INTRODUCTION OF RECENT THIN BONDED CONCRETE OVERLAY CONSTRUCTION AND EVALUATION OF THOSE PERFORMANCES IN JAPAN

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1. Introduction

The concrete overlay paving results in Japan have become successful through the technical development of the steel fiber reinforced concrete (hereinafter referred to as SFRC) overlay, which was started in mid 1970's. Typical examples are overlays for worn down asphalt paved surface[1], and overlays for deteriorated concrete slabs on bridges. In the past, adapting concrete overlay for use on concrete pavement was not considered possible because of low performance road planer and insufficient bond with existing slabs. However, recently, a heavy duty road planer has been developed and materials and construction methods for overlay have improved, therefore, construction of concrete overlay has become practical and possible on concrete pavement. Therefore, the yearly road repair losses caused by using asphalt materials in cold weather regions have been eliminated, along with it now being possible to economically reclaim a durable road surface.

This paper presents a recent example of the application of thin bonded concrete overlay (hereinafter referred to as TBCO) onto jointed Portland cement concrete pavement (hereinafter referred to as PCCP) and continuously reinforced concrete pavement (hereinafter referred to as CRCP) and reports on these results in Japan.

2. Outline of Construction Work

The construction site is on the Mori Bypass Highway On Hokkaido's National Highway Route Number 5 as shown in Figure 1. The average daily traffic flow volume of this bypass highway is approximately 8000 vehicles/in both directions and the percentage of so-called large-sized vehicles (buses for more than 11 passengers or more than 5 ton-axle-load trucks, according to the enforcement regulations of the Japanese Road Traffic Law) is 29%.

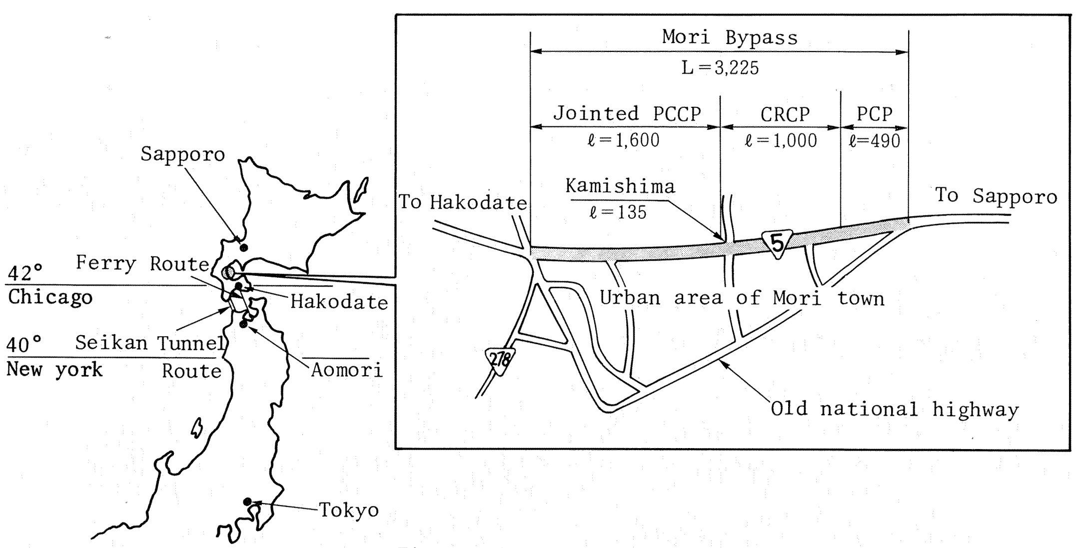


Fig. 1 Location Map

2.1 Existing Concrete Pavement

The existing concrete pavement was constructed using jointed PCCP; length 1600 m (approx. 5249 ft), thickness 23 cm (approx. 9.06 in.), CRCP; length 1000 m (approx. 3280 ft), thickness 20 cm (approx. 7.87 in.), and prestressed concrete pavement (hereinafter referred to as PCP); length 490 m (approx. 1607 ft), thickness 15 cm (approx. 5.91 in.). These 3 types of concrete pavement were compared and analyzed in this overall section when the bypass was built in 1972. The Thin bonded concrete overlay (TBCO) was laid on the PCCP and CRCP sections. Already the 1488 m (approx. 4881 ft) of PCCP, and 544 m (approx. 1784 ft) of CRCP have been completed through the execution of road work in recent years, and works on the remaining sections are to be done in 1988. Resin concrete was used in the PCP, however, this will not be referred to in this report on TBCO.

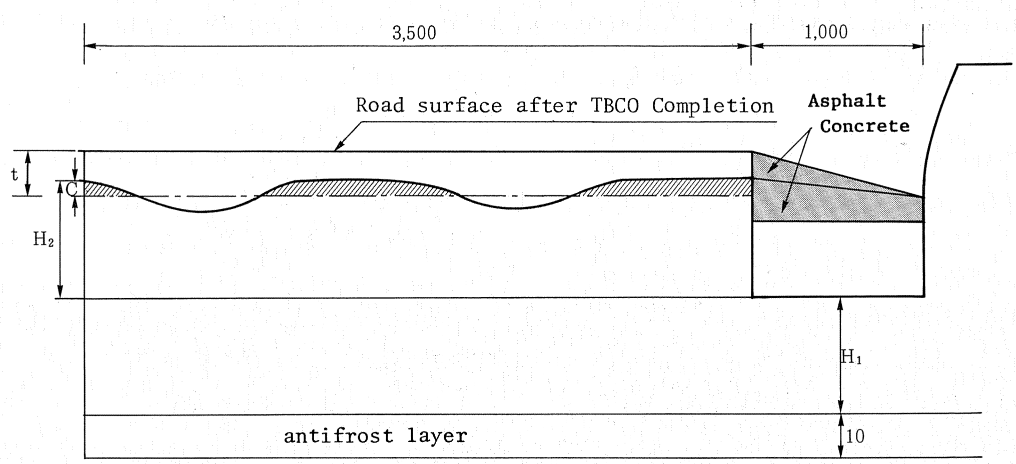
The structures of existing jointed PCCP and CRCP are as shown in Figure 2. The 20 to 23 cm (approx. 7.87 to to 9.06 in.) thick of PCCP and CRCP are laid over mechanically stabilized crushed aggregate[2)]. The 35 to 38 cm (approx. 13.78 to 14.96 in.) thick crushed aggregate is on top of a 10 cm (approx. 3.94 in.) antifrost layer. The deterioration degree of the existing pavements is as shown in Table 1[3)]. The average abrasion loss from studded tires varies from 23.0 to 38.8 mm (approx. 0.9 to 1.5 in.) during 12 year services. The deflection of the concrete slab caused by 5 t axle load ranges from 0.33 to 0.43 mm (approx. 0.13 to 0.17 in.) on average. All ranks of the crack length ratio to the pavement area vary from 22.6 to 25.5 cm/m^2 (approx. 7.44 to 8.39 in./sy) for PCCP. The cracks do not perform as an index of deterioration degree for CRCP. The average cracking index for CRCP vary from 51.0 to 51.4 cm/m^2 (approx. 16.78 to 16.92 in./sy), and average cracking space is about 0.6 m. The average paching amount is 20.0 to 75.9 m^2/1000 m^2 (approx. 0.02 to 0.08 sy/1000 sy). The cracks of concrete

Table 1 Nature of Existing Pavement

Item \ Pavement Type		Jointed PCCP	CRCP
Average Rut Depth (mm)	Up track	31.4	23.0
	Down track	38.8	34.1
Average deffection (mm)	Up track	0.38	0.43
	Down track	0.42	0.45
(*1)Cracking index (cm/m^2)	Up track	25.5	(*2) 51.0
	Down track	22.6	51.4
Patching (m^2/1000m^2)	Up track	20.0	75.9
	Down track	25.5	59.4

(*1) So called cracking index in Japan: Total length of all ranked cracks divided by paved area.

(*2) In CRC mean crack spacing is about 0.6 m.



H_1: crushed-run; 35 to 38 cm

H_2: existing concrete slab thickness, PCCP; 23 cm, CRCP; 20 cm

C: cutting depth, 3 cm

t: overlay thickness, jointed PCCP; 5 cm, CRCP ; 6 cm

Fig. 2 Cross-section & Profile of Repaired Pavement slab caused by the increasing traffic flow and the lowering of subgrade bearing capacity and increase of deflection caused by immersion in rain water, frost heaving, and frost action were confirmed by analyzing the existing slab. This was done before laying the TBCO.

2.2 Design of TBCO

The following items were taken into consideration for the repair of existing pavements.

(1) In the Hokkaido region, wear during winter can be up to 10 to 15 mm (approx. 0.39 to 0.59 in.) during winter, therefore, the pavement should be made into wearing resistant pavement and the road surface should be repaired so that it is very flat.
(2) The construction period should be shortened as much as possible, because the road is presently in use.
(3) An economical repair method should be created, while considering changes in the height of the road facilities such as sidewalks and guard cables.
(4) The structure should be reinforced by increasing the thickness of the pavement in order to withstand the future traffic flow volume.

The results for TBCO with regard to items (1) to (4) written above demonstrate the superiority of TBCO. Further, the deterioration degree such as cracking and/or broken joint edge onto the existing slabs was decided to be structurally repairable, although the wear of slab was severe. This deterioration was judged to be able to repair by partial replacing (entire replacement for some parts), and undersealing. Therefore, these methods are believed to be efficient for TBCO.

The damaged existing road surface was scraped down 3 cm deep, and then, the surface was cleaned by steel shot blasting. The concrete overlay was laid down after these procedures. In this method, the PCCP is then thickened from 23 cm to 25 cm (approx. 9.06 to 9.84 in.) and CRCP from 20 cm to 23 cm (approx. 7.87 to 9.06 in.), along with the construction of a stable and smooth road surface.

2.3 Outline of constructed TBCO

Table 2 shows the conclusion of an experimental TBCO construction from 1984 to 1987. The object of 1984's experimental construction was to confirm the possibility of using TBCO, plus, to decide on a suitable bond treatment method for bonding the overlay to existing concrete. An ultra rapid setting cement was used in practical stage of the overlay beginning in 1985 because the road was urgently needed in service by the local citizens. The following preventative repair treatments were done where needed: Joint sealing materials were re-applied, undersealing was put in place on places with large deflections, and places with big cracks were partially or totally replaced. Steel fiber reinforced concrete (SFRC) was used for PCCP with great cracks, that however, did not need to be replaced. SFRC was also used for CRCP in the 1986 experimental CRCP slab construction area in consideration of crack-control. The new TBCO, similar to the one laid in 1987, will be laid on the remaining CRCP in 1988, and the TBCO construction work of the Mori Bypass Highway will be completed.

3. Construction of TBCO

There are no big differences in the construction method for TBCO with the methods of the U.S.A. or other countries. Simple guidelines for the constructing method is written in the following.

3.1 Undersealing of Existing Concrete Slab

The undersealing was done using injection holes put in every 3.5 m^2 (approx. 11.5 square feet) of the slab with existing PCCP having large deflections. The method for the stabilization treatment on poor ground was used in this treatment, although the bituminous material injection is normally made in paving construction field. This method type injected high pressure stabilizer horizontally under the concrete slab through the inserted nozzle. A colloid cement grout adjusting its gelling time was used as the stabilizer so the road could be used quickly after the execution of the work. The deflection obtained from Benkelman beam, showed an improvement result of 5 to 15% after undersealing.

3.2 Cutting of Existing Concrete

The cutting of the existing PCCP to the specified depth was completed without any trouble in one pass, using a heavy cold planer.

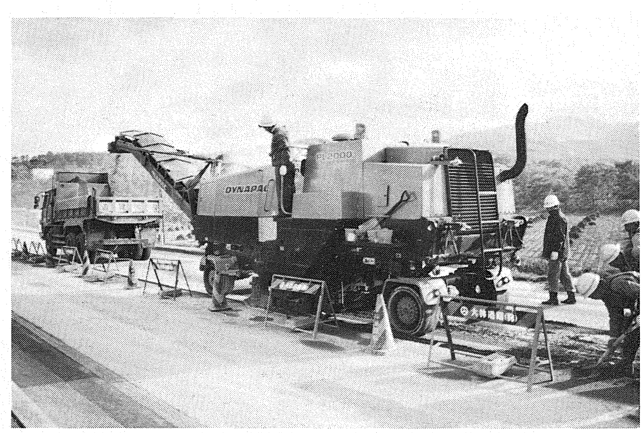


Photo 1 Cutting of existing concrete by large size cold planer

Table 2 Outline of the Work

NO.	Year	Existing Slab	Construction Length(*1)(m)	Overlay Type (*2)	Overlay Thickness(cm)	Preventative Construction Method	Bond Treatment
1	1984	PCC	80	PCC	5	—	Steel Shot Blasting(S.B.)
							(S.B.)+Cement Paste
							Polymer Cement Paste
2	1985	PCC	816	PCC	5	—	S. B.
			338	JCC			
3			14	—	—	JCC for All Layers by Partial Replacing	—
4	1986	PCC	872	PCC	5	—	S. B.
5			264	JCC	5	—	S. B.
6			24	PCC	5	Under-sealing	S. B.
7			8	JCC	5		S. B.
8			280	SFRC	5		S. B.
9			24	JSFRC	5		S. B.
10			112	—	—	Partial Replacing	—
11			96	—	—	Entire Replacing	—
12		CRC	80	PCC	8	—	S. B.
13			80	SFRC	8	—	S. B.
14	1987	CRC	312	SFRC	6	—	S. B.
15			34.5	JSFRC	6	—	S. B.
16			506.5	SFRC	6	Under-sealing	S. B.
17			75	—	—	Entire Replacing, PCC	—

*1 Total lenghth equivalent to 3.5m in constructed width of single-lane highway.

*2 JCC: Ultra Rapid Setting, SFRC; Steel Fiber Reinforced Concrete, JSFRC; Ultra Rapid Setting SFRC.

If the planer breaks the main reinforcing steel bar when cutting CRCP, the damage will be great for both pavement and planer. Therefore, the depth of the reinforcing steel bar must be detected with the reinforcing steel bar detector, before conducting cutting work. Still, the efficiency of cutting work is greatly affected by the hardness of the existing pavement, therefore, adequate analysis of the hardness is necessary beforehand. Photo 1 shows the existing concrete pavement being cut.

3.3 Bond Treatment of Boundary Surface

The bonding to the boundary surface of existing concrete pavement is very important for TBCO. Therefore, further precaution was taken before the execution of the work. The first step was to perform shot blasting with Φ1.4 mm (Φ0.055 in.) diameter steel balls commonly used for removing rust from a deck of a ship. The polished dust was able to be collected and the steel balls were retrieved with the vacuum device. The shot blasting density, which means the weight of steel balls for shot blasting, per square meter can be adjusted. The density was set to 100 kg/m^2 (approx. 184 ℓb/sy) to create minute irregularities on the cut concrete surface, and then the loose aggregate was eliminated by shot blasting. The second step was to select an adequate adhesive and to apply it on the shot blasted concrete surface. The construction efficiency and the bond strength of the adhesive were superior when a new concrete was placed onto a completely dried shot blasted surface. This was

Photo 2 Shot blasting with Φ1.4 mm steel balls

demonstrated in the adhesion experiment indicated later. Because of the abovementioned effects, this method was chosen.

3.4 Overlay of Pavement

PCC and SFRC were used for the overlay concrete. The use of steel reinforcement is for the crack control, as explained above. PCC is the matrix of SFRC at the same time, and the following items were considered as measures for increasing the wear resistance of the PCC. The mix proportion is as shown in Table 3.

Table 3 Mix Proportion for Overlay Concrete

No.	Max Size of Coarse Aggregate (mm)	Slump (cm)	Air Content (%)	Water Cement Ratio, W/C(%)	Sand Percent-age, s/a (%)	Unit Volume (kg/m^3)					
						Water (w)	Cement(c)	Fine Aggregate (S)	Coarse Aggregate (G)	Steel Fiber (SF)	Admixture
1	25	6 ± 2	4 ± 1	40	40	148	370	781	1185	—	0.148 3.70
2	25	6 ± 2	4 ± 1	45	50	173	384	928	826	100	0.061 4.99
3	25	10± 3	—	37	38	137	370	784	1287	—	7.4 0.74 37.0
4	25	10± 3	—	39.5	53	158	400	1035	836	100	8.0 0.8

No.1: High Early Strength Portland Cement Concrete

No.2: Steel Fiber Reinforced High Early Strength Portland Cement Concrete.

No.3: Ultra Rapid Setting Cement Concrete

No.4: Steel Fiber Reinforced Ultra Rapid Setting Cement Concrete.

(1) The maximum size of aggregate was not able to be enlarged, because the overlay was a thin surface. Therefore, the water content per unit volume of concrete was lowered to make stiff consistency concrete although, the construction efficiency was improved by adding a plasticizer.
(2) The quality of the coarse aggregate is important for increasing wear resistance, therefore, coarse aggregates with minimal abrasion loss were selected.

Cost of concrete paving were rationalized, by using a paver capable of placing, compacting, and surface finishing the concrete by itself after receiving concrete from the agitator truck. Since the ultra rapid setting cement is available in only a short time, a moving mixer carrying concrete material was moved to the site, and man power was used to compact the concrete.

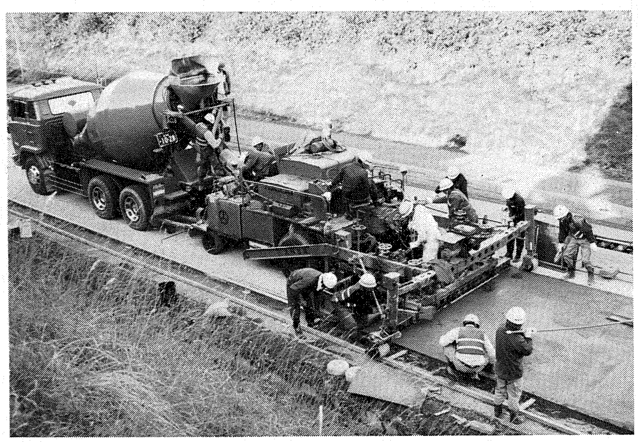


Photo 3 Concrete placing by using a paver

In principle, the TBCO joint should be set by the same type and at the same location as the existing PCC slab joint. Though, as for TBCO used on the existing CRCP, a cut joint has been applied at every 16 m (approx. 52.05 ft) since 1987, based on a number of experimental constructions in 1986.

4. Serviceability of TBCO

In Japan, actual successful cases of laying TBCO on an existing concrete pavement surface began in 1983. Accordingly, adequate service evaluation data and the technical level of other countries, have not yet been obtained. Further, cases of putting TBCO on the existing CRCP are rarely found even in the foreign countries, therefore, continuing checks of the pavement in service are necessary.

4.1 Cracks

Cracks on TBCO were fine, and will not effect serviceability, although, it is necessary to analyze cracks as an index for the deterioration which may occur in the future.

4.1.1 Cracks of TBCO with Jointed Concrete Pavement and Effects of the Applied Preventative Repair Method

Cracks on the TBCO depend greatly on the soundness of the existing PCC slab. Cracks should be classified as being one of the following three types:

(1) There were no cracks on the existing slab, but there were cracks on the TBCO. (Type I)
(2) The crack on the existing slab was located on a different position from that of TBCO. (Type II)
(3) The crack on the existing slab was located on the same position as that of TBCO. (Type III)

Table 4 and Fig. 3 show typical examples of the jointed PCCP in 1985 and 1986 in which the preventative repair method was not used, according to each type. In the section repaired in 1985, the cracking index of the existing slab was 2.67 cm/m^2 (approx. 5.67 in./sy) while the cracking index of TBCO indicated 3.56 cm/m^2 (approx. 7.56 in./sy) 30 months later. Although the cracking index of Type III at 1.75 cm/m^2 (approx. 3.72 in./sy) was still smaller than the numeric value of existing slab, it is true that cracks in Type I have gradually increased. In the section constructed in 1986, the cracking index of the existing slab was 6.51 cm/m^2 (approx. 13.83 in./sy) while the cracking index of TBCO and the cracking index of entire section was relatively small, being 2.15 cm/m^2 (approx. 4.57 in./sy), but the cracks of Type III will be probably getting growth.

The cracks of the overlay concrete of Type I can be speculated as occurring due to the fact that the volume change (i.e. shrinkage) of its overlay concrete is restrained by the existing slab bonded. Further, the cracks in Type II mean that cracks occur on the existing slab but they are small and the location of the cracks is different from those of TBCO. In such a case, the cracks of the existing slab are not assumed to influence TBCO at all, and the occurrence of cracks may also be caused by the fact that the volume change (i.e. shrinkage) of overlay concrete is restrained by the existing slab as same as Type I. Type III means that the cracks of

Table 4 Cracking (May, 1988)

No.	Year	Total Length of Existing Slabs (m)	Crack Length of Existing Slabs (cm)	Crack Length of TBCO (cm)			Remarks
				Type I	Type II	Type III	
1	1984	80	0	994			PCC
2	1985	816	7867	3601	1024	5918	PCC
		338	2925	1905	801	1150	JCC
3		14	0	—			—
4	1986	872	22144	254	375	6998	PCC
5		264	3747	119	99	690	JCC
6		24	2001	—	771	1340	PCC + Undersealing
7		8	632	—	25	—	JCC + Undersealing
8		280	34110	—	449	2564	SFRC + Undersealing
9		24	2734	—	—	84	JSFRC + Undersealing
10		112	15390	31	568	—	Partial Replacing
11		96	16726	40	—	—	Entire Replacing
12		80	8580	—	350	1750	PCC CRC
13		80	8050	—	350	350	SFRC CRC
14	1987	312	53289	—	352	3176	SFRC CRC
15		34.5	5706	—	370	442	JSFRC CRC
16		506.5	121668	—	4019	8063	SFRC + undersealing
17		75	8974	—	—	9552	Replacing

Type I: cracks occurred on no crack slab
Type II: cracks located on a different position
Type III: cracks located on a same position

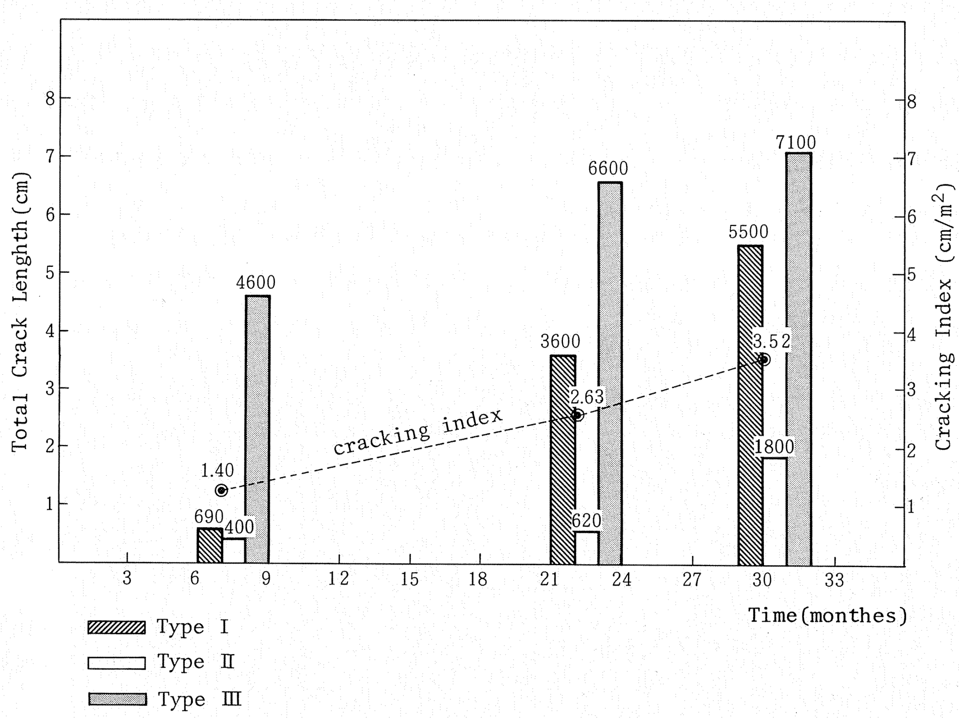


Fig. 3 Secular Change of Cracks on TBCO

the existing slab affect the TBCO, and the longer the cracks of the existing slab are, the greater the slab movement is and the greater the reflection coefficient on TBCO is, as shown in Fig. 4. These cracks are still tiny and there is no separation of new and old concrete on the cracking portion. However, when the cracks of Types I and II increase and the deterioration becomes greater at that portion in the future, the spacing and structure of the joints made in TBCO should be reconsidered.

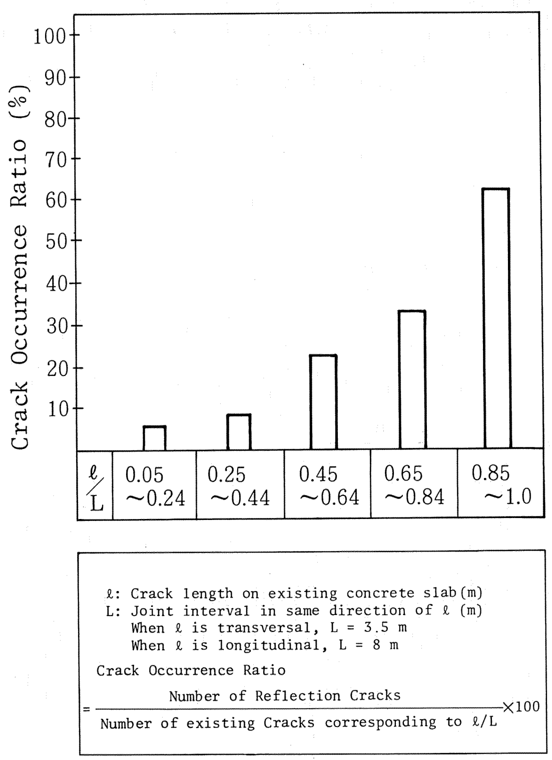


Fig. 4 Existing Cracks and Reflection Crack Occurrence Ratio

Table 5 indicates the state of crack occurrence in the case that the preventative repair method is performed. It also gives the reflection coefficient of the cracks for the TBCO. According to this table, the reflection coefficient in the case that undersealing is performed, is remarkably greater than that having no preventative repair method. The practicability by only undersealing is limited by the amount of cracking occurring in the case that the cracking degree of the existing slab is remarkable. In the case that the TBCO of SFRC is applied after undersealing, the reflection coefficient is 7.2 % even when the cracking index of the existing slab is relatively great, thus indicating that the effect of SFRC is very large. It is also clear that the greater effect can be expected in the case that a partial or entire replacing is carried out. However, it is difficult from the economic point of view to apply this method on roads in service because this produces difficult traffic control problems and on the section where the cracking index is small. Thus, the limited use of this method is recommended.

4.1.2 Cracks of TBCO with Continuously Reinforced Concrete Pavement

Table 4 aforementioned and table 6 indicate the state of crack occurrence six months after being in service when TBCO was applied to the existing continuously reinforced concrete pavement. Since SFRC was used to control cracks, the average cracking index 55.0 cm/m^2 (equivalent to 116.81 in./sy) was considerably reduced to 5.6 cm/m^2 (approx. 11.89 in./sy). As for the state of crack occurrence, the absolute value of the cracking index was great, compared with the case that TBCO was applied to jointed PCC. However, the discussion about cracks of TBCO onto CRC can, in principle, be done by the same method as those of jointed PCC, that is, when the occurrence of cracks of TBCO is discussed they are classified into 3 types as explained in 4.1.1. There are no cracks

Table 5 Effect of Preventative Construction Method Constructed in 1985, 1986

As of May, 1988

Preventative Construction Method	Existing Slab			TBCO		Reflection Ratio (%)	Cost (yen/m^2)
	Area (m^2)	Total Crack Length (cm)	Cracking Index (cm/m^2)	Crack ※ Length (cm)	Cracking Index (cm/m^2)		
None	8015	36683	4.58	14756	1.84	40.2	6700
Undersealing	112	2633	23.51	1340	12.00	51.0	10200
Undersealing +SFRC	1064	36844	34.63	2648	2.49	7.2	13900
Partial Replacing	392	15390	39.26	0	0.0	0.0	12500
Entire Replacing	336	16726	54.31	0	0.0	0.0	

*) For Type III cracks only.

Table 6 CRC constructed in 1987

	Existing Slab			TBCO		Reflecting Ratio (%)	Construction Cost (yen/m2)
	Area(m^2)	Total Crack Length (m)	Cracking Index(cm/m2)	Total ※ Cracking(cm)	Cracking Index(cm/m^2)		
SFRC	1092.0	53289	48.8	3176	2.91	6.0	10400
JSFRC	120.8	5706	47.2	442	3.66	7.8	27800
Undersealing + SFRC	1772.8	121868	68.7	8063	4.55	6.6	14800

*) For Type III cracks only.

which were classified as being Type I in CRC. Therefore, there in practice are only two types. There are 63 cracks classified as being Type 3 among the 93 cracks occurring 6 months after going into service. The 63 cracks are also divided into the 39 cracks reflecting passing-through of cracks from the existing slab and into the 24 cracks reflecting nonpassing-through cracks. If the reflection crack occurs due to a great movement of the existing slab crack portion, it is clear that the 39 cracks are large cracks with relatively wide hinge effect that occurred during the early construction phase (1 to 2 weeks). The 24 cracks are classified as being Type III. However, since the passing-through cracks were not found on the existing slab, the actual cracks may have occurred because the volume change (i.e. Shrinkage) of TBCO is restricted by the existing CRC, which is the same phenomenon as the cracks classified as being Type II. It is also clear that the greater part of dense cracks closed to each other which are characteristic of CRCP do not influence the crack occurrence in TBCO.

Photo 4 Typical cracks of TBCO on existing CRCP

As a preventative repair method in the case of applying TBCO to the existing CRC, SFRC was totally used. Accordingly, only the effect of undersealing was estimated, but a considerable effect was not found in these works. Thus, it is better to discuss the reflection cracks in this undersealed section as the entire subgrade soil problem.

4.2 Road Surface Wear

The road surface of Hokkaido is subject to wearing action in winter due to the use of studded tires and tire chains, leading to repair work, rather than problems of cracks. The relationship between the cumulative traffic flow volume of large sized vehicles and the cumulative abrasion loss is shown in Fig. 5 for the section fixed in 1984 which has the longest in service results. When compared with the data concerning the existing PCC of the Mori Bypass and the asphaltic concrete pavement at other locations, the following facts were made clear:

(1) The coarse aggregate with a maximum size of 25 mm (approx. 0.98 in.) was used in TBCO taking into account the thickness. By selecting the coarse aggregate with little abrasion loss with the Los Angeles Abrasion Test, the same durability in resisting against abrasion loss was obtained as that of the existing slab with maximum size of 40 mm (approx. 1.57 in.).

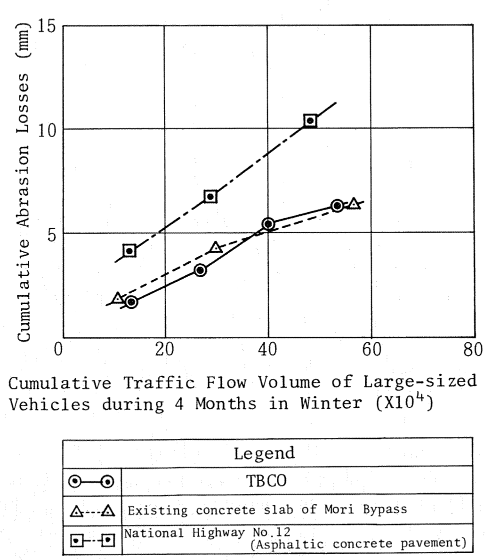


Fig.5 Abrasion Loss of Rutting Portion

(2) Durability was twice that of high quality asphaltic concrete pavement which showed its superiority in resisting abrasion loss.
(3) The abrasion loss in ruts in TBCO is 1.6 mm/year (approx. 0.06 in./year), which means that repair dues to wearing will not be necessary for more than ten years, even after taking the increase in traffic flow volume into account.

Moreover, the surface smoothness was measured with a 3 m (approx. 9.84 ft) profilemeter. As a result, the road keeps its smoothness, compared with its original smoothness immediately after construction.

4.3 Bond strength of TBCO

There are reports saying that 14 kg/cm^2 (approx. 199.08 psi) or more of shear strength is sufficient for bonding between the existing pavement and TBCO[4]. However, the bond-tensile strength was measured in-situ, taking into account the application to the execution control. It was performed as follows:

(1) A core was made into a TBCO layer.
(2) A cap was tied or bonded to the top of the cored TBCO pavement by means of a bolt or adhesive accordingly, then,
(3) The cap was pulled by a hydraulic jack.

Fig. 6 shows the results of the tests conducted in 1984 for the purpose of obtaining an optimum bonding method. This figure also indicates other construction examples on the bond-tensile strength between the existing pavements and TBCO. In order to obtain the maximum strength, the figure shows that it is better to apply the method in which TBCO is placed after drying the road surface by blasting the surface with Φ 1.4 mm (Φ0.055 in.) steel balls, However, breaking did occur on existing concrete and TBCO portions other than on bond surface and also greater fluctuation occurred. As for the degree of increase in bond strength (see Fig. 7), when cement paste materials were used as an adhesive agent, there was not sufficient strength in the early phase. Thus, shot blasting makes small unevenness and blasting is performed to remove the loose aggregate, then dust, etc. are removed by pneumatic recovery method. This method may be used to obtain satisfactory bond, rather than varying the type of bond material. In the other execution examples shown in Fig. 6, there were no boundary breakings in the laying TBCO. As of the present time, these tests indicate that a safe TBCO has been obtained when it has a 9 kg/cm^2 (approx. 127.98 psi) bond-tensile strength.

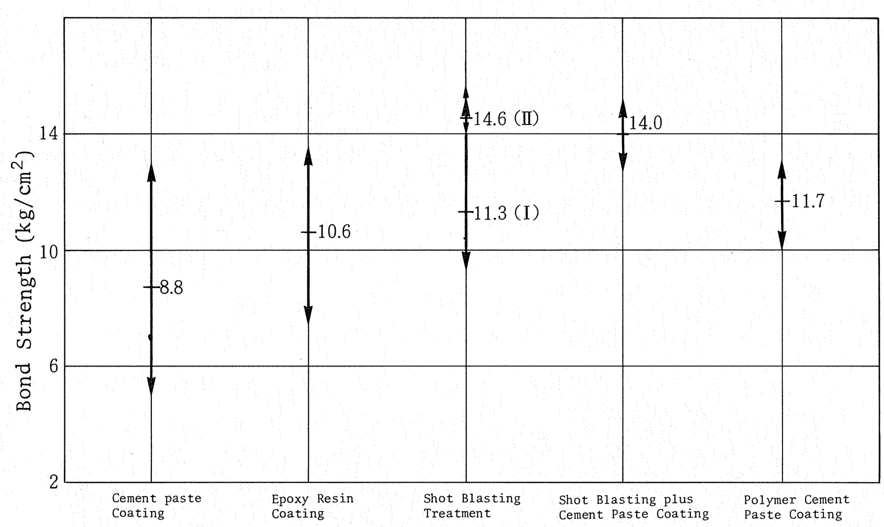


Fig. 6 Bond Strength

5. Conclusion

The items made clear by this examination by laying TBCO and observing it afterwards, can be summarized as follows:

(1) Some tests were performed to secure the bond of TBCO. In these tests, there was no obvious difference into crack occurrence, etc. The method that should be selected differs according what is economical and practical. In the case of a route that is in service, it would

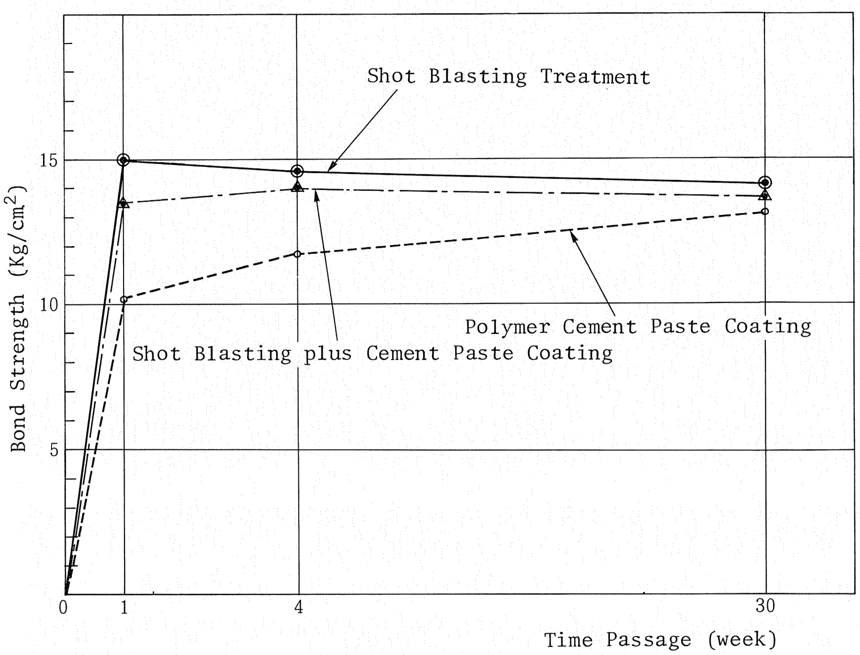


Fig. 7 Change in Time of Bond Strength

be better to use shot blasting of steel balls to obtain the advantages of quick construction and secure bonding.

(2) The cracks occurring on TBCO are tiny at the present phase (width; approx. 0.6 mm equivalent to 0.24 in. or less) and have no influence on serviceability. These cracks should be classified into three types according to the state of crack occurrence. In addition to the reflection of the existing cracks, there are cracks occurring by regarding the existing slab as a restrictive body. This is the same situation that exists for both PCC and CRC.

(3) As a preventative repair method, the use of SFRC is effective. In particular, replacement is more effective in locations suffering from severe damage.

(4) When TBCO is applied to CRC, many existing cracks did not reflect on TBCO, since SFRC, which is resistant to cracks, was used. It is reasonable to suppose that the reflecting cracks are cracks with wide hinge effect which occurred during the early phase of construction of the existing CRCP. Accordingly, TBCO using SFRC may be designed the same as PCCP, regardless of CRCP.

(5) In developed regions in Japan, old roads naturally require repair work under various restrictions. In such circumstance, TBCO is one of the most promising methods. However, Japan is far behind in the study of this field, because concrete pavement occupies too small a portion of Japanese pavement methods. TBCO as well as its preventative repair methods should be studied from now on.

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