Application of Coarse Steelmaking Slag Aggregates to Water Drainage Pavement

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ABSTRACT: Water drainage pavement composed of coarse steelmaking slag aggregates and high viscosity modified asphalt was applied to the heavy traffic down slopes and crossings on the national highway in Okinawa prefecture, Japan. During two years of observation after start of the application in February,2005, skid resistance, dynamic friction coefficient and in situ permeability volume were traced in period of four months, eight months,one year and two years.The value of skid resistance remained almost at the same level as that at the start time , whereas the value of the dynamic friction coefficient continued to increase during the observation period. Although the in situ permeability volume value worsened during the period, the level of the value after two years application was nearly equal to the value of the nearby pavement composed of natural crushed stones applied during the same period. Considerable abrasion was not observed on the road surface paved with the coarse steelmaking slag aggregates compared to the abraded surface condition paved with the natural crushed stones nearby. The excellent performance serviceability confirmed from the measured results depends on the quality of the coarse steelmaking slag aggregates, which is the small abrasion loss, the high hardness, abrasion resistance and the high skid resistance value. High viscosity modified asphalt which shows the high aggregate disperse resistance to the twist stress of tires is becoming a signature material using the steelmaking slag aggregates on the application for drainage pavement.

KEY WORDS: Steelmaking slag, high viscosity modified asphalt

1 INTRODUCTION

Water drainage pavement has been widely used to mitigate heat island phenomena, control city-type floods during local torrential rains, and reduce traffic noise. Deterioration in durability and skid resistance caused by wearing of coarse aggregates on road surfaces have been observed in water drainage pavement on heavy traffic highways and have been a serious problem.

In this study, steelmaking slag, which is a byproduct of steel production, was used as coarse aggregates for asphalt concrete of water drainage pavement. Steelmaking slag is harder and has better skid resistance than natural crushed stones, and has been widely used for base courses and civil engineering structures.

High viscosity modified asphalt binder, which had improved resistance against dispersion of aggregates caused by torsion of tires, was combined to develop an asphalt concrete mixture for water drainage pavement of improved durability. The developed asphalt concrete was applied on a national highway in Okinawa Prefecture and was assessed. An overview is reported below.

2 QUALITY OF MATERIALS USED FOR THE ASPHALT CONCRETE FOR WATER DRAINAGE PAVEMENT

As water drainage pavement has high void ratio and the mixture mainly consists of coarse aggregates, the characteristics of the coarse aggregates and the binder determine the characteristics of the entire mixture. The quality of the polymer-modified asphalt of improved durability, which used steelmaking slag, are described below.

2.1 Quality of coarse aggregates made of Steelmaking slag

The quality characteristics of the coarse aggregates used in the asphalt concrete for water drainage pavement are shown in Table1. The steelmaking slag was prepared by adjusting the grain size of slag produced at Hirohata iron mill of Nippon Steel Corporation so as to be 5 to 13 mm. The natural crushed stones were hard sandstones produced in Moji, Fukuoka Prefecture, and limestone produced in Okinawa; and they were used after adjusting the grain size at 5 to 13 mm.

The abrasion loss of the steelmaking slag used as coarse aggregates was 9.5%, which was smaller than that of hard regulations (10.3%). It had a PSV of 48, which was lager than 39 of hard sandstone. Therefore, the steelmaking slag was harder, had higher abrasion resistance, and was thus better materials for water drainage pavement than natural crushed stones. The coarse aggregates made of steelmaking slag also satisfied all standards stated in the Manual for Asphalt Pavement by Japan Road Association.

Table1 : Quality of coarse aggregate

Assorted traits		Coarse aggregate			Standard
		Steelmaking slag	Hard sandstone	Limestone	
Density in saturated surface-dry condition	g/cm^3	3.74	2.73	2.71	≧2.45
Water absorption	%	1.3	0.6	0.2	≦3.0
Abrasion loss	%	9.5	10.3	21.9	≦30
Soundness	%	2.5	2.3	2.2	≦12
Submergence expansive ratio	%	0.35	-	-	≦2.0
Stripping area rate	%	3	5	14	-
Skid resistance	(PSV)	48	39	28	-

2.2 Quality of the Highly durable polymer-modified asphalt binder

The quality of the polymer-modified asphalt binder used for the asphalt concrete for water drainage pavement are shown in Table2. The highly durable polymer-modified asphalt binder had improved resistances against twist stress and dispersion of aggregates.

The characteristics of the highly durable polymer-modified asphalt binder were estimated to improve the resistances of the pavement against plastic flow (softening point: 95℃, viscosity at 60℃: 10 Pa・s), twist stress, and dispersion of aggregates (bending strain: 182×10^{-3} cm/cm). Thus, the asphalt binder was estimated to make the best use of the superior characteristics of the steelmaking slag aggregates.

Table2 : Quality of the polymer-modified asphalt binder

Assorted traits		Polymer-modified asphalt binder		Standards
		Highly durable	Generally durable	
Penetration ratio(25℃)	1/10mm	60	47	≧40
Softening point	℃	95.0	92.0	≧70.0
Flash point	cm	322	325	≧260
Heating mass rate of change	%	-0.03	-0.02	≦0.6
Heating Residual penetration ratio rate	%	78	79	≧65
60℃ viscosity ($\times10^4$)	Pa・s	10	8.4	-
Bending strain(-20℃)	cm/cm	182×10^{-3}	27×10^{-3}	-
Separation area rate	%	0	0	-
Best mixture temperature	℃	175～185	170～180	-
Best soil compaction temperature	℃	150～160	150～160	-

3 QUALITY OF THE ASPHALT CONCRETE FOR WATER DRAINAGE PAVEMENT

Table3 shows the quality of the asphalt concrete combined the coarse aggregates made of steelmaking slag and the highly durable polymer-modified asphalt binder and the asphalt concrete combined natural crushed stones and ordinary polymer-modified asphalt binder. The fine aggregates and filler were sea sand and stone widely used in Okinawa.

The asphalt concrete of the coarse aggregates made of steelmaking slag and the highly durable polymer-modified asphalt binder had a stability of 5.71 kN, dynamic stability of 12,600 wheel passes/mm, Cantabro loss of 9.0%, and distorsion deformation of 0.8 mm, showing higher durability than conventional mixtures. The mixture was thus likely to be effective for reducing the abrasion of the pavement surface and improving its abrasion resistance.

Table3 : Quality of the asphalt concrete for water drainage pavement

Mixture ratio (%)	Coarse aggregate	84.8 (Steelmaking slag 100%)	82.0 (Limestone 70% Hard sandstone 30%)	Standards
	Fine aggregate	7.4	8.6	
	Filler	3.6	4.8	
	Polymer-modified asphalt binder	4.2 (Highly durable)	4.6 (Generally durable)	
Density	g/cm^3	2.627	2.016	−
Void content	%	20.2	20.3	15～25
Stability	kN	5.71	5.26	≧3.50
Residual stability	%	89.1	89.2	≧75
Coefficient permeability	cm/15sec	1.63×10^{-1}	1.43×10^{-1}	1.0×10^{-2}
Dynamic stability	passes/mm	12,600	5,730	≧3,000
Cantabro loss	%	9.0	9.7	≦20
Distorsion deformation	mm	0.8	5.7	−

4 APPLICATION TO THE RENOVATION OF THE PAVEMENT OF NATIONAL HIGHWAY ROUTE 329

4.1 Contents of paving test

The asphalt concrete for water drainage pavement combined the coarse aggregates made of steelmaking slag and the highly durable polymer-modified asphalt binder was used on downhill and at intersections of the national highway, where the effects of improving traffic safety could be hoping.

Follow-up surveys were conducted immediately after execution and 4 months, 8 months, 1 year and 2 year after the start of service. The skid resistance, dynamic friction coefficient, and in situ permeability of the pavement surface were measured to check the long-term durability of the asphalt concrete that used coarse aggregates of steel slag.

4.2 Overview of work

The work was executed in February 2005 on National Highway Route 329 in Okinawa City, Okinawa Prefecture. The area of the work was 7,976 m^2. Of the area, 1,950 m^2 on the outbound lanes and at intersections was paved using the steelmaking slag aggregates. The work involved cutting and replacing 5 cm from the pavement surface. A view of the highway after the work is shown in Photo 1. The sites and a plan of the work are shown in Figs. 1 and 2, respectively.

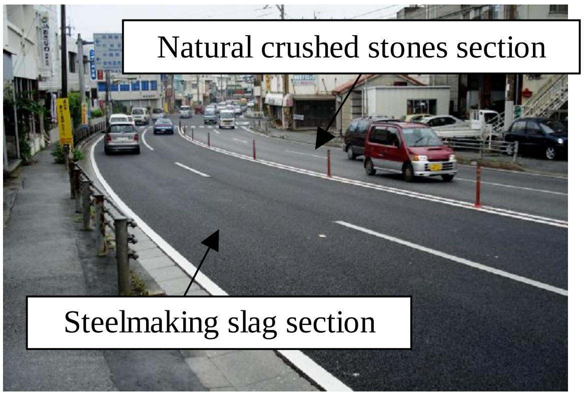

Photo1 : View of the highway after the work

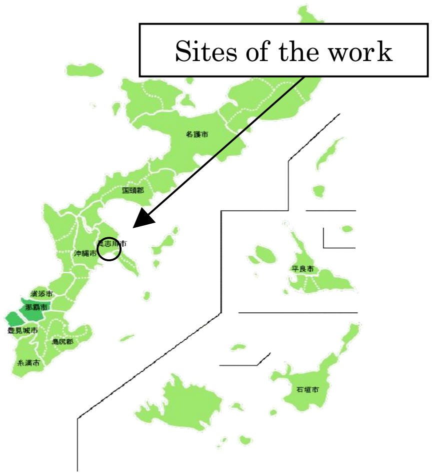

Figure1 : Sites of the work

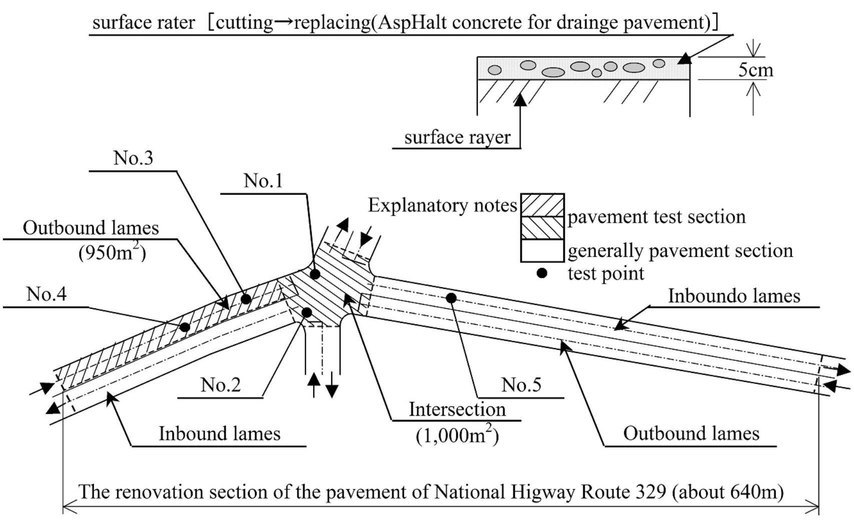

Figure2 : Plan of the work

5 RESULTS OF FOLLOW-UP SURVEYS

Follow-up surveys were conducted aiming to understand the long-term durability of the asphalt concrete for water drainage pavement combined the coarse aggregates made of steel slag and the highly durable polymer-modified asphalt binder. It involved measuring the skid resistance (British portable skid resistance number), dynamic friction coefficient using a dynamic friction tester, and in situ permeability to clarify the time historical changes in skid resistance and in situ permeability, which are the key performances of water drainage pavement. The results are described below

5.1 Skid resistance

The skid resistance values measured using a portable skid resistance tester and the dynamic friction coefficients measured using a dynamic friction tester are shown in Table 4. The dynamic friction coefficients were converted into values for the contact pressure at a traveling speed of 40 km/h. The time historical changes in skid resistance are shown in Fig. 3, and the time historical changes in dynamic friction coefficient are shown in Fig. 4.

Target skid resistance values measured using portable skid resistance testers are 60 or larger for newly constructed pavement on expressways. The highway sections paved using steelmaking slag has kept high skid resistance of skid resistance values of around 60 since its construction throughout the period of 2 years in service. The skid resistance values of sections paved using natural crushed stones have dropped during the service period.

The target value of dynamic friction coefficient, which is measured using a dynamic friction tester, is at least 0.4 for ordinary roads in cities. The dynamic friction coefficients of the highway sections paved using steelmakig slag were slightly lower than the target value immediately after construction but increased sharply while in service. This was likely because the asphalt film that surrounded the aggregates was worn away and the actual resistance of the aggregates was manifested. The dynamic friction coefficient of the sections paved using natural crushed stones dropped after the start of service.

The measurements showed that the sections paved using steelmakig slag maintained high skid resistance over a long period of time.

Table4 : Results of follow-up surveys(Skid resistance)

Assorted traits	A part	Survey station		H17.2	After the start of service			
				Directly	4 months	8 months	1 year	2 years
Skid resistance values (BPN)	Intersection (Steelmaking slag)	No.1		63	64	58	53	61
		No.2		61	70	68	58	61
	Outbound lane (Steelmaking slag)	No.3	Inside	56	58	55	55	63
			Outside	53	59	57	57	64
		No.4	Inside	56	65	69	59	62
			Outside	51	65	57	57	64
	Inbound lane (Natural crushed stones)	No.5		58	53	41	42	44
Dynamic friction coefficient (DF tester)	Intersection (Steelmaking slag)	No.1		0.30	0.49	0.51	0.57	0.59
		No.2		0.31	0.47	0.52	0.57	0.59
	Outbound lane (Steelmaking slag)	No.3	Inside	0.32	0.54	0.55	0.57	0.61
			Outside	0.35	0.52	0.52	0.58	0.56
		No.4	Inside	0.33	0.52	0.56	0.59	0.61
			Outside	0.35	0.50	0.53	0.58	0.60
	Inbound lane (Natural crushed stones)	No.5		0.40	0.36	0.35	0.34	0.32

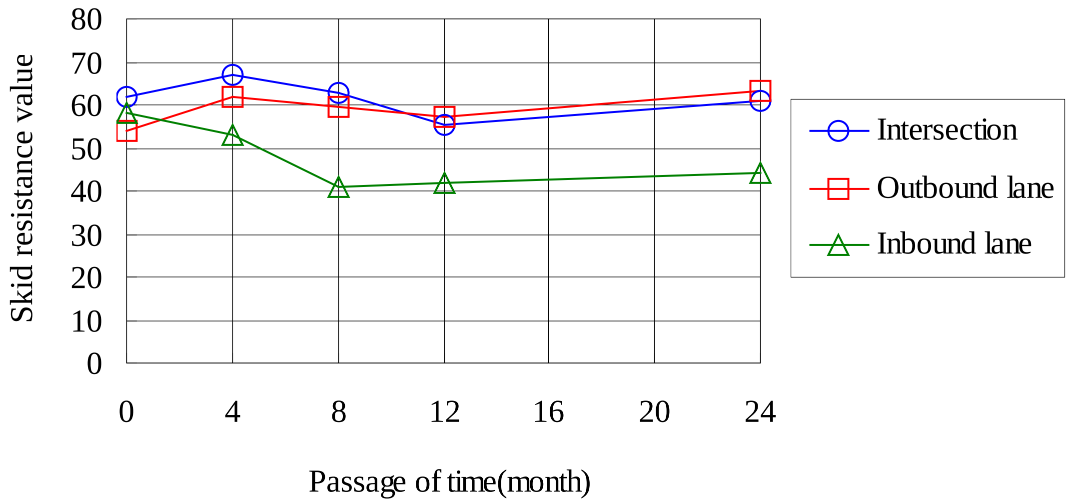

Figure3 : Skid resistance values

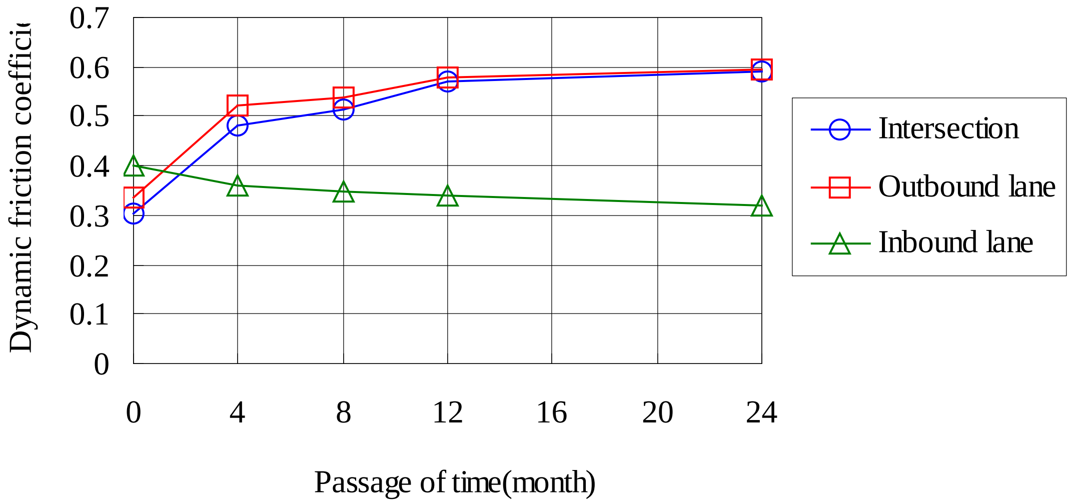

Figure4 : Dynamic friction coefficient

5.2 In situ permeability

The measured in situ permeability is shown in Table 5. The time historical changes in in situ permeability are shown in Fig. 5.

In situ permeability was similar between the sections paved with steel slag and natural crushed stones, and gradually decreased as time passed in both sections. The advantage of using steel slag aggregates in terms of in situ permeability could be not confirmed from the results. The in situ permeability at the time of construction satisfied the standards.

Table5 : Results of follow-up surveys(In situ permeability)

Assorted traits	A part	Survey station	H17.2	After the start of service				Standards
			Directly	4 months	8 months	1 year	2 years	
In situ permeability	Intersection (Steelmaking slag)	No.1	1,131	1,138	1,090	1,060	913	1000 ml/15sec (Directly)
		No.2	1,173	1,147	1,057	1,010	915	
	Outbound lane (Steelmaking slag)	No.3	1,072	1,088	1,039	1,032	1,007	
		No.4	1,107	1,106	1,065	1,069	1,027	
	Inbound lane (Natural crushed stones)	No.5	1,089	1,140	1,087	1,083	988	

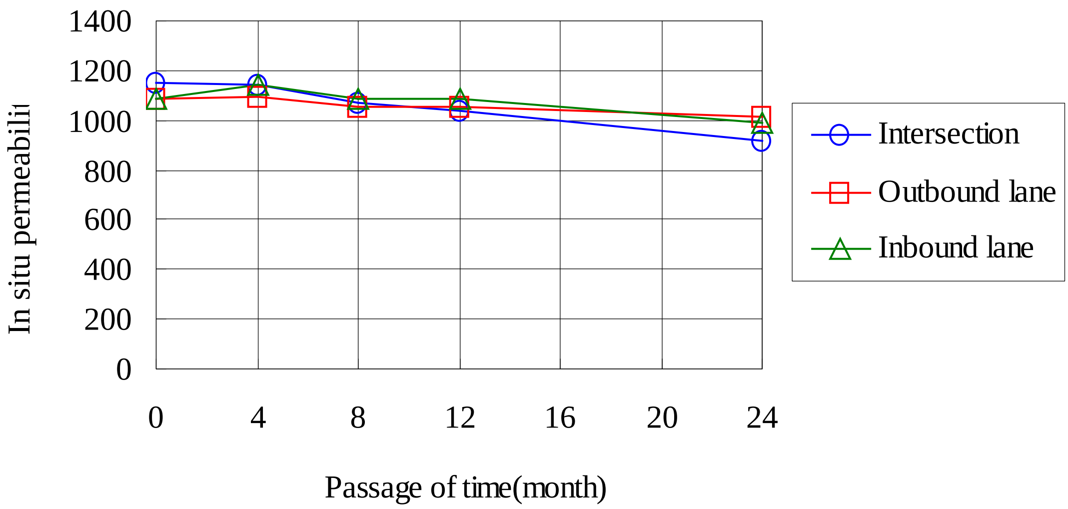

Figure5 : In situ permeability

5.3 Results of visual observation of pavement surface

Pavement surfaces after 2 years in service of the sections paved using steel slag and natural crushed stones are shown in Photos 2 and 3, respectively. The sections paved using steel slag have shown almost no dispersion of aggregates, which might have been caused by twisting of tires, and have shown no visible abrasion of the surface. On the other hand, the surface of the sections paved using natural stones have been worn away and looked whitish.

The visual observation also showed that the sections paved using steel slag maintained good surface conditions.

Photo2 : Steelmaking slag section

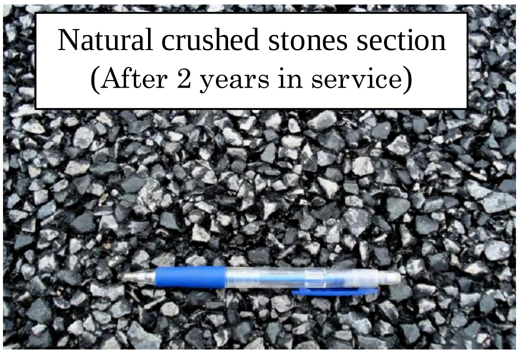

Photo3 : Natural crushed stones section

6. CONCLUSIONS

Asphalt concrete for water drainage pavement, which was combined coarse aggregates made of steelmaking slag and highly durable polymer-modified asphalt binder, was used to pave sections of a national highway. Follow-up surveys showed that the pavement maintained good conditions. This was likely because the characteristics of the materials have been effectively manifested. Based on the results, the technologies will be applied to similar processes and will be spread.

REFERENCES

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