Highly-aged and Highly-modified Asphalt Concrete Recycling in Japan

T. Kanou
Taisei Rotec Corporation Research Institute, Kounosu, Saitama, Japan

H. Nitta, I. Sasaki, A. Kawakami, & K. Kubo
Public Works Research Institute, Tsukuba, Ibaraki, Japan

ABSTRACT: In Japan, the penetration of asphalt contained in reclaimed asphalt pavement (RAP) is declining owing to the dissemination of techniques for recycling RAP and the increased usage of polymer modified asphalt. Accordingly, there is concern that the supply of RAP available for recycled hot mix asphalt will decrease in the coming years. This paper presents the status of recycling RAP, and reports on the results of examining desirable methods for recycling RAP using repeatedly recycled hot mix asphalt and polymer modified asphalt.

KEY WORDS: Reclaimed asphalt pavement, recycled hot mix asphalt, repetitive recycling, polymer modified asphalt, rejuvenator.

1 INTRODUCTION

The history of technological development of recycling reclaimed asphalt pavement (RAP) in Japan dates back to the early 1970s. As manuals have been improved based on further research, techniques for recycling RAP have spread. As a result, the recycling rate of RAP in Japan is as high as 99%. Recently, however, a new problem has arisen due to the decline of penetration of old asphalt contained in RAP, since in Japan, RAP with the penetration of old asphalt of lower than 20 is not allowed to be used as recycled aggregate for recycled hot mix asphalt (R-HMA).

There are three main reasons for the declines of old asphalt penetration. Firstly, RAP which has been repeatedly recycled has increased due to the diffusion of RAP recycling techniques. Secondly, the ratio of RAP to R-HMA has increased. Thirdly, the usage of polymer modified asphalt mixed with SBS for high durability and multi-functionality has increased. As RAP available for R-HMA will decrease, countermeasures are urgently needed.

This paper presents the status of recycling RAP in Japan. In addition, changes in the properties of old asphalt which has alternated between degradation and reclamation were observed through indoor experiments. The paper proposes desirable recycling methods based on the results of indoor experiments. In addition, the results of construction tests of porous asphalt pavement using reclaimed polymer modified asphalt pavement are reported.

2 THE PRESENT STATUS OF ASPHALT MIXTURE RECYCLING

2.1 Quantity of production of R-HMA

Figure 1 shows the trend of the ratio of R-HMA to All HMA and ratio of RAP to R-HMA in Japan. The ratio of R-HMA to All HMA has been increasing as techniques of recycling RAP have spread in Japan, reaching 50% in 1998 and 73% in 2008. Given that the renewal cycle of asphalt pavement is 10 years, more than half of the RAP produced after 2008 will have been recycled at least once in the past. Moreover, the ratio of RAP to R-HMA is increasing year by year; in 2008 the ratio nationwide was 31%, reaching 45% in some areas. Accordingly, the penetration of old asphalt is expected to decline, since RAP which has been repeatedly recycled and the ratio of RAP to R-HMA will increase.

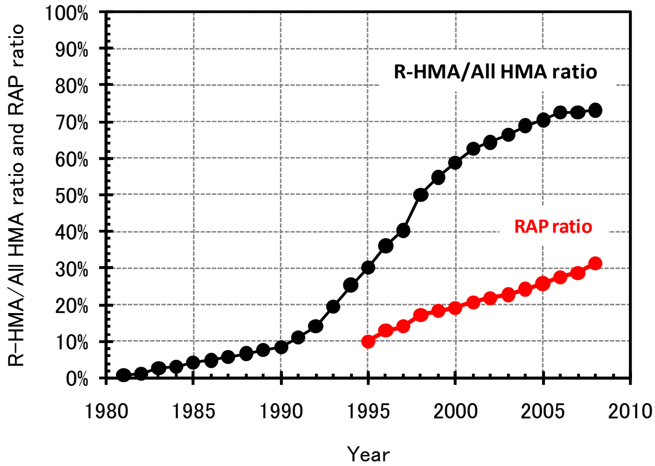

Figure 1: Changes in R-HMA/All HMA ratio and RAP ratio in Japan

2.2 R-HMA/All HMA ratio mixed with polymer modified asphalt

Polymer modified asphalt is used to improve abrasion resistance and rutting resistance in Japan. Highly polymer modified asphalt is used also for porous asphalt mixture. The characteristic of polymer modified asphalt in Japan is the high ratio of polymers such as SBS: generally in Japan, about 4 to 8% of a polymer such as SBS is mixed with asphalt.

Figure 2 shows changes in the ratio of HMA mixed with polymer modified asphalt to All HMA in Japan. The ratio has been increasing year by year, reaching 14% in 2008. The HMA that used polymer modified asphalt early on now needs to be renewed. Accordingly, there is concern that as reclaimed polymer modified asphalt pavement increases in the coming years, the penetration of old asphalt will decline.

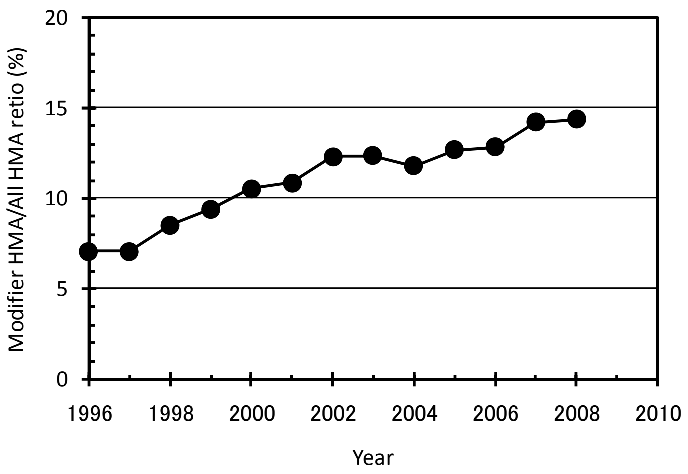

Figure 2: Changes in the ratio of HMA mixed with polymer modified asphalt to All HMA in Japan

2.3 Changes in the penetration of old asphalt

Figure 3 shows the penetration of old asphalt of RAP which was collected from recycling factories throughout Japan from 1982 to 1983, and 2004 to 2007. It can be seen that the penetration of old asphalt in the 2000s is significantly lower than that in the 1980s. This might be attributed to the increase of reclaimed polymer modified asphalt pavement in accordance with the increase of repeatedly recycled RAP owing to the dissemination of recycling techniques as well as the increase in the ratio of RAP to R-HMA.

Thus, it is critical to establish recycling techniques without degrading the penetration of old asphalt as well as those for reclaimed polymer modified asphalt pavement.

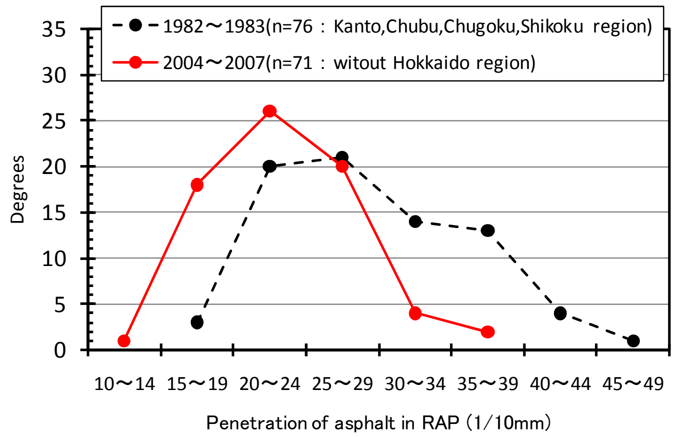

Figure 3: Research results of the penetration of asphalt in RAP

3 METHODS OF RECLAIMING ASPHALT WHICH HAS ALTERNATED BETWEEN DEGRADATION AND RECLAMATION

3.1 Outline

As RAP is repeatedly recycled, the degradation of old asphalt gradually worsens. It is therefore necessary to consider methods of reclaiming RAP which will suppress further degradation. Accordingly, we conducted indoor experiments to confirm changes in the properties of asphalt by alternating between degradation and reclamation using various softening agents to recover the properties of old asphalt. Based on the results, desirable softening agents were selected.

3.2 Materials and procedure of experiment

Table 1 shows the kinds and properties of softening agents used for the reclamation of old asphalt. Figure 4 shows the procedure of the experiment. Type A and Type B are popular reclamation methods in Japan, while typical softening agents include a rejuvenator with a large paraffin constituent similar to lubricant (paraffin-rich type), a rejuvenator with a large aromatic constituent, and asphalt with large penetration. In this experiment, we used the paraffin-rich type of rejuvenator and the asphalt with large penetration, both of which have performed well in Japan.

Table 1: Kinds and properties of softening agents

Kinds of softening agent		Proportion of old asphalt to agents	Density g/cm³	Penetration 1/10 mm	Composition			
					Asphal-tene	Resin	Para-ffin	Aroma-tic
A	Straight Asphalt (Pen60-80)	60:30:7	1.038	70	–	–	–	–
	+Rejuvenator (paraffin-rich type)	– 60:21:19	0.966	–	0	6.3	67.1	26.6
B	Rejuvenator (paraffin-rich type)	85:15 – 76:24	0.966	–	0	6.3	67.1	26.6
C	Straight Asphalt (Pen300-400)	60:40	1.015	395	12.3	21.6	7.3	58.8

*The first line of Type A shows the properties of straight asphalt (Pen60-80), and the second line shows the properties of rejuvenator (paraffin-rich type).

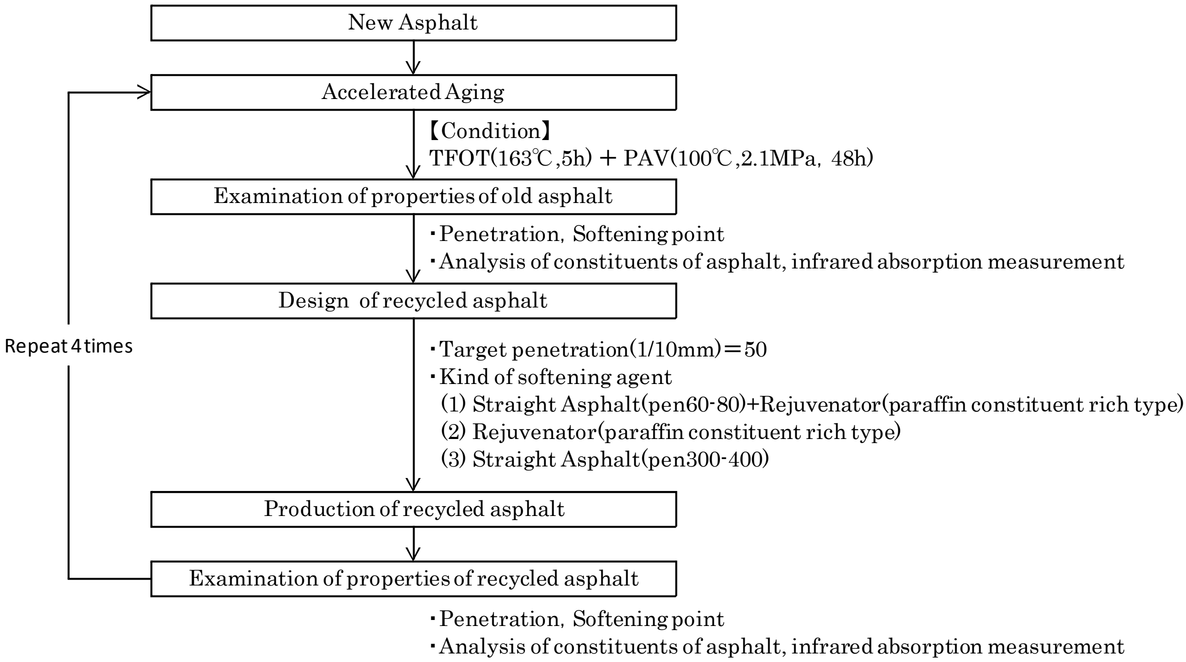

Figure 4: Procedure of the experiment

3.3 Accelerated aging of asphalt binder

Accelerated aging of asphalt binder was conducted using the Thin Film Oven Test (TFOT) and a Pressurized Aging Vessel (PAV). Table 2 shows the conditions of the experiment. The duration of heating in the PAV was set to 48 hours, based on the result of a preliminary test with a target penetration of 20 (1/10 mm).

Table 2: Conditions for accelerated aging experiment

Test method	Pressure (MPa)	Temperature (°C)	Time (hr)
TFOT	Ordinary pressure	163±1	5
PAV	2.1±0.1	100±0.5	48

3.4 Reclamation method

We reclaimed asphalt with a target penetration of 50 (1/10 mm), and added the asphalt softening agent to the asphalt after the accelerated aging test (TFOT+PAV). This penetration was selected considering that the penetration of asphalt reclaimed in many asphalt mixing factories in Japan is 50 (1/10 mm).

3.5 Experiment method

We conducted the asphalt penetration test and softening point test to identify the physical properties at each stage of aging and reclaiming of asphalt. To determine the chemical properties, we measured the increase of carbonyl groups (carbonyl index: *CI*) using Fourier transform infrared spectroscopy (FT-IR), to evaluate the degree of oxidative aging of asphalt. Table 3 shows an outline of the method of measuring *CI* using FT-IR.

Table 3: Outline of method of measuring *CI* using FT-IR

	Conditions and others
Absorption spectrometry method	Transmission measurement by forming a thin membrane of a specimen on the crystal KBr with a solvent
Carbonyl index: *CI*	$CI = \dfrac{\log(I_{o1}/I_1)}{\log(I_{o2}/I_2)}$ I_1, I_2 : transmittance of peak spectrum at approx. 1700 cm^{-1} and 1600 cm^{-1} respectively I_{01}, I_{02} : transmittance of background corresponding to the above wave numbers respectively

3.6 Test results

Figures 5 and 6 show the results of measuring the softening points and *CI*.

It can be seen that the softening point tends to become higher as the number of times of reclamation increases. When Type A and Type C are used, the softening point does not greatly rise, reaching approximately 60°C, even when repeatedly reclaimed. When Type B is used, however, the softening point after three times of reclamation reaches about 80°C. This shows that the asphalt reclaimed with the rejuvenator became hard after repeated reclamation. Thus it is estimated that asphalt that has been repeatedly reclaimed with rejuvenators becomes brittle, losing deformation resistance.

Meanwhile, *CI* tends to become larger as the number of times of reclamation increases, proving that oxides accumulate due to repetitive reclamation. The extent of oxide accumulation becomes smaller in the order of Type C < Type A < Type B. This suggests that oxides are more easily accumulated in the case of reclamation with rejuvenators (Type A and B) than the one with straight asphalt with large penetration (Type C).

Accordingly, the use of rejuvenators with large paraffin constituent should be avoided, and straight asphalt should be used chosen instead.

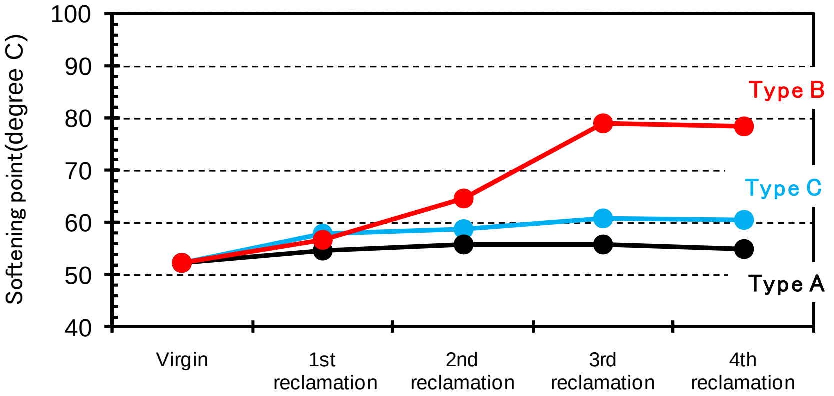

Figure 5: Softening point test results

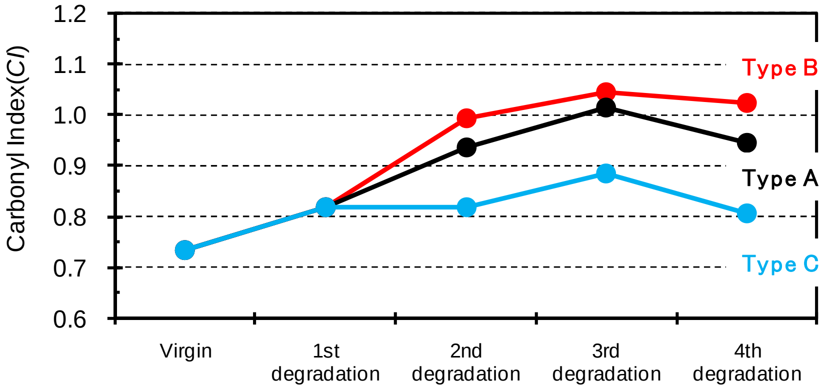

Figure 6: Changes in *CI*

4 THE RECYCLING OF RAP USING HIGHLY POLYMER MODIFIED ASPHALT

4.1 Outline

The number of construction projects using porous asphalt pavement with highly polymer modified asphalt has rapidly increased since 1995. At present, porous asphalt pavements account for 25% of government roads and 60% of expressways. The porous asphalt pavements that were constructed at the early stage are now approaching the time for renewal. Accordingly, RAP with highly polymer modified asphalt will be produced in large quantities in the coming years, but techniques for recycling RAP with highly polymer modified asphalt have not yet been established.

We therefore conducted construction tests to establish techniques for reclaiming polymer modified asphalt pavement for porous asphalt pavement.

4.2 Outline of construction tests

We conducted construction tests on government roads in three locations, as summarized in Table 4. We regularly measured rut depth, permeation water amount, and tire/road surface noise level in each location after the construction test.

Table 4: Outline of construction test locations

Construction test location	One-way daily traffic volume of heavy vehicles	In-service period	RAP ratio (%)
Chiba prefecture Ichihara City R16	more than 3,000	5 years	20%, 30%
Hyougo prefecture Nishinomiya City R176	1,001 to 3,000	7 years	20%, 30%, 50%
Yamaguchi prefecture Shimonoseki City R2	more than 3,000	7 years	20%, 30%, 50%

4.3 Performance results in the construction test locations

Figure 7 show the results of test construction. 2 or 3 years have elapsed since the construction. The performance of reclaimed porous asphalt pavement was equivalent to that of virgin porous asphalt pavement in each location. Especially in the case where the ratio of reclaimed polymer modified asphalt pavement is lower than 30%, there is no difference between the reclaimed porous asphalt pavement and the virgin porous asphalt pavement.

Thus, it is judged that reclaimed polymer modified asphalt pavement can be recycled for porous asphalt pavement.

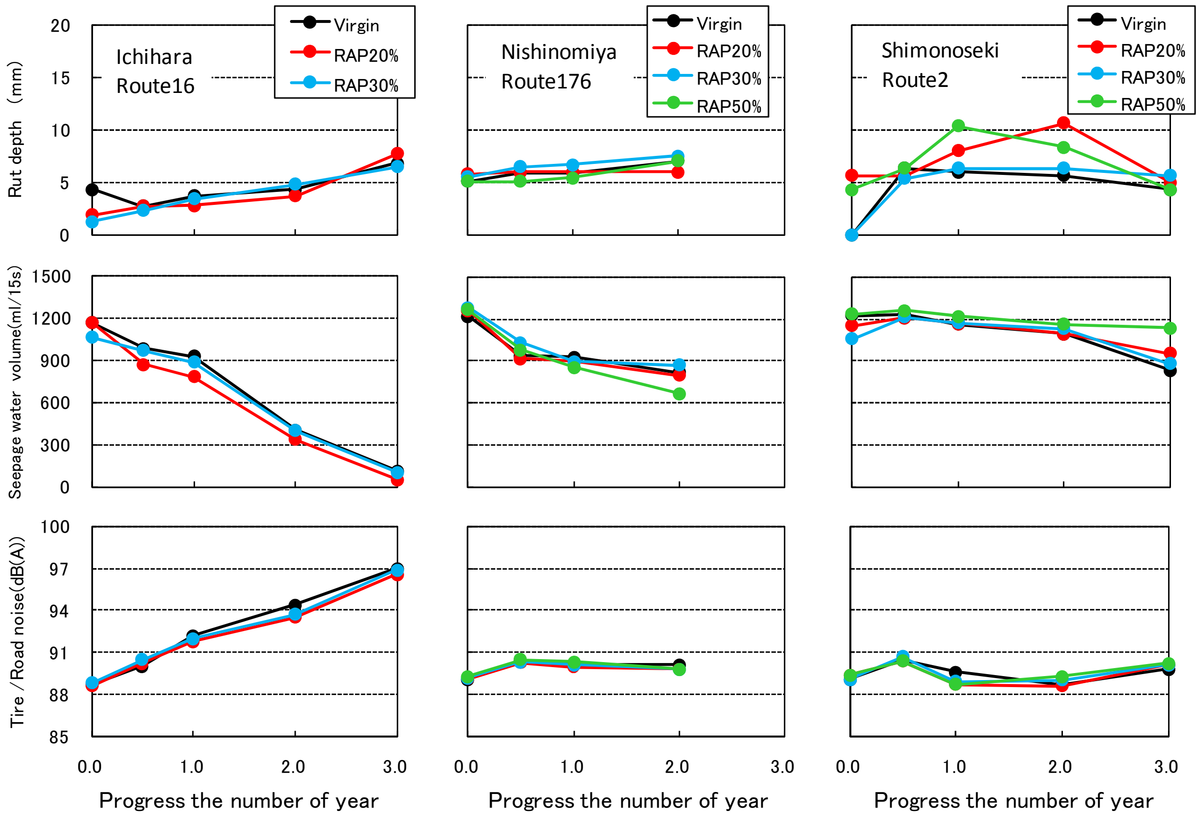

Figure 7: Results of test construction

5 CONCLUSIONS

The findings of this research are summarized below:

(1) Researches on recycling RAP started in the 1970s in Japan, and manuals which reflected the results were drawn up from the 1980s. The ratio of recycling RAP has now reached 99%.

(2) The ratio of R-HMA to All HMA was 50% in 1998 and 74% in 2008 in Japan. Moreover, the ratio of RAP in R-HMA is increasing year by year. The national average ratio of RAP in R-HMA in 2008 was 31%, and exceeded 45% in some areas.

(3) The ratio of polymer in polymer modified asphalt is 4 to 8% in Japan. The ratio of HMA with polymer modified asphalt to All HMA has been increasing, reaching about

14% in 2008. Hot mix asphalt using polymer modified asphalt early on is now approaching the time for renewal.

(4) The penetration of old asphalt in RAP is declining owing to the development of repetitive recycling of asphalt, the increase of ratio of RAP to R-HMA, and the increase of usage of polymer modified asphalt in Japan. Accordingly, there is concern that the supply of RAP will become scarce.

(5) Generally in Japan, rejuvenators with large paraffin constituent similar to lubricant, rejuvenators with large aromatic constituent, and straight asphalt with large penetration are used as softening agents. However, when RAP is repeatedly recycled, the use of rejuvenators with large paraffin constituent should be avoided, and straight asphalt should be used instead.

(6) The durability of reclaimed porous asphalt pavement containing 30% reclaimed polymer modified asphalt pavement is equivalent to that of virgin porous asphalt pavement.

REFERENCES

Japan Road Association, 1984. *Guideline of recycling technology for RAP (Draft).*

Japan Road Association, 1987. *Guideline of in-place basecourse recycling (Draft).*

Japan Road Association, 1988. *Guideline of in-place surface recycling (Draft).*

Japan Road Association, 1992. *Guideline of recycling technology for central plant recycling*.

Japan Road Association, 2004. *Handbook for Pavement Recycling*.

Ministry of Land, Infrastructure, Transport and Tourism, 2006. *A survey of construction by-products in 2005.*

Japan Asphalt Mixture Association, *Asphalt mixture statistics – Annual report*

T. Kanou, H. Nitta, I. Sasaki, I. Nishizaki and K. Kubo, 2009. *Study on a method of recycling asphalt mixture repeatedly*, Japan Society of Civil Engineers, 14th Journal of Pavement Engineering.

Japan Road Association Environment and Recycling Subcommittee, 2006. *An interim report of the trial construction on a national highway to develop technology for recycling reclaimed porous asphalt pavement.*

East Nippon Expressway Company Limited, 2009. *CSR Report 2009.*

Nippon Expressway Company, 2009. *CSR Report 2009*.

Metropolitan Expressway Company Limited, 2009. *CSR Report 2009*.