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Enhancement of Singgora Roof Tile Using Chemical Modification Method

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ABSTRACT. Singgora roof is a Malay traditional design of roof construction. Singgora was very popular among Malay traditional houses and buildings long time ago but now suffering declining of customer demand. Several problems were known such as low fracture toughness, growth of fungus and the irregular surface finishing. Extensive work should be conducted to sustain the historical heritage and the mentioned problem must be overcome. Throughout this research, the properties of commercial Singgora roof was identified and characterized. To enhance the properties, Feldspar was added to the raw clays as flux materials at different concentration (0, 10, 15, 20 wt.%) during mixing process. Samples were shaped by using POP and fired at 800 °C for 16 hours. The final products were characterized for mechanical and physical properties such as density, impact and three-point bending test. From the result, enhanced product showed higher density and toughness based from Charpy impact test.

Keywords: *Singgora, Roof, Clay, Chemical modification;*

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1. INTRODUCTION

Singgora roof is a Malay traditional architecture design for roof construction. Most of the traditional Malay houses at Eastern Malaysia were using this type of roof for more than 200 years ago. The roof is in pyramid-liked shape and known as the roof of Perak (Fig. 1). It is also called as Senghora brick or simply as roof brick among Kelantanese when referring to the roof tile. However, the name of Singgora itself is came from Thai words which means Lion City and speculated due to lion shape of a hill in Songkhla, Thailand. At the end of 20th century, when Malaysia joined other developing countries, major development model overhauled classic housing structures and the architectures as well that caused the popularity of Singgora roof is reducing and recently was abandoned at all. Currently, only one place that manufacturing Singgora roof tiles in Kelantan which is Kampung Beris, Bachok [1].

Limited manufacture of Singgora roof is due to lack of demand and less popular among current society. The remaining usage of this roof tile is coming from conservation of old heritage building by the government agency or private sector. The weaknesses of Singgora roof become public well known as it mechanically weak and short life span. In this study, the properties of commercialSinggora roof tile will be defined and improved by adding feldspar. Clay based product including Singgora roof is a porous body and adding flux materials like feldspar will improve the properties.

Fig. 1 Singora Roof tile

2. MATERIALS AND METHODS

Commercial Singgora roof tiles and raw clay material were bought from a Singgora manufacturer in Bachok, Kelantan. They were crushed and ground to fine powder for phase and elemental analysis using XRD and EDXRF. To fabricate the Singgora product, similar procedures that were done in factory were followed in this study. Clays were mixed with feldspar at 0, 10, 15, and 20 wt.% and shaped into samples. They were dried for 1 days and fired at 800 °C for 16 hours. Samples were tested for physical and mechanical properties and for commercial product, the sampling was carried on cut body. The studied mechanical properties are tensile test, three points bending and impact test.

3. RESULTS AND DISCUSSION

Analysis of EDXRF on Singgora raw clays and ground fired commercial Singgora roof are showed in Table 1. Based on the result, there are a few oxides presented, which were SiO_2, Al_2O_3, Fe_2O_3, K_2O, TiO_2, SO_3, P_2O_5, Cl, CaO and ZrO_2. The raw materials are having high concentration of SiO_2 (52.5 wt.%), followed by Al_2O_3 (16.5 wt.%), Fe_2O_3 (15.7 wt.%), K_2O (5.94 wt.%) and TiO_2 (2.59 wt.%). Others are existed at small part lower than 2 wt%. EDXRF analyzed the concentration of samples based on the characteristic x-ray energy come from the elements. The compound chemical compositions are calculated as assumption of all the elements existed in from of oxide in the soil. Three compounds are very high in the samples, which are silica, alumina, and iron oxide. Based from the literatures [1–7], silica and alumina are common compounds in clays. Iron rich clay in this study are common in Kelantan state, which gave reddish color of the clay products including Singgora roof [4,6]. The high amount of SiO_2 in clay will increase the amorphous phase in the microstructure [8]. The small amount of Cl is expected from NaCl salt in the clay and the missing of Na in the result is because of out of detection limit by EDXRF. Hassan et al. [3] reported that, the clay raw materials are taken from the clash of saltwater and freshwater at *Kemasin* River. The high content of the salt in clay is considered suitable and gives strength to the tile compared to other clay source without the salt. This can be assumed that, the salt reacted as flux naturally as we did in this study by adding feldspar as flux materials.

Table 1 Chemical composition of grinded commercial Singgora roof tile and clay raw materials

Compound	Clay raw materials (wt.%)	Ground and fired Singgora roof
SiO_2	52.5	58.1
Al_2O_3	16.5	17.4
Fe_2O_3	15.7	12
K_2O	5.94	5.3
TiO_2	2.59	2.05
SO_3	1.78	1.42
P_2O_5	1.69	1.34
Cl	1.26	0.756
CaO	1.25	0.848
ZrO_2	0.194	0.131

XRD patterns of the raw clay, crushed commercial Singgora roof, and feldspar added samples are showed in Fig. 2. From the pattern, three major mineral compounds were found in the raw clay and commercial Singgora which are quartz (COD 9012600), muscovite (COD 9015623) and kaolinite (COD 9014999). Samples produced for 0 and 20 wt.% added feldspar doesn't appear the muscovite/mica and kaolinite peak. It is suggested, firing for 800 °C for 16 hours in furnace decomposed mica and kaolinite compounds. According to Gabor et al. [10] kaolinite decompose at 315 °C and 700 °C for mica. The existence of mica compound from commercial Singgora proved that temperature to produce Singgora in factory is less than 700 °C. The sharp peak and higher intensity of quartz are due to long firing time (3 days) of the commercial Singgora and caused high crystallinity of product atomic structure. Missing of feldspar phase in the sample of feldspar added Singgora is expected due to liquid phase formation during firing and form amorphous structure at the clay porous microstructure. The increasing of amorphous phase can be noticed from the pattern in Fig. 2 when comparing to 0 wt.% samples.

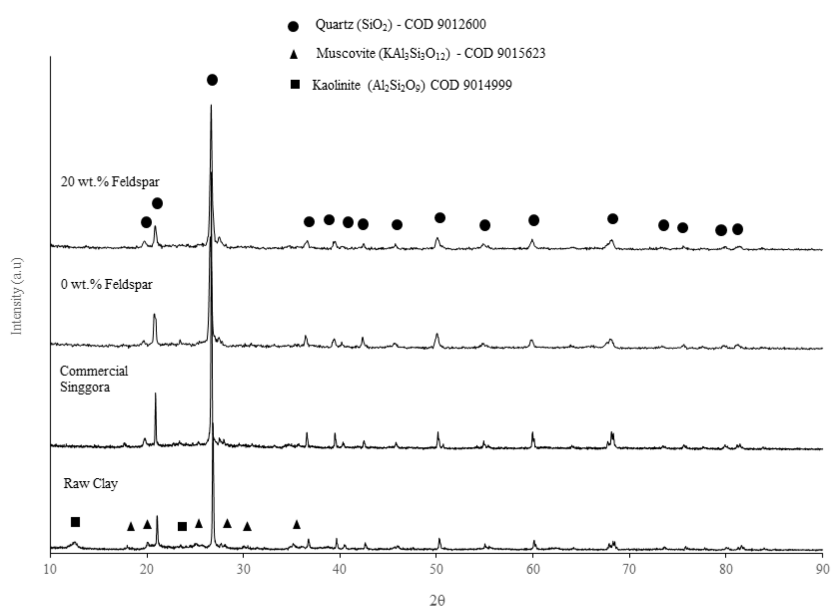

Fig. 2 XRD pattern of raw clay, crushed commercial Singgora and feldspar added samples

Modulus of rupture (MOR) or flexural strength was measured for commercial, and felspar added samples (Fig. 3). The results showed that the highest MOR was obtained from 20 wt.% feldspar which is 173.643

N/mm^2. The lowest MOR was 0 wt.% feldspar added product which the value is 44.593 N/mm^2. Increasing the feldspar up to 20 wt.% was proven to increase the MOR to three times. However, the MOR for 15 wt.% and 20 wt.% are not much differ and this can be assumed by the effect of flux to reduce the porosity is already enough and their effect to mechanical properties is insignificance. The enhanced MOR for the sample proved that adding feldspar mineral is capable to improve their strength and lowered the firing time for sintering process. The 0 wt.% feldspar has low MOR and this is suggested by insufficient firing time which is only 16 hours compared to industry 3 days and very low flux content (only NaCl).

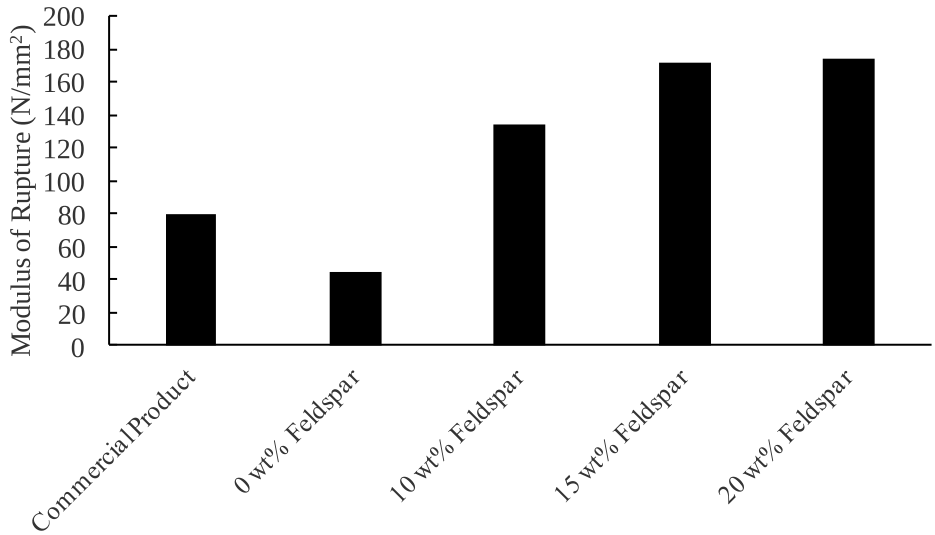

Fig. 3 Modulus of rupture of commercial and feldspar added product of Singgora

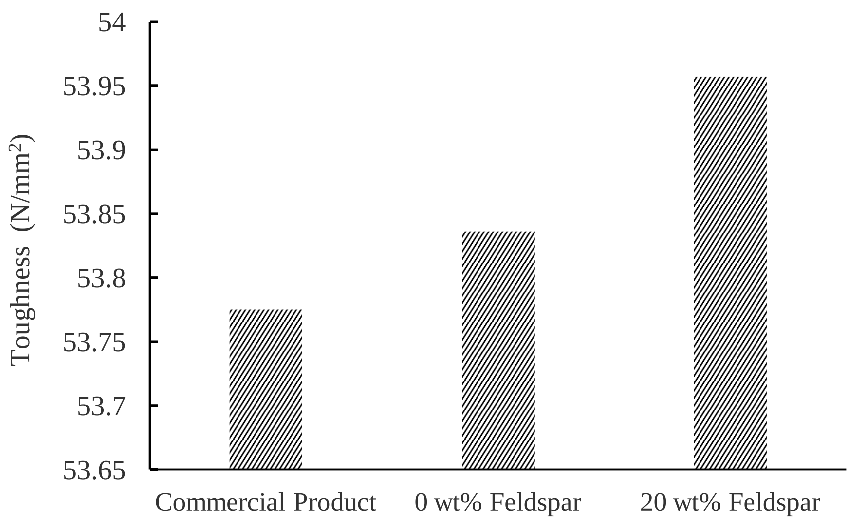

Fig. 4 Toughness of commercial and feldspar added sample of Singgora clay

Fig. 4 displayed results of energy used to break the different samples of Singgora (commercial and feldspar added clays) using Charpy impact test. Adding feldspar to the clay proved the increasing of energy to break the sample from 53.557 N/mm^2 of the commercial Singgora, 53.836 N/mm^2 for 0 wt.% added feldspar and 53.957 N/mm^2 for 20 wt.% added feldspar. Feldspar content in the sample caused the increasing of density or reducing of porosity which will strengthen the clay body. This can be seen on the Fig. 5, the density of clays body increases with the feldspar content. There had other factors that affects the energy to break the sample which are presence of impurities, pores, small stones, dry dusts from grass or leaves.

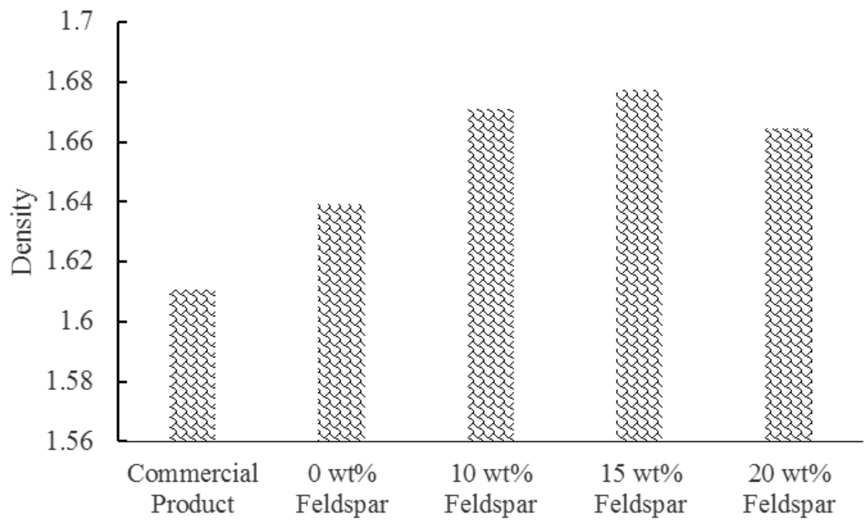

Fig. 5 Bulk density of commercial and feldspar added product of Singgora

4. SUMMARY

Mixed commercial clay with feldspar for 20 wt.% caused improvement of modulus of rupture up to 173.643 N/mm^2 from 79.475 N/mm^2 for commercial Singgora roof samples. The firing time also can be decreased from 3 days for commercially firing method to 16 hours at 800 °C. The improvement of the mechanical properties are caused by the pore elimination by the feldspar that meld and hold the clays particles. At the 15 wt.% concentration of feldspar, the mechanical properties start to stagnant and density also decreased a bit. Based on this study, 15 wt.% of feldpar is enough to improve the mechanical properties and suitable to be applied in the industries.

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