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Technical Notes

Technical report on 100% hot-in-place asphalt recycling trial pavement

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ABSTRACT

This technical report summarizes the results of the trial pavement of 100% Hot In Place Asphalt Recycling (HIPER) for the first time in Korea. Through the trial pavement, the analysis of existing pavement samples, development of mixing design method, performance of new equipment system and characteristics of recycled mixture were checked. As a result of the pavement, it was confirmed that there was little change in the aggregates gradation before and after the application, and it was confirmed that 100% RAP recycling is possible without the need of inputting the new asphalt mixture for gradation correction. Also, the bonding between the lower layer and the recovered layer was excellent and the longitudinal joint treatment was also excellent. However, due to the inexperience of the equipment operator, the pre-heating showed a large variation in temperature in certain sections and regions. It will be necessary to supplement this and to have skilled workers.

Keywords: Hot-in-Place, Recycling, Asphalt, 100%, Gradation, Heating, Rejuvenator, Emulsion, Recover

1. Introduction

The company introduced 100% hot-in-place recycled asphalt pavement (HIPER, Hot In Place Emulsion Retreatment) in Korea for the first time. This technique is to have Preheater heated up the road surface, followed by a secondary heater with Recycler, which remove the heated top surface and inject into a continuous drum mixer, and then aged asphalt is remixed with special rejuvenator and repaved. This method is an eco-friendly pavement maintenance method that removes an existing mixture without its gradation change and recycles the existing mixture without moving it or mixing it with a new mixture (new aggregate).

Through the trial construction, we could confirm the functions of the Preheater and Recycler used in the HIPER process, the performance of the new rejuvenator, and the change in the properties of the mixture before and after construction. However, during this construction, the company only checked the extraction content and aggregate mix through conventional asphalt mixture combustion test machines and checked the general properties of asphalt mixture. In the future, recovery of aged asphalt using the Pave Analyzer (Controls, Italy), etc. will be necessary and a more detailed analysis process will be required.

Fig. 1. Preheater : HIPER-XLP (Angelo Benedetti, USA)

Fig. 2. Recycler : HIPER-XLR (Angelo Benedetti, USA)

2. Construction Overview

- Project Name: The Re-pavement Construction of Cheongan Samgeori-Cheongan Bridge on County Road Line 1 (Goesan County, Chungbuk, Korea)
- Scale of construction: 2,236.5 m^2 of road retreatment pavement
- Extensions and road width : L = 355 m, W = 6.3 m
- Thickness of pavement : T = 15 cm (base 10 cm + surface 5 cm)

- Construction Period: April 19, 2019 to April 30, 2019.
- Location: Gwangjang-ro geumgye-gil, Cheongan-myeon, Goesan-gun, Chungcheongbuk-do, Korea (Two lanes between Cheongan Samgeori and Cheongan Bridge)

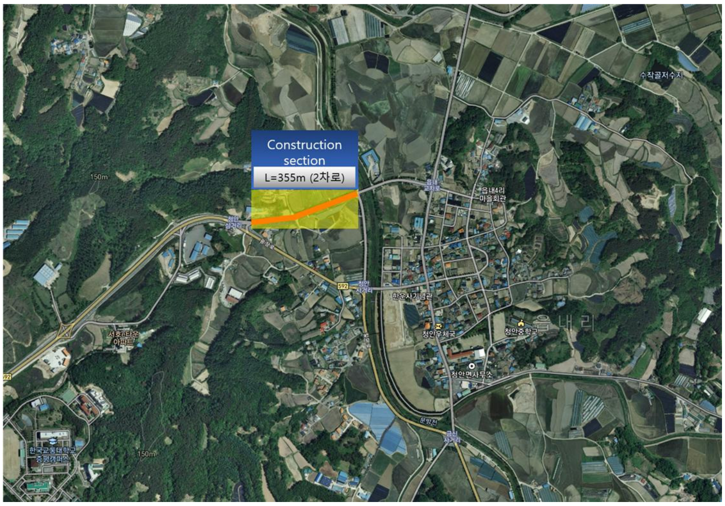

Fig. 3. Location

3. Pre-Survey

3.1 Pavement Status

This section is a provincial county road, with a low number of vehicles passing through it, and a two-lane road. However, due to its shortcut connection, heavy vehicles pass through the road.

Table 1. Pavement Status

Division	Content	Note
Pavement thickness	15 cm (base 10 cm + surface 5 cm)	Loss of subbase in wheel pass area
Mixture Types	Surface WC-2 (Dense 13 mm)	Aggregate maximum size close to 10 mm

3.2 Damage Type

- Permanent Deformation: Weak deformation of about 2~3 cm, Deposition of substrate and decrease of bearing capacity
- Fatigue Crack: Serious cracks have been carried out due to reduced bearing capacity of the base and long

fatigue loads, from the bottom of the pavement to the surface layer

- Wear, Labeling: Progress of typical pavement aging with long-term public use
- Basement Loss: Long term load transfer and moisture penetration break the binding force of the base mixture and lose some of the base mixture in the area of the wheel

Fig. 4. Field Cores before Construction

Fig. 5. Deformation and Fatigue Crack

4. Analysis and Mix Design

4.1 Field Sampling

The Hot Spot equipment is used to collect and analyze the target field mixture in the same way as the HIPER heating process, and to check the material properties change and optimal mix by the content of the rejuvenator.

Fig. 6. Hot Spot Equipment & Sampling

4.2 Material : Rejuvenator

Applying ACF2000 GREEN (by Iterchimica, Italy), this product is different from the domestic standards of rejuvenators and is not within the viscosity classification standard. Although direct comparison is not possible due to differences in the measurement method and unit of the given viscosity, visual comparison seems to be lower than the lowest level of RA 1.

<ACF 2000 GREEN Physical Properties>

Aspect: liquid, Colour: Brown - Purple, Density at 25°C: 0,93 ± 0,1 g/cm^3

Viscosity at 25°C: 100 ± 50 cP, Flash point: > 200°C, Water content: < 2%

Table 2. Domestic Standard of Rejuvenator

Division	Rejuvenator grade				
	RA 1	RA 5	RA 25	RA 75	RA 250
Viscosity (60°C cSt)	50 ~ 175	176 ~ 900	901 ~ 4,500	4,501 ~ 12,500	12,501 ~ 37,500
Flash point (°C)	more than 218	more than 218	more than 218	more than 218	more than 218
Saturates (wt, %)	less than 30	less than 30	less than 30	less than 30	less than 30
RTFO (or TFO) after Viscosity	less than 3	less than 3	less than 3	less than 3	less than 3
RTFO (or TFO) after mass change rate (±, %)	less than 4	less than 4	less than 4	less than 4	less than 4

4.3 Asphalt extraction content and aggregate gradation : dense grade 13 mm (WC-2)

As a result of combustion testing of recovered RAP samples, the type of mixture corresponds to normal asphalt 13 mm (WC-2). The gradation distribution was above the upper limit of the standard acceptance of 9.5 mm sieve, but at other sizes the reference range was met, and the distribution of fine aggregate less than 2.36

mm was shown to be relatively good. The asphalt content from the combustion test was 4.91%, slightly lower than that of a typical dense graded mixture.

Table 3. Extracted Aggregate Gradation

Division	Passing, %									Asphalt content, %
	19	12.5	9.5	4.75	2.36	0.6	0.3	0.15	0.075	
Extracted gradation	100	99.7	96.1	68.4	46.7	22.4	15.6	9.6	6.1	4.91
Gradation standard	100	100~95	92~84	70~55	50~35	30~18	21~10	16~6	8~4	-

4.4 Physical Properties Variation of Recovered RAP by Additives Content: 10% Optimal Additives Content

The Marshall samples were made after mixing the rejuvenator again into five types of content from 0 to 10%. All specimens show a defect in compaction, and the air void also exceeded the standard range of 3~6%. The amount of additives is on the decline as they become high. Nevertheless, overall Marshall stability values were high (approximately 1.5 to 2 times the typical new material mixture). It is estimated as the stability value does not fall and goes up due to the addition of additives is due to the increase in the compaction rate.

Specimens with an additive content of less than 5% have severely reduced aggregate debris on the surface and began to exhibit sticky viscosity at least 7.5% of the additive. However, since this phenomenon may be caused by lack of additives or lack of asphalt content in existing RAPs, additional confirmation is required. In this case, additional aggregate input and new asphalt are required besides additives.

Fig. 7. Specimens for Marshall Test

Table 4. Marshall Properties Trend depending on Additive Content

Type	Additive content (Extracted Asphalt weight, %)					Note
	0%	2.5%	5.0%	7.5%	10%	
Marshall stability (N)	15,136	17,417	22,652	18,475	18,505	
Flow value (1/100 cm)	35.5	36.1	28.2	34.6	37.4	
Air Void (%)	16.39	14.41	12.19	12.19	9.8	
Density (g/cm^3)	2.069	2.118	2.173	2.173	2.232	
Theoretical maximum density (g/cm^3)			2.475			

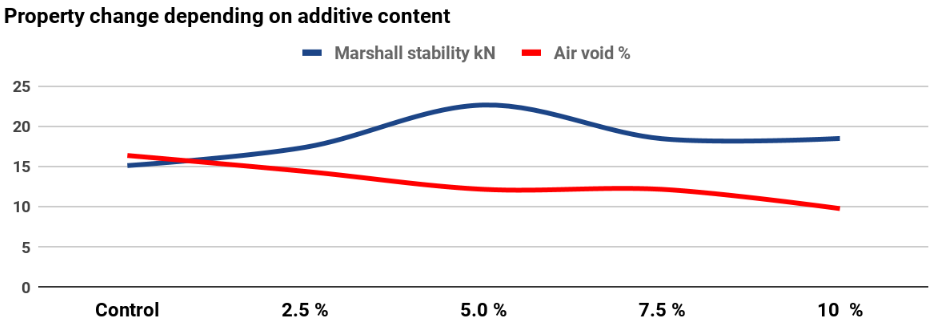

Fig. 8. Property Change Graph

In case of additive 10%, the properties were compared by mixing 5:5 mixture of additive and neat asphalt (Pen. 80~100), but the compaction ratio of only used additive was remarkably lower than the other. Testing of the additional content is necessary, but considering the various conditions at this site and the first test

Table 5. Result of Marshall Design

Division	Result		Criteria
	Additive 10%	Additive 5% + AP-3 5%	
Compaction (times)	Both sides 50		Marshall stability both sides 50 (75)
Marshall stability (N)	21668	21568	>5 000 >(7 500)
Flow value (1/100 cm)	30.2	17.8	20 ~ 40
Deformation strength (MPa)	8.21		>3.2 , >(4.25)
Indirect tensile strength (N/mm^2)	1.77	1.07	>0.80
Toughness (N·mm)	20274		>8 000
Air Void (%)	8.2	13.4	3.0 ~ 6.0
Lab density (g/cm^3)	2.260	2.141	-
Theoretical maximum density (g/cm^3)	2.462	2.473	-

construction, the decision was made by putting 10% of the rejuvenator.

4.5 Cause of Compaction Defect

Asphalt content was 4.91% (average of general dense graded asphalt mixture 5.3~5.8%) and the lack of binder content and the degree of aging progressed more than usual levels and viscosity of existing asphalt was considerably increased.

The maximum size of the extracted mixed aggregate was within 9.5 mm, but the granularity distribution showed a (internal flow) form of the coarse aggregate with more than 0.25 mm. In addition, there was a high ratio of rag stone of the aggregate between 4.75 and 0.25 mm in the extracted aggregate. These factors may have facilitated fatigue cracks at the site.

5. Construction

5.1 Pre-Heater

The preheating was heated 3 to 5 times in the 5 to 15 m section, advancing 5 m by 5 m, and the surface temperature after heating was set to 250 to 300°C.

The temperature measurement at the normal running section of the equipment showed that the road was in

Fig. 9. Preheater road surface after heating

the range of 230 to 280°C on average immediately after preheating, but the surface was overheated by 350 to 380°C or more, including malfunction of the equipment, and the road was severely burnt by fire. In particular, the burners are arranged in a row rather than in a progressive direction, causing local overheating.

It is expected that it will be difficult to control the direction to move on roads with narrow width, acceleration, and linear sections due to difficulties in adjusting heater plate width and the equipment that will monitor in real time is needed due to difficulties in checking surface heating temperature and road conditions.

5.2 Recycler (Secondary Heating, Milling, Mixing, Paving)

When the surface reaches 300°C through pre-heating, the recycler follows and starts the second heating, and the pavement is removed by 3 to 5 cm through the blade after the second heating plate. The collected mixture is streamed from the central mill and is supplied with a continuous drum mixer, mixed with the prepared additive Rejuvenator), and then spread through the screed.

It was possible to cut the depth of 3 to 5 cm in the overheating section, but the average cutting depth of the normal heating section was measured from 2 to 3 cm. After cutting, the surface temperature was measured at 70°C to 90°C, and the surface of the cutting surface was rough.

The thickness of the existing surface layer in this section (3~4 cm) is so thin that coarse aggregate for the base layer is hung on the blade. If only 2~3 cm surface is removed from the sufficiently heated section, the cutting side is in smooth condition.

Fig. 10. Overheating Area before Cutting

Fig. 11. Blade Cutting Side

Nevertheless, the temperature of the product remixed through center mill and continuous drum mixer is maintained at around 160~180°C, and does not appear to be a problem at all for paving and re-compaction. However, the combination of oil mist and additives at high temperatures is causing nauseous smoke, which seems to require improvement.

Table 6. Construction Temperatures

Division	Pre-Heater		Recycler		
	Before heating	After heating	Secondary heating (before cutting)	Cutting side	Post-combination product
Measured temperature	32 ~ 36°C	230 ~ 280°C	220 ~ 300°C	70 ~ 90°C	150 ~ 180°C

5.3 Compaction

For compaction, two tandem rollers (including a combo roller) were used, and the site compaction rate was found to be 98% to 100% with the tandem roller alone, with an average temperature of 160°C or higher.

However, after the construction, the road surface is not smooth and the retreated mixture of cohesion is lower than that of the new material mixture. Therefore, it is necessary to increase the weight of the tandem roller use the tire roller for the treatment of the pavement surface and the cold joint.

5.4 Speciality

As the surface temperature outside the heating line of the heater was heated up to 180°C, roadside trees and the concrete structure such as the L-type gutter were partially damaged. Additional measures such as heat-protecting panel will be needed to reduce the damage of trees and plants on the roadside.

Fig. 12. Damage to Roadside Trees and Structures

6. Mixture test

6.1 Extraction Content and Gradation

Combustion tests of the recovered mixture of before and after construction showed that the range of error of

± 5% was satisfied in all the sizes except that the 4.75 mm passing rate in 3rd construction mixture was increased by 8.6% compared to before construction. In the case of 3rd construction site sample, it is also possible that the particle size of the existing mixture in this section has appeared rather than the change in particle size before and after the construction.

In case of extracted asphalt content, the deviation of before and after construction was very large. The goal of adding additive during construction was 10% (4.9 kg / Ton) of the weight of existing mixture extracted asphalt, but 2~3 times more of additives were added. Bleeding phenomenon occurred due to additive oversupplying in the section where the actual equipment stopped or slowed down.

Table 7. Gradations before and after Construction

Type	Passing, %									Asphalt content, %
	19	12.5	9.5	4.75	2.36	0.6	0.3	0.15	0.075	
Before Con.	100	99.7	96.1	68.4	46.7	22.4	15.6	9.6	6.1	4.91
1st Con.	100	99.2	96.6	71.9	50.4	25.6	17.4	11.1	6.1	6.17
2nd Con.	100	100	96.6	70.9	45.7	24.4	16.1	9.8	4.2	6.48
3rd Con.	100	97.4	97.4	77.0	51.9	22.4	13.9	8.0	3.5	6.62
Gradation standards	100	100~95	92~84	70~55	50~35	30~18	21~10	16~6	8~4	-

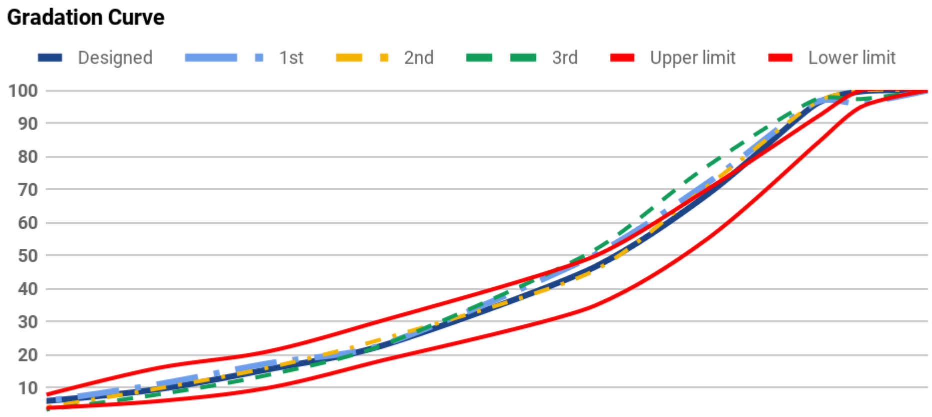

Fig. 13. Gradation Curve

6.2 Mixture Properties

As a result of confirmation of the physical properties of the mixture, the initial design value and actual construction result showed similar values. Overall, the rigidity was 2 to 3 times higher than that of regular new mixtures.

The Marshall stability value was similar, and the deformation strength and indirect tensile strength showed a slight upward trend. The fact that the stiffness of the mixture is maintained and elevated means that asphalt recovery is lacking or deteriorating. Exposure to high temperatures during construction may result in additional asphalt aging or uneven mixing of added additives.

The porosity due to indoor compaction was very high (8 ~ 9%), but the actual compaction density was good. It seems that the compaction ratio of the existing mixture is considerably lowered in the compact compaction of the interior rather than the rolling compaction due to the high aggregate composition ratio and the degree of aging of the asphalt.

Table 8. Construction Results

Type	Result				Standard
	Design	1st (4/27)	2nd (4/30)	3th (5/1)	
Compaction (times)	Both side 50				Marshall both side 50
Marshall stability (N)	21668	21203	23239	19336	5 000 more than
Flow (1/100 cm)	30.2	32.4	30.1	30.2	20 ~ 40
Deformation strength (MPa)	8.21	10.3	9.1	9.4	more than 3.2
Indirect tensile strength (N/mm^2)	1.77	2.41	1.83	1.82	more than 0.80
Toughness (N·mm)	20274	23245	19143	19029	>8 000
Air Void (%)	8.2	8.2	8.7	9.6	3.0 ~ 6.0
Lab density (g/cm^3)	2.260	2.252	2.219	2.438	-
Theoretical maximum density (g/cm^3)	2.462	2.454	2.430	2.204	-
Rejuvenator content	4.9 kg/Ton	Not checked	4.9 kg/Ton	4.9 kg/Ton	AP wt. 10%
Site compaction density (g/cm^3)	-	2.288	-	2.340	Lab density > 96%
Field Air Void (%)	-	6.76	-	4.02	-

6.3 Condition After Construction

The compatibility and compaction of the cold joints and joints were better than the existing pavement methods. However, the surface at the beginning and at the ending was not smooth, and the surface deflection phenomenon were occurred at the beginning.

After completion of the compaction, the newly recycled layer was completely bonded to the existing layer so as not to be distinguished from the existing layer. In some cores, a carbonized mixture was found to be broken after core picking.

Influence of the heater on the lower layer (base course) was not confirmed.

Fig. 14. Field Cores after Construction

7. Conclusions

- Additive (rejuvenator) content to existing aged asphalt is found to be over 10% in this test section. In the future, additive type and amount need to be selected depending on the field conditions.
- The mixture stiffness due to the aging of the asphalt is expected to decrease with the additive, but there is

little change, so that a larger amount of additive or new asphalt is needed.

- It is confirmed that there is no change in the mixture gradation before and after the construction, and 100% RAP recycling of HIPER equipment is successfully conducted without adding the new asphalt mixture.
- Bonding between the existing pavement layers and the bonding of the construction joint are observed to be excellent. However, distortion at the end point (insufficient mixture) and step difference occur.
- During the preheating, there is a temperature fluctuation of the specific section and the others. In particular, near the burner of furnace shows overheating and ignition. This may cause aging of the existing asphalt mixture.
- Cutting depth of the blade is limited to 2 ~ 3 cm at the normal operating section of the equipment. At partial overheat section, 3 ~ 5 cm is possible, but when cutting 3 ~ 5 cm, coarse aggregate of the lower mixture is hanging on the blade sometimes. Cutting depth needs to be considered carefully.
- The field compaction rate is over 98%, which makes it possible to secure good pavement quality, but smoothness seems to be insufficient.

Fig. 15. Before Construction

Fig. 16. After Construction