Typical Distress of Drainage Asphalt Pavement in Japan

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ABSTRACT: The first Drainage asphalt pavement (DAP) was constructed in 1987 in Tokyo, and now more than 60% of expressways have been paved by drainage asphalt pavement. The merits of DAP are improvement of traffic safety in rainy days and reduction of traffic noise. Through our 20 year experience, we have found numerous pavement failures, which are peculiar to DAP and do not occur in conventional asphalt pavements such as dense-graded asphalt concrete. In particular, the mechanism of lateral flow deformation, which occurs relatively earlier after open service, is not clear. This paper examines the causes of these lateral flow deformations found that this deformation is attributable to the characteristics of binder course asphalt concrete against plastic flow, the adhesion between surface and binder course, and the imperviousness of the binder course. Finally, countermeasures against these early distresses were proposed.

KEY WORDS: Drainage asphalt pavement, plastic flow, early deformation, lateral flow, wheel tracking test.

1 INTRODUCTION

In Japan, the DAPs are popularly used in national highways and expressways. They are expected to reduce traffic noise especially in urban areas and also to reduce the number of traffic accidents especially in expressways. Figure1 shows the relation between accident rate and passed months after DAP construction in expressways. In this figure, accident rate means the possible number of traffic accidents while 1 million vehicles travel 1 hundred km. The number of traffic accidents decreased sharply after the construction of DAPs. For this traffic safety effect, more than 60% of expressways are paved by DAP in Japan.

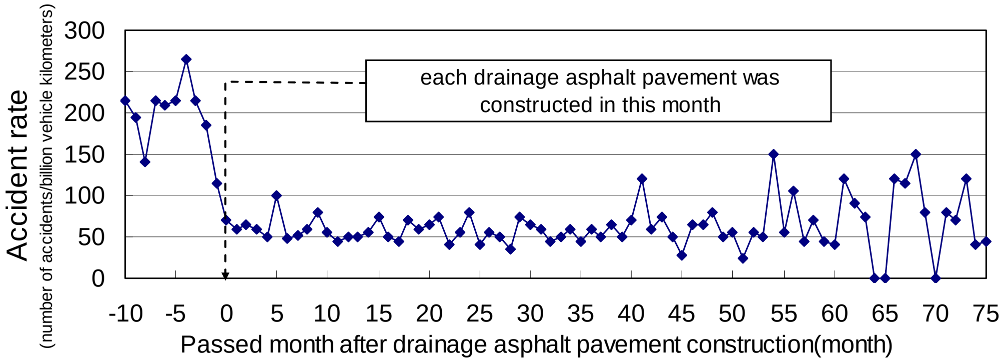

Figure1: Accident rate and passed month after drainage pavement construction.

While DAP can solve the traffic and noise problem, it has become frequent to be reported to cause very critical failures peculiar to DAP. Most peculiar failure is a lateral flow deformation, which occurs in one or two years after construction.

In this paper, we examined the cause of this early lateral flow and propose the countermeasures through laboratory tests.

2. PECULIAR FAILURES TO DRAINAGE ASPHALT PAVEMENTS

Table1 shows the major failure of DAP and its causes. Very highly modified asphalt (SBS content is more than 10%) is usually used for DAP in order to thicken the asphalt mortar film covering coarse aggregates. This makes asphalt mixtures very sensitive to its temperature, and causes insufficient compaction. Porous asphalt concrete is very weak against snow chains, because the contacting area of each aggregate is relatively smaller than conventional asphalt concrete such as dense- graded asphalt concrete. It is also weak against oil leaks, because oil can permeate into pavement and strip asphalt.

Table1: The major failure of DAP

Cause	Failure pattern	Probable cause
Properties and workmanship of porous asphalt mixture	Aggregate scattering	Low application temperature, insufficient compaction, etc.
	Potholes	
	Cracking	
External factors	Aggregate scattering	Snow chains, oil leaks, etc.
	Rutting	
	Potholes	
	Bleeding	
	Cracking	
Pavement structure to infiltrate rainwater into the surface course	Lateral flow	Stripping resistance of the binder course,etc.

The early lateral flow was estimated to be caused by water permeated into pavement. In order to simulate this lateral flow, accelerated loading test was conducted as shown in Photo 1 (Kawakami 2008, Kubo 2008). Usually test pavements are constructed newly in full depth, however, for this simulation test pavement was constructed by milling existing pavement and overlaying new porous asphalt concrete at its surface layer.

Photo1: Pavement Test Field and Loading Vehicle

Figure 2 shows the test result. X axle shows the number of 49kN equivalent wheel loads which is based on the same concept of ESALs. After 700 thousands wheels had passed, the rutting depth had become sharply large, and this could be estimated to be caused by lateral flow.

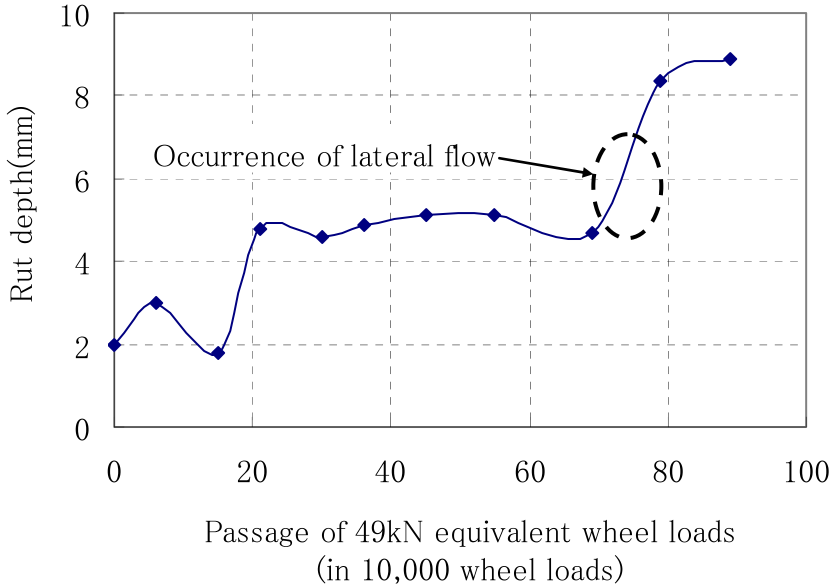

Figure 2: Monitored rut depth in the accelerated loading test

Photo 2 shows the cut specimen of surface and binder course after loading test. Heavy lateral flow was found in both surface and binder layer at wheel pass. These lateral flow were seemed to be caused by insufficient adhesion between surface and binder course, aggregate stripping in binder course, and layer separation due to stagnant water. Figure3 shows the concept of lateral flow occurrence.

Photo2 Cut specimen after accelerated loading test

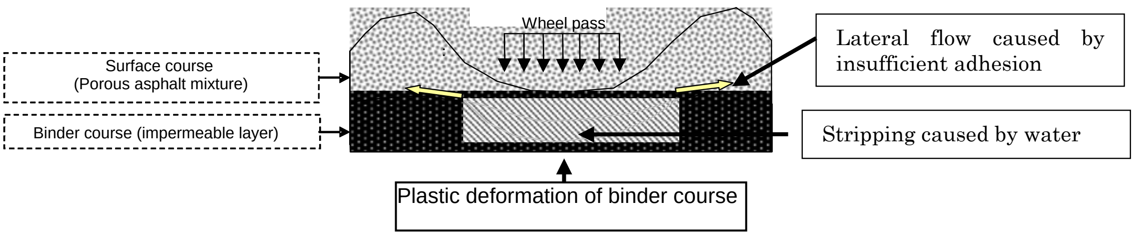

Figure3: Concept of lateral flow occurrence

3. LABORATORY TEST FOR LATERAL FLOW

In order to simulate lateral flow, modified immersion wheel tracking test was conducted. Wheel tracking test is an accelerated test which is widely used in Japan in order to evaluate the rut resist performance of asphalt mixtures. Figure 4 shows the concept of this test. Water was sprinkled as an artificial rainfall. Test temperature was 60 degree C, and the size of specimen was 30cm width and 30cm length. Specimen consisted in two layers with 3cm surface course and 4cm binder course. Test conditions are shown in Table 2.

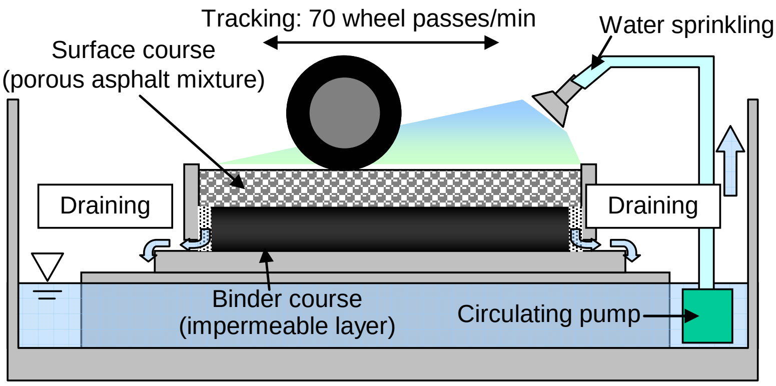

Figure 4: Concept of modified immersion wheel tracking test

Table 2: Test conditions for modified immersion wheel tracking test

Air and water temperatures	60°C
Tracking velocity	70 wheel passes/min.
Traverse width	10 cm
Traverse velocity	10 cm/min.
Test duration	Until deformation reaches 30 mm
Load	1.12 MPa
Wheel width	50 mm

For the purpose of reconfirming the effect of water on the durability of DAP, with and without water sprinkling test were conducted as shown in Table 3. As is shown in Figure 5, the amount of deformation in No.1 case became about double as large as that in No.2 after 2 hours later. This result proves that water in pavement is a critical factor to decrease its durability. There could be found asphalt stripping and severe deformation of binder course asphalt concrete just like the concept shown in Figure4, this modified immersion wheel tracking test was regarded to be able to simulate the same situations as full-scale accelerated loading test.

Table 3: Test conditions in order to identify the effect of water

	Surface course material	Binder course material	Cutting of the upper surface of the binder course	Boundary between the surface and binder courses	Water sprinkling
No.1	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	Rubberized emulsion applied (0.4 L/m^2)	Implemented
No.2	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	Rubberized emulsion applied (0.4 L/m^2)	Not implemented

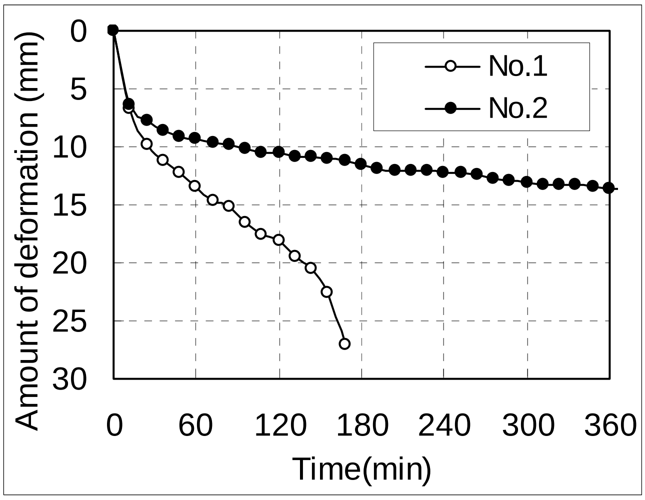

Figure 5: Test results of test condition No.1 and No.2

In order to identify the difference between construction conditions, three types of specimens were prepared as shown in Table 4. No.3 specimen simulated a newly constructed DAP. No.4 specimen simulated an overlaid porous asphalt concrete on milled existing asphalt pavement with asphalt emulsion which was sprayed in order to improve the adhesion between surface and binder course. No.5 specimen simulated an overlaid porous asphalt concrete on milled existing asphalt pavement without asphalt emulsion. Figure 6 shows the results. No.5 specimen showed early distress comparing to other specimens, while there was less difference between No.4 and No.5. According to these results, the importance of tack coating was reconfirmed, and modified asphalt emulsion was recommended to be used. Adding to say, two layer reconstructions would be preferable to one layer milling and overlay.

Table 4: Test conditions in order to identify the difference between construction conditions

	Surface course material	Binder course material	Cutting of the upper surface of the binder course	Boundary between the surface and binder courses	Water sprinkling
No.3	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Not implemented	Rubberized emulsion applied (0.4 L/m^2)	Implemented
No.4	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	Rubberized emulsion applied (0.4 L/m^2)	Implemented
No.5	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	No emulsion applied	Implemented

Table 5 shows specimens to compare the performance of different binder course materials. In this table, DS means dynamic stability, which is an index to evaluate asphalt concretes' performance against permanent deformation. No.6 specimen used a coarse graded asphalt concrete, which is most popular material for binder course. No.7 specimen used a dense graded asphalt concrete, which is usually used for surface course, and was expected more stable against water. No.8 specimen used stone mastic asphalt, which was expected more impermeable and durable. No.9 specimen used a coarse graded asphalt concrete with modified asphalt to improve its durability. Figure7 shows the test result. The more durable (higher DS value) binder course is, the more durable pavement itself is. We had regarded impermeability was essential for the durability of pavement, however, dense-graded asphalt concrete could not provide enough durability.

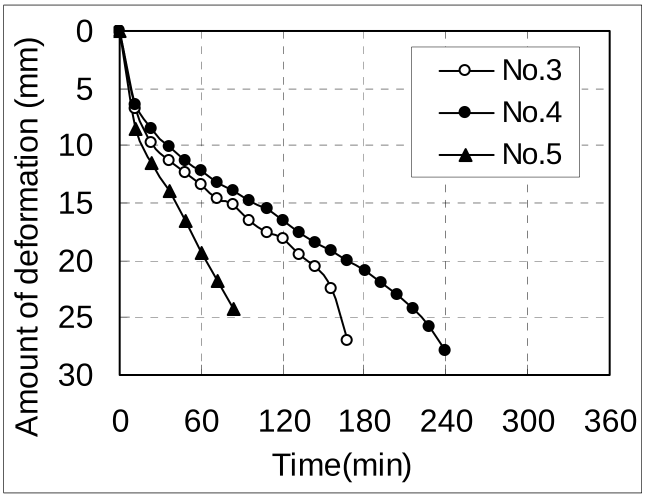

Figure 6: Test results of test condition No.3, No4, and No.5

Table5: Test conditions in order to identify the difference between binder course materials

	Surface course material	Binder course material	Cutting of the upper surface of the binder course	Boundary between the surface and binder courses	Water sprinkling
No.6	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used) DS: 1,410 wheel passes/mm	Not implemented	Rubberized emulsion applied (0.4 L/m^2)	Implemented
No.7	Porous asphalt mixture	Dense-graded asphalt mixture (straight asphalt 60/80 used) DS: 970 wheel passes/mm	Not implemented	Rubberized emulsion applied (0.4 L/m^2)	Implemented
No.8	Porous asphalt mixture	SMA (straight asphalt 60/80 used) DS: 5,250 wheel passes/mm	Not implemented	Rubberized emulsion applied (0.4 L/m^2)	Implemented
No.9	Porous asphalt mixture	Dense-graded asphalt mixture (improved asphalt Type II used) DS: 6,300 wheel passes/mm	Not implemented	Rubberized emulsion applied (0.4 L/m^2)	Implemented

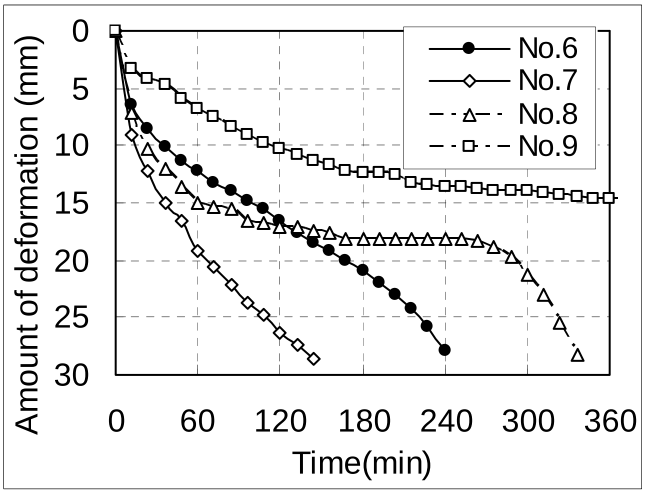

Figure 7: Test results of test specimen No.6 – No.9

Table 6 shows the test conditions to evaluate the effect of emulsion type and quantity on pavement durability. No.10 was a case of newly construction. No.11 was a case of porous asphalt concrete overlay on existing milled pavement without tack coat. No.12 used rubberized asphalt emulsion for tack coat. No.13 used the same emulsion, however the quantity is triple as much as No.12. No.14 used the same amount of asphalt emulsion as

No.11, however improved asphalt emulsion was used. No.15 used improved asphalt emulsion with triple quantity. Test results are shown in Figure10, which was almost the same as we expected. In order to assure the similar durability as newly construction, improved asphalt emulsion or triple amount of rubberized asphalt emulsion is necessary.

Table 6: Test conditions in order to identify the difference between boundary treatments

	Surface course material	Binder course material	Cutting of the upper surface of the binder course	Boundary between the surface and binder courses	Water sprinkling
No.10	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Not implemented	Rubberized emulsion applied (0.4 L/m ^{2})	Implemented
No.11	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	No emulsion applied	Implemented
No.12	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	Rubberized emulsion applied (0.4 L/m ^{2})	Implemented
No.13	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	Triple quantity of rubberized emulsion applied (1.2 L/m ^{2})	Implemented
No.14	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	Improved emulsion applied (0.4 L m ^{2})	Implemented
No.15	Porous asphalt mixture	Coarse-graded asphalt mixture (straight asphalt 60/80 used)	Implemented	Triple quantity of improved emulsion applied (1.2 L/m ^{2})	Implemented

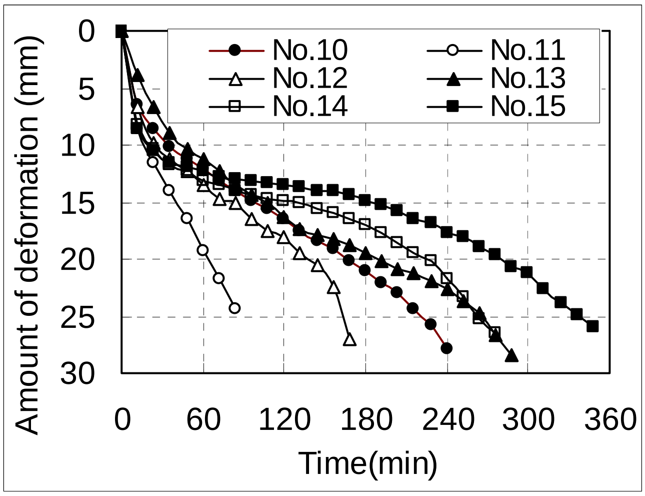

Figure 8: Test results of No.10 - 15

4. CONCLUSIONS

The lateral flow deformation of DAP, which occurs soon after construction, is attributable to the plastic flow resistance of binder course and the adhesion between surface and binder course. Following results have been obtained by these laboratory tests.

1) The forms of failure of DAP greatly differ depending on the immersion conditions.
2) The plastic flow resistance of binder course improves the durability of DAP.
3) Higher adhesion between surface and binder courses improves the durability of DAP. In order to obtain higher adhesion, enough amount of rubberized asphalt emulsion or improved

asphalt emulsion is necessary.

DAP is still expanding in Japan road network, especially in expressways and national highways. Results of these laboratory tests should be reflected to technical guidelines in order to supply good infrastructures to the people.

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