Use of 3D modelling techniques to better understand road surface textures

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Road surface textures

• Influence a wide range of properties including:
  – Friction, noise, rolling resistance to how load is transferred from the vehicle tyre down through the pavement structure.

• Texture is important at differing scales:
  – micro-level on the aggregate surface
  – macro-level on the road surface
  – mega level when roads become rutted, cracked or form pot holes.
• The use of PSV to measure aggregate micro-texture, volumetric sand-patch or 2D laser types of measurement have been used for many years.

• However, their data is limited particularly when trying to understand what is happening.
Thermal image showing heat transfer from friction tyre
This paper

• Considers 3D modelling as a means of getting more information.
• Two techniques considered:
  – close range photogrammetry (CRP)
  – 3d laser scanning (3dLS) using a hand held 3D scanner.
• These produce 3D models.
• Analysed using proprietary software to produce parameters in accordance with harmonised European Standards for 3D Areal Surfaces.
CRP methodology

- Apply a control framework
- Obtain a stereo image pair
- Prepare a 3D model using photogrammetric software
- Spatial analysis
Control framework
Stereo image pair

Camera position 1

Camera position 2

Asphalt surfacing

Elevation of image capture configuration

Plan view of asphalt surfacing
Software

- Topcon Image Master
- 3D Flow 3DF Zephyr PRO
- Autodesk AutoCAD Civil 3D
- ESRI GIS
- Digital Surf Surface Intelligence
- Mountains Surface Imaging & Metrology Software
3d laser scanning methodology

- Preparation of test specimen for scanning
- Apply a control framework
- Obtain a point cloud
- Edit point cloud
- Spatial analysis
Preparation of surface
Control framework
Point cloud before editing
Point cloud after editing
3D model of a newish, dirty road surface
Extracting data from the 3D model

Storage volume (l/m²)

Height above lowest point on model (mm)

Potential Water Retention
Texture bearing ratio v. depth

![Graph showing the relationship between surface texture bearing ratio and depth. The ratio increases as depth increases.](image)
Comparison of texture depth data using CRP and volumetric sand patch

$y = 0.97x$

$R^2 = 0.91$
Laboratory made pothole 3D modelled in Zephyr
Some usable data about the pothole

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Horizontal Area</td>
<td>18916 mm²</td>
</tr>
<tr>
<td>Developed Area</td>
<td>29165 mm²</td>
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<tr>
<td>Complexity</td>
<td>54.2 %</td>
</tr>
<tr>
<td>Depth</td>
<td>46.2 mm</td>
</tr>
<tr>
<td>Volume</td>
<td>469959 mm³</td>
</tr>
<tr>
<td>Perimeter</td>
<td>568 mm</td>
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</tbody>
</table>
Examples of PSV 3d models

3D models generated by Zephyr Software
PSV control framework for CRP
Modified PSV testing

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Time0</th>
<th>Time3</th>
<th>Time6</th>
<th>Time9</th>
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<tbody>
<tr>
<td>Carboniferous Limestone A</td>
<td>68</td>
<td>61</td>
<td>40</td>
<td>22</td>
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<tr>
<td>Carboniferous Limestone B</td>
<td>72</td>
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<td>57</td>
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<tr>
<td>Quartz Dolerite</td>
<td>71</td>
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<td>55</td>
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<tr>
<td>Tertiary Basalt</td>
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<td>Silurian Greywacke</td>
<td>73</td>
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<td>58</td>
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<tr>
<td>Carboniferous Sandstone</td>
<td>85</td>
<td>81</td>
<td>70</td>
<td>44</td>
</tr>
</tbody>
</table>
PSV test specimen colour banded 3D model - curved (left image) and flattened (right image)
Single greywacke aggregate particle at Time 0 (left image) and at Time 6 (right image)
Use of Abbott-Firestone Curve to describe surface textures (BS EN ISO 25178-2-2012)

Vmp  Peak material volume
Vmc  Core material volume
Vvc  Core void volume

Void volume $V_v$
Material volume $V_m$

$m_r = 100 \times \frac{(A + B + C + D)}{L}$
Vmp v. Bearing Ratio for Limestone A
Gyratory test specimen after modified wheel track test

3D model generated by ImageMaster Pro Software
Surface texture recovery of a white road marking
Failing in-situ construction joint

With overlaid raster image of the surface

Depth classified model

3D model generated by CRP, ImageMaster Pro Software and ArcGIS
Test Mould and Braking System
Measuring material loss in a new durability test
Poorly compacted AC14 slab tested in water at 60° C for 5 minutes

Recovered data

Digital Surf MountainsMap7
Compaction (bulk density) v. average depth and volume of ravelled material

![Graph showing the relationship between bulk density, average depth, and volume loss. The graph indicates a negative correlation between bulk density and both average depth and volume loss.](image)
Volume loss v. average depth

\[ y = 33847x - 22399 \]

\[ R^2 = 0.9992 \]
Conclusions

• CRP and 3DLS based 3D models can be used to better understand texture related issues for surfacing materials.

• The 3D models can be manipulated and analysed using proprietary software to achieve otherwise unattainable surface parameters.

• This ability to easily measure and quantify parameters opens new opportunities to investigate issues at scales ranging from the macro to the micro.