ASSESSMENT INFLUENCE OF MICROWAVE HEATING ON A PHYSICAL PROPERTIES OF DRIED CLAY BRICKS COMPARED WITH CONVENTIONAL METHODS

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Abstract— The current state of brick manufacturing process is still very traditional where drying of clay brick takes very long time and labour intensive. Adding to this problem, uneven heating during drying and firing affect a lot to bricks quality which often cause cracks. This paper aims to evaluate the effectiveness of microwave energy source against the conventional methods for drying clay bricks. Green clay samples were pressed into a slab specimen at different compositions (%red clay, %water, %charcoal). Later, the green samples were dried under four different heat methods (natural, hot air, electric oven and microwave). The quality of dried bricks was compared in terms of water absorption, density, and crack. From the results obtained, it is concluded that microwave technology has a great potential to be applied as a heating source in the production of bricks. The usage of this technology is foreseen able reduce the intensive labour dependent in brick manufacturing industry and this method is able to manufacture brick in a more sustainable environment.

Keywords— Clay brick; microwave; drying; cracks; water absorption.

1. INTRODUCTION

Sustainability in manufacturing are becoming very important issues in today technologies. These days the main emphasis is not only to increase productivity, but also to make processes cleaner, less energy consumption and more environmental friendly. According to the United States, Department of Commerce sustainable development can be defined as the produce of manufactured products that use processes that are use natural resources, save energy, non-polluting, safe and economically for employees, communities and consumers [1]. Tijjani and S. Abdullah[2] summarized sustainable as approaches to develop sustainable products with a lowest environmental impact, high productivity as possible. Microwave is one of the cleaner heating source in industrial sectors. The dielectric properties of the chemical microwave process and the resultant materials interaction was responsible for continues growth of microwave application in various diversified fields of manufacturing. These applications may include: Sintering (microwave advantages of deep penetration and uniform heating to produce Si3N4 cutting tool inserts) [3]. Lam [4] highlighted the advantages of microwave heating to include: reliable heating, low cost (in terms of operation and maintenance), powerful heat source, with modern equipment operating at over 90% efficiency. The impact of microwave heating has been investigated by many researchers. Numerous literatures reported that microwave heating offers better heating capability compared to conventional heating [5][6][7][8]. The early application of microwave heating is for cooking by microwave processing [9]. Wang and Shi [10] conducted experiment study characteristics of beef drying used Microwave and conventional freeze-drying of foods, where were compared, and they found some advantages of microwave over conventional freeze drying with radiant heating. The Food Research Laboratory of Raytheon have made extensive studies that led.to the first microwave freeze-drying pilot plant unit [11]. In the past, microwave heating had been successfully applied in the next fields: tempering meat, preheating rubber slugs, vulcanizing rubber, precooking bacon, drying pasta, drying crushed oranges, and so on [12]. Researchers have been looking for ways to utilize the advantages of microwave for industrial applications. Microwave heating of industrial applications was initiated by the domestic oven. It has recorded application in drying materials from textiles to ceramics and from coated paper to leather. Other examples include the drying of onions, snack foods fabrics, leather, ceramic cores and moulds and ceramic wares [13]. Hammouda and Mihoubi (2014) studied the kaolin clay by using different heating source, the result was the convective–microwave drying gives a good quality of dried product [14]. Makul, et al.[15] observed that used microwave radiation improve the cementations properties of RHA-incorporating cement, especially cement that is microwave-sintered at 800^{o}C. Todaro, et al. [16] applied microwave on pine wood and drying characteristics of firewood. Malafronte, et al. (2012) [17] developed and describe combined convective/microwave to assisted drying process of foodstuff (potatoes), the model was found able to describe the drying process. Tontand and Therdthai [18] have been confirmed that increasing microwave power and decreasing drying time could improve the weight gain ratio of dried on of chili. Several types of microwave absorbers have been utilized by different researchers. These include biomass char [19], particulate carbon [20], graphite [21] and glycerol and ionic liquid [21]. Domínguez, et al. [21] have found that addition of microwave absorber significantly increase the heating rate and reaction temperature, thus the oil yield. Temperature of feedstock mixed with microwave absorber can go up to as high as 10000C^0 within a few minutes.

Bricks are construction materials which have been used since ancient times and currently display different states of deterioration in numerous historic buildings [22]. Clay bricks are usually fired using fuel, gas or even natural wood. These conventional heating often creates uneven heating in the clay brick which cause cracking. Cracking is one of the major issues facing by brick manufacturers and the losses can be up to 20% of monthly production [23]. Brick production can be categorised as energy and labour intensive industry [24]. Since a lot of energy used for drying process as well as involving many manual operations. Microwave technology has been seen a more sustainable method to the current heating techniques for this industry. Despite many studies using microwave technology in drying processes, however, there is not much research reported that applies this technology for brick drying and firing process.

2. EXPERIMENTAL

Experimental methods and process for testing and material characterization were also detailed out in this section. It was started with the preparation of raw material for making clay samples, followed by the preparation of clay brick specimens. The samples were prepared by molding clay into a brick as: the dry powder of red clay 150 g mixed with 5g charcoal into 30 g water. The purpose of adding small percent of charcoal to improves microwave absorption [25]. The mixed was pressed in the mold made of wood compacted by force 1.2 KN (122 Kg). The final shape of clay brick size was (85 x 60 x 20 mm). The main components of red clay consisted of Fe_2O_3, TiO_2, and SiO_2, and the median particle size was 0.75 mm. The drying experiments were also carried out for brick samples immersed in water for 20 minutes. Once they were ready, the drying process begins, the samples were placed in conventional and technology heating sources at a certain parameter. The four drying methods were Oven, Hot air, Natural air and Microwave. Two

(2) parameters were varied in these experiments, i.e. temperature and drying time. The Table 1 shown these parameter settings for each method.

Green and dried bricks samples were evaluate on their changes of their moisture contents, water absorption, crack and density. The equation (1), (2) and (3) below are the formulas were used to calculate this changes of properties.

$$moisture\ content(\%) = \frac{wetweight - dryweight}{dryweight} \times 100 \tag{1}$$

$$Absorption(\%) = \frac{(Ws - Wd)}{Wd} \times 100 \tag{2}$$

$$Density\left(\frac{g}{cm^3}\right) = \frac{Wd}{V} \tag{3}$$

Where are *Ws*, *Ww* and W_d saturated weigh of sample (Kg), immerse weigh of sample (kg) and heat-dry weigh of sample (kg) respectively, *V* is a volume of sample (mm^3).

Microscope was used to observe micro cracks on the brick samples. The crack intensity or amount of crack occurs on specimen was measured based on crack density. The three dimensional crack density is defined as Equation (4).

$$\Gamma_{3D} = \frac{Na^3}{V} = N_V a^3 \tag{4}$$

Where are *N* number of cracks in two dimensions, *a* lengths of cracks, N_V number of cracks per unit volume and *V* volume of sample.

3. RESULTS AND DISCUSSIONS

The evaluation of physical properties of brick which were moisture, water absorption, crack and density to parameters during drying process are now presented. In this experiment, the results of the samples dried are given and the comparison between microwave and conventional drying were electric oven, hot air, and natural air.

Fig. 1 shows the drying behavior of a clay samples heated by different sources which were electric oven, hot air, natural air and microwave based on the drying time. Dried clay bricks using microwave energy source exhibit reduce the heating time for more than 400% efficient as compared to others drying method. It shown also less water absorption, increased brick density and without cracks. The reasons of that due to rapid and heating uniformity in the microwave had been reduced the time of drying. Thus, the energy consumption reduced.

From Fig. 2 that shown when increase in drying temperature, the percentage of crack is tends to increase for conventional heating sources. The percentage of crack of the brick which was dried by oven is the highest value compared to the other four sources. The rapid and heating uniformity in the microwave had been reduced the time of drying with no crack occurred.

Table 1: Parameter settings for each method

DRYING METHODS	TEMPERATURE	TIME
Microwave	60ºC	6 minutes
	70ºC	8 minutes
	80ºC	10 minutes
Oven	150ºC	10 minutes
	200ºC	30 minutes
	250ºC	60 minutes
Hot Air	40ºC	10 minutes
	50ºC	30 minutes
	60ºC	55 minutes
Natural Air	25ºC	10 hours
	25ºC	25 hours
	25ºC	48 hours

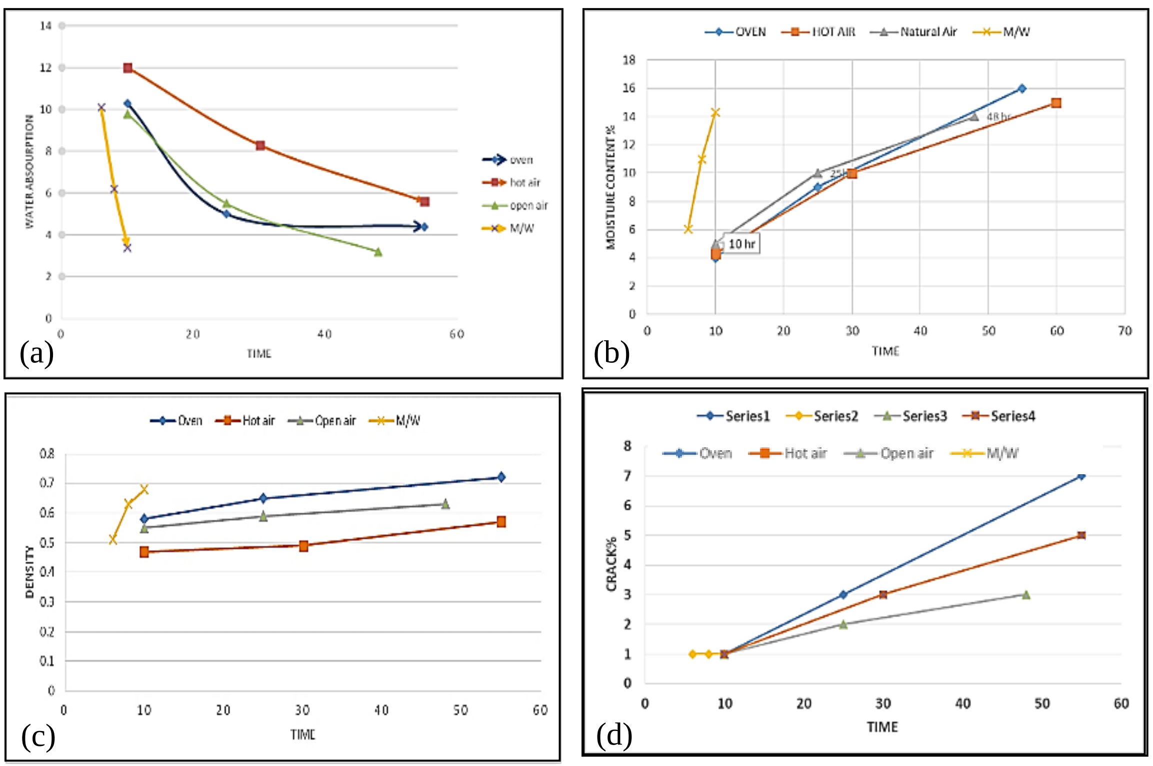

Figure 1: Percentage of (a) water absorption (b) moisture content (c) density (d) crack against time.

Fig. 3 illustrates the scanning structures of dried clay brick with additions of 5% of charcoal that have been dried using four different heating sources. The optical microscope was used to characterize those sample, and examine the different the particles The micrograph in figure 3 shown very small crack for the samples that have been dried using microwave source while others specimens shown crack occurred with variation percentage. Therefore, this clearly indicates that the microwave better in terms of reducing potential occurred of potential cracking.

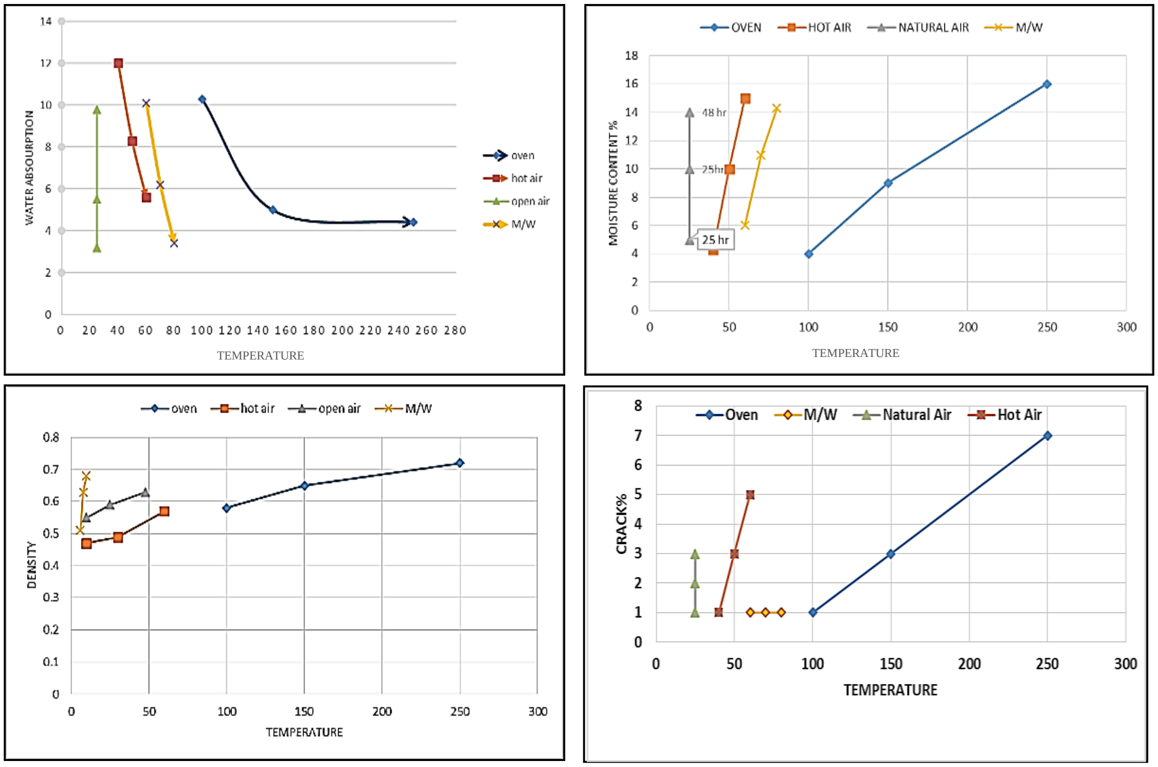

Figure 2: Percentage of (a) water absorption (b) moisture content (c) density (d) crack against temperature

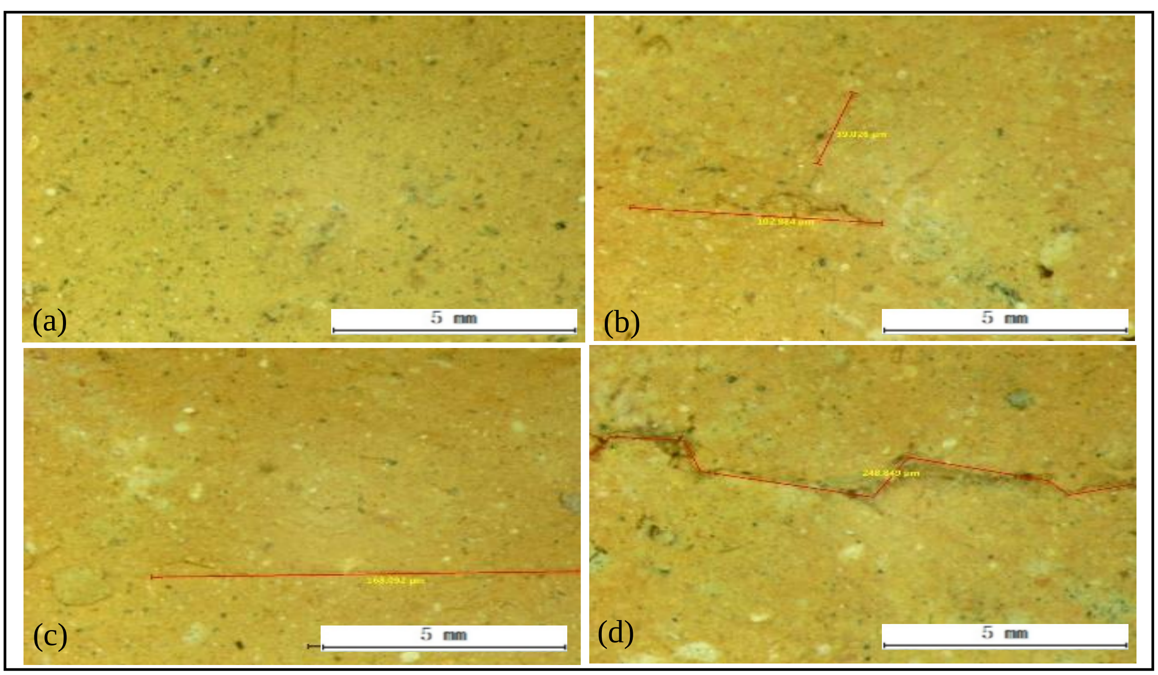

Figure 3: Structures of clay brick dried by (a) Microwave (b) Hot Air (c) Natural Air (d) Oven

4. CONCLUSIONS

Based on the results obtained from the experimental, can be concluded the microwave technology is proven can be used for drying brick and it has a great potential to replace others heating sources. The effective temperature and time for microwave drying on bricks are 70°C and 8 minutes respectively. The rapid heating in microwave is able to reduce the heating time for more than 400% efficient. Dried clay bricks using microwave energy source exhibit less water absorption, increased brick density and without cracks as compared conventional drying method. In addition, this technology consume less energy, low equipment and operational costs, and capable to provide more uniform heating on the brick which the latter results less cracks. The current research opens for more investigations on brick manufacturing and require further analysis. Future work recommendations for brick drying using microwave suggested to conduct numerical study of microwave heating behavior on clay bricks. This will reduce a lot of resources that are required through experimental works. Fly ash is readily available in various charcoal based power plant generation in the form of by product. Currently, it has very limited usage in commercial products. It is suggested that fly ash to be used for making building masonry or other manufacturing applications by exploiting microwave energy for drying and sintering purposes. The future research will be conduct more study thorough sustainability on microwave heating, so as to optimize the drying and sintering parameters in order to find the desirable values that minimize the environment impact without affecting the final aspect of the product

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