

สมบัติการกดของยางธรรมชาติผสมยางมะตอยและวัสดุมวลรวม Compression Properties of Natural Rubber - Asphalt - Aggregate Blends

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บทคัดย่อ

การศึกษาสมบัติการกดของยางธรรมชาติผสมยางมะตอยและวัสดุมวลรวม ภายใต้อิทธิพลของขนาดวัสดุมวลรวม และผลของความเร็วของการกด ในการเตรียมพอลิเมอร์เบลนด์ ใช้เครื่องกวนที่มีความเร็วรอบ 320 รอบต่อนาที ที่อุณหภูมิ 110 องศาเซลเซียส เป็นเวลา 2 ชั่วโมง แล้ววัดสมบัติการกด จากกราฟความเค้น การเปลี่ยนรูปโกซีและมอดูลัสการกดเวลา ภายใต้อิทธิพลของขนาดวัสดุมวลรวม พบว่าค่าความเค้นของการเปลี่ยนรูปของโกซีที่ 0.15 ค่าความเค้นที่ได้จะเพิ่มขึ้น เมื่อขนาดวัสดุมวลรวมขนาดเล็กลง และสำหรับความสัมพันธ์ของมอดูลัสการกดกับเวลาการกด จะเพิ่มขึ้นเมื่อขนาดวัสดุมวลรวมผสมมีขนาดเล็กลงเช่นกัน ส่วนค่าความเค้น ของการเปลี่ยนรูปของโกซีที่ 0.15 ภายใต้อิทธิพลของความเร็วในการกด พบว่าค่าความเค้นมีแนวโน้มที่เพิ่มขึ้น เมื่อความเร็วการกดเพิ่มขึ้น นอกจากนี้ความสัมพันธ์ของมอดูลัสการกดกับเวลา ค่ามอดูลัสการกด ก็จะเพิ่มขึ้นตามความเร็วการกดเช่นเดียวกัน

คำสำคัญ: สมบัติการกด ยางมะตอย ยางธรรมชาติ การเปลี่ยนรูปโกซี

Abstracts

This research purposed was to investigate the compression properties of natural rubber - asphalt - aggregate blends under the effects of aggregate material and the speed of the compression. This polymer blends were stirred with the machine mixer at 320 rpm and temperate 110° C for 2 hours. From the graph of Stress – Cauchy's deformation and compression modulus - time under the effects of aggregate material (rock) size, it was found that the stress of Cauchy's deformation at 0.15 increased when aggregate size decreased. For the relationship of compression modulus and time, it also increased by smaller aggregates. The stress of Cauchy's deformation at 0.15 under the

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influence of the speed of the compression tended to increase when the speed of the compression increased. In addition, the relationship of compression modulus and time, the compression modulus increased by the speed of compression.

Keywords : Compression Properties, Asphalt, Natural Rubber, Cauchy's Deformation

Introduction

In consideration of increased traffic loads and in order to improve pavement performance, rubber modified asphalts have been developed during the last few decades. The added rubber can strongly enhance the binder properties and permit the building of safer roads and the reduction of maintenance costs [1]. Asphalt has numerous applications and one of its major uses is as a binder for aggregate materials in the construction of highways and runways [2]. However, this material has poor mechanical properties because it is hard, fatigue cracking and brittle in cold weather (low temperature), soft, rutting and fluid in hot environment (high temperature) and it has a low elastic recovery. The brittle character of the asphalt makes it easy to fracture when it is subjected to stress. For these reasons asphalt is usually reinforced by rubber to improve its mechanical properties [3]. The main objective of this work has been to study on the compression properties of natural rubber - asphalt - aggregate blends. The effects of aggregate size and the speed of the compression. Cauchy's equation, compression modulus and true stress were used in order to characterize the linear and non-linear behavior of polymer blends.

Materials and Methods

Materials

STR 5L Grade Rubber (Chana Rubber Company Limited), Penetration Grade liquid asphalt (AC 60/70) (Pattani Highway District) and aggregate diameter of 4.75 - 9.50 mm, 9.50 - 12.50 mm and 12.50 - 19.00 mm. were used for preparation of samples.

Sample preparation

The polymer blends were prepared using a high shear mixer. Firstly, asphalt was heated until it became fluid in a small iron container, then upon reaching about 110° C, the rubber (based on 100 parts asphalt) and aggregate were added. The stirring time was 2 hours at the stirring speed of 320 rpm. Finally, the sample was poured into a PVC tube, 2.6 cm in diameter and 5 cm in height.

Compression property test

The compression properties of polymer blends were tested by the speed of compression at 50, 150 and 250 mm/min (25°C). Cauchy's equation, compression modulus and true stress were used in order to characterize the linear and non-linear behavior of polymer blends, which can be calculated by the following equation:

$$\text{True stress} = \sigma(t) = \frac{F(t)}{A(t)}$$

where F (t) is the force and A (t) is the cross-sectional area at time t.

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The compression modulus $D(t)$ can be determined as follows

$$D(t) = \frac{\sigma(t)}{-\left(\lambda^2 - \frac{1}{\lambda}\right)}$$

where $\sigma(t)$ is the true stress at time t and $\lambda^2 - \frac{1}{\lambda}$ is Cauchy's deformation.

where λ is the compression ratio, $\lambda = \frac{h_t}{h_0}$.

and $h_t = h_0 - vt$

where h_t is the height (mm) at time t , h_0 is the initial height (mm), v is the speed of the compression (mm/min) and t is the time (min) or (sec).

Results and Discussion

- The deformation behavior of polymer blends

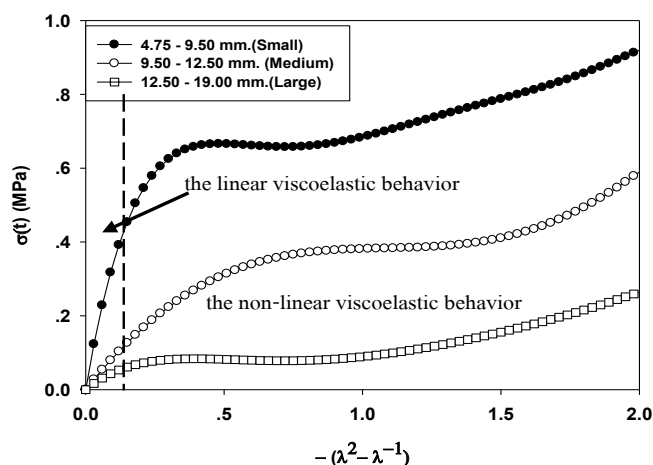


Fig. 1. Stress - Cauchy's deformation, aggregate diameter of 4.75 - 9.50 mm (Small, S), 9.50 - 12.50 mm (Medium, M) and 12.50 - 19.00 mm (Large, L), the amount of natural rubber (Rubber, R) 0 % wt, the speed of the compression (Speed) at 50 mm/min and the time at 0 min for mastication (Masticate).

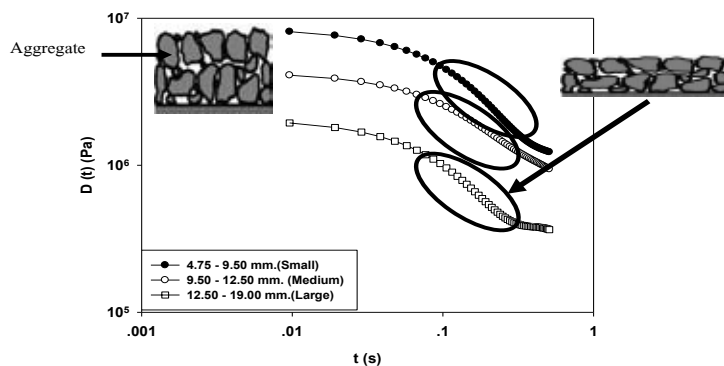


Fig. 2. Compression modulus ($D(t)$) – time, aggregate diameter of 4.75 - 9.50 mm (Small, S), 9.50 - 12.50 mm (Medium, M) and 12.50 - 19.00 mm (Large, L), the amount of natural rubber (Rubber, R) 0 % wt, the speed of the compression (Speed) at 250 mm/min and the time at 0 min for mastication (Masticate).

Fig. 1. and 2. show the deformation behavior of polymer blends, it was found that the linear viscoelastic behavior at the initiation of the compression due to the relaxation of polymer blends [4]. The linear viscoelastic region describes the resistance of the polymer blends to loading and thus rutting and cracking due to fatigue [5]. As the deformation increases, it was found that the non-linear viscoelastic behavior was apparent due to the relaxation and creep of polymer blends and the movement of the aggregate [6].

- Effect of aggregate size

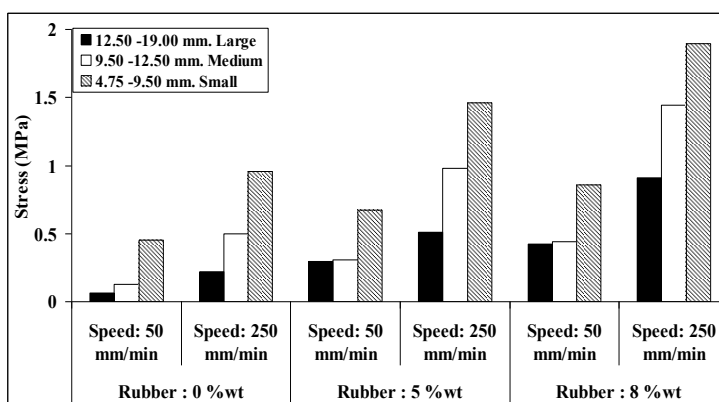


Fig. 3. Stress - Cauchy's deformation at 0.15, aggregate diameter of 4.75 - 9.50 mm (Small, S), 9.50 - 12.50 mm (Medium, M) and 12.50 - 19.00 mm (Large, L), the amount of natural rubber (Rubber, R) 0, 5, 8 % wt, the speed of the compression (Speed) at 50, 250 mm/min and the time at 10 min for mastication (Masticate).

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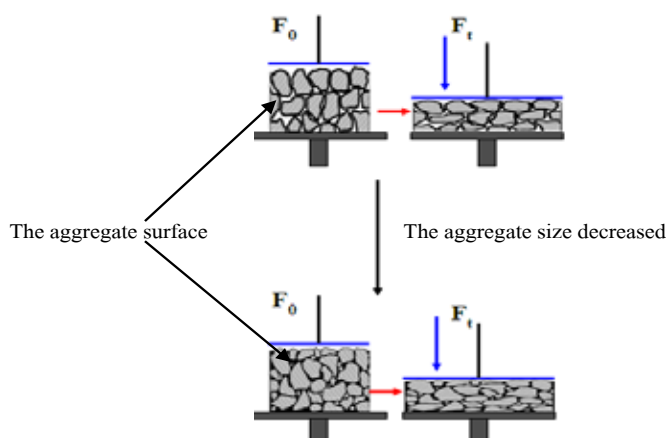


Fig. 4. Effect of aggregate size

From Fig. 3. and 4. , the stress of Cauchy's deformation at 0.15 (less time in the compression), it was found that the stress increased when aggregate size decreased. In addition, the relationship of compression modulus – time, the compression modulus also increased by smaller aggregates. Due to aggregate size smaller, the internal friction between the aggregate surface increased [7] and the adhesion between the rubber modified asphalt and the aggregate surface increased [3]. As a result, the stress increased.

- Effect of the speed of the compression

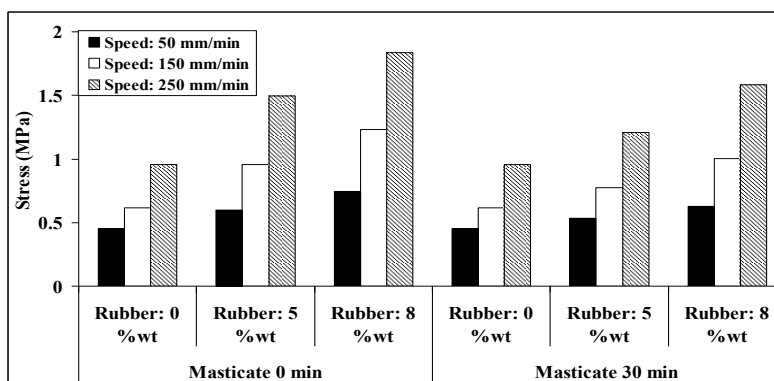


Fig. 5. Stress - Cauchy's deformation at 0.15, the speed of the compression (Speed) at 50, 150 and 250 mm/min, the amount of natural rubber (Rubber, R) 0, 5, 8 % wt, aggregate size, diameter of 4.75 - 9.50 mm (Small, S) and the time at 0, 30 min for mastication (Masticate).

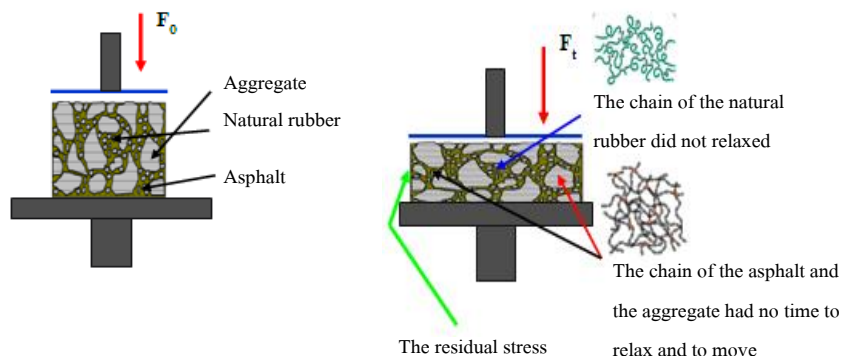


Fig. 6. Effect of the speed of the compression

From Fig. 5. and 6. the stress of Cauchy's deformation at 0.15 (less time in the compression), it was found that the stress increased when the speed of the compression increased. In addition, the relationship of compression modulus - time, the compression modulus increased by the speed of compression. When the speed of the compression increases, the chain of the natural rubber did not relaxed [6]. The chain of the asphalt and the aggregate had no time to relax and to move [6]. The residual stress was within the polymer blends [6]. As a result, the stress increased.

Conclusions

The effects of aggregate size were found to cause the increase of the stress as the aggregate size became smaller. The compression modulus also increased when the aggregate size increased. The effects of the speed of the compression made the stress increased as it was increased. It was also found that the compression modulus increased as the speed of compression increased.

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