EFFECT OF TIRE RUBBER TYPE ON ASPHALT-RUBBER BINDERS

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1. INTRODUCTION

The disposal of scrap tires has become an important problem around the world. In Japan, for instance, 106.000.000 tires are discarded yearly (Bridgestone, 2003). Several studies have been developed in order to recycle these discarded tires. The addition of grinded tire rubber into asphalt binder is one way studied to recycle the discarded tires and improve the asphalt binder properties. This paper presents an analysis developed for asphalt-rubber binders considering the influence of grinded rubber type, in other words, from passenger car tires and from truck/bus tires. In both cases, the tire grinding process produced rubber particles whose diameters were almost 0.4 millimeters. The grinded tire rubber was added to Japanese asphalt type 60/80, the asphalt type most used in Japan, prior to the addition of aggregates (wet process). Considering the total asphalt-rubber binder weight, grinded rubber from passenger car tires was mixed with asphalt at rates of 0%, 9%, 12%, 15% and 18%. The same process was repeated for grinded rubber from truck/bus tires. The performance of these asphalt-rubber binders was analyzed through conventional and Superpave tests.

2. ASPHALT-RUBBER BINDER (WET PROCESS)

Grinded tire rubber is mixed to asphalt binder at elevated temperature, typically between 150ºC and 175ºC, for 10 to 45 minutes, prior the addition of aggregates (wet process). During this period, rubber particles tend to swell, the interparticles distance is reduced and the viscosity of asphalt-rubber binder is increased (Hicks *et al.*, 1995). The swelling of grinded rubber is not a chemical reaction since these rubber particles do not melt into the asphalt binder. The reaction is similar to a compressed, hard, dry sponge being placed in a water bath. As the sponge absorbs the water, it swells and softens (FHWA, 1992). The swelling of grinded rubber is due to the absorption of asphalt components. Asphalt binder is composed by a variety of petroleum fractions (asphaltenes, resins, cyclics and saturates) (Hicks *et al.*, 1995). Rubber particles absorb aromatic oils from the asphalt cement into the rubber chains which are the key components of the natural and synthetic rubber. Natural rubber provides elastic properties while synthetic rubber improves the thermal stability properties. The reacted particles become tacky and develop adhesive properties. Furthermore, the viscosity of asphalt-rubber binder is increased as the amount of aromatic oils to lubricate the binder is reduced (FHWA, 1992).

3. FINDINGS

3.1 Conventional Analyses

3.1.1 Penetration test at 25ºC and softening point

The penetration of unaged asphalt-rubber samples (Figure 1) decreased continuously as the percentage of grinded rubber increased. This fact was observed for grinded rubber from truck/bus tires as well as grinded rubber from passenger car tires. When adding 18% of grinded rubber to straight asphalt (0% rubber), the penetration for unaged asphalt-rubber binder decreased 61.1% for passenger car tires and 39.6% for truck/bus tires. This means that the resistance to rutting was improved with rubber addition. However, when asphalt-rubber binders were aged using the Rolling-Thin Film Oven Test (RTFOT) machine, it was observed that despite the increasing percentage of grinded rubber, the penetration values tended to be constant, around 41 tenths of millimeter. Despite this, the penetration values for aged asphalt-rubber binders were lower than the values measured for unaged binders, so the resistance to rut depth was made better.

Considering the softening point test for unaged binder (Figure 2), it was observed that grinded rubber from passenger car tires as well as truck/bus tires have the same performance, increasing continuously as the percentage of grinded rubber raised. When adding 18% of grinded rubber to straight asphalt the softening point increased 42%. As a result of this, the resistance to permanent deformation was improved. After aging at RTFOT equipment, the softening point for rubber from passenger car tires and truck/bus tires showed a very close performance, increasing 40% for 18% of grinded rubber addition. Moreover, when compared to unaged binders, the aged asphalt-rubber binders presented higher values of softening point as the percentage of grinded rubber added to straight asphalt increased. So the resistance to permanent deformation was enhanced.

3.1.2 Flash point and ductility

The flash point test for unaged binder (Figure 3) showed that as the percentage of grinded rubber increased, the temperature to reach the ignition point decreased. Furthermore, rubber from passenger car tires presented a higher performance than the rubber from truck/bus tires. For 18% of passenger car rubber the flash point decreased 12% whereas for 18% of truck/bus rubber, the flash point decreased 18%. Ductility tests were developed for unaged binder (Figure 4) but the results were unsuccessful. In both cases, grinded rubber from truck/bus tires and passenger car tires, presented similar performance. The elongation values measured varied between 13 and 16 centimeters.

Keywords: asphalt-rubber, grinded rubber, Superpave, conventional tests
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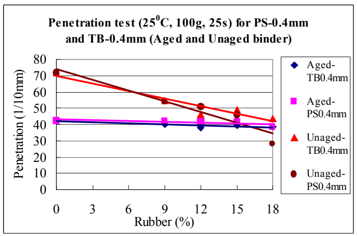

Figure 1 – Penetration test

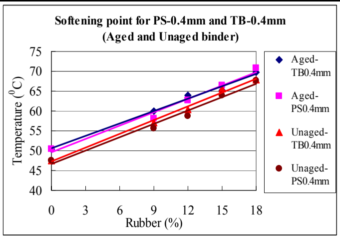

Figure 2 – Softening point

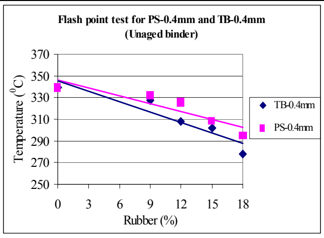

Figure 3 – Flash point

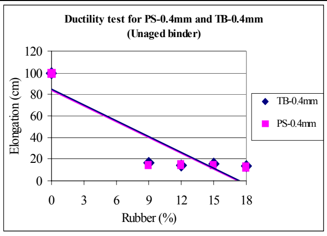

Figure 4 – Ductility test

3.2 Superpave Analyses

3.2.1 Flexural Creep Stiffness and slope of response ("m-value")

The flexural creep stiffness of asphalt-rubber binders (Figure 5) was analyzed for a temperature of -15ºC. It was observed that the stiffness was reduced as the percentage of rubber addition increased for unaged and aged binders at RTFOT machine. Furthermore, grinded rubber from passenger car tires and truck/bus tires showed similar performance. For 15% of rubber addition, the stiffness decreased 42%, compared to straight asphalt (0% rubber). In other words, the resistance to thermal cracking was improved. As for the slope of response (m-value) (Figure 6), the addition of grinded rubber did not improve it. Unaged and aged "m-values" presented slight decrease as the percentage of rubber addition raised.

3.2.2 Dynamic Shearing

The Dynamic Shearing was measured using the Dynamic Shearing Rheometer (DSR) machine. This analysis was accomplished for a temperature of 65ºC. It was observed (Figure 7) that as the percentage of rubber increased, the quotient G*/Sin δ also raised, improving the resistance to rut depth. In addition, grinded rubber from passenger car tires and truck/bus tires presented similar performance for aged and unaged asphalt-rubber binders. For 18% of rubber, the unaged G*/Sin δ increased 910% whereas for aged binder at RTFOT, the G*/Sin δ increased 570%.

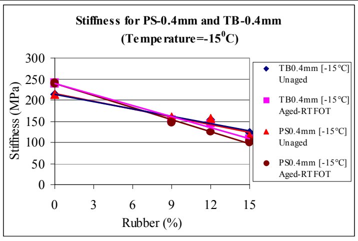

Figure 5 – Stiffness

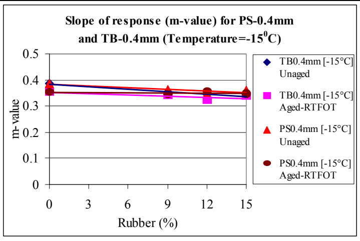

Figure 6 – Slope of response

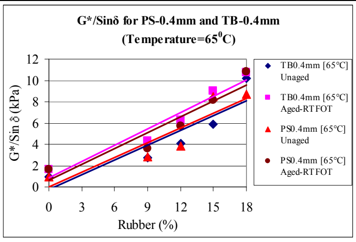

Figure 7 – G*/Sin δ

4. CONCLUSIONS

This paper analyzed the influence of grinded rubber type (from passenger car tires and truck/bus tires) on Japanese asphalt-rubber binders. It was observed that:

- For almost conventional and Superpave tests accomplished, considering unaged and aged asphalt-rubber binders at RTFOT machine, rubber from both types of tire presented similar performance.
- The ductility tests presented very low values for asphalt-rubber elongation despite the increasing addition of grinded tire rubber to straight asphalt (0% rubber).
- The flash point data showed that when the percentage of grinded rubber increased, the ignition point decreased progressively, and this reduction was more meaningful for truck/bus tires.
- For unaged asphalt-rubber binders, the resistance to permanent deformation improved as the percentage of rubber increased. Moreover, comparing the data from penetration test, softening point and from DSR machine, it was observed that the DSR values presented higher and meaningful enhancement to rut depth.
- The flexural creep stiffness was reduced as the percentage of rubber addition increased for unaged and aged binder at RTFOT.
- The slope of response (m-value) did not improve as the percentage of grinded rubber increased. Unaged and aged "m-values" presented slight decrease as the percentage of rubber addition raised.

REFERENCES

Bridgestone (2003). Personnal Communication. Tokyo, Japan.

FHWA (1992). State of practice. Design and construction of asphalt paving materials with crumb rubber modifier. Federal Highway Administration. United States Department of Transportation.

Hicks, R. G.; Lundy, J. R.; Leahy, R. B.; Lunson, D. & Epps, J. (1995). Crumb rubber modifiers (CRM) in asphalt pavements: Summary of practices in Arizona, California, and Florida. FHWA-SA-95-056. Federal Highway Administration. 152p.

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