HIGH PERFORMANCE PAVEMENT OF RECYCLED MIXTURE, NEW WAVE FOR RECYCLING AND TRANSFORMING OF ASPHALT CONCRETE

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ABSTRACT

Being faced with the asphalt price increase and the increasing shortage of aggregates, we need to rightly evaluate the value of existing pavement as reusable asset. A totally new technology concept of Hot In-place Transforming has been invented in Japan based on successful recycling experiences using Hot In-place Recycling technology, which preserves aggregates through a milling process, which usually crushes them. The newly developed technology transforms, rather than recycles, the existing dense graded asphalt concrete into two layers of porous asphalt concrete as a surface layer and of mastic gap asphalt, which supports the layer. The surface layer is made both of selected portions of the existing asphalt concrete and of new admix to be added as designed. The supporting layer is made of the rest of the existing asphalt concrete. Mechanically a train of pre-heating, milling, separating, and mixing and dual paving machines work in tandem followed by conventional rollers. The existing dense graded asphalt concrete has been successfully transformed on site into porous asphalt concrete in Okinawa, Chiba and Hokkaido, Japan. The required permeability of porous asphalt and surface evenness have been confirmed to be satisfied. It has also been confirmed the huge reduction of total greenhouse gas emission through all the rehabilitation processes should be possible by the use of the technology. Therefore the technology meets with current needs of saving asphalt, of preserving aggregates, of reducing global warming gas emission and of offering the good serviceability to users.

INTRODUCTION

There is a growing recognition in the world of our coming to be faced with the limited capacity of the ecosystem of the planet. This applies to the pavement business. Asphalt and aggregates which constitute asphalt mixture are coming in shortage, which will result in much increased price. Asphalt has no substitute available and will not find any substitutable product of the same characteristics and of the same volume availability, which would be otherwise the case for manufactured products. The shortage of aggregates is coming obvious already in some parts of the world. It will be more so in the face of huge construction demand taking place in the world and of environmental considerations needed.

The existing asphalt concrete per se needs to be reevaluated in this context. It meets with every criterion for good and easy recycle-ability, i.e., reusability, huge amount availability, localized existence and easy access. The existing aged asphalt pavement has been for long time regarded as valueless. However, good technologies have emerged, which can recover or even increase the value of such pavement. We are now entering into the Era of PAVE, which means Pavement Asset Value Evaluation.

WAYS OF PAVEMENT REHABILITATION

There are off-site work and on-site work for the asphalt pavement rehabilitation. Off-site work has been the traditional and most frequently used method so far using a local plant. In terms of recovery of used asphalt and aggregates, and of saving new asphalt and aggregates, off-site work is becoming obsolete. It will be more so when prices of asphalt and aggregates are increased. When the issue of greenhouse gas emission is taken into considerations, it should be noted the total energy used for off-site work far exceeds the corresponding amount of energy for on-site work, in particular on-site work not to generate waste of the existing asphalt mixture.

There are two ways of on-site work, i.e., Hot In-place Recycling (HIR) and Cold In-place Recycling (CIR). Table 1 shows the comparison between HIR and CIR. HIR has high advantages over CIR in terms of recovery of used asphalt and aggregates, and of saving new asphalt and aggregates as well as of energy saving. The most important differences are that HIR does not crush used aggregates and uses them as black aggregates whereas CIR can not avoid crushing aggregates and has to use as white aggregates, and that CIR needs a longer construction term than HIR because CIR needs pretreatment for milled surface. Therefore HIR is more appropriate for the Era of PAVE economically as well as environmentally. CIR, however, can strengthen base structure, which HIR is not supposed to do.

Table-1 Comparison between HIR and CIR

	HIR	CIR
Existing Asphalt Mixture	Loosening	Hard Milling
Aggregate	Not crushed (Black Aggregate)	Crushed (White Aggregate)
Aggregate for reusing	Reused on Site	Crushing & Sieving & Stock at Plant
Mixture Gradation	Unchanged	Changed
New Admix	20% (min) 50% (max)	70% (min) 100% (max)
Pre-treatment under Layer	Not Required	Cleaning & Tack coat
Transport to Plant	Not Required	By Truck
Operation Speed ／ Construction Term	On average 3～7 (m/min)	Longer construction term than HIR because of pre-treatment needed
Total Energy Consumption*	0.35	1

*Distance between site and plant is supposed to be 20km.

BRIEF HISTORY OF HIR AND RECENT INCLINATION TOWARD HIR IN THE WORLD

HIR has a long history for its application. It goes back to 1930s (Joharifard and Emery 2005). In Japan HIR work once reached a peak in 1980s with 2 million square meters’ job per year offered by the Government of Japan then. However, too much competition for a HIR job as a result of many entrants including un-prepared companies led to poor HIR performance and until recently HIR has been almost a forgotten technology. However, in the face of growing interests in and concerns with the environmental and economic issues mentioned above, and also in the face of increasing needs for pavement rehabilitation of expressways in particular on the one hand and the government budget constraint on the other hand, more serious attentions have restarted to be paid to good HIR technologies.

In the U.S. HIR specifications have officially started to be introduced state by state, and state government budget has started to be spent for HIR job. Number of such states has increased to 14 in 2007 from 7 in 2006 and 2 in 2005, and is likely to increase. Those states are shown in Figure 1 as colored.

In Canada British Columbia province has been using HIR technologies over years and an annual job volume has reached 2,000 lane km. There are some other provinces, which are planning to introduce HIR.

In China there was the noteworthy policy change for in-place road resurfacing stressed by the Chinese Government in May, 2006. The first national conference was held for pavement resurfacing and recycling technologies in August, 2006. It is said 5.3 million square meters have been recycled so far.

In India HIR has been officially accepted and a job offered by Delhi State Public Work Department (PWD) has started for resurfacing Delhi city road. The Tender Authorities of Delhi PWD asked for “Improvement of MB Road New Delhi from Qutab Minar T-Junction to Badarpur T-Junction SH: Resurfacing by Hot In-place Recycling process of existing bituminous layer”.

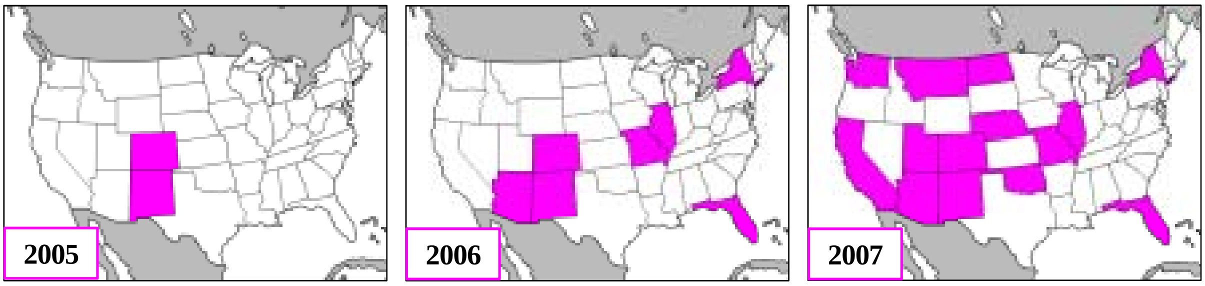


Figure1 Recent Inclination toward HIR

Photo1 Recycled pavement in service for 7 years (Minakami City road, Toyama prefecture, Japan, Photo taken in July, 2007)

Concerning the quality of recycled pavement, the mixing capacity of recycling machine has been much improved and recycled pavement has been in good use for years in Japan. Photo 1 shows recycled pavement of 7 years' use. There is no difference in pavement quality between the recycled pavement and newly constructed pavement, which would have been otherwise a case of difference. It has proven that recycled pavement done by well prepared mixture design work and good operation control should be able to enjoy the good durability equivalent to newly paved asphalt mixture.

NEW TECHNOLOGY AND IDEA BEHIND – HOT IN PLCE TRANSFORMING (HIT)

It has been proven through several recycling jobs done by HIR technology that asphalt coated aggregates (black aggregates) in use are not crushed through its milling process and remain totally reusable for recycled pavement. Figure 2 shows grading unchanged after the milling process taken by a recycling machine at Ube, Japan in December, 2001, which shows aggregates in use have not been crushed.

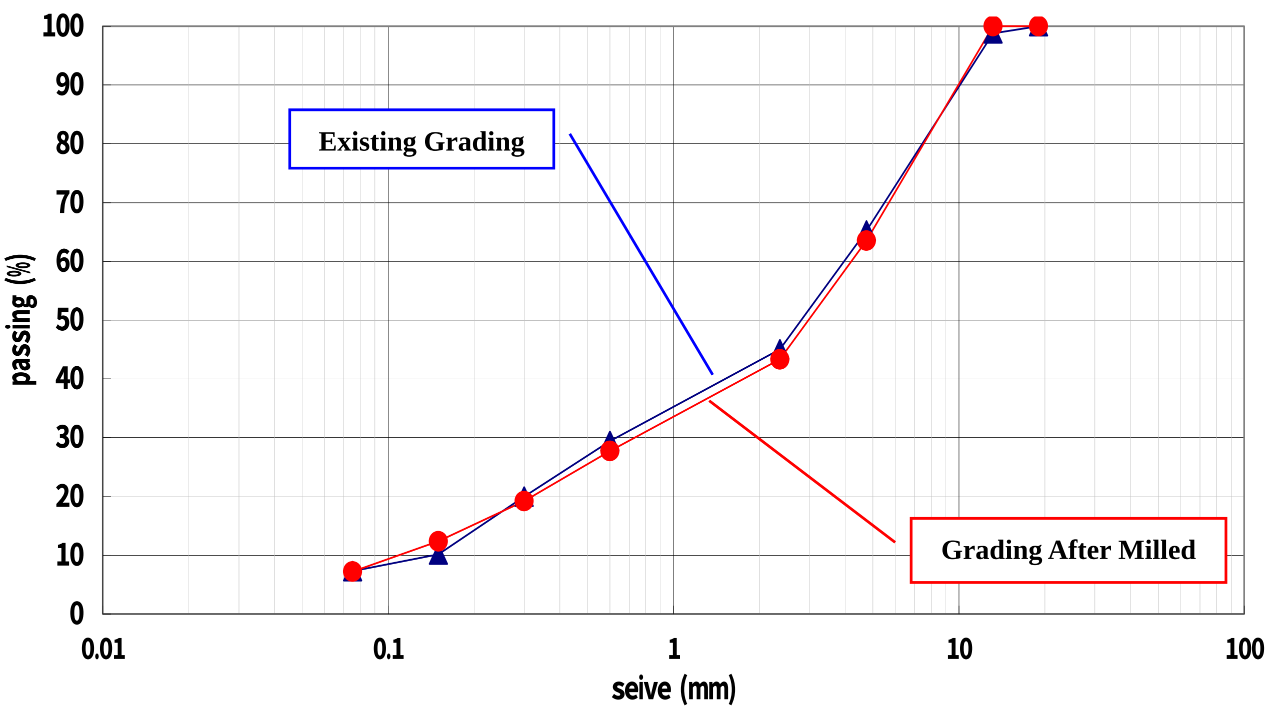


Figure2 Grading after milled

This feature having been recognized, we challenged to separate asphalt-coated aggregates in accordance with their sizes with a view to directly transforming in place dense graded asphalt concrete into permeable porous asphalt concrete. Such a separating device has been developed successfully. Together with a dual paver developed in August, 1998 in Japan [Uchiyama 1999], the development of such a separating device has made it possible to construct in place two layered pavement directly from the existing dense graded asphalt concrete with a permeable porous asphalt layer, as a surface layer, of separated medium sized fraction mixed with new admix as designed, and mastic gap asphalt layer consisting of separated fine and over-sized fractions as a supporting layer. The technology has been named as Hot In-Place Transforming (HIT).

A process patent has been granted in Japan (JP3849124). An international patent application (PCT/JP2004/018450) and another patent application (Japan Patent Application No. 2005-363989) concerning the heating system are now under examination in several countries.

Hot In-place Transforming (HIT) Machines

The whole HIT train of machines consists of Pre-Heaters which are usually two units and might need additional ones depending on operating conditions, Heater Miller, Separator and Mixer Dual Paver to be followed by conventional compaction rollers as shown in Figure 3. Specially developed Separator has proven to be able to separate high viscosity modified asphalt coated aggregates in accordance with sizes of aggregates in use. Dual Paver creates two layered asphalt pavement through one pass.

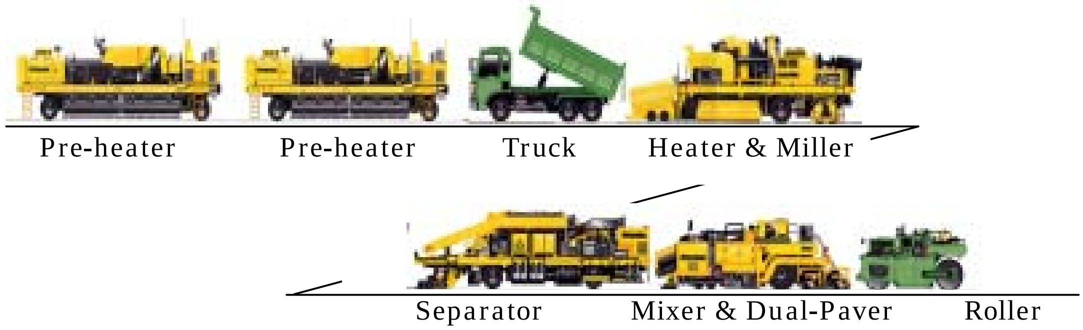


Figure3 Train of Hot In-place Transforming machines

Figure 4 shows the whole system of HIT technology illustrating each process to be taken by each unit.

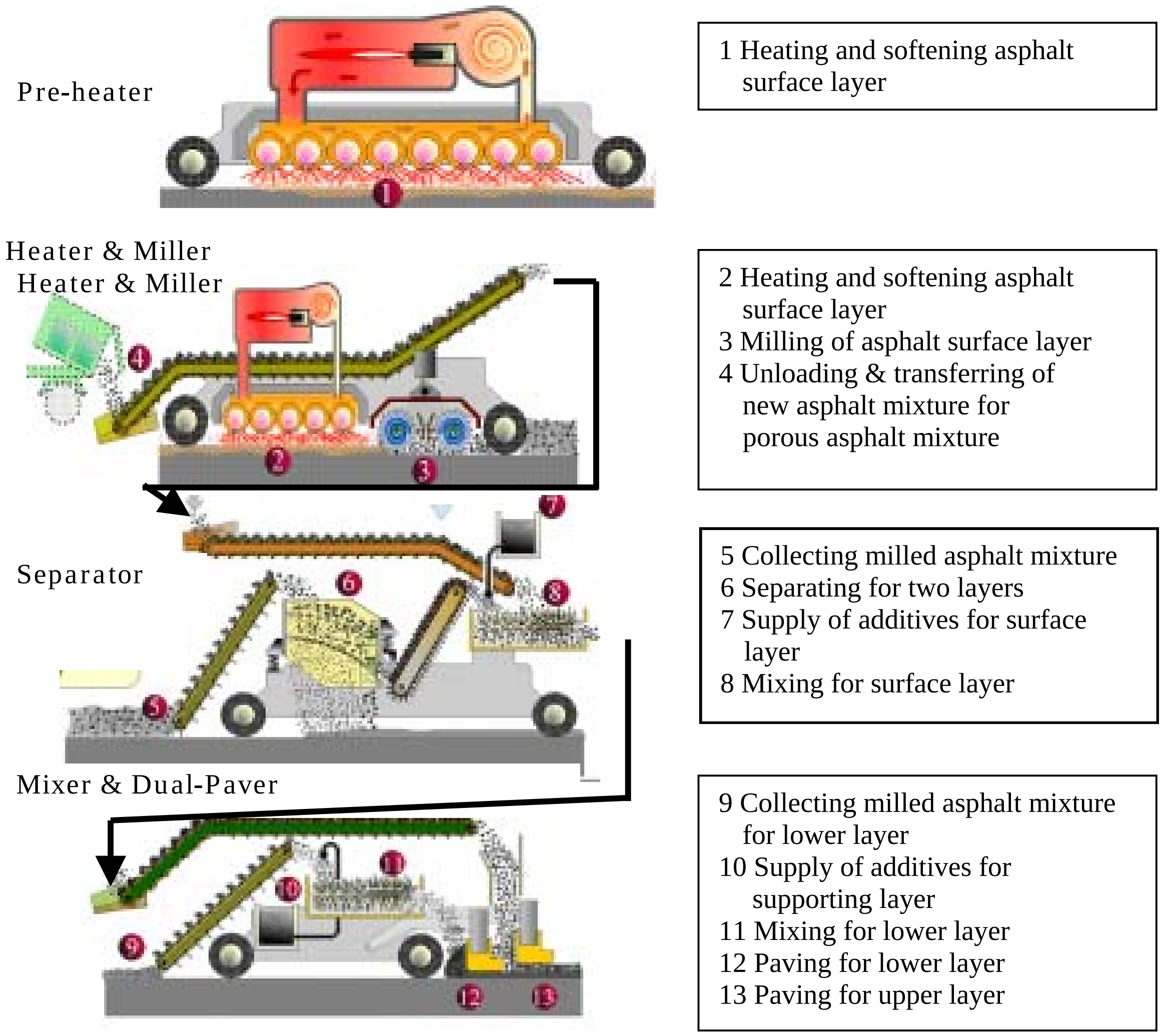


Figure4 Whole system of HIT technology

HIT technology and its implementation

Mixture Design Process

The basic design process to be taken for HIT is as follows;

(1) Mixture design for an upper asphalt layer will be determined based on pavement thickness, permeability coefficient, void ratio and etc., which are given by a job owner.
(2) Aggregate ratios to be extracted from the existing asphalt mixture and to be used for asphalt mixture for an upper porous asphalt layer and for a lower mastic asphalt layer will be determined.
(3) Optimum asphalt content (OAC) will be determined through Marshall test for the upper layer and for the lower layer.
(4) The serviceability will be examined through wheel tracking and stripping tests for the durability of pavement.

Mixture Design

The new technology of HIT first heats and then mills the existing asphalt pavement surface, and separates the milled asphalt mixture into two groups of asphalt-coated aggregates passing 7-13 mm sieve size and of the rest, i.e., aggregates passing 7 mm sieve size and remained at 13 mm sieve size. The technology reuses them all for porous asphalt concrete and mastic gap asphalt.
Aggregate gradation consisting of recycled aggregates passing 7-13 mm sieve size and of aggregates of new asphalt mixture to be added will be determined in order to make designed void of a surface layer. OAC will then be determined for the combined aggregates consisting of the both aggregates. Mastic gap asphalt consists of the remaining recycled aggregates only and does not use new aggregates. Asphalt binder and rejuvenator content to be added to the mastic gap asphalt will be determined through Marshall test and permeability test.

In the mixture design authorized for a general use asphalt content for porous asphalt concrete has been determined through content of new asphalt binder and/or rejuvenator required to recover degraded penetration of used asphalt contained in the existing asphalt concrete. However, it would be rather rational to take that through the in-place heating and mixing process new asphalt binder would cover the used asphalt-coated aggregates (black aggregates) than to take such a thin asphalt film as of a few micron meters thick adhered to the aggregates would get integrated with new asphalt binder through the heating process. Therefore with regard to mixture design we determine asphalt content based on overall considerations of test results of Marshall, wheel tracking and permeability.

Grading of Separated Milled Aggregates And Marshall Test Results

Followings are an example of mixture design. Figure 5 shows grading of the existing dense graded asphalt concrete at a job site on National Road Route 126 in Chiba prefecture. Figure 6 and 7 respectively shows grading of porous asphalt concrete for the surface layer and of mastic gap asphalt for the supporting layer made of the existing asphalt concrete separated as above mentioned. Table 2 shows Marshall test results for the porous asphalt concrete. Every measured value is well above the corresponding specifications. Photo 2 shows a core sample taken from the job site. The porous asphalt concrete layer has been constructed of enough thickness as designed. Each layer has been fully bonded with a adjacent layer(s) through compaction.

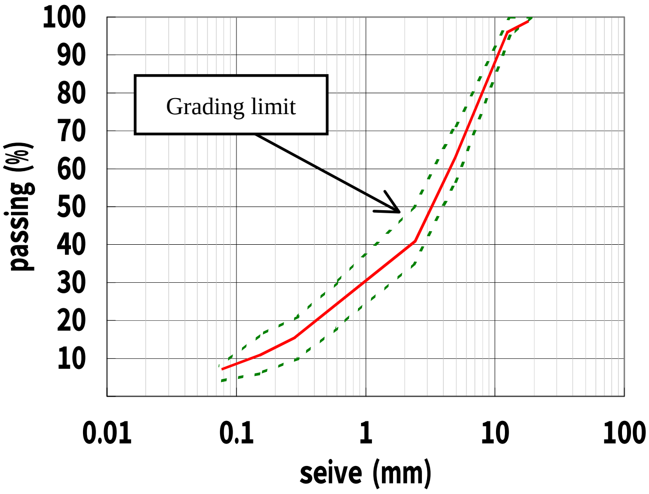
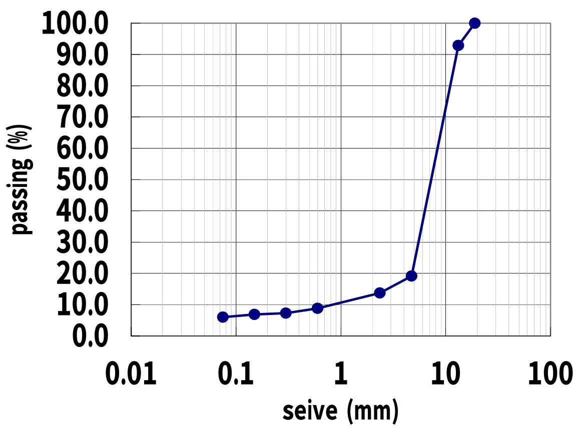


Figure6 Grading of Separated Asphalt Mixture for Surface Layer



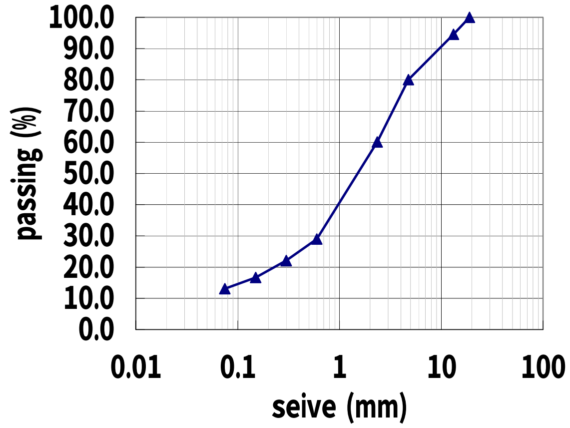


Figure7 Grading of Mastic Gap Asphalt for Supporting Layer

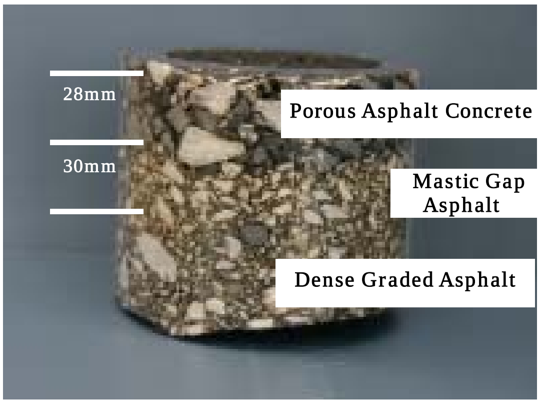


Photo2 Core Sample

Table-2 Marshall Test Results of Porous Asphalt Concrete

	Unit	Specifications	Measure value
Marshall stability	kN	＞3.5	4.0
Flow value	mm	2.0-4.0	2.6
Air void	%	＞15	20.0
Coefficient of permeability	cm/s	＞0.01	0.198
Dynamic stability by wheel tracking test	pass/mm	＞3,000	4,400

Implemented cases and serviceability

The HIT technology has been implemented at three sites on public road in Japan since the first pilot machine was built, namely on Okinawa Prefecture Road Route 77 at Osato Mura, Okinawa prefecture in August, 2005, on National Road Route 126 at Asahi city, Chiba prefecture in September, 2006 and on National Road Route 36 at Sapporo city, Hokkaido in July, 2007. The last one is a public work program of the Government of Japan. The first two projects have been continuously monitored with the serviceability exposed to the daily traffic load and to the natural weather. Photo 3 is a latest picture of the site of National Road Route 126, which keeps enough permeability and rainwater does not stay.

Photo3 National Road Route126 in Chiba Prefecture

Profile

Figure8 shows the profile of Okinawa prefecture Road Route 77 at Osato Mura over a year after the construction. There have been confirmed through visual inspection on site no cracking, rutting, stripping with the both sites of Okinawa and Chiba. The profile index has increased over one year slightly but the profile condition has been kept good at present.

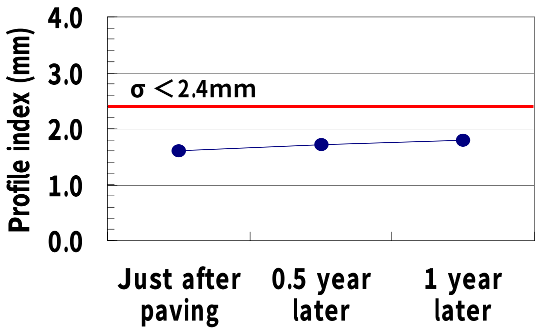


Figure8 Evenness of Pavement Surface in Okinawa

Skid Resistance

Fig.9 shows skid resistance of the job site of Okinawa. With respect to Skid Resistance British Pendulum Number (BPM) has not changed over a year and the skid resistance has not changed since the construction finished. The pavement surface having been exposed to traffic loads and the natural weather including heavy rainfalls and temperature fluctuation, the pavement serviceability has been confirmed to be maintained.

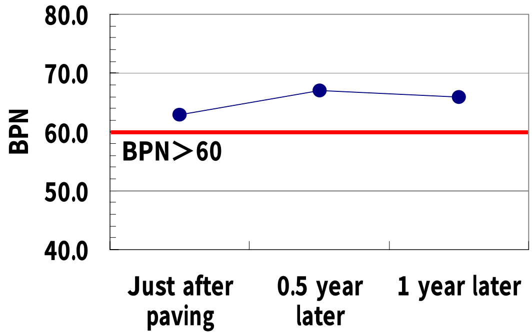


Figure9 Skid Resistance in Okinawa

Permeability

The permeability of porous asphalt pavement constructed by HIT technology has cleared the specification of 800m1/15sec as shown in Table-3 and compared with the permeability the usual method achieves it has been proven the permeability brought about by HIT technology is much better.

Table-3 Field Permeability Test

Site	unit	Specificatrion	Just after paving
Chiba	ml / 15sec	higher than 800	1258
Okinawa			1375

Environmental Effects

In accordance with the total energy saving through the whole process of road rehabilitation, the reduction of the total greenhouse gas emission has been confirmed. (Hosokawa et al. 2006) It is expected further reduction will be materialized as the operation speed by HIT technology gets faster.

CONCLUSION

The new technology of HIT has made it materialized for the existing dense graded asphalt concrete to be transformed on site into two layered pavement structure of porous asphalt concrete of higher serviceability and of non-permeable mastic gap asphalt concrete. It has also materialized to upgrade the pavement using the existing asphalt concrete, which adds the permeability to the pavement surface. Thereby high quality service of better safety and of improvement of environment will be offered to users through sharp reduction of traffic accidents avoiding the slippery in rain and lower traffic noise.
The technology has been confirmed to offer the good enough serviceability through the results of the projects done for the public roads, which has been more than equivalent to the conventional method with respect to the durability and serviceability.

Optimum asphalt content for porous asphalt concrete is determined by results of Marshall test of asphalt mixture made of both aggregates extracted from the existing asphalt concrete and new aggregates. The validity of this way of determination is based on the recognition that the quality improves of residual asphalt adhered to the extracted aggregates well coated with new asphalt binder and that the property improves in the mechanical stability and durability of synthesized asphalt mixture with the property of new asphalt mixture dominant. It has been confirmed by daily quality control tests and monitorings to follow that asphalt pavement has been created, which satisfies design specifications.

Environmentally the technology contributes to saving asphalt and aggregates through full reuse of them and to reducing greenhouse gas emission through saving the total energy consumption needed for the pavement resurfacing.

It is widely recognized that the permeability of porous asphalt pavement decreases inevitably over time with voids choked with fine particles such as dusts and sands, and. The technology equipped with a separating device makes it possible to recover the permeability decreased of porous asphalt pavement and has paved a way for porous asphalt pavement to be resurfaced on site, which has been desperately wanted.

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