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The Tensile Properties and Morphology Analysis of Recycled Mattress Filled Natural Rubber Compounds

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ABSTRACT

The tensile properties and morphology analysis of Recycled Mattress (rMat) filled Standard Malaysian Rubber (SMR L) and Epoxidized Natural Rubber (ENR 50) was successfully studied. The both compounds were prepared by two roll mill at five different compositions of rMat (5, 15, 25, 35 and 50 phr). Two different ranges of rMat particles i.e, (300-700 micron) fine, and (3-5 cm) coarse size were used. Results show that fine sizes of rMat filled both SMR L and ENR 50 recorded better tensile performance including tensile strength, rigidity at 100% of elongation and elongation at break, respectively. Ultimately, scanning electron microscopy (SEM) micrographs of tensile fracture surface was also obtained to further clarify the failure mechanism experienced by both compounds.

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INTRODUCTION

Disposal of rubber and plastic is the sensitive issue that we are facing today. The main concerns are at the landfills, ocean, nature environment and river side’s. The disposals of mattress to landfill are dangerous to the environment and human health due to the chemical degradation occurs inside the foam. Therefore, a good way of mattress removal is mattress recycling. Currently, there are large numbers of mattress recyclers around the world. The foam taken from old mattresses can be used for refurbishments or simply thrown away, as this component will disintegrate over time. The disposals of mattress to landfill are dangerous to the environment and human health due to the chemical degradation occurs inside the foam. To solve this environmental issue, a recycled PU mattress (waste) was used as reinforcement in natural rubber compound as an effort to create a value added instead of being scrapped. However, there is limited number of works that were concerned on this kind of issue and it remains as a major challenge in recycling perspective. Based on this concern, the experiment reported here was purposefully designed to fulfill the lack of information in this recycling area. To achieve the goals, recycled products from waste mattress (rMat) with a different range of sizes (300-700 micron and 3-5 cm) were used to be reinforced with both Standard Malaysian Rubber (SMR L) and Epoxidized Natural Rubber (ENR 50) compounds. Tested specimens response were then characterised in terms of their tensile performance including their tensile strength, rigidity at 100% of elongation and elongation at break, respectively. Post damage analysis was also carried out on tensile fracture of tested specimens to further study the failure mechanism experienced by each of tested specimen.

Experimental details:

Materials and Sample Preparation:

The materials used in this study were Standard Malaysia Rubber (MR L) and Epoxidised Natural Rubber (ENR 50) as raw rubber, a recycled product from waste mattress (rMat) with a different range of sizes which fine size (300-700µm) and coarser size (3-5 cm). The other following ingredients such zinc oxide (ZnO), N-

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cyclohexyl- 2-benzothiazyl sulfenamide (CBS), stearic acid, sulphur, calcium carbonate ($CaCO_3$) and processing oil were used for the compounding process. The fine size was obtained by passing the recycled mattress through a two-roll mixing mill for a fixed time (5 min) and then undergo mechanical grinding using grinding machine to achieve a polydispersed powder. The coarser size was prepared directly from recycled mattress in 3-5 cm. The SMR L/rMat and ENR50/rMat compound were formulated with 95/5, 85/15, 75/25, 65/35, 50/50, respectively.

Measurement of Tensile Properties:

Tensile tests were determined using Instron machine according to ASTM D 638. The exposed specimens were pulled out at constant cross-head speed of 500 mm/min and at a temperature of 25±3˚C. The readings of tensile strength, elongation at break (EB) and tensile modulus, M100 (stress at 100% elongation) were recorded. Five measurements were taken for each case, in order to quantify the average behaviour of tested specimens.

Post-damage analysis:

Scanning Electron Microscopy (VPFESEM), model Zeiss SUPRA 35VP was used to analyse the tensile fracture surface of the tested specimens. The surfaces of the samples were mounted on aluminium stubs and sputter coated with a thin layer of gold about 2 nm thickness prior to avoid electrostatics charging and poor resolution during examination.

RESULTS AND DISCUSSION

Tensile strength:

Figure 1 shows the effects of different sizes of SMR L/rMat and ENR 50/rMat for both fine and coarse size particle for tensile strength properties. It is clearly shown that tensile strength of SMR L/ rMat and ENR 50/rMat decreased as the rMat loading increased. However, 15 phr rMat showed optimum value among the entire blend ratio for SMR L/ rMat and ENR 50/rMat blends, respectively. At similar loading, the fine size of rMat loading into rubber exhibit higher tensile strength than that of coarse size. It was believed that finer size allowed faster movement of the rubber crosslink and strongly bonded which gave strong three dimensional network formation of the rubber vulcanizate [1]. Meanwhile, ENR 50/rMat had recorded higher tensile strength with better properties as compared to SMR L/rMat for all tested filler loadings. This was attributed to the presence of epoxide group with adjacent double bond at ENR 50 rubber matrix provided strong intermolecular interaction and high cohesion energy which increase tensile strength and toughness of the rubber [2].

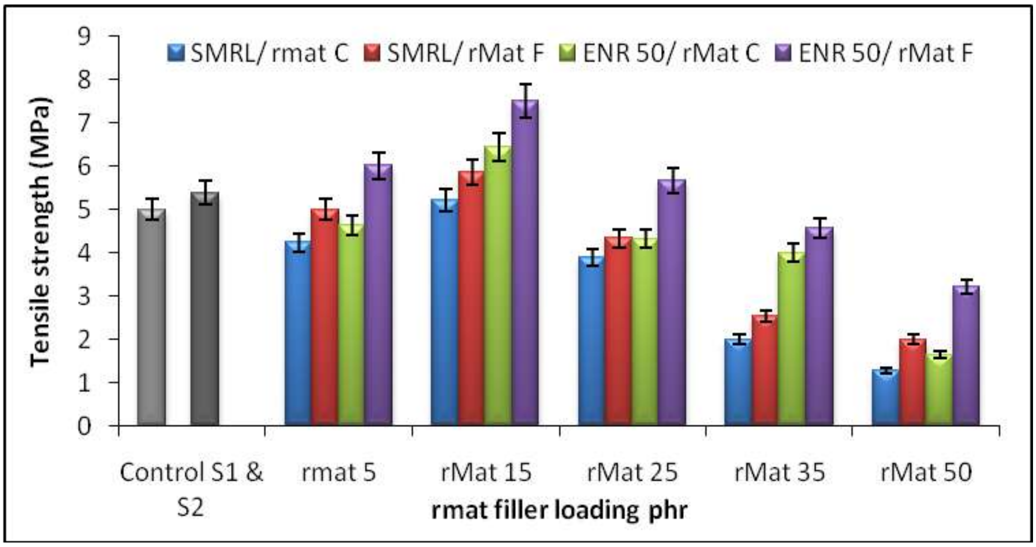

Fig. 1: The combination of the effect of rMat loading on tensile strength (MPa) filled both SMR L and ENR 50 rubber matrices with two different sizes (coarse and fine)

Modulus at 100% Elongation (M_{100}):

Figure 2 shows result of Modulus at 100% Elongation (M100) of SMR L/ rMat or ENR 50/ rMat with different sizes (i.e. Fine and coarse) of rMat fillers. From the bar chart graph, it can be pre-concluded that Modulus at 100% elongations was directly proportional to the tensile strength. In this case, the M_{100} increased from 5 phr to 15 phr while decreased from 25 phr to 50 phr for SMR L/ rMat or ENR 50/ rMat, respectively. It was believed that the increments for 5 phr to 15 phr were due to the better evacuation effectiveness of stress on rubber matrix thus increased the M_{100} than that of control specimens (i.e. where there is no additional stress supplied by other filler to increase the effectiveness of the rubber) [3]. In addition, the penetrated rubber inside and between tubules act as part of filler network and form three dimensional crosslink network at optimum value (i.e. 15 phr) and therefore increased the M_{100}. Meanwhile, the decrements of M_{100} at 25 phr to 50 phr were attributed to the poor crosslink and dispersion of rMat within both rubber matrices and therefore indirectly decrease the M_{100} values.

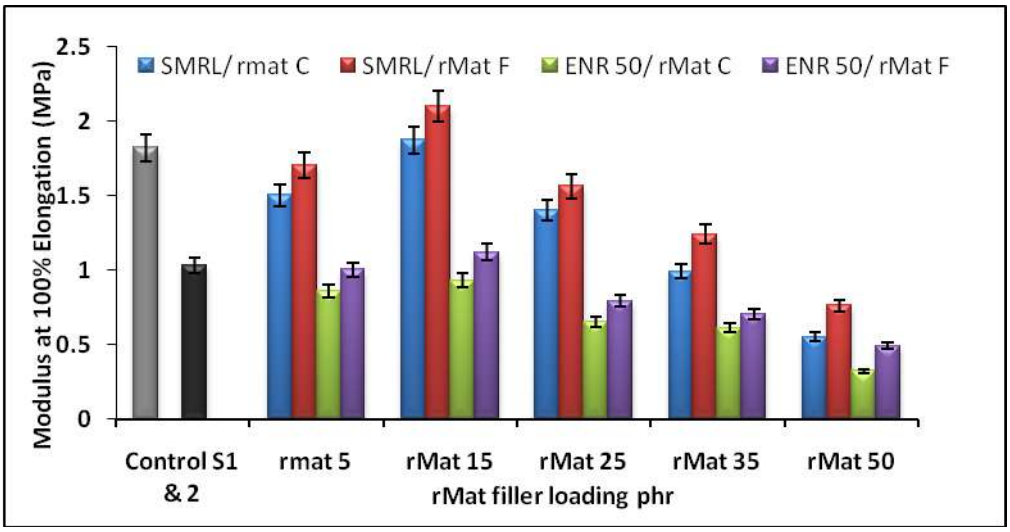

Fig. 2: The combination of the effect of rMat loading on Modulus at 100% Elongations (M_{100}) filled for both SMR L and ENR 50 with two different sizes (coarse and fine)

Elongations at Break, Eb (%):

Figure 3 shows the elongation at break for both SMR L/rMat and ENR 50/rMat with different sizes (coarse and fine). From the bar graph, it can be seen that E_b values decreased with increasing rMat loading. This decrement was due to the restriction of rubber chains at higher filler loading. This also indicates that rubber compound becomes rigid and stiffens (with increasing rMat loading) and indirectly increases the tendency to break. Not only have that, the E_b values were also affected by the filler sized where fine rMat filler show lower E_b values than that or coarse rMat filler. It was reported that the fine size filler may induce to the low viscosity of vulcanized rubber where the rubber compound is easier to be break [4]. Interestingly, it was recorded that ENR 50/rMat show lower elongation at break where it attributed to better tensile strength. This was again due the presence of adjacent double bond in ENR 50 rubber matrix.

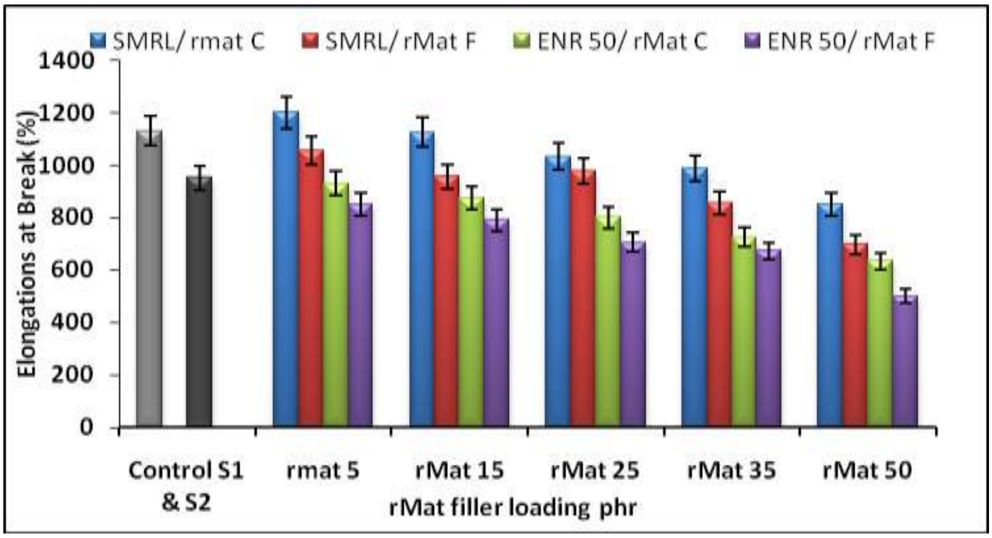

Fig. 3: The combination of the effect of rMat loading on Elongations at Break (%) filled for both SMR L and ENR 50 with two different sizes (coarse and fine).

Post-damage analysis:

Figure 4 showed the SEM Micrograph of tensile fracture surface of (A) SMRL/rMat fine size (B) ENR50/rMat fine size, (C) SMRL/rMat coarse size, (D) ENR50/rMat coarse size for the optimum phr loading (15 phr). From SEM micrographs in Figures 4 (A and B), it can be observed that rMat particles were homogeneously distributed within rubber matrix tearing line with less filler pull-out. Specifically, Figure 4B illustrates better adhesion between rMat and the ENR 50 matrix where it was still well bonded within the SMR L matrix. The SEM images can be supportive arguments on the tensile performance explanation where SMRL/rMat with coarser fracture surface required less energy to be break and indirectly resulted in lower tensile properties. Figure 4C and 4D showed the SEM images of coarser size of rMat loading into both SMRL and ENR50 rubber matrices. It was schematically proven that coarser sizes had induced poor dispersion and caused more rMat filler pulled-out and detachments at the tensile fracture surface [5].

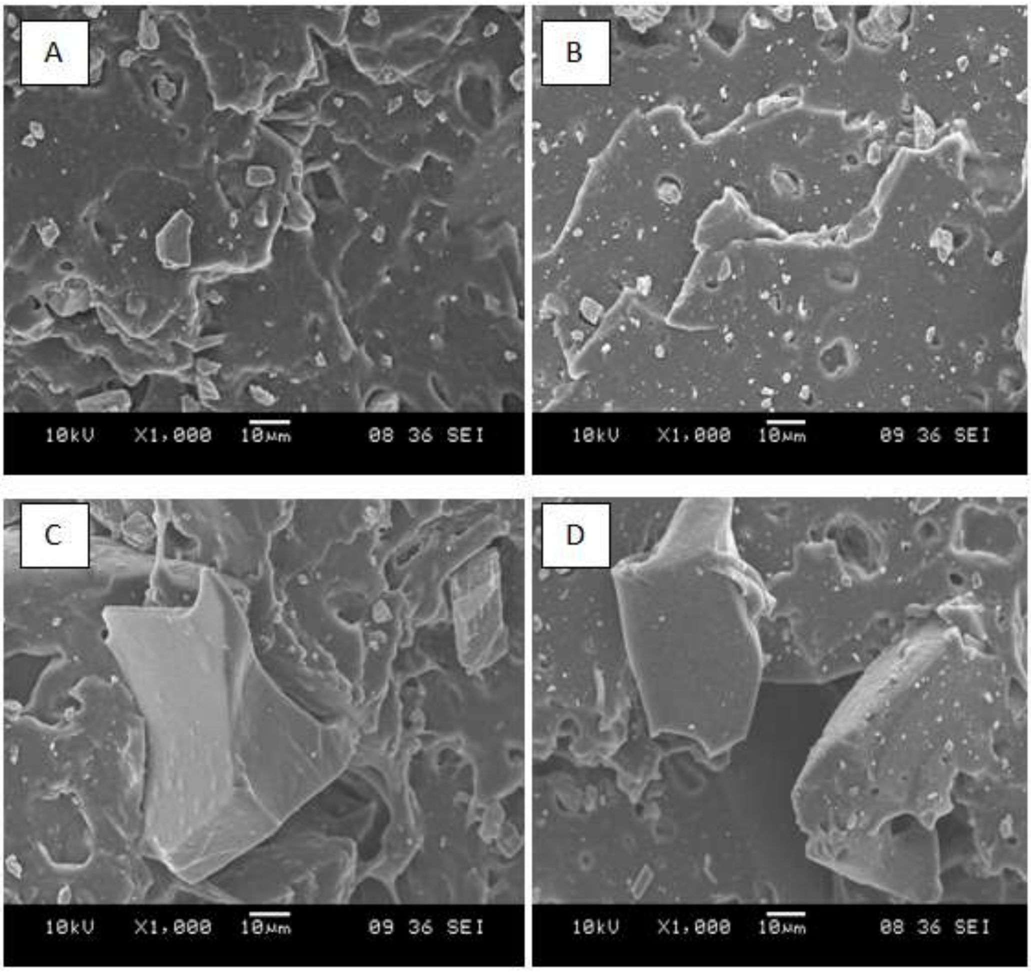

Fig. 9: SEM Micrographs of tensile fracture surface of (A) SMRL/rMat fine size (B) ENR50/rMat fine size, (C) SMRL/rMat coarse size, (D) ENR50/rMat coarse size for the optimum phr (15 phr) at 1000X magnification

Conclusions:

The tensile properties and morphology analysis of Recycled Mattress (rMat) filled Standard Malaysian Rubber (SMR L) and Epoxidized Natural Rubber (ENR 50) was successfully studied using both Instron machine and scanning electron microscopy, respectively. From the results, the following conclusion can be drawn:

- The fine size of rMat loading up to 15 phr gave an increment in terms of tensile strength, modulus at 100% elongations and low elongations at break in SMR L/rMat and ENR 50/rMat compounds.
- Meanwhile, ENR 50/rMat had recorded higher tensile performance with better properties as compared to SMR L/rMat for all tested filler loadings
- Post-damage analysis by Scanning Electron Microscopic (SEM) showed that fine size of rMat filled both SMR L and ERN 50 exhibited smoother surface fracture as compared to coarser size rMat fillers

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