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Compressive properties and water contact behavior of opened-cell green rubber foam at different blowing agent concentration

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ABSTRACT – Green rubber foam from reclaimed rubber has high potential to replace available foam products in the market. It provides choices for cheaper material with only small trade-in in the properties and durability. This study is part of our effort to develop new green rubber foam from reclaimed rubber glove. It is focusing on the effect of sodium bicarbonate concentration at 4, 6, 8, 10 and 12 parts per hundred rubber (phr) as blowing agent for the foaming process. The samples were prepared by melt compounding using an internal mixer and expanded via two step heat transfer foaming process. Performance of the green rubber foam was tested for compressive strength and water contact behavior via compression testing and water absorption. The results were supported with morphological analyses using scanning electron microscopy (SEM). From the experimental, sodium bicarbonate with concentration of 4 phr generated the smallest pores and highest relative density of 0.9. The pore structure of the open cell resulted to the lowest water absorption rate of 1.7 x 10^{-3} g/min as well as the highest compressive strength of 105 kPa.

1. INTRODUCTION

Rubber foam is important in various applications due to its unique structural properties, such as its low weight, buoyancy, cushioning performance, low cost and light aging as previous study [1-2]. All these properties are reasonable from rubber materials due to their relatively high tear and tensile strength, high abrasion resistance and durability [3]. Reclaimed rubber (RR) is one initiative for reducing the environmental problem and at the same time to produce significant products at lower cost.

Generally rubber foam consist minimum of two phases, a solid polymer matrix and a gaseous phase derived from a blowing agent [4]. Rubber foam also known as sponge rubber which has open- cell structure and usually contain sodium bicarbonates as their blowing agents. Several finding suggested *N,N'*-diniteosopentam [5], 4,4'oxybis benzenesulfonylhydrazide) [6], azodicarbonamide [7] , and zinc carbonate as a blowing agent.

In this work, the effect of sodium bicarbonate concentration as blowing agent was investigated according to the optimum pores structure and compressive properties of rubber foam, followed by SEM observation.

2. METHODOLOGY

2.1. Materials and Specimens

Rubber foam prepared based on 100 phr of reclaimed rubber and different proportions of sodium bicarbonate at 4, 6, 8, 10 and 12 phr. Curing additives for all formulations based on 100 parts of rubber were: 1 phr of sulphur (S), 4 phr of Zinc oxide (ZnO), 2 phr of stearic acid, 2.5 phr of Tetramethyl Thiuram Disulphate (TMTD) and 1 phr of Benzothiazyl-2-cyclohexylsulphenamide (CBS). Compounds were prepared using a Haake internal mixer working at 60°C and a rotor speed of 60 rpm according to ASTM D-3182. A heat transfer foaming technique was used for the vulcanization and foaming process. This two-stage involved 1 minute of compression molding at the temperature 100°C for pre-vulcanization and was followed by simultaneous curing and foaming in an air-circulating oven for 30 minutes at 150°C.

2.2 Testing

Relative foam density: The relative foam density of the foam was measured in accordance to ASTM D-3575 by using Equation (1):

$$Relative\ density = \frac{Foam\ density\ (g/cm^3)}{Solid\ density\ \ (g/cm^3)} \qquad (1)$$

Water absorption: Water absorption test was conducted in accordance to ASTM C-1083 to determine amount of water absorbed under specified conditions at certain time. Water absorption rate was calculated based on following Equation (2):

$$Absorption\ rate = \frac{Final\ weight\ - Initial\ weight}{Time} \qquad (2)$$

Compression test: Compression test was conducted in accordance to ASTM-D575 to determine compressive strength.

Open cell morphology: The SEM was used to investigate the pore structure of sample using a Zeiss EVO-50 SEM at maginification of 35x.

3. RESULTS AND DISCUSSION

Figure 1(a) illustrates the effect of the blowing agent concentration on the relative density of green rubber foam. Higher concentrations of blowing agent subsequently generate more gaseous media and reducing the relative foam density. Zakaria [7] reported at high blowing agent concentrations, the growth time of the foam is shorten, thus restricting the gas from escaping through the foam surface, allowing the foam to expand more, and consequently, producing foam with a lower relative density.

Figure 1(b) describes the increase of water absorption rate of foam with the increase of blowing agent concentration. At high blowing agent concentrations, more carbon dioxide gas is present. Hence, the gas phase is more prominent than the solid phase, allowing the foam to expand more and consequently produce foam with large unfilled space (Figure 2). Larger pores were observed in foam with higher blowing agent concentration. Since the pores are open cellular, more water is absorbed into the unsaturated part of the foam.

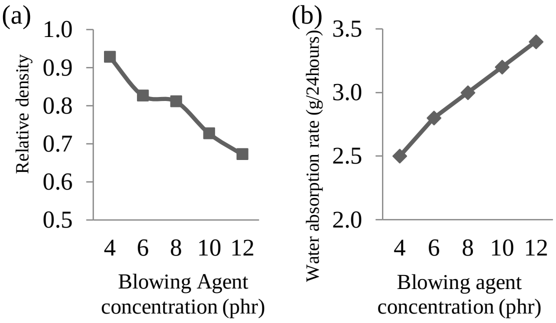

Figure 1 Plot of (a) Effect of blowing agent concentration on relative density and (b) Water absorption rate.

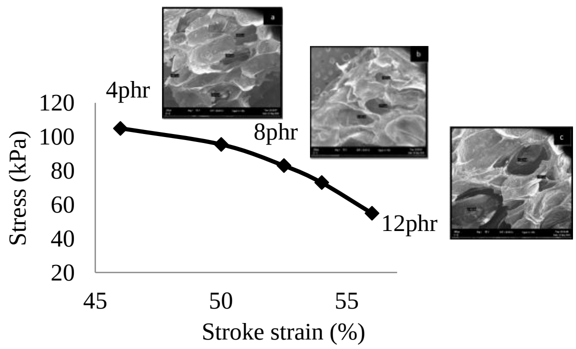

Figure 2 Compressive properties and scanning electron micrograph of samples at magnification of 35x.

The relationship between the force and the displacement at different blowing agent concentrations, obtained from compression testing is presented in Figure 2. The highest force was recorded for foam with a blowing agent concentration of 4 phr with the smallest pores dimensions compared to other samples. The results revealed that the foams produced at lowest blowing agent concentrations sustained higher compressive stress. On the other hand, higher blowing agent concentrations resulted in lower foam relative densities since more gas was generated. The unique properties of foam are due to the presence of the gas phase, which has excellent energy-absorbing characteristics. However, the ability of the pores' structure to sustain the applied stress is critical to examine the strength of the foam since as more gas phase is present, the foam becomes softer and losing its elastic properties to recover to their shapes once force is removed.

4. CONCLUSION

It is proven from the result of this study that using sodium bicarbonate alone is capable in exerting enough carbon dioxide to produce rubber foam. The different blowing agent concentrations which are 4 phr, 6phr, 8phr, 10 phr and 12 phr were shown to influence the pore morphology of rubber foam, thus simultaneously affecting the compressive properties as well as physical characteristics of the foam. From the study that was conducted, it was found that the lowest amount of sodium bicarbonate with percentage concentration of 4 phr generated smallest pores, highest relative density, lowest water absorption rate as well as the highest compressive strength.

5. REFERENCES

[1] J. H. Kim, J. S. Koh, K. C. Choi, J. M. Yoon, and S. Y. Kim, "Effects of foaming temperature and carbon black content on the cure characteristics and mechanical properties of natural rubber foams," *Journal of Industrial and Engineering Chemistry*, vol. 13, no. 2, pp.198–205, 2007.

[2] J. L. Ruiz-Herrero, M. A. Rodriguez-Perez, and J. A. De Saja, "Design and construction of an instrumented falling weight impact tester to characterize polymer-based foams," *Polymer Test*. vol. 24, pp.641–647, 2005.

[3] R. M. Silva, J. L. Rodrigues, V. V. Pinto, M. J. Ferreira, R. Russo, and C. M. Pereira, "Evaluation of shock absorption properties of rubber materials regarding footwear applications," *Polymer Testing*, vol. 28, no.6, pp. 642-647, 2009.

[4] G. L. A. Sims and J. A. Bennett, "Cushioning performance of flexible polyurethane," *Polymer Engineering Science*, vol.38, no. 1, pp. 134–142, 1998.

[5] G. Lin, X. J. Zhang, L. Liu, J. C. Zhang, Q. M. Chen, and L. Q. Zhang, "Study on microstructure and mechanical properties relationship of short fibers/rubber foam composites," *European Polymer Journal*, vol. 40, No. 8, pp. 1733-1742, 2004.

[6] W. Yamsaengsung, and N. Sombatsompop, "Effect of chemical blowing agent on cell structure and mechanical properties of EPDM foam, and peel strength and thermal conductivity of wood/ NR composite-EPDM foam laminates," *Composites*, vol. 40, no. 7, pp. 594-600, 2009.

[7] Z. Zakaria, "Characterization of polyethylene foam and its structure-properties relationship in shock absorbing application," MSc. Dissertation, Universiti Sains Malaysia, Pulau Pinang, Malaysia, 2007.