Application of laser scanning for deformation measurements: a comparison between different types of scanning instruments.

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Outline

- Introduction
- Tunnel measurements
- Processing scan data
- Monitoring conclusions
- Comparison scanning instruments
- Conclusions

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Introduction

- Terrestrial laser scanning
- Deformation monitoring (ovalisation measurements) of newly built concrete tunnels
- Placement ---> 3 months after placement

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Introduction

- Diabolo Project (April 2009 – January 2010)

  2 side-by-side tunnels of 1 km

  Testing and implementation of measurement and processing workflows

- Liefkenshoek Rail Link Project (March 2010 – October 2011)

  2 side-by-side tunnels of 6 km

  Adjusting - optimization of workflows

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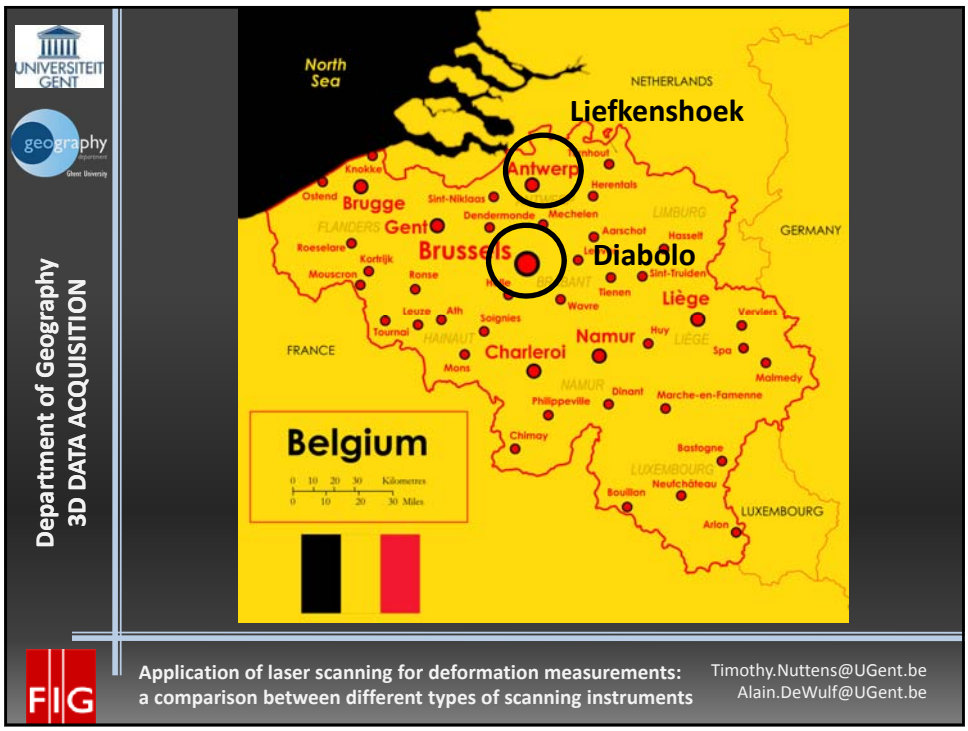
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Tunnel measurements

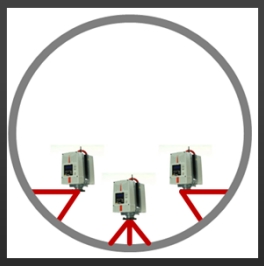
- 14 sections in each tunnel tube
- 7 measurements per section

- Measurement immediately after placement
- Every week during 1st month (C1 – C4)
- After 2 and 3 months (C5 – C6)

Tunnel measurements

- Measurement immediately after placement

  3 scanning positions (left, right and middle)



- Control measurements

  1 scanning position (middle)

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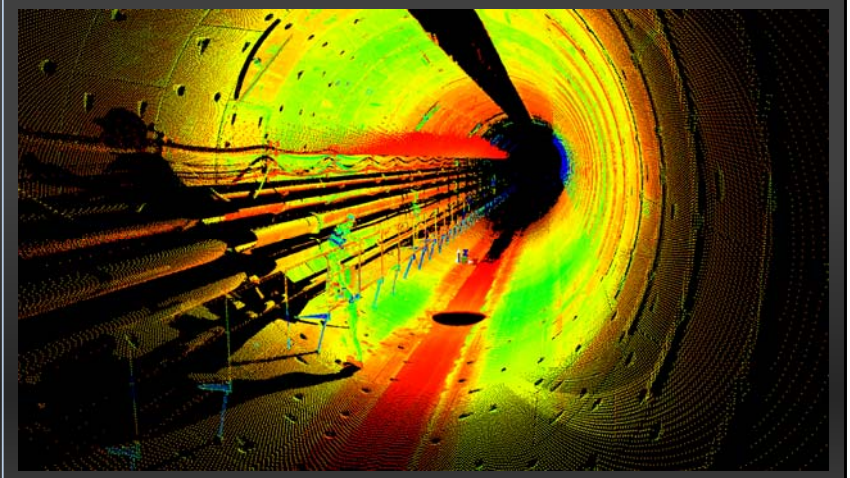
Tunnel measurements



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Processing scan data

- Manual filtering (70 – 80 % discarded)
- Best-fit cylinder with free diameter
- Meshing
- Cross-section through 'Master Target'
- Ray length every 0.1 grad
- Smoothing over 1 grad (X-0.5 to X+0.5)

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Monitoring conclusions

- Averaged radii compared with:
  - Design radius (3.6500 m)
  - Measurement after placement
  - Previous control measurement
- 2σ significance level

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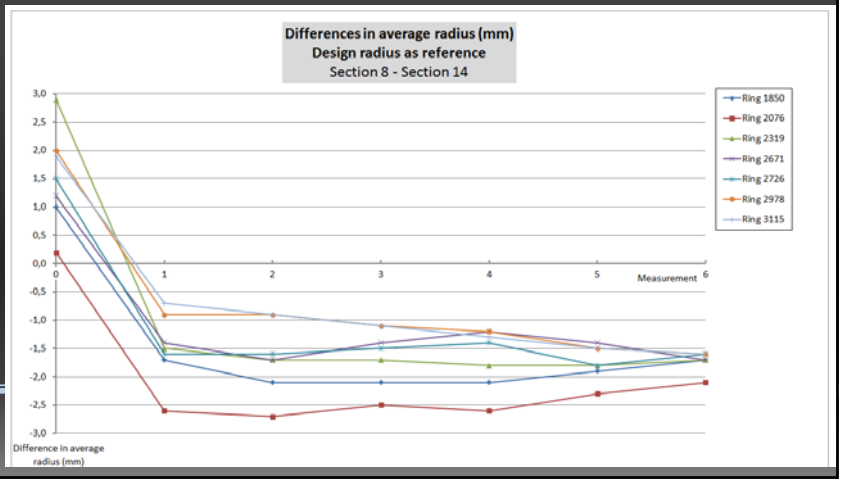
Monitoring conclusions

- Significant changes only during first week after placement



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Comparison scanning instruments

- Control measurements – 1 scanning position

- Scanning the same tunnel section 4 times (within 1 – 2 hour time frame)

- Calculating experimental standard deviation for each scanning instrument (σ)

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Comparison scanning instruments

- Pulse-based Leica ScanStation2 laser scanner

(50 000 points/sec)

(FOV = 360° - 270°)

4-5 million points

σ = 1.6 mm

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Comparison scanning instruments

- Phase-based Leica HDS 6100 laser scanner

(500 000 points/sec)

(FOV = 360° - 310°)

40 million points

σ = 0.4 mm

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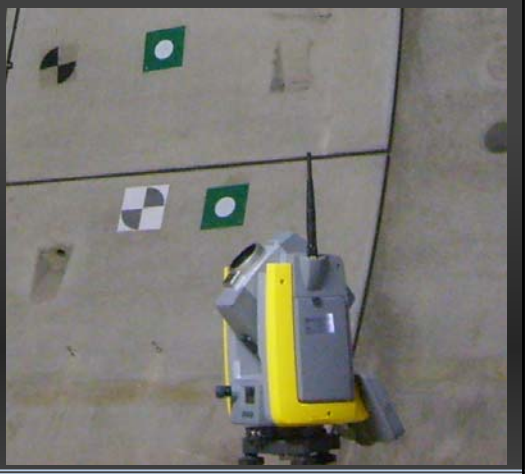
Comparison scanning instruments

- Trimble Robotic Total Station S6

(1 point/sec)

700-800 points

σ = 0.8 mm



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Comparison scanning instruments

- Pulse-based Leica C10 laser scanner

(50 000 points/sec)

(FOV = 360° - 270°)

10 million points

σ = 0.4 mm

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Comparison scanning instruments

- Trimble Spatial Station VX

(5 points/sec)

3 000 points

Section only 1 time measured

Difference with Leica C10:

Alg. difference = -1.6 mm

Abs. difference = 1.7 mm

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Conclusions

- Laser scanning is very applicable for ovalisation measurements
- Achievable standard deviations are calculated:

Leica ScanStation2: σ = 1.6 mm
Leica HDS 6100: σ = 0.4 mm
Trimble Robotic S6: σ = 0.8 mm
Leica C10: σ = 0.4 mm
Trimble Spatial VX:
Difference with C10 = -1.6 / 1.7 mm

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Conclusions

- Results let us conclude that Leica HDS 6100 is currently the most suited, due to
  - Standard deviation
  - Scanning speed
  - Field-of-view

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