The Field Study of the Conformed Porous HMA at Heavy Snow Region

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ABSTRACT: Hokuriku region, literally North Land Region, is a region in the northeastern part of Honshu, the main island of Japan. The region managed by "Ministry of Land, Infrastructure, Transport and Tourism Hokuriku Regional Development Bureau" is a unique in heavy wet snowfall and rainfall not only in Japan but on worldwide. Regarding with the noise environment of residents nearby, the porous HMA has been applied to the noise-sensitive area as the quiet pavement. Correspondingly, the porous HMA has been applied to reduce the potential for splash and spray from a viewpoint of the improvement of the vehicle-surface safety. After paving two or three years, it is, however, pointed out that the raveling by the fresh/compacted snow-removal work and snow chains during winter season causes the serviceability deterioration. Reinforcing the durability of the porous HMA at heavy snow region, the field tests on different air voids were conducted. In addition, regarding with the raveling-sensitive area such as at intersection/road junction, the high functional stone mastic asphalt (SMA) has been applied to the area, experimentally. The texture depth of the high functional SMA is the same as that of porous HMA. In this paper, the properties of the porous HMA are evaluated and considered relevance under the circumstance of the heavy snow region. Furthermore, the verified performance of the highly functional SMA due to the raveling-sensitive area and heavy snow area is described.

KEY WORDS: Snow-covered regions, porous HMA pavements, air void content, highly functional stone mastic, texture depth.

1 INTRODUCTION

In recent years, porous hot-mix asphalt (HMA) pavements have been applied to roadways everywhere in Japan as a standard practice to enhance the roadside environment and promote vehicular traffic safety. This is ascribable to the attention to the effectiveness of porous HMA pavements for reducing tire and/or surface noises and preventing visibility deterioration due to splash and/or spray.

In the Hokuriku region where the authors are held responsible for highway administration as well as in other regions, porous HMA pavements have been applied because the level of annual precipitation is high among major areas not only in Japan but also in the world (Figure 1). Of 1,010-km national highways under the control of the Hokuriku Regional Development Bureau [HRDB], porous HMA pavements have been in service over a length of approximately 140 km. The standard porous HMA pavements constructed in Japan generally have approximately 20 to 23 % air voids.

The Hokuriku region has high rainfall amounts in summer and heavy wet snow, which are rarely seen all over the world. When removing compacted snow, surface aggregate is delaminated because compacted snow combined with air voids of the porous HMA pavement is peeled off. Vehicles with tire chains cause the coarse aggregate of porous HMA pavements to ravel during the winter raveling of aggregate) (Photograph 1,2). As a result, the loss of the above features of porous HMA pavements in a few years, or after a winter at the earliest, has been an issue.

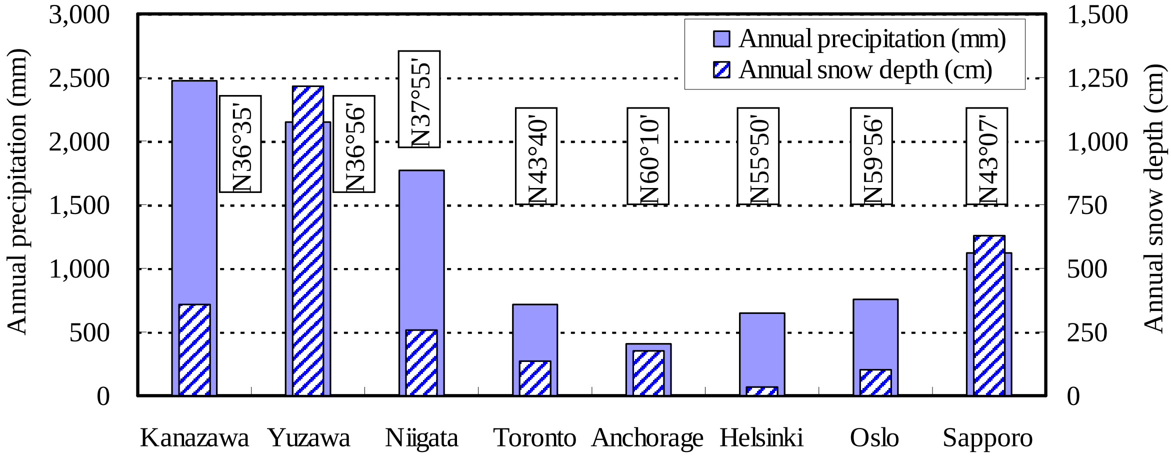

Figure 1: Annual precipitation and snow depth[1),2)]

Photograph 1: Porous HMA pavements right after pavement

Photograph 2: Porous HMA pavements right after the raveling of aggregate

This paper describes the investigations and studies conducted to solve the problem that is except tire and/or surface noises.

This paper also presents the results of recent trial construction of highly functional stone mastic asphalt (SMA) pavements at intersections and other locations under heavy traffic conditions. The Hokkaido Development Bureau and NIPPO CORPORATION jointly developed the SMA pavement as a new mixture for cold districts to substitute for porous HMA pavements

Chapter 2 discusses the study on air void content and Chapter 3 describes the highly functional SMA pavement.

2 EXAMINATION OF POROUS HMA PAVEMENTS IN SNOW-COVERED AREAS

2.1 Porous HMA Pavements Required in Snow-covered Regions

The porous HMA pavements in snow-covered areas like the Hokuriku region need to be durable durability.

As the principal means of preventing the raveling of aggregate, a problem in ensuring durability, increasing the adhesive between coarse aggregates was considered necessary. In addition, increasing of asphalt mortar, in other words, reducing the air void content was considered the deliberate solution at the point. Another requirement was to secure the amount of permeation right after pavement (1,000 ml/15 sec) specified by the Ministry of Land, Infrastructure, Transport and Tourism [MLIT]. In order to seek the air void contents to meet the above requirements, porous HMA pavements with varying air void content were constructed on a trial basis and a follow-up survey was conducted.

2.2 Examination of Optimal Air Void Content

The objective of the investigation was to obtain an air void content clarify for the Hokuriku region. The deliberate approach by authors to prevent aggregate from being raveled without deteriorating the features of porous HMA pavements was found to be reducing the air void content, or enhancing the aggregate tenacity by increasing the amount of binder. The performance provisions of the MLIT stipulate that porous HMA pavements shall meet a permeability requirement of 1,000 ml/15 seconds. An air void content was sought that would meet the requirement to ensure traffic safety during the summer.

For the trial tests, a dense-graded and porous HMA pavement with a maximum size of 13 mm was constructed after milling the existing pavement for a depth of 5 cm in November 1999 on National Highway No. 8 in Minami-ku Kohya, Niigata City (heavy vehicular traffic volume: 5,300 vehicles per day per direction, total traffic volume: 22,800 vehicles per day per direction) . Different air void content of 10, 15 and 20% were conducted for porous HMA pavement. As the binder, polymer modified asphalt type H (modified AS (H) below) was used. However, HRDB stipulates, based on the design guidelines of 2006 concerning aggregate raveling control, that polymer modified asphalt type H-F (high-viscosity binder for cold regions, modified AS (H-F) below) shall be used for porous pavements.

(1) Rut Depth

The changes of rut depth with time are shown in Figure 2. Rut depth increases either on dense-graded HMA pavements (20 FH modified type) (dense-graded HMA pavement II) or on porous HMA pavements at any given air void content. Rutting of porous HMA pavements is ascribable not to the fluidization of asphalt mix but to the scattering raveling of aggregate regardless of the air void content.

Rut depth was lowest at an air void content of 15%, lower than at an air void content of 10%. Rut depth increased at an air void content of as low as 10% because, unlike in porous HMA pavements with ordinary particle size distribution, excessive amounts of sand enter the gaps in the structural basis of stone-on-stone contact in the asphalt mix.

It was then concluded that the optimal air void content in porous HMA pavements should be set at approximately 15% rather than simply reducing the rate where only rutting resistance was considered.

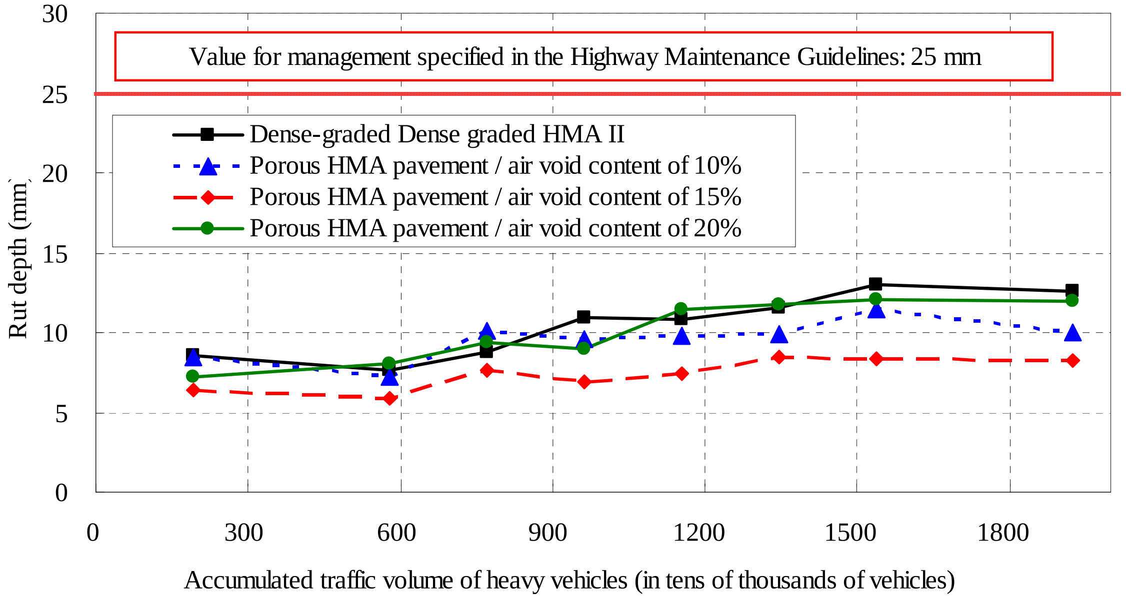

Figure 2: Accumulated traffic volume of heavy vehicles and rut depth

(2) Cracking Ratio

The changes of cracking ratio with time are shown in Figure 3. Cracks were detected on dense-graded HMA pavement II at an accumulated traffic volume of approximately 10 million heavy vehicles (after the pavement was in service for five years). Cracking ratio was slightly below 15% at an accumulated traffic volume of 15 million heavy vehicles. Cracking ratio was low at less than 3% on porous HMA pavements with little difference at different air void content. This is mainly ascribable to aggregate tenacity of modified AS (H) used on porous HMA pavements.

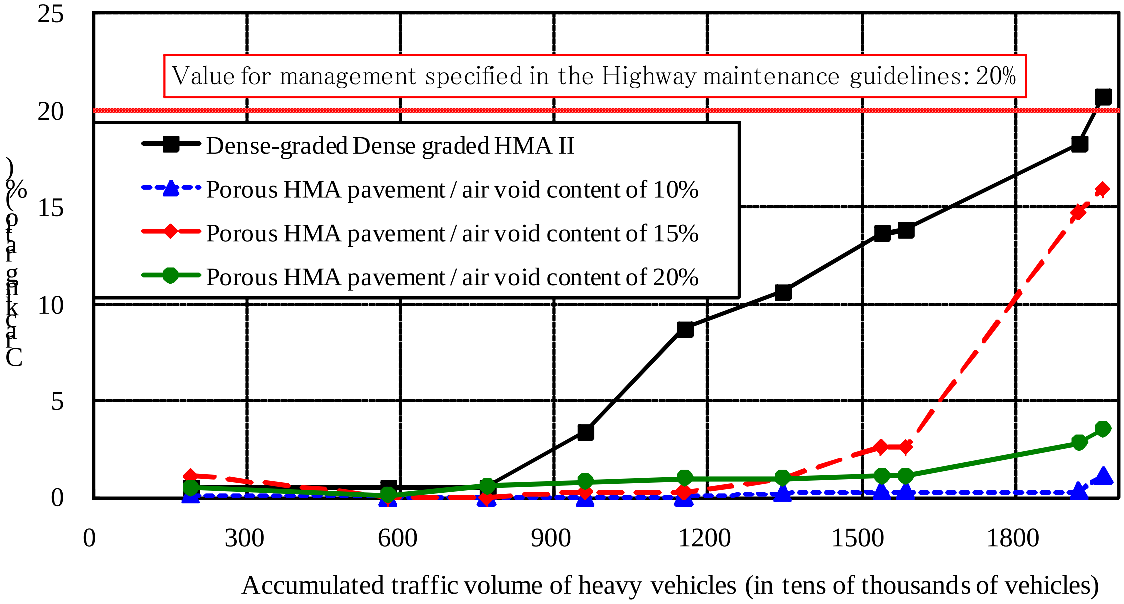

Figure 3: Accumulated traffic volume of heavy vehicles and cracking ratio

(3) Roughness

Roughness based on 3m straight edge was around 1.0 mm (one standard deviation) right after the construction. It gradually increased to approximately 2.0 mm at an accumulated traffic volume of 15 million vehicles (after the pavement was in service for approximately eight years). No outstanding difference was, however, found among different types of mixture.

(4) Volume of Permeation

The changes of permeation with time are shown are shown in Figure 4. After the pavement was in service for one month (after the passage of approximately 150,000 vehicles), the volume of permeation was 942 ml/15 sec at an air void content of 20%, 777 ml/15 sec at an air void content of 15% and 309 ml/15 sec at an air void content of 10%. Thus, the difference according to the air void content was outstanding. At an air void content of 10% in particular, the volume of permeation was low from right after the pavement. The volume of permeation was below 100 ml/15 sec, a marginal level for functional restoration, after the pavement was in service for two years regardless of the air void content. Subsequently, permeation peaked. The pavement became nearly impermeable at an accumulated traffic volume of 1,000 vehicles (after the pavement was in service for five years). As a result of surface observation, it was found that air voids were clogged on the outer wheel pass (OWP).

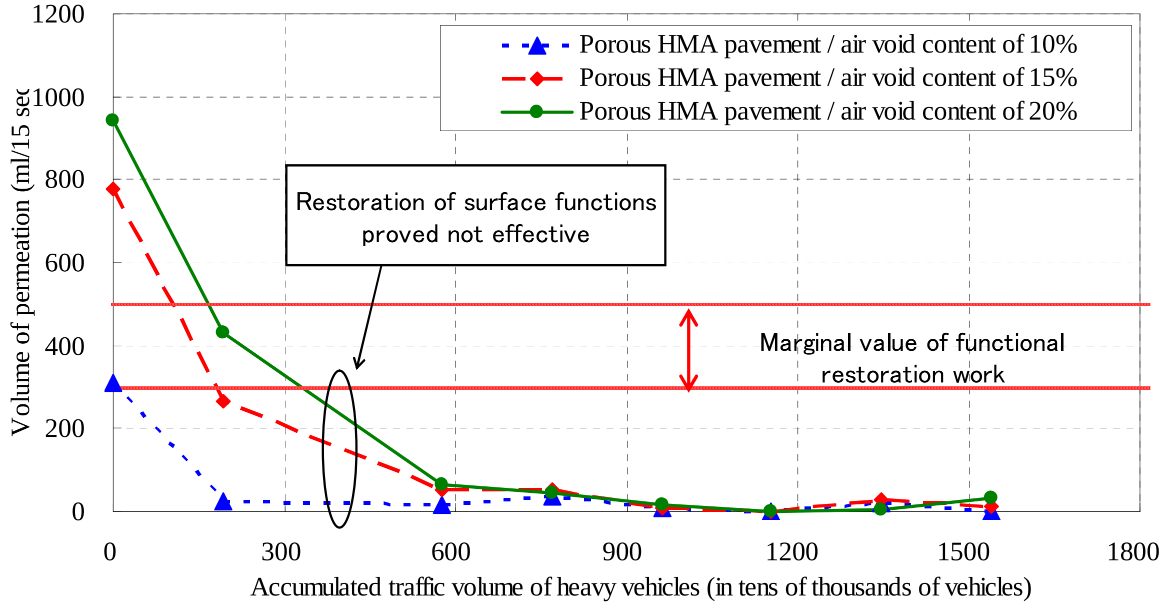

Figure 4: Accumulated traffic volume of heavy vehicles and volume of permeation (Study of air void content of porous HMA pavement)

An attempt was made to restore surface functions after the pavement was in service for two years, but it failed to produce any effects because the volume of permeation had already decreased to less than 200 ml/15 sec.

The volume of permeation at each air void content right after the pavement was estimated based on the follow-up survey data and the volume of permeation on ordinary porous HMA pavements with an air void content of 20%. The results are shown in Figure 6. It was found that a target volume of permeation of 1,100 ml/15 sec to meet a requirement of the MLIT of 1,000 ml/15 sec right after the pavement could be achieved by setting the air void content at 17% in view of a variation of 10% during construction.

2.3 Examination Result of Optimal Air Void Content

As a result of examination of air void content, the effective air void content that could meet the durability and functionality requirements for porous HMA pavements in the Hokuriku region was estimated to be 17%. Then, an attempt was made to construct a trial pavement with the air void content. Before trial pavement, the volume of permeation was measured using wheel tracking specimens developed during the design of mix proportions and an attempt was made to verify that the volume of permeation could meet a level of 1,000 ml/15 sec, a requirement specified by the MLIT. As a result, the volume of permeation was 1,018 ml/15 sec, nearly the same as the requirement, in a specimen with an air void content of 17%. The requirement was, however, not likely to be met during construction. The mix proportions at an air void content of 18% that achieved a volume of permeation of 1,110 ml/15 sec with some allowance were therefore adopted to construct the pilot porous HMA pavement. For the binder, modified AS (H-F) was used. After the construction, volume of permeation is 1,241 ml/15 sec and degree of compaction is 99.0%.

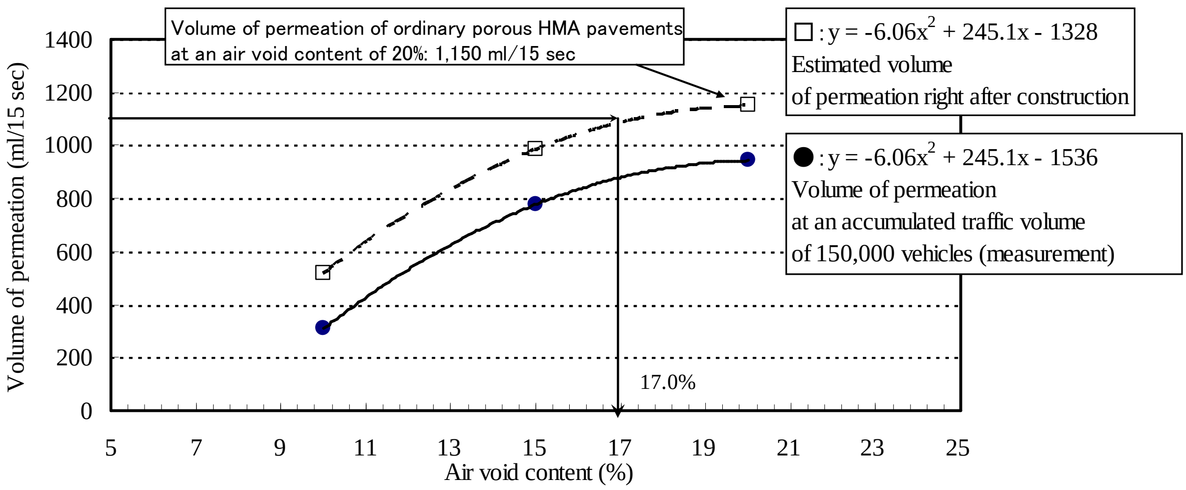

Figure 5: Estimation of air void content to achieve a required volume of permeation of 1,000 ml/15 sec right after construction

The trial pavement has been in service for three years. At present, permeation is at a favorable level of 668 ml/15 sec. Rut depth is 8.0 mm and the cracking ratio is 0.2%. Aggregate has been raveled at a few locations. No aggregate raveling has, however, occurred that caused potholes or noise problems. The surface has been kept in excellent condition. The result has been obtained on a single trial pavement and after it was in service for three years. Therefore, it is expected that similar pavements should be necessary at several other locations because of verificating the optimal air content.

3 VERIFICATION OF HIGHLY FUNCTIONAL SMA PAVEMENT

3.1 Historical Background

As an alternative to porous HMA pavements substitute for snow areas including the Hokuriku region, a highly functional SMA pavement was developed in Hokkaido based on a new concept. The pavement has no drainage capacity but is as fine-textured as porous HMA pavements and as durable as stone mastic asphalt pavements. Thus the pavement has a good track record as the pavement resistant to aggregate raveling. This chapter describes the results of a follow-up survey concerning the durability of highly functional SMA. Because snow conditions of Hokuriku and Hokkaido were different, the experimental pavement was done.

3.2 Outline of Method for Constructing Highly Functional SMA Pavement

The highly functional SMA pavement is a new type of multi-functional pavement with the durability of SMA pavements and the noise absorption capacity of porous HMA pavements[3]. An SMA structure is shown in Figure 6. It is structurally composed of a porous top layer with a high air void content, and dense medium to bottom layers. This structure is held together by a mortar of inactive particles and asphalt binder. The respective layers with conflicting properties are constructed as a single layer.

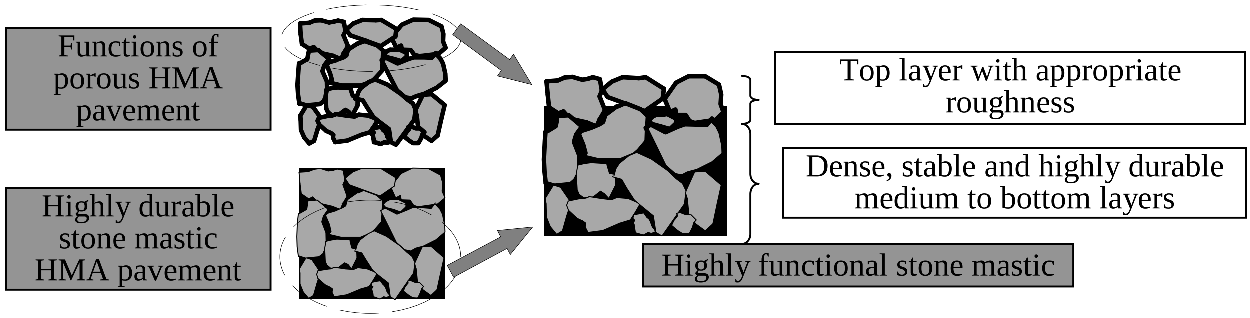

Figure 6: Highly functional SMA structure

The highly functional SMA pavement was developed as

(i) High durability: surface layer of highway can have enough bearing capacity for heavy traffic load,

(ii) High skid resistancy: the pavement during a rain on the slope areas can have enough safety level for driving vehicle,

(iii) High adaptability: the pavement during winter can have enough performance level for the deterioration instead of porous HMA pavement in cold area｝

3.3 Trial Construction of Highly Functional SMA Pavement

Sites of trial construction of highly functional SMA pavements and field conditions are listed in Table 4. The maximum size was 13 mm. Modified AS (H) was used as the binder.

(1) Durability

As a result of follow-up surveys, it was found that neither the raveling of aggregate nor the cracking occurred in both work sections and no shaking of heavy vehicles was visually confirmed in relation to the roughness of the pavement. It was therefore assumed that no deterioration occurred since the commencement of service.

Table 4: Locations of highly functional SMA pavements

Construction site	Date constructed	Duration of service※1	Traffic volume of heavy vehicles※2	Objective of construction
Bandai, Chuo-ku, Niigata City	Mar. 2004	Five years seven months	3,466 vehicles/day /direction	Prolong service life (function of SMA)
Anno-cho, Agano City	Sept. 2006	Three years and one month	3,878 vehicles/day /direction	Control the raveling of aggregate

The changes of rut depth with time are shown in Figure 7. Little rutting progressed under traffic loads of heavy and other vehicles. At a point four years after the completion of construction (at an accumulated traffic volume of approximately eight million heavy vehicles), adequate durability was assumed to be available.

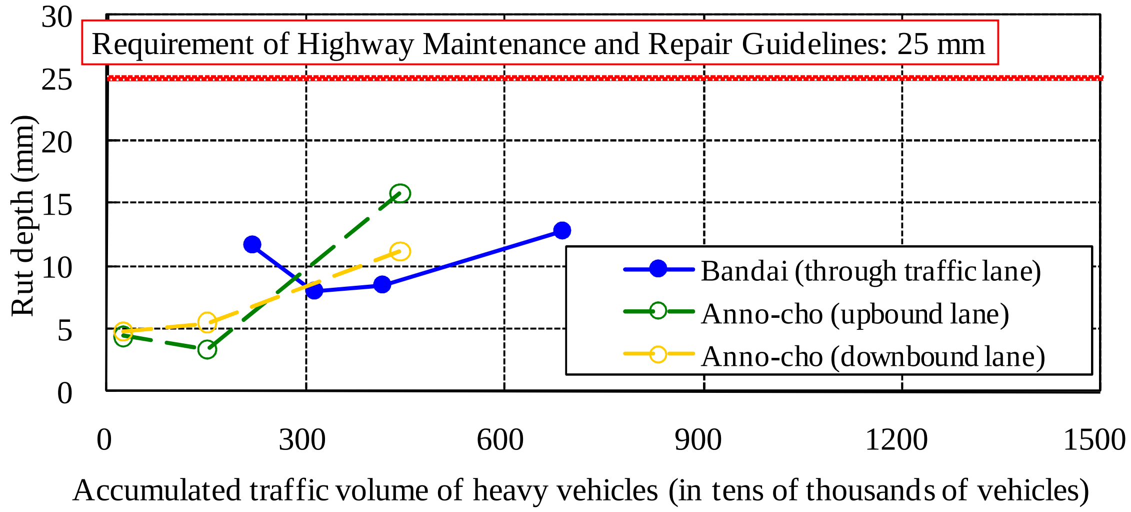

Figure 7: Number of months the pavement was in service and rut depth (for highly functional SMA pavements)

(2) Texture Depth

The results of measurement of texture depth of highly functional SMA pavements are shown in Figure 8.

Texture depth was approximately 0.6 mm at the commencement of service either for highly functional SMA pavements or for porous HMA pavements with an air void content of 20%. As described in the preceding section, it has been verified that the surface of highly functional SMA pavements was as well textured as that of porous HMA pavements.

The data in Bandai is decreased in the texture depth slightly but it is expected that the texture depth should be around 0.5 mm.

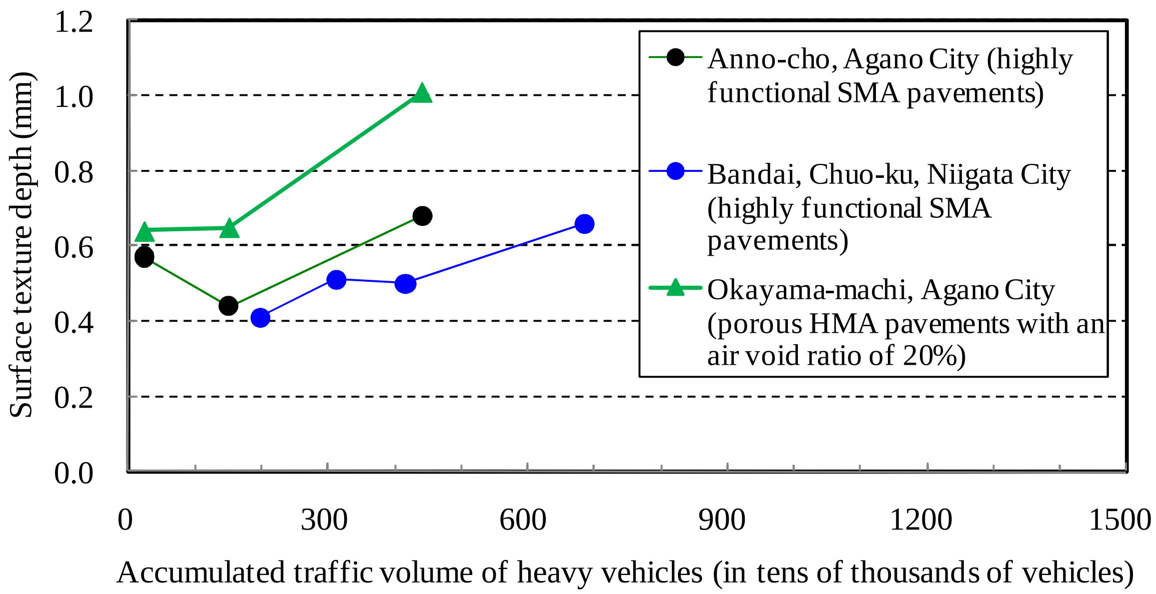

Figure 8: Accumulated traffic volume of heavy vehicles and texture depth

3.4 Verification Study based on the Trial Construction

Few data is yet available on the surface properties of highly functional SMA pavements in service. The pavements are, however, considered to be more durable than porous HMA pavements with an air void content of around 20%.

No measurements were taken on the trial pavement to determine the ratio of noise reduction. Laboratory test data (Hayasaka et al. 2000) shows that the ratio is 19% for highly functional SMA pavements (55% for porous HMA pavements) at a peak absorption ratio of 500 Hz while the ratio is 2% for densely-grained HMA pavements. Highly functional SMA pavements are therefore expected to reduce tire and surface noises. In the future, it will be necessary to identify the effects on the surrounding environment by measuring the tire and surface noises or surface reflection ratio.

A comparative study was also made concerning the deicing chemicals retention capacity among highly functional SMA, porous HMA and dense-grade HMA pavements. The results were more favorable for highly functional SMA pavements than for porous HMA and dense-grade HMA pavements.

Therefore, it is necessary that trial pavements should be still necessary at several other locations because of verificating the ideal highly functional SMA.

4 CONCLUSIONS

With decreasing investment in public utilities and increasing demand for CO2 emission reduction, developing long-life pavements requiring less frequent repair is expected to become all the more important to the reduction of maintenance costs.

In this paper, the air void content of porous HMA pavements that are durable and achieve the designated volume of permeation in snow-covered areas was estimated at around 17% based on the results of actual construction, and the results of trial construction of a pavement with an air void content of 18% were presented. It was also described that data was collected that suggests the possibility of highly functional SMA pavements as fine-textured as porous HMA pavements having greater durability than porous HMA pavements.

Therefore, it is expected that collecting data should be necessary at several other locations because of confirming and clarifying a rational design guideline (e.g. applying porous HMA pavements with an air void content to the specifications for snow-covered areas in ordinary sections, and highly functional SMA pavements at intersections and on steep slopes that require greater durability, with a view to reducing roadside noise).

The social demand is expected to increase among highway drivers concerning the level of serviceability. Needs of technical development will further increase for reducing maintenance costs. Finally, it is necessary that the continuous follow-up surveys and new research development due to the snow-covered area should be conducted. Therefore, the ideal the design guideline should be revised because of changing the current and future social demands.

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