Research and Application of Thin Slag Porous (TSP) Pavement Method

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ABSTRACT: With the natural quality resources being increasingly consumed, the pavement repair method utilizing recyclable materials from the other industries such as steel slag is today more anticipated, for its capability of resource-saving, cost-reduction and minimizing CO_2 emission. The method we developed has shown about 15 % of cost and 20 % of CO_2 reduction, compared with the conventional method, by utilization of recyclable resources from the other industries and by adoption of thin cut and overlay on thick tack coating. Herein, we intend to verify the feature of this method by means of various indoor tests and several experimental field-pavements, and consequently will confirm that the section of repaired pavement stands workable from the viewpoint of the layer structure analysis (elasticity theory).

KEY WORDS: Porous pavement, steel slag, modified asphalt emulsion, cost reduction, CO_2 emission reduction

1 INTRODUCTION

This study intends to develop pavement repair method that contributes to cost/energy-saving, well environment-friendly and good for local areas.

In the regional road maintenance program, particularly under recent financial difficulties, an establishment of new pavement repair method is anticipated, in which “locally -produced / locally-consumed” recyclable materials available from the other industries, such as steel slag, are efficiently utilized and quality-wise improved by the use of modified asphalt, that eventually will lead to lower cost and CO_2 emission (Figure 1).

The technology we developed for the mentioned purpose, called Thin Layer Slag Porous Pavement method, or “TSP” method, unlike the conventional standard one, does not require large-scale cutting or replacing. Instead, it involves reinforcing the cut road surface by spraying a large amount of special tack coat on the existing cracks(Fujimoto et al.2009) and overlaying with highly durable porous asphalt mixture which contains hard and potentially hydraulic steel slag and high durable modified asphalt thereon. The method was developed to construct a thin but durable pavement structure (Figure 2).

This method is, in principle, to be applied for roads of daily traffic volume of less than 1,000 vehicles a day (traffic class: N5). The results of development and investigations were verified by executing test pavements and follow-up surveys in relation therewith.

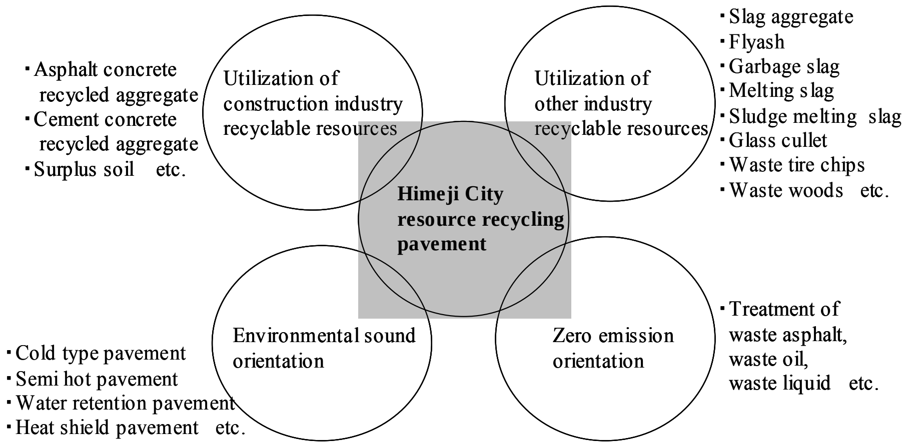

Figure1: Relationship of resource recycling pavement and road needs

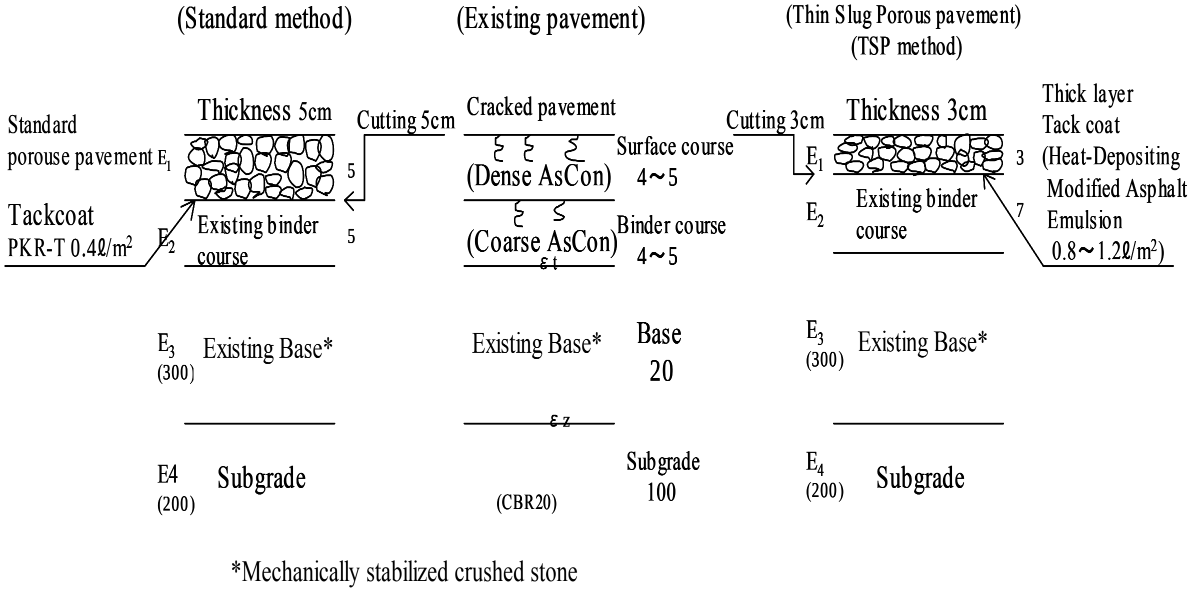

Figure2: Basic cross section of repaired pavement

2 OBJECTIVES OF DEVELOPING THE TSP METHOD

The TSP method was developed with the following objectives:
(1) Improve the quality of steel slag to work out mix design of TSP asphalt mixture which can hold highly water-resistant in thin layer porous pavement.
(2) Develop Highly Durable Modified Asphalt highly affinitive with steel slag, in order to produce durable and thin pavement.
(3) Develop tack coat to be sprayed massively on the existing cracked road surface after removing thin layer of the surface course and develop Heat-Depositing Modified Asphalt Emulsion required for such tack coating.
(4) Investigate the performances and problems of the TSP method by executing two or more test pavement works, and verify the layer structure of the repaired pavement (of which cross-section shown per Figure 2).

3 INVESTIGATIONS ON DEVELOPMENT SUBJECTS

3.1 Development of Applied Materials

3.1.1 Utilization of Steel Slag, Melting Slag, and Other Industrial Wastes

From the viewpoint of resource-recycling, the use of steel slag which is produced during the process of steel manufacture, particularly converter slag (in our case available from Hirohata Works of Nippon Steel Corporation), has been investigated to take advantage of their potential properties (hydraulic property, hard abrasion resistance, etc.) for porous pavement (Michishita et al. 2003).

In this Research and Development project, the use of electric arc furnace slag for coarse aggregates and the use of urban solid waste melting slag for fine aggregates were also investigated as shown in Table 1. In Kansai Region (where we are based), the use of natural sea sand (which we used to procure from the Inland Sea) has been banned, and thus the utilization of artificial sand will become important issue (Yamada, 2008). As to steel slag, a crusher (Adjust grading machine, Barmak, Japanese make) and a special screening machine (Jumping Screen, Germany make) were partly used to reduce and regulate the particle size.

Table1: Properties of investigated slag

Test Item		Test method[*1]	Converter slag (Hirohata Mill of Nippon Steel Co.,Ltd)[*2]	Electric furnace slag (Sanyou Special Steel Co.,Ltd)	Garbage molten slag (Garbage disposal plant in TATSUNO city)
Apparent density (g/cm^3)		A001	3.88	3.44	2.82
Water absorption(%)		A001	1.32	1.23	0.34
Abrasion Loss(%)		A005	9.5	17.8	-
PSV(BPN After accelerated polishing)		A006	48	-	-
Weight percent passing sieve, (%)	13.2m/m	A003		100	
	9.5		100	74.5	
	4.75		13.5	9.8	100
	2.36		4.1	3.3	99.2
	0.6				41.0
	0.3				14.0
	0.15				4.6
	0.075				1.8

*1 Japan road association, Manual for Pavement-survey and Test method

*2 (Michishita et al.2003)

3.1.2 Development of Highly Durable Modified Asphalt

(1) Objectives of Development and Properties of Highly Durable Modified Asphalt

Development of modified asphalt has already been investigated in relation with practical performances of the pavement (Yamanokuchi et al. 2008). Meanwhile in this particular study, a highly durable modified asphalt designed for the TSP method being water resistant even under severely watery conditions and aggregate stripping resistance even in thin layer ("EverFix-TLa" by our product code; hereinafter referred to as Highly Durable Type-H) was developed, aiming for the following properties (Uesaka et al. 2009) (patent under application).

Form an even film over the porous surface of slag aggregates and make the mixture highly water resistant.

Make the mixture have high dynamic strength and aggregate fretting resistant (which is to be evaluated mainly by splitting test and Cantabro-test).

The properties of the developed Highly Durable Type-H are shown in Table 2.

Table2: The properties of Highly Durable Type-H

Test Item		Test method*1	Result	Standard properties*2 (Standard Type H)
Softening point	(°C)	A042	91	80 and over
Ductility(15°C)	(cm)	A043	75	50 and over
Toughness	(kN)	A057	21	20 and over
Penetration	(1/10mm)	A041	53	40 and over
Residue of penetration by Thin film oven test	(%)	A046	77.4	65 and over
Density	(g/cm^3)	A049	1.031	Report

*1 Japan road association, Manual for Pavement-survey and Test method

*2 Standard properties are defined as per "Pavement Works Manual" (Japan Road Association)

(2) Results of Mixture Test

To assess its water resistance, 20°C Cantabro-test of the immersed mixture was made. Immersion condition was set as severe as 60°C water temp. x 96 hours. Figure 3 shows comparison between standard Polymer Modified Asphalt Type-H (hereinafter "Standard Type-H") and Highly Durable Type-H .

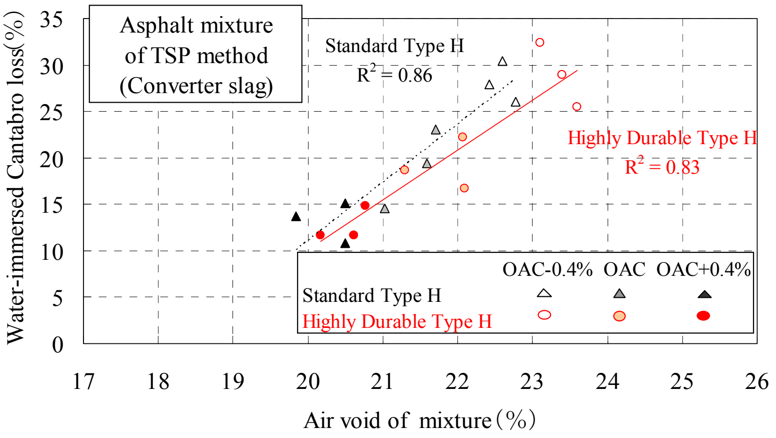

Figure3: The relation between air void of mixture and water-immersed Cantabro test loss

3.1.3 Development of Heat-Depositing Modified Asphalt Emulsion

(1) Objectives of Development and Properties of Heat-Depositing Modified Asphalt Emulsion

The Heat-Depositing Modified Asphalt Emulsion (hereinafter HDMA emulsion) for the thick tack coat ("HighBrawn-SA" by our product code) was developed so as to have the following properties (Fujimoto et al. 2009) (patent under application):

Well penetrate into and fill cracks on existing road surface. Engler viscosity and dissolubility of the emulsion are to be adjusted for this purpose.

Well bleed at the bottom of the overlying porous pavement. For this purpose, a modified asphalt used for this emulsion has to have asphalt residue after dissolution less viscous at around 130°C, which is the temperature during the late roller compaction process, and viscous enough not to drip at lower temperatures.

Enable large amounts (0.8 to 1.2 l/m^2) of tack coat material to be sprayed on the existing road surface in order to be bound with surface pavement to form a strong water-proof binding layer. For this purpose, asphalt to be emulsified has to have been modified with petroleum resin eligible to form strong binding layer densely water-proof and less adhesive to vehicle's tires after dissolution of the emulsion. The properties of the HDMA Emulsion are shown in Table3.

Table3: The properties of the HDMA Emulsion

Test item	Test method	Results	Standard properties*
Engler viscosity(25°C)	JIS K 2208	15	3 to 30
Residue sieve(1.18mm) (%)		0.3	max. 1.0
Particle charge		Positive(+)	Positive(+)
Residue from evaporation test (%)		62	min. 60
Penetration(25°C) (1/10mm)		10	max. 20
Strage stability(24hr) (%)		0.4	max. 1.0

*Our own Standard properties

(2) Test Results

Penetration Test: To improve the penetration of HDMA Emulsion, the test was made with smaller particle size than usual, judging from the past results of prior tack-coating works on cracked road surfaces (Kobayashi et al. 2007). Consequently, particle size as small as approximately 2 X 10^{-6} m was found to be most effective. Mix design was then decided after further adjustments of viscosity, etc. Penetration of HDMA Emulsion improved this way is as shown in Figure 4.

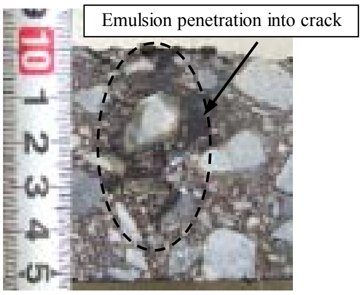

Figure 4: Penetration of HDMA Emulsion for crack (example of field cutting core, No.1 pavement project)

Adhesion Test: The adhesive strength of tack coat materials was tested using the tensile testing machine (made according to Building Research Institute's guideline) (Table 4).

The results showed that the tack coat using HDMA Emulsion had the largest adhesive strength. Failure was not found on tack coat surface (but at the mixture), proving HDMA Emulsion's eligibility.

Table 4: Adhesive strength test of several tack coat materials by tensile test method of the Building Research Institute type (cutting sample of WT specimen)

Kinds of Emulsion and distribution amount	Typical size of particles(10^{-6}m)	Test temperature(°C)	Adhesive strength(MPa)	Fractured point
PKR-T 0.4 l/m^2	3.6	20	0.60	Tack coat interface
		35	0.21	Tack coat interface
Emulsion POS 1.2 l/m^2	3.8	20	0.70	Tack coat interface
		35	0.32	Central part of binder course
Reclamait disposition +PKM-T 1.2 l/m^2	1.8 +6.2	20	0.62	Upper part of binder course
		35	0.31	Upper part of binder course
HDMA Emulsion 1.2 l/m^2	2.1	20	0.77	Upper part of binder course
		35	0.45	Central part of binder course

3.2 Mix Design of the Asphalt Mixture for TSP Method

As the TSP method should be designed and executed with different types of aggregates, the following investigations were made to determine mix design:

Investigate mix design for each two different kinds of fine aggregate and coarse aggregate within the regular aggregate gradation range for porous pavement (mainly at test pavement work No.1 pavement project).

Assessing the mechanical properties of the mixture by conducting Cantabro Test (water-immersion test included) in which aggregate fretting resistance is mainly considered.

Mix-A is a fine grade type (void ratio 17 to 18%) with smooth surface for light traffic roads, while Mix-B (and C) is a coarse grade type (void ratio 22 to 23%) with higher functions such as permeability, for roads in residential areas. The optimum amount of asphalt (%) was determined in consideration of the results of physical property tests, etc. These mix properties, such as aggregate gradation, respectively at the time of in-door mix test and manufacture at plant, are shown in Table 5.

Table 5: The properties of the asphalt mixture for the TSP method

Kind of mix proportion			A <Type of fine grade>		B,(C) <Type of coarse grade>	
			(No.1)	(No.2)	(No.1)	(No.2)
Aggregate mix proportion (%)	Coarse aggregate(steel slag)		85	82	91.6	90
	Fine aggregate(natural sand)		11.5	7.3	5.0	-
	(melting slag)		-	7.2	-	6.6
	Filler		3.5	3.5	3.4	3.4
	Fiber (outside)		0.1	0.1	0.1 (-)	0.1 (-)
Quantity of asphalt (%)			4.3	4.7	4.1 (3.8)	4.2 (4.0)
Density (g/cm^3)			2.66	2.46	2.53 (2.51)	2.33 (2.30)
Voids (%)			16.5	17.4	22.0 (23.0)	24.0 (24.5)
Hot bin combined gradation (mix design target gradation,%)		13m/m	100 (100)	100 (100)	100 (100)	100 (100)
		10	97.5 (100)	80.3 (76)	96.5 (100)	78.7 (78)
		5	26.2 (26)	25 (26)	20.9 (20)	19.0 (20)
		2.5	18.7 (20)	19.3 (20)	15.4 (13)	14.1 (13)
		0.6	10.6 (10)	6.0 (7)	11.2 (10)	5.1 (7)
		0.074	4.7 (3.5)	3.1 (3.5)	5.1 (3.5)	3.0 (3.5)
Properties of the mixtures	Standard cantabro loss (%)		7.9		13.8 (14.3)	
	Immersion cantabro loss (%)		7.9		15.2 (17.6)	
	Cantabro residual rate[*1] (%)		100		89.9 (76.9)	
Remarks			Converter slag 10m/m top	Electric arc furnace slag 13m/m top	Same left section. ( ) is the C mix proportion (Same the B mix proportion, but has no fiber)	

*1 Residual rate＝{1-(immersion －standard)／standard}×100 (%)

Test condition Standard cantabro:20°C Immersion cantabro:After 48 hours of 60°C water immersion,test at 20°C

4 PAVEMENT STRUCTURE ANALYSIS ON THE REPAIRED PAVEMENT SECTION

4.1 Estimating the Elastic Modulus by In-door Test

We used elastic modulus of hypothetically proportional to the splitting stiffness (= splitting strength / displacement up to the maximum load (MPa/mm)) which is given by splitting test (20°C) of core sample (Equation (1)), to analyze the pavement structure engaged in TSP method mixture (according to the multi-layer elasticity theory).

$$E(\text{ or } E') = Es \times \frac{S(\text{ or } S')}{Ss} \tag{1}$$

Here;

E(or E’) : Elastic Modulus of the mixture to be compared with standard mixture (MPa)

Es : Elastic Modulus of standard mixture (MPa)

S(or S’) : Splitting stiffness of the mixture to be compared with standard mixture (MPa/mm)

Ss : Splitting stiffness of standard mixture (MPa/mm)

4.1.1 Elastic Modulus of the Slag Mixture for Surface Course

Having compared standard porous mixture and TSP mixture, both with Standard Type-H and Highly Durable Type-H, variation by different binder was not found significant, while the splitting stiffness of the TSP mixture(S) was about 2.0 to 2.3 times greater than that of standard porous mixture that uses hard sandstone(Ss), in case of either binder (Table 6). Therefore, assuming that the elastic modulus of the standard porous mixture (Es) is 3,000MPa, which is smaller than that of a standard dense grade mixture (Hisari et al. 2008), E of the TSP mixture is now set at 3,000 × 2.0 = 6,000 MPa.

Table 6: Splitting test results of Standard porous mixture and TSP mixture

Kinds of mixture(Kinds of aggregate)	Kinds of asphalt	Density(g/cm^3)	Splitting strength(MPa)	Splitting stiffness(MPa/mm)
Standard porpous(Hard type sandstone)	Standard Type-H	2.062	1.92	0.91 (Ss)
	High Durable Type-H	2.044	1.82	0.85
TSP mixture(Converter slag)	Standard Type-H	2.644	1.98	2.12 (S)
	High Durable Type-H	2.630	1.84	1.71

4.1.2 Elastic Modulus of Existing Pavement Mixture after Tack Coat

A splitting test was made on core sample of assumedly cracked layer which is filled with HDMA Emulsion to estimate its elastic modulus (Figure 5).

The following three samples were used for the test:

a) Standard specimen of dense grade mixture (13)
b) Above a) with a 0.5 mm slit (in terms of crack) made using a steel plate of 6 X 6.35 cm
c) Above b) filled with HDMA Emulsion

The test results are shown in Table 7. The density differed among specimens because the void ratio of the one with slit increased for the amount of the slit, and the density of the one filled increased by filled emulsion. Now, the elastic modulus of the standard dense grade mixture (a) is interpreted to be 5,000MPa(Es) in consideration of average road surface temperature, etc. in Himeji City (where our test sites are)(Japan road association, 2006), then the same modulus of the cracked pavement surface (b) will be 5,000 X 0.5 = 2,500MPa(E’), from the splitting stiffness ratio shown in Table 5 (S’/Ss = 1.09 / 2.29 = 0.5), and that of the surface reinforced with HDMA Emulsion (c) will be 5,000 X 0.8 = 4,000MPa(E) from the corresponding ratio (S/Ss = 1.75 / 2.29 = 0.8).

Figure 5: Splitting test of several specimen (test temperature:20^{o}C)

Table 7: Splitting test results of several specimen (20^{o}C, loading speed, 50mm/min)

Kinds of samples	Density(g/cm^3)	Splitting strength(MPa)	Splitting stiffness(MPa/mm)
a)Dense graded mix(standard mixture)	2.313	1.87	2.29 (Ss)
b), a) with 0.5mm thick slit, not emulsion applied	2.103	0.77	1.09 (S')
c), b) with the HDMA emulsion applied	2.246	0.80	1.75 (S)

4.2 Pavement Structure Analysis of the Repaired Section TSP

Using the theoretical design method (according to the multi-layer elasticity theory)(Japan road association, 2006) a comparative examination was made on the pavement structure analysis for cross section repaired by the conventional method (= 5 cm cut and overlay) and the one repaired by TSP method (= 3 cm cut and thin-layer slag overlay). (See Table 8. Also refer to Figure 2 quoted earlier.) Respective value of elastic modulus (= E) of each layer of the pavement is determined based on the results of in-door tests (4.1.1 and 4.1.2). The analysis shows that the cross section of TSP method satisfied the required allowable horizontal tensile strain $Stra_t$ ($300 X 10^{-6}$) on the bottom of mixture layer and the allowable vertical compressive strain $Stra_Z$ ($-700 X 10^{-6}$) on the top of the subgrade, if traffic volume falls in N5 class (= number of passes until fatigue fracture: 10^6) as easily as or easier than the section repaired using the conventional standard method. This shows that the strength of the thin layer slag porous mixture and the heat-depositing tack coat contributed to TSP method, namely, to strengthening of the surface course (E1) and the existing binder course (E2).

Table 8: Compared result of conventional standard method and TSP method by pavement structure analysis (elasticity theory)

Setting term	Structure layer	Cross section of standard method			Cross section of TSP method		
		Material	Layer thickness(cm)	Elastic modulus(MPa)	Material	Layer thickness(cm)	Elastic modulus(MPa)
	Surface course(E1)	Standard porous	5	3000	Slag porous	3	6000
	Existing binder course(E2)	Coarse AsCon	5	2500	Dense AsCon +Coarse AsCon[*2]	7	4000
	Existing base(E3)	Crushed stone[*1]	20	300	Crushed stone[*1]	20	300
	Subgrade(E4)	(CBR 20)	100	200	(CBR 20)	100	200
Result of analysis strain($\times 10^{-6}$)		$Stra_t$ 265 $Stra_z$ -437			$Stra_t$ 216 $Stra_z$ -390		

[*1] Mechanically stabilized crushed stone [*2] With HDMA emulsion applied

5 VERIFICATION BY TEST PAVEMENT WORKS

Seven test pavement works(approximately 4,800 m^2) have been so far executed in line with aforementioned studies and developments of materials and method. The objectives of the tests were to determine the area that can be completed in one day, to serve for the convenience of residents by seeking for shortest construction time possible, check work methods to be taken care during winter, etc., and to verify the performances of the paved mixture and road surface.

Examples of measured results in in-door and field tests are shown in Table 9. From these results, Mixture B (coarse grade type, fiber added) was decided to be appropriate and in a good balance between durability (in-door water-immersion Cantabro test, etc.) and performances (field permeability, skid resistance coefficient of the road surface, etc.), and thus was used as a standard for subsequent test pavement works.

Table 9: Measured results indoor and field test (No.1 pavement project)

Kinds of mixture	A (fine grade type)	B (coarse grade type)	C (coarse grade type)
Core density(g/cm^3) (Degree of compaction,%)	2.67(100)	2.58(98)	2.55(97)
Degree of voids(%)	15.8	22.1	22.7
Field permeability test(ml/15sec.)	930	1180	1220
Skid resistance coefficient(DF tester μ60)	0.37	0.37	0.4
Noise measurement[*1](db)		67.3〜69.1(69.4〜72.8)[*2]	

[*1] Noise meter:Lion NL-22, vehicle speed 35km/hr, max value of noise level

[*2] Road of Dense grade AsCon. Surface

6 COST REDUCTION EFFECT

The unit cost was compared between the TSP method and the standard repair method (= cost for preparing and paving 100 m^2). The reduction was mainly attributable to the reductions in the cut and overlay volume (from a removal of 5 cm to 3 cm), while the use of locally produced and consumed materials (i.e., slag in this case) also contributed to cost reduction. Consequently, the cost was reduced by about 15% as shown in Table 10.

Table 10: Unit price comparison of TSP and standard method <trial balance> (per 100m^2)

	A:Standard method (Porous asphalt mixture, 5cm)				B:TSP method (Slag porous asphalt mixture, 3cm)*			
	Specifications	Amount	Unit	Amount of money(yen)	Specifications	Amount	Unit	Amount of money(yen)
Preparations construction	Road cutting 5cm (0.11t/m^2)	100	m^2	48,500	Road cutting 3cm (0.08t/m^2)	100	m^2	48,500
	Wastes hauling 2km	5	m^3	2,110	Wastes hauling 2km	3	m^3	1,266
	Wastes disposal specified	1	set	12,925	Wastes disposal specified	1	set	7,755
	Subtotal-1			63,535				57,521
Pavement construction	Personnel expences	1	set	8,590	Personnel expences	1	set	8,590
	Mixture 5cm (0.107t/m^2)	10.7	t	140,170	Mixture 3cm (0.074t/m^2)	7.4	t	96,200
	Emulsion (PKR-T)	43	ℓ	3,268	Emulsion (HDMA Emulsion)	120	ℓ	19,200
	Plant charge	1	set	10,160	Plant charge	1	set	10,160
	Overhead sharge	1	set	2,625	Overhead sharge	1	set	2,625
	Subtotal-2			164,813				136,775
Direct construction		1	set	228,000		1	set	194,000
Cost of construction		1	set	191,000		1	set	162,000
Subtotal-3				419,000				356,000
Total (Subtotal-3 × Consumption tax 1.05)				440,000				373,800(B/A=0.85)

* Case of using electric furnace slag (Tab.5, B, No.2)

7 CO$_2$ EMISSION REDUCTION EFFECT

The CO$_2$ emissions from the TSP method and the standard repair method were calculated as the total of the unit CO$_2$ emissions of the materials used only in the paved asphalt mixture and asphalt emulsion. The unit CO$_2$ emissions of the materials was defined by the Public Works Research Institute by totalizing but not including CO$_2$ emitted through transportation. A relative comparison of the emissions from the materials shows that the TSP method would reduce CO$_2$ emissions by about 30% from the below-mentioned equation (Japan road association, 2008). This shows that the reduction effect in cut volume (from 5 cm to 3 cm) as well as the effect of using slag, which is locally produced and consumed, does contribute to the total effect, offsetting enough additional emissions by increased volume of Highly Durable Type-H and heat-depositing tack coat (Table 11).

Table 11: The relative comparison of CO$_2$ emission for the mixture and emulsion of TSP method <trial balance>—Based on the unit CO$_2$ emissions of the materials only

	A:Standard method (10.7t/100m^2)					B:TSP method (7.4t/100m^2)^{*6}				
Specifications	Material	Unit	Unit CO$_2$ emissions^{*1} (kg)	Amount	CO$_2$ emissions (kg)	Material	Unit	Unit CO$_2$ emissions^{*1} (kg)	Amount	CO$_2$ emissions (kg)
Coarse aggregate	Natural crushed stone	t	1.25	8.63	10.8	Steel slag	t	1.25	6.36	7.98
Fine aggregate	Natural sand	m^3(t)	0.55(0.46)^{*2}	1.07	0.49	Melting slag	m^3(t)	0.28^{*3}(0.23)^{*2}	0.48	0.11
Filer	Limestone powder	t	1.21	0.46	0.56	Limestone powder	t	1.21	0.24	0.30
Asphalt	Standard Type-H	t	589.08	0.54	318.1	Highly Durable Type-H	t	650^{*4}	0.31	201.5
Subtotal					329.95					209.88
Emulsion	PK-4	ℓ	0.164	42	6.89	HDMA Emulsion	ℓ	0.264^{*5}	120	31.68
Total : Mixture + Emulsion (per 100m^2)					336.8					241.6(B/A=0.72)

*1 The unit CO$_2$ emissions is a thing of Japan road association.2008 (appended table 1.9.2) , It is the ratio that it piles it up, and requested by an expression, by the transportation does not include it. *2 ( ) is value converted unit into t *3 This value is established 0.5 times of natural sand

*4 This value is established 1.1 times of standard Type-H *5 This value is established 1.5 times of PK-4

*6 Case of using electric furnace slag (Tab 5, C, No.2)

8 CONCLUSIONS

Thin layer overlay by modified binder has been generally believed to be applicable only when there are no cracks on the road surface after cutting. The TSP method developed this time, however, turned to be applicable on the cracked roads by forming thick layer of heat-depositing tack coat (massive spraying) prior to overlaying thin layer of slag porous pavement mixture made with highly durable modified asphalt binder. Further, according to the pavement structure analyses led by various in-door mechanical tests, such as the one shown per Table 8 herein, the TSP method is expected to have sufficient bearing capacity, in spite of its thinner cross section than that of conventional standard method. Meanwhile, the aforementioned TSP test pavements show no crack or rutting yet for the two years we have observed. We will continue this observation to more firmly verify the eligibility of the Method. The authors hope that the models by this method would be a help for improving the pavement maintenance of local roads in residential districts.

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REFERENCES

Fujimoto, H., Takeda, K. and Adachi, A., 2009. *The development and construction of heat-depositing modified asphalt emulsion for thick layer tack coat to use for pavement repair method.* Journal of 11th Hokuriku Road Pavement Conference, Japan.

Hisari, Y., Sato, A., Kamada, O., Haga, J. and Kodama, T., 2008. *A Research on Measurement of Stiffness of Asphalt Mixture at High Temperature.* Journal of Pavement Engineering, Vol.13, Japan Society of Civil Engineering, Japan.

Japan road association, 2006. *Manual for Design of Pavement, Appendix-4 and 5 (Theoretical design method).* Japan.

Japan road association, 2008. *Evaluation method for the pavement performance,* CO_2 *emission reduction value, a separate volume 1-9.* Japan.

Kobayashi, Y., Goto, R. and Adachi, A., 2007. *The follow-up survey about the applicability of the microsurfacing in case of municipal road pavement.* 27th Japan Road Conference, Japan.

Michishita,Y., Shibamoto, S. and Hamamoto, R., 2003. *The application to the pavement methods which utilized potential characteristics of the converter slag aggregate.* Journal of 25th Japan Road Conference, Japan.

Uesaka, K., Sugiura, M. and Yamanokuchi, H., 2009. *The development and the application of the special modified asphalt to have supported a purpose.* Journal of 11th Hokuriku Road Pavement Conference, Japan.

Yamada, M., 2008. *About aggregate resources for the pavement and the effective utilization.* Aggregate, Japan.

Yamanokuchi, H., Uesaka, K. and Sugiura, M., 2008. *The study about the performance evaluation test for porous asphalt pavement material (State of the arts).* Hoso(pavement), Japan.