Development of Preventive Maintenance Methods Appropriate for the Service Conditions in Japan

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ABSTRACTS: Preventive maintenance helps reduce the life cycle cost of pavement. Surface dressing mainly using asphalt emulsion has been adopted as a popular method of preventive maintenance. Although use of preventive maintenance has been discussed in Japan from the viewpoint of effective management of maintenance costs, surface dressing is facing many difficulties because of the high standard posed by Japanese road users and roadside residents. Specifically, aggregate particles are scattered immediately after application of chip sealing and microsurfacing, and traffic control is applied to the roads for a long time during the surface dressing work because of the long time curing period. Various new techniques for preventive maintenance have been developed as solutions to those problems including the new version of microsurfacing that ensures a high standard of application based on the improved construction control method, chip seals that use foamed asphalt in place of the conventional asphalt emulsion, and thin layer overlay developed by means of the warm mix technology. These new techniques have been applied to actual construction work based on the understanding that they satisfy the quality and durability requirements of Japanese road users, and their performance has been verified.

KEY WORDS: Preventive maintenance, surface dressing, microsurfacing, chip seal, thin layer overlay

1 INTRODUCTION

In Japan, since preventive maintenance was introduced in the Strategic Highway Research Program (SHRP), the usefulness of preventive maintenance has widely been understood. But its application is very much limited. Today few preventive maintenance techniques have been applied. One of the reasons is that the reliability of surface dressing is low. Surface dressing has various defects such as scattering of aggregate immediately after paving, concerns over durability such as peeling during service and the long period of traffic restrictions from completion of work to opening to traffic. One of the particularly serious problems in Japan is that the pavement, after being treated by preventive maintenance, must have a high level of durability immediately upon completion because road users and roadside residents do not tolerate any scattering of aggregate.

The following three methods have been developed as preventive maintenance techniques that eliminate the conventional defects of surface dressing, promote diffusion of preventive maintenance and match the traffic conditions in Japan:

(1) Microsurfacing, which causes almost no scattering of aggregate immediately after paving (name of method: Microgrip)

(2) Chip sealing, which uses foamed asphalt instead of asphalt emulsion (name of method: Foamed Dressing)
(3) Thin layer overlay, with the applied pavement being no more than 20 mm thick, which uses an additive for warm mix asphalt (name of method: Refresh Seal Mix)

This paper reports the outline of these methods and the results of surveys on their performance.

2 MICROSURFACING

2.1 Outline of the Method

Microsurfacing is a rapid-curing cold paving system with thin layer. The procedure includes a cold slurry mixture consisting of rapid-curing modified asphalt emulsion, controlled aggregate, cement and water produced by a dedicated machine, or micro grip paver (Figure 1), which is loaded with the necessary materials, and the freshly mixed mixture is spread over an existing road surface to an average thickness of 4 to 5 mm. It only takes about one to three hours after compaction using tire roller until the paved road is open to traffic. Figure 2 shows how the application work is conducted.

Figure 1: Microgrip paver

Figure 2: Application site (paving with microgrip mixture)

The Microgrip method has the following features:

(1) Since the technique creates thin pavement, it does not affect the road elevation and has small impact on nearby facilities.

(2) Being a resource-saving technique, it is designed to reduce the amount of construction byproducts.
(3) It is applicable to roads with very heavy traffic and has sufficient durability appropriate for such heavy traffic loads.
(4) It has high skid resistance to contribute to greater traffic safety.
(5) Capable of applying the asphalt while cold, the technique is effective in maintaining the global environment by reducing CO_2 emission.

2.2 Technical Problems Facing the Application of Microsurfacing to Japan

Microsurfacing was first introduced to Japan in the 1990s. We introduced the production technology from Spain and the spreading machine from Germany. In Japan, hot-mix asphalt pavement is most widely used. Since it is a type of asphalt emulsion paving, microsurfacing is also required to show performance equal to that of the hot-mix asphalt. Scattering of aggregate immediately after paving, in particular, was never tolerated by road users. It was presumed that aggregate scattering was caused by the specific character of the paving practice in Japan. That is, whether or not microsurfacing pavement shows sufficient strength is largely dependent on the weather condition at the site, but in Japan, it was generally up to the visual check or empirical judgment of engineers at the site to make sure the pavement sufficiently hardened. As a solution, we conducted a thorough survey on the influence of meteorological conditions such as temperature or sunlight on the quality of the microsurfacing pavement and established (1) criteria for judgment on whether or not microsurfacing is executable based on the meteorological conditions and (2) criteria for judgment on when to open the paved road to traffic.

2.2.1 Laboratory Testing

To establish the criteria for whether or not microsurfacing can be applied to a specific site, the following were investigated:

(1) How to make sure the microsurfacing mixture has been sufficiently cured and hardened

The hardening mechanism of microsurfacing mixture is the water content in the mixture gradually decreasing with the passage of time until completely hardened. As the hardening of the asphalt is related to the decrease in water content of the asphalt, we judged it is possible to indirectly make sure whether the asphalt has sufficiently hardened or not by measuring the water content (water content ratio).

It was decided that the wear test should be used to check whether the microsurfacing mixture has hardened enough to reopen traffic. With microsurfacing, the abrasion in a mix test should not be more than 540 g/m^2 as per the wet track abrasion test (ASTM D 3910) (Japan Emulsified Asphalt Association, 1998). Then, we identified the relationship between the water content ratio of the mixture and the abrasion (Figure 3) and decided to conduct execution management based on a water content ratio that does not make the abrasion exceed the specified limit of 540 g/m^2. Based on these results, we set the standard for when to open the road to traffic to not more than 3% in water content ratio for quality control.

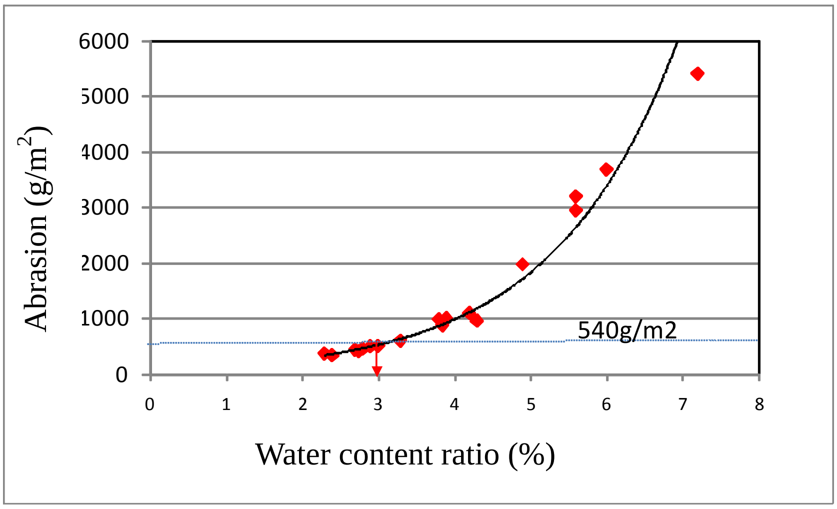

Figure 3: Relationship between abrasion and water content ratio (Yoshida et al. 2001)

(2) Factors affecting the curing time

Changes in the hardness of the microsurfacing asphalt (that is, changes in water content ratio) are affected by daylight, humidity, wind velocity and many other factors. The impact of five of these factors (daylight, temperature, humidity, wind velocity and the existing road surface temperature) on the change in water content ratio were reproduced in a laboratory test for analysis. Specifically, we measured the time it takes for the water content ratio to drop to 3%. With zero hour of daylight, 15°C atmospheric temperature, 15°C road surface temperature, 60% humidity, and zero m/sec wind velocity set as the standard conditions, the time it takes the water content ratio to decrease to 3% as the duration of daylight, humidity, atmospheric temperature, road surface temperature, and wind velocity were changed was measured, and the ratio to the curing time under standard conditions was calculated. The results for humidity are shown in Figure 4. As indicated in the figure, the necessary curing time at 80% humidity is 2.3 times longer than at 60% humidity.

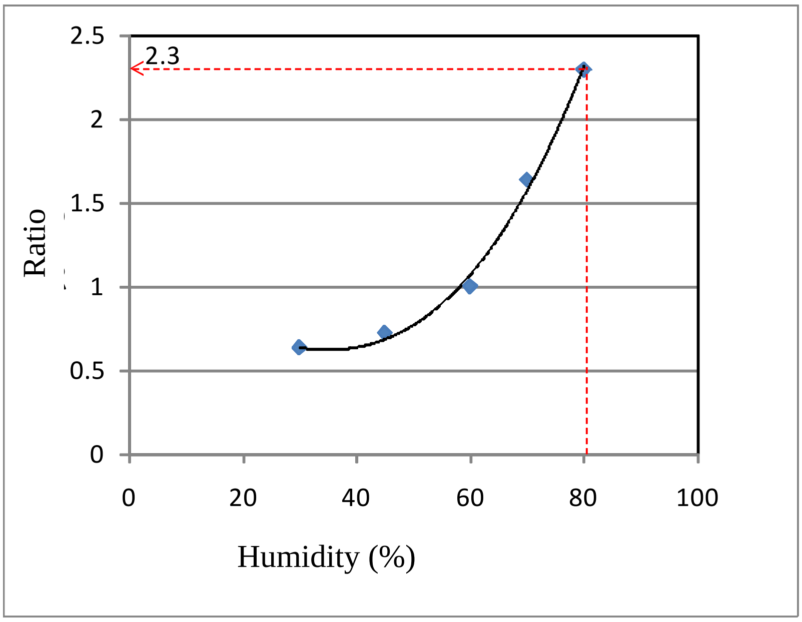

Figure 4: Time it takes the water content ratio to decrease to 3% for each weather condition (ratio to the standard condition) (Yoshida et al. 2001)

2.2.2 Application conditions

Based on the results of the laboratory test, we were able to set the conditions that allow a paving job to be completed within a single day. Table 1 shows an example of application conditions for a long offshore bridge (meteorological conditions that allow fulfillment of the target water content ratio of 3% by natural curing in only six hours of curing). With these criteria now established for application to microsurfacing work, we can provide highly durable pavement that promise comfort to road users without worrying about aggregate scattering.

Table 1: Example of application conditions for a long offshore bridge

Average temperature	Weather		Rainfall probability	Humidity
	When judged	Forecast at the time of application		
10 to 20°C	Fine	Fine	34% or less	70% or less
		Partly cloudy		
		Cloudy, later partly sunny		
	Cloudy	Fine		
		Partly cloudy		
		Cloudy, later partly sunny		

2.3 Performance

Changes in the cracking ratio of road surfaces were studied as an indicator of the service life elongation effect of microsurfacing, and the results are shown in Figure 5. As shown in the figure, the cracking ratio 80 months after application of the microsurfacing paving became equal to that before microsurfacing, which indicates that an elongation benefit of about 7 years has been achieved.

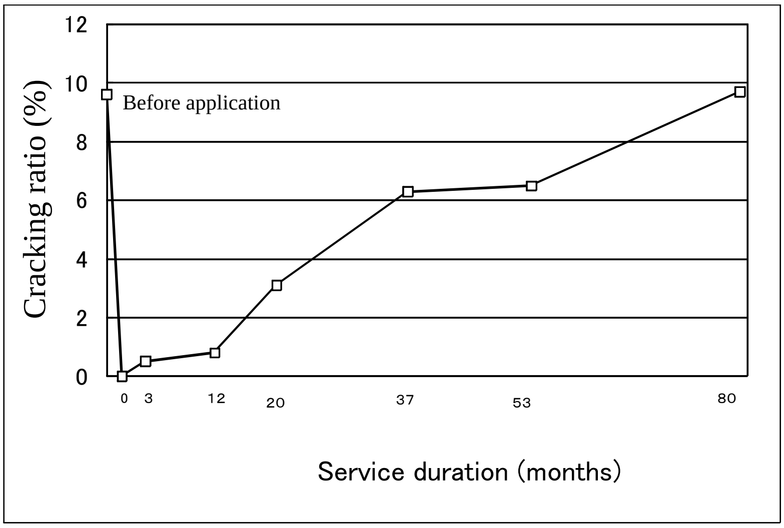

Figure 5: Changes in cracking ratio after service start (ordinary road) (Takeda, 2005)

Figure 6 shows changes in skid resistance over time, indicating that microsurfacing-paved roads maintain good skid resistance for a long time.

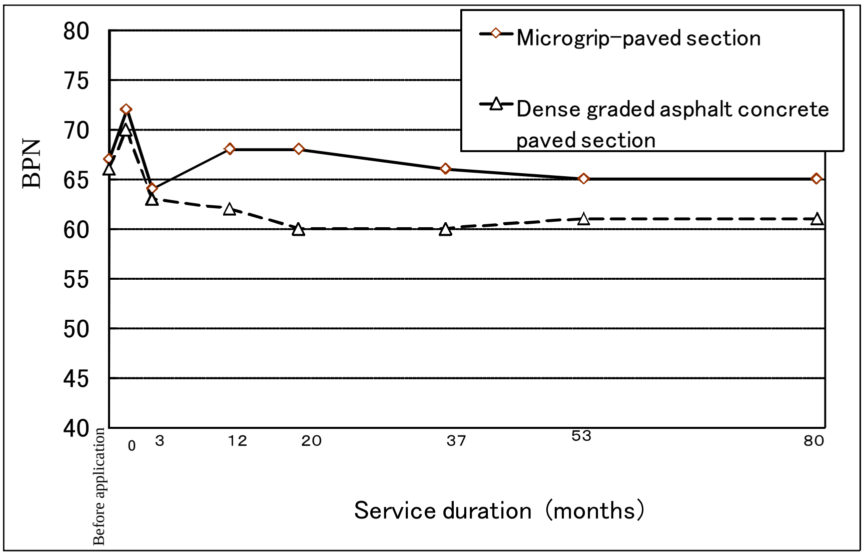

Figure 6: Changes in skid resistance over time (ordinary road) (Takeda, 2005)

3 FOAMED DRESSING

3.1 Outline of the Method

Foamed Dressing is a paving system that uses a dedicated machine loaded with the necessary components (Foamed Dresser, Figure 7) to spread foamed modified asphalt (1.0 kg/m^2) and precoated chips (5-2.5mm crushed stone and sand covered with asphalt) (6.5 kg/m^2)over the road, and then rolls the road surface with tire rollers. A single fill of aggregate enables the machine to pave an area of about 350 m^2 and to complete the paving job in about 30 minutes. It is a pavement repairing technique that requires only a short time for curing and allows quick opening of the paved road to traffic. A conceptual diagram of Foamed Dressing is shown in Figure 8. Figure 9 shows how the application work is done. Foamed Dressing is a type of chip sealing. The conventional chip sealing method requires a long time until decomposition and hardening because it uses asphalt emulsion, thereby making it susceptible to meteorological conditions. But foamed asphalt is resistant to weather conditions and returns to a solid state in less than a minute and can therefore greatly reduce the time it takes to open the road to traffic. Foamed asphalt is a technique to foam asphalt by mixing hot asphalt with water under high pressure to disperse minute water drops inside the asphalt and using the expansive force of steam generated as the hot asphalt is sprayed into the air through the nozzles used to turn it into a foam. This process can enlarge the apparent volume of asphalt and thus allows spreading of asphalt more evenly than when emulsion is used.

Figure 7: Foamed dresser

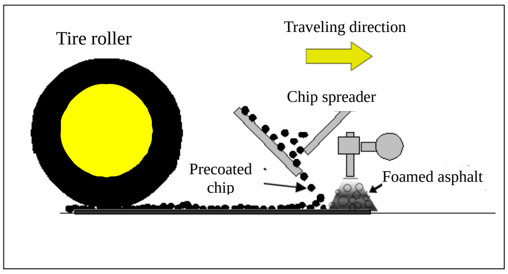

Figure 8: Schematic illustration of Foamed Dressing

Figure 9: Spreading of foamed asphalt and precoated chips

Foamed Dressing has the following features:

(1) High skid resistance
(2) Excellent water shielding performance
(3) The applied pavement is thin (3 to 5 mm), which allows road elevation changes to be ignored and eliminates the need to repair road structures or cut the existing road surface before paving.
(4) The curing time is short unlike surface treatment with asphalt emulsion which requires a long curing time.
(5) It is applicable to various types of roads with not too heavy traffic such as local roads, urban roads, residential roads, farm roads, and forest roads.

3.2 Application Work, Application Examples and Performance

Foamed Dressing was applied as a surface dressing to the restoration of skid resistance and service life elongation of cracked road surfaces. Since the method is relatively new, the longest service period after its application is only about two years. The change in skid resistance for that service case is shown in Figure 10, while the change in crack ratio is shown in Figure 11. At the place where the wheels pass, the skid resistance decreases relatively early, but still it is apparent that the pavement maintains sufficient skid resistance.

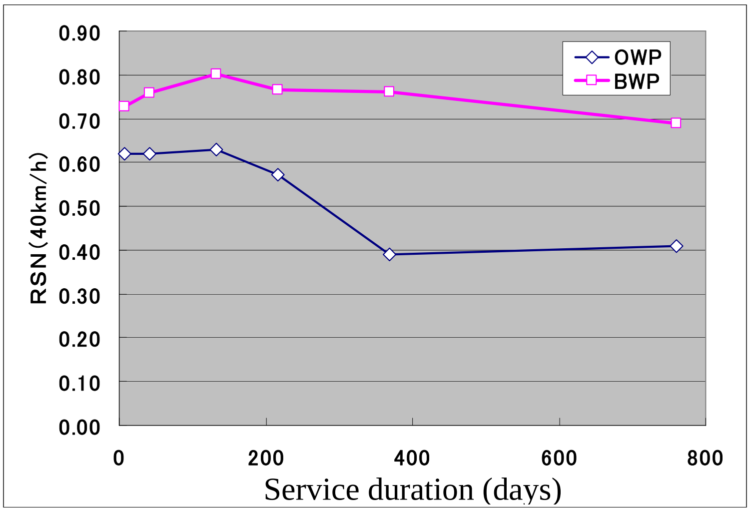

Figure 10: Changes in skid resistance over time (Hiyama et al. 2007)

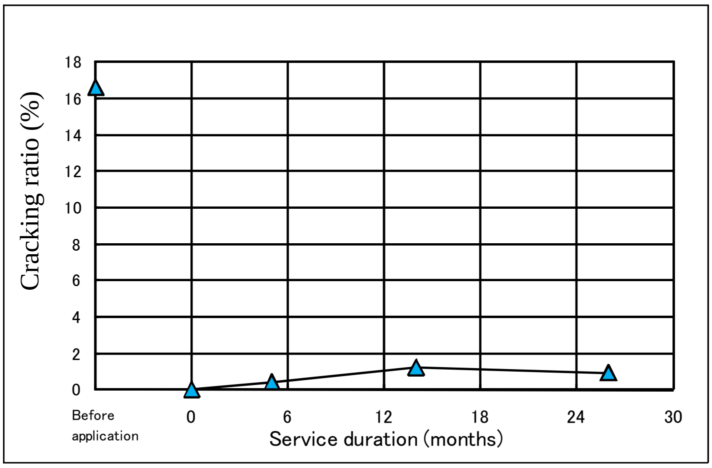

Figure 11: Changes in cracking ratio over time

5 THIN LAYER OVERLAY NO MORE THAN 20 MM THICK

5.1 Outline of the Method

Thin layer overlay no more than 20 mm thick (hereinafter Refresh Seal Mix) is a hot asphalt pavement with an average pavement thickness of 15 mm to 20 mm. Straight asphalt is used for this method, and SBS, an additive for warm mix asphalt, and plant fibers are added during production of the asphalt mixture. Use of the additive can prevent reduction of the asphalt temperature during thin layer application, and SBS helps improve its durability, while the plant fibers help mitigate cracking. The largest aggregate particle size is 5 mm, which is close to that of microsurfacing, this means that a high skid resistance is maintained. The typical particle size of the mixture is shown in Figure 12.

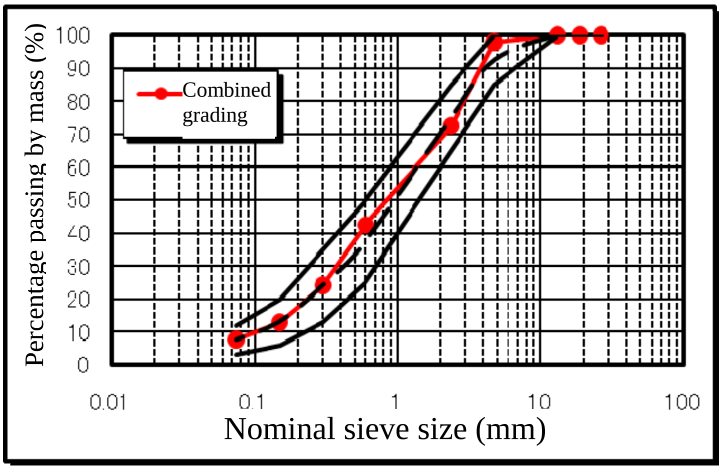

Figure 12: Standard aggregate grading

Refresh Seal Mix has the following characteristics:

(1) Since it is applied in thin layers, it does not require cutting of existing road surfaces and therefore does not promote generation of cut waste.
(2) It provides high skid resistance to help ensure high vehicle traveling safety.
(3) The asphalt mixture quickly cools after application, reducing the traffic control time.
(4) Addition of plant fibers helps control cracking.
(5) It provides a fine road surface texture, reducing tire noise.
(6) This asphalt, which is applied to the road surface as a hot mixture, is less affected by weather conditions.

Refresh Seal Mix is appropriate for application to the rejuvenation of deteriorated roads, improvement of skid resistance, and repair of cracked road surface like microsurfacing.

5.2 Performance

Application of Refresh Seal Mix requires no special machines. An conventional asphalt finisher, macadam roller, and tire roller are all that are required, and application is conducted the same way as ordinary asphalt paving. Figure 13 shows the application of the asphalt mixture to a spread thickness of 10 mm.

Figure 13: Application work (thickness of 10 mm)

In terms of performance, a case in which Refresh Seal Mix was applied to a road with a crack ratio over 40% proves the effectiveness of crack prevention as the crack ratio in five years of service after application still remains 0%. Although the road surface is flat and smooth, the BPN value is over 60, which indicates sufficient skid resistance.(Table ２)

Table ２: Performance of Refresh Seal Mix (5 years of service after application)

		Remarks
Cracking ratio	0%	Before application ：43%
Rutting depth	3mm	Before application ：11mm
Skid resistance	65	BPN

6 CONCLUSION

This paper introduces the improved surface dressing techniques modified to match the conditions in Japan for the preventive maintenance of pavements. Microsurfacing has a service history of over 10 years, and its effectiveness in preventive maintenance is fully proven. On the other hand, Foamed Dressing, which is improved chip seal, is still a technique under examination, but is a promising system for the preventive maintenance of pavement. Capable of being produced and executed the same way as ordinary hot asphalt, Refresh Seal Mix is expected to be widely used for its superior ability to be used in a wide variety of situations. The authors hope that these techniques will be further studied for their potential to elongate the service life of pavement, reduce life cycle costs, and also be used to promote the efficient maintenance of pavement.

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