

The effects of partial replacement of cement in cement mortar and brick by Microwave Incinerated Rice Husk Ash (MIRHA)

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Abstract

The demand for high quality sustainable materials has increased and encouraged the researchers in building technology to find new alternatives. Rice husk generated from the rice production poses a major problem of disposal especially when open burning is no longer permitted due to the environmental issues. The use of pozzolanic materials is being investigated to reduce the carbon dioxide emitted per tonne of concrete produced and utilized. This study investigates the potential of using Microwave Incinerated Rice Husk Ash (MIRHA) in mortar mixes made of Ordinary Portland Cement (OPC). The MIRHA was obtained by burning rice husk at controlled temperature using microwave incinerator. In the experimental study on compressive strength of cement mortar the water-binder ratio was kept constant at 0.5. Control mortar without any replacement of cement and also mortar with 5%, 10%, 15%, 20% and 25% of OPC replaced by MIRHA were studied with different binder-sand ratio of 1:3, 1:4, 1:5 and 1:6. The compressive tests were conducted for the samples at 7 and 28 days. The result has revealed that, the MIRHA could be used in cement mortar due to its refined microstructures. In addition to that, the compressive test results were compared with three different standards: ASTM, MS and BS for bricks manufacturing. The results show the potential of using MIRHA in cement brick production. Amongst the cement replacement mixes, 20% MIRHA has shown highest compressive strength.

Keywords: Microwave Incinerated Rice Husk Ash, mortar, brick, cement replacement material.



1 Introduction

Malaysia is one of the major rice producing countries with approximately 3.21% of total land in peninsular Malaysia under rice cultivation. On average, paddy production in Malaysia is about 2 million tonnes per year [1]. The rice husk generated from rice production has posed a major problem of disposal especially when open burning is no longer permitted due to environmental issues. Rice Husk Ash (RHA) has high amorphous silica content (85%–90%) which can enhance the quality of mortar through the formation of calcium silicate [2].

The cement industry contributes 5% of global CO₂ emission. The cement sustainability initiative progress report shows that of the total emissions from the cement industry, 40% occur during combustion and 60% during calcinations from the cement manufacturing process [3]. The intense consumption of concrete and brick in construction leads to a higher usage of cement and thereby higher emission of CO₂.

Due to its pozzolanic effect, RHA is being used to partially replace Ordinary Portland Cement (OPC). When rice husks are burnt using a microwave incinerator to obtain MIRHA, they have enhanced silica content. MIRHA is an amorphous material that gives a positive effect to mortar as a binder in concrete as well as an option to reduce Portland cement consumption in the construction material [1]. This research intended to investigate the effect of partial replacement of cement with MIRHA in mortar and brick.

2 Replacement of cement with MIRHA in bricks

The research into the use of agriculture waste in construction material has made huge progress. Disposal of agriculture waste has posed an environmental problem since it possessed rough and abrasive surfaces which have high resistance to natural degradation [4]. Recent studies have shown that these agriculture wastes have a pozzolanic property which contains high amorphous silica. It gives an opportunity for the construction industry to reduce their cost by reducing the amount of cement used, while preserving the environmental quality [5]. RHA obtained from different locations possess different chemical compositions. Abu Bakar reported that silica content in RHA varies in range of 85–95% [2].

The experiment to investigate the effect of MIRHA on the compressive strength of concrete was conducted at ages of 3, 7 and 28 days. Super plasticizer was used to increase the workability and MIRHA was used as a replacement of cement on a weight basis at 5, 10, 15 and 20% of cement content in concrete [6]. In addition to that, Sensale proved that the use of RHA in concrete leads to workability improvement, reduction of heat evolution and permeability as well as promoting good strength development of concrete [7].

Rame has investigated the utilization of RHA and Quarry Dust (QD) as partial cement replacement in self-compacting mortar (SCM) mixes [8]. The performance of SCM mixes has been observed at all ages and the rate of strength



reduction decreased as the age progressed and it was concluded that the compressive strength of SCM will reduce with addition of the RHA at all ages.

An experimental study on cement mortar with replacement of 10, 15, 20, 25 and 30% of OPC with RHA was conducted by Muhammad *et al.* [9]. In their experimental work, RHA was obtained from an uncontrolled combustion process. It was concluded that the cement mortar with replacement of RHA at 20% has significantly improved the mortar strength, whilst 30% replacement of cement with RHA showed increment in porosity of mortar at age of 28 days and 90 days as compared to OPC mortar.

3 Methodology

3.1 Materials

For this study the RHA was obtained from Padiberas National Berhad's (BERNAS) factory. The water-binder ratio was kept constant at 0.5. Ordinary Portland Cement (OPC) type 1 and fine quarry sand was used as the fine aggregate where the sand passes sieve number 2.36 mm.

In order to obtain the optimum MIRHA, the rice husks were burnt at a temperature of 400°C using an UTP Microwave Incinerator but in fact due to the incinerator condition the RHA were burnt at a temperature of 800°C as required [6]. This temperature will increase the silica content and the resulting ash has gray colour [1]. After the burning process, MIRHA was ground using abrasion machine to increase its fineness. It was subjected to 3000 cycles to obtain the particles of optimum fineness and it took 1 hour and 30 minutes. The processed MIRHA was placed in air tight container to prevent any contamination. The preparation of the material is summarized in Figure 1.

3.2 Mix design

Trial and error method was adopted to determine the appropriate design proportion for the mortar used to produce the bricks. A total of 24 different mixtures were prepared. The replacement percentages of MIRHA are 5, 10, 15, 20 and 25%. The binder-sand ratios are 1:3, 1:4, 1:5 and 1:6. Control mixtures without any replacement of MIRHA for the binder-sand ratios were also prepared and tested. In general for each binder-sand ratio, about 6 mixes were prepared including of the control samples as shown in Table 1.

3.3 Laboratory testing

Cube specimens of 100 x 100 x 100 mm were used to determine the compressive strength of MIRHA mortar. The compressive tests were carried out as per provisions of relevant codes (BS, ASTM and MS) at 7 and 28 days of curing using digital compressive testing machine. The compressive strength for each cube was recorded and the average values were determined.



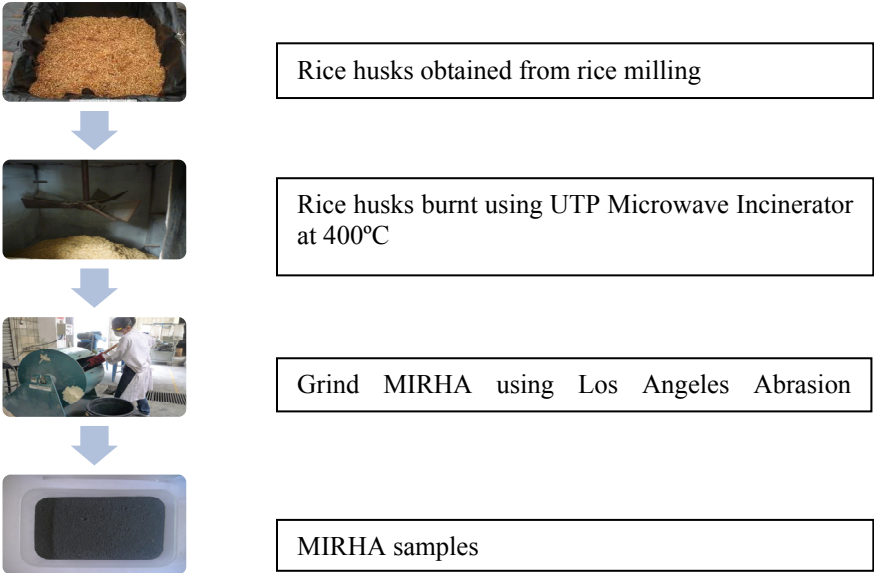


Figure 1: Material preparation.

Table 1: Mortar mixes showing percentage of cement replaced by MIRHA.

MIXTURE ID	CM	MIRHA5	MIRHA10	MIRHA15	MIRHA20	MIRHA25
Percentage of MIRHA	0%	5%	10%	15%	20%	25%

4 Result and discussion

4.1 Compressive strength of normal mortar

Compression test was carried out to determine the strength of cement mortar with different percentage of MIRHA in the mortar mixtures at different mixes ratio. Results of the tests obtained for mortar with 5, 10, 15, 20 and 25 percent of cement replaced by MIRHA were compared with control mix for each of the mixes (1:3, 1:4, 1:5 and 1:6) as shown in Table 2.

The results are also presented in Figure 2 and Figure 3. It can be seen that, there is clear trend of decreasing compressive strength of mortar strength with decreasing cement content. On average, normal cement mortar has higher compressive strength than cement mortar incorporated with MIRHA. However, among that, cement mortar with 20% of MIRHA has shown higher results comparing to other MIRHA mixtures and at ratio of 1:6 the strength is seems slightly higher than the control mix.



Table 2: Compression strength of cement mortar of different mix proportions and different percentage of MIRHA replacement.

Mixture Code	MIRHA (%)	Mix Proportions	Compressive strength (MPa)	
			7 days	28 days
Control mix (CM)	0	1:3	35.76	52.75
		1:4	21.31	29.34
		1:5	12.87	20.29
		1:6	11.34	12.64
MIRHA5	5	1:3	23.63	29.81
		1:4	3.07	4.75
		1:5	2.78	3.19
		1:6	2.38	3.32
MIRHA10	10	1:3	15.33	13.88
		1:4	9.37	8.77
		1:5	4.14	5.62
		1:6	3.46	3.99
MIRHA15	15	1:3	18.26	23.02
		1:4	12.65	15.58
		1:5	7.39	8.59
		1:6	5.94	6.80
MIRHA20	20	1:3	25.08	36.34
		1:4	10.58	18.29
		1:5	11.95	19.48
		1:6	12.06	20.24
MIRHA25	25	1:3	13.15	24.85
		1:4	7.81	15.27
		1:5	7.35	13.66
		1:6	4.32	8.21

Compressive strength that was shown by cement mortar with 20% cement replacement of MIRHA indicated that MIRHA is pozzolanic materials gave



higher compressive strength than 5%, 10%, 15%, and 25% replacement of MIRHA in mortar. Although the strength is lower compared to controlled mortar but it has satisfied the minimum requirement for mortar compressive strength for some application such as bricks.

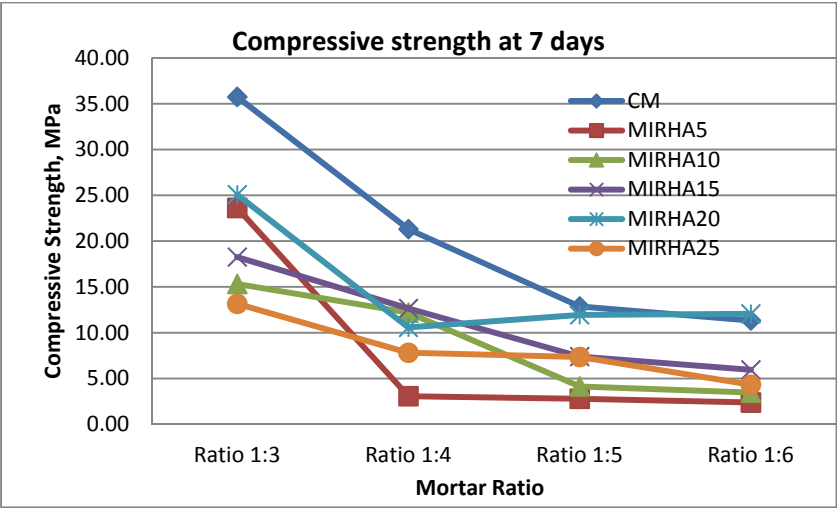


Figure 2: Compressive strength of cement mortar with MIRHA at 7 days.

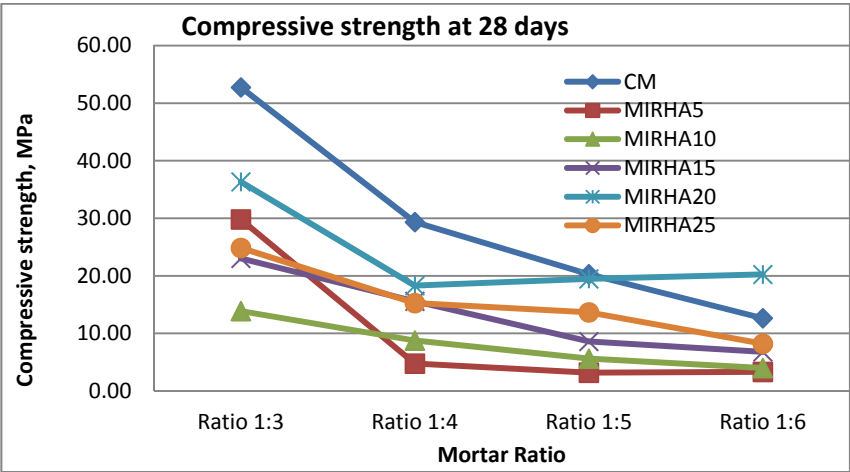


Figure 3: Compressive strength of cement mortar with MIRHA at 28 days.

4.2 Application of MIRHA mix in brick mortar

From the experimental work, it was observed that the compressive strength at ages of 7 days and 28 days of cement mortar incorporating 20% of MIRHA has



shown good strength performances in terms achieving the least minimum compressive strength of brick. At ratio of 1:5 and 1:6, the compressive strength has also reached the minimum strength with less usage of cement.

The detailed summary of the mixtures meeting the requirements of brick for loading bearing wall and non-loading bearing wall in the British Standard, ASTM and Malaysian Standard are presented in Tables 2 and 3 respectively.

Table 3: Loading brick minimum requirement.

Standard	British Standard (7.0 MPa)				ASTM (8.6 MPa)				Malaysia Standard (4.0 MPa)			
Ratio	1:3	1:4	1:5	1:6	1:3	1:4	1:5	1:6	1:3	1:4	1:5	1:6
MIRHA5	√				√				√	√		
MIRHA10	√	√			√	√			√	√	√	√
MIRHA15	√	√	√		√	√	√		√	√	√	√
MIRHA20	√	√	√	√	√	√	√	√	√	√	√	√
MIRHA25	√	√	√	√	√	√	√	√	√	√	√	√

Table 4: Non-loading brick minimum requirement.

Standard	British Standard (2.0 MPa)				ASTM (3.5 MPa)				Malaysia Standard (1.5 MPa)			
Ratio	1:3	1:4	1:5	1:6	1:3	1:4	1:5	1:6	1:3	1:4	1:5	1:6
MIRHA5	√	√	√	√	√	√			√	√	√	√
MIRHA10	√	√	√	√	√	√	√	√	√	√	√	√
MIRHA15	√	√	√	√	√	√	√	√	√	√	√	√
MIRHA20	√	√	√	√	√	√	√	√	√	√	√	√
MIRHA25	√	√	√	√	√	√	√	√	√	√	√	√

4.3 Environmental implication

Most of the vertical walls in Malaysia are made from bricks especially in residential premises. Thus, by using the bricks made from mortar with MIRHA, it able to reduce the amount of the used cement at least 20–25% in total.

For the non-structural wall, the replacement could extend to more than 25% which inherently will further reduce the amount of cement used. Most walls in Malaysia are acting as partition walls only. Further investigations are required to determine the exact mix proportion that could be adopted. This preliminary research intended to investigate the potential of MIRHA application in brick industry.

5 Conclusion

The following conclusions could be drawn from the study:

- The MIRHA has shown potential as a cement replacement material in cement mortar from the experimental results and able to reduce the



amount of cement used in construction sector especially in brick production and promote to be environmental friendly construction product.

- Bricks with the binder sand ratio of 1:6 with 20% MIRHA meets the minimum requirement of three (3) brick standard; ASTM, BS and MS, essentially used least amount of cement.

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