Test Application of Micro Surfacing Method to Steel Deck Pavements

T.Tamura & G.Tokunaga
Honshu-Shikoku Bridge Expressway Company Limited, Kobe, Hyogo, Japan

ABSTRACT: There are very large areas of pavements for orthotropic steel decks on long-span bridges of the Honshu-Shikoku Bridges. The Micro Surfacing (MS) is a surface treatment, which is thinly paved with a special emulsion and forms a protection layer on the steel deck pavements. For the preventive maintenance, the MS method is expected to control the deterioration of the surface course (modified asphalt pavement) and extend the repair period of the cutting overlay. In addition, the refreshed surface course is expected to protect the base course (Guss asphalt pavement). The test application of MS method has been carried out as a new maintenance technology for steel deck pavements. This paper describes the application guideline for the MS method, considering the various conditions in the deterioration degree of the modified asphalt pavement; the penetration value, crack ratio, etc.

KEY WORDS: Micro Surfacing, Steel deck pavement, Penetration, Softening point, LCC

1 INTRODUCTION

The three routes of Honshu-Shikoku Expressways have been constructed since 1975 in order to improve the traffic and the transportation between Honshu and Shikoku islands, and to develop a balanced country in the western region of Japan.

By the entire opening of Nishi-Seto Expressway in 1999, the three routes were almost completed, which resulted in the service length of approximately 173km and the regular stage of maintenance. Especially, the steel deck pavement with the total area of approximately 470,000m^2 is one of the most important subjects of maintenance for Honshu-Shikoku Bridge Expressway Company Limited (HSBE).

The steel deck pavement, as shown in Fig. 1 and Fig. 2, consists of the Guss asphalt pavement for a base course and the modified asphalt pavement for a surface course mainly for long-span bridges crossing the straits. The steel deck pavement is able to follow the displacement of the steel deck plate enough. And it also has an excellent performance for crack-tightness, waterproof and fluidity-resistance.

This paper describes the cold surfacing, i.e., “the Micro Surfacing method,” hereinafter “MS,” to protect the surface of pavement on “the orthotropic steel deck,” hereinafter “steel deck,” and its life-cycle cost (LCC).

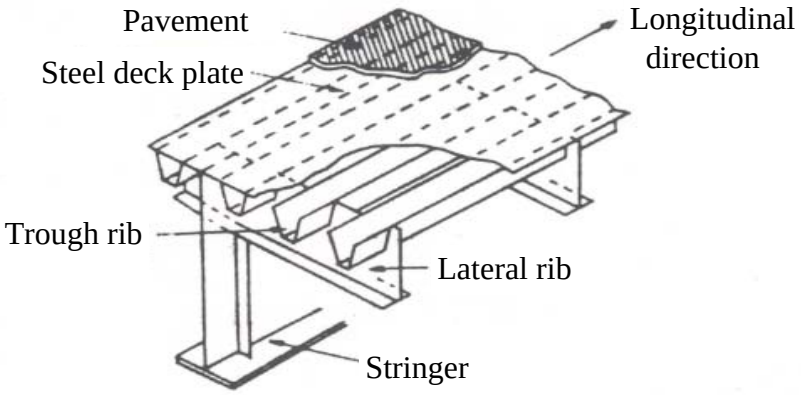

Figure 1: Structure of orthotropic steel deck

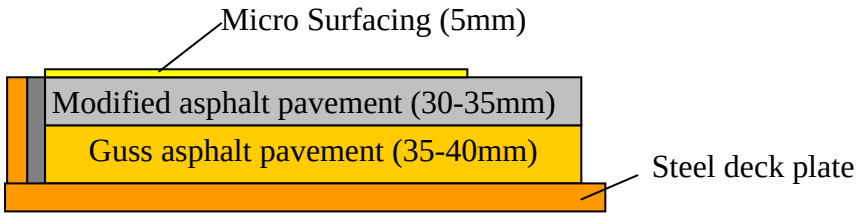

Figure 2: Steel deck pavement configuration

2 TEST APPLICATION OF MS

Generally, in the maintenance of pavement, the cutting overlay or the cut and cast for all deteriorated courses are adopted. However, when the cut and cast is executed to change the Guss asphalt pavement for the base course, there are some problems as follows.

Firstly, a very strict quality control is needed because of high temperature up to approximately 240 degrees Centigrade, which affects the displacement of steel deck and the durability of the paints.

Secondly, the repair cost is expensive since the Guss asphalt is made of the natural asphalt.

Thirdly, repair works are large in scale and they cause drivers inconvenience due to a long-term regulation of traffic.

In order to resolve above subjects, MS was experimentally adopted to the steel deck pavement. MS consists of a modified asphalt emulsion with quick-hardening agent, aggregate, water, cement and adjustment agent for workability, and they become slurry by a mixing and paving machine called as MS paver, as shown in Photo. 1.

MS is a repair method which covers the pavement thinly with the slurry (5mm of thickness). MS is executed at a normal temperature, which forms a protection layer on the steel deck pavement, and which can control deterioration of surface of the pavement. It is expected that a period of the next cutting overlay would be extended.

Furthermore, by keeping the surface course healthy, the Guss asphalt pavement is protected simultaneously.

Photo 1: MS method execution

3 APPLICATION GUIDELINE OF MS

3.1 Outline of guideline

HSBE maintains many numbers of long-span bridges over the straits (Honshu-Shikoku Bridges), as shown in Table1. From the Innoshima Bridge (opened in 1983) to the Kurushima Kaikyo Bridges (opened in 1999), there are various degrees of their deterioration in the steel deck pavement because of the differences in their opening years and traffic volumes.

Table 1: Honshu-Shikoku Bridges

As of Oct.2009

Name	Open to traffic	Service year	Daily traffic volume in 2009	Refarrence
Akashi-Kaikyo Bridge	April,1998	11.5	25,154	
Ohnaruto Bridge	June,1985	24.3	19,255	
Shimotsui-Seto Bridge	April,1988	21.5	14,980	
Hitsuishijima Bridge	April,1988	21.5		
Iwakurojima Bridge	April,1988	21.5		
Yoshima Bridge	April,1988	21.5		
Kita Bisan-Seto Bridge	April,1988	21.5		
Minami Bisan-Seto Bridg	April,1988	21.5		
Shin-Onomichi Bridge	May,1999	10.4	12,765	
Innoshima Bridge	Dec.1983	25.8	14,237	24.7years as of Aug.2008
Ikuchi Bridge	Dec.1991	17.8	9,813	16.7years as of Aug.2008
Tatara Bridge	May.1999	10.4	5,006	
Ohmishima Bridge	May.1979	30.4	6,185	RC deck
Hakata-Oshima Bridge	Jan.1988	21.7	7,136	
Kurusihima Kaikyo Bridge	May.1999	10.4	7,358	

In order to apply MS effectively as the preventive maintenance to the steel deck pavements which have different conditions, “the application guideline of MS”, hereinafter “guideline”, was established. The guideline mainly describes deterioration indexes, including the penetration value and the crack ratio of the modified asphalt pavement. In order to keep the steel deck pavement healthy over a long period, it is preferable to take a measure from the early stage, where the physical properties of the modified asphalt pavement are not severe, and MS shall be carried out as early as possible.

On the other hand, a frequent execution of MS would become uneconomical if the deterioration is not appropriately evaluated, considering the durability of the steel deck pavement.

Therefore, the following examinations were carried out in order to find out the most applicable condition that the health and the cost are compatible.

(1) Estimation on the deterioration characteristic of the modified asphalt pavement
(2) Investigation on the durability of MS
(3) Determination on the applicable condition of MS based on LCC

3.2 Estimation on deterioration characteristic of modified asphalt pavement

Deterioration of the physical property of asphalt begins immediately after paving and continues gradually. Although there are differences among them, depending on traffic volumes or climate conditions, the asphalt hardness increases gradually and it becomes easy to generate cracks.

As a characteristic of straight asphalt, the decrease of the penetration value, the increase of the softening point value, etc., are closely related to crack generating. The following results are reported; it is easy to generate alligator cracks under the condition where the penetration value is less than 25 and the softening point value is more than 60 degrees centigrade, or the condition where the penetration value is less than 25 and the 60 degrees-centigrade-viscosity is more than 20,000 poises.

Table 2: Physical properties of steel deck pavement during construction

Name	Penetration Value(25℃) 1／10mm	Softening Point Value ℃	60℃Consistency Value poise	Date of testing
	60～100	55～65	≧4,000	
Akashi-Kaikyo Bridge	73	65	10,500	Jan.1998
Tozaki Viaduct	78	57	6,870	June 1983
Ohnaruto Bridge	75	58	10,360	Dec.1984
Muya Bridge(for Kobe lane)	75	64	7,790	Oct.1986
Muya Bridge(for Shikoku lane)	62	63	8,900	Aug.1997
Shimotsui-Seto Bridge	68	58	9,200	Dec.1987
Hitsuishijima Bridge				Nov.1987
Iwakurojima Bridge				Nov.1987
Yoshima Bridge				Nov.1987
Kita Bisan-Seto Bridge	74	60	9,700	Dec.1987
Minami Bisan-Seto Bridge				Dec.1987
Bannosu Truss Bridge				Nov.1987
Shin-Onomichi Bridge	74	64	13,200	Feb.1999
Innoshima Bridge	76	61	9,500	Aug.1983
Ikuchi Bridge	65	61	12,000	Sep.1991
Tatara Bridge	72	64	13,400	Oct.1998
Hakata Bridge	74	60	9,700	Oct.1987
Oshima Bridge				Oct.1987
Kurusihima Kaikyo Bridge s	70	63	9,500	Apl.1999

Although the characteristic is considered to be the same tendency as the modified asphalt pavement, there are more disadvantageous conditions on the steel deck which bends easily. The basic test result of the modified asphalt pavement during construction is shown in Table 2, and the relation between the physical property and service year is shown in Fig. 3 and 4.

Fig. 3 and 4 show the data of the modified asphalt pavement of the Honshu-Shikoku Bridges over the straits. Although the number of data is not enough, these data confirmed that the physical properties value decreased gradually, which means the asphalt hardened, and the penetration values decreased by half in ten years.

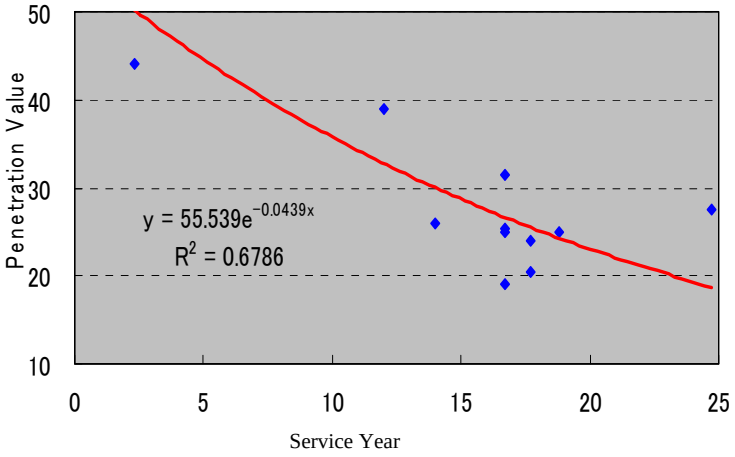

Figure 3: Penetration value (1/10mm) and service year

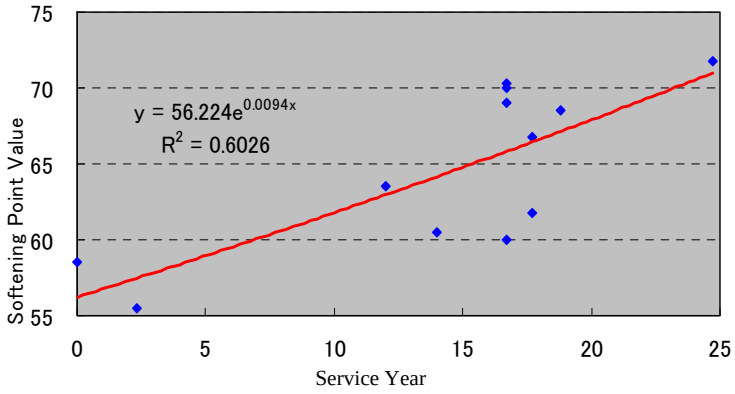

Figure 4: Softening point value (degrees centigrade) and service year

3.3 Investigation on durability of MS

The follow-up survey results of MS (5mm of thickness), which executed on the Shimotsui-Seto Bridge in 2001, are shown in Fig. 5 and 6, and the results on the Innoshima Bridge in 2000 are shown in Fig. 7.

Thickness of MS on the Shimotsui-Seto Bridge varies from 1.2 to 1.5mm after 60 months (after five years) since 2001, as shown in Fig. 5. On the other hand, although crack ratio of the Shimotsui-Seto Bridge once became zero immediately after execution, the crack ratio increased gradually and exceeded the numerical value before execution in two or three years, as shown in Fig. 6. One reason of this phenomenon is considered to be propagation of the crack which had existed before execution (reflection crack).

The visual investigation clarified that the cracks newly occurred in the longitudinal direction near the boundary between the surface rutting where MS layer was worn away and the healthy part where MS layer was not worn away. The longitudinal cracks are considered to be a major factor of increasing the crack ratio.

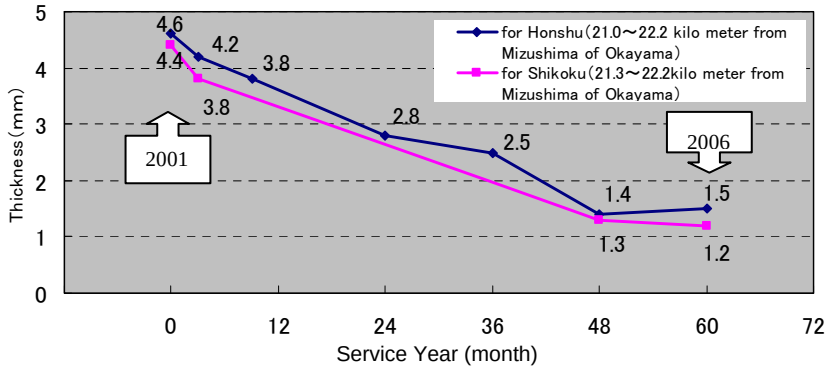

Figure 5: MS thickness and service year of Shimotsui-Seto Bridge

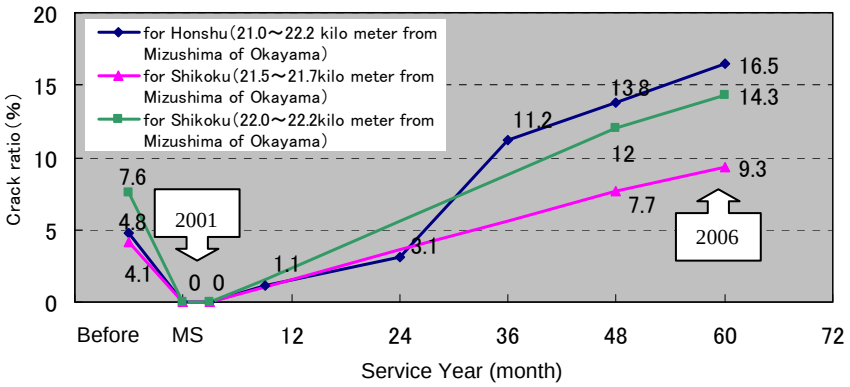

Figure 6: Crack ratio and service year of Shimotsui-Seto Bridge before/after MS

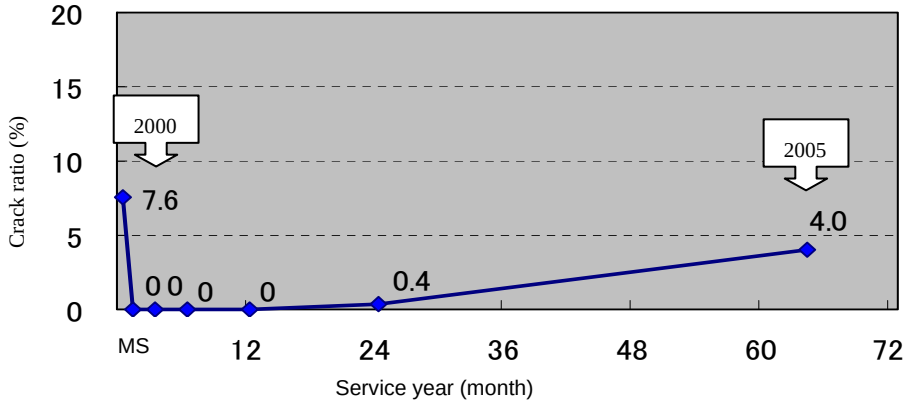

Figure 7: Crack ratio and service year of Innoshima Bridge before/after MS

The longitudinal crack stopped at depth of about 1-2mm from the surface of the modified asphalt pavement. Therefore, the generated tension is considered to be comparatively small. The penetration value of the modified asphalt pavement decreased to around 20, and is considered that a comparatively small tension which generated on the boundary part exceeded the bond strength in the substances of the pavement for some reason.

On the other hand, on the Innoshima Bridge which is shown in Fig. 7, the speed of crack generating after execution of MS was slow, and the crack ratio was less than the value before execution even though 64 months had passed.

Thus, on the Shimotsui-Seto Bridge and on the Innoshima Bridge, since the big difference was seen at crack ratio by service years, comparison by the traffic after MS was performed.

The accumulative traffic volumes of all vehicles for five years after MS are 21,215,000 vehicles on the Innoshima Bridge and 25,768,000 vehicles on the Shimotsui-Seto Bridge, respectively. Especially, the accumulative traffic volumes of heavy vehicles are 1,553,000 vehicles (27%, compared with Innoshima) on the Innoshima Bridge and 5,739,000 vehicles on the Shimotsui-Seto Bridge, respectively.

As shown in Fig. 8, the relationship between the crack ratio and the accumulative heavy traffic volume (one-side-lane traffic volume, half of the above-mentioned volume) is clarified to agree with two bridges. Therefore, it suggests MS is not suitable in the condition of relatively heavy traffic volume.

Since the main purpose of MS is to perform the surface treatment, the repair of cracks, which reduce the physical property, or the control of subsequent cracks, is not effective. Therefore, it is preferable to apply the MS method while the crack ratio is low.

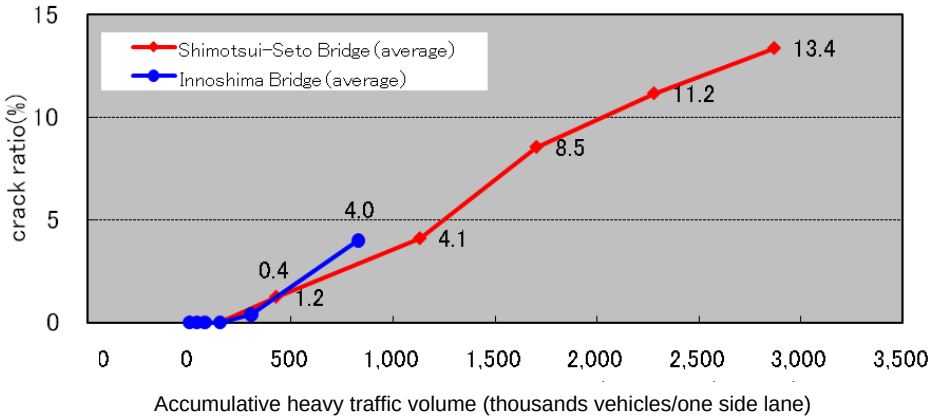

Figure 8: Comparison of crack ratio and heavy traffic volume

3.4 Determination on applicable condition of MS

In order to reduce the life-cycle cost of the steel deck pavement in maintenance, it is necessary to apply MS before the deterioration of the modified asphalt pavement goes on a progress stage.

However, there is not sufficient data that can solve the deterioration characteristic of the modified asphalt pavement based on the difference in traffic volume or a climate condition, and that can determine the best time and condition for MS.

Therefore, the applicable condition was selected as a tentative standard for the penetration degree and crack ratio from the example of the straight asphalt mentioned above, and from the

data of physical property of modified asphalt pavement, etc. Moreover, the life-cycle cost of MS was compared with that of the cutting overlay under the several assumptions.

1) Condition of penetration value

The penetration value at the time of applying MS is determined to be around 40 depending on the report by Kawaguchi (see Figure9,reference #4 below), examples of straight asphalts, that it is easy to generate hair cracks in less than around 35 of the penetration value (in more than 54 degrees Centigrade of softening points).

We thought that the value is mostly in sound stage, but it is in just before beginning stage of deterioration. Therefore we supposed that it is appropriate time for preventive maintenance.

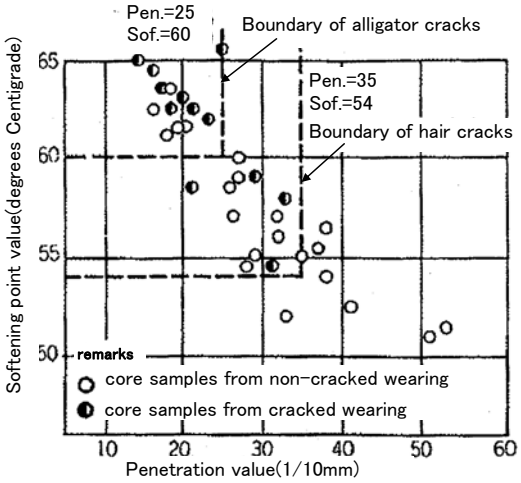

Figure 9: Correlation between cracks and Penetration

On the other hand, the lower limit of the penetration value is determined to be more than around 30. In addition, when the penetration value is less than around 25, it is reported that an alligator cracks often generates from data of Figure 9, other repair methods, such a radical measures as cut and cast, should be examined. We thought that the value of 30 is mostly in not so heavy damaged stage yet. Therefore we supposed that it is a dead line for preventive maintenance.

Moreover, when the penetration value goes down to the range of 40 to 30 in a decade, as shown in Fig 3, investigations of material properties of the modified asphalt pavement and the Guss asphalt pavement shall be carried out, and the application of MS shall be judged.

2) Condition of crack ratio

Although MS is adopted in a late stage which many cracks have generated, the effect to prolong the life time for the preventive maintenance can not be expected, because the reflection crack or the penetration crack to the Guss asphalt pavement would generate.

Generally, repair works, cutting overlay or cut and cast and others, shall be done at the crack ratio of less than around 20 percent. Also the works for a pavement of steel deck shall be done up to crack ratio of 20 percent depending on the maintenance repair guideline of HSBE.

In Japan, the crack ratio of 10 percent is used as an aim for investigation with non-destructive inspection or open cut inspection depending on Guideline for Design and Execution of Pavement. This stage, the value of 10, would not be a mild stage and need some

repair works, injection, sealing and cutting overlay. Therefore we set this stage as beginning of full scale repair works. Finally, the crack ratio of 10 percent is temporarily selected for dead line of application such light repair work as MS.

3) Comparison of MS with cutting overlay

Since the durability of the repair method depends on the traffic condition, various service lives for MS and the cutting overlay are assumed and compared by means of their life-cycle costs.

Assumptions for comparison are as follows,

(1) Service life of MS for the preventive maintenance is assumed in two cases; five years and seven years. After MS is carried out in two times, respectively, the cutting overlay is required.

(2) Service life of cutting overlay for the essential maintenance is assumed in two cases; 10 years and 15 years.

(3) Repair cost of MS or the cutting overlay is assumed in one case, considering the past repair costs.

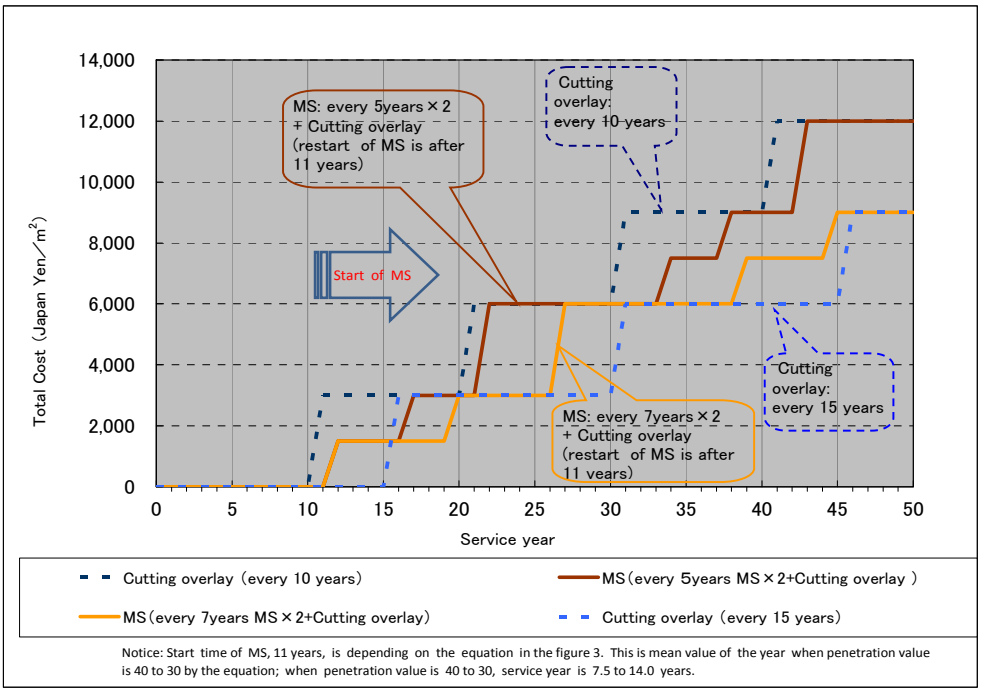

Figure 10: Comparison of MS and cutting overlay in LCC

Depending on each service life in the comparison, MS is not necessarily advantageous to the cutting overlay, as shown in Fig 10. Especially, MS with the service life of 7 years and the cutting overlay with the service life of 15 years are the most advantageous in their life-cycle costs after 50 service years. Consequently, the application shall be judged after comparing MS with cutting overlay in their life-cycle costs, considering an individual condition on each bridge.

In addition, the second and the third repair work of MS shall be judged, based on deterioration status, including physical properties and penetration cracks of the modified asphalt pavement as well as the Guss asphalt pavement, and service years from the last repair work, etc.

4 CONCLUSION

The conclusions are summarized as follows,
1) The physical properties of the modified asphalt decreases gradually in service years (asphalt hardens), and the penetration value becomes half of the original value in ten years.
2) Since the crack ratio and the accumulated heavy traffic volume are correlated to each other, the MS method can not control the crack and may not have the effect under the heavy traffic.
3) The application standard of MS is considered to be the penetration value of more than around 30 and the crack ratio of less than 10 percent.
4) Each LCC is estimated to be almost equivalent, assuming the durability of MS and the cutting overlay are 7 years and 15 years, respectively.

MS is also expected to have the effect of reducing the environmental impact, including the resource-saving and the energy-saving. However, the application of MS shall be judged, considering the deterioration of pavement, the traffic volume, the service year, etc. If the application is not appropriately judged, the effect in the preventive maintenance can not be expected. It may also shorten the life of pavement.

The guideline shows the conditions for applying MS effectively by the knowledge acquired until now, considering the health and the economy of steel deck pavements. However, a sufficient data about the correlation with traffic volume is not obtained and considered as the future subject. Therefore, the efficient maintenance is required for the steel deck pavement, performing the accumulation of data, the verification of effect and the feedback to the guideline in the future.

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