Double-layer Asphalt Pavement in a Single Process and Noise Reductions Properties of Double-Layer Porous Asphalt

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ABSTRACT: In Japan, the social needs to the road pavement are diversified with progress of social economy in recent years. Especially, promoting performance of road pavement in an urban area is requested. Double-layer asphalt pavement is a single process of supplying two different kinds of asphalt mixtures separately to a lower screed and an upper screed and laying down these respective mixtures simultaneously onto the existing surface and compacting together these two layers by road rollers. Double-layer asphalt pavement can be applied to various cases by combining different mixtures for the upper and the lower layer, and can be developed to noise-reducing pavement, thin color pavement, rutting-resistance pavement, and wear-resistance pavement, etc. The authors developed the small-sized paving machine applicable to narrow city streets with their own technology, and put Double-layer asphalt pavement to practical use.

This paper describes the outline, the features, examples of the test section, laboratory test results and tire/road noise properties of Double-layer porous asphalt.

KEY WORDS: Double-layer, a single process, porous asphalt, tire/road noise properties

1 INTODUCTION

Double-layer asphalt pavement (hereinafter referred to as DL Pavement) is a single process of supplying two different kinds of asphalt mixtures separately to a lower screed and an upper screed and laying down these respective mixtures simultaneously onto the existing surface (see Fig. 1) and compacting together them by road rollers. It has the following merits.

1) Improved durability due to a unified structure with no seam between two layers (see Photo 1).
2) A work period shortened by the simultaneous placement of the binder and surface courses.
3) Reduction in a material cost by making thinner the thickness of the layer with a special mixture.
4) Reduction in tire/road noise by applying a very thin layer with a fine grain for the upper layer.

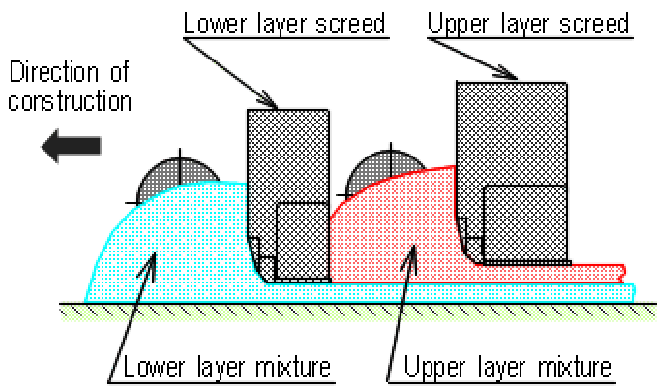

Figure 1: Construction method
(schematic diagram)

Photo 1: Cross section of DL Pavement

The history of DL Pavement goes back to early 1990s when Warrenite-Bitulithic paving was invented in the USA. As for the paving equipment, Mr. Iijima, former president of Sanei Kogyo Co.,Ltd. in Japan, had obtained the utility model in 1971, however the invention was not put to practical use.

In the latter half of 1990s, though the Double-layer asphalt paver was developed in Germany, it was not suitable for paving in narrow-city streets as the paver was fairly large in its size. Accordingly, NIPPO Corp. and Wirtgen Japan Co.,Ltd. jointly developed the small-sized paving machine also applicable to narrow-city streets with their own technology, and put DL Pavement to practical use (see Photo 2).

Photo 2: DL Pave construction situation

2 FEATURES

2.1 Equipment for DL Pavement

The fleet of equipment used for DL Pavement is shown in Figure 2. The asphalt loader, operating in front of the DL Paver, will feed the two storage hoppers with two different kinds of asphalt mixtures. The DL Paver is an asphalt paving machine especially adapted to lay the two layers in a single process. The schematic of the DL Paver and the Asphalt Loader are shown in Figure 3, 4 respectively. Specifications for the DL Paver and the asphalt loader are shown in Table 1.

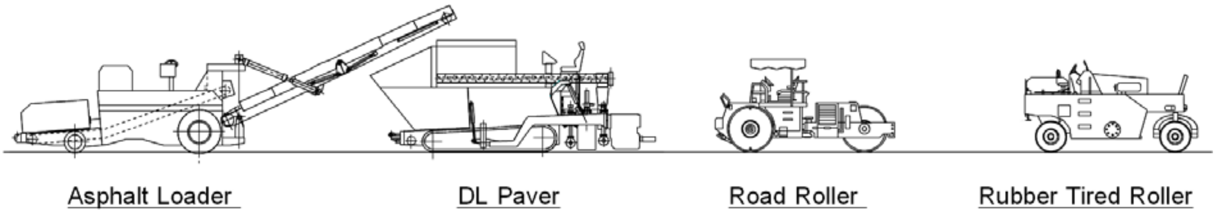

Figure 2: Fleet of equipment used for DL Pavement

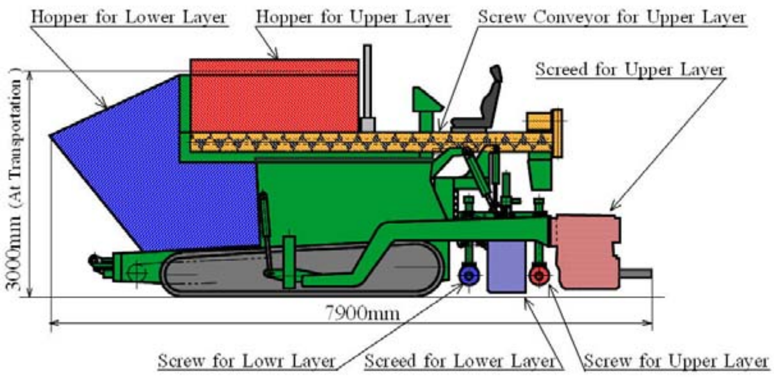

Figure 3: DL Paver

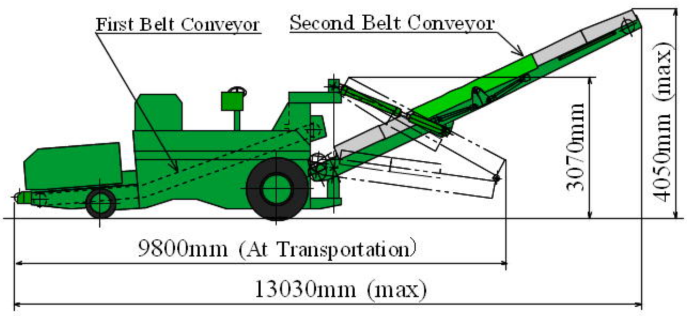

Figure 4: Asphalt Loader

Table 1: Specifications of the DL Paver and the Asphalt Loader

	DL Paver	Asphalt Loader
Total weight	28,000kg	23,000kg
Overall Length	7,900mm	9,800mm
Overall Width	3,000mm	3,000mm
Overall Height	3,000mm	3,070mm
Paving Width	2.5~4.75m	-
Hopper Capacity	Upper: 5.8 m^3 Lower: 8.5 m^3	4.0 m^3
Speeds	(Paving) 0~5 m/min	Up to 3.7 km/h
Engine Rated Power	160kW/2200min^{-1}	61kW/2200min^{-1}

2.2 Features of the DL Paver

The DL Paver has the following merits.

1) The DL Paver can be transported by a common large trailer for conventional asphalt pavers without disassembling it since its dimensions are only 3.0m in width, 3.0m in height, 7.9m in length and 28tonnes in weight.
2) The DL Paver can travel by itself without fitting auxiliary wheels, since two- layer paving device consisting of the hopper and the screw conveyor unit for an upper layer, the screeds and screw units for a lower and an upper layer are well arranged to install in balance using Vögele S-2100 asphalt paver as a base unit (see Figure 5).
3) The DL Paver is equipped with a large hopper. Thus, the paver can execute continuous paving without stopping while dump trucks are replaced.
4) The DL Paver can be also utilized as a conventional asphalt paver, since the double-layer paving devices are detachable (see Figure 6).

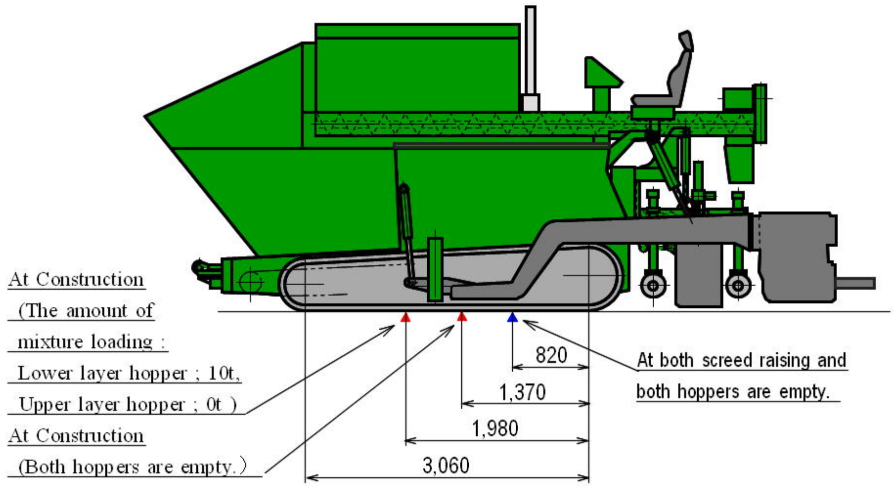

Figure 5: The weight balance of DL Paver

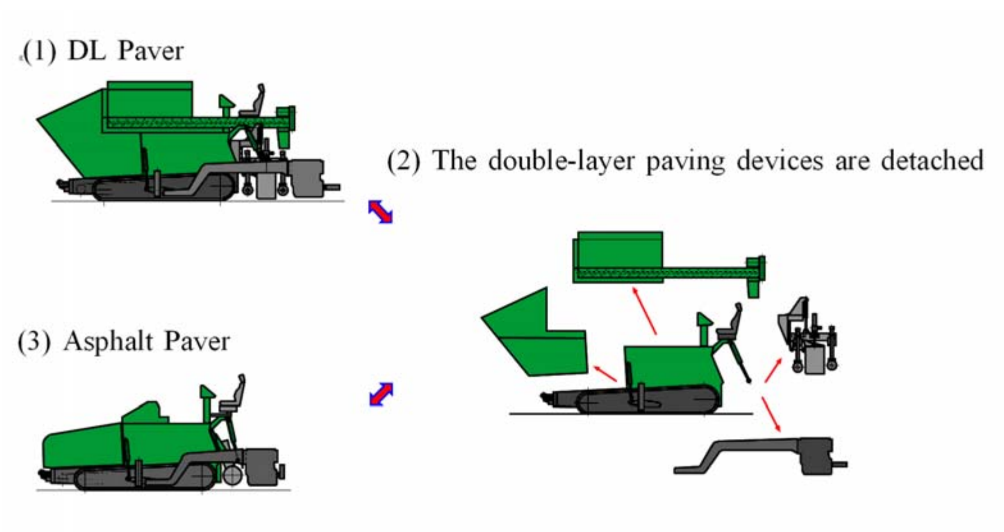

Figure 6: Conversion DL Paver to Conventional Asphalt Paver

3 DESIGN EXAMPLE

Design example and the advantage of DL pavement are shown in Table 2. DL Pavement can be applied to various purposes by combining mixtures of an upper layer and a lower layer, and can be developed to noise-reducing pavement, thin color pavement, rutting- resistance pavement, and wear- resistance pavement, etc.

Table 2: Design example of DL Pavement

	Low Noise Pavement	Thick Dranage Pavement	Colored Pavement	Rutting and Wear Resistance Pavement
Cross Section of Pavement (cm)	Porous asphalt (8) 2 Porous asphalt (13) 3 Coarse-graded asphalt (20) (5)	Porous asphalt (8) 3 Porous asphalt (20) 7	Colored porous asphalt (8) 2 Porous asphalt (13) 3 Coarse-graded asphalt (20) (5)	SMA (13) 3 Coarse-graded asphalt (20) 7
Effects	● Reduced Traffic Noise ● Improved Rutting Resistance	● Reduced Work Period ● Improved Drainiage and Permeability	● Cost Savings ● Reduced Traffic Noise ● Improved Landscape	● Strengthened Structure ● Reduced Work Period
Application Sites	● Urban Highways ● Urban Roads	● Arterial Road of Urban Area ● Sag Points and Nearside Lanes ● Water-Permeable Roadways	● Urban Roads ● Scenic Routes ● Bus Lanes	● Heavy Traffic Roads ● Highways ● Factory Roads

4 LABORATORY TEST RESULTS

4.1 The structure of the Test Pavement

We carried out a test pavement to compare standard pavement, which lays down two types of mixture for a binder and a surface course separately by a conventional paver, with DL Pavement in properties. Table 3 shows the structure of the test pavement.

Table 3: Structure of test pavements

Indexes		A	B	C
Upper layer	Mixture (Grain size)	Porous (13)	Porous (5)	SMA (13)
	Thickness	3cm	2cm	4cm
Lower layer	Mixture (Grain size)	Coarse-graded (20)	Porous (13)	Coarse-graded (13)
	Thickness	7cm	3cm	6cm

4.2 Rutting-Resistance

Figure 7 shows comparison between DL Pavement and standard pavement in rutting-resistance. DL Pavement shows superiority, apparently due to the seamless structure leading to a high-range of density.

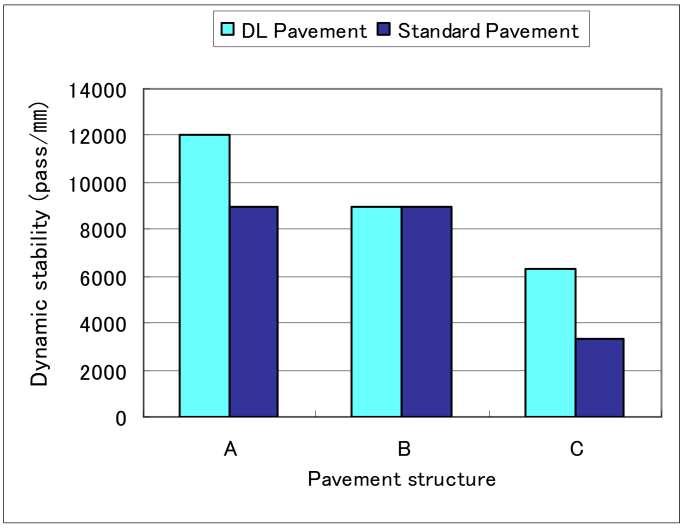

Figure 7: Comparison of rutting-resistance

4.3 Tensile Strength

Figure 8 shows comparison between DL Pavement and standard pavement in tensile strength. DL Pavement shows superiority, apparently due to the excellent interlocking between mixtures of the upper and the lower layer.

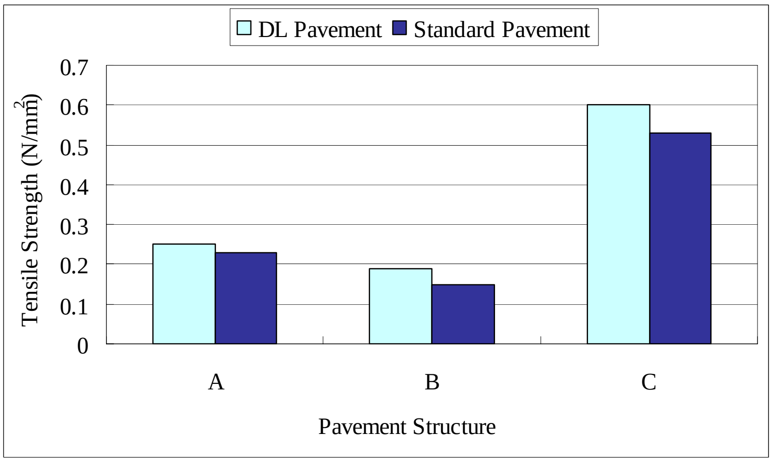

Figure 8: Tensile strength of DL Pavement

5 TIRE/ROAD NOISE PROPERTIES OF DL PAVEMENT

5.1 Structures of Asphalt Layers

Some combinations of asphalt mixtures used for the upper and the lower layer were tested to evaluate tire/road noise properties of DL Pavement, compared to the standard pavement. Table 4 shows the structure of asphalt layers in performance-specification projects. The structure is abbreviated like “DL5-8”, in which “DL” means DL Pavement, “5” is a total thickness, “8” is a maximum grain size of the upper layer.

Table 4: Structure of pavements in performance specification project

Pavement			DL Pavement				Single Layer Pourus			
Identification mark			DL5-5	DL5-	DL6-8	DL8-8	4-8	5-10L	5-10H	5-13
Thickness (cm)		Upper Layer	2	2	2	2	4	5	5	5
		Lower Layer	3	3	4	6				
Mixture	Grain size (mm)	Upper Layer	5	8	8	8	8	10	13	13
		Lower Layer	13	13	13	20				
	Percentage of air voids (%)	Upper Layer	25	25	25	25	20	20	22	22
		Lower Layer	23	23	23	23				

NOTES: DL: DL Pavement, H: Standard Pavement (Porous asphalt with high air void content), L: Standard Pavement (Porous asphalt with low air void content)

5.2 Change in Tire/Road Noise Properties

In performance-specification projects the tire/pavement noise is measured with a vehicle called a “Road Acoustic Checker Vehicle” (RAC Vehicle), which is equipped with a special tire mounted behind the rear axle, and a microphone near the side of the tire (CPX measurement type). And the tire/road noise level is measured twice; the first time soon after the construction, the second time one year after the construction. In each case, the average value of measured levels must not exceed specified limits (89dB after the construction, 90dB after one year). By the way, the noise level of dense-graded asphalt pavement measured by this method is about 98dB.

Figure 9 shows the tire/road noise level of “5-10H”, “DL5-5”,”DL5-8” after the construction compared to that of one year later. The tire/road noise level in all three types increases by about 1 dB one year after the construction.

Figure 10 shows the relationship between the tire/road noise level after the construction and the increment after one year. Despite large dispersion of the data, the trend is seen that the lower the noise level is after the construction, the larger the increment is after one year.

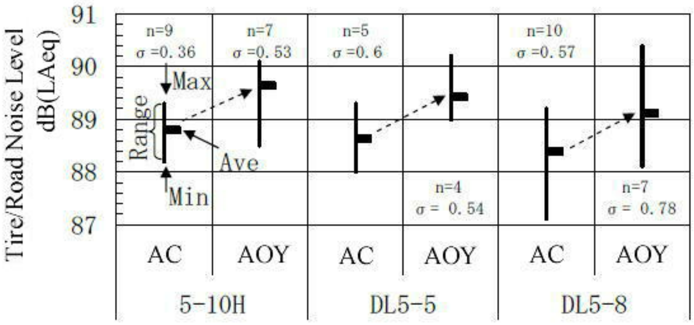

Figure 9: The difference of obtained result from tire/road noise level between after the construction (AC) and after one year (AOY)

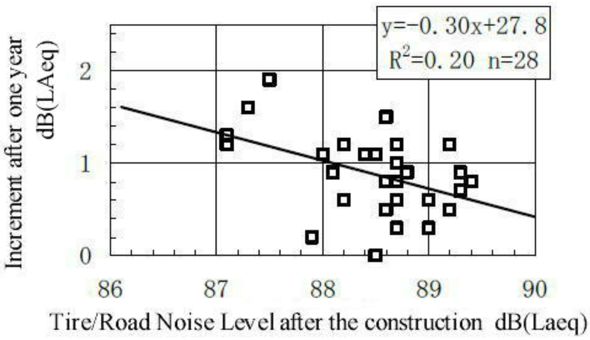

Figure 10: The relationship between the tire/road noise level after the construction and after one year

5.3 Grain Size

It is believed that the tire/road noise level becomes lower, the smaller the grain size is. The grain size of the mixtures used in “5-10H”,“DL5-5”,”DL-5-8” is 10mm, 5mm, 8mm respectively. But as seen in Figure 9, the order of the small tire/road noise level is ”DL-5-8”, “DL5-5”, “DL5-10H” as opposed to the accepted theory. This is probably connected with good interlocking on the interface between the two layers of DL Pavement, because air void content of the mixtures near the interface with good interlocking is reduced, compared with standard pavement.

5.4 Thickness

Figure 11 shows the relationship between the tire/road noise level and the layer thickness of DL Pavement using the data from ”DL-5-8”, ”DL-6-8” and ”DL-8-8”. The data indicates that the thickness is a very important factor of the tire/road noise level, showing that the thicker the layer is, the quieter the noise is.

Figure 12 shows the comparison of the tire/road noise level of the mixture placed on a milled surface and a non-milled surface of the asphalt layer. The noise on a milled surface is larger than that on a non-milled surface, apparently because the aggregate on a milled surface is interlocked at the bottom of the layer with a rugged streak, reducing air void content and effective thickness.

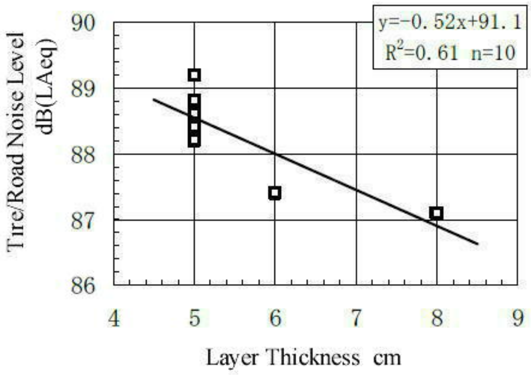

Figure 11: The relationship between the tire/road noise level and the layer thickness.

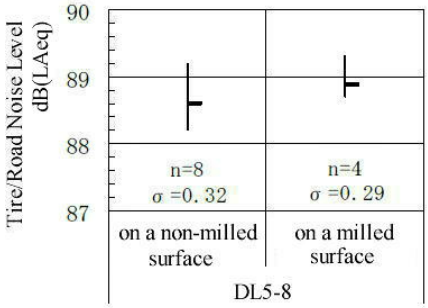

Figure 12: The relationship between the tire/road noise level of the layer on a non-milled surface and a milled surface.

6. SUMARRY OF TIRE/ROAD NOISE PROPERTY

Considering all results of research and analysis regarding tire/road noise, the following conclusions were drawn:

1) Tire/road noise level of one year later was approximately 1dB higher on average than the noise level after the paving.
2) There is a tendency that the lower the tire/road noise level is after the paving, the increment after 1 year becomes larger.
3) With the mixture with air void content of 25%, the tire/road noise level of the mixture with the grain size of 8 mm is lower than that of the grain size of 5mm.
4) The thickness of porous asphalt has an influence on the tire/road noise level, and its contribution rate is high (0.52dB/cm).
5) The tire/road noise level of porous asphalt on a milled surface is larger on average than that on a non-milled surface.

7. CONCLUSION

Mentioned above are the process of the construction, examples of the application, properties of the pavement, and tire/road noise property of DL Pavement. As for the tire/road property, DL Pavement seems to have a little superiority over standard pavement. Since there appears to be limitation to improvement of the tire/road noise only by combination of conventional technologies, new and innovative ideas may be needed in progressing further study.
However, DL Pavement can be extended to various purposes by combining various mixtures for the upper and the lower layer, meeting diverse needs regarding road pavement. We will continue improving the equipment and construction methods for higher performance.

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