A Sophisticated Overlaying Approach to Improving Riding Quality for Aged Concrete Pavement in NEXCO

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ABSTRACT: A 35km long section with cement concrete pavement in Chuo Expressway has been in operation over 35 years as a heavily trafficked beltway for carrying 20,000 truck vehicles a day. Recently cracking and joints faulting have come to arise remarkably in the concrete section and there have been claims about decrease of riding quality form toll users. In order to improve both riding quality and durability, a big overlaying project that continues several years had to be planned. Since the beltway cannot be closed, the given repair condition was really tough; asphalt materials need to be overlaid for every 3 kilometer long lane section during 4 days, while the other lane being open to traffic. In addition to assuring road safety during repair works, a durable repair method that also assures riding quality has to be selected. As a durable asphalt mix reported in Zurich ISAP symposium 2008, 4cm hybrid mix was selected. It is composed of rough macro texture similar to that of porous asphalt, as well as the same waterproof as that of stone mastic asphalt. Since the occurrence of reflective cracking is concerned near joints, 4cm porous asphalt is planning to overlay after hybrid overlaying is finished. In actual repair stages there have been several hardships to overcome. Since some concrete panels are severely abraded especially around joints, which induce severe faulting, thickness control for improving a smooth profile was one of the key points to better riding quality. This paper introduces considerate design concept and overlaying construction procedures.

KEY WORDS: Concrete pavement, hybrid mix, overlay, FWD, IRI.

1 INTRODUCTION

Hachioji Bureau of Central Nippon Expressway Company Limited manages about 305km length of Chuo Expressway between Tokyo and Nagano. Of the entire sections, concrete pavement is shared with approximately 36km (Figure 1). Over 30 years has passed since this section opened. Recently the damages of crack and faulting of joints occurred on the pavement slabs (Figure 2). As a result, riding quality has been worsened by outbreak of traffic vibration with remarkable noise, and thus this entire concrete section has come to be repaired immediately.

This paper reports considerate design concept and construction procedures including the effectiveness of hybrid mix as an overlaying layer.

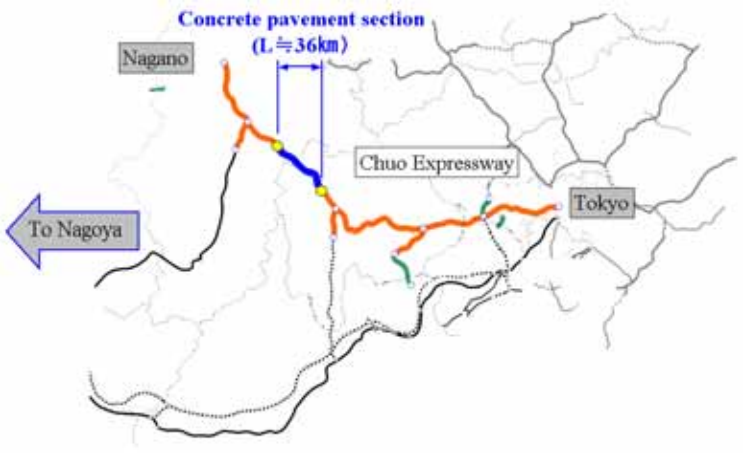


Figure1: Location of Concrete Pavement

Figure2: Joint faulting (left) and transverse crack (right)

2 STATUS OF CONCRETE PAVEMENT

The concrete pavement section has been damaged with reduction of riding quality because of aged deterioration, although it seems still structurally sound. Table 1 shows a road surface property, and Figure 3 shows IRI (International Roughness Index) of the existing concrete pavement. The concrete pavement is generally in a good state, but over 20mm rutting is seen partially. IRI is 2.2 mm/m on average of the concrete pavement section, while 1.8 mm/m on that of the neighboring asphalt pavement section. In addition, the point with more than 4.0mm/m was confirmed partially in the former, too. According to a riding quality study performed in the past, IRI 2.2 mm /m is the level in which more than 50% of passengers begin to feel not good in riding on the roadway (Kamiya, 2005).

Table 1: Road surface property of concrete pavement

Division	traffic lane	rutting (mm)		IRI (mm/m)	
		average	maximum	average	maximum
To Tokyo	Ordinary lane	12.6	19.0	2.35	3.8
	Passing lane	4.5	15.0	2.00	3.8
To Nagano	Ordinary lane	10.9	23.0	2.29	4.0
	Passing lane	3.9	16.0	2.05	3.6

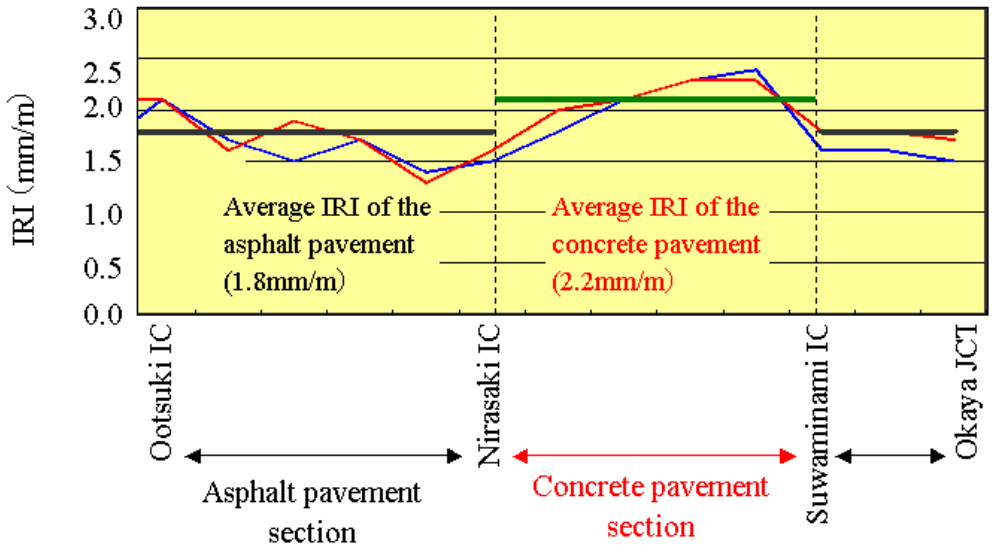


Figure 3: Comparison of IRI

3 REPAIR PLANNING

3.1 A Repair Policy

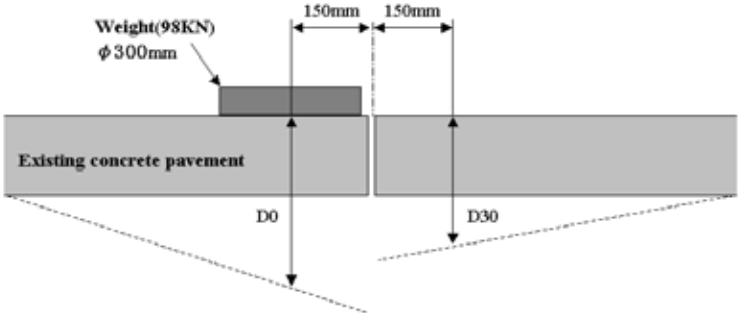
A technical committee was set up by inviting experts for establishing a repair policy for the concrete pavement. As a result of the investigation by the committee from 2000 to 2003, the structural state of concrete pavement was found almost sound. The experts judged that it is necessary to first improve damaged road surface of the concrete slab, and then move on to overlaying new asphalt materials. In order to improve the serviceability, the committee recommended as a basic policy the composite structure that is first to overlay stone mastic asphalt (4cm) on the existing concrete slab, and then followed by overlaying porous asphalt layer (4cm). The committee also recommended short-term and mid & long-term measures as follows.

<<Short-term measures>>
1) Rutting & Skid resistance: where necessary, steel-blast must be carried out.
2) Crack: where necessary, bar-stitching and crack sealing must be done.
3) Deficit of joint: under-sealing and bar-stitching must be done.

<<Mid & long-term measures>>
4) Rutting & Crack：After short-term measures are over, the composite structure as above mentioned is to be achieved.

3.2 Evaluation of Existing Concrete Pavement

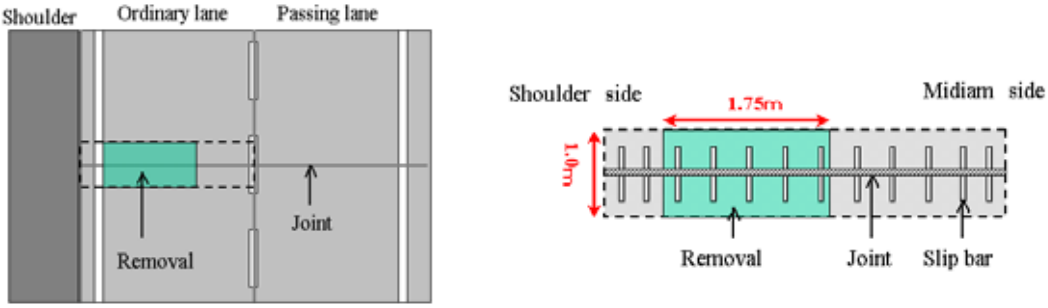
Structural evaluation of existing concrete pavement is very important, because asphalt overlaid materials are apt to be affected by joint roughness of the underlying existing concrete pavement. According to FWD Operation Manual from JSCE (JSCE, 2002), the ratio of load transmission between joints is defined as shown in Figure 4.



Load transmission ratio: e_{ff} $\quad e_{ff} = \dfrac{D30}{(\ D0\ +\ D30\ )/\ 2} \times\ 100\%$

Figure 4: Ratio of load transmission

From the past studies, there was a strong concern about the possibility of existing slip bars to be broken, if the ratio undergoes 65%. Therefore a cut open investigation was carried out in several points to find specific repair criteria for bar-stitching. Figure 5 depicts the procedures of block sampling after FWD measurement in the field.



about a point of 42%,64%, and 82%. Therefore a field investigation it was needed

Figure 5: Sampling of block materials

As shown in Figure 6, four out of five slip bars were found broken at the points with the transmission ratio being 42% and 64%. On the other hand, only one slip bar was broken with the ratio being 82% and 77%.

Figure 6: Point with slip bars broken (load transmission 64%)

Finally it was judged that the ratio of load transmission be 70% or lower as criterion for bar-stitching. Moreover there could be a cavity under the concrete slab when the FWD maximum deflection is 0.4mm or higher. Therefore it was also determined that under-sealing should be done in case of this deflection level.

3.3 Repair Strategy

In order to sooner realize a basic policy by the committee within limited budget, an efficient repair strategy was needed to establish. The strategy was required to keep the overlaying policy (porous asphalt mix + stone mastic asphalt) that the committee had recommended. Therefore the possibility of only overlaying hybrid mix was first examined between Nirasaki IC and Kobuchizawa IC (L 24㎞) because road surface condition in this section is better than that of the other section between Kobuchizawa IC and Suwaminami IC (L 12㎞). Figure 7 shows the location map of this repair strategy.

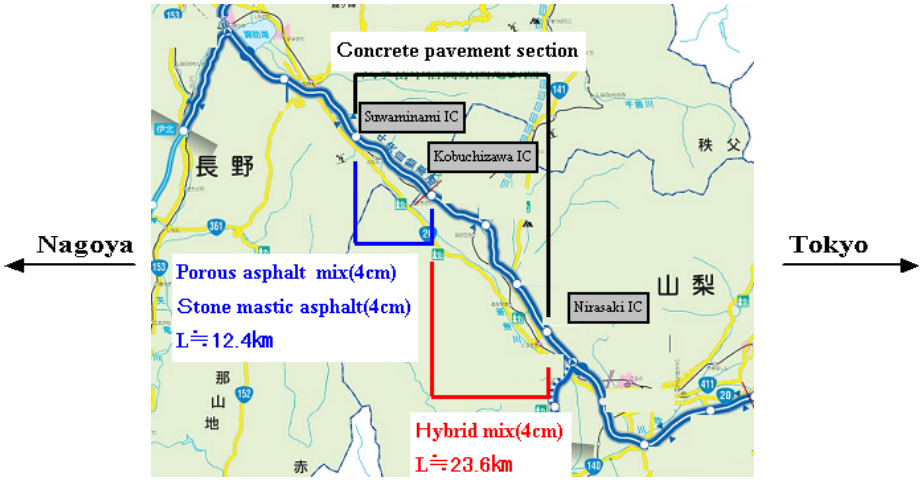


Figure 7: Location of repair strategy

As reported in Zurich ISAP symposium 2008, hybrid mix is composed of rough macro texture similar to that of porous asphalt, as well as the same waterproof as that of stone mastic asphalt (Kamiya et al. 2008). Although the occurrence of reflective cracking was concerned near joints, it was judged that overlaying 4cm hybrid mix layer is worth trying because of its high stiffness. Also 4cm porous asphalt layer can be overlaid several years later when budget is available. Figure 8 shows diagrammatic illustration of hybrid mix.

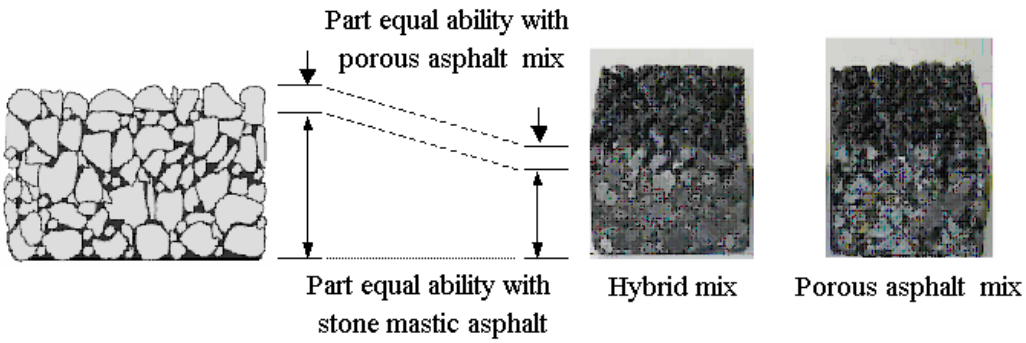


Figure 8: Diagrammatic illustration of hybrid mix

4 REPAIR PROCEDURES

Because hybrid mix has never been used for overlaying on concrete pavement, several points were needed to arrange for the field conditions.

4.1 Arrangement of Hybrid Mix

Although polymer modified asphalt is usually used for hybrid mix, the occurrence of bleeding or asphalt run-off problems were much concerned during construction. This is because it took as long as 70 minutes for shipping materials from asphalt plant to the paving field. For the purpose of avoiding those asphalt problems, the type of modified asphalt was needed to examine. In simulation of the shipping time, Figure 9 and Figure 10 show photos in case of using ordinary modified asphalt and highly polymer modified asphalt, respectively. The SBS content of the former is 4% and that of the latter is 8%.

Figure 9: Asphalt run-off problems (Ordinary modified asphalt, SBS 4%)

Figure 10: Satisfactory road surface as designed (Highly polymer modified asphalt, SBS 8%)

The test pavement with SBS 4% had run-off and flush of asphalt, while SBS 8% didn’t. Therefore highly polymer modified asphalt was adopted in 2006 and in 2007.

Table 2 shows conventional aggregate gradation which was used in 2006 and 2007 and new one for 2008. This new gradation was obtained from another study in order to realize less compaction energy in the field. Furthermore, the change of asphalt plant in 2008 shortened shipping time from 70 minutes to 40 minutes. Consequently use of ordinary modified asphalt turned out possible in 2008. The use of this less expensive asphalt contributed to cost reduction of the hybrid paving projects and thus to wider achievement of repair.

Table 2: Revision of aggregate gradation

Opening of sieve (mm)	Conventional gradation(%) in 2006 & 2007	New gradation(%) in 2008
13.2	95～100	95～100
9.5	—	—
4.75	28～32	30～38
2.36	22～25	22～27
0.6	18～20	17～21
0.3	12～17	15～18
0.15	10～13	10～13
0.175	8～10	9～11
Asphalt content	5.6%	5.4%

4.2 Reflective Cracking Countermeasures

Before overlaying asphalt layer mix, it is important that the mix can be durable against reflective cracking from the concrete joints. Therefore countermeasures against reflective cracking had to be considered. Setup of the cutting joint (30mm in depth and 3mm in width) in the underlying layer of two layers overlaying has been observed effectively workable from experiences. However it is unknown whether or not this is true of only a layer of hybrid mix.

Figure 11 shows the comparison of joint patterns. The right one is to seal three kinds of asphalt injection materials that can prevent from penetration of rainwater, while the left is only to cut open. A monitoring survey on the trial sections showed no differences in cracking mitigation between the patterns. Therefore it was judged that the left pattern be adopted.

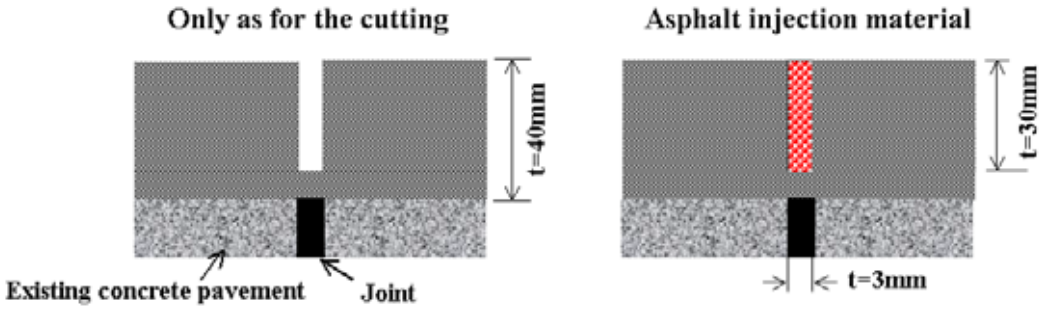


Figure 11: Diagrammatic illustration at joint.

4.3 Improvement of Riding Quality

Hybrid mix layer with 4cm thickness was generally paved at first. However, where the concrete slab was severely abraded or deteriorated, the slab had to be cut 1cm and overlaid with 5cm hybrid mix layer. According to monitoring in the trial sections for comparison, there was not difference in IRI between hybrid overlaying with 4cm and 5cm thicknesses.

Figure 12 shows the improvement of IRI on average from 2.1mm/m to 1.7mm/m. However because there still remained wiggle vibration at the concrete joints, there was still room for improvement at the joints.

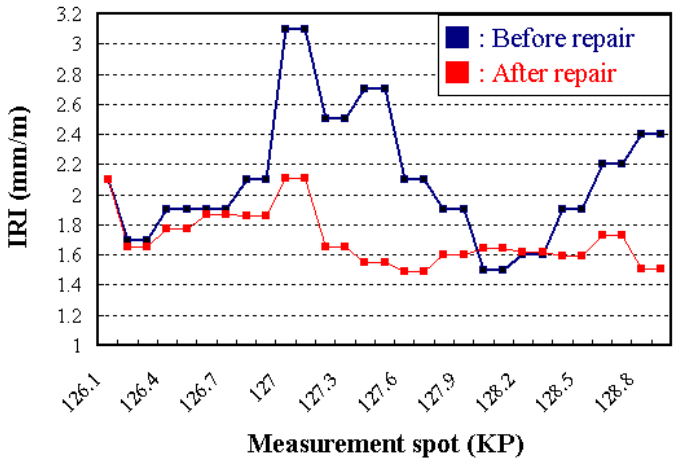


Figure12: Improvement of IRI

In order to find a way to further improve riding quality at the concrete joints, construction procedures were reviewed in 2007. Figure 13 compares the methods of finishing asphalt mix over the joints. By setting a slope outside the finisher, so that the materials can be smoothly overlaid, it was made possible to gradually change the thickness of overlaying hybrid layer.

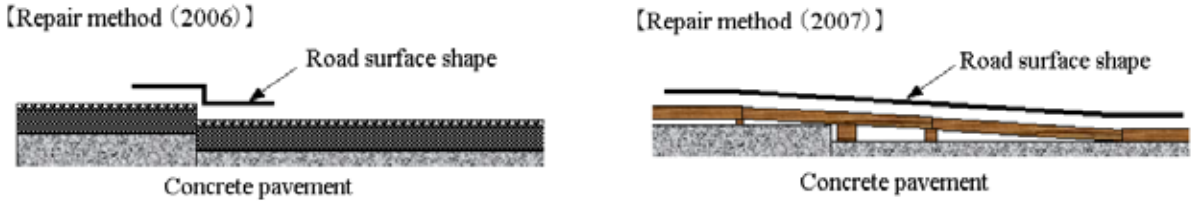


Figure 13: Slope for finishing smoothly

There have been not any damages in the sections where only 4cm thick hybrid mix was overlaid in 2007. The road surface has been in a good riding quality there.

From all mentioned above, it was finally confirmed that overlaying only 4cm thick hybrid mix can be widely implemented to sufficiently improve durability and riding quality as targeted.

5 SUMMARY

In order to upgrade serviceability of the entire deteriorated concrete pavement section in Chuo Expressway, through establishment of repair planning and achievement of repair procedures, the following findings were summarized as follows.

1. In structural evaluation of existing concrete pavement, the ratio of load transmission using FWD at the joint was set 70% or lower as criterion for barstiching according to cut open investigation in the several fields.
2. It was found that bleeding or asphalt run-off problems of hybrid mix in the field can be avoided by two ways. One is use of highly polymer modified asphalt in case of as long as 70 minutes for shipping materials from asphalt plant to the paving field. The other is a more economical way by using ordinary modified asphalt with new aggregate gradation, which can realize less compaction energy in the field.
3. In order to mitigate reflective cracking from the concrete slab, joint patterns of hybrid mix layer were examined in the field. A monitoring survey revealed no differences in cracking mitigation between the patterns. Therefore setup of the cutting joint (30mm in depth and 3mm in width) without asphalt injection materials was adopted.
4. In order to further improve riding quality at the concrete joints, by setting a slope that can smoothly finish asphalt materials it was made possible to gradually change the thickness of the overlaying hybrid layer.
5. Finally it was confirmed that overlaying 4cm thick hybrid mix can sufficiently improve durability and riding.

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