EVALUATION OF RECYCLED ASPHALTS BY SHRP BINDER SPECIFICATION

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Recycled asphalts were evaluated based on SHRP binder specification. DSR (Dynamic Shear Rheometer) and BBR (Bending Beam Rheometer) tests were carried out on samples of the recycled asphalts under three conditions: original binder, RTFOT (Rolling Thin Film Oven Test) residue and RTFOT+PAV (Pressurized Aging Vessel) residue. PG (Performance-Graded) classification was conducted. New straight asphalts at which the recycled asphalts are aimed with a same penetration were also tested as control samples. It is indicated that there is no significant difference between the recycled and the controlled samples for the obtained results. It is suggested the agent for asphalt recycling is effective with respect to the SHRP specification.

Key Words: *recycled asphalt, BBR, DSR, performance-graded, recycling agent*

1. INTRODUCTION

It has been for a long time to develop the recycling technologies of old asphalt pavement in Japan. No doubt, it is very important for the recycled asphalt to show as good engineering properties as wanted so that it can be accepted. Currently, the properties of the recycled asphalt are mostly evaluated by conventional routine tests such as penetration test, and strength test on asphalt mixtures which the recycled asphalt is used in[1),9)]. The effectiveness of recycling agent is usually illustrated by the results from the tests. The evaluation system on recycled asphalts is now restricted because the grade system of new pavement asphalts is the same as the conventional test. However, the conventional grade system has been gradually replaced by a new advanced method called PG (Performance-Graded) method in SHRP (Strategic Highway Research Program) binder specification in USA since 1997[2), 3)]. All the binders are graded by this system. In Japan, it is still in discussion whether or not to introduce the advanced grade system[4)].

It is not the purpose of the presented paper here to deal with the necessary and possibility to adopt the SHRP specification in Japan. It is more interesting right now to know how the recycled asphalts would behavior by SHRP binder test apparatus and to release the difference between recycled asphalts and new straight asphalts by the new grade system. The purpose of the study is actually through the study to encourage road builders to make full use of the recycled asphalts by showing that the recycled asphalt is equivalent to, at least not worse than, the new asphalt in quality regarding to SHRP binder specification.

In the study, the properties of the recycled asphalts and the effectiveness of the recycling agent were investigated by a series of DSR and BBR test. Control samples of new asphalts at which the recycled asphalt are aimed with same penetration were tested also. Consequently PG classification of all the tested samples is carried out. A normal recycling agent, which is currently available in Japanese market, was used for the study. Old asphalts with two various penetrations of 20 and 30 (1/10mm) were recycled by the recycling agent for study purpose. The control samples were made from three new straight asphalts commonly used as pavement asphalts in Japan.

2. TEST DETAILES

(1) Materials used

a) New asphalts used for control samples

The new straight asphalts, at which the recycled asphalts are targeted in penetration, are used in the study for control samples. They are normal asphalts currently used for pavement asphalts. Three types with different penetration, namely, st40-60 for heavy-duty traffic area, st60-80 for ordinarily area, and st80-100 for cold area where snow is accumulated in as well[5], are used. The physical properties are listed in **Table-1**.

b) Old asphalts for recycling

Old asphalts with two different penetrations, 20 and 30 (1/10 mm under 25 degree, called later Pen 20 and Pen 30) are selected in the study to investigate the effectiveness of the recycling agent used for. Considering the difficulty to get from recycling pavements the old asphalts having the exact desired penetration, they are actually obtained by PAV after RTFOT experiment from the new st60-80. For this purpose, an empirical relationship between the penetration of PAV residues and the PAV time is at first established. Then, the time needed for the desired two penetrations is calculated by means of the relationship established.

The old asphalts, Pen 20 and Pen 30, are produced by PAV for 20 and 13 hours respectively after RTFOT for 45 minutes is finished. The properties of the old asphalts are listed in **Table-1** also.

c) Recycling agent

Recycling agent used for recycled asphalt available now is divided into four categories: asphalt type; petrol lubricant type; oils from animal and vegetation; asphalt emulsion as well. Among those, asphalt and petrol lubricant types are the most popularly used and differ from manufactures in properties. Research on the influence of the popularly used recycling agents with various compositions on the properties of recycled mixtures has been reported[6]. Findings indicated that there is a little difference between the mixture properties using the asphalt recycled with the recycling agents especially with the aging. In the study, only one of the recycling agents currently available in the market was preliminarily selected. The properties of the recycling agent are presented in **Table-2**.

d) Content of recycling agent added

The content of the recycling agent needed, according to the Guideline of Recycling Pavement Technology[7], is determined in principle when the recycled asphalt has the same value as a designed penetration. The design penetration required for recycled asphalt is specified considering the site where the recycled asphalt is to be used, i.e., the traffic condition and environment situation as well[7]. However, it is obvious that the penetration of

Table-1Properties of the new and old asphalts

Types	Penetration (25, 1/10 mm)	Softening Point (℃)	Ductility (cm)
st40-60	51	50	100+
st60-80	66	48	100+
st80-100	87	46	100+
Pen 20	20	58	6.5
Pen 30	30	50	5.8

Table-2 Properties of the recycling agent

Dynamic viscosity, 60℃ (Pa·s)	Flash point (℃)	Ratio of viscosity	Density (g/cm^3)
202	232	1.37	1.011
Asphaltene	**Saturate**	**Aromatic**	**Resin**
2.0%	51.9%	33.2%	12.7%

Table-3 Content of the recycling agent needed for different targeted asphalt

Targeted Asphalt		st40-60	st60-80	st80-100
Penetration of RTFOT residue		41	50	65
Content (%)	From Pen 20	/	11.6	/
	From Pen 30	6.0	9.0	14.0

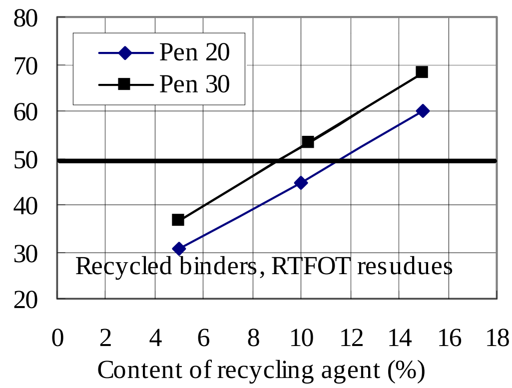

Fig. 1 Content of the agent versus penetration

the recycled asphalt from the hot mix asphalt sooner after from the plant will be less than the designed one due to the aging in plant. Thus, it is necessary to adjust the content of the actually needed agent again to reach the desired one. The adjustment of the content depends on how much the aging of the recycled asphalt is caused. It is certainly not easy to command exactly the aging in the plant. Additional tests are thus needed.

In the study, the content of the agent is determined in a way that the penetration of the recycled asphalt after RTFOT is equal to that of the targeted straight asphalt after RTFOT. In the way, the influence of the hot aging on the decrease of the penetration of recycled asphalt need not to be considered.

Fig. 1 is the penetration of recycled asphalts from Pen 20 and Pen 30 after RTFOT versus the content of recycling agent. The penetration of the RTFOT residue of the st40-60, st60-80, st80-100 is 41, 50 and 65 respectively. The content of the agent need is thus determined and listed in **Table-3**.

(2)Test methods [8)]

a) Preparation of testing samples

The SHRP binder specification is carried out with binders in three states: original binder; RTFOT residue; PAV residue. For the preparation of the binders of the three states, RTFOT and PAV tests are performed. The two tests are briefed hereby, followed by DSR and BBR tests.

RTFOT is a test to simulate, with blowing air and high temperature, the aging process occurred during mixture production in plant. The rolling thin film of testing asphalt in a glass bottle with 35g asphalt is expected to be 5-10 mm in thickness. The test is for 45 minutes with temperature of 160℃ and air pressure of 0.4kPa, which was proved to simulate the aging occurred in plants. The reference[8)] recommended test time, 85 minutes, was not adopted due to the overestimated loss of penetration observed in most of the plants in Japan.

PAV is a test to simulate, with high-pressurized air and high temperature, the weathering process occurred after the mixture lay down. Plates with testing asphalts are placed in the vessel. The test is for 20 hours with an air pressure of 2.1MPa and temperature 100℃.

The air left in both the RTFOT and PAV residues is pumped by a dry vacuum machine.

b) DSR

DSR is used for evaluation of the dynamic visco-elastic properties of asphalt under high temperature. The testing sample clamped by two parallel plates is applied a sin rotating load with a frequency of 10 rad/s. The stress and the strain are recorded and thus used for the calculation of the needed parameters, G*/sin(δ), a parameter of rutting-assistance, and G*sin(δ), a parameter of fatigue resistance. The plate changes in size for binders in different states. 8 mm in diameter is for the PAV residue, 25 mm for the original and RTFOT residues. The test temperature is 40-70℃ for original and RTFOT residue, and 19-40℃ for PAV residue.

c) BBR

BBR is used for evaluation of the static visco-elastic properties of asphalt under low temperature. The beam supported at the two ends of it is loaded in the middle with a force of 0.98N. The relationship of the deflection at the loading with the time is recorded and consequently the stiffness is calculated. Besides, m-value, defined by log (S(t))/log(t), is obtained at the same time. The test temperature is –20 to –5℃.

3. RESULTS AND DISCUSSIONS

The results of the recycled asphalts from old asphalt Pen 30 are shown in Figs from **Fig.2** to **Fig.6**. R40-60 in the Figs stands for recycled asphalt with a target of penetration the same as the st40-60 after RTFOT. The others are in a similar meaning.

(1) DSR

The relationship between the test temperature versus G*/sin(δ) of the three recycled asphalts in original state is shown in **Fig.2**. The relationship of the RTFOT residues is shown in **Fig.3**.

In general, there is a similar trend that G*/sin(δ) of all the binders decreases with the temperature. That is the parameter decreases in almost a same pace with the

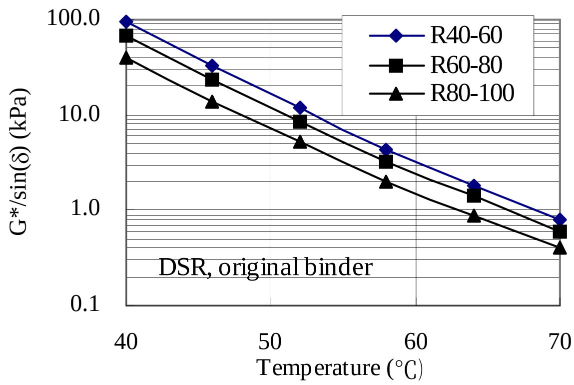

Fig.2 DSR of the recycled asphalts in original state

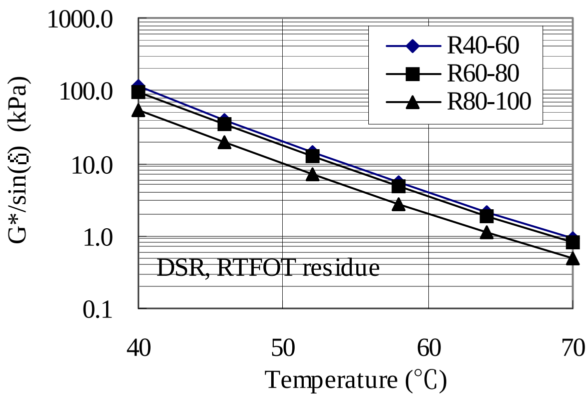

Fig. 3 DSR of the recycled asphalts after RTFOT

temperature for both original binders and RTFOT residues, and the G*/sin (δ) of R40-60 is the biggest of all and that of R80-100 the smallest under a same test temperature. The result is in consistent with the fact that the stiffer the asphalt is, the better the rutting resistance. There is no exception for the recycled asphalts. By referring to the SHRP specification, when the G*/sin(δ) reaches 1.0kPa for the original binders and 2.2kPa for the RTFOT residues the binders are supposed to fail, it can be obtained from the Figs that the failure temperature of R40-60, R60-80, R80-100 is 68.0, 66.2, 63.3 ℃ respectively for original binders and 64.0, 64.0, 60.7℃ respectively for RTFOT residues.

The relationship between test temperature and the G*sin(δ) of the recycled asphalts of PAV residues is shown in **Fig.4**. In general, the value of the G*sin(δ) decreases with the increase of the test temperature of all of the binders, and the value is the biggest for R40-60 and the smallest for R80-100 under a same test temperature. The result is in consistent with the fact the softener the asphalt is, the better the fatigue resistance. No exception was found for the three recycled asphalts too. When the G*sin(δ) increases up to 5000kPa, the asphalt is expected to fail according to the SHRP specification. It did not reach that value within the temperature scope discussed in the study, but the fail will happen at 19.4, 20.2, 15.8℃ for R40-60, R60-80, R80-100 respectively by extension method.

(2) BBR

The relationship between the test temperature and the stiffness and the m-value, two parameters of brittle fractures at low temperature, of the recycled asphalts of PAV residues, are presented in **Fig.5** and **Fig.6**. It is apparent that the stiffness of R40-60 is the biggest, R60-80 the second and R80-100 the smallest under a same test temperature. On the contrary, the m-value of the three binders is in the opposite order. That means the bigger the penetration is, the better the brittle resistance at low temperature. There is also no exceptional finding for the recycled asphalts. The binder is assumed to fail when the stiffness is larger than 300MPa and the m-value is less than 0.3 according SHRP specification. The failure temperature is thus –16.0, -17.0, -18.5℃ for R40-60, R60-80, R80-100 for the stiffness to reach 300MPa respectively and –15.0, -16.5, -19.0℃ for the m-value to reach 0.3 respectively.

(3) A comparison between the recycled and targeted asphalts and PG classification

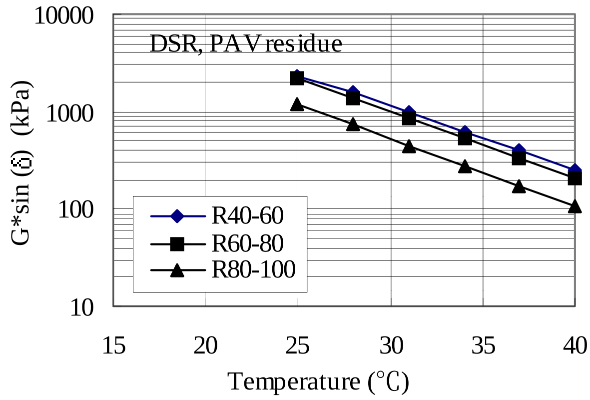

Fig.4 DSR of the recycled asphalts after PAV

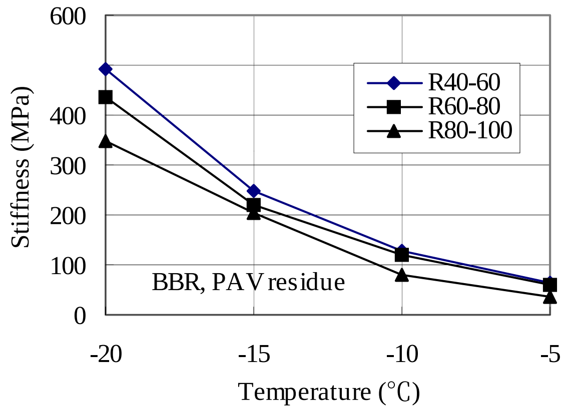

Fig.5 BBR of the recycled asphalts after PAV(1)

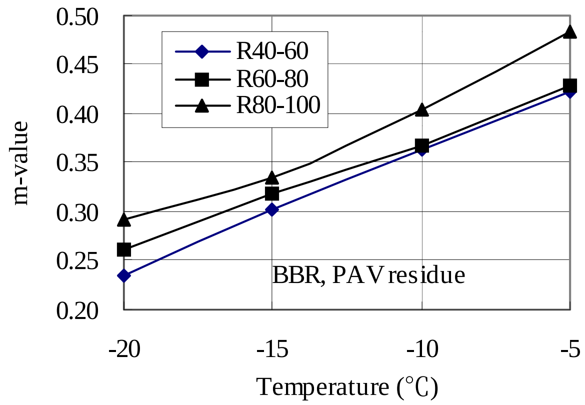

Fig.6 BBR of the recycled asphalts after PAV(2)

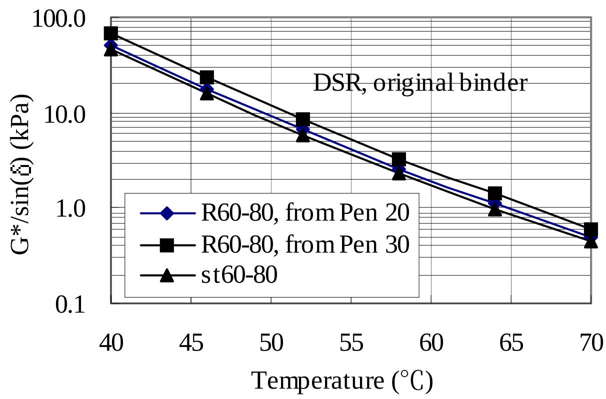

Fig.7 A comparison of the recycled and new asphalts-DSR in original state

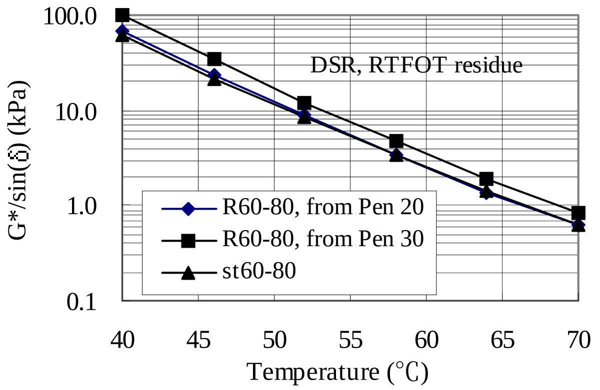

Fig.8 A comparison of the recycled and new asphalts –DSR after RTFOT

To evaluate the difference between recycled asphalt and the targeted new asphalt and the effectiveness of the recycling agent on different old asphalts, a comparison was made in Figs. from **Fig.7** to **Fig.11**. Here, only the results of the control st60-80 and the recycled asphalts from Pen 20 and Pen 30 (labeled as R60-80 from Pen 20 and Pen 30 respectively) are presented.

The difference of the properties in DSR and BBR between the two recycled asphalts from Pen 20 and Pen 30 can be found in the Figs. As a whole, the recycled one from Pen 30 is slightly different that from Pen 20. As it can be seen that the high failure temperature of the recycled asphalt from old asphalt Pen 20 is 64.4℃ for the original binder, see **Fig.7**, 61.3℃ for the RTFOT residue, see **Fig.8**. The immediate failure temperature is 15.3℃, see **Fig.9** and the low failure temperature is –18.0℃, see **Fig.10** and **Fig.11**.

It is indicated also in **Fig.7 to Fig.8** that the R60-80 from both Pen 20 and Pen 30 has a higher value of the G*/sin(δ) in both the original state and after RTFOT, than that of the new st60-80, meaning that the rutting resistance of the recycled asphalts is a little better than the new asphalt at the same temperature. It can be found, see **Fig.9**, that the G*sin (δ) of the recycled asphalt from Pen 20 after PAV is slightly less than the new st60-80 which is almost the same as that of the recycled asphalt from Pen 30, indicating the recycled asphalts were not worse than the new asphalt in fatigue resistance. Results from BBR test showed, see **Fig.10** and **Fig.11**, that the recycled asphalt has a lower stiffness and a larger m-value than the st60-80 indicating a better brittle fracture property at low temperature. Therefore, the recycled asphalts are at least not worse than the control samples regarding the DSR and BBR results.

The failure temperature of both the recycled asphalts from Pen 30 and the targeted new asphalts are listed in

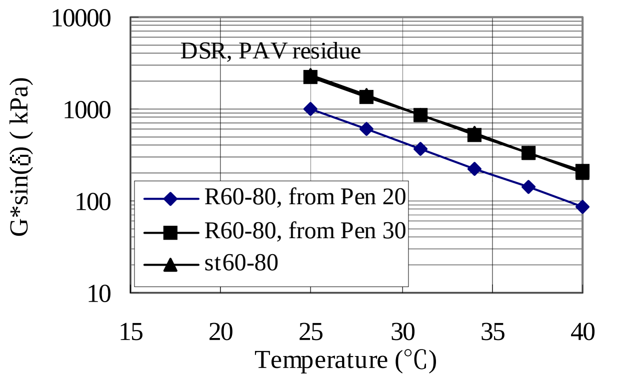

Fig.9 A comparison of the recycled and new asphalts-DSR after PAV

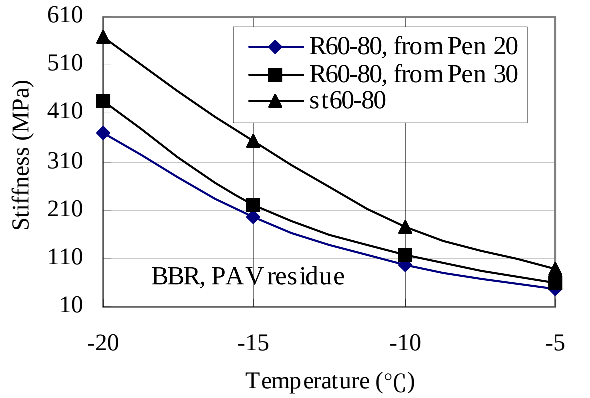

Fig.10 A comparison of the recycled and new asphalts-BBR after PAV (1)

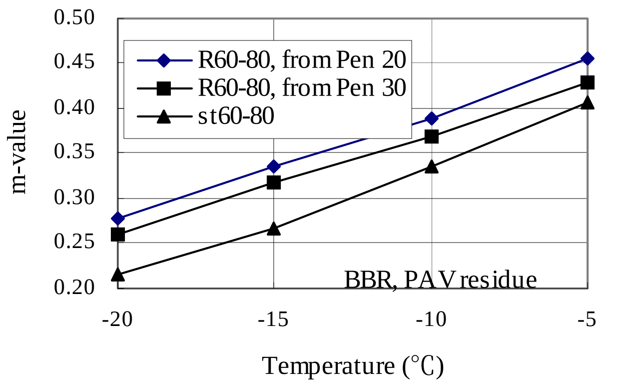

Fig.11 A comparison of the recycled and new asphalts-BBR after PAV(2)

Table-4. The recycled asphalts have a little higher high failure temperature and a lower low failure temperature. The immediate failure temperature is a little bit better for recycled asphalts than the control targeted new asphalts.

All the tested samples were graded using the SHRP specification and the results are listed in **Table-5**. The results of the new asphalts are no different with those reported[10]. st40-60, st60-80 and st80-100 are graded in to PG(64-22), PG(58-22) and PG(58-22) as well. The

Table-4 Failure temperature of all the binders tested (℃)

Items	States	40-60		60-80		80-100	
		st-	R-	st-	R-	st-	R-
DSR	Original binders	66.9	68.0	64.0	66.2	62.6	63.3
	RTFOT residues	64.6	64.0	62.0	64.0	59.4	60.7
	PAV residues	20.0	19.7	22.0	20.2	17.0	15.8
BBR	PAV residues (stiffness)	-14.2	-16.0	-14.5	-17.0	-17.0	-18.5
	PAV residues (m)	-12.5	-15.0	-13.0	-16.5	-15.5	-19.0

Table-5 Classification of all the tested binders with PG classification

Type of asphalt		40-60	60-80	80-100
Straight		PG(64-22)	PG(58-22)	PG(58-22)
Recycled (from Pen)	**20**		PG(58-22)	
	30	PG(64-22)	PG(64-22)	PG(58-28)

st40-60 has a higher grade at high temperature than the st60-80 and st80-100. But all of the new asphalts located in a same low service temperature, although a little difference of the property at low temperature was found for the three new asphalts. R40-60, R60-80 and R80-100 from Pen 30 are graded in to PG(64-22), PG(64-22) and PG(58-28) as well. The R80-100 has a higher grade at low temperature than the R40-60 and R60-80, whereas it has a lower grade at high temperature than the other two.

The R60-80 from Pen 20 is graded into PG(58-22). It has the same low temperature as the st60-80 and the recycled from Pen 30. Although, the grade of high temperature is a grade lower than the recycled from Pen 30, it is still the same as that of control sample st60-80.

The results of the PG classification of all the asphalts suggested the recycled asphalts have at least the same service temperatures as the controlled samples—the targeted straight asphalts. In addition, both the recycled from Pen 20 and Pen 30 can reach the grade of the asphalts targeted. It thus concluded that the recycled asphalts have the same qualities as those of the new asphalts and the recycling agent are effective with respect to the SHRP specification.

4. CONCLUSIONS

The conclusions from the study can be drawn as follows:

1) A largest value of the G*/sin(δ), a parameter of rutting resistance at high temperature from DSR test, of both original state and RTOFT residue, is observed for the recycled asphalt R40-60 that has a smallest penetration, and a smallest value of the parameter for R80-100 under same temperature. This trend is similar for the recycled asphalts to the new asphalts, and it is observed that the G*/sin(δ) of the recycled asphalt is slightly larger than that of the targeted new asphalt under same test temperature, indicating a little better rutting resistance.

2) A largest value of the G*sin(δ), a parameter of fatigue resistance at immediate temperature from DSR test, of PAV residues, is observed for the R40-60 and a smallest value of the parameter for R80-100 under same temperature. The trend of the G*sin(δ) of the recycled asphalts has no significant difference from the control new asphalts. The G*sin(δ) of both the recycled asphalts from old asphalt with Pen 20 and Pen 30 is not less than that of the targeted new asphalt, indicating a little better fatigue resistance.

3) The stiffness of the R40-60, which has the smallest penetration, is the largest of all the recycled asphalts and the stiffness of the R80-100 has the smallest stiffness. On the contrast, the m-value of the R40-60 is the smallest and the R80-100 has a largest m-value. The recycled asphalts have a smaller stiffness and a bigger m-value than the targeted new asphalts, showing a better brittle fracture resistance.

4) There is a very little difference between the results of DSR and BBR of the recycled from Pen 20 and from Pen 30. The PG classification shows that the high service temperature is a grade higher for the recycled from Pen 30 than that from Pen 20. The low service temperature is the same for both of the recycled asphalts. However, the PG classification of recycled asphalts from both Pen 20 and Pen 30 can reach to that of the targeted new asphalt. That suggested that the recycling agent is effective to different old asphalt with respect to the SHRP specification.

5) All of the three recycled asphalts discussed in the study can at least reach the PG classification of the three

corresponding targeted new asphalts. Some of them even show a better PG classification. The recycled asphalts are not worse than the targeted new asphalts with the SHRP specification.

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SHRP バインダ仕様における再生ｱｽﾌｧﾙﾄ性状の評価について

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SUPERPAVE で用いられている DSR および BBR により再生アスファルトの評価を実施した。再生アスファルトは、供用後の性状に着目し、グレードの異なる３種類の新規アスファルトの混合物の練り落とし時の針入度を目標に回復を行ったものである。これらの評価結果を基に SUPERPAVE バインダ仕様に基づいた PG（Performance-Graded）分類を行った。この結果、再生アスファルトと新規アスファルトの PG 分類はほぼ同じであることが確認され、ここで用いた再生用添加剤を用いることで新規アスファルトと同 PG の再生アスファルトが製造できることが確認された。