High resolution terrestrial laser scanning for tunnel deformation measurements

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Outline

- Introduction – Diabolo project
- Surveying instruments
- Deformation measurements
- Processing scan data
- Analysis cross-section
- Conclusions
- Future research
Introduction

Diabolo project (Brussels National Airport)

2 tunnels (1.07 km long)

12 sections to monitor

Simultaneous tension measurements

http://ecms.infrabel.be/DMS/ds/nl/7918749
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Introduction

Monitoring:
7 measurements per section

- After placement (Measurement 0)
- Every week (1st month) (1 – 4)
- After 2 months (5)
- After 3 months (6)
Surveying instruments
Laserscanning?

Accurate 3D data (mm-order)

Difficult site measurement conditions

Very high point density (5 mm resolution)

Short time frame (3 – 30 min)

Surveying instruments
Leica ScanStation 2

Time-of-Flight
Pulse-based

Up to 50 000 pts/sec
Surveying instruments

Leica HDS 6100

Phase-based

Up to 500 000 pts/sec

Trimble S6

Robotic Total Station with scan function

1 pt/sec
Surveying instruments

Experimental standard deviation

<table>
<thead>
<tr>
<th>Scanning instrument</th>
<th>Experimental Standard Deviation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leica ScanStation 2</td>
<td>1.6</td>
</tr>
<tr>
<td>Pulse-based Laser scanner</td>
<td></td>
</tr>
<tr>
<td>Leica HDS6100</td>
<td>0.4</td>
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<tr>
<td>Phase-based Laser scanner</td>
<td></td>
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<tr>
<td>Trimble S6</td>
<td>0.8</td>
</tr>
<tr>
<td>Robotic Total Station</td>
<td></td>
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</tbody>
</table>

(When using 5 gon smoothing)

Deformation measurements

Scanning positions:

- Left / Right tunnel bracket
- Central position on tripod

Depending on site conditions

Resolution = 5 mm or higher
Deformation measurements

Targets

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Processing scan data

- Filtering point cloud

Laserscanning:
1.7 – 20.4 million ---> 1.0 – 6.7 million

Robotic total station:
360 – 720 points

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- Best-fit cylinder
- Mesh
- Cross-section using Master Reference Target

Analysis cross-section

Radius every 0.1 grad

Smoothing (5 grad)

- no excessive noise
- minimal difference standard deviation
- significance of displacements does not alter substantially
Non-smoothed

Smoothed
Analysis cross-section

Cross-section drawings
Measurement $i$ compared to:

- Design (radius 3.650 m)
- Measurement 0
- Measurement $i-1$

2 sigma intervals (depending on instrument)
Differences in average diameter (mm) - Nominal tunnel section as reference

Differences in average diameter (mm) - Measurement immediately after placement as reference
Conclusions

- High accuracy in difficult site conditions (mm order)
- Phase-based scanner best results
- Workflow to process scan data
- Determination of the deviations of the cross-sections
- Stabilization after 1 – 2 week(s)

Future research

- Optimization workflow
- Correlation with tension measurements
- Best-fit segments
- General trends in movement tunnel...

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