CONDITION ASSESSEMENT OF THE OVERVAAL TUNNEL

10 November 2023

CONTENT

EXECUTIVE SUMMARY

Assessments done to date

- IM2000 inspections
- Routine/ daily visual inspections include trolley inspections
- A detailed visual inspections was done during the 2013 shutdown which focused on structural defects on the track slab and tunnel lining.
- Design of the second Overvaal tunnel
- A comprehensive structural condition assessment was done in 2018 using digital tools to capture all structural defects on the tunnel components
- Structural health monitoring (SHM) was implemented on the identified defects to understand the tunnel's behavior under its current condition.

Assessment findings

- The existing tunnel has a few design flaws that lead to some of the challenges experienced today i.e. no water-proof on tunnel walls, single wall lining design, etc.
- The Track Quality Index (TQI) inside the tunnel is greater than target. S-Line TQI target = 6 and the Overvaal TQI = 14
- Water seepage through tunnel walls was observed. It was clear that it is ground water that has found a way through the walls.
- This is caused by the lack of water-proofing on tunnel walls and a high water table levels in the affected area due to a river stream that runs above the tunnel
- Cavities were observed at the junction of the track slab and the inside of one the drains. Only a few of these areas are visible, there could be more cavities underneath the slab.
- A total of 2 327 cracks were observed on the tunnel components, ranging between the widths of 0.1mm to 5.5mm. Critical crack width on railway track slabs is ≥0.3mm
- From SHM, deformation of the tunnel lining was recorded at KM 23+658. this is due to the hydrostatic pressure due to high water table at this section. Significant vertical slab deflection was observed at KM 24+000

EXECUTIVE SUMMARY

Risks associated with defects

- The poor TQI state could lead to derailments or hook-ups inside the tunnel
- Cavities underneath the slab (known & unknown) create uneven load distribution resulting in the formation of cracks, excessive slab deflection or worse, slab breaks under load leading to derailment
- The cracks allow water to seep through the walls causing rust on the steel reinforcement, reducing capacity to withstand tension forces, weakening the structural integrity of the lining & track slab
- Seismic actions(natural occurrence) from the identified fault zones could have devastating effects on the already weakened structural integrity

PROJECT OVERVIEW

Project Aim:

- Collect baseline data to study structural behavior
- Protect Transnet against potential claims during construction

Project Scope:

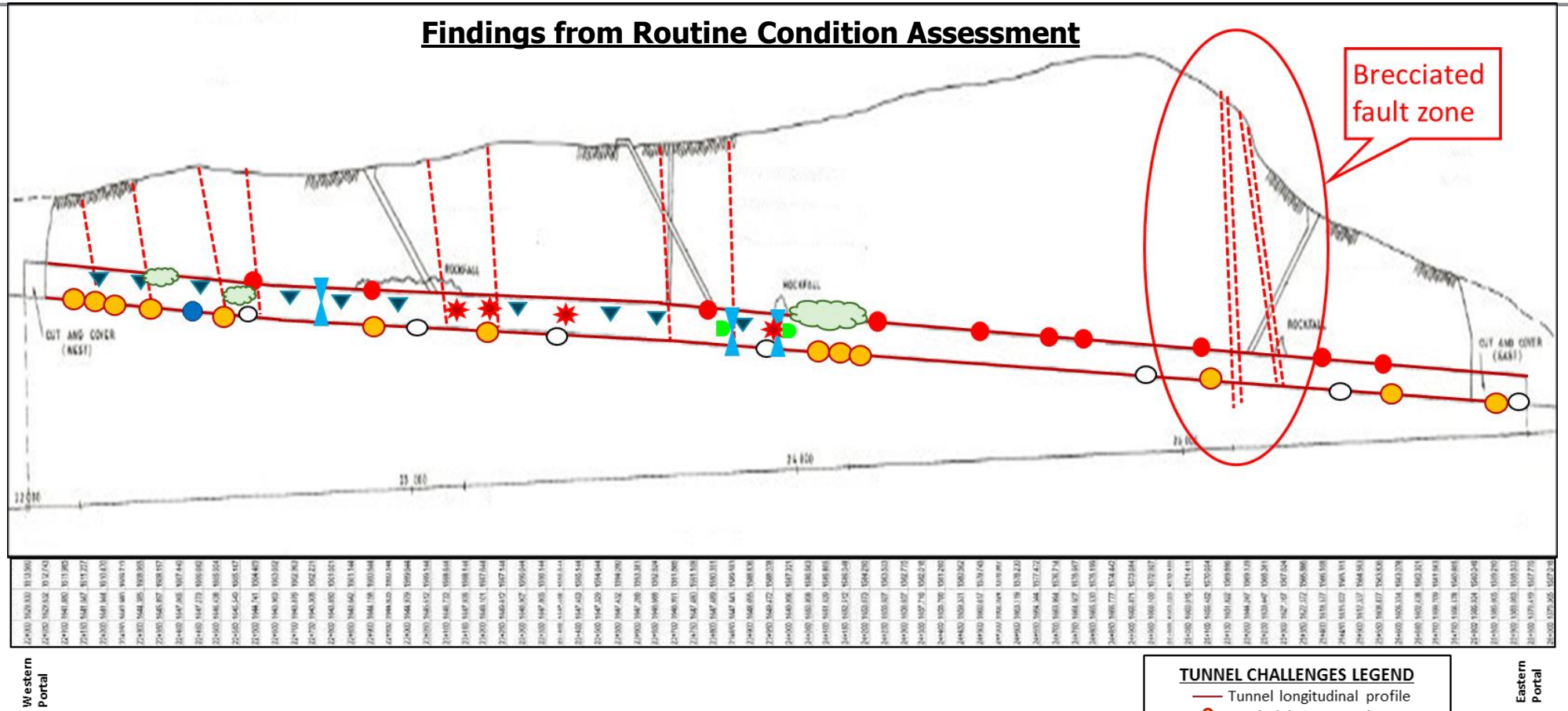
Comprehensive Structural Condition Assessment	•Detailed information on current structural condition •Corrective measures to be implemented to mitigate identified weaknesses.
Structural Design Check	•Determine vibration limits for each structure •Determine vibration impact for each structure
Structural Condition Monitoring	•Select appropriate instruments or sensors to monitor each structure •Monitor all structures for 12 months
Works information for monitoring during construction	•Propose a system & procedure to monitor during new tunnel construction

Project Benefits

- Holistic understanding of the tunnel components' structural integrity
- Baseline data collection to enable Predictive Maintenance Strategy (Inline with Transnet's 4.0 theme)
- Effecting progress towards establishing safety limits for safe construction of the second Overvaal Tunnel

STRUCTURAL CONDITION ASSESSMENT

ERM

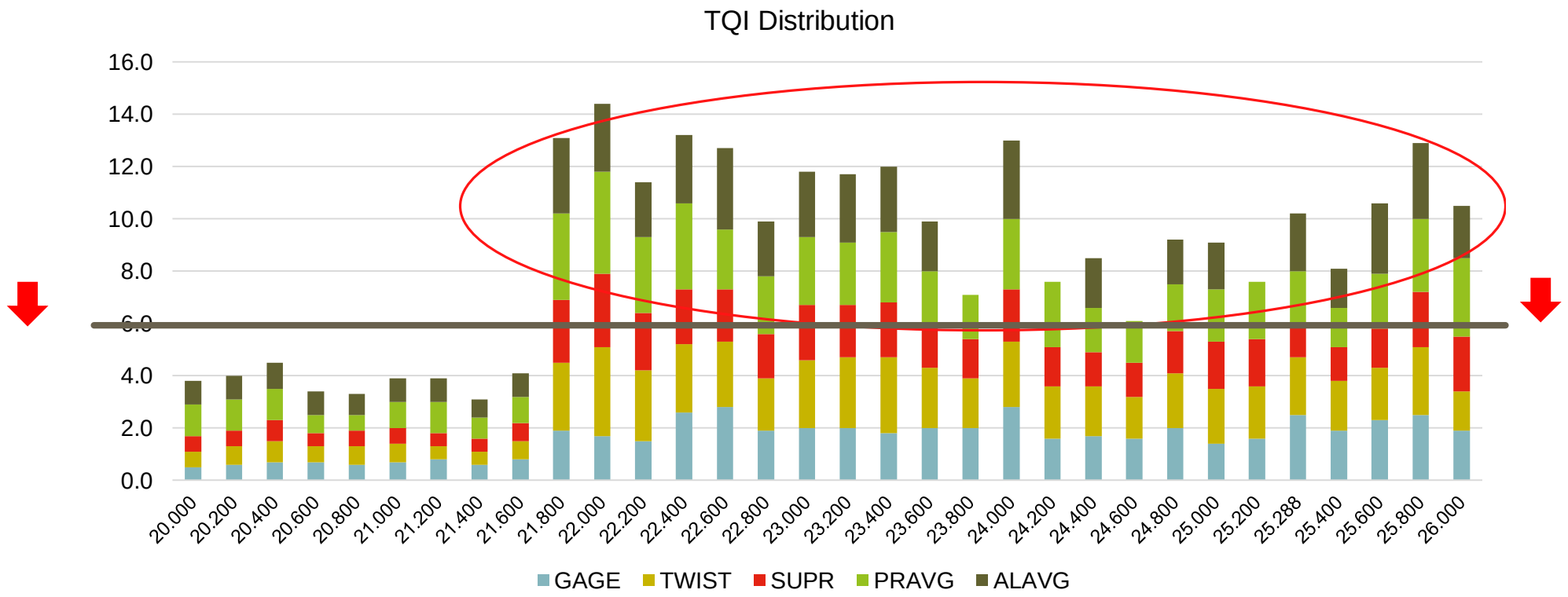


RCB

- Perway - IM2000 inspection results
- Civils - Visual inspection including trolley inspections

STRUCTURAL CONDITION ASSESSMENT

Findings from Routine Condition Assessment



- S-Line classification: Adopted TQI target = 6
- Increased variance in TQI specifically in the Overvaal tunnel.
- TQI range is relatively similar before and after the tunnel.

STRUCTURAL CONDITION ASSESSMENT

Digital Condition Assessment

- Semi-automatic 360° UHD imaging system was used to capture the tunnel lining's condition.
- The assembled HD orthophotography was used to perform the remote inspection of the tunnel lining
- The first 300m of the track slab was visually inspected and used as a reference and scale.

Benefits

- Digital assessment of defects
- Off-site tunnel inspection
- Can be fully automated**

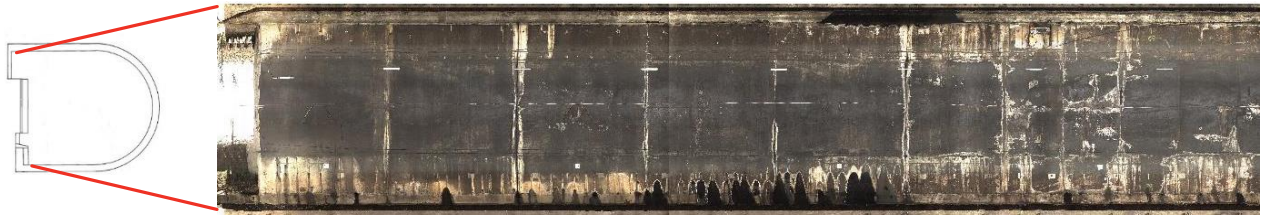


Image of tunnel lining captured for inspection

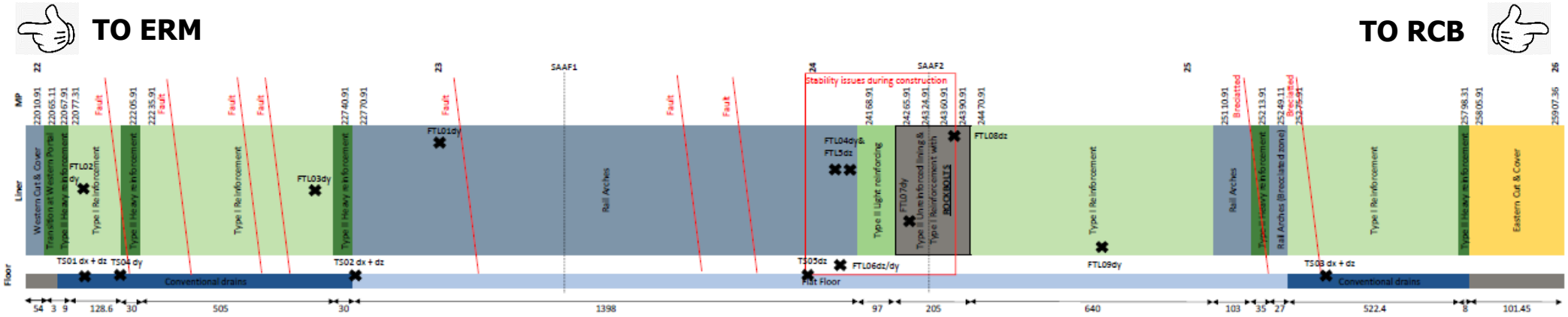
STRUCTURAL CONDITION ASSESSMENT

Tunnel Lining Condition

Defect	Quantity	Total length/Area
Cracks	**2230**	**5887.9m**
Horizontal	418	2313.3m
Vertical	1684	3065.8m
Diagonal	100	246.9m
Horizontal + Diagonal	2	6.9m
Horizontal + Vertical	26	255m
Crazing	**13**	**186.4m²**
Water Seepage	**96**	**1607.6m²**
Delamination	**2**	**0.04m²**
Miscellaneous defects	**38**	**3252m²**
Spalling	2	7.8m²
Efflorescence	21	772.8m²
Efflorescence + Seepage	14	2471m²

- Significant cracks on the light density reinforced tunnel lining are mainly induced by the rock mass movement as well as the hydrostatic pressure
- Interconnected cracks presents a risk of collapse
- No corrosion visible: Potential corrosion none destructive test recommended
- Evolution of the cracks is being monitored

STRUCTURAL CONDITION ASSESSMENT



Summary of Structural Cracks

Design Type	Unreinforced (Rock Bolt)	Light Reinforcement	Rail Arches
Length of section (m)	302	1796	1582
Max. width (mm) **Ave. width (mm)** **Max length (m)**	5.5 2.2 13.5	4 1.5 14.4	3.5 1.4 13.4
Section Condition	Severe cracks	Dense cracks Map pattern	Cracks follow arch position

STRUCTURAL CONDITION ASSESSMENT

Track Slab Condition

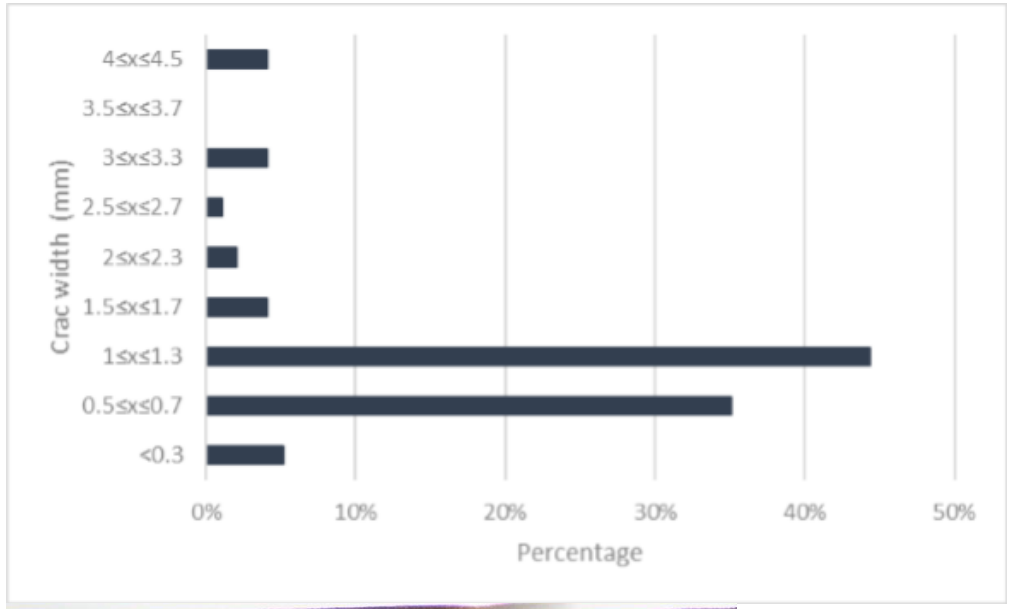
Defect	Quantity	Total length/Area
Cracks	**97**	**62.8m**
Transversal	94	47m
Longitudinal	3	15.8
Crazing	**0**	**0**
Water Seepage	**1**	**0.3m²**
Delamination	**10**	**1.5m²**
Miscellaneous defects	**7**	**21.95m²**
Spalling	5	0.25m²
Efflorescence	2	21.7m²
Efflorescence + Seepage	0	0

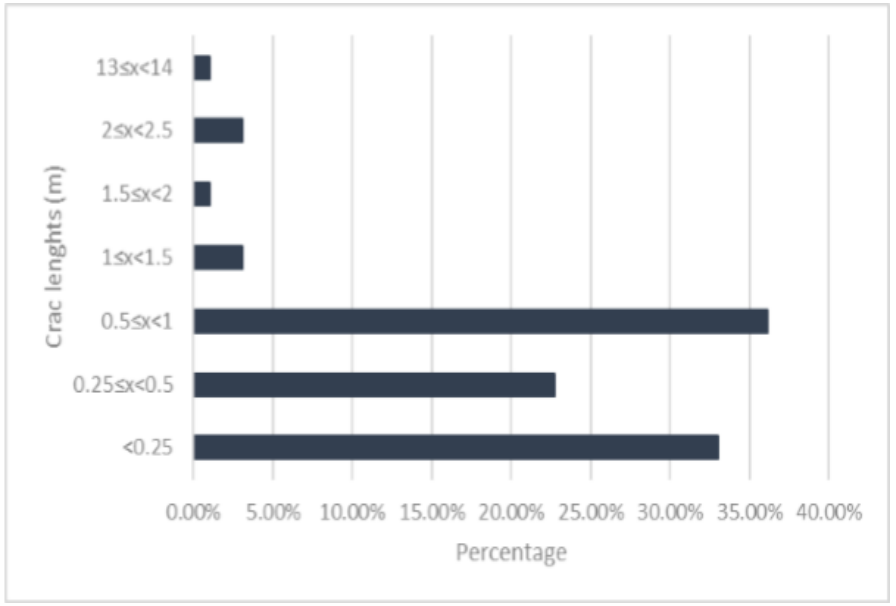
Findings

- No critical cracks observed
- Water seepage from cracks with width > 2mm posing a threat of corrosion of rebar
- Minor areas of de-bonding
- The movement is to be confirmed by the continuous condition monitoring

STRUCTURAL CONDITION ASSESSMENT

Track Slab Condition cont.





- 85% of the cracks have a width of less or equal to 1.3mm
- Only six (6) cracks have an opening ranging between 2mm to 4mm.
- 92% of the crack's lengths are less than 1m

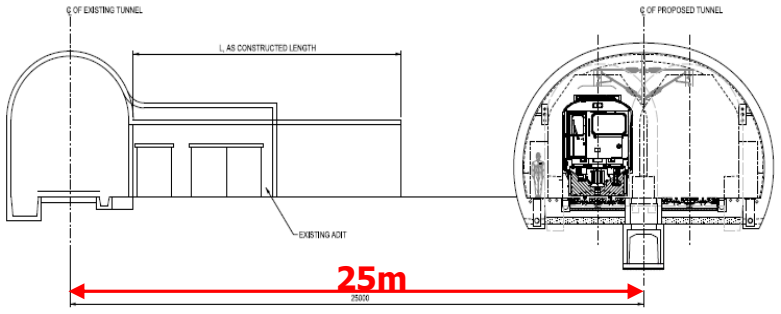
STRUCTURAL DESIGN ASSESSMENT

Vulnerability of structures

Aim

- Study the vulnerability of existing structures in relation to proposed second tunnel excavation
- Determine the vibration limits for existing structures.

Structures	Distance from new tunnel (m)	Condition
Existing tunnel	25	• Major cracks on the tunnel lining due design flaws • Water seepage through the cracks
AfGRI Silos	1000	• Good condition (Small thin cracks) • No settlement
Cell C tower	159	• Good condition • No settlement
Community houses (lowest)	154	• Mud houses are in a poor condition; present a risk of collapsing.
Community houses (closest)	109	• Mud houses are in a poor condition; present a risk of collapsing.



STRUCTURAL DESIGN ASSESSMENT

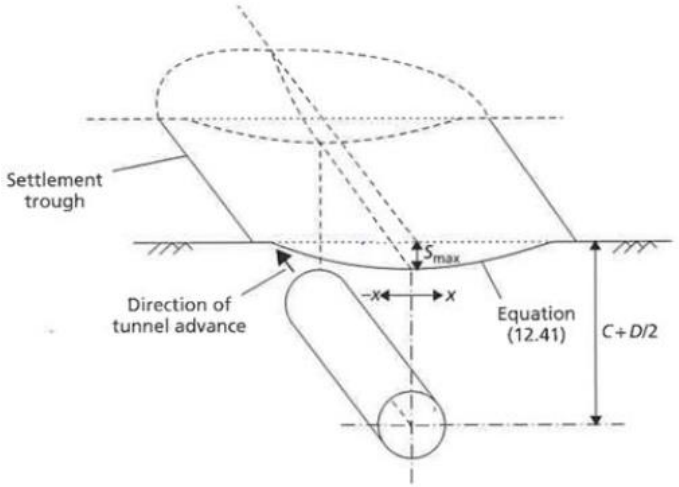
Vulnerability = Hazard x Sensitivity

$$i = 0.35\,(C + \frac{D}{2})$$
$$i = 0.35(110 + \frac{12{,}044}{2})$$
$$i = 40{,}608\text{m}$$

Hazard estimation

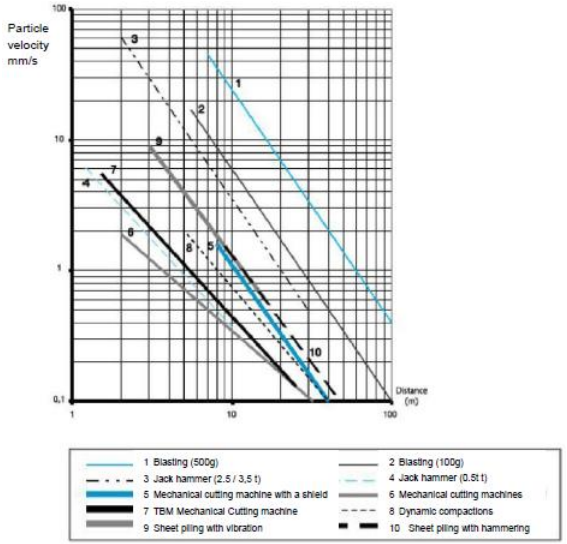
1. Deformation/Settlement hazard

- Influence zone = 40.6m (20.3m from center of new tunnel)
- The existing tunnel is affected by excavation
- Δ_{max} = 33.6mm



2. Vibration hazard

- Influence zone: Drill and blast = 100m from center of new tunnel
  TBM = 50m
- Only the existing tunnel will be affected by vibrations



Structure	Distance from new tunnel (m)	Level of signal expected PV (mm/s)		Hazard (Y/N)
		Drill & Blast	TBM	
Overvaal Tunnel	25	4	0.13	Y

STRUCTURAL DESIGN ASSESSMENT

Sensitivity estimation

1. Sensitivity of existing structures due to deformation (settlement)
   - Damage category of the Overvaal Tunnel is ***Structural***

Structures	Function	Geometrical & structural characteristics	Current Condition	Sensitivity to Deformation
Overvaal Tunnel	Railway tunnel	Underground structure with mixed type of reinforcement in cast in-situ concrete lining	Structural	Highly sensitive

2. Sensitivity of existing structures due to vibration
   - Sensitivity is based on the type of building, foundation & geology.

Structures	Type of structure	Type of foundation	Soil type
Overvaal Tunnel	Underground structure with mixed type of reinforcement in cast in-situ concrete lining	Class B	Type A

Vulnerability = Hazard x Sensitivity

Structures	Hazard			Sensitivity		Vulnerability
	Deformation	Vibration (TBM)	Vibration (Drill & Blast)	Deformation	Vibration	
Existing Overvaal tunnel	Yes – primary pattern Trough area Smax = 33,57mm i = 40,61m	Yes PV = 0,13mm/s	Yes PV =4mm/s	Highly sensitive	Sensitive	Yes
AFGRI Silos	No	No	No	Moderately sensitive	Not sensitive	No
Cell C Tower	No	No	No	Moderately sensitive	Not sensitive	No
Community houses	No	No	No	Sensitive	Highly sensitive	No

STRUCTURAL DESIGN ASSESSMENT

Design Standards
1. SANS 10100: 2011
2. SANS 4866: 2011
3. EUROCODE EN 1997
4. AFTES RECOMMENDATIONS: GT16R1A1
5. DIN 4150-3 – GERMAN VIBRATION STANDARDS
6. USBM R18507 – BLASTING VINRATIONS

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THANK YOU

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