรอเฉลี่ย 4.675, 5.230 และ 5.437 กรัม/ชั่วโมง ตามลำดับ โดยไม่มีนัยสำคัญที่ระดับ α=0.05

คำสำคัญ: ดินเหนียวเผา ลูกหินขัดข้าว วัสดุประสาน กระบวนการขึ้นรูป การออกแบบการทดลอง

Abstract

The objective of this research was to develop calcined clay the Northeast of Thailand as a binder in the casting process of rice polishing cylinders in replacement of the imported calcined magnesite cement and to reduce production costs of the cylinder. Calcined clay from 3 different regions namely, Nakhon Ratchasima, Buriram and Ubon Ratchathani was mixed with rice husk ash to increase hardness. The design of experiment analysis using MINITAB Release 14 Program was evaluated base on the compressive strength and tensile strength testing. According to the analysis results, it was found the optimal formulas as calcined clay: rice husk ash from Nakhon Ratchasima, Buriram and Ubon Ratchathani equal to 83: 17, 75: 25 and 78: 22 respectively. When using the optimal formulas to cast and test the rice milling, it found Nakhon Ratchasima, Buriram and Ubon Ratchathani calcined clay cylinders showed the average broken rice percentages as 31.48, 32.41 and 38.91 respectively and were significant at a level as α=0.05. While the average rates of Nakhon Ratchasima, Ubon Ratchathani and Buriram calcined clay cylinders were 4.675, 5.230 and 5.437 g/hr respectively by not having significant at level as α=0.05.

Keywords: Calcined clay, Rice polishing cylinder, Binder, Casting process, Design of experiment

1. Introduction

In the last decades, rice milling machine has been used as the agriculture based machinery for Thai agriculturists. Currently, a small rice milling machine which has capacity as 1-2 ton per day is widely used by agriculturists since a small rice milling machine uses less production time and more convenient to use in household. Normally, a small rice milling machine has two different types: vertical axle and horizontal axle. Generally, the horizontal axle which is driven by electric motors is extensively used because it has low price and it can be easily purchased locally. The quality of peeled rice depends on several factors such as types of paddy, grain shape and size, paddy moisture content, and processes of shelling and polishing [1]. The process of rice polishing is an important step and the percentage of good peeled rice depends on the quality of rice polishing cylinder [2]-[4]. In general, the rice polishing cylinder consists of two composite materials which are abrasive material and binder material [5]. The abrasive material consists of the emery grain stone and silicon carbide. The binder material comprises calcined magnesite cement and magnesium chloride that this binder have affect the quality of rice polishing cylinder and milling performance [6-8].

Nowadays, calcined magnesite cement was imported from abroad. In order to minimize the amount of the imported calcined magnesite cement, using the domestic pozzolan material which is an agricultural waste such as rice husk ash, bagasse ash, and metakaolin as a part of binder material can reduce the production cost and improve the desired properties of the rice polishing cylinder [9]-[12]. The research about application of pozzolan material used as binder in the casting of rice polishing cylinder for example: T. Boonkang et al. [13] have applied pozzolan material used as binder in the casting process of rice polishing cylinder by using a natural pozzolan materials which were rice husk ash, bagasse ash from the northeast, and metakaolin from the north of Thailand. These pozzolan materials were replaced the imported calcined magnisite cement in the ratio of 40 percent. The experimental results revealed that the suitable proportion was rice husk ash: bagasse ash : metakaolin as 15:25:60. When applied this proportion to cast the rice polishing cylinder, it found that average broken rice percent was 19.88 and average wear rate was 4.43 g/h, while the rice polishing cylinder made from only an imported binder had average broken rice percent as 23.98 and average wear rate as 7.02 g/hr. Therefore, the pozzolan rice polishing cylinder has polishing efficiency better than the imported binder rice polishing cylinder. From this study, it also found that metakaolin from the north of Thailand had the highest replacement ratio of pozzolan material. In addition, T. Boonkang et al. [14] have applied experimental design techniques to study the development of metakaolin from the northeast to replace the metakaolin from Lampang because it reduces transportation costs. However, it was found that metakaolin from northeast region has limited only mine closed. Therefore, we considered pozzolan material has available easy in the local. It was found calcined clay available easy in the local and similarly property as metakaolin [5]. The research about calcined clay used as binder or example: Thiraphong Phanket et al. [14] investigated the pozzolan material properties of the calcined clay, it found calcined clay has property that can be used as a binder which is a mixture of concrete forming. Watee Homtrakul [15] has researched the strength characteristics of Bangkok calcined clay that improved with cement and fine rice husk ash, it found the high compressive strength allowed by quantity of cement and rice husk ash. In addition, the research by Thanawat Charupongsakun et al. [16] was researched the quality of clay from northeast and found these materials have the potential to be used as a binder material good ceramic production.

According to the survey of clay popular source to make ceramic product, It has 3 source important of materials, including 1) Ban Dan Kwian clay, Nakhon Ratchasima Province 2) Ban Kruat Clay, Buriram province 3) Pak Huai Wang Nong clay, Ubon Ratchathani province. In addition, clay sources from Moon river has different area on upstream (Nakhon Ratchasima clay), midstream (Buriram clay) and downstream (Ubon Ratchathani clay) have affected to the quality of clay. Therefore, in order to develop quality clay form northeast has benefit in the industry of rice polishing cylinder by applying the combination with rice husk ash used as binder which affects the

hardness and tensile of rice polishing cylinder. The above reason has the important of this research.

2. Materials and methods

2.1 Material preparation and equipment

1) Control factors were calcined clay and rice husk ash. These materials were baked at 800 °C around six hours in an electrical furnace. After that, it was mashed and screened by the sieve size 325 following the ASTM C618 standard.

2) Calcined clay was collected from three local sources; Nakhon Ratchasima, Buriram, Ubon Ratchathani.

3) The casted specimen and the casted rice polishing cylinder used the same proportion of abrasive material: binder material as 5:1. The horizontal axle rice milling machine was used to test the rice milling.

4) Rice for testing was Jasmine Rice 105 (Industrial standard 888-2532) and paddy moisture content was controlled not to be exceed 14%, and all scraps were removed. Each testing batch consisted of 20 kilograms of Jasmine Rice and repeat test 3 times/ 1 rice polishing cylinder.

5) MINITAB Release 14.00 program was used to evaluate the experimental results and design of experiment (DOE) by Mixture Design function. In addition, the response surface method was applied to identify the suitable proportion of calcined clay**.**

2.2 Design of Experiments

The experiment was separated into two parts.

1) Determine the suitable proportion of calcined clay material based on the compressive strength and tensile strength. Then, the suitable proportion was used to cast the rice polishing cylinder.

2) Test the rice mill efficiency of each calcined clay cylinders and the imported calcined magnesite cement cylinder based on the broken rice percent and the wear rate values. All cylinders used the proportion of abrasive materials:binder material as 5:1.

3. Results

3.1 Results of suitable calcined clay proportion from 3 sources

MINITAB Release 14.00 program had Response Optimizer function to find the right value of the factors which was the best value of the set of experiment. The researcher had chosen to use desirability function to determine the suitable factor. In this step, the response target must be identified including the lower level, the target and the upper level as well as weight of response and the significance of response. In this research, the weight and significance of response was 1 to focus the response near the target and it must be within certain limits. In addition, the ranges of response in terms of compressive strength and tensile strength were chosen closed to the average compressive strength and tensile strength of original binder which was the average compressive strength at 13 MPa with lower level at 12 MPa and upper level at 14 MPa, whereas the average tensile strength was at 3 MPa with lower level at 2 MPa and upper level at 4 MPa.

After evaluating all testing data including both compressive strength results and tensile strength results from each calcined clay source, it was found that the optimal formula was Nakhon Ratchasima calcined clay : rice husk ash was equal to 0.82809 : 0.17191 as shown in Fig. 1 or roughly around 83 : 17 percent. This proportion yielded the compressive strength as 13 MPa, the satisfaction as 1, the tensile strength as 2.9310 MPa, and the satisfaction as 0.93098. The overall satisfaction as 0.96487 was near the target value of 1, which implied that this formula was reasonable to cast the rice polishing cylinder. Furthermore, it was also found that the optimal formula was Buriram calcined clay : rice husk ash equal to 0.7457 : 0.2543 as shown in Fig. 2 or roughly around 75 : 25 percent. This proportion yielded the compressive strength as 12.8458 MPa, the satisfaction as 0.84585, the tensile strength as 2.8524 MPa, and the satisfaction as 0.85242. The overall satisfaction as 0.84913 was near the target value of 1, which implied that this formula was reasonable to cast the rice polishing cylinder.

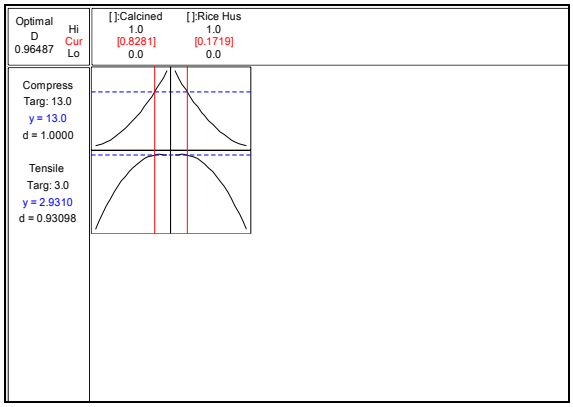

Figure 1 Optimal proportion of Nakhon Ratchasima calcined clay

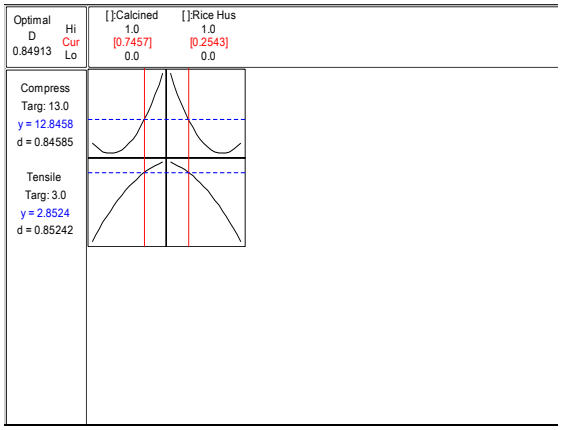

Figure 2 Optimal proportion of Buriram calcined clay

Lastly, it was also found that the optimal formula was Ubon Ratchathani calcined clay : rice husk ash was equal to 0.78267 : 0.21733 as shown in Fig. 3 or roughly around 78 : 22 percent. This proportion yielded the compressive strength as 13.1272 MPa, the satisfaction as 0.87283, the tensile strength as 2.9224 MPa, and the satisfaction as 0.92238. The overall satisfaction as 0.89726 was near the target value of 1, which implied that this formula was reasonable to cast the rice polishing cylinder.

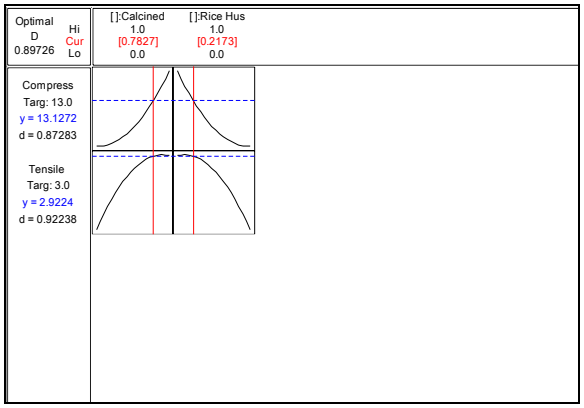

Figure 3 Optimal proportion of Ubon Rathathani calcined clay

3.2 Results of Suitable Clacined Clay Proportion from three sources

The comparison of rice milling efficiency has separated 2 parts were broken rice percent and wear rate. The evaluation of rice milling efficiency has used function T-Test for analysis data at significant 0.05. The rice polishing cylinders have 3 samples were Nakhon Ratchasima (NR) calcined clay cylinder, Buriram (BR) calcined clay cylinder and Ubon Ratchathani (UB) calcined clay cylinder. The casing process of rice polishing cylinder has 3 pieces per source and to test wear rate and broken rice percent. After evaluation, we found the average broken rice percent from Nakhon Ratchasima, Buriram and Ubon Ratchathani cylinder as 31.48, 32.41 and 38.91 respectively and have significant at level as 0.05 as shown in Fig. 3. While the average wear rate of Nakhon Ratchasima, Ubon Ratchathani and Buriram calcined clay cylinders as 4.675, 5.230 and 5.437 g/hr respectively has not significant at level as 0.05 as shown in Fig. 5

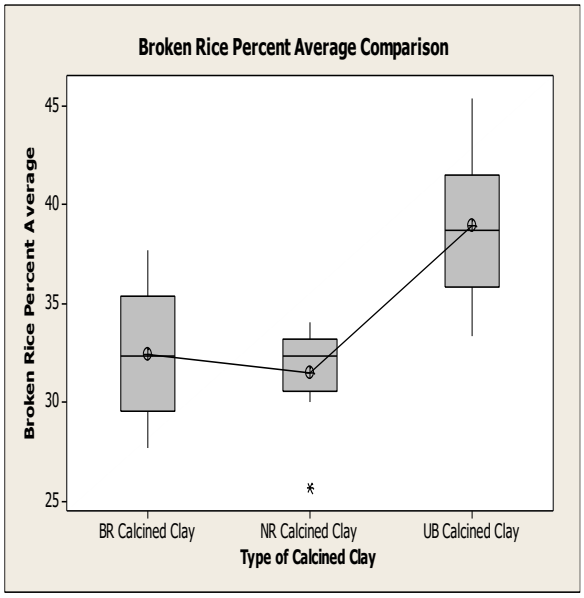

Figure 4 Comparison of broken rice percent average of three sources cylinder

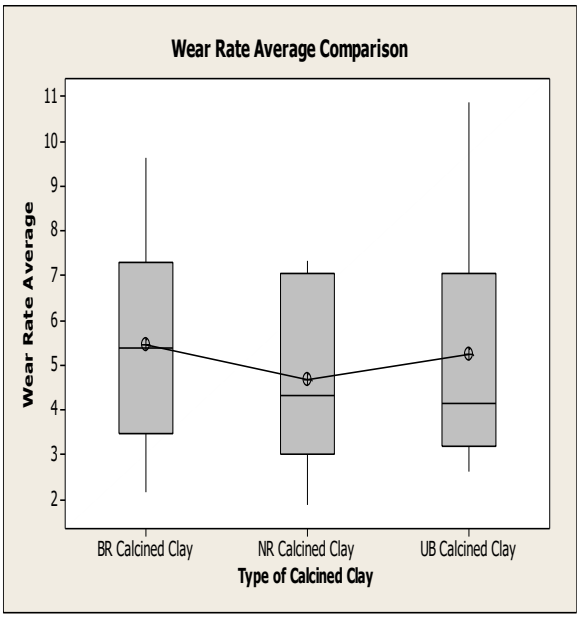

Figure 5 Comparison of wear rate average of three sources cylinder

3.3 Testing Result of Rice Mill Efficiency

From the rice milling evaluation between calcined clay cylinder from three sources with import binder cylinder, we concluded the results of efficiency testing have shown in the table I.

Table 1 Efficiency Evaluation of Rice Polishing cylinder

Item	NR Calcined clay cylinder	BR Calcined clay cylinder	UB Calcined clay cylinder	import binder cylinder
Average broken rice percent	31.48	32.41	38.91	26.65
Milling time per rice 20 kg	39	39	43	53
Average wear rate	4.675	5.437	5.230	5.26
Average mill rice percent	62.90	61.82	63.14	60.32
Cost of material (baht)	982.15	982.10	982.12	1,016

4. Conclusions

1) When brought calcined clay from three different sources which were Nakhon Ratchasima, Buriram, and Ubon Ratchathani for casting the testing specimens and then mechanical properties testing based on the compressive strength and tensile strength, the optimal formulas of calcined clay from Nakhon Ratchasima, Buriram, and Ubon Ratchathani as 83: 17, 75: 25 and 78: 22, respectively.

2) From evaluation result of rice milling, Nakhon Ratchasima calcined clay cylinder has the best effective cylinder of three sources when evaluated from broken rice percent and wear rate lowest. However, the cylinder from three sources still have a higher broken rice percent than import binder cylinder but wear rate is lower than import binder cylinder. In addition, the calcined clay cylinder from three sources have milling time less than import binder cylinder. Therefore, calcined clay cylinders from northeast are the good choice for rice polishing cylinders.

3) Calcined clay from northeast of Thailand can replace the imported calcined magnesite cement

around 30 percent resulting in the reduction of overall imported cement and increase value of local material.

4) The suggestions for improving the efficiency of rice polishing cylinder about broken rice percentage by horizontal machine casting or use the experimental design techniques from the factors of rice mill that the research in future**.**

5. Acknowledgements

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