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## Properties of Natural Rubber/Recycled Chloroprene Rubber Blend: Effects of Blend Ratio and Matrix

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### Abstract

The present study investigated the effects of two types of natural rubber and different blend ratios on the cure, tensile properties and morphology of natural rubber/recycled chloroprene rubber blends. The blends of natural rubber/recycled chloroprene rubber were prepared by using laboratory two-roll mill. The result showed that the cure time prolonged with the addition of recycled chloroprene rubber (rCR). Comparability, natural rubber/recycled chloroprene rubber (SMR L/rCR) blend cured rapidly than epoxidized natural rubber/recycled chloroprene rubber (ENR 50/rCR) blend. The addition of rCR also caused a decrement in the tensile strength and elongation at break for both rubber blends. The SMR L/rCR blend showed higher tensile strength and elongation at break compared to those of ENR 50/rCR blends at any blend ratios.

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**Keywords:** Recycled chloroprene rubber; Rubber blends; Mechanical properties

### 1. Introduction

In the glove manufacturing, common problems such as the formation of blisters, pinholes, thin patch, and gel latex between the gloves fingers are the main reason for great amount of glove rejected due to poor in quality. Hence, due

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to these common problems in glove manufacturing, the idea to reuse the rejected gloves in blending with virgin rubber is developed.

In this work, the blending of recycled chloroprene rubber (rCR) gloves with two different types of natural rubber is investigated. It is well known that chloroprene rubber (CR) has demonstrated resistance to hydraulic fluids, gasoline, alcohols, organic acids, alkalis, oils and fats and may also provide enhanced chemical and wear resistance compared to natural or other synthetic rubbers in some situations<sup>1</sup>. These properties indicate CR is stable and high resistance towards common degrading agencies. Hence, the recycling of CR is necessary as a solution for disposal problem.

Two types of natural rubber with different in polarity were used namely Standard Malaysian Rubber (SMR L) and modified natural rubber known as Epoxidized Natural Rubber (ENR). The epoxidation of NR to produce ENR involves the random introduction of epoxide groups onto the double bond of the NR polymer chain<sup>2</sup> where ENR properties resembling those of synthetic rubbers rather than natural rubber<sup>3</sup>. ENR 50 is a chemically modified natural rubber which contains 50 mol% of epoxidation<sup>4</sup>. It is reported that the blends of NR/CR are immiscible<sup>5, 6</sup> and the ENR 50/CR blends are miscible up to certain degree depended on several factors<sup>7-9</sup>. However, the works mentioned are based on the CR and only a few studies work on blending with recycled chloroprene rubber was reported to the best knowledge of the authors. This study will be reported and compared the effects of various blend ratios on the cure characteristics, tensile properties, and morphology of SMR L/rCR and ENR 50/rCR blends.

## 2. Experimental

### 2.1. Material and formulation

NR from Standard Malaysian Natural Rubber grade L (SMR L) and epoxidized natural rubber (ENR 50) were supplied by Rubber Research Institute Malaysia (RRIM), whereas Juara Resources (M) Sdn. Bhd. was the supplier for the recycled gloves. At first, the recycled gloves were grounded into powder form using a table-type pulverizing machine from RongTsong Precision Technology Co., Ltd. The average size of ground rCR was 600  $\mu\text{m}$ . CB of high abrasion furnace (N330) was purchased from EXCELKOS Sdn. Bhd. All other reagents, such as zinc oxide (ZnO), sulfur ( $\text{S}_8$ ), *N*-cyclohexyl-2-benzothiazole sulfonamide (CBS), tetramethylthiurammonosulfide (TMTM), magnesium oxide (MgO), and stearic acid, were purchased from Bayer (M) Sdn. Bhd. The detailed of five different formulations of the rubber blends are shown in Table 1.

Table 1. The experimental formulations.

Materials	Loadings (phr)				
	1	2	3	4	5
NR*	95	85	75	65	50
rCR	5	15	25	35	50
ZnO	5.0	5.0	5.0	5.0	5.0
Stearic acid	3.0	3.0	3.0	3.0	3.0
CBS	0.5	0.5	0.5	0.5	0.5
TMTM	1.0	1.0	1.0	1.0	1.0
MgO	2.0	2.0	2.0	2.0	2.0
$\text{S}_8$	2.5	2.5	2.5	2.5	2.5
N330	30.0	30.0	30.0	30.0	30.0

\*Two different types of NR were used; SMR L and ENR 50

### 2.2. Blending preparation

Blending of rCR with SMR L or ENR 50 and all the ingredients listed in the Table 1 were carried out on a laboratory two roll mill model XK-160 with the size of 160 mm x 320 mm. These procedures were based on ASTM D 3184-89.

### 2.3. Sample preparation

The cure time ( $t_{90}$ ), and maximum torque ( $M_H$ ) of the rubber blends were determined by a Monsanto moving die rheometer (MDR 2000) at 150 °C according to ASTM D5289. Based on the obtained data, cure rate index (CRI) was calculated.

The tensile properties of the rubber blends, such as tensile strength, and elongation at break, were determined using Instron machine model 3366 at room temperature ( $25 \pm 2$  °C) at 500 mm/min crosshead speed in accordance with ASTM D412. The tensile fractured surfaces of the rubber blends were coated with a thin layer of Pd-Au. Then, the morphology features were characterized by a Supra-35VP field-emission SEM.

### 3. Result and discussion

Fig. 1 shows that both rubber blends exhibited longer cure time with the addition of rCR. At the same blend ratio, the blends of ENR 50/rCR displayed longer cure time than SMR L/rCR blends as shown in Fig. 1. This indicates the vulcanization process in the ENR 50/rCR blends is decelerating. Lower cure rate index (CRI) of ENR 50/rCR blends than SMR L/rCR blends as shown in Fig. 1 supported the observation. In general, the epoxy group of ENR can be activated during vulcanization when heated during the vulcanization and opened by sulfonic acid, thus facilitating the formation of crosslinks<sup>7</sup>. However, different trend is observed in this ENR 50/rCR blends which can be explained due to significant effect of rCR in the cure time. This can also relate to the different cure characteristics of SMR L and ENR 50 in vulcanization system. It has been elucidated that the use of accelerator efficiency based on sulfenamide in the ENR is lower than in NR<sup>10, 11</sup>.

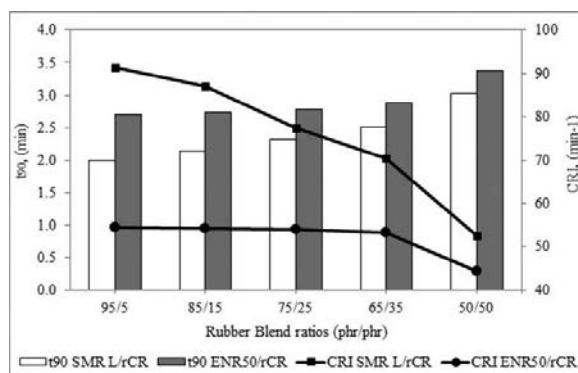


Fig. 1. Cure time and cure rate index for SMR L/rCR and ENR 50/rCR blends at various blend ratios.

Minimum torque (ML) value of ENR 50/rCR and SMR L/rCR blends with various blend ratios is shown in Table 2. The addition of rCR caused an increment in ML value for both rubber blends. Theoretically, the lower ML value the better processability of the blend<sup>12</sup>. This indicates that the rCR increases the flow resistance and reduces the processability in the rubber blends. It can be seen that the ML value fluctuate in both rubber blends. Lower ML value in ENR 50/rCR blends can be observed with rCR content below 25 phr but showed drastic increment at higher content of rCR as compared to that SMR L/rCR blends.

Table 2 also shows that the maximum torque (MH) value is increased with the addition of rCR in both rubber blends. ENR 50/rCR blends showed higher MH values than SMR L/rCR blends. This indicates that the modulus of ENR 50/rCR blends is higher than that SMR L/rCR blends. This is attributed to the formation of ether linkage as a result of the interaction between the epoxide groups in the ENR with the chlorine moiety in the CR<sup>13</sup>. Besides, there is possible molecular interaction between the ENR 50 and metal oxides (MgO and ZnO) since both materials are polar in nature<sup>14</sup>. These factors decrease the chain mobility in the ENR 50/rCR blends.

Table 2. Torques of SMR L/rCR and ENR 50/rCR blends.

Blend ratio (phr/phr)		ML	MH
95/5	SMR L/rCR	0.75	16.96
	ENR 50/rCR	0.19	17.32
85/15	SMR L/rCR	0.95	17.83
	ENR 50/rCR	0.40	18.69
75/25	SMR L/rCR	1.05	19.57
	ENR 50/rCR	1.03	21.15
65/35	SMR L/rCR	1.27	21.95
	ENR 50/rCR	1.93	23.89
50/50	SMR L/rCR	2.25	24.25
	ENR 50/rCR	4.02	26.29

Fig. 2 shows the effects of different rubber types and blend ratios on the tensile properties of SMR L/rCR and ENR 50/rCR blends. The tensile strength (TS) and elongation at break (Eb) for both rubber blends are decreased with the addition of rCR. The grinding process to produce shorter segments made recycled rubber blends unable to withstand high load and thus lower the TS and Eb. As comparison, the TS and Eb are higher in SMR L/rCR blends than that of ENR 50/rCR blends owing to the strain-induced crystallization in SMR L. Besides, as reported earlier in the  $t_{90}$ , SMR L/rCR blends cured faster than that ENR 50/rCR blends. When crosslinks are formed more rapidly, with a lower degree of desulfuration, polysulfidic linkages are prone to take <sup>15</sup>. Hence, higher tensile strength is obtained in the SMR L/rCR blends. In addition, the incorporation of CB is able to influence the degree of other ingredients and act as physical compatibilizer which can enhance the TS of the rubber blends.

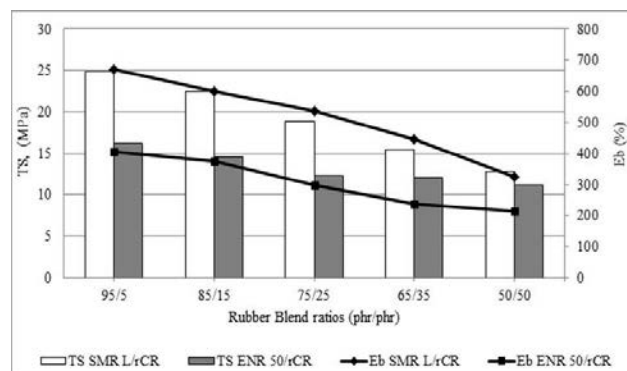


Fig. 2. Tensile properties of SMR L/rCR and ENR 50/rCR blends.

The SEM micrographs of tensile fractured surfaces of 50/50 (phr/phr) of SMR L/rCR and ENR 50/rCR blends are shown in Fig. 3 (a) and (b), respectively. There is two distinct surfaces can be compared between these rubber blends. It can be seen that the surface of SMR L/rCR blend is rougher than that the ENR 50/rCR blend which is smoother and flatter surface. The rough surface in SMR L/rCR blend indicates that the rubber blends undergo ductile failure. This is credited to the better interaction between SMR L and rCR and strain-induced crystallization in SMR L which increases the failure resistance during the tensile test. This is responsible for higher tensile strength and elongation at break in SMR L/rCR blends.

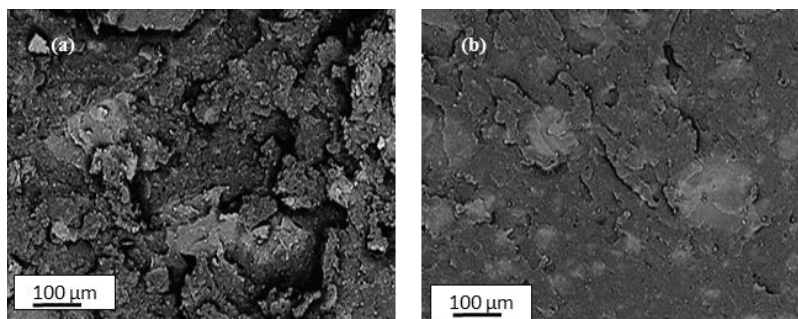


Fig. 3. SEM micrographs for (a) 50/50 SMR L/rCR blends; (b) 50/50 ENR 50/rCR blends at 150x magnification.

#### 4. Conclusion

The properties of SMR L/rCR and ENR 50/rCR blends were compared and reported. At the same blend ratio, the SMR L/rCR blends showed shorter cure time and faster crosslink formation than that ENR 50/rCR blends. In addition, SMR L/rCR blends showed higher tensile strength and elongation at break than that ENR 50/rCR blends.

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