Study on Repair Method of Porous Asphalt Pavement Constructed by Thin Layer Overlay Method

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ABSTRACT: For the porous asphalt pavement, regardless of the fact that the cases of functional damage such as functional degradation of drainage capacity or noise reduction caused by clogging or crushing of the pores took place more frequently than the cases of structural damage affecting the pavement such as cracking, most of the existing pavement was repaired by the cut and overlay method, thus the maintenance cost becomes high, which is less attractive from economical viewpoint in the recent trend of reducing budgets for road construction projects.

The authors has developed the repair technology using the thin layer overlay method which has advantages of increased daily construction areas and of reduction in cost as an effective repair method alternative to the cut and overlay method. This technology is to apply the porous asphalt mixture with small size particles consisting of two kinds of aggregates of maximum size of 8 mm and 5 mm mixed at an optimum mix proportion into a thin layer of 20 mm – 30 mm thickness on the existing porous asphalt pavement.

This study revealed that the optimum mix proportion of the two kinds of aggregates were obtained simply by the solid volume percentage test, and that the fretting resistance of aggregate and the period of sustained function were improved due to interlocking effect of aggregates. In addition, solutions to the technical issues with regard to the bonding capacity to the existing pavement or the workability of the mixture when this technology was applied were found and the serviceability for approximately two years was confirmed by a trial construction on existing pavement.

KEY WORDS: Thin layer overlay method, porous asphalt pavement, special modified emulsion, aggregate dispersion resistance, cost reduction

1 INTRODUCTION

In Japan, porous asphalt pavement was introduced around 1985 in an attempt to insure the safety in vehicle driving in stormy weather and to improve the roadside environment by reducing of road traffic noise. Thereafter, this paving method has become prevailing in express ways and major highway routes by virtue of the advancement in construction methods, durability due to the improved properties of asphalt binder used for paving, and other reasons, and, as shown in Figure 1, has been on a steady increase in terms of construction area of porous asphalt pavements. From now on, the porous asphalt pavements intensively built in these ten years will all together enter the re-construction time.

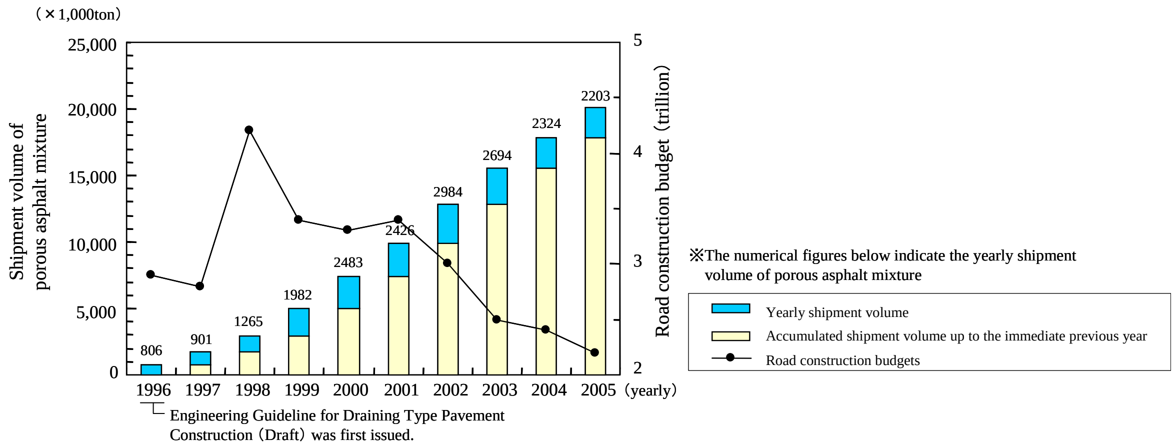


Figure 1: Trend of shipment volumes of porous asphalt mixtures

On the other hand, the road construction budgets have been curtailed year by year to show a stringent trend, which seems to be unchanging in the future also. In such a background, any efficient scheme for repair cost through a life cycle is needed to assure the proper upkeep of the existing porous asphalt pavement roads.

The existing porous asphalt pavements usually demand repairs due to such malfunction in dewatering and noise control as caused more frequently by the pores being filled and crushed than such structural failures as cracking. The fact is that though a pavement structure itself is in a sound condition, almost all existing pavements are repaired by the cut and overlay construction method, which adds to the maintenance costs and is less economical in view of the downward trend of the construction budgets. In such a background, we noticed a thin overlay paving method which is advantageous in daily construction output and cost reduction, from an angle of attaining more effective upkeep of the porous asphalt pavements, and have developed the effective composition of the porous asphalt mixture using special small size particles for the improvement in durability etc.

This paper describes the test results on the performance of the selected asphalt mixture, and, engineering issues and measures to be taken when they are used for the thin overlay construction, and further the verification results obtained from test construction on roads in service.

2 THE OBJECTIVE OF MIXTURE DEVELOPMENT

The repair construction method, here proposed, for the porous asphalt pavement using thin overlay pavement (hereafter called “Proposed Method”) uses porous asphalt mixture consisting of crushed stones of 5-8 mm in particle size (hereafter “8 mm crushed stones”) and No.7 crushed stones of 2.5-5 mm in particle size, these two being mixed in optimum proportion (hereafter “Selected Mixture”). The Selected Mixture is overlaid in a thin layer of 20 to 30 mm in depth onto the existing porous asphalt pavement to restore the original function of the existing pavement. Figure 2 illustrates the notional concept of the Proposed Method. In comparison with the conventional cut and overlay method, the Proposed Method intended to reduce the cost and extend the durability beyond that of the conventional porous asphalt mixture of smaller particle size. Table 1 describes the objectives of the Proposed Method.

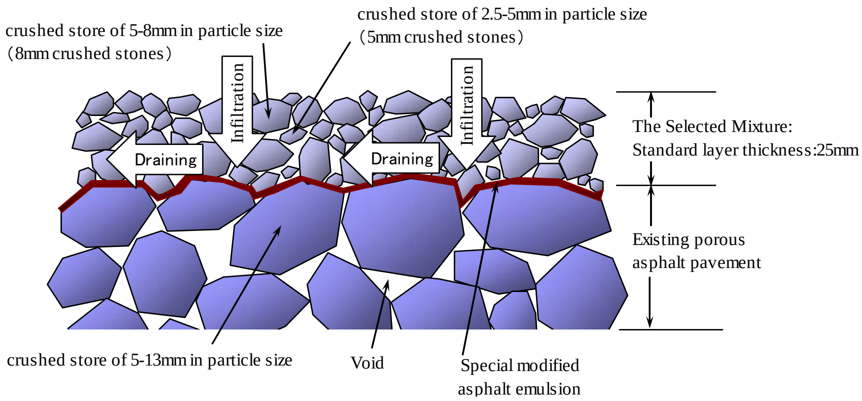


Figure 2: Notional concept of the Proposed Method

Table 1: Objectives of the Proposed Method

Issues	Objectives
Applicable sites	N_6 or below in Traffic Volume Classification. Have an adequate water resistance. Structurally sound existing pavement.
Cost	Repair should be done in 60% of the cost required for cut and overlay method.
Durability	More durable than the case of the conventional small particle size porous asphalt mixture
Sustainability of functions	Same level as for the conventional small particle size porous asphalt mixture
Adhesiveness	Same level as for general porous asphalt mixture laid on coarse-graded mixture
Workability	Should enable the mixture to keep the required quality in cold weather.

3 STUDY ON DURABILITY OF MIXTURE

In the laboratory study we made at earlier time, we studied the durability of mixture by changing a mixing proportion only, while keeping at a same level a 2.36-mm sieve passing volume and a binder volume. In consequence, a certain correlation was recognized between a mixing proportion and durability of mixture.

In this study, an aggregate mixing proportion and a binder volume were selected so as to keep same air voids (23%) with an eye to find the optimum mixing proportion of coarse aggregates. As a binder, commonly used polymer-modified asphalt H was used.

3.1 Engagement Properties of Coarse Aggeregates

In this study, the engagement effect was to be verified. For this purpose, by taking note of fact that the penetration resistance in a CBR test changes with the engagement condition of aggregates, CBR tests were conducted by changing mixing proportions of 8 mm crushed stones and No.7 crushed stones, and the load strength was measured at a 2.5 mm penetration point. In this course, a test specimen was compacted 25 times in three layers encased in a CBR test mold. Figure 3 shows the correlation of mixing proportions and load strength. As for the load strength, a maximum value was obtained at 7:3 in mixing proportion of 8 mm crushed stones and No.7 crushed stones. Solid volume percentage tests were made in an attempt to evaluate the engagement properties of coarse aggregates in a rough and ready way. Figure 3 shows the test results. Consequently, the solid volume percentage tests showed a similar results as to the CBR tests.

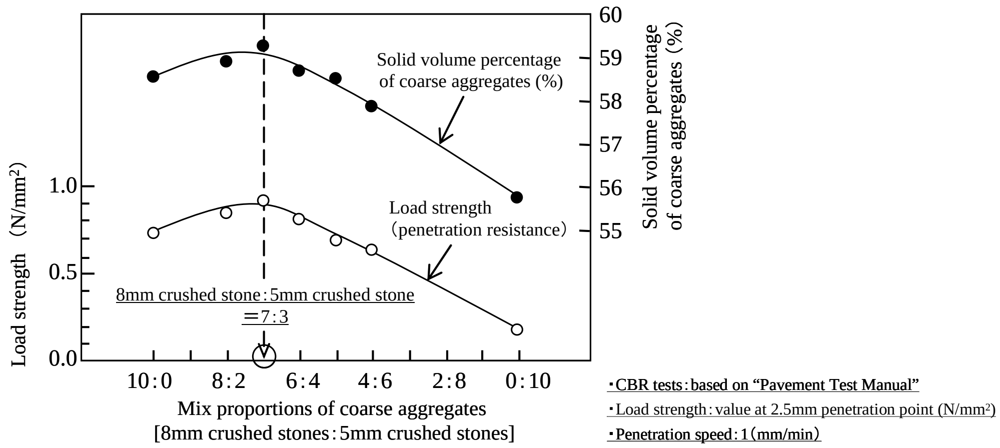


Figure 3: Engagement properties of coarse aggregates

3.2 Aggregate Dispersion Resistance

On the basis of the foregoing test results, we tried to grasp the correlation between the index of engagement properties of aggregates and the aggregate dispersion resistance in the mixture. For this purpose, we performed a Cantabro test and the torsional aggregate dispersion test which simulates the dispersion of aggregates due to twisted tire movements. The latter dispersion test is illustrated in Figure 4 in an outline concept. Though this test is often made at 60°C, it is considered problematic to evaluate, by this method, the aggregate dispersion due to a simple torsional action, since in the actual scene, the mixture would fracture through it being subjected to plastic deformation due to vehicle tire's rotation traveling. For this reason, in our test, the temperature was lowered down to 40°C so that the influence of plastic deformation over the dispersion of aggregates could be reduced. Under such test conditions, a volume of aggregates dispersed during 60 minutes was measured. Figure 5 shows the relation of the mix proportion of coarse aggregates, volume of torsional aggregate dispersion ("Dispersion Volume") and Cantabro loss ratio. From this figure, it can be known that the Dispersion Volume reaches a minimum around 6:4 to 7:3. Such result shows a trend similar to the results of the solid volume percentage test and other tests as described in the preceding subsection. Also, as for Cantabro loss ratio, the mix proportion reaches its inflection point around 6:4 to 7:3. As a result, the optimum mix proportion can be obtained from the solid volume percentage of coarse aggregates, and, the aggregate dispersion resistance and the solid volume percentage of coarse aggregates have close correlation with each other.

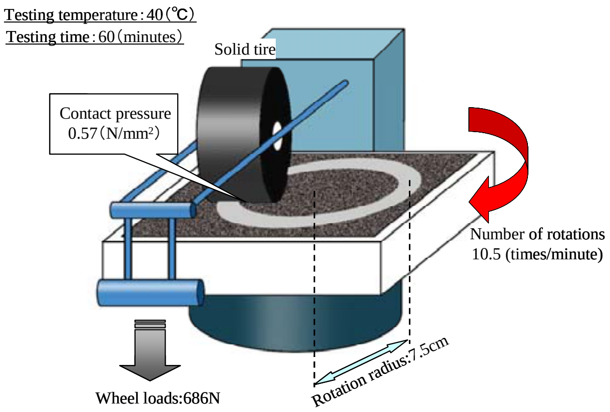


Figure 4: Outline concept of torsional aggregate dispersion test

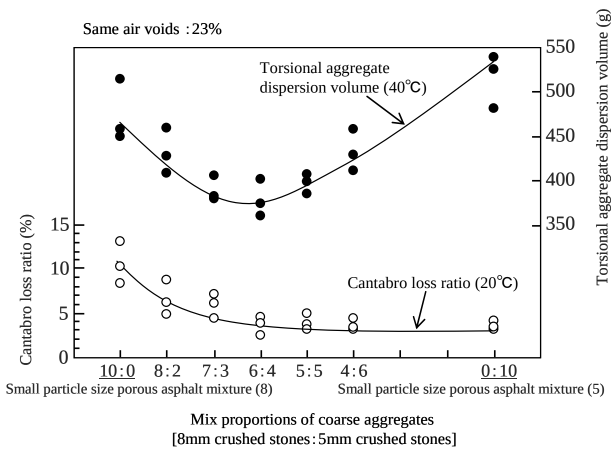


Figure 5: Test results of aggregate dispersion resistance

3.3 Resistance to Void Choking (Sustainability of Permeability Function)

Since small particle size porous asphalt mixture has small voids in size, the Proposed Mixture was made to have a larger void ratio by 3 to 5 % than that of the ordinary porous asphalt mixture (13) as countermeasures to keep continuous voids and prevent a void from choking. As the Selected Mixture consisted of small particles and includes coarse aggregates, we were concerned for any decrease of a permeable water volume.

Such being the case, we performed a permeability sustaining test as shown in Photo 1, by which the void choking resistance was evaluated for singly graded 8 mm particle size porous asphalt mixture and same 5 mm particle size asphalt mixture as well as the Selected Mixture. In this test, a specimen, 150 mm in diameter and 50 mm in thickness, molded with a gyratory compactor was soaked with water at 60°C, and a wheel tracking test machine was operated to make a traverse travel to evaluate the sustainability of permeability function based on the correlation between the number of travels and water-soaked condition. Figure 6 shows the relation between the number of traverse travels and the volume of soaking water. Though there was a slight difference in the initial values of soaking water between the Selected Mixture and the small particle size porous asphalt mixture of singly graded type (8 mm), the soaking water volume progressed in a similar level for both of the mixtures. From the test results, the Selected Mixture and the conventional small particle size porous asphalt mixture (8 mm) can be concluded to have a same level of sustainability in the permeability function.

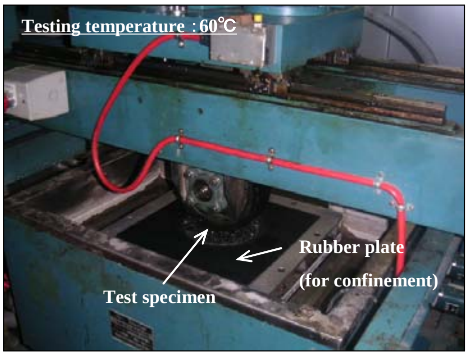
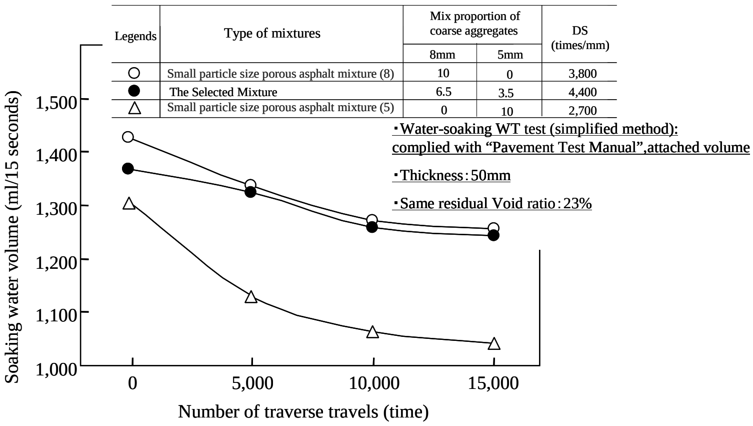


Photo 1: Scene of the sustainability test for permeability function



Legends	Type of mixtures	Mix proportion of coarse aggregates		DS (times/mm)
		8mm	5mm	
○	Small particle size porous asphalt mixture (8)	10	0	3,800
●	The Selected Mixture	6.5	3.5	4,400
△	Small particle size porous asphalt mixture (5)	0	10	2,700

Figure 6: Test results of permeability function sustainability

4 STUDY ON ADHESIVENESS OF ABUTTING LAYERS

Where a thin layer of small particle size porous asphalt mixture is laid on porous asphalt pavement, the upper layer and lower layer spot-adhere with each other, thus adhesion area becoming small and adhesive strength being most likely weakened. To cope with the weakened adhesive strength, an idea is that rubber-mixed emulsion should be abundantly sprayed so that monolithic solidity is improved between the two layers; however, in the case of roads with heavy vehicle traffic, much stronger adhesive strength is indispensable. Also, abundant spray of emulsion alone cannot solve a problem of the emulsion draining out. Then, new specially modified emulsion was developed which has a higher concentration and is more advanced in quality and more breakable than the conventional rubber-mixed emulsion, and was compared with the conventional emulsion for the adhesive strength.

A test specimen of two layer construction was prepared for three types of models noted in

Table 2, and was measured for tensile strength before and after the soaked wheel tracking test (60°C). The test was made as tensile test of a cylindrical specimen according to JEAA-5. Figure 7 shows the results of the tensile tests. As a result, newly developed specially modified emulsion showed the same degree of adhesive strength per 1.0 liter/m^2 as for the conventional one, and the decrease in adhesive strength after soaked WT test was small.

Table 2: Outline specifications of tensile strength test specimens

Test conditions \ Construction Methods		Conventional Method	The Selected Method	
Construction of specimens (2 layers)	Upper layer	Porous asphalt mixture (13) t=50 mm	Selected Mixture t=25 mm	Selected Mixture t=25 mm
	Emulsion (sprayed volume)	Rubber-mixed emulsion (0.4 liter/m^2)	Specially modified emulsion (0.4 liter/m^2)	Specially modified emulsion (1.0 liter/m^2)
	Lower layer	Coarse-graded asphalt mixture (20) t=50 mm	Porous asphalt mixture (13) t=50 mm	Porous asphalt mixture (13) t=50 mm

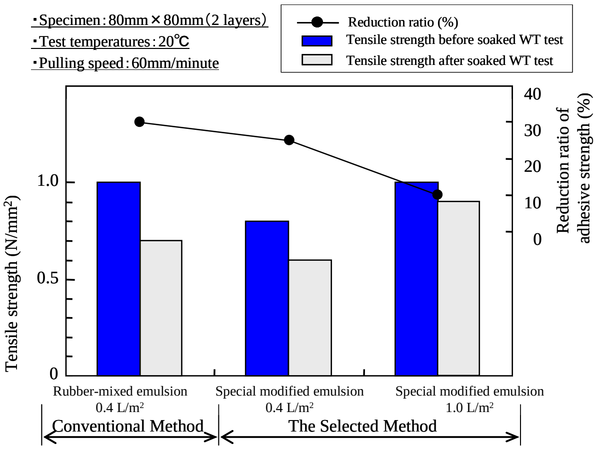


Figure 7: Results of tensile strength tests

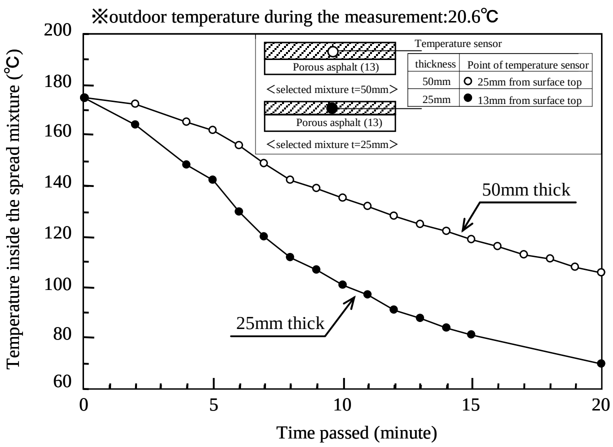


Figure 8: Measurement result of temperature inside spread mixture

Also, using the same two-layers specimen as for the tensile tests, water sealing effect was verified by a pressurized permeability test. In consequence, it was ascertained that the water sealing performance was obtainable at the same level as for the conventional method. Then, it can be concluded that the abundant spraying of emulsion can be expected to exert water sealing effect for the existing pavement and high adhesive strength as well.

5 STUDY ON WORKABILITY

A change in temperature after the mixture has been laid out largely varies with the thickness of pavement as shown in Figure 8. In case of a thin layer, the temperature rapidly declines immediately after it has been spread out. For this reason, a thin layer should be expeditiously wrought out, but the compaction temperature can decline depending on the construction conditions.

On this study subject, the compaction properties and aggregate dispersion resistance were evaluated as to whether the mixture is mixed with the warm mix additives or not, in a certain compaction temperature range (160, 140, 120, 100°C). For this purpose, a circular specimen (150 mm in diameter, 25 mm in thickness) was prepared by using a gyratory compactor. The number of rotations of the gyratory compactor was taken as 20 times so that the same density can be obtained as that obtainable by a Marshall compactor (50 times on each side) at the compaction temperature of 160°C without any warm mix additive. The aggregate dispersion resistance was evaluated by the torsional aggregate dispersion test, using the same specimen as described above. Though that test method is as described in subsection 3.2, the rotation radius and test time were changed without any change to other aspects. During the test, the specimen was confined with a rubber plate. The testing time was taken as a period required until the dispersion of aggregate started in the specimen at the compaction temperature of 160°C. Figure 9 shows the correlation between the compaction temperature, compaction factor and torsional aggregate dispersion volume. From the figure, the compaction factors of 25 mm thick specimens were found to be substantially equal irrespective of whether warm mix additives were used or not. On the other hand, as for the dispersion volume, it increased as the compaction temperature lowered in the case of mixture with no additive. In the case of mixture with the warm mix additives, it remained unchanged even at the compaction temperature of 100 to 140°C, or the dispersion volume was equal to that of the non-additive mixture was compacted at 140°C. From this result, it can be said that the use of the warm mix technology enables the mixture to attain the required quality even in a cold weather period.

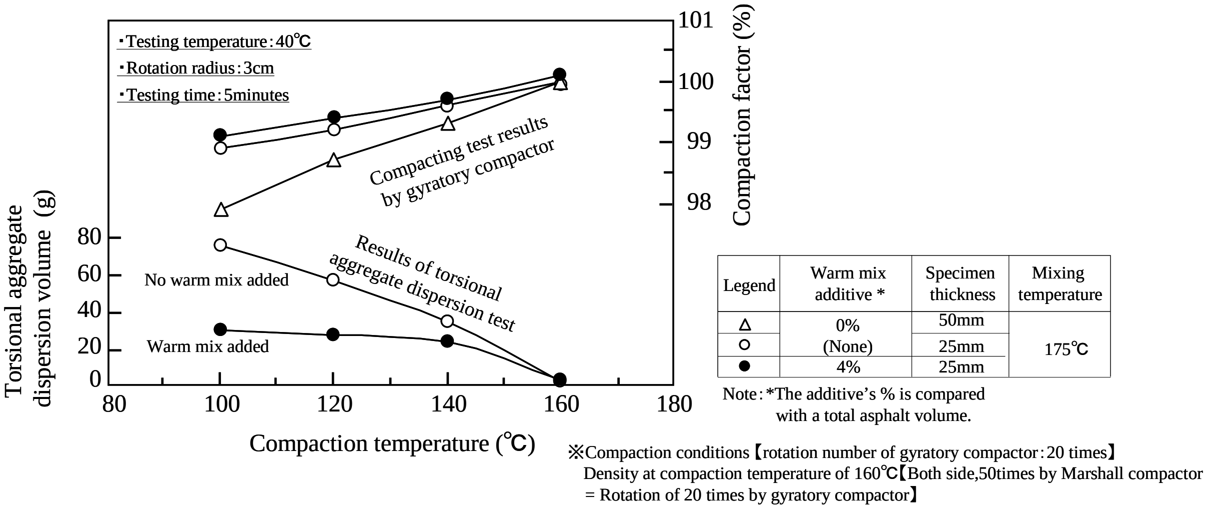


Figure 9: Correlation between compaction temperature, compaction factory and the dispersion volume

Since the foregoing laboratory test results showed favorable ones on the major three subjects of this new repair method, namely, (1) Durability of mixture, (2) Adhesiveness of abutting layers and (3) Workability, the workability and the performance were verified on existing roads in service, using the mixture shown in Table 3. In selecting the type of mixture, traffic volume and road surface properties were taken into account.

Table 3: Composition of mixture

Item	Composition
Proportion of coarse aggregates	8 mm crushed stones : No.7 crushed stones = 6.5 : 3.5
Binder	Modified polymer-based asphalt H type (for small particle size)
Target air voids	20%
Warm mix additive	None added (since the test was made in the summer season.)

6 TEST PAVEMENT ON ROADS IN SERVICE

6.1 Outline of test pavement

The test pavement was aimed at measuring noise of tire/road surface by using our own exclusive measurement vehicle to confirm the noise abatement function etc. as well as evaluating the workability and performance of the Selected Mixture. Table 4 shows an outline of the test scheme. If the tapering method used in the conventional thin overlay construction is employed for the Selected Method, steps would be formed or the pavement be fractured after the completion of pavement due to the specific features of the Selected Mixture; therefore, for the Proposed Method, small cutting was made at the starting and ending parts and edges of pavement to keep the required paving thickness for tapering.

Table 4: Outline of Test Pavement

Items		Outline specifications
Site scheme	Time	September 2006
	Site	City roadway in Yokohama (Sanmai cho, Kanagawa-ku)
	Scale	About 500 m^2 (60 m in overall linear length, 3.3m wide x 2 (Expanded))
	Pavement depth	25 mm
	Traffic volume	N_5: not less than 250, but less than 1,000 (Unit: number of vehicles /day-direction)
Construction	Paving machine	Asphalt finisher with emulsion-spraying device
	Rolling compaction machine	Tandem roller, 6 tonf (Breakdown and secondary rolling), tire roller, 25 tonf (finish rolling)
	Tack coat	Specially modified asphalt emulsion
	Spray volume	1.0 liter/m^2

6.2 RESULTS OF TEST PAVEMENT

The on-site construction scene of the test pavement is shown in Photo 2. The finished surface was good enough and free from dragging of aggregates. The target values were all satisfied as to the pavement thickness (27mm in actual measurement), air voids (19.8% in the measurement) and degree of compaction (99.4% in the measurement).

The road surface properties before and after the repair construction and in two years after the road was put into operation were traced as shown in Table 5. As for the existing porous asphalt pavement prior to the repair, the noise level of tire/road surface was 92.2 dB, and permeability 189 mliter/15 seconds. Immediately after the repair, the noise level of tire/road surface was 87.4 dB, and permeability 1,293 mliter/15 seconds. Thus, a drastic improvement in function was ascertained. As a consequence of the follow-up investigation, it was found that the permeability was in a decline due to the void clogging; however, the other aspects largely kept the functions in favorable conditions as expected (see Photo 3).

Photo 2: On-site construction scene

Photo 3: Scene of Test Pavement Site (Two years after)

Table 5: Measured results of road surface properties

Items	Before completion	Immediately after	8 months after	1 year after	2 years after
Noise of tire/road surface* (40km/h, dB)	92.2	87.4	86.6	86.5	86.2
Permeability(mliter/15sec.)	189	1,293	1,158	887	489
Dynamic friction coefficient (40km/h)	—	0.47	0.55	0.58	0.52
Texture depth of pavement surface (MPD)	—	1.06	1.01	1.01	1.07
Cracking ratio (%)	0.9	0	0	0	0
Rutting (mm)	3	0	1	1	1
Smoothness (mm)	3.1	1.7	2.1	1.8	1.7

Note: *as measured by our own exclusive measurement vehicle

7 COMPARISON IN ECONOMY

In order to evaluate the cost effectiveness of the thin overlay method applied for the repair to porous asphalt pavement, the cut and overlay method and the Proposed Method are compared in direct construction costs. The comparison results are as shown in Figure 10. Out of the construction costs, the material costs comprise a very large portion; therefore, it is easily understandable that to make a depth small would lead to a possible curtailment of the total costs. The Selected Method basically excludes the cutting method; however, the cutting is unavoidable at the starting and ending parts and the edge parts, since the tapering at those parts inevitably require the cutting. It should be noted that the total cutting costs as part of the Selected Method is in the order of one third of the costs involved in the cut and overlay method, and the resultant cutting material is very small. If cut and overlay method is changed to the thin overlay method as repair method for the porous asphalt pavement, the construction costs can be curtailed by about 40%.

In addition, as a construction output a day can be increased to about 1.5 times, by which incidental effects can be expected, including shortening of a repair work period and relaxation of the traffic control.

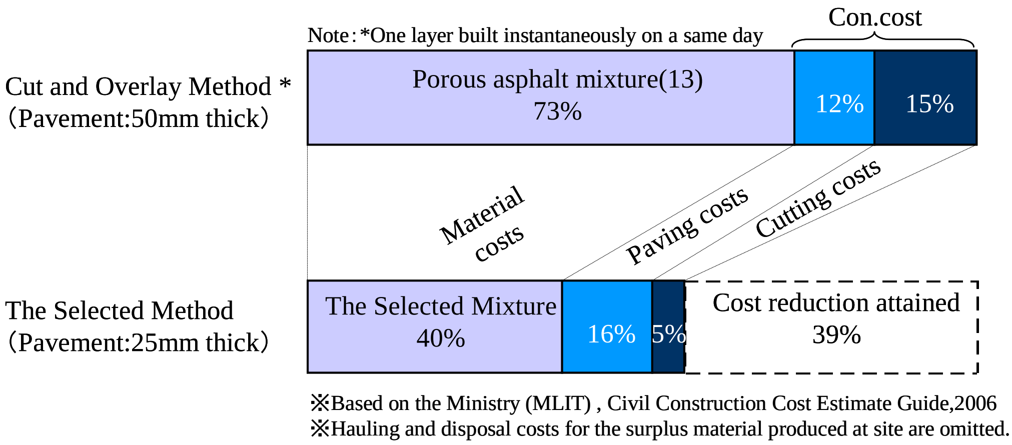


Figure 10: Comparison of direct construction costs

8 CONCLUSIONS

There occurred certain engineering issues during the putting the thin overlay method into the practical use as a repair method for the porous asphalt pavement. These issues were verified in the laboratory tests and test pavement on a road in service to obtain the following results.

1) The reinforcement in aggregate formation was fortified by finding the correlation between the aggregate dispersion resistance and the solid volume percentage and by combining the varying particle sizes of aggregates in the optimum mix proportion (8 mm crushed stones : No.7 crushed stones = 6.5 : 3.5). By this solution, the aggregate dispersion resistance and the sustaining of functions can be improved which have been pending issues for small particle size porous asphalt mixture.
2) By abundant spray of the specially modified emulsion, large adhesiveness is obtained and yet the adhesiveness persists for a longer time; therefore, it is possible to solve such issues as dislocation of the abutting layers and peeling off.
3) For the purpose of the thin layer construction, the warm mix technology is applied, so that the aggregate dispersion resistance during the lowered compaction temperature is improved to add to the workability of mixture. Consequently, the workability in cold weather is also assured.
4) According to the follow-up investigation within two years of the performance, the properties of pavement surface has not been subjected to any considerable change from the completion and kept in a favorable condition. Also, as for a noise reduction effect, the pavement has kept same noise reduction level as about minus five dB as compared with the pre-repair pavement. On the other hand, though the draining function has been on a slight decline due to clogging of voids, it is not due to the choking; therefore, this aspect is considered not to have unfavorable influence on the durability of pavement itself.
5) As compared with the cut and overlay method, the Selected Method has the advantage of the construction costs most likely to be curtailed by 40%; thus, the cost effectiveness would be largely increased. In addition, it can be declared that the construction output per day will be increased in the order of some 1.5 times.

REFERENCES

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