A Case Study of Work done by a HOT IN-PLACE RECYCLING (HIR) Machines

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ABSTRACT

China 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. Green ARM, which is a company located in Tokyo, Japan to manufacture a line of products for on-site solutions including Hot In-Place Recycling machinery licensed from Martec Recycling Corporation of Canada and a provider of the related services, addresses the above challenge. Recently it has eventually successfully finished a highway recycling work of 128 km lane (32km x 4 lanes) of Vadodara Highway, Gujarat State, India, 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 asphalt mix has been 100% reused and recycled with new admix added as designed. This is the first single project of such a large scale HIR work ever done by the same train of machines in the world. The experiences of success, which have overcome technical 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. 90 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 have been accumulated through the entire operation and will much improve the whole HIR method including AR2000. In conclusion the AR2000 recycling work done on the above highway has assured the economic viability of HIR method using AR2000 and the efficiency of the method.

1. INTRODUCTION

Deteriorated pavements are characterized by poor ride quality and physical distress, such as cracking, raveling, corrugations, rutting and potholes. Pavement deterioration is greatly influenced by harsh climatic conditions, high traffic volume and excess loads as well as by road construction process and maintenance. The deterioration of

asphalt pavements will be accelerated in several years after the start of service but timely rehabilitation such as resurfacing and recycling can restore pavement quality and extend a roadway's lifetime.

The surface course of asphalt pavement is made of bituminous material and mineral aggregates which are mixture of high-quality rocks and sands.

These materials are in short supply, making them more costly. The world of today, conservation of environment is of utmost importance and more so in the road construction industry which uses huge quantity of natural resources and energy.

The above mentioned situation being considered, the Hot In-place Recycling process by using the AR2000 Super Recycler was adopted, which is an innovative method in road recycling besides being environmentally friendly. The superiority of HIR was confirmed over CIR which was an alternative method. Table 1 shows results of the comparison between HIR and CIR in terms of economics, quality and execution characteristics.

Table 1: HIR vs CIRs

	Hot In-place Recycling	Cold In-place Milling + Hot mix asphalt from asphalt plant	Cold In-place Milling + Cold mix asphalt in-place
Existing aggregates to be recycled	Maintained	Crushed	Crushed
New asphalt binder required	Less; because of existing aggregates maintained	More; because of existing aggregates crushed and smaller average size of particles	Asphalt emulsion (+ Cement or Lime)
Mixture design	Original design maintained	Redesign	Redesign
Truck delivery frequency	Less; one way delivery	Much more; two way deliveries	Less; one way delivery
Surface course durability	Good	Good	Poor

2. CONSTRUCTION SUMMARY

2-1. 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.

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

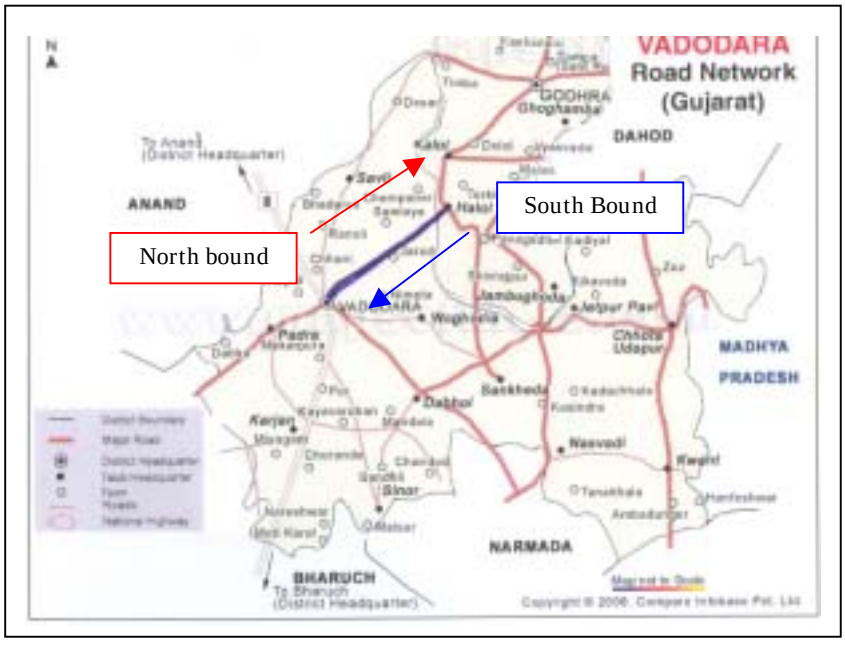


Figure 1: Recycling job site

2-3. The machine used was AR2000, which already did successful recycling work in Canada, the U.S., Mexico, Italy, Japan and some other countries.[1)~4)] 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, the Pre-Heater-Miller, which mills the softened surface while still heating and a Post-Heater Mixer, which mixes for repavement milled materials to be recycled and new admix, to be followed by a conventional paver.

3. AR2000 AND CHARACTERISTICS OF THE SYSTEM

3-1. AR2000 was developed by a Canadian company, Martec and has been installed with the internationally patented technologies. The concept was based on the Japanese company's patented technology of on-site recycling by heating the surface layer. The technological advance of the AR2000 more efficiently 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.

3-2. Characteristics of the system

3-2-1. 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. Results are more environmentally friendly.

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

iii) The deafening noise associated with conventional digging is significantly reduced through softening asphalt pavement surface.

3-2-2. 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 becomes on easy job operation and offers safe working conditions for workers.

ii) Diesel fuel rather than propane is used as radiant heating method, and minimizes the risk of explosion.

3-2-3. Substantial Time Saving

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

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

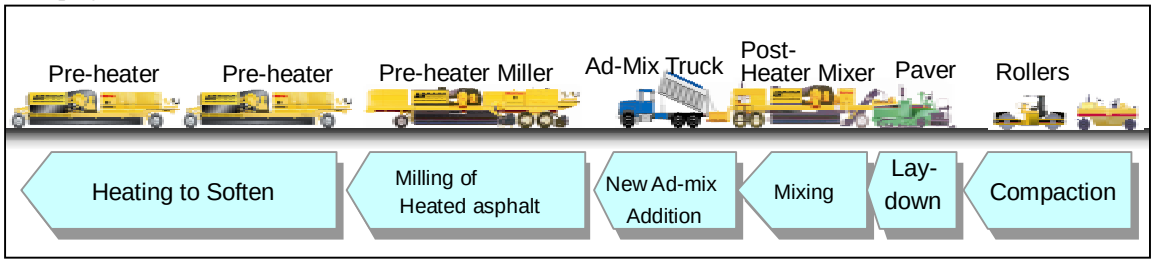


Figure 2: AR2000 train of machines

4. FUNCTIONING OF EACH MACHINE

4-1. 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. The Pre-Heater is shown in Figure 3.

Figure 3: Pre-Heater

4-2. 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 controller permits asphalt mixture removal to a desired depth depending on a rehabilitation design and the milling heads can be adjusted to a working range from 3.3m to 3.9m or even beyond 4.0m as required. Pre-Heater-Miller is shown in Figure 4.

Figure 4: Pre-Heater Miller

4-3. Post-Heater Mixer

The Post-Heater Mixer has installed a series of devices to be used to continuously mix the milled asphalt mixture and to expose the mixture to hot air and infrared heat. The asphalt mixture is taken up from the milled pavement surface and transferred to the 160tph twin-shaft pugmill, where the transferred asphalt mixture and new admix as required by a mixture design adopted 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 material. The Post-Heater Mixer is shown in Figure 5.

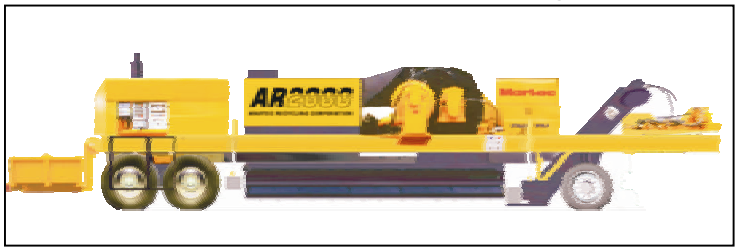


Figure 5: Post-Heater Mixer

4-4. Paver

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

4-5. Rollers

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

5. MIX DESIGN

A mix design was made in such a way as to satisfy the quality requirements given by the pavement standard in India with respect to the quality of recycled asphalt mixture composed of mixture of existing pavement surface recycled and of the new admix added. In the Vadodara case several material tests required were done for the mix design with 29 core samples collected from the site in order to examine the existing asphalt pavement including

gradation and asphalt content.

5-1. Gradation

Results of a gradation analysis are shown in Figure 6.

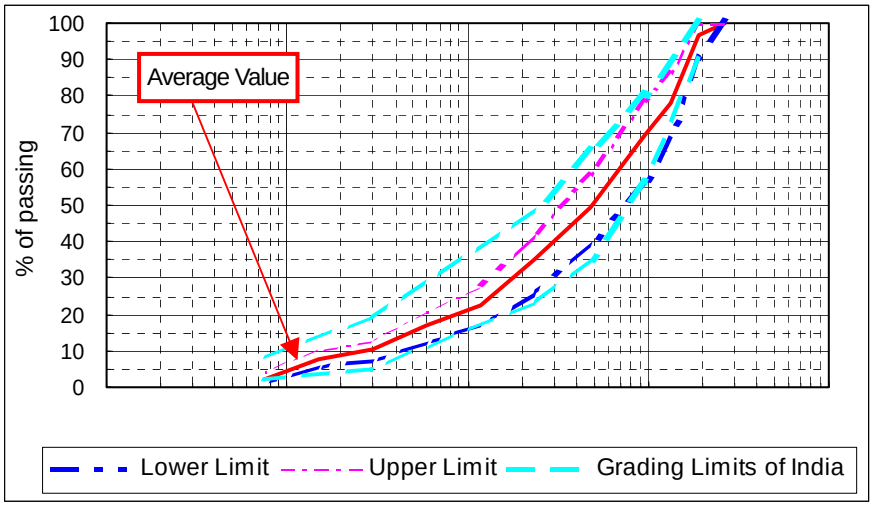


Figure 6: Particle Size Distribution of Existing Asphalt Mixture

5-2. 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 met the Target Gradation within the range of gradation shown in the Requirement of India. Table 2 shows combined gradation to be made of gradation of EAM and NAM.

Table 2: Combined Gradation of Recycled Asphalt Mixture

		Existing Asphalt Mixture	New Asphalt Mixture	Combined Gradation	Gradation Limits in India
Blend Proportion		75%	25%	100%	-
Gradation % in Passing	26.5mm	75.0	25.0	100	100
	19.0mm	72.5	24.6	97.10	90-100
	9.5mm	51.8	19.48	71.28	56-80
	4.75mm	37.2	13.71	50.91	35-65
	2.36mm	26.5	9.1	35.60	23-49
	0.3mm	7.70	2.65	10.35	5-19
	0.075mm	1.80	1.12	2.92	2-8

5-3. Determination of Asphalt Content

Marshall test was done with RAM. Table 3 shows the Marshall test results.

Table 3: 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, meeting the Requirement in India.

Table 4 shows asphalt contents concerning EAM, NAM and RAM.

Table 4: Asphalt Content

Blend proportion (%)	Exisiting Asphalt Mixture (EAM)	New Asphalt Mixture (NAM)
	75	25
Binder content (%)	4.57	6.29
Recycled Asphalt Mixture (RAM) Binder content (%)	(3.428)	(1.572)
	5	

6. CONTRUCTION MANAGEMENT

6-1. Quality Management

The following tests were done for the quality control; Degree of Compaction, Temperature Management, Marshall Stability, Sieve Analysis, the test results of which are shown in Figure 7 to Figure 10.

6-1-1. Degree of Compaction

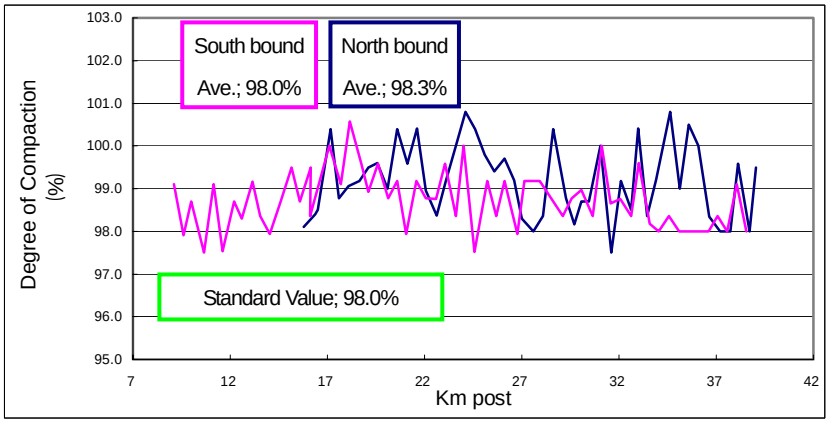
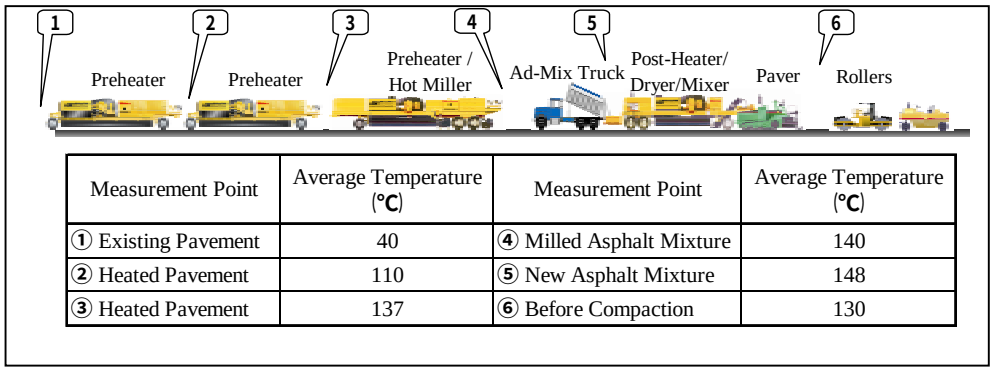


Figure 7: Degree of Compaction

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%.

6-1-2. Temperature Management



Measurement Point	Average Temperature (℃)	Measurement Point	Average 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. 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.

6-1-3. Marshall Stability

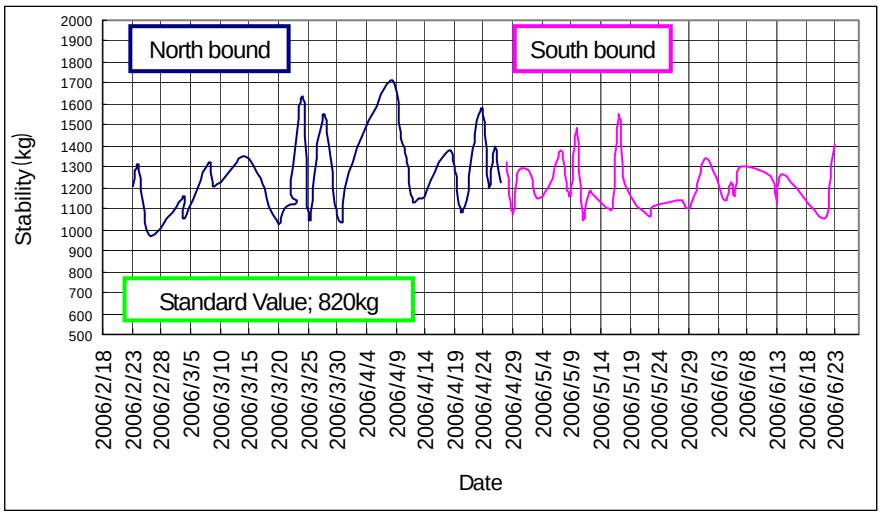


Figure 9: Marshall Stability

Figure 9 shows the variation of Marshall Stability. The average 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.

6-1-4. Gradation

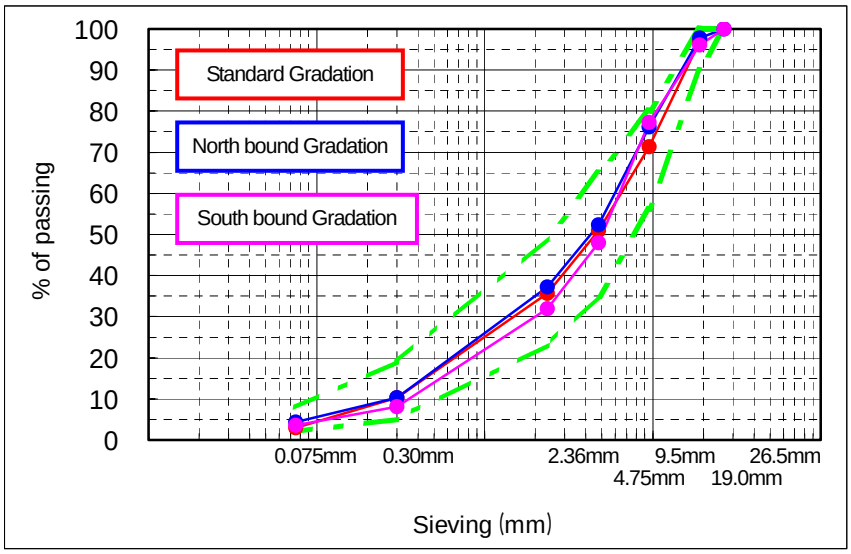


Figure 10: Particle size distribution

As is shown in Figure 10, all the gradation test results were quite close to the Standard Gradation and fell within the range of allowable gradation.

6-2. Operation Speed

AR2000 works fast and enables to significantly shorten the conventional work duration. 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 troubles. As shown in Figure 11 as an typical example of normal operation excepting the working record on May 8th, the operation speed achieved above 3.5m/min with the average speed of 4.22m/min.

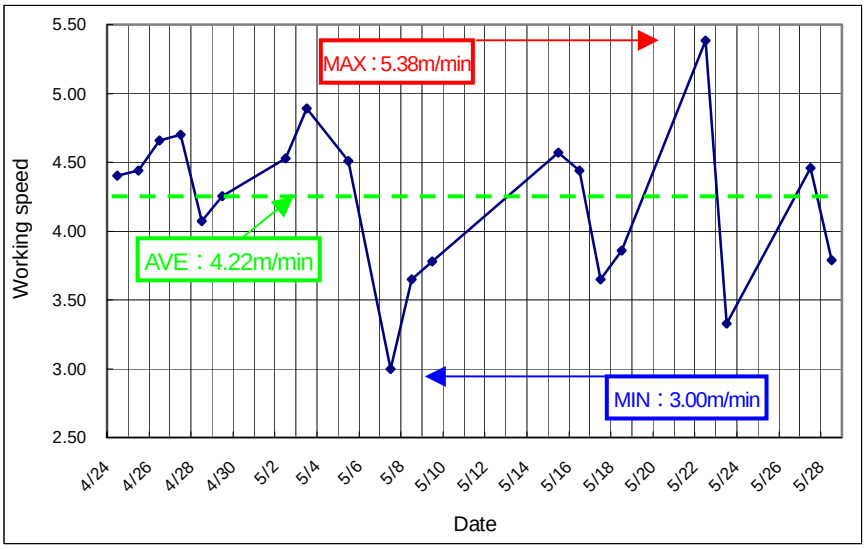


Figure 11: Average Operating Speed in India

7. 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 and 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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