HOT IN-PLACE RECYCLING OF POROUS ASPHALT CONCRETE

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ABSTRACT: ANAS of Italy, Hitachi Construction Machinery Co. Ltd. and Green ARM of Japan successfully did as a joint research project a test hot in-place recycling of porous asphalt concrete over 5km in length in Perugia, Italy in late summer, 2004. The objective was to fully achieve recycling porous asphalt concrete in-situ with Green ARM's AR2000 using jet hot air to soften the surface layer first with milling, mixing and repaving processes to follow for recycling and was achieved through the confirmation of excellent test results concerning air void, grading, permeability, Marshall test and Gyratory compaction test. The test results also have confirmed the recycling method would contribute to the reduction of carbon dioxide emission, of new resource requirement as well as of repaving cost; Thus both direct and external cost will be much reduced by the method.

KEY WORDS: Hot in-place, recycling, porous asphalt, permeability, air void, grading

1. HOT IN-PLACE RECYCLER

Hot in-place recycling (hereafter HIR) technology was first invented and patented in Japan in 1989 [1]. It has been further improved and patented since then mainly in Canada [2, 3,], in particular by Martec Recycling Corporation (hereafter Martec) [4], whose product is called AR2000 Super Recycler (hereafter AR2000). Green ARM with Hitachi Construction Machinery Co. Ltd. (hereafter HCM) as a sub-licensee manufactures the machinery licensed from Martec.

AR2000 is a self-propelled equipment train, usually consisting of two Preheaters, a Preheater/Hot Miller and a Postheater/Dryer/Mixer as the main units [5]. The patented technology of the AR2000 is based on the concept of using combined jet hot-air, heated to about 600 degrees Celsius in the diesel-fueled combustion chamber, with low-level radiant heating onto the deteriorated asphalt concrete to be softened, which is milled and then mixed with new asphalt mixture, and 100% recycled. Rejuvenator is added into the windrow according as a mixture design prepared in advance of recycling work. The fully mixed and renewed asphalt mixture being kept hot is transferred to a conventional paver for laydown followed by compaction (Figure 1). Since direct flame is not used, there is no risk of the asphalt being burned, and smoke and unpleasant odors are minimized under the normal operation. The old asphalt concrete softened, milled and mixed is not damaged and carbon dioxide emission levels are very low. Thus, the asphalt repaving operation is safe, low-cost and speedy.

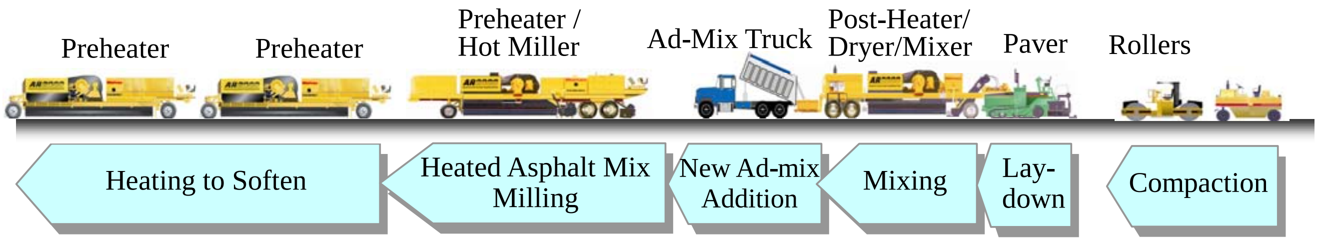

Figure 1. How AR2000 works-Composition of the machines

The machines have been put in use both for commercial work and for demonstration in Canada, the U.S., Mexico, Costa Rica, Italy, China, India and Japan. In Canada a train of the machines has been working over ten years commercially with an average speed of 3 to 6 meters per minute. Carbon dioxide emission has been observed much less (Table 1), and paving resources requirement for recycling work are also much less than the conventional method using a central asphalt plant. The technology has been proven as applicable to recycling dense graded asphalt concrete.

Table 1. Comparison of Emission Factors in Kilograms/Tonne for Two Types of Hot In-Place Recycling Trains Compared With Average Emissions from 400 Conventional Asphalt Plants in The United States [5]

POLLUTANT		MARTEC AR2000 SUPER RECYCLER	TYPICAL INFRA-RED RECYCLER	ASPHALT PLANT STACK EMISSIONS (1990)
CO_2	kg/t	.0085	.290	.019
NOx	kg/t	.0014	.015	.018
SOx	kg/t	.0017	---	.146
Particulates	kg/t	.0009	.002	---
Total Hydrocarbons	kg/t	.0007	.013	.014

2. JOINT RESEARCH PROJECT FOR RECYCLING POROUS ASPHALT CONCRETE

Italy and Japan are the world leading nations in the use of porous asphalt concrete. Since this type of asphalt concrete is increasingly used for safety and environmental reasons, its recycling in particular in-situ as alternative to the conventional landfilling or reuse somewhere else than the site is a priority issue to be shared by the Italian and Japanese authorities. Whereas the need for such recycling is estimated to grow in the near future, effective recycling technology has yet to be established because chemical binder used for the asphalt concrete is very strong and because aggregates tend to be damaged by milling. Having noted AR2000 has good capacity to heat and to mill dense graded asphalt concrete without damaging aggregates, ANAS, HCM and Green ARM agreed to undertake a two year joint project for such recycling technology.

2.1. Improvement of AR2000

A temperature sensor has been newly installed to each machine of AR2000 since good temperature control is needed both for milling without damaging aggregates and for not aging asphalt binder through overheating (Figure 2 and 3). The temperature sensor is a radiation thermometer. The sensors have proven effective.

Figure 2. Temperature Indicator

Figure 3. Temperature Sensor

2.2. Test Recycling Site

The test recycling was done on Route 318 near to Perugia 10 km east of the city, Italy, where raveling and cracking had taken place. Figure 8 shows the most heavily deteriorated site spot.

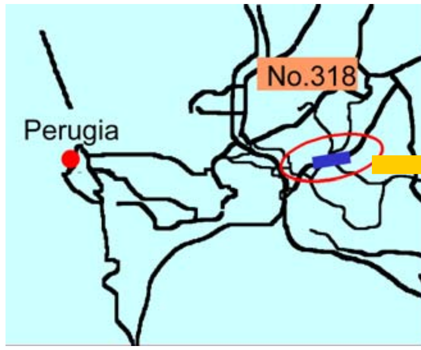

Figure 4. Site Map Figure 5. Site Map enlarged Figure 6. AR2000 at site

Figure 7. Cracks

Figure 8. Raveling and Patching before AR2000

2.3. Quality of existing porous asphalt concrete and combined grading

Quality of existing porous asphalt concrete to be recycled and combined grading with new admix as targeted grading are shown in Table 2. Milling depth was designed to be 30mm and laid layer thickness to be 50mm. Thus the designed mixing ratio was 40 % of new admix material and 60 % of existing porous asphalt mixture.

Table 2. Grading and Asphalt Content

Mixing Ratio		40%	60%	Combined grading (%)	Test Results (%)	ANAS Standards (%)
		NAM (New Admix Material)	EPA (Existing Porous Asphalt)			
		Passing Percentage				
Sieve Size (mm)	19.0	100.0	100.0	100.0	100.0	100
	13.2	70.6	95.6	85.6	90.9	80-100
	9.5	22.1	54.4	41.4	43.3	15-35
	4.75	12.5	34.2	25.5	22.1	5-20
	2.36	11.1	29.1	17.5	18.9	4-10
	0.6	5.9	13.6	10.6	10.8	4-8
	0.3	4.2	10.3	7.9	8.4	
	0.15	3.3	7.8	6.0	6.5	4-8
	0.075	2.5	5.7	4.4	4.8	4-8
Asphalt Content		4.35	4.13		4.76	5.10

Figure 9. AR2000 under operation at site

3. TEST OPERATION

3.1. Test operation

The test operation was continued for 7 days. The test operation sites, the operation work in length and the average operation work speed are shown in Table 3. The porous asphalt pavement of 21,000 square meters were recycled and rehabilitated. The combination of all the work elements including every machine of AR2000, paver, roller and new admix supply from an asphalt plant near by was important for efficient operation work. Operation speed would have been faster if the constant supply had been secured.

Table 3. Test Operation

Date		Recycled lane	Recycled length (m/day)	Average operation work speed (m/min.)
①	Aug.27,2004	3+750 ~ 4+650 (Passing lane)	900	2.6
②	Aug.30,2004	4+650 ~ 5+175 (Passing lane)	525	2.3
③	Aug.31,2004	3+750 ~ 4+625 (Main lane)	880	2.6
④	Sept.1,2004	4+625 ~ 5+175 (Main lane)	545	2.9
⑤	Sept.2,2004	0+300 ~ 1+100 (Passing lane)	750	2.7
⑥	Sept.3,2004	0+300 ~ 1+520 (Main lane)	1,220	3.1
⑦	Sept.4,2004	1+100 ~ 1+520 (Passing lane)	420	2.6

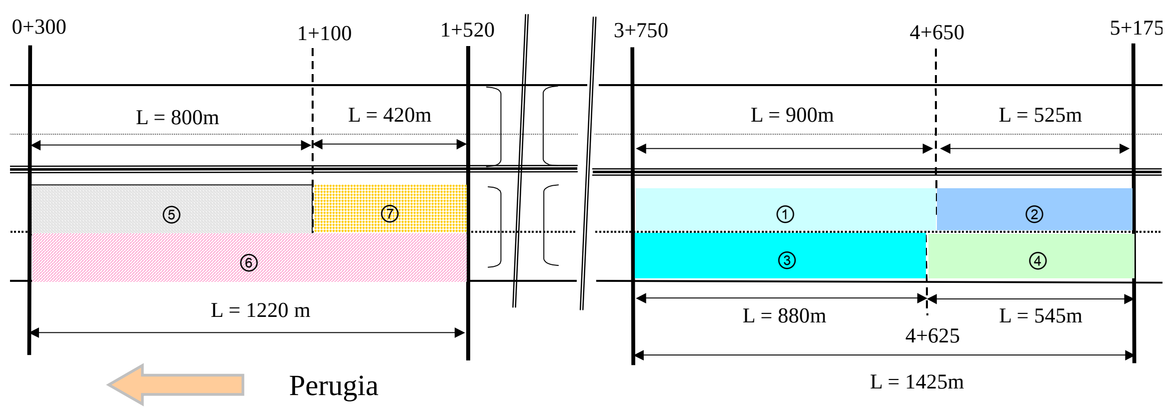

Figure 10. Test Operation Site

3.2. Temperature measurement

Temperature measured at each point is shown in Table 4.

Table 4. Temperature Measurement

Measurement Point		Existing Road Surface	Heated Road Surface	Heated Road Surface	Milling	New Admix	Recycled asphalt mixture	First Compaction
Work in Perugia	Aug.27	46℃	145℃	210℃	167℃	138℃	162℃	131℃
	Sept.1	39℃	123℃	172℃	143℃	137℃	141℃	136℃
	Sept.3	45℃	117℃	154℃	138℃	162℃	132℃	127℃

The temperature was carefully controlled to achieve necessary degrees to mill without damaging aggregates 30 mm below road surface, which is 80 degrees Celsius minimum and to compact enough, which is around 130 degrees Celsius. 210 degrees Celsius at the heated road surface at the tail of the second preheater on Aug.27 was a little too high, which was raised that high because of the first day trial.

4. QUALITY OF RECYCLED POROUS ASPHALT CONCRETE

4.1. Grading

Degrees of grading of recycled porous asphalt are shown also in Table 2. Relationship between degrees of grading of existing porous asphalt concrete and of new admix material, combined grading, and degrees of grading of recycled porous asphalt is shown in Figure 8. It is noted degrees of grading of recycled porous asphalt and degrees of combined grading are close to each other. The both degrees of grading are beyond ANAS standards toward finer sieve size, which reflects the grading of existing porous asphalt chosen as the operation site.

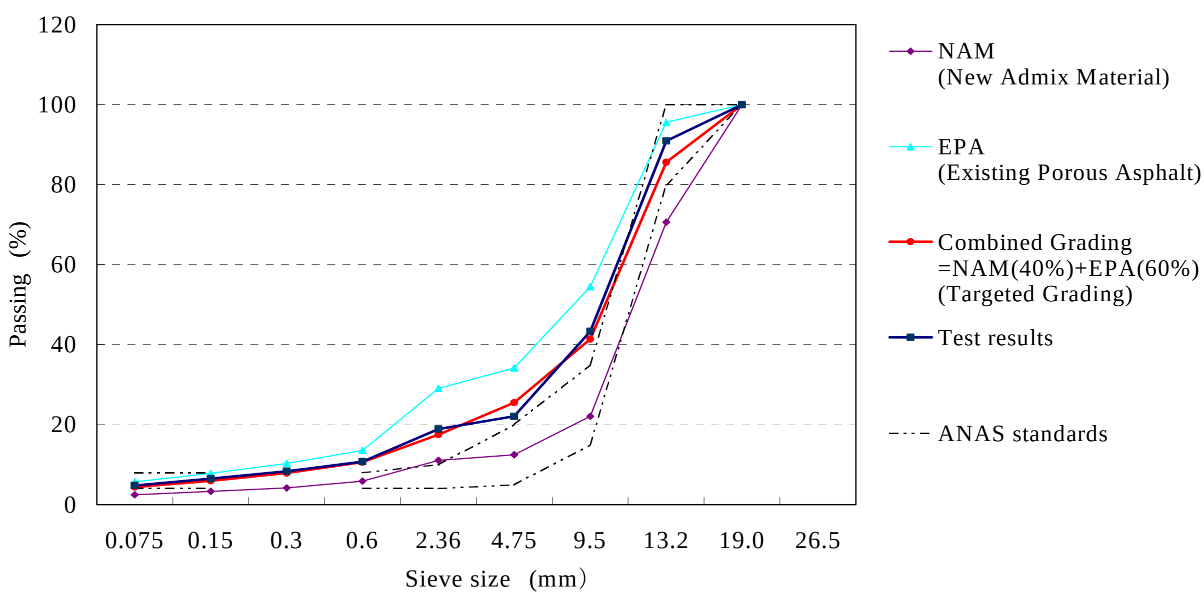

Figure 8. Grading Curves of Porous Asphalt

4.2. Marshall Test, Gyratory Compaction Test and Permeability Test

Results of Marshall Test and of Gyratory compaction test, and coefficient of permeability test are shown in Table 5. The results fell within the requirements satisfactorily.

Table 5. Marshall Test, Gyratory Compaction Test and Permeability Test

Tests			0+440	0+700	0+650	0+850	0+930	1+100	4+100	4+800
			Passing lane	Passing lane	Main lane	Main lane	Main lane	Main lane	Main lane	Main lane
Marshall Test	Marshall stability	daN	592	710	529	714	802	741	805	698
	Flow	mm	2.3	3.0	3.6	3.0	3.2	3.1	3.1	3.5
	Stiffness	daN/mm	257	237	147	238	251	239	260	199
Gyratory Compaction Test	Specific gravity	g/cm^3	1.847	1.848	1.821	1.865	1.867	1.821	1.935	1.863
	void	%	27.1	27.0	28.4	26.4	25.9	28.7	24.0	26.7
Permeability test	Coefficient of permeability	cm/sec	3.44×10^{-1}	4.22×10^{-1}	4.83×10^{-1}	4.24×10^{-1}	3.83×10^{-1}	4.19×10^{-1}	2.07×10^{-1}	3.49×10^{-1}

5. COST AND RESOURCES SAVING

It is a widely shared view that resulting cost savings by HIR with improved methods for mix design and quality control for recycling are bigger enough when compared with an equivalent amount of resurfacing by the conventional "mill and fill" method [6].

Table 6 shows cost and resources savings in the test recycling case, which is self-explanatory.

Table 6. Comparison between the conventional method and the method adopted

		Conventional Method	Adopted Method	Saving
Dump Truck Delivery	Carry out	104 Dump Trucks (Loading 25tons)	0	159 Dump Trucks (Loading 25toms)
	Bring in	87 Dump Trucks (Loading 25tons)	32 Dump Trucks (Loading 25tons)	
Existing Asphalt Mixture	To be recycled somewhere else	2,100t (100%)	0	2,100t
New Asphalt Mixture	Brought in	2,100t (100%)	674t (32%)	1,426t (68%)

6. PERFORMANCE

There have been found joint cracks, which took place at certain site surface. This was perhaps due to the recycling work overlapped at the joint. The rest of the recycled site has had no problem.

7. CONCLUSIONS

A brief summary of the above study is given as follows:

1. ANAS, HCM and Green ARM undertook a first year test recycling. It was done on Route 318 near to Perugia, Italy, where raveling and cracking had taken place.
2. HIR using AR2000 was adopted. Temperature control was a priority point of interest. For this reason temperature sensors were newly installed to AR2000, which was effective.
3. Milling depth was designed to be 30mm and laid layer thickness to be 50mm. Thus the designed mixing ratio was 40 % of new admix material and 60 % of existing porous asphalt mixture.
4. The average operation speed was about 2.7 m per minute but it would have been faster if the constant supply of new admix had been secured.
5. The temperature was carefully controlled to achieve necessary degrees to mill without damaging aggregates 30 mm below road surface and to compact enough. Such required temperature was achieved.
6. Degrees of grading of recycled porous asphalt and degrees of combined grading were close to each other.
7. Results of Marshall test and of Gyratory compaction test, and of permeability test fell within the requirement satisfactorily.
8. There have been found joint cracks, which took place at certain site surface. This was perhaps due to the recycling work overlapped at the joint. The rest of the recycled site has had no problem.
9. From the point of economics cost and resources were much saved.

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