Development and application of recyclable asphalt pouring material

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This study is concerned with the development and application of a specific asphalt mixture which can be reused by recycling as many times as requested by heating. This mixture is a joint material for road repair works used by impregnation. It comprises short cut and fine fiber, flake-shaped inorganic powder and rubber or resin together with asphalt at optimum ratios, carrying high initial strength and high impact strength, still keeping high fluidity at elevated temperatures.

This report describes the properties of the mixture and its applications to road repair works.

Keywords: Asphalt pouring material, pavement cracks, additives, viscosity, elastic modulus, Recyclability

I. INTRODUCTION
In Japan, as long as about 1100 thousand km of road networks have been paved, and about 80 % (870 thousand km) there is with asphalt. About 420 million tons of petrol asphalt in average per year have been used for them. However, the amount of asphalt for this usage have become declined year by year from in 1992 (4.49 million tons as a peak), and have reached 3.60 million tons in 1999. Recycled use (see Fig.1) by the efforts of reclamation of resources may be pointed out as a reason for the promotion as well as the decrease of investment for roads.

Fig.1. Demand quantity of road Asphalt and ratio of recyclable material.

This study is to investigate an asphalt pouring material which enables the maintenance of asphalt pavement easy and to describe its effects, considering recycling and environment.

II. OBJECT OF THIS STUDY
Traffic load gives asphalt pavement a compressive force at its upper layer and a tensile force at its lower layer. Then maximum compressive stress occurs at its upper surface and maximum tensile stress at its lower surface respectively. As the tensile strength of asphalt is about 1/10 of the compressive strength, the compressive stress at the upper surface of asphalt pavement becomes a major factor of the pavement breakdown. Namely, when the tensile stress at its lower...
surface becomes larger than the tensile strength of the asphalt, the pavement is broken down and cracking occurs (see Fig.2).

Overlay is a general method for repairing pavement cracks. By this method, asphalt pouring material is poured into cracks and then all the pavement is overlaid with asphalt. However, cracking troubles have been happening frequently at the repaired points. They may be due to the thermal dependency inherent to asphalt. Namely, heat sensitive pouring materials become soft and fluid in summer since the temperature of the pavement surface rises 50–60 °C and become solid and fragile in winter since that falls 0 °C. By repeating heated and cooled, cracks occur at the pavement surface.

Therefore the object of this study has been settled to develop a pouring asphalt material which resists to traffic load and to thermal variation. More precisely, it has been focused to develop an asphalt material which is not fragile and is impact resistant when it is cold in winter and has little fluidity in summer by adding various additives. Besides, initial high fluidity when heated which enables easy permeation in pouring and initial high strength which enables rapid traffic availability have also been investigated considering actual workability.

III. DEVELOPMENT OF AN ASPHALT POURING MATERIAL

III-A. Main component of the asphalt material

Straight asphalt is highly heat sensitive. Namely it is solid when it is cold and becomes very soft when it is hot. In order to prevent crack recurrence, it is preferable that the properties of the material have little thermal sensitivity and is as constant as possible. We have chosen a blown asphalt which is least sensitive thermally and most stable chemically among straight, blown and natural asphalts.

III-B. Additives

Additives have been investigated because blown asphalt solely is fragile and weak against impact when it is cold. We would like to stress that the additives have been chosen among materials which do not hinder health.

First, addition of small length and short diameter carbon fiber has been tried. It has been found that straight asphalt by being mixed with carbon fiber gets toughness and is not broken when knocked by a hammer at normal temperature. It is supposed that carbon fibers give reinforcement effect by being dispersed in the asphalt. It has also been found that mechanical strength such as compression strength is enhanced by being mixed with carbon fiber.

Mixing of mica which is flake shape powder has also been investigated. Among mica a heat resistant and uniformly dispersible type which does not precipitate nor float when mixed with hot asphalt has been selected.

Second, addition of SBR as a rubber component has been tested in order to improve impact resistance at low temperature.

Third, addition of amorphous poly-α-olefin (PP) has been tested which has a record of actual performance as a soft lubricant which makes fluidity of the material large.

IV. PROPERTIES OF THE ASPHALT COMPOSITION

As a method for testing of the properties of the asphalt composition, measurement of dynamic
viscoelasticity by DSR (Dynamic Shear Rheometer) has been adopted. By this method the relation among viscosity $E^\prime$ (Pa·s), complex elastic modulus $G^\prime$ (Pa), temperature and frequency and others can be determined. As to temperatures, minimum and maximum have been settled to be 0 °C and 60 °C respectively and properties have been measured between 0 °C and 60 °C. Frequency has been settled from 0.1 to 10 rad/s that corresponds to a traffic speed from 0 to 80 km/h.

Measurement have been done about Toyo Asphalt G (called ASG hereafter), Toyo Asphalt B (called ASB hereafter), generally used pouring material (called marketing material hereafter) and blown asphalt without additives. Among them ASG is the asphalt added with carbon fiber, mica, SBR and PP, and ASB is the asphalt added with mica and SBR.

Figure 3 shows relations between viscosity and temperature at the frequency 0.1 rad/s. Viscosity becomes linearly low depending temperature elevation as to ASB, blown asphalt and marketing material, but becomes almost constant higher than 20 °C as to ASG, showing higher viscosity than the other asphalt materials at high temperature. This means that ASG has less fluidity at high temperature and can prevent crack recurrence.

Figure 4 shows complex elastic modulus and temperature at the frequency 0.1 rad/s. In this case too, ASG shows almost constant elasticity at temperatures higher than 20 °C, showing lower value than the other materials at 0 °C and becomes smaller by temperature elevation. Compared to ASG, the other materials show linearly smaller elasticity by temperature elevation. This means that ASG at 0 °C has moderate softness is not fragile and shows good impact resistance. This also means that ASG at 60 °C has higher complex elastic modulus than the other materials and gives higher supporting effect to the asphalt pavement against sink by traffic loads.

Similar tendency has been observed at higher frequency, showing that asphalt pavement using ASG has not been influenced by traffic conditions. These facts obtained by the determination through DSR method show that ASG has little variation of both viscosity and modulus of elasticity against temperature, has high impact resistance at low temperature and has little fluidity at high temperature range, showing good bearing properties and preventive ability against recurrence of cracks.

Influence of the pouring materials on the critical tensile stress of the asphalt pavement has been measured indirectly by a splitting test. The splitting test is that the compression strength downward of a cylindrical asphalt pavement material sample laid down keeping the length side horizontally is measured which has a 100 mm diameter and is 59 mm long added with asphalt pouring material layers of 8 mm thick on both cylinder tops. By this test, as shown in Fig.5, tensile stress acts to the orthogonal direction to the neutral axis of the cylinder. Since breakdown of samples occurs by the tensile stress rather than by the compression stress, the tensile stress of the bound surface of the asphalt pavement material and the asphalt pouring material can

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**Table 1. Quality of Asphalt im pregation meteial**

<table>
<thead>
<tr>
<th>Item</th>
<th>ASB</th>
<th>ASG</th>
<th>Marketing material</th>
<th>Blown 20-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration</td>
<td>12</td>
<td>7</td>
<td>32</td>
<td>21</td>
</tr>
<tr>
<td>Softening point (°C)</td>
<td>106.0</td>
<td>110.5</td>
<td>102.5</td>
<td>93.0</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>340</td>
<td>335</td>
<td>290</td>
<td>365</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>1.131</td>
<td>1.130</td>
<td>1.045</td>
<td>1.030</td>
</tr>
<tr>
<td>Kinematic viscosity @150°C</td>
<td>24050</td>
<td>21950</td>
<td>31850</td>
<td>6225</td>
</tr>
<tr>
<td>(cP) @180°C</td>
<td>2725</td>
<td>3625</td>
<td>8625</td>
<td>780</td>
</tr>
</tbody>
</table>

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be evaluated indirectly by this method. As a result shown in Fig. 6, it was found that the tensile strength of ASG was higher than the marketing material in the temperature range tested. This fact might mean that ASG has a higher preventive ability than the marketing material.

It is noteworthy next that the values of kinematic viscosity. General properties of pouring materials are shown in Table 1. The kinematic viscosities of ASG and ASB are as small as 3.625 cp and 2.725 respectively, compared with that of the marketing material which is 8.625 cp. This means that ASG and ASB have high fluidity when heated in case of paving and can readily permeate into cracks.

For high initial strength, penetration must be small. By being mixed with flake shape mica the compound becomes thermally less sensitive. As shown by the data measured by DSR (Fig.3), ASG has the highest viscosity at 60 °C among materials tested, showing that early traffic release is possible when it is used.

V. RECYCLABILITY

Influence of ASG on the recycled asphalt material stripped from pavement with ASG has been studied. The strength of asphalt material mixed with ASG 0.2% to it was compared by stability test with that not mixed. The asphalt material mixed with ASG showed 10.3 kN, though the asphalt material not mixed showed 10.6 kN. The flow values of both materials were 0.35 (mixed with ASG) and 0.33 (not mixed) respectively, showing they were in the standard range of 0.2 ~ 0.4 cm. Sticking or lack of uniformity of the mixture were not observed as well as in case of paving tested. It has been found that asphalt material stripped from pavement mixed with ASG can be recycled.

VI. FIELD CONSTRUCTION TEST

In November 1998, field construction tests were carried out to pavement cracks and undulation at a JR freight yard in Shikoku in Japan. The tests had to be done and finished in the night time at a shipping and discharging container yard where usually large-sized trucks and large-sized forklifts were going in and out.

Asphalt pavement of a block of 600 m² was cut out having 10 cm thickness. Below the pavement was a cement concrete board having tortoise-shaped cracks of 0.5~1.5 m diameter. The tortoise-shaped cracks were cleaned by air and ASG was poured in. After a few minutes the surface of ASG could be touched with hands due to its improved initial strength. Pouring could be finished by the early morning. Two hours after that a loading work of containers onto trains by a forklift was carried out. It was confirmed by eyes that cement concrete board was unificated. Then it was covered by a 2~3 cm thick leveling layer of asphalt material and overlaid by a substrate layer of 5 cm thick and a surface layer of 5 cm thick. Two years and half have passed and no cracks have not occurred.

This actual spot could not have been repaired many times without crack occurrence not longer than one year after overlaying or surface treatment. Besides, by usual construction method, both asphalt pavement and a cement concrete board are to be cut out at the same time and all layers are to be reconstructed. However, at this time, reconstruction of all layers need not have been carried out and the work costed about 1/3 of usual.

VII. CONCLUSION

It has been found that the newly developed ASG can be mixed with asphalt material without affecting recyclability and has improved stability in terms of strength. As a pouring material it has a good permeability due to high fluidity when heated, and has high initial strength and little penetration due to low thermal sensitivity. It shows stable viscoelasticty in the temperature range of 20~60 °C. It has been confirmed also that ASG gives improved tensile strength and can prevent cracks for a long period when used in overlay method.

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