RESEARCH PROGRESS

Skid and Abrasion Resistance of Concrete Pavements with Manufactured Sands

Vute Sirivivatnanon
Research Manager
Cement Concrete & Aggregates Australia

This presentation contains some test data provided by the RMS. Interpretation and conclusions are those of the author.
Specific Objectives

To establish the influence of manufactured sands on the *intrinsic skid* (after wear) and abrasion resistance of concrete pavements, and possible correlation with some *properties of manufactured sands* and concrete.

In collaboration with RMS, start examine how the *intrinsic skid* property of concrete influences *pavement performance* (SCRIM) recognising that field performance is influenced by both the intrinsic properties as well as other factors such as finishing, macro texture and road geometry.

SCRIM: SIDEWAY-FORCE COEFFICIENT ROUTINE INVESTIGATION MACHINE
Lab-field Research Outline

**Source Rocks**
- Coarse Aggregates
- Man Sands
- Natural Sand

**Mineralogical compositions**
- Silica Content

**Historical perspective**

**MAN SAND TESTING**
- Micro-Deval - abrasion
- Na₂SO₄ Soundness - stability
- Absorption – stability
- MBV x Passing 75-micron - durability

**LAB CONCRETE TESTING**
- Skid before & after wear
- Abrasion loss

**LAB-prepared Concrete Specimens**

**Field-retrieved Concrete specimens**

**FIELD ASSESSMENTS**
- SCRIM by Road Authority
- Pendulum Friction

**Performanc e Criteria**

Figure 1
Skid and Abrasion Resistance Tests

- **Skid**
  - Pendulum friction test (AS 1141.42) of concrete wet surface prior to and after 4 & 8 hours (8,000 & 16,000 cycles) of PAFV test.

- **Abrasion**
  - *Abrasion index* of concrete subjected to impact and rolling action of steel ball bearings (AS 4456.9). Determine weight loss after 3600 tumbling cycles.
Pendulum friction test (AS 1141.42)
Friction Value FV
PAFV abrasion resistance (AS 1141.41)
33-35 revs/min (8,000 & 16,000 cycles after 4 & 8 hours)

2-hr with coarse abrasion [Balck silicon carbide No. 320 @ 2g/min]
2-hr with fine abrasion [Optical emery No. 600 @ 2g/min]
Abrasion index (AS 4456.9)
4 circular faces subjected to 600 steel balls
60 rev/min x 1 hr = 3600 cycles
Stage I Research

Sensitivity of Various Test Methods on Micro-texture

skid after wear of *workmanship-independent* surfaces

Abrasion by abrasion index & weight loss after wear
Off-form and sawn surface
Skid (friction) after abrasion by PAFV of concrete made from different man sands
Common skid resistance of off-form & saw-cut surfaces after 4-6 hrs of polishing

“Characteristic skid resistance”
Stage II Research

Laboratory Study

Sand: 1 Control, 9 man sands, 2 natural sands
% Sand: 50%, 80% coarse manufactured sands
85% natural coarse sands
Fine/Total Agg 0.4 or 40%
## Natural and manufactured sands tested

<table>
<thead>
<tr>
<th>Random Designation</th>
<th>Description by Supplier</th>
<th>Petrographic Report Description</th>
<th>Approx free silica (1), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS Control</td>
<td>Emu Coarse</td>
<td></td>
<td>69</td>
</tr>
<tr>
<td>MS1</td>
<td>Meta-argillite</td>
<td>Meta-argillite</td>
<td>22</td>
</tr>
<tr>
<td>MS2</td>
<td>Olivine Basalt</td>
<td>Olivine Basalt</td>
<td>2</td>
</tr>
<tr>
<td>MS3</td>
<td>Micro-granite</td>
<td>Micro-diorite</td>
<td>6</td>
</tr>
<tr>
<td>MS4</td>
<td>Basalt (Latite)</td>
<td>Latite</td>
<td>45</td>
</tr>
<tr>
<td>MS5</td>
<td>Ignimbrite</td>
<td>Rhyolitic tuff</td>
<td>36</td>
</tr>
<tr>
<td>MS6</td>
<td>Adamellite</td>
<td>Granite</td>
<td>48</td>
</tr>
<tr>
<td>MS7</td>
<td>Ignimbrite (Rhyodacite)</td>
<td>Rhyolitic tuff</td>
<td>31</td>
</tr>
<tr>
<td>MS8</td>
<td>Meta-Greywacke</td>
<td>Meta - Greywacke</td>
<td>27</td>
</tr>
<tr>
<td>MS9</td>
<td>Rhyodacite</td>
<td>Rhyolitic tuff</td>
<td>29</td>
</tr>
<tr>
<td>NS10</td>
<td>ex Wagga Wagga</td>
<td>Metasiltstone, quartzite</td>
<td>80</td>
</tr>
<tr>
<td>NS11</td>
<td>ex Billabong</td>
<td>Quartzofeldspathic and lithic</td>
<td>64</td>
</tr>
</tbody>
</table>

(1). Petrography
Durability tests on sands

- Micro-Deval
  - abrasion in water
- Sodium Soundness
  - stability due to expansive salt crystallization
- Absorption
  - Porosity
- % free silica
  - Petrography
  - Chemical method (Boral)
Concrete Mix Design to RMS Specifications

Concrete mixes with fly ash were targeted at RMS specifications as follows:

- 28-day compressive strength: 40-58 MPa
- 28-day flexural strength: Min 4.7 MPa
- Slump: 55-65 mm
- Air content: 3-6%
**Compressive Strengths of Concrete**

*40-58 MPa at 28-day*

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**Compressive Strength**

- **Avg of 7d compressive strength**
- **Avg of 28d compressive strength**

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**Graph Description:**

- The graph illustrates the compressive strengths of different concrete mixes ranging from 30.0 to 55.0 MPa.
- The mixes are represented by bars, with Mix 1-Emu at the bottom and Mix 21-NS11 at the top.
- Each bar is divided into two sections, indicating the average compressive strength at 7 days and 28 days.

**Mix Details:**

- Mix 1-Emu
- Mix 2-50% MS1
- Mix 3-80% MS1
- Mix 4-50% MS2
- Mix 5-80% MS2
- Mix 6-50% MS3
- Mix 7-80% MS3
- Mix 8-50% MS4
- Mix 9-80% MS4
- Mix 10-50% MS5
- Mix 11-80% MS5
- Mix 12-50% MS6
- Mix 13-80% MS6
- Mix 14-50% MS7
- Mix 15-80% MS7
- Mix 16-50% MS8
- Mix 17-80% MS8
- Mix 18-50% MS9
- Mix 19-80% MS9
- Mix 20-NS10
- Mix 21-NS11
Skid before & after wear (50&80% man sand)
Skid before & after wear (50&80% man sand)
Skid before & after wear (50&80% man sand)
Skid Friction Values

Characteristic & Intrinsic Skid

Skid after 4-hr polishing of saw-cut surface

Skid after 4-hr polishing of off-form surface

R² = 0.5752

Skid after 8-hr polishing of off-form surface

R² = 0.3814

76% Corr

62% Corr
Characteristic Skid resistance of concrete with various sands

- Top wearing surface
- Off-form surface, 80% man sand
- Saw-cut surface, 80% man sand

<table>
<thead>
<tr>
<th>Material</th>
<th>Skid after 4-hr polishing</th>
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</thead>
<tbody>
<tr>
<td>Emu</td>
<td>55</td>
</tr>
<tr>
<td>MS1</td>
<td>45</td>
</tr>
<tr>
<td>MS2</td>
<td>50.5</td>
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<tr>
<td>MS3</td>
<td>49</td>
</tr>
<tr>
<td>MS4</td>
<td>51.5</td>
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<td>MS5</td>
<td>51</td>
</tr>
<tr>
<td>MS6</td>
<td>49.5</td>
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<tr>
<td>MS7</td>
<td>51.5</td>
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<td>MS8</td>
<td>61.5</td>
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<td>MS9</td>
<td>64</td>
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<td>NS10</td>
<td>52</td>
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<tr>
<td>NS11</td>
<td>53.5</td>
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<tr>
<td>Mttg</td>
<td>46</td>
</tr>
<tr>
<td>Tarc</td>
<td>0</td>
</tr>
</tbody>
</table>
Stage II Field Study

RMS Parallel Field Study

Sites: 2 man sands, 2 natural sands

Results from 2 sites made available to CCAA
Test site is on the S/B, opposite the entrance to the Truck Bay.
Condition of the Pavements

Mittagong bypass

Tarcutta Range
Skid (friction) before & after PAFV polishing of tyned and off-form surfaces

- Rosebrook 42
- S51 LS/Dolomite
- T68 Quartzite
- G80 Meta greywacke
- Emu
- Rosebrook 27
- Mittagong
- Tarcutta

Mittagong
Tarcutta
Tynded surface
Off-form

Skid
PAFV, hour
Skid (friction) after abrasion by PAFV of saw-cut surfaces

- Saw-cut surfaces
  - Rosebrook 42
  - S51 LS/Dolomite
  - T68 Quartzite
  - G80 Meta greywacke
  - Emu
  - Rosebrook 27
  - Mittagong
  - Tarcutta

Graph showing the skid (friction) over PAFV, hour.
Skid after wear of concrete with various sands

SCRIM results: Mittagong 68, 71
Tarcutta 74, 68
Coefficient of Friction ($\mu$) of Surfaces with different Textures  ICAR Barborak and Rached, (2010)
**Intrinsic Skid** (after 16,000 cycles of polishing) and micro-Deval or free silica content of Sands

![Graph 1](R^2 = 0.4875)

- Skid of off-form surface after 8 hr polishing
- % Free Silica (chemical)

![Graph 2](R^2 = 0.6931)

- Skid of off-form surface after 8 hr polishing
- MDV of indiv sand

83% Corr
Fowler and Rached, ‘Evaluation of the Polish Resistance of Fine Aggregates in PCC Pavements’, (to be published in TRR)
Possible performance-based specification

MANUFACTURED SANDS

• Micro-deval ≤ 15%

CONCRETE

• Characteristic skid > 50 for off-form surface
Abrasion index of concrete

Abrasional Index

Mix 1-Emu
Mix 2-50% MS1
Mix 3-80% MS1
Mix 4-50% MS2
Mix 5-80% MS2
Mix 6-50% MS3
Mix 7-80% MS3
Mix 8-50% MS4
Mix 9-80% MS4
Mix 10-50% MS5
Mix 11-80% MS5
Mix 12-50% MS6
Mix 13-80% MS6
Mix 14-50% MS7
Mix 15-50% MS7
Mix 16-50% MS8
Mix 17-50% MS8
Mix 18-50% MS9
Mix 19-50% MS9
Mix 20-NS10
Mix 21-NS11

Abrasion index (%)

Mix

Off-form surface Mean abrasion index
Saw-cut surface Mean abrasion index
Abrasion resistance indicator

Off-form abrasion index vs 28-day Compressive Strength, MPa

71% Corr

R² = 0.5089

65% Corr

R² = 0.4282
CONCLUSIONS

• The optimum quantity of man sand in concrete pavement depends on its effect on water demand and air entrainment i.e., mix design consideration.

• The free silica content is not a good indicator of skid resistance of the concrete after 8,000 & 16,000 cycles of polishing.

• The micro-Deval value can be used to specify sand (natural or manufactured sand) to give good intrinsic skid resistance. A maximum micro-Deval loss of 15% can be the performance limit.

• A minimum characteristic skid resistance of 50 can be used to specify the 4 hours (8,000 cycles of polishing) skid resistance of off-form concrete surface.

• The abrasion resistance of concrete surface is compressive strength dependent and does not seem to be effected by the type of sand used.
Thank you

vute@ccaa.com.au
SUMMARY

MIX DESIGN

• Most man sands demand greater AEA & SP to give similar air & slump. Greater effect @80% than 50%.

SKID AFTER WEAR (Cycles of polishing)

• Skid characteristics of concrete with 50% & 80% manufactured sands are similar.

• Skid after 4 hours (8000 cycles) polishing of “workmanship-independent” saw-cut & off-form surfaces are similar – characteristic skid resistance.

• Most man sands give characteristic skid of 50 & above (Tarcutta Range has skid of 50 for saw-cut surface & a SCRIM value range of 68-74 for the wearing surface).
SUMMARY

SKID AFTER WEAR (Cycles of polishing)

- There appears to be no relationship between the **intrinsic skid resistance** of concrete and the free silica content of sands used.
- The **intrinsic skid resistance** of concrete decreases with increasing micro-Deval value of sands.

ABRASION RESISTANCE

- There is a broad relationship between the compressive strength of concrete and its **abrasion index** independent of the type of sand used in the concrete.
Silica Content & Durability of Sands

% Free Silica (Petrographic) vs. % Free Silica (Chemical)

- $R^2 = 0.9253$

Sodium Sulphate Soundness, % vs. Micro-Deval (indiv), %

- $R^2 = 0.2112$
## Compressive Strength

<table>
<thead>
<tr>
<th>Mix/Sand</th>
<th>Sand/Rock type</th>
<th>W/C</th>
<th>Compressive Strength</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix 1 C1</td>
<td>Rosebrook C</td>
<td>0.42</td>
<td>42.0</td>
<td>28 d</td>
</tr>
<tr>
<td>Mix 2 S51</td>
<td>Limestone/dolomite</td>
<td>0.43</td>
<td>45.0</td>
<td>28 d</td>
</tr>
<tr>
<td>Mix 3 T68</td>
<td>Quartzite</td>
<td>0.71</td>
<td>20.5</td>
<td>28 d</td>
</tr>
<tr>
<td>Mix 4 G80</td>
<td>Meta greywacke</td>
<td>0.42</td>
<td>48.5</td>
<td>28 d</td>
</tr>
<tr>
<td>Mittagong</td>
<td>ex Staffords Penrose Q</td>
<td>-</td>
<td>56.5</td>
<td>15-20 y</td>
</tr>
<tr>
<td>Tarcutta</td>
<td>ex SMC Wagga</td>
<td>-</td>
<td>67.5</td>
<td>15-20 y</td>
</tr>
</tbody>
</table>

Johns River coarse & Stockton fine sand are used for all mixes 1-4
Condition prior to Polishing

Mittagong bypass

Tarcutta Range