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The Surface Hardness of Mild Steel and Plywood Coated With Different Blending Ratio of Rice Husk Ash-Based Geopolymer

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***Abstract:** Malaysia has a great potential to reuse the agro-waste and reduce the environmental issues generated from the painting industry and agro-waste and achieve the objective of sustainable development. The objective of this work is to analyse physical effects of different blending ratio of rice husk ash based geopolymer binder (GB) surface coating on the hardness of mild steel and plywood. Geopolymer is an inorganic material produced by activated alkaline solution and aluminosilicate sources. Since Malaysia has been producing abundant of rice husk, this rice husk as the aluminosilicate source is used to form geopolymer. As it is known that filler is one of the combinations in paint including epoxy paint, the rice husk ash which has an abundant of silica content can be a ground-breaking source. Thus, an efficient eco-friendly coating that have a good fire resistance properties are very demanding. An optimum coating was formed by optimizing different ratio of GB with water-based or oil- based paint in term of hardness of surface coated. Based on the Rockwell hardness test, the result showed that 2:1 ratio of water-based coated mild steel plate has the highest Rockwell hardness number of 53.08, which meant the lowest depth of impression of 0.1538mm due to 150kgf major and minor load. This implies that different blending ratios addition of GB on plate surface have an effect on the hardness of mild steel and plywood.*

***Keywords** : Aluminosilicate, geopolymer, hardness, rice husk*

I. INTRODUCTION

The downfall of the Twin Towers of the World Trade Center (WTC) in New York City of United States of America (U.S) due to being struck by two jet airliners hijacked by terrorists. This well-known accident has initiated research on the use of fire protection materials in the construction building. Without a fire protection material, the lives of those who are in the building are situated at a high danger when fire disasters occur. The common problems of fire protection in buildings are the metal structural integrity, speedy flame spread, smoke and poisonous fume discharges. Based on the U.S Fire Administration report, there are more than 2,500 people killed per year due to residential fires. Thus, active, and passive fire protection systems are being advised to be install for the human safety [1]. The fire protection material which is one of the passive fire protection system play a key role in delaying the fire effect, increasing the time for lives to escape. Therefore, fire protection material is usually rated by the time taken for the fire effect on structural abilities [2].

An inexpensive, extra efficient, and lately, renewable raw resources for exterior coatings is continuously a demand for different industry through study and development attempts. Due to the depletion of remnant which is a non-renewable source, the worldwide has steadily evolution to a much green resource which is renewable. The solution to over-dependence on fossil fuels lies in harnessing and utilizing the vast quantities of lignocellulosic materials available and devising eco- friendly processes and technologies for converting them into useful industrial products [3]. This has inspired a novel awareness in extenders from agro-waste rice husk.

It is the left-over product from the agriculture sector throughout the process of rice refining. Industrials are assured to have boundless potentials with this renewable resource on plentiful applications. It has recognized that this resource has a prodigious potential applicability in paints and other surface coatings. Based on the research of an Organization by the United Nations (FAO) from Canada on food and agronomy, the paddy growth together with harvest is snowballing annually [4]. Rice husk is the external shelter of paddy and it consists of around 25% the paddy mass. In common, million tons of rice husks are produced yearly and form the dumping problematic [5]. In Malaysia, rice paddy production conferring to FAO estimated that there is an increase of 0.1 tons every year [6]. The demand of rice paddy is growing and about 0.52 tons of rice husk, an agro-waste is produced annually [7].

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The husk weight averages about 20% of total grain weight. Thus, during the milling of rough rice (paddy), it is removed as husk. Therefore, a ton of rough rice generates approximately 200 kg of husk [8].

More recently, the appropriate way to use RHA as extender along with paint has been investigated in some paints known as textured emulsion, cellulose matt paint and matt wood varnish [9]. As it is known that filler is one of the combinations in paint including epoxy paint, the RHA which has an abundant of silica content can be a ground- breaking source. Numerous researchers around worldwide have investigated the effects after applying RHA with resin on substrate. Some mechanical properties for example wear, hardness, and elongation are analyzed. Malaysia which has a great potential to reuse the agro-waste and reduce the environmental issues generated from the painting industry and agro-waste and achieve the objective of sustainable development.

Besides that, RHA can be produced in few structure forms reliant on the combustion temperature. Most of the researches have revealed that the crystallization of RHA occur when temperature is above 600 °C while below than 600 °C is considered amorphous silica [10]. Fig. 1 below shows the phase transformation of RHA when heated in different temperature.

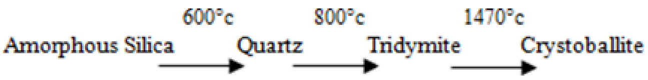

Fig. 1. RHA phase transformation

However, the property of RHA with respect to the temperature variation of above 600 °C required some study. The characterizations of silica, silica content, surface roughness, surface area and porosity can be altered with different temperature. The optimum temperature which has the best result to be applied in paint should be considered.

II. CLASSIFICATION BASED ON TYPE OF SOLVENT AND BINDER

A. Water-based Paint

When monomers are mixed continuously in a water stage in order to form polymer the process is known as emulsion polymerization process. In water-based paint, the term sometimes referred as emulsion paints. The resin or binder that generally use in this type of paints is polyvinyl acetate (PVA) [11]. A water-soluble resin structure comprising a soluble organic compound, a soluble crosslinking agent, a minimum of one in every active agent designated from alkyne alcohols, alkyne glycols, polyethoxylates of alkyne alcohols and polyethoxylates of alkyne glycols, and a solvent comprising of water or a mix of water and a soluble solvent [12].

This soluble organic compound composition is practical onto a resist pattern, then heated to crosslink by an acid provided from the resist, followed by growing to get rid of the non-cross linked soluble organic compound coating layer. This soluble organic compound composition is great in coating features on stages of resist patterns and in dimensional regulation upon fining of patterns [13]. Waterborne coatings utilize water as a solvent to scatter a resin, hence making these coatings ecological and easy to put on. In utmost cases, waterborne coatings comprise up to 80% water with minor quantities of additional solvents, such as glycol ethers. High water gratified cause waterborne coatings equally ecologically friendly and easy to apply. Walls and buildings ceilings are extensively utilizing this type of paints due to it provide good light reflectance, quick evaporating and inexpensive of materials [14].

B. Oil-based Paint

Oil-based paint is an oldest form of paint. It is still being use until now. It is a paint that uses a solvent or easy to understand as the distribution medium that use oil-based lacquer or hard resin. The solvents are basically depends on the drying processed technique which is by oxidation or evaporation of solvent. Alkyd resin (vegetable oil as driving oil) is commonly used as the binder in this type of paint [15]. Due to their ability to liquefied or diluted solely in their solvents, they are sometimes termed as solvent-thinned paint. Alkyd resins can be formed by reaction of dicarboxylic acids, polyols and long chain unsaturated monocarboxylic fatty acids which is resulted from natural oils [16]. In the presence of some catalytic systems such as light, heat and enzymes, alkyd resins are prone to undergo oxidation progression. Subsequently, oxidative drying process arises as the paint's binder oxidized by the environment air oxygen molecular. Following, curing of this resin is a process of drying and hardening of paint due to autoxidation effect. During this period, oxygen comes to the organic compound and crosslinking the formation. The oxygen molecule in the air will combined to the double carbon- hydrogen bond of the unsaturated fatty acid. The fatty acid chain then starts forming the bonds and resulted as a film which visible as the coating. Oil-based paint is remarkable with their preparation adaptability, cheap price, and durability. Oil-based Binders has sturdy odour which is obvious in buildings that are newly painted. When the paint applying and drying process are done, the evaporated solvents can unleash Volatile Organic Compounds (VOCs) into the atmosphere [17]. They are conjointly doubtless risky for each human wellbeing and for the atmosphere.

III. METHODOLOGY

A. Sample Specimen

Ratio of Geopolymer Binder (GB) with water and oil-based paint (0:1, 1:1, 2:1 and 1:2) were mixed for this test. The coating was then applied onto the mild steel plate and plywood. The specimen size is 10 cm x 10 cm. Mild steel has been used in many applications and industrial manufacturing. It has been used in welding field for its outstanding ease of bolting, drilling, and machining process. This mild steel is characterized as low carbon steel and retains tensile strength around 250 MPa while medium strength steel will have around 310MPa and high strength steel will have around 415 MPa. Due to its wide application, cheap, and able to cut into variable shape, ASTM A36 mild steel from SOON SING ENGINEERING CONTRACTOR as shown in Fig. 2 was used in this analysis.

Fig. 2. 10x10 cm mild steel plate before cleaning (left) and after cleaning (right)

Uniform thicknesses of 1mm mild steel plates were obtained from the above-mentioned supplier. Mild steel plates had been cut into 10 x10 cm respectively for this study. After that, 600 grit abrasive grinding papers were used to clean each of the plate to remove any surface rust and better smoothness. Furthermore, they were cleaned with acetone to ensure the plates were free from grease or oil. Lastly, they were placed at room temperature drying for 15 minutes before the fabrication process begin. The plywood was ready obtained from supplier as shown in Fig. 3 Softwood plywood has a 3mm thickness and one of the thinnest in the plywood category. 3-ply was named for it because it has three layers and it was constructed with grains which moving in dissimilar ways to lessen the usual swelling and shrinking of the wood. Each layer of the grain was attached tightly to the other thus resulting in a solid structure.

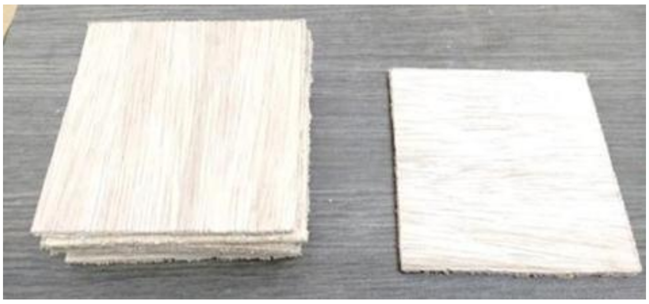

Fig. 3. 10x10 cm plywood

B. Rockwell Hardness Test

Each of the substrate with coating was being measured the hardness for three times. The hardness testing machine was Rockwell FR-X1 which located in lab H2.2 of Faculty of Aerospace Engineering Universiti Putra Malaysia. It is a digital type tester as shown in Fig. 4. The hardness conversion was in compliance with SAE (J –417b) & ASTM (E-18).

Fig. 4. Future-Tech Rockwell Hardness test machine

Before the experiment was done, the measurement mode of the machine was carefully selected based on indenter type used. In this study, 1 ⁄ 16 -inch- diameter (1.588 mm) steel sphere indenter was used. Rockwell hardness test was performed by putting each of the coated steel plate on anvil and the elevating screw was being slowly raised to touch the indenter. Fig. 5 showed some of the perfect indentation points on one of the coated sample after the hardness test. The distance between each indentation point should not be too near where at least 1 cm of separation distance was practiced in this study.

Fig. 5. Perfect indentation points on a coated sample after hardness test

The indentation point for hardness test should be smooth because unevenness on the coated sample surface could deviate the result consistency. Some coated samples may also contain empty voids which caused the cracking of the coating and hence hardness test for indentation could not be measured as shown in Fig. 6.

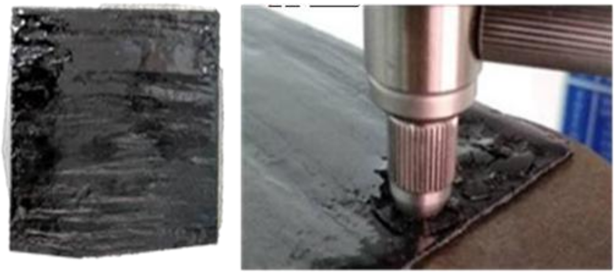

Fig. 6 Unevenness of coated sample (left) resulted in cracking of the sample (right)

IV. RESULT AND DISCUSSION

Rockwell hardness test measure the hardness of materials. A harder material will give higher Rockwell hardness HR number. Precise selection for testing and the accurate result for water-based coated samples were tabulated in Table 1 and then plotted onto graph in Fig. 7.

Table. 1 Overall average Rockwell hardness, HR number of different water-based coated sample with HRF, HRG, HRB SCALE

Ratio	HRF	HRB	HRG
0:1	73.82	61.03	21.30
1.1	67.23	56.87	34.82
2:1	57.92	52.32	53.08
1:2	46.43	31.27	28.07

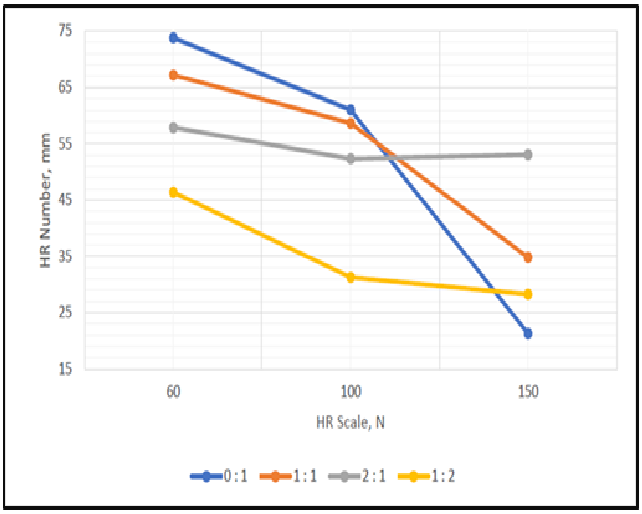

Fig. 7. HR number against HR scale for different water-based ratio coated sample

Therefore, the trend line in fig 7 shown above was precise because the hardness number was decreasing inversely proportional to the major load N for all the coated ratio samples. Although the ratio 0:1 having the highest hardness value against the major load when the first major load being applied, the hardness value of ratio 0:1 decreased drastically when higher major load was applied. Water- based coating solely has the least hardness as obtained from the experiment results.

On the other hand, ratio 2:1 has the highest hardness value. It decreased steadily although it shown there was a slight increase when HRG scale load applied. This might be due to the surface being indent was not smooth which caused a little deviate. Overall, the trend lines for all the coated samples were correct. Ratio 1:1 was decreased quite drastically compared to ratio 1:2 when HRG major load applied. However, ratio 1:1 has higher hardness value compared to ratio 1:2. Therefore, higher amount of water- based paint used was not an added advantage if the amount of GB mixed was less.

In term of depth of impression, it showed the deepness of the coated substrate when the indenter hit the surface of the sample. The higher the hardness of a sample will present a lower depth of impression. Every unit in the depth of impression caused by major load was 0.002 mm which was a constant scale factors for the load in this study. For scales, B, F, G, the E is a constant of 130. At 150 kgf major load, ratio 2:1 has 53.08 Rockwell hardness number while ratio 1:1 has 34.82 Rockwell hardness number. Therefore, the depth of impression could be calculated as shown below.

Ratio 2:1 has

$$e = E\text{-}HR = 130 - 53.08 = 76.92 \text{ unit} = 0.1538 \text{ mm}$$

Ratio 1:1 has

$$e = E\text{-}HR = 130 - 34.82 = 95.18 \text{ unit} = 0.1904 \text{ mm}$$

Furthermore, result for oil-based coated samples were tabulated in Table 2 and then plotted onto graph in Fig. 8.

Table. 2 Overall average Rockwell hardness, HR number of different oil-based coated sample with HRF, HRG, HRB SCALE

Ratio	HRF	HRB	HRG
0:1	100.50	93.93	67.00
1.1	72.50	59.35	53.17
2:1	74.58	63.93	55.60
1:2	88.55	78.35	85.40

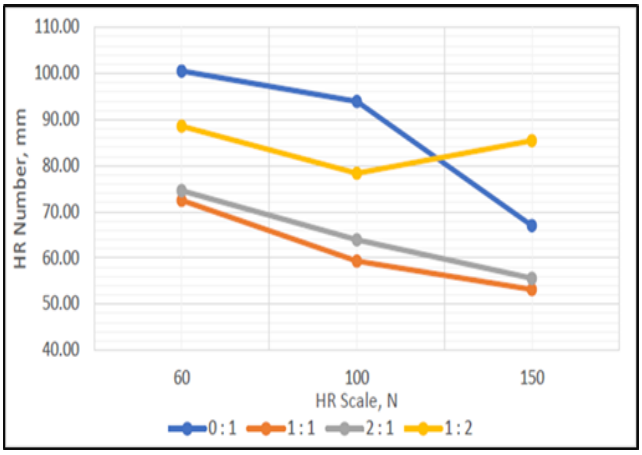

Fig. 8. HR number against HR scale for different oil-based ratio coated sample

Based on table 2, the coated samples hardness number was decreased against the hardness scale except some deviate in ratio 1:2 at HRG scale load. The trend line was accurate as discussed previously. Mixture of GB to oil- based paint was dense and concentrated. This affected the roughness at the coated sample surface and the indentation on it was not consistent.

These two ratios have a low hardness number as shown in Fig 8. Subsequent, ratio 1:2 increasing again after HRB load demonstrated that the reading was incorrect. By observing ratio 1:2 results at HRF and HRB in table 2, the differences of coated mild steel plate 1 and 2 was big. Reading of repeated coated substrate was not near to each other. Results for oil-based coated substrate were basically having error.

The main observation to the error of oil-based coating during the testing was the coating was very sticky even though it had dried for more than 24 hours. The stickiness had caused the indentation over the samples to be inaccurate because Rockwell hardness testing was set to test the hardness of solid sample and it should not adhesive easily to the indenter as in this case.

V. CONCLUSION

The effect of blending different ratio of rice husk ash-based geopolymer binder coating on surface hardness of mild steel and plywood have been studied through Rock Hardness Test. Coating formed by mixing water-based paint with GB was smoothly applied on mild- steel plate and plywood's but oil-based paint with GB resulted in sticky and concentrated coating which was difficult to apply on both substrates.

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2:1 ratio of water-based coated mild steel plate has the highest Rockwell hardness number of 53.08 which meant lowest depth of impression of 0.1538mm due to 150kgf major and minor load. Increased ratio of GB to the coating would provide higher hardness value but the increased of water-based paint ratio did not have the same result.

Oil-based coating was not suitable for hardness test because the coating surface was uneven. 1:2 ratio has the highest Rockwell hardness number of 85.40 while ratio 2:1 has 55.60. The higher the GB mixed resulted a higher the stickiness of coating. An optimum coating was formed by optimizing different ratio of GB with water-based or oil-based paint in term of hardness. GB which comprised of NaOH, Na_2SiO_3 and RHA was the main factor in increasing the coating weight. The ratio 2:1 (GB:Paint) will increase the coating weight by double compared to ratio 1:1 for all substrates.

Water-based coating with ratio 2:1 on mild steel was the best ratio in providing the hardness but this ratio caused addition in weight. Moreover, incorporating of GB into water-based paint has successfully been applied on mild steel which previously solely water-based paint could not do so.

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