Overview of Porous Asphalt Pavement
Overview of Porous Asphalt Pavement

Porous Pavement

Binder Course (Impervious)

Surface

Pervious

Impervious

Conventional Pavement

Binder Course (Impervious)
Porous Pavement in Rain (Expressway)

【Movie – 1】
Introduce of
Porous Asphalt Pavement
Effects of Porous Pavement

Permeable Effects
- Improvement in Skid Resistance
- Prevention from Smoking and Splash
- Improvement in Visibility
- Restraint of Hydroplaning
- Restraint of Traffic Jam in Rainy Day
- Restraint of Urban Flood

Durable Effects
- Rutting Resistance
- Cracking Resistance

Noise Reduction Effects
- Improvement in Roadside Environment
- Reduction in Driver’s Tiredness
Porous Pavement in Rain at night

Conventional Pavement Area

Porous Pavement Area

(General Road)
Effects to Safety Driving

Comparison of Accident Number Between Conventional Pavement and Porous Pavement

(1998.10)

Data shown here are plotted by author in accordance with reference shown below.


※ Decrease by 85 %
Driving Velocity vs Noise Level

Car, Tire / Road Surface Noise

- Dense Graded (13mm)
- Porous asphalt
Low-noise Effects of Porous Pavement

Noise Reduction Effects of 3dB(A)

Dense-Graded

Almost Same as Slowdown 20%

Porous Mixture

Almost Same as Decrease of 50% of Traffic Volume

Almost Same as Decrease of 50% of Traffic Volume
Example of Change in Rutting Depth of Porous Pavement

- **Y = 3.16 Ln(x) + 3.31**

- **Average of Whole Expressway including Snowy & Cold Area**
Note: Based on the amount of high viscosity asphalt used, Nakanishi calculated the area paved. Conditions of calculation are; thickness of 4cm, Asphalt content of 4.8%, mixture density of 2.0g/cm³.
Design of Porous Asphalt Pavement
Cross Section of Porous Pavement

Coefficient of Layer Equivalency = 1.0

Layer for Prevention from Rain Penetration

Asphalt Mixture (binder course) (Impervious Layer)

Base Course
(Mechanically stabilized Crushed Stone, Asphalt Stabilization, Cement Stabilization, Crusher-Run)

Sub-base Course
(Crusher-run)

Subgrade

Rubberized Emulsified Asphalt Spray: 0.4~0.6 ℓ/m²
- Improvement in adhesion
- Prevention from Penetration of water into Binder Course

4~5cm
Flow of Rainwater from Pavement

Penetration of Rainwater

Air Void 20%

Flow of Rainwater

Below Surface

(Pervious)

Surface

(Pervious)

Porous Pavement

Drainage method

At Side of Shoulder, Free Draining Edge

Draining Way to Median
Mix Design of Porous Asphalt Mixture
# Standard Gradation Range for Porous Asphalt Mixture

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Gradation Range in Japan</th>
<th>Gradation Range in Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. size (20)</td>
<td>Max. size (13)</td>
</tr>
<tr>
<td>26.5 mm</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>19.0 mm</td>
<td>95 ~ 100</td>
<td>100</td>
</tr>
<tr>
<td>13.2 (12.5) mm</td>
<td>64 ~ 84</td>
<td>90 ~ 100</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>10 ~ 31</td>
<td>11 ~ 35</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>10 ~ 20</td>
<td>10 ~ 20</td>
</tr>
<tr>
<td>1.19 mm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.075 mm</td>
<td>3 ~ 7</td>
<td>3 ~ 7</td>
</tr>
<tr>
<td>Asphalt Content (%)</td>
<td>4.0 ~ 6.0</td>
<td>&gt; 5 / 4.0 ~ 6.0</td>
</tr>
</tbody>
</table>

Note: Besides that, when the road noise needs to be lowered more, the porous asphalt mixture with the maximum size of 10mm or 8mm is sometimes adopted.
Standard Gradation Range in Japan

Gradation Range
in Japan (Max, Min)

Passing weight percentage (%)

Sieve Size (mm)
### Determination of Optimum Aggregate Proportion in Thailand

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Result (Tested Dec. 2015)</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mix proportion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>Coarse aggregate (Limestone)</td>
<td>85</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>Sand (Screenings)</td>
<td>12</td>
</tr>
<tr>
<td>Mineral filler</td>
<td>Mineral Filler Calcium carbonate</td>
<td>3</td>
</tr>
<tr>
<td><strong>Synthetic gradation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Sieve size mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>100.0 %</td>
<td>100</td>
</tr>
<tr>
<td>13.2</td>
<td>100.0</td>
<td>90 – 100</td>
</tr>
<tr>
<td>9.5</td>
<td>64.2</td>
<td></td>
</tr>
<tr>
<td>4.75</td>
<td>15.6</td>
<td>11 – 30</td>
</tr>
<tr>
<td>2.36</td>
<td>15.0</td>
<td>10 – 20</td>
</tr>
<tr>
<td>0.6</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>0.075</td>
<td>5.1</td>
<td>3 – 7</td>
</tr>
</tbody>
</table>
# Mix Properties of TPS Porous Asphalt in Thailand

Note; AC60/70 : TPS = 88 : 12 (%)

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quality control In Dec, 2015</th>
<th>Standards In Japan</th>
<th>Standards In Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Content</td>
<td>(%)</td>
<td>4.5</td>
<td>4 ~ 6</td>
<td>4 ~ 6</td>
</tr>
<tr>
<td>Maximum Theoretical Density</td>
<td>(g/cm³)</td>
<td>2.552</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Density</td>
<td>(g/cm³)</td>
<td>2.043</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Air Void</td>
<td>(%)</td>
<td>19.9</td>
<td>Around 20</td>
<td>20 ± 2</td>
</tr>
<tr>
<td>Connected Air Void</td>
<td>(%)</td>
<td>16.9</td>
<td><strong>Min. 13</strong> (Recommended)</td>
<td>Min. 13</td>
</tr>
<tr>
<td>Marshall Stability</td>
<td>(kN)</td>
<td>5.16</td>
<td><strong>Min. 3.43</strong></td>
<td><strong>Min. 800 lbs</strong></td>
</tr>
<tr>
<td>Flow Value</td>
<td>(1/10mm)</td>
<td>18</td>
<td>-</td>
<td>8 - 16</td>
</tr>
<tr>
<td>Asphalt Drain Down Test</td>
<td>(%)</td>
<td>-</td>
<td>-</td>
<td>Max. 0.3</td>
</tr>
<tr>
<td>Cantabro Loss at 20°C</td>
<td>(%)</td>
<td>7.6</td>
<td><strong>Max. 20</strong></td>
<td><strong>Max. 20</strong></td>
</tr>
<tr>
<td>Dynamic Stability</td>
<td>(pass/mm)</td>
<td>7,000</td>
<td><strong>Min. 3,000</strong></td>
<td>-</td>
</tr>
</tbody>
</table>
On Ring-road No. 9 in Bangkok, Thailand in December, 2015
Current Situation of Porous Asphalt after 2 years

By Thai Standards Using “Thai PMA”

By Japanese Standards Using “TPS”

*Photos in February 2018
Materials used for Porous Asphalt Pavement
Properties Desired for Porous Pavement Mixture

- High-Viscosity Modified Asphalt
  - Thick Asphalt Film
  - Higher Toughness
  - Higher Adhesion

- Aggregate
  - Strong, Durable, Hard
  - Good Shape, Cubical
  - Higher Affinity for Asphalt

- Stone to Stone Contact

- Higher Air Void (about 20%)
Coarse Aggregate used for Porous Asphalt Mixture

<table>
<thead>
<tr>
<th>Hard sandstone</th>
<th>Lime stone</th>
<th>Granite</th>
<th>Andesite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan (TAIYU)</td>
<td>Thailand, Vietnam</td>
<td>Vietnam, Malaysia</td>
<td>Thailand, Japan</td>
</tr>
</tbody>
</table>
Standard for Coarse Aggregate

<table>
<thead>
<tr>
<th>Items</th>
<th>Unit</th>
<th>Target value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bulk specific gravity in saturated surface-dry</strong></td>
<td>g/cm³</td>
<td>Min. 2.45</td>
</tr>
<tr>
<td><strong>Water absorption</strong></td>
<td>%</td>
<td>Max. 3.0</td>
</tr>
<tr>
<td><strong>Abrasion loss by Loss Angels test</strong></td>
<td>%</td>
<td>Max. 30 *</td>
</tr>
</tbody>
</table>

**Note:**
Abrasion loss test shall be carried out using of 4.75 to 13.2 mm. The standard of abrasion loss is Max.30%. However, in our opinions, 20% or less would be recommended.
## Fine Aggregate used for Porous Asphalt Mixture

<table>
<thead>
<tr>
<th></th>
<th>River sand</th>
<th>Washed sand</th>
<th>Screenings</th>
<th>Pit sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan (TAIYU)</td>
<td>Japan</td>
<td>ASEAN, Japan</td>
<td>Japan</td>
<td></td>
</tr>
<tr>
<td>Gradation Range of Fine aggregate</td>
<td>2.36 mm ~ 0 mm</td>
<td>Japan</td>
<td>ASEAN, China</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.75 mm ~ 0 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: It would be better to use the finer sand which has the size from 2.36 mm to 0 mm.
Mineral Filler used for Porous Asphalt Mixture

Gradation range for Mineral Filler

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Passing weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>100</td>
</tr>
<tr>
<td>0.15</td>
<td>90 ~ 100</td>
</tr>
<tr>
<td>0.075</td>
<td>70 ~ 100</td>
</tr>
</tbody>
</table>

Note;
Hydrated lime or cement can be available as countermeasure for anti-stripping.
Filler together with asphalt works in order to improve stability or durability of mixture.
Asphalt Modifier
for Porous Asphalt Pavement

Yellow Type

Black Type

TAFPACK-Super (TPS)
## Properties of Modified Asphalt

<table>
<thead>
<tr>
<th>Properties</th>
<th>StAs+TPS12% Test Results</th>
<th>Standard in Japan</th>
<th>Standard in Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration (25°C : 1/10mm)</td>
<td>43</td>
<td>Min. 40</td>
<td>40 - 65</td>
</tr>
<tr>
<td>Softening point (°C )</td>
<td>93.0</td>
<td>Min. 80</td>
<td>Min. 70</td>
</tr>
<tr>
<td>Ductility at 15°C in JP, 13°C in TH (cm)</td>
<td>96</td>
<td>Min. 50</td>
<td>Min. 55</td>
</tr>
<tr>
<td>Elastic Recovery at 25°C</td>
<td>-</td>
<td>-</td>
<td>Min. 70</td>
</tr>
<tr>
<td>Toughness (25°C, kg.cm)</td>
<td>255</td>
<td>Min. 200</td>
<td>Min. 200</td>
</tr>
<tr>
<td>Tenacity (25°C, kg.cm)</td>
<td>196</td>
<td>-</td>
<td>Min. 100</td>
</tr>
<tr>
<td>Viscosity at 165 °C (cP)</td>
<td>555</td>
<td>-</td>
<td>300 – 800</td>
</tr>
<tr>
<td>Viscosity at 135 °C (cP)</td>
<td>2615</td>
<td>-</td>
<td>1100 - 3000</td>
</tr>
<tr>
<td>Storage Stability at 163°C, 24hrs (°C )</td>
<td>Not Applicable</td>
<td>-</td>
<td>Min. 2</td>
</tr>
<tr>
<td>Flash Point, COC (°C )</td>
<td>310</td>
<td>Min. 260</td>
<td>Min. 220</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer at 76°C (kPa)</td>
<td>3.11</td>
<td>-</td>
<td>Min. 1</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer at 82°C (kPa)</td>
<td>2.04</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Performance Grade (PG)</td>
<td>82</td>
<td>-</td>
<td>76</td>
</tr>
</tbody>
</table>
EXPERIENCES OF TPS POROUS PAVEMENT

<< In **THAILAND**, TPS Porous pavement and porous pavement using PMA have been paved and compared in 2015 on Motorway >>

On porous pavement using PMA, a lot of fretting and raveling have arisen and some parts have been repaired after 2 years.
On TPS porous pavement, there are no deteriorations like fretting, raveling, Cracking, and rutting after 2 years.
WHY IS TPS POROUS SUSTAINABLE?

There should be many reasons. But, important one of them is difference of Shearing strength of asphalt.

In my experiences, porous asphalt pavement is easy to deteriorate at high temperature. That’s because shearing strength of asphalt is going down along with increase in temperature.

PMA used for porous pavement belongs to PG 76 while TPS asphalt belongs to PG 82.

That means TPS asphalt has higher shearing strength than PMA even at high temperature.
Production of Porous Asphalt Mixture
Production of TPS Porous Mixture

Adding Order
① Aggregate (190-20°C)
② Mineral Filler
③ TPS
④ Straight Asphalt 60/80

Mixing Time
Dry : 5~10 sec
Wet : Min. 40 sec

Mixing Temperature
180 ± 5 °C
System to Measure and Add TPS Automatically
On Ring-road No.9 in Thailand in December, 2015
Production of TPS Porous Asphalt Mixture in ASEAN

The Asphalt Plant in Vietnam

The Asphalt Plant in Malaysia
Production of TPS Porous Asphalt Mixture

【 Movie – 2 】
Production of Porous Asphalt Mixture
Paving of Porous Asphalt Mixture
Paving

Conveyance
By Dump Truck
(Temp. Min. 170°C)

Lifting
As. Finisher
(155~170°C)

Break down
Rolling
Macadam Roller
8-12 t
(150-165°C)
5-7 passes

Second Rolling
Tire Roller
8～16 t
(Temp. About 60°C at Surface)
About 3 passes
On Nakhon In Rd in Thailand in February, 2018

North-South Expressway in Malaysia in June, 2017
New Xi’an-Xian yang Airport Expressway in China in April, 2009
Expressway “Cau Gie - Ninh Binh” in Vietnam

【Movie – 3】
Comparison of Porous asphalt in Vietnam
Serviceability, Maintenance, and Economical Advantage of TPS Porous Asphalt Pavement
Follow-up Survey Results after 43 months on the Expressway in Vietnam

Permeability

Skid Resistance

Rutting
### Sustainability & Maintenance of Functions of Porous Asphalt Pavement

<table>
<thead>
<tr>
<th>Cause</th>
<th>Air void may become small by traffic load</th>
<th>Dust, Clay and others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanation</strong></td>
<td>If the mechanical strength is small, the air void may decrease by the traffic loads.</td>
<td>If dusts, clays and others come to this pavement, the air void may be clogged.</td>
</tr>
</tbody>
</table>
| **Prevention & Countermeasure** | To enhance the mechanical properties  
  ➢ To strengthen Dynamic stability  
  ➢ To use higher modified asphalt  
  ➢ To increase the connected air void instead of decrease of total air void | To select the roads where dusts etc. hardly come to like,  
  ➢ Motorway etc.  
  ➢ Elevated roads  
  ➢ Street located in clean areas |
|                         | ➢ To clean up periodically before having been clogged with dusts etc.  
  ➢ Especially, on road side  
  ➢ Using sweeper with suction etc. |
Sweeper with Vacuum, & Special Machine for function recovery

Sweeper with Vacuum

Special machine for Function recovery
## COMPARISON OF ASPHALT COST (THAILAND)

<table>
<thead>
<tr>
<th>For surface course</th>
<th>Porous Asphalt by Japanese Standard</th>
<th>Conventional Pavement used Modified Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt content</td>
<td>About 4.5 %</td>
<td>About 5.4 %</td>
</tr>
<tr>
<td>Unit Asphalt price</td>
<td>47,600 THB/ton</td>
<td>36,000 THB/ton</td>
</tr>
<tr>
<td>TPS price (CIF), 12%</td>
<td>250,000 THB/ton</td>
<td>-</td>
</tr>
<tr>
<td>Normal As price (Jan.2016)</td>
<td>20,000 THB/ton</td>
<td>-</td>
</tr>
<tr>
<td>Modified As price (Jan.2016)</td>
<td>-</td>
<td>36,000 THB/ton</td>
</tr>
<tr>
<td>Density of Asphalt mixture</td>
<td>About 2.0 g/cm³</td>
<td>About 2.4 g/cm³</td>
</tr>
<tr>
<td>Needed weight of Asphalt at 1m² x 5cm thickness</td>
<td>4.50 kg</td>
<td>6.48 kg</td>
</tr>
<tr>
<td>Asphalt price for 1m²</td>
<td>214 THB (91.8%)</td>
<td>233 THB (100%)</td>
</tr>
</tbody>
</table>
Conclusion

• Porous asphalt pavement has a lot of advantages, the permeable effect, the noise reduction effect and the durable effect.

• The conditions for drivers were able to be dramatically improved, like safety driving, comfortable driving and so on.

• Porous asphalt pavement has high durability therefore this pavement can be applied on various roads, like expressway, elevated road, bypass road and so on.

We are going to promote the porous asphalt pavement, and we hope that this pavement technology could spread widely in Thailand.
Thank you for your attention

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