High Performance Topping Material for Semi-Rigid Pavement

Dr Wu Dong Qing  
Chemilink Technologies Group, Singapore  
wu@chemilink.com.sg

Sun Dao Jun  
Chemilink Technologies Group, Singapore  
daojun_sun@chemilink.com.sg
Table of Contents

1. Introduction
2. Topping Materials
3. Composite and Components
4. Semi-Rigid Pavement
5. Application Procedures
6. Completed Projects (Examples)
7. Conclusions
1. Introduction

- As traffic intensity / frequency, axle loading and aircraft size continue to increase, so does the demand for improved airfield and road pavements to cater for the increasingly heavy wear and tear of the pavements.

- Challenges:
  - design and construction of durable, low-maintenance and economical pavements;
  - difficulty in scheduling the repair of concrete pavement, e.g. airports, seaports and road junctions (months of demolishing and strength development)

- Composite pavement as a wearing course: open AC + topping material = semi-rigid (days of work)
2. Topping Materials

Difficulties in producing topping materials:

For example:

- Flowability
- Strengths and Modulus
- Balance of the above two
# 2. Topping Materials

**Chemilink™ SS-141**

- High performance polymer modified cementitious material
  - High workability → Easy application
  - High early strength → Early opening to traffic
  - High long-term strength → Low maintenance

- Requires only the addition of water to produce a highly flowable mixture

- Result of extensive research work with the introduction of nano-technology.
## 2. Topping Materials

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test Methods</th>
<th>Typical Values of SS-141</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability (Flowability)</td>
<td>ASTM C939</td>
<td>• 10 ~ 14 seconds</td>
</tr>
<tr>
<td></td>
<td>JASS 15 [1]</td>
<td>• 200 ~ 250 mm</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>12 hrs</td>
<td>• 20 ~ 30 MPa</td>
</tr>
<tr>
<td></td>
<td>1 day</td>
<td>• 55 ~ 70 MPa</td>
</tr>
<tr>
<td></td>
<td>7 days</td>
<td>• 85 ~ 100 MPa</td>
</tr>
<tr>
<td></td>
<td>28 days</td>
<td>• 115 ~ 140 MPa</td>
</tr>
<tr>
<td>Flexural Strength at 28 days</td>
<td>EN 196</td>
<td>• 7 ~ 15 MPa</td>
</tr>
<tr>
<td>Setting Time</td>
<td>EN 196</td>
<td>• 4 ~ 6 h (normal setting)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 2 ~ 3 h (fast setting)</td>
</tr>
</tbody>
</table>

[1] Optional at the jobsite
2. Topping Materials

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability (flow), sec</td>
<td>10 ~ 14</td>
<td>10 ~ 14</td>
<td>10 ~ 14</td>
</tr>
<tr>
<td>Comp. Strength, MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 hrs</td>
<td>25</td>
<td>10</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>1 day</td>
<td>60</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>7 days</td>
<td>90</td>
<td>80</td>
<td>30</td>
</tr>
<tr>
<td>28 days</td>
<td>130</td>
<td>110</td>
<td>40</td>
</tr>
<tr>
<td>Setting Time, hours</td>
<td>Normal</td>
<td>4 ~ 6</td>
<td>7 ~ 9</td>
</tr>
<tr>
<td>Fast</td>
<td>2 ~ 3</td>
<td>-</td>
<td>2 ~ 3</td>
</tr>
</tbody>
</table>

2. Topping Materials

Comparison of Topping Materials

- SS-141
- SS-141-A
- SS-141-B

Strength, MPa vs. Curing Age, hours
2. Topping Materials

Compressive Strength development with curing time at different w/s

$R^2 = 0.99$

$R^2 = 0.94$

Compressive Strength, MPa

Maturity, ($^\circ$C.day)

Circle: $w/s = 0.27$

Square: $w/s = 0.20$
3. Composite and Components

- Parallel Model (Iso-strain; upper bound):
  \[ E_c = E_1 V_1 + E_2 V_2 \]

- Series Model (Iso-stress; lower bound):
  \[ \frac{1}{E_c} = \frac{V_1}{E_1} + \frac{V_2}{E_2} \]

  \( V_i \) = volume fraction of components 1 and 2
  \( E_i \) = modulus of components 1 and 2
  \( E_c \) = modulus of composite

  \( \Sigma V_i = 1 \), e.g. \( V_1 + V_2 = 1 \)
3. Composite and Components

Given $V_{AC}, V_m$ and $E_{AC}$ the same for different semi-rigid composites, $E_{sr}$ increases as $E_m$ increases for both parallel and series models.

\[
E_{AC} V_{AC} + E_m V_m = E_{sr}
\]

\[
\frac{V_{AC}}{E_{AC}} + \frac{V_m}{E_m} = \frac{1}{E_{sr}}
\]

Similarly, given $V_{AC}, V_m$ and $E_m$ the same, $E_{sr}$ increases as $E_{AC}$ increases.
3. Composite and Components

High quality SS-141 topping material leads to

- high performance at initial stage
- high reliability of semi-rigid pavement
- further development of semi-rigid pavement when asphalt concrete technology advances
## 4. Semi-Rigid Pavement

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test Method</th>
<th>Semi-Rigid Pavement (SS-141 as topping)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength at 12 hrs</td>
<td>EN 12190</td>
<td>• 3 ~ 5 MPa</td>
</tr>
<tr>
<td>Compressive strength at 1 day</td>
<td></td>
<td>• 6 ~ 8 MPa</td>
</tr>
<tr>
<td>Compressive strength at 28 days</td>
<td></td>
<td>• 9 ~ 12 MPa</td>
</tr>
<tr>
<td>Flexural strength at 28 days</td>
<td>EN 12190</td>
<td>• ≥ 3 MPa</td>
</tr>
<tr>
<td>Modulus</td>
<td>ASTM D4123</td>
<td>• ≥ 6,500 MPa (at 25°C)</td>
</tr>
<tr>
<td>Skid Resistance</td>
<td>ASTM E303</td>
<td>• ≥ 50 ~ 60 BPN</td>
</tr>
<tr>
<td>Impermeability</td>
<td>DIN 18130</td>
<td>• impermeable</td>
</tr>
<tr>
<td>Curing time</td>
<td>-</td>
<td>• 4 ~ 8 hours</td>
</tr>
</tbody>
</table>
### 4. Semi-Rigid Pavement

<table>
<thead>
<tr>
<th>Curing Age</th>
<th>Compressive strength (MPa) of semi-rigid pavement with different topping materials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SS-141</td>
</tr>
<tr>
<td>12 hrs</td>
<td>3 ~ 5</td>
</tr>
<tr>
<td>1 day</td>
<td>5 ~ 8</td>
</tr>
<tr>
<td>7 days</td>
<td>8 ~ 10</td>
</tr>
<tr>
<td>28 days</td>
<td>9 ~ 12</td>
</tr>
</tbody>
</table>

[1] or dependent on the properties of the open AC;

[2] the strength of composite pavement is believed to be inadequate.
5. Application Procedures

- Porous asphalt concrete
- Mixing of SS-141
- Flowability Check
- Filling into porous asphalt concrete
- Scraping
5. Application Procedures

Right after filling

Hardened surface
6. Completed Projects (Examples)

Singapore Changi Airport Apron 1 (2007)
6. Completed Projects (Examples)

Singapore Changi Airport Apron 2 (2007)
6. Completed Projects (Examples)

Heavy Loading Yard  (Hanson, Singapore AC Plant, 2005)
7. Conclusions

- Demand for semi-rigid pavement due to increased heavy wear and tear of pavements and difficulty in scheduling the repair work

- Chemilink™ SS-141 topping
  - Easy application (high flowability)
  - Early opening to traffic (high early strength)
  - Low maintenance (high long-term strength)

- Given the same asphalt concrete and the same mix proportion, a higher quality topping would yield a composite pavement of better performance
Thank You for Your Attention!