Study on Asphalt Pavement Technologies
Targeting the Prevention of Global Warming

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Outline of Presentation

◆ Use of Warm-Mix Asphalt
  - Basic concept
  - Laboratory test results
  - CO$_2$ reduction at paving work
◆ Solar Heat-blocking Pavement
  - Basic concept
  - Effect of temperature reduction
  - Case study (Airport taxiway)
◆ Conclusions

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Warm-mix Asphalt
- Background -

Warm-Mix Asphalt:
- Reduction in CO$_2$
- Improvement of workability, especially in winter

• In 1997, NIPPO developed the additive agent called “ECOFINE”
• It can be used for both straight and modified asphalts
• 30 °C to reduction in mixing temperature was achieved
What is **ECOFINE**?

Forming-based special additive agent for WMA technology

**Production**: Fine forms occur in bitumen

A volume of bitumen increases considerably

Workability of bitumen will be improved

**Laying**: Good compaction is achieved by “bearing effect”

**Roller Compaction**  Coarse aggregate  Mastic

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**Asphalt mixture**

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**Fine forms**
Properties of ECOFINE
-Micro-form generation-

- Add the agent of 2 kg/ton
- Keep forming state for a long duration;
- Laboratory: Approx. 120 min.
- Site: 4 to 5 hours

[Graph of foaming duration vs. time]

<table>
<thead>
<tr>
<th>Special Additive</th>
<th>Straight Asphalt 60/80, 130°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>7% by mass of bitumen</td>
<td></td>
</tr>
</tbody>
</table>

[Image of foaming agent and special additive]
Warm-mix Asphalt Laboratory test results

- **ECOFINE**
- **Without Additive**

<table>
<thead>
<tr>
<th>Compaction Degree (%)</th>
<th>Compaction Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td>130</td>
</tr>
<tr>
<td>102</td>
<td>120</td>
</tr>
<tr>
<td>101</td>
<td>110</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>99</td>
<td>99</td>
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<tr>
<td>98</td>
<td>98</td>
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<tr>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td>95</td>
<td>95</td>
</tr>
</tbody>
</table>

- Normal Asphalt Mixture
  - Mixing Temp.: 160°C
  - Compac.Temp.: 140°C

- Dense Asphalt Concrete / Max.Size13mm
  - Straight Bitumen 60/80
  - Mixing Temp.: 130°C

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Warm-mix Asphalt
Laboratory test results

Dense Asphalt Concrete / Max. Size 13mm Straight Bitumen 60/80

- Marshall Stability
  - Normal Asphalt Mixture
  - ECOFINE 30°C Lower
  - Without Additive 30°C Lower

- Ravelling Abrasion (cm²)

- Stability

- Ravelling Abrasion
Simplification of paving equipment train: CO$_2$ reduction at paving work

◆ Simplified compaction train was examined
<table>
<thead>
<tr>
<th>Items</th>
<th>Type of Mix.</th>
<th>Surface Mixture Type 20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A (Control)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B (Simplified)</td>
</tr>
<tr>
<td>Applied Section</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Special Addition</td>
<td>0</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Mixing Conditions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity of Mixer</td>
<td>2,000 kg/batch</td>
<td></td>
</tr>
<tr>
<td>Dry Mixing Time (sec)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Wet Mixing Time (sec)</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Mixing Temp. (°C)</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td><strong>Compaction (time)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macadam Roller</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Pneumatic Tired Roller</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>6 t Combined Roller</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td><strong>Cored Sample</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>2.339</td>
<td>2.324</td>
</tr>
<tr>
<td>Air Void (%)</td>
<td>4.8</td>
<td>5.4</td>
</tr>
<tr>
<td>Compaction Degree (%)</td>
<td>98.9</td>
<td>98.6</td>
</tr>
<tr>
<td>Evenness (σ) (mm)</td>
<td>0.79</td>
<td>0.78</td>
</tr>
</tbody>
</table>
CO₂ reduction at paving work
- Calculated CO₂ emission -

- Approx. 53% of CO₂ reduction can be saved thanks to the special additive.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>CO₂ Discharge (kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 ton Combined Roller</td>
<td>24.8</td>
</tr>
<tr>
<td>Asphalt Paver</td>
<td></td>
</tr>
<tr>
<td>Pneumatic Tired Roller</td>
<td>52.9</td>
</tr>
<tr>
<td>Macadam Roller</td>
<td></td>
</tr>
<tr>
<td>Asphalt Paver</td>
<td></td>
</tr>
</tbody>
</table>

Simplified Normal Combination
Solar Heat-blocking Pavement
Solar Heat-blocking Pavement - Background -

Urban areas and pavements in Japan

- Surface temperatures of asphalt pavement reach 60°C or higher in summer
- Asphalt surfaces cover approx. 20% of urban areas
- Pavement is a source of heat, similar to concrete structures

Hotter pavement:
- leads to the urban heat island phenomenon
- may affect the health of pedestrians due to the higher temperatures

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Basic concept of solar reflective technology

Surface course of hot mix asphalt

- Low reflection for the visible rays
- High reflection for the near infrared rays

Solar radiation

Apply high albedo and dark colored thin treatment materials

Component of hot mix asphalt

Hollow ceramic particle

Highly reflective pigment

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Albedo characteristics of treatment materials

Albedo: Degree of reflection

Visible ↔ Near-infrared rays

New surface treatment materials $L^*40$ (dark gray)

Straight asphalt 60/80

Normal paint materials $L^*40$ (dark gray)

- Straight asphalt has a **very low albedo**
- Dark-gray treatment materials have a **low albedo for visible rays, but a very high albedo (about 90%) for near-infrared rays**
The maximum temperature of the conventional pavement rose to 57.4°C.
The temperature of the treated surface was reduced by about 16°C.
Case study
- Rutting mitigation at airport taxiway -
Narita International Airport

Temperatures both in conventional surface and S.H.P. were measured at 20 mm, 80mm and 200mm below the surface

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Temperature of pavements

Surface (20 mm below)

Milled Surface (200 mm below)

Max. temperature (°C)

Month

2006 2007 2008

Conventional  S.H.P  Ambinet temp.
Differences of rut depth

Rut depth (S.H.P.)
Rut depth (Conventional)

Max. rut depth (Conventional)

Max. rut depth (S.H.P.)

- After
- 2 months
- 1 year
- 1.5 years
- 2 years
- 2.5 years
- 3 years
- 3.5 years
- 4 years
- 4.5 years

2006.7
2007
2008
2009

Rut depth (mm)
Max. rut depth (mm)
Conclusions

◆ The application of micro-forms WMA(ECOFINE) enables the production and laying temperature to be 30 °C lower than normal bitumen.

◆ Approx. 50% of CO₂ generation can be reduced by decreasing the number and size of rollers.

◆ The reduction in surface temperatures for the heat-blocking pavement is approximately 16 °C.

◆ This technology would be effective to the rutting as the rate of rut depth was approximately a half, compared to the dense-graded asphalt surface at the taxiway.
Thank you
Properties of ECOFINE
Estimated CO₂ emission; 30 to 50 °C reduction

Asumption for calculation:
- Moisture content % agg.: 3%
- Ambient Temp.: 30°C

Estimated CO₂ Discharge (kg/ton)

Mixing Temperature (°C)

14%
23%
Case studies

- Highway maintenance -

- Divided the maintenance area into 4 sections
- Compared construction time between Control and ECOFINE sections in surface, binder course and L.S.M.

<table>
<thead>
<tr>
<th>Section</th>
<th>Surface</th>
<th>Binder Course</th>
<th>Large Stone Mix (L.S.M.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (ECOFINE)</td>
<td>2 cm</td>
<td>3 cm</td>
<td></td>
</tr>
<tr>
<td>B (Control)</td>
<td>3 cm</td>
<td>2 cm</td>
<td></td>
</tr>
<tr>
<td>C (ECOFINE)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D (Control)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L = 400 m
W = 3.5 m

Plane figure

Section

- t = 6 cm
- t = 4 cm
- t = 10 cm

Thermo-Couple

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Case studies
- Highway maintenance -

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Surface</th>
<th>Binder course</th>
<th>Large Stone Mix.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>2.314</td>
<td>2.309</td>
<td>2.369</td>
</tr>
<tr>
<td>Air Void (%)</td>
<td>5.7</td>
<td>5.9</td>
<td>4.1</td>
</tr>
<tr>
<td>Compaction Degree (%)</td>
<td>97.7</td>
<td><strong>97.5</strong></td>
<td>100</td>
</tr>
</tbody>
</table>
### Case studies - Highway maintenance -

<table>
<thead>
<tr>
<th>Section</th>
<th>Rut depth (mm)</th>
<th>Evenness (mm)</th>
<th>Skid resistance (BPN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After construction</td>
<td>After 6 months</td>
<td>After construction</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>0.86</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>2</td>
<td>0.74</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1</td>
<td>0.98</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>1</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Note: Section A Surface + Binder course (*ECOFINE*), B Surface + Binder course (Control), C Surface + Large Stone Mix. (*ECOFINE*), D Surface + Large Stone Mix. (Control)
Case studies - Highway maintenance - Surface & Binder courses

- ECOFINE Binder
- Control Binder
- ECOFINE Surface
- Control Surface
- Existing Surface
- Ambient Temp.

Temperature (°C)

Time difference when surface temp. is at 60°C: about 50 min.

Temp. difference of Surface Layer: about 4°C
Temp. difference of Binder Layer: about 4°C
Case studies - Highway maintenance - Surface & Large Stone Mix.

Time difference when surface temp. is at 60°C: about 70 min.

- ECOFINE L.S.M. (Section C)
- Control L.S.M. (Section B)
- ECOFINE Surface (Section C)
- Control Surface (Section D)
- Existing Surface
- Ambient temp.

Temperature difference of Surface Layer: about 8°C
Temperature difference of Large Stone Mix: about 6°C
Environmental issues

Hotter pavement:
- leads to the urban heat island phenomenon
- may affect the health of pedestrians due to the higher temperatures

Public demand to reduce the temperature of road pavement
Research & Development
Basic concept

**Highly reflective pigment**
Highly reflective for near-infrared rays → Prevention of heating
Low reflectivity for visible rays → Enables various colors to be selected

**Hollow ceramic particles**
- Reflect solar radiation to the atmosphere

Hollow ceramic particles
(5～150µm)

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What is solar radiation?

- Solar radiation mainly consists of visible rays and near-infrared rays and includes some ultraviolet rays.
- 50% of solar energy is visible rays; the rest is near-infrared rays.

![Diagram showing the distribution of solar radiation wavelengths and their energy content.](chart1.png)
Section of pavements

Solar Heat-blocking Pavement

Conventional Surface

Construction overview

- Coated layer
  - Surface: Large stone mix. (Modified Asphalt) \( t = 80 \text{ mm} \)
  - Binder course: Large stone mix. (Modified Asphalt) \( t = 120 \text{ mm} \)
  - Bituminous stabilization
  - Cement stabilization
  - Crusher-run

- Depth of Thermo-couple

- Inter layer (80 mm below)
- Milled surface (200 mm below)
- Surface (20 mm below)