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# Construction and pavement properties after seven years in porous asphalt with long life

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## HIGHLIGHTS

- Pavement properties after seven years.
- Construction by Kyoto Specifications.
- Factors of long life in porous asphalt.
- Relation between rut depth and temperature.

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## ABSTRACT

This paper describes the construction and pavement properties after seven years in porous asphalt with long life in Kyoto Jukan Expressway, comparing with conventional methods. It was constructed in 1998 in accordance with various kinds of specifications (Kyoto Specifications), regarding modified binder, aggregate, asphalt mixture, asphalt plant, construction machine and construction method. It consists of four different sections in pavement and they were constructed in order to aim the long life and to evaluate their effects on the life in porous asphalt. In this study, it was described construction and pavement properties including with effects of water content of materials on temperature in porous asphalt in Kyoto Jukan Expressway and relation between local rut depth and local cooling on surface after finishing in dense type mixture.

It was concluded that the long life in porous asphalt related to the quality of materials, uniformity of surface temperature after finishing, cubic stone in porous asphalt, and local temperature on pavement surface after finishing connected with local rut depth in dense type mixture.



## 1. Introduction

Generally, it has been common belief that the damages such as rutting and cracks in asphalt pavement occurred when ambient temperature changed [1–3]. Especially, it was said that it was very difficult to construct the pavement of long life in porous asphalt, because severe damages such as pothole and stripping of aggregate in porous asphalt occurred, and the causes of those damages after service in asphalt pavement were not yet clarified [4,5]. But porous asphalt in Kyoto Jukan Expressway was maintenance free for fifteen years using Kyoto Specifications, and pothole and stripping of aggregate in Kyoto Jukan expressway were not observed. Beside, aging of modified binder in Kyoto Jukan Expressway was not also observed, because the color of pavement surface on porous asphalt

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is held in real black and modified binder covered aggregate on pavement surface is not stripped for fifteen years.

Generally, on one hand, it has been believed that pothole and stripping of aggregate were caused by inappropriate technique in pavement construction, and appropriate construction methods have been pursued [6]. On other hand, we suppose that damages such as stripping of aggregate and pothole in porous asphalt were caused by the large strain due to movement of aggregate under moving load at high temperature [7–9], and the those damages in porous asphalt were mainly caused by high void of mixture in local cooling points in porous asphalt just after finished.

This paper describes the construction included with the effect of water content in porous asphalt and pavement properties after seven years (the life for seven years was initially assumed) in Kyoto Jukan Expressway, comparing with conventional asphalt pavement [10] and relationship between local rut depth and local cooling in dense type mixture.

It was concluded that crack patterns in porous asphalt in Kyoto Jukan Expressway connected with properties of binder, type of crushed stones and pavement structure, and they were very important factors for long life in porous asphalt, and local temperature on pavement surface after finishing connected with local rut depth in dense type mixture.

## 2. Outline of Kyoto Jukan Expressway

Kyoto Jukan Expressway is located in mountainous area of northern Kyoto in Japan and the ambient temperature exceeds 30 °C in summer and it becomes −10 °C for ten years and it also snows a lot in winter. It was required to hold the long life with seven years or more and no damage such as pothole or stripping of aggregate. Then the following innovative techniques for porous asphalt in those test sections were introduced firstly in Japan. They are very severe specifications, comparing with those of conventional porous asphalt in Japan [11]. Both specifications are shown in Table 1. New concepts in porous asphalt in Kyoto Jukan Expressway are as follows.

The four new items were required, firstly, to maintain uniformity of pavement material (shipment temperature in mixture and temperature of pavement surface just after finishing, water content of mixture, modified binder), secondly, to introduce the proper composition which has less movement of aggregate in mixture (good interlocking between aggregate), thirdly, to improve adhesion of binder (large strength and fracture strain of modified binder), lastly, to take counterapproach (new method for aging) in order to prevent deterioration of modified binder. Therefore, the Kyoto Specifications were newly specified to satisfy the above four items.

Kyoto Jukan Expressway was constructed in 1998 using those Kyoto Specifications and total length was 12.6 km. In those sections, traffic volume per day has been anticipated two thousand vehicles/day/one lane after opening.

The actual test section in porous asphalt (surface course: 4 cm, void ratio: 20%) was divided into four test sections (Section A-1, Section A-2, Section X and Section B) as shown in Fig. 1. The almost section in Kyoto Jukan Expressway (12.6 km) was constructed in Section A-2. Whereas, Section T was not section and it was located in Section A-2 and it was a new sample just after completion. The thickness of binder course and asphalt treated base course were all the same in four sections (Table 2). Crushed stone in surface course in Section A-2, Section X and Section B was used in all the same type (selected hard sandstone and cubic type using Barmac crusher, water absorption: 0.45 %), but conventional crushed stone (local hard sandstone, water absorption: 0.98 %) was also used in Section A-1. Two types of binder were used in those sections, and Binder Type A in Section A-1, Section A-2, Section B and Binder Type B were used in Section X (Fig. 1). The characteristics of both modified binder in porous asphalt (surface course) satisfied with Kyoto Specifications (described later).

In this study, results for various tests after seven years in Kyoto Jukan Expressway and properties in hot mixture after construction were described.

## 3. Three dimensional crack analyses

Three dimensional crack analyses was used to evaluate the degree of damage using micro focus CT scanner (CT) and soft program (ExFact Analysis 2.0 for Porous/Particles, Nihon Visual Science Corporation) for the cored specimens taken from the four test sections after seven years in Kyoto Jukan Expressway.

The specimens for CT and three dimensional crack analyses with a size of 2.5 × 2.5 × 8 cm were cut from the each layer of sampled cores of ten centimeter. One thousand four hundred forty tomographic images of specimens in 16 bits grey scale with

**Table 1**
Properties and specifications of porous asphalt in Kyoto Jukan Expressway and Japan.

| | Binder Type A | Binder Type B | Specification of Japan[a] | Specification of Kyoto Highway |
|---|---|---|---|---|
| Penetration (25 °C,100 gr, 5 s) (1/10 mm) | 41 | 79 | >41 | >40 |
| Softening point (°C) | 98.0 | 101.0 | >80.0 | >80.0 |
| Ductility (15 °C) (cm) | 100+ | 100+ | >50 | >50 |
| Flashing point (°C) | 325 | 310 | >260 | >260 |
| Toughness (25 °C)(N m) | 26.0 | 26.5 | >20 | >20 |
| Tenacity (25 °C)(N m) | 21.4 | 25.0 | >15 | >15 |
| Viscosity at 60 °C (kPa s) | 100+ | 100+ | >20 | >20 |
| Weight loss after TFOT (%) | +0.06 | +0.04 | <0.6 | <0.6 |
| Degree of penetration | 85.4 | 76.0 | >65 | >65 |
| *After TFOT* | | | | |
| FBP after TFOT (°C) | −25 | −20 | – | $<T_{AV}(-4)$[b] |
| MBP after TFOT (°C) | −27 | −38 | – | $<T_L(-10)$[c] |
| MBP before TFOT (°C) | −28 | <−40 | | |
| Strength at (FBP)°C, (MPa) | 7.4 | 5.2 | – | >5 |
| Strength at (FBP-10)°C, (MPa) | 8.5 | 8.0 | – | >5 |
| Fracture strain at (FBP-10)°C, ($\times 10^{-2}$) | 0.68 | 0.80 | – | >0.3 |
| HTLTD (163 °C, 72 h), (°C) | −11 | −16 | – | <−10 |
| Wax | None | None | – | Not be included |

[a] Specification in Japan, Technical Guide for Porous Pavement (Proposal).
[b] $T_{AV}$: Average daily temperature in coldest month.
[c] $T_L$: Minimum ambient temperature in coldest month for ten years.