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Theme-2: Recycling of Pavement Material
(ii) Hot In-Place Recycling

HOT IN-PLACE RECYCLING WORK OF VADODARA HIGHWAY ROAD SURFACE

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Abstract
India is faced with a challenge of the urgent need to rehabilitate the existing roads as well as to construct new roads under growing concerns with energy prices, aggregate shortages and the global warming.
TATA Eco Resurfaces Private Ltd., called as TERPL started in 2004 as a JV of TELCON, IVRCL, Hitachi Construction Machinery and Green ARM to address the above challenge. Recently it has eventually successfully finished a highway recycling work of 128 km lane (32km x 4 lanes) of Vadodara Highway, using a Hot In-Place recycler, AR2000 despite of mechanical, operational and new asphalt supply problems and/or difficulties which took place during the operation. The existing road surface of asphalt mix has been 100% reused and recycled with new admix added as designed. This is the first large scale HIR work ever done as a single recycling project in the world as well as in India. The experiences of success, which have overcome such problems and difficulties, will give a good solution to the above challenge.
AR2000, which has made such a work possible, is based on the concept of using jet hot air to soften the surface layer of pavement with milling, mixing and repaving processes to follow for recycling. Thus it consists of two pre-heaters, one pre-heater miller and one post-heater mixer as a train. The heating system installed with an internationally patented technology achieves enough temperature required for the existing road surface to be recycled and does not crush aggregates of the surface pavement. Thus AR2000 implements a 100% recycling work of required quality with the original gradation unchanged and with

the temperature of milled asphalt mixture maintained, as required, for compaction, which has been confirmed by a quality control check done by the job owner.

The job owner did every day quality control check with results of each day operation. Marshall test concerning Stability, Density, Void and other items was done and the results have been confirmed to clear the strict quality criteria.

X days were taken for the whole recycling work done by AR2000. The average operation speed was 3.77m/min., which is far beyond the speed of work by the conventional manual method.

Lots of experiences and expertise accumulated through the entire operation will much improve the whole HIR method including AR2000.The AR2000 recycling work done at Vadodara has assured the economic viability of HIR method using AR2000 and the efficiency of the method.

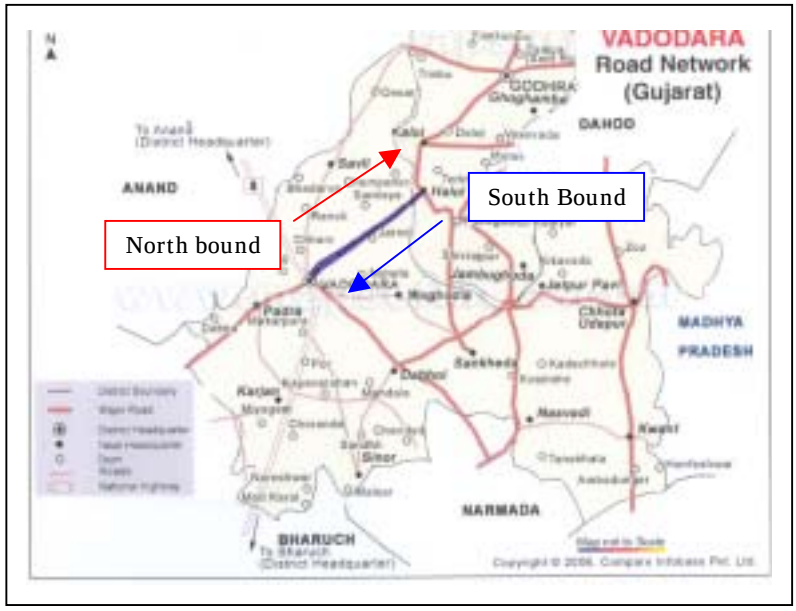
KEY WORDS: Hot, In-place, Recycling, Asphalt, Energy, Aggregate, Speed

THE TEXT

1. CONSTRUCTION SUMMARY

1-1. A road rehabilitation work was done by Hot In-place Recycling (hereafter HIR) method at Vadodara, Gujarat State on the highway between Vadodara and Holol.

1-2. 128km lane, i.e., 32km x 4lanes was rehabilitated with the total lane pavement surface 100% recycled. Figure 1 shows the site map.



【Figure 1】Recycling job site

1-3. The machine used was AR2000, which already did successful recycling work in Canada, the U.S., Mexico, Italy, Japan and some other countries. But for the first time in India and in terms of scale as a single recycling project for the first time in the world. As is shown in Figure 2, it is a train of machines consisting of two Pre-Heaters, which heat and soften the existing pavement surface, a Pre-Heater-Miller, which mills the softened surface while still heating and a Post-Heater Mixer, which mixes milled

materials to be recycled and new admix for repavement, to be followed by a conventional paver.

2. AR2000 AND CHARACTERISTICS OF THE SYSTEM

2-1. AR2000 was developed by a Canadian company, Martec and has been installed with the internationally patented technologies. The concept has been based on the Japanese idea of recycling by heating the surface layer. The technological advance of the AR2000 allows for 100% recycling of the existing asphalt mixture on-site without crushing aggregates in use as well as without burning the surface layer. The AR2000 can generate 38,000 mega-joules/hour.

2-2. Characteristics of the system

2-2-1 Technology Designed and Manufactured to Operate Virtually Emission Free

i) It uses a hot jet air circulation system utilized to soften asphalt pavement surface, not using direct flames. The results are more environmentally friendly.

ii) Old asphalt is 100% recycled, generating from the site no waste.

iii) The deafening noise associated with conventional digging is significantly reduced through the process of softening and recycling of asphalt.

2-2-2 Securing On-site Construction Safety

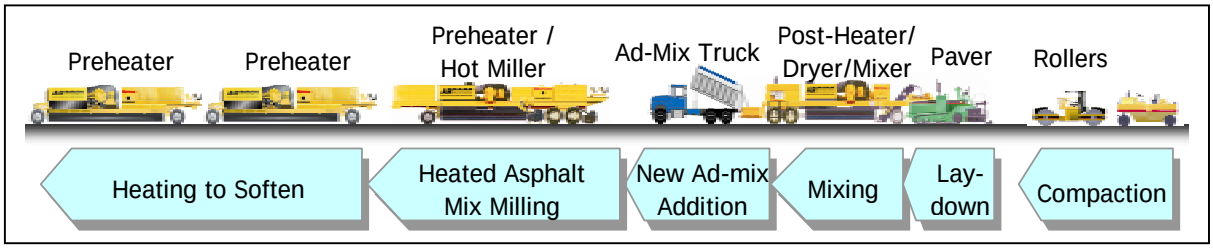
i) Machine operating skills are required and have to be acquired by operators. But they can easily do so. Once acquired it results in simpler operations and creates safer working conditions for workers.

ii) Diesel fuel rather than propane is used for a radial heating method, thus minimizing the risk of explosion.

2-2-3. Substantial Time Saving

i) Based on the actual job records, the average operation speed was 3 to 5m/min. calculated from actual working hours and the highest speed was over 5m/min., which could not have achieved by the conventional resurfacing method.

ii) Consequently compared to the conventional resurfacing method, HIR method considerably reduces project duration.



【Figure 2】AR2000 train of machines

3. FUNCTIONING OF EACH MACHINE

3-1. PRE-HEATER

Two Pre-Heaters, operating in tandem, gently heat and soften the existing asphalt pavement surface. With the Hot Air Heating System incorporated, air is heated to about 600 degrees Celsius and in combination with low level infrared heat, blown directly onto the pavement surface. A cover that prevents loss of circulation shields the hot air. A Pre-Heater is shown in Figure 3

【Figure 3】Pre-Heater

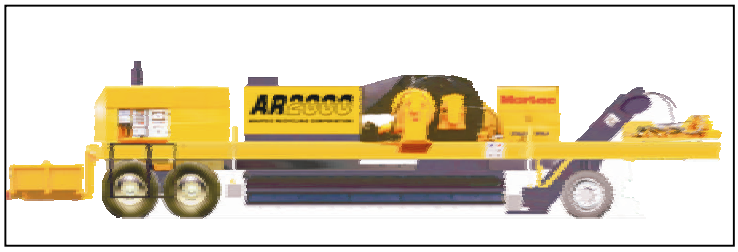
3-2. Pre-Heater-Miller

The Pre-Heater-Miller applies additional heat, which helps its milling heads easily loosen and mill the softened pavement. The automated depth control feature permits asphalt mixture removal to a desired depth depending on the rehabilitation work and the milling heads can be adjusted to a working range from 3.3m to 3.9m. Pre-Heater-Miller is shown in Figure 4.

【Figure 4】Pre-Heater Miller

3-3. Post-Heater Mixer

Post-Heater Mixer has installed a series of devices to be used to continuously mix and expose the milled asphalt mixture to hot air and infrared heat. The asphalt mixture is taken up and transferred to the 300tph twin-shaft pugmill, where the transferred asphalt mixture and new admix as required by a mixture design are mixed. The Post Heating and Stirring Process, which is a patented technology, helps thorough and uniform heating of the recycled asphalt mixture and also removes excess moisture from the materials. Post-Heater Mixer is shown in Figure 5.



【Figure 5】Post-Heater Mixer

3-4. Paver

The fully mixed material is transferred from the pugmill to the hopper of a conventional paver for laydown.

3-5. Rollers

Compaction is done by conventional rubber-tired and vibratory rollers.

4. MIX DESIGN

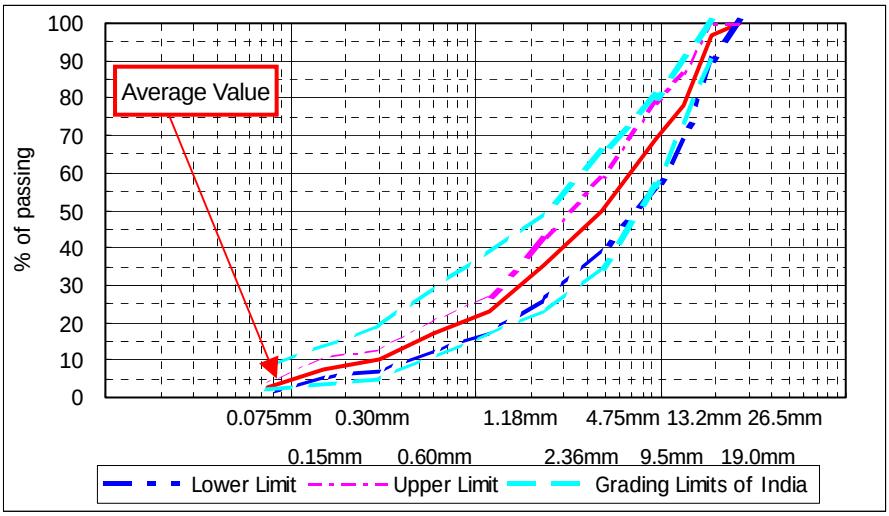
Mix design is made in such a way as to satisfy the quality requirements given by the pavement standard in India with the quality of recycled asphalt mixture composed of mixture of existing pavement surface recycled and new admix. In the Vadodara case several material tests required were done first with 29 core samples collected from the site in order to grasp the quality of the existing asphalt pavement

4-1. Gradation

Results of a gradation analysis are shown in Table 1 and Figure 6. 8 out of 29 pieces of data, which showed irregular figures were excluded and the average value was thus calculated out of 21 pieces of data.

【Table 1】Existing Asphalt Mixture Quality Test Results

		Average Value	Minimum Value	Maximum Value
Density (g/cm^3)		2.516	2.437	2.553
Bitumen Contents (%)		4.57	4.00	5.10
Sieve Analysis after Bitumen Extraction				
Gradation % in Passing	26.5mm	100.00	100.00	100.00
	19.0mm	96.55	90.53	100.00
	13.2mm	78.17	67.80	86.32
	9.5mm	68.96	55.26	78.42
	4.75mm	49.59	39.47	58.42
	2.36mm	35.33	26.04	41.58
	1.18mm	22.74	16.93	27.51
	0.60mm	17.01	12.23	21.05
	0.30mm	10.17	6.91	12.77
	0.15mm	7.61	5.32	10.64
	0.075mm	2.43	1.00	4.20



【Figure 6】Particle Size Distribution of Existing Asphalt Mixture

4-2. Gradation Design

A mixture ratio was chosen at 75% of the existing asphalt mixture (EAM) and 25% of new asphalt mixture (NAM) so that the gradation of recycled asphalt mixture (RAM) composed of EAM and NAM almost meets the Target Gradation within the range of gradation shown in the Requirement of India. Table 2 shows Target Gradation.

【Table 2】Target Gradation

		Target Gradation	Gradation Limits
Gradation % in passing	26.5mm	100	100
	19.0mm	95	90-100
	9.5mm	68	56-80
	4.75mm	50	35-65
	2.36mm	36	23-49
	0.3mm	12	5-19
	0.075mm	5	2-8

An aggregate ratio, which would meet the Target Grading of RAM was calculated by trial and error and chosen. Table 3 shows combined gradation and every composing aggregate ratio for new admix.

【Table 3】Combined Gradation of New Asphalt Mixture

		Kapchi	Grit	Semi Grit	Filler	Combined Gradation
Blend		12%	30%	53%	5%	
Gradation % in Passing	26.5mm	12	30	53	5	100
	19.0mm	10.38	30	53	5	98.38
	9.5mm	0.14	19.8	53	5	77.94
	4.75mm	-	0.33	49.51	5	54.84
	2.36mm	-	-	31.47	5	36.47
	0.3mm	-	-	5.93	4.7	10.63
	0.08mm	-	-	1.62	2.85	4.47

The target of quality improvement through adding new admix is to recover the original quality of the existing surface mixture. Table 4 shows combined gradation to be made of mixed gradation of EAM and NAM.

【Table 4】Combined Gradation of Recycled Asphalt Mixture

		Existing Asphalt Mixture	New Asphalt Mixture	Combined Gradation
Blend Proportion		75%	25%	100%
Gradation % in Passing	26.5mm	75.0	25.0	100
	19.0mm	72.5	24.6	97.10
	9.5mm	51.8	19.48	71.28
	4.75mm	37.2	13.71	50.91
	2.36mm	26.5	9.1	35.60
	0.3mm	7.70	2.65	10.35
	0.075mm	1.80	1.12	2.92

4-3. Determination of Asphalt Content

Marshall test was done with RAM, which was composed of EAM collected from the site and NAM, and mixture design was prepared. Table 5 shows the Marshall test results.

【Table 5】Marshall Test Results

No.	Bitumen Content (%)	Bulk Density (g/cc)	Maximum Theoritical Density (g/cc)	Voids in Mixture (%)		Void in Mineral A.G.G. (%)	Voids Fills with Binder (%)		Corrected Stability (kg)		Flow Value (mm)	
1	4.50	2.437	2.576	5.40	×	16.22	66.70	○	995	○	2.90	○
2	5.00	2.450	2.558	4.22	○	16.31	74.10	○	1,098	○	3.10	○
3	5.50	2.481	2.536	2.16	×	15.63	86.18	×	1,028	○	4.02	×
4	6.50	2.467	2.531	2.52	×	17.13	85.28	×	1,005	○	4.30	×
The Requirements in India				3~5		-	66~75		820~		2~4	

With respect to the test results 5% of asphalt content was chosen as a corresponding figure to the Requirement in India. Table 6 shows properties of the asphalt used.

【Table 6】New Asphalt Mixture Quality Test Results

Item \ Type	60/70
Penetration at 25℃	64.5
Softening Point	54.5
Ductillty at 27℃	91.0
Specific Gravity	1.01

Table 7 shows asphalt contents concerning EAM, NAM and RAM, which is mixture of EAM and NAM.

【Table 7】Asphalt Content

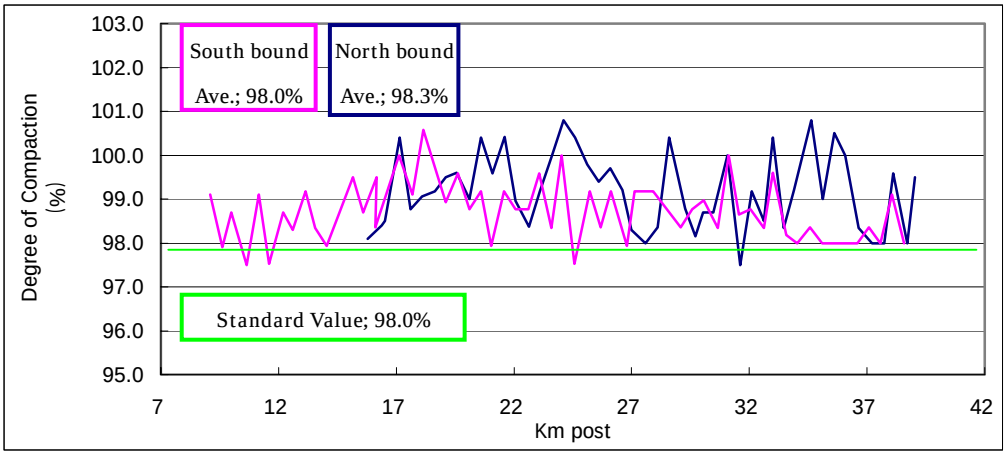
EAM Blend Proportion & Binder Content(%)	75	4.57
Binder Content EAM (%) (Weigt of RAM)	3.428	
Binder Content of RAM (%)	5	
Binder Content of NAM (%) (Weigt of RAM)	1.572	
NAM Blend Proportion & Binder Content (%)	25	6.29

5. CONTRUCTION MANAGEMENT

5-1. Quality Management

The following tests were done for the quality control; Degree of Compaction, Temperature Management, Marshall Stability, Flow Value and Grading, the test results of which are shown in Figure 7 to Figure 11.

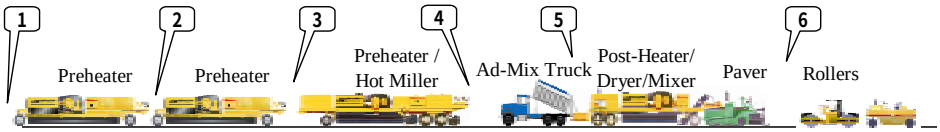
5-1-1. Degree of Compaction



【Figure 7】Degree of Compaction

As shown in Figure 7, the test results concerning the both North and South bound highways nearly met the Standard Value of 98% with North bound average 98.3% and South bound average 98.0%.

5-1-2. Temperature Management

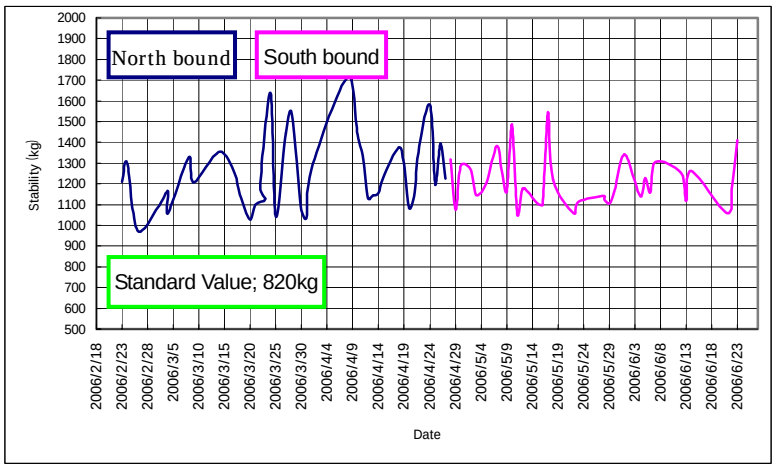


Measurement Point	Ave. Temperature (℃)	Measurement Point	Ave. Temperature (℃)
① Existing Pavement	40	④ Milled Asphalt Mixture	140
② Heated Pavement	110	⑤ New Asphalt Mixture	148
③ Heated Pavement	137	⑥ Before Compaction	130

【Figure 8 】Temperature Measurement

The temperature level of EAM heated by Pre-Heaters is essentially important for the efficiency of milling, mixing and compaction. Figure 8 shows temperature measurement results at the specific measurement points heated by AR2000. The existing pavement surface was heated enough by the two Pre-Heaters to be milled. The temperature of asphalt mixture right after paving work done by an asphalt paver was almost 130 degrees Celsius, which falls in the range of required compaction temperature. Therefore the enough heating capacity of AR2000 has been proven to secure good quality work.

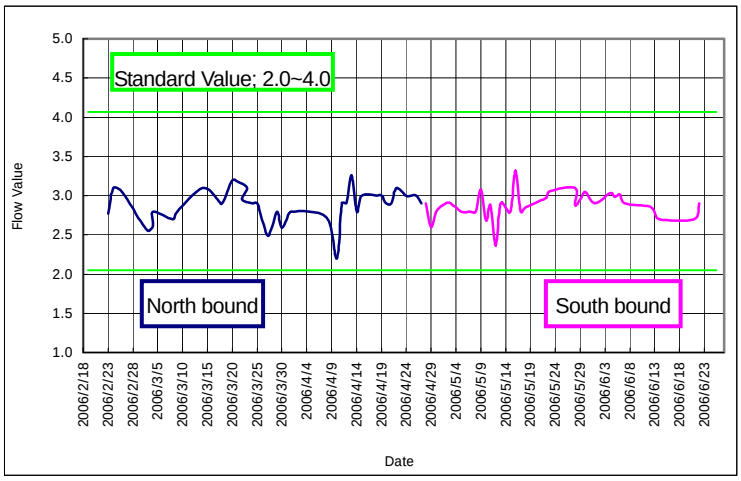
5-1-3. Marshall Stability



【Figure 9】Marshall Stability

As shown in Figure 9, the average Marshall Stability was 1,229kg whereas the standard figure is 820kg. The North bound and South bound average figures were 1,247kg and 1,210kg respectively, which were well beyond the standard figure.

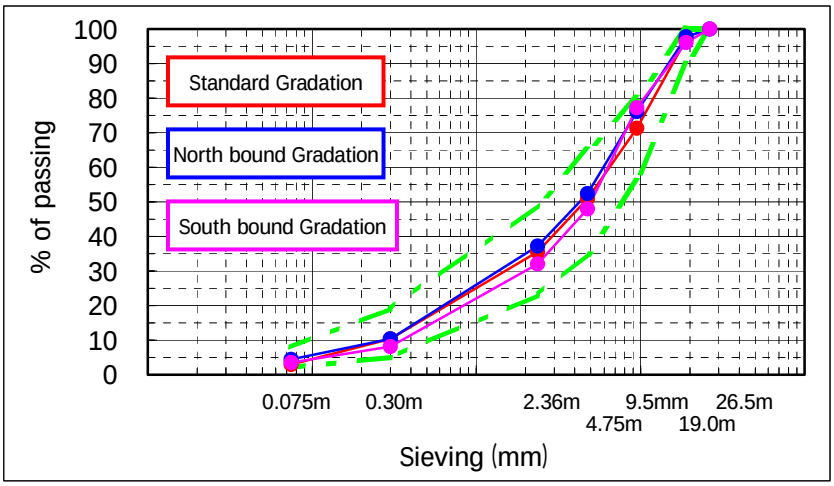
5-1-4. Flow Value



【Figure 10】Flow Value

As is shown in Figure 10, Flow Value test results fell in the range of the Standard Value.

5-1-5） Gradation

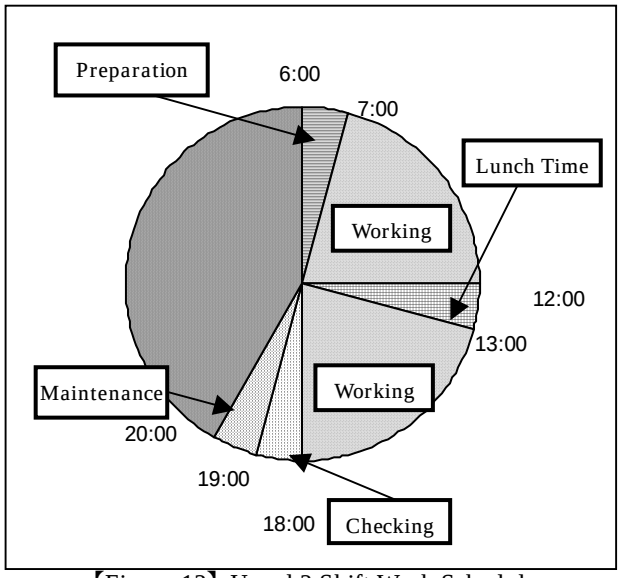


【Figure 11】Particle size distribution

As is shown in Figure 11, all the gradation test results concerning were quite similar to the Standard Gradation and fell within the range of allowable gradation.

5-2. Operation Speed

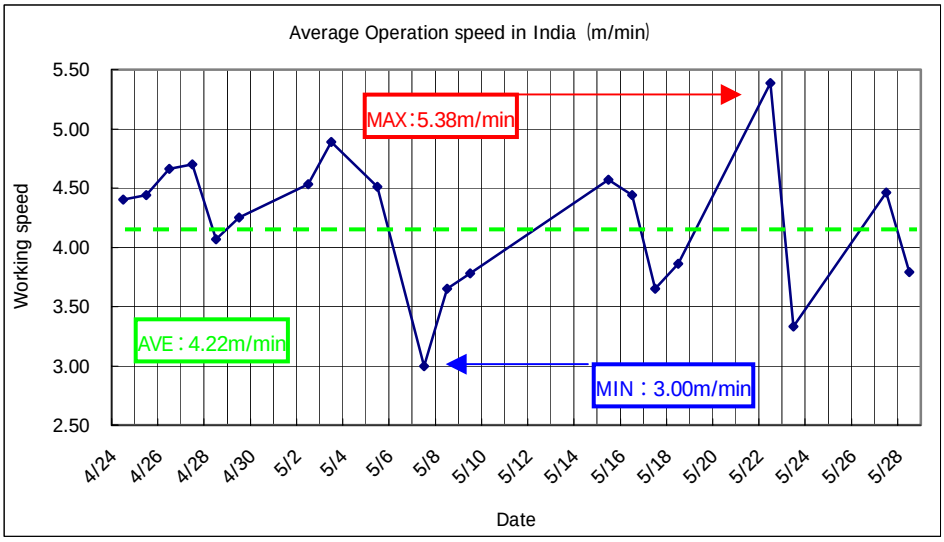
AR2000 works fast and enables to significantly shorten the conventional work duration. Figure 12 shows a usual 2 shift work schedule. The average working hours were from 6:00 to 20:00 and the actual working hours of AR2000 were 10 hours from 7:00 to 18:00 including one hour for lunch.



【Figure 12】Usual 2 Shift Work Schedule

It is essentially important to keep the machines always in a good condition, which would shorten working hours. In the beginning of work, which started in February, 2006, the operation speed varied due to the then learning process of operation, interruption of asphalt supply from the asphalt plant and lack of every day mechanical check as well as mechanical problems. As from April, however, smoother operation

started and Figure 13 shows such normalized working data.



【Figure 13】Average Operating Speed in India

6. Conclusion

The Vadodara Highway rehabilitation work done by AR2000 HIR method has proven;

1. The mechanical work results meet the Requirement of India.
2. The work will be economically viable, saving the total cost, working hours, new asphalt mixture requirement, new aggregates, etc as well as shortening job duration by high speed operation once the operating conditions get normalized.
3. The work is environmentally friendly in terms of the total energy use, and of asphalt and aggregate use as well as in terms of gas emission.

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