In-site Base Course Recycling Method for Keeping Safety and Improving Durability under Heavy Traffic

S. Ikehata, M. Yamada, K. Mamiya & S. Kono
Central Nippon Expressway Company Limited, Nagoya, Japan

T. Kazato & K. Kamiya
Nippon Expressway Research Institute Company Limited, Tokyo, Japan

ABSTRACT: Meishin Expressway has been in operation over 45 years as a heavily trafficked beltway for carrying 25,000 truck vehicles a day. It is high time to conduct extensive renewal rehabilitation. Hikone among other Meishin sections has long suffered from serious distress with deep cracking to granular base, due to heavy traffic loadings in only two lanes for one way. Also Hikone's snowy and mountainous location may induce underground water to immerse into the pavement, which could be another trigger to severe damage. In 2007 it was required in Hikone to replace existing 25cm thick asphalt layer and 15cm granular base with new materials for nearly 5.3km long lane section during only 10 days, while the other lane being open to traffic. Under this critical condition, not to mention road safety, a longer durable repair method has to be selected. So, in-site base course recycling was considered. This method was judged to assure safety and to reduce amount of wastes, as well as shorten construction time for the base course. In order to find a cost effective in-site base recycling method, trial construction was conducted in the two sections, namely section with foamed asphalt and that with cement and foamed asphalt. The reason of selection of the two materials came from environmental view. This paper presents effectiveness of in-site base course recycling in construction conditions even under heavy traffic, durability through FWD monitoring and finally environmental advantage of reduction in CO_2 emission.

KEY WORDS: in-site base recycling, formed asphalt, FWD, structure, CO_2 emission

1 INTRODUCTION

Since 1963 Meishin Expressway that connects Nagoya and Osaka has been in operation for over 45 years as a nation’s heavily trafficked beltway for carrying 25,000 truck vehicles a day. Hikone, shown in Figure 1, among other Meishin sections has long suffered from deep cracking to granular base (Photo 1), due to heavy traffic loadings in only two lanes for one way. Also Hikone's snowy and mountainous location may induce underground water to immerse into the pavement, which could be another trigger of damage. In order to keep providing toll road users with safe and durable roadways, it was judged high time to conduct extensively structural rehabilitation.

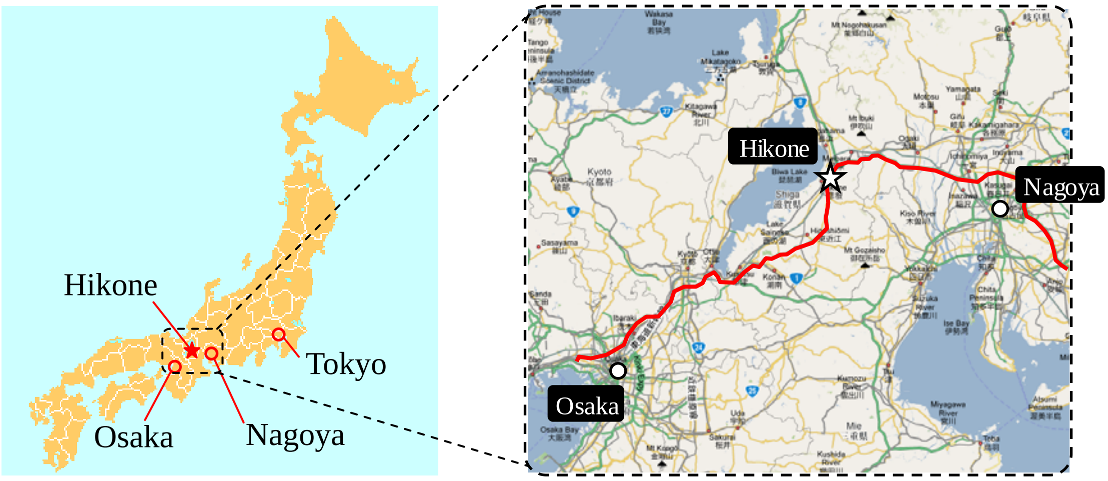

Figure 1: Hikone Section in Meishin Expressway

Photo 1: Cracking to granular base

As is usually a common construction condition in Japan, however, the rehabilitation has to be planned on a lane basis traffic regulation, in which road operators can close a lane for repair for 2km and during 8hours at the maximum but must open to traffic for the other lane. Not to mention road safety, a quick repairing method that can assure longer durability had to be considered. Under this critical condition, in-site base course recycling method was selected, although this was the first application in the Japanese expressway under heavy traffic.

2 STRUCTURAL EVALUATION

2.1 Repair History

Because CBR method was used for structural design of pavement in Meishin Expressway, the bituminous layer's thickness at the time of construction in 1963 was only 10cm over upper and lower granular base layers. Several years after opening to traffic, however, longitudinal cracking intensively occurred in left lane. Since 1971, bituminous layers' overlaying has been conducted three times until 1983. For the latest 10 years since 1999, 10cm thick layer from the top has been replaced with 4cm thick porous asphalt layer and underlying 6cm thick binder layer. Thus the oldest 10cm and second oldest 5cm thick bituminous layers have been still remaining at the bottom. Figure 2 shows repair history for Meishin Expressway.

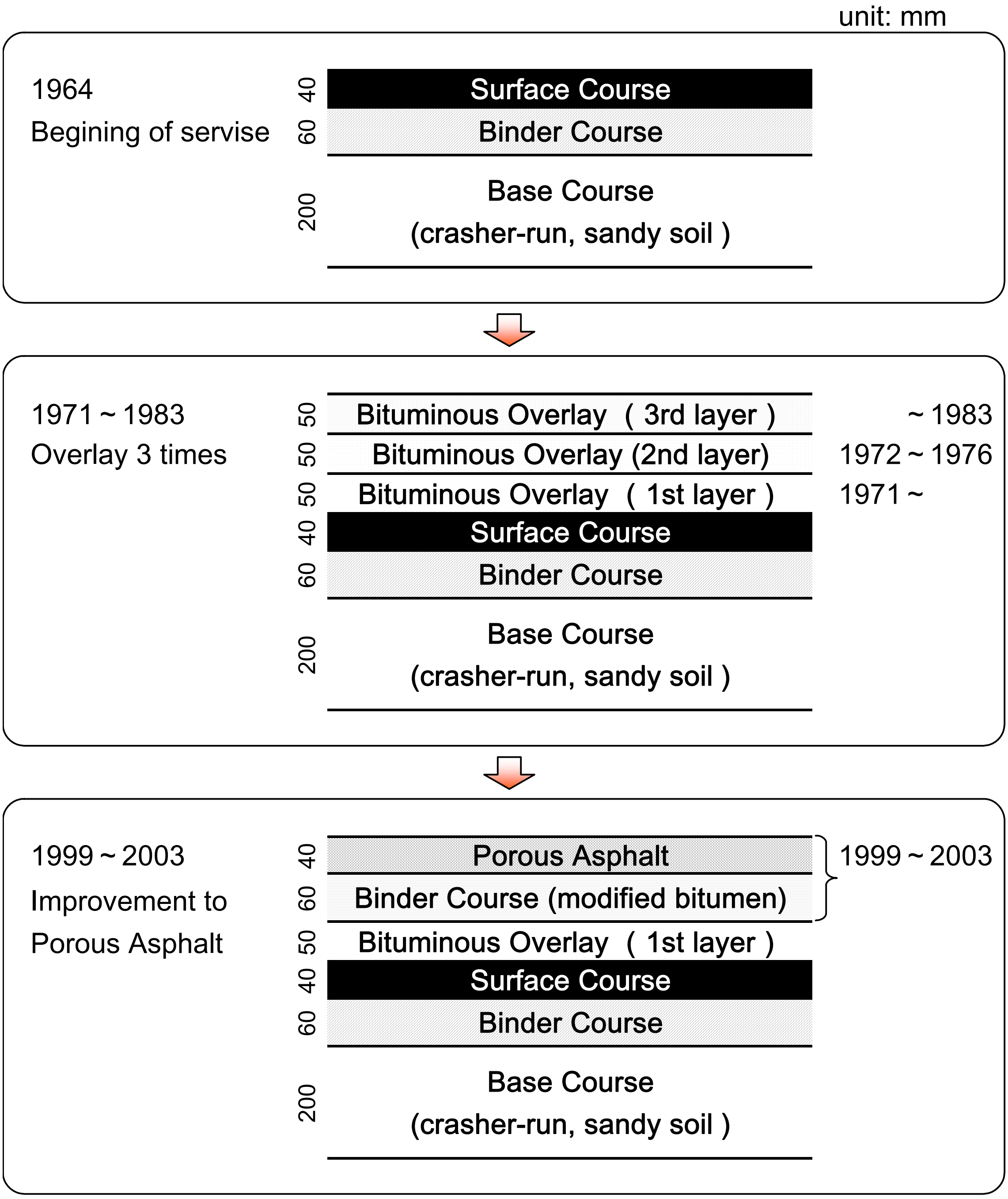

Figure2: Repair history for Meishin Expressway

It is noted here that polymer modified bitumen was used for both current surface and binder layers for having sufficient rutting resistance. However potholes (Photo 2) are popping up at earlier times in Hikone compared with the other sections, since Hikone is located in snowy mountainous areas with a higher annual rainfall of 1600mm. Mountainous underground water that is apt to immerse into the base layers could be one of the causes.

Photo 2: Potholes from porous asphalt

2.2 Structural Survey

In order to objectively evaluate the structural distress, pavement structure in Hikone was diagnosed using FWD. As a result from over 3000 data points the pavement structure was considered to have reached higher deflection levels for a 25cm thick bituminous layer. Figure 3 shows shares and levels of the maximum deflection (D_0) with its average and standard deviation. The standard deviation tends to remain almost the same level up 0.25mm. This means 90% of the section is being structurally deteriorated at almost a constant speed. Therefore all this section was judged to better repair consistently with a deeper thickness.

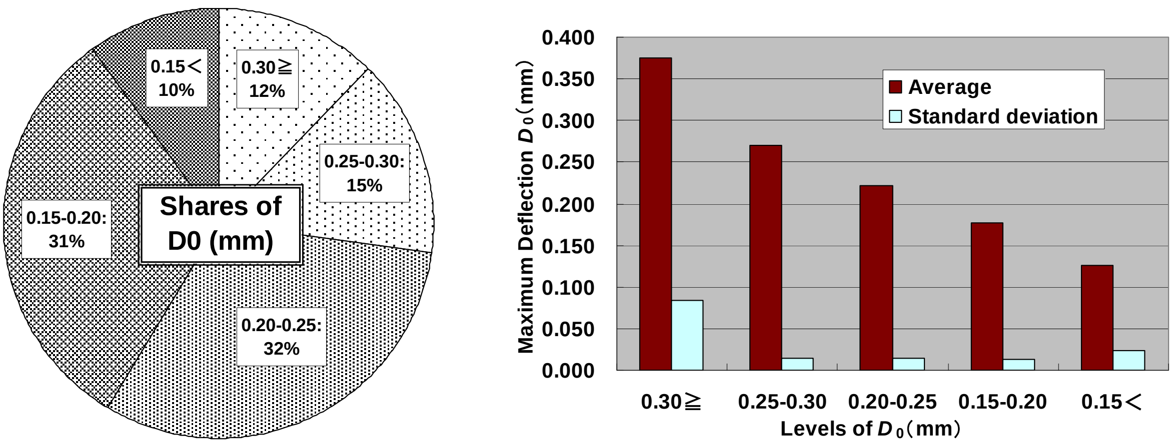

Figure 3: Shares and levels of maximum deflection (D_0)

Based on this research as well as visual observation of deteriorated road surface, several sections having average maximum deflection of 0.25mm or higher were cut open. Photo 4 and Photo 5 respectively show bituminous layers and granular base at one of those cut open sites. As shown in the photos, cracks were found in the original surface and binder layers at the bottom while base layer was subjected to water being supposed to come from the underground. Finally it was judged that all the Hikone sections need to be replaced with new materials including 25cm thick bituminous layers and 15cm thick granular base layer.

Photo 3: Cracks in bituminous layers

Photo 4: Water in granular base layer

3 DESIGN AND CONSTRUCTION

At first existing 40cm thick materials were planned to mill and overlay with new materials for as long as every 5km lane during 10 days, while the other lane being open to traffic. This method, however, was difficult to assure keeping safety during construction. Since safety was first concerned in case 40cm thick existing materials were planned to mill and carry out of the site, in-site base course recycling was considered. This method was judged to assure keeping safety by reducing amount of shipping materials, as well as shorten construction time for the base course. However structural improvement in the long term was hard to judge. Therefore it was judged to continue doing structural survey using FWD monitoring after rehabilitation.

In order to find a cost effective in-site base recycling method, trial construction was conducted in the two sections in 2006 before implementation, namely section with foamed asphalt and that with cement and foamed asphalt. The reason of selection of the two materials comes from environmental view. After milling and removing 20cm thick bituminous layers, in-site base course recycling method was applied to existing 5cm thick remaining bituminous layer and 15cm thick granular base. Then overlaying 10cm thick bituminous treated base, 6cm binder and 4cm surface layers followed the recycling. Figure 4 shows layered cross section for the whole rehabilitation.

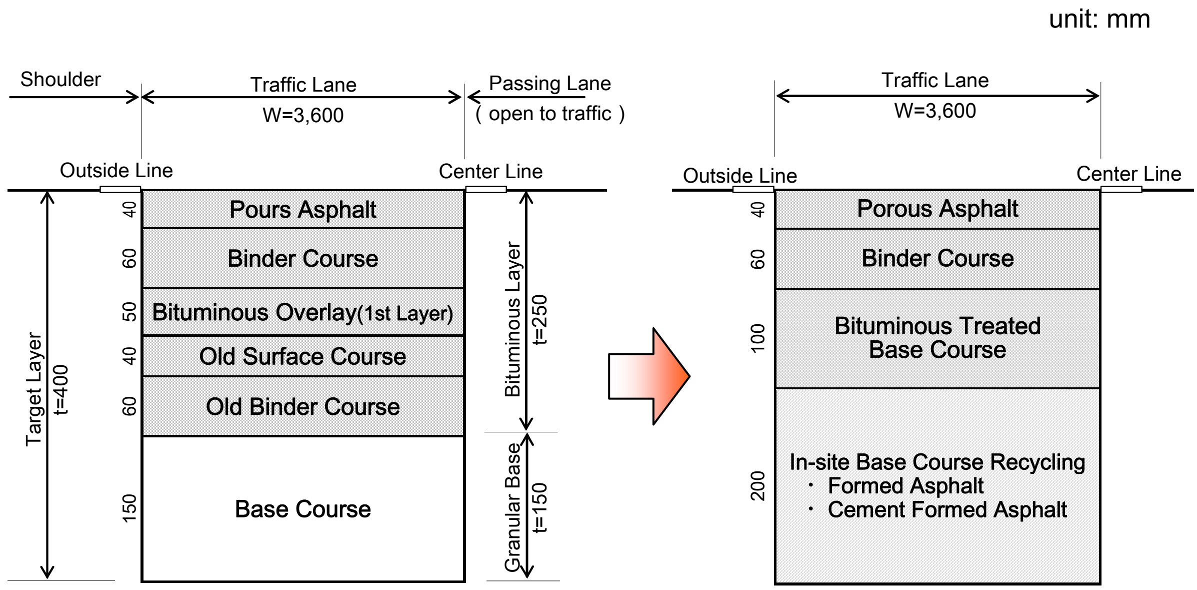

Figure 4: Layered Cross Section

Table 1 shows mix condition of in-site base course recycling materials using Foamed Asphalt. This condition means that maximum of immersed Marshall stability is obtained at the time when changing bitumen content and its corresponding optimum water content. Cement content of the Cement Foamed Asphalt recycling materials was determined 2.5% in consideration of workability in the site.

Table 1: Mix proportion of in-site base course recycling materials (Foamed Asphalt)

	Mix Proportion (%)	
	Existing bituminous treated base	27.6
	Existing granular base	72.4
Bitumen content (%)	4.0	
Optimum water content (%)	4.0	

Lane-basis rehabilitation for as long as 5.3km (19,000m^2) using in-site base course recycling with foamed asphalt was conducted during 10 days in May of 2007. Photo 5 shows the ongoing machinery of the in-site base course recycling with foamed asphalt.

Photo 5: Ongoing Machinery with Foamed Asphalt

Figure 5 shows mechanism of foamed asphalt. Bitumen under high temperature that is to be added with evaporated water can entrain very small foamed air. This foamed air will decrease the viscosity of the bitumen and thus finally will be able to improve workability in the field.

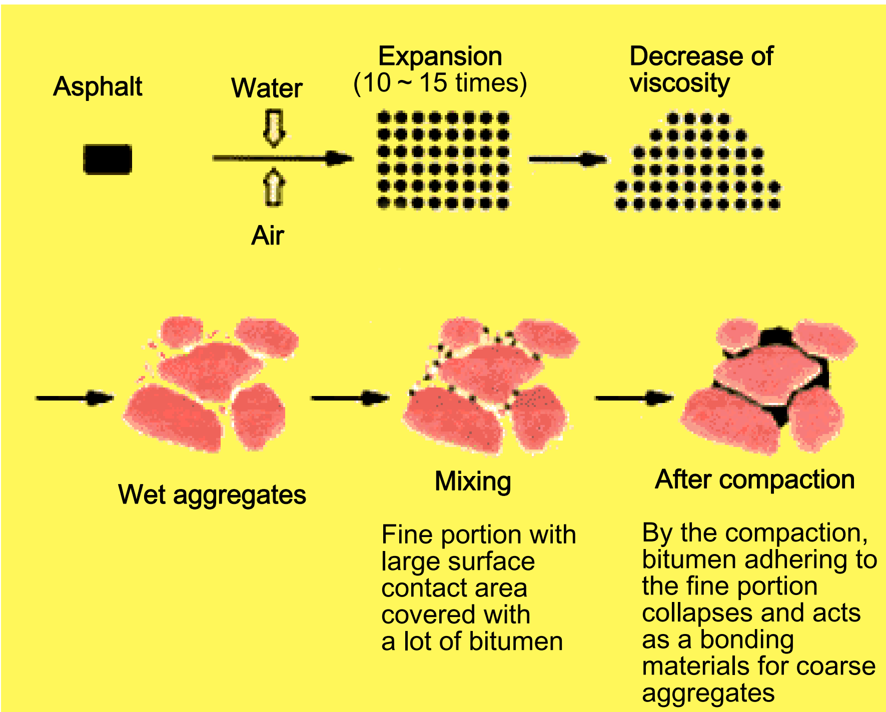

Figure 5: Mechanism of foamed asphalt

4 STRUCTURAL IMPROVEMENT

In order to evaluate the effectiveness of in-site base recycling using foamed asphalt with and without cement, FWD monitoring has been conducted for a few years to compare deflections at the same points before and after the rehabilitation. Milling and overlaying sections only for surface and binder layers nearby were also compared with the in-site base course recycling section. Figure 6 shows changes in average maximum deflection for every trial construction section since 2006.

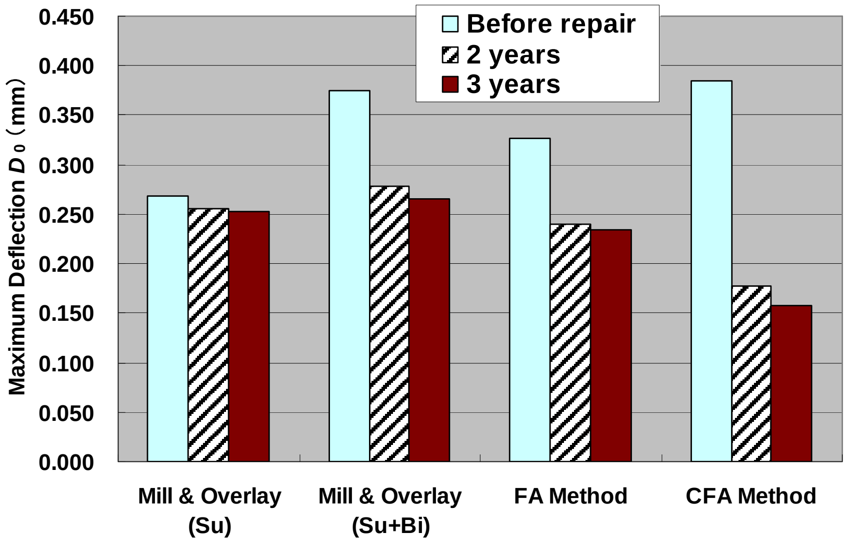

Figure 6: Change in maximum deflection

Although there has been structural improvement in every method before and after rehabilitation, deflection of milling and overlaying surface layer method has not much been decreased. This is because of only change of porous surface layer in this method, while the other three methods mean structural change that covers replacement of underlying layers. Especially in-site base course recycling with cement and foamed asphalt (hereafter called CFA) method shows dramatic and steady improvement of pavement structure. This naturally shows the effectiveness of improving all the problematic layers and using cement for higher stiffness lower base.

At present CFA method is judged the most cost effective, since there is not much difference in initial cost between FA and CFA methods. However there is a slight concern of occurrence of reflective cracking from the base layer in CFA method. Therefore it judged that structural survey through FWD monitoring needs to be conducted for more years.

5 REDUCTION OF CO_2

One of the environmental advantages of in-site base course recycling is to do without amount of carrying materials out of the site. This is considered to sufficiently work for the reduction of CO_2 emission from the field.

Figure 7 compares by calculation amounts of CO_2 emission arising from in-site base course CFA method and base course replacement method. Obviously the former is advantageous in excluding the carrying of existing materials from the site. The amount of CO_2 reduction in

CFA method is 15.3 t・C/100m^2 or 25% of base course replacement method. In terms of all rehabilitation areas of 19,000m^2 in 2007, 2900t・C of CO_2 was supposed to be reduced.

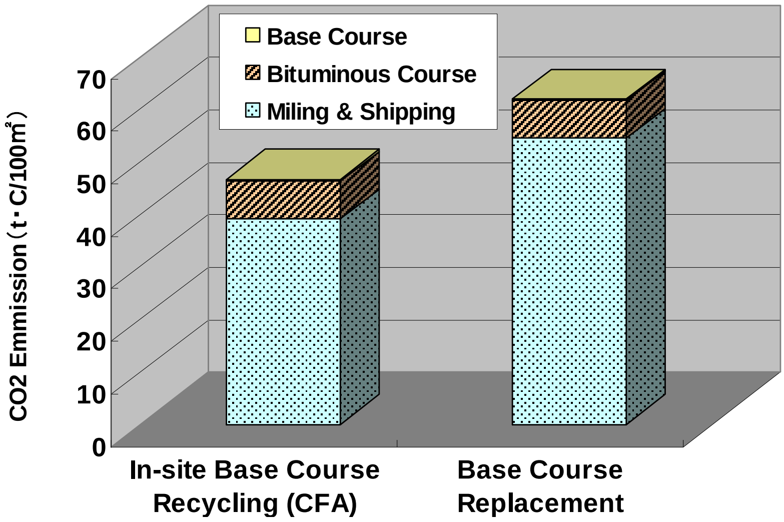

Figure 7: Comparison of CO_2 emission

6 CONCLUSION

In-site base course recycling method (FA and CFA method) was adopted for the first time in Japanese expressway in 2007. The section rehabilitated using this method has been in a good condition and no damage has relapsed.

In this paper the findings are summarized as follows.

1. In-site base course recycling method can assure safety under heavy traffic even in lane basis traffic control by reducing amount of carrying materials, as well as shorten construction time for the base course.
2. According to FWD monitoring before and after rehabilitation, it was observed that in-site base course recycling with cement and foamed asphalt (CFA) method shows dramatic and steady improvement of pavement structure.
3. Compared with only milling and overlaying surface layer, the effectiveness of improving all the problematic layers was confirmed.
4. In-site base course recycling can reduce CO_2 emission in the amount of dispensing with shipping materials out of the site.

Because it is not yet sufficient time to evaluate long term durability, monitoring survey is planned to be conducted in the trial sections. If longer life cycle cost is validated, this in-site base course recycling method will be widely implemented as an eco-friendly method.

REFERENCES

Iwahara, H., et al., 1998. *Properties and Adaptation of Formed-Stabilizer Asphalt Mixture.* Pavement, Vol.33 No.10, pp.9-15