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By email
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1 July 2025

Mr Callan Salter
Development Manager
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Level 30, 420 George Street
Sydney NSW 2000

Dear Callan

Proposed Development at 105 Miller St, North Sydney - Structural Impact Assessment of Sydney Metro Tunnel Lining

1. Introduction

This report presents the structural impact assessment undertaken by WSP in accordance with iCentral SM-20-00081444 – *Sydney Metro Underground Corridor Protection Technical Guideline* (the Guideline). The assessment focuses on the Sydney Metro tunnel lining in relation to the proposed development at 105 Miller Street, North Sydney (the Site). Douglas Partners Pty Ltd (DP) has been commissioned to perform the geotechnical investigation and numerical analysis to assess potential impacts on the adjacent Sydney Metro tunnel to the west and Victoria Cross station shaft to the north of the site. WSP has used DP's numerical analysis results to assess the potential structural impact on the metro tunnel lining only.

2. Summary of geotechnical impact assessment

Douglas Partners Pty Ltd (DP) has carried out numerical modelling to assess the potential impacts of the proposed development on the Sydney Metro tunnel lining. The methodology and results are detailed in DP's report (Ref: 86964.03.R.002.Rev0).

Based on our previous experience, it is expected that ground relaxation of at least 90% will occur before the tunnel lining becomes structurally engaged. However, to account for potential variations in ground relaxation due to the influence of the tunnel boring machine's (TBM) effective confining pressure, additional analyses were carried out assuming 60% ground relaxation.

The following load cases and sensitivity analyses were considered:

Load Cases:

- **Load Case 1:** Pin connection at segmental joints, 60% ground relaxation
- **Load Case 2:** Reduced stiffness accounting for number of joints, 60% ground relaxation
- **Load Case 3:** Pin connection at segmental joints, 90% ground relaxation
- **Load Case 4:** Reduced stiffness accounting for number of joints, 90% ground relaxation

Sensitivity Analyses:

- **Case 1:** Load Case 1 with 50% of Young's modulus (long-term modulus)
- **Case 2:** Load Case 3 with 50% of Young's modulus (long-term modulus)

Table 1 provides a summary of the structural actions in the tunnel lining before and after the proposed development. The results show that the changes in structural actions are within 5–10%, suggesting that the impact of the proposed development on the tunnel lining is minimal.

DP's report notes that changes in structural actions due to these sensitivity analyses are within 1–2% of the base case.

Selected outputs from these analyses were provided by DP and have been used in the structural impact assessment outlined below. Graphical results are included in **Attachment A**.

Table 1: Summary of structural actions – Load Case 1

Parameter	Pre-Development	Post-Development	Change (%)
Axial force (kN)	797	831	4
Bending moment (kNm)	9.6	9.9	3
Shear force (kN)	38.8	42.1	8

3. Structural impact assessment

The structural impact assessment focused on the following aspects of the tunnel lining:

- Structural capacity
- Movement and differential movement
- Cracking

3.1 Structural properties of lining

It is understood that the segmental lining within this section of the metro tunnel comprises Steel Fibre Reinforced Concrete (SFRC). Table 2 provides the SFRC properties adopted in the structural assessment.

Table 2: SFRC properties adopted for the assessment

Parameters	Value
Thickness of segmental lining (mm)	260
Characteristic compressive concrete strength, $f'c$ (MPa)	50
Concrete short-term modulus (GPa)	34
Concrete long-term modulus (GPa)	17
Poisson's ratio for concrete	0.2
Characteristic residual tensile strength of SFRC, $f'1.5$ (MPa)	1

3.2 Structural capacity

To assess whether the structural actions induced by the proposed development fall within the structural capacity of the tunnel lining, the bending moment and axial force have been plotted on a Moment (M) – Axial Force (N) interaction diagram as per Australian Standard AS5100.5-2017, as shown in Figure 1. The structural actions in the lining were provided by DP, and the

assessment was carried out using the parameters presented in Table 1 above. Load factors of 1.5 and 1.0 were applied for Ultimate Limit State (ULS) and Serviceability Limit State (SLS) conditions, respectively.

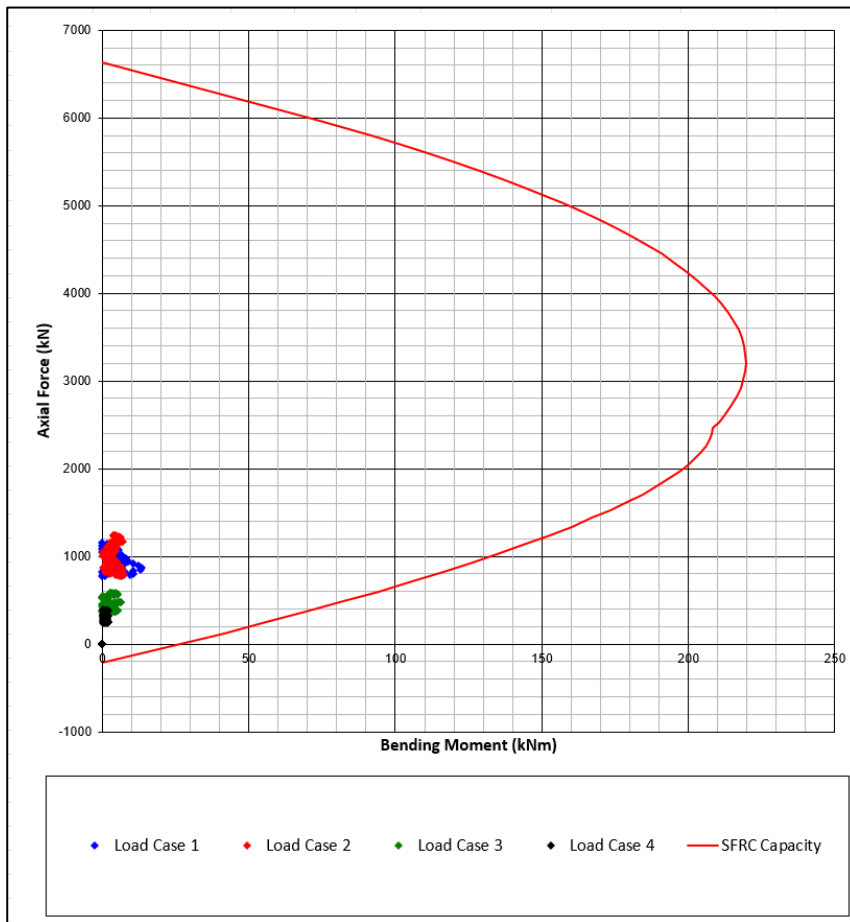


Figure 1: M-N diagram for ULS case

As presented in Figure 1 above, the structural actions after post-development are within the lining structural capacity.

3.3 Movement and differential movement

To check compliance with Section 9.1.2 of the Guidelines, an assessment of the tunnel's response to predicted deformations was conducted. Figure 2 presents the tunnel lining movement pre and post development stages obtained from DP's report.

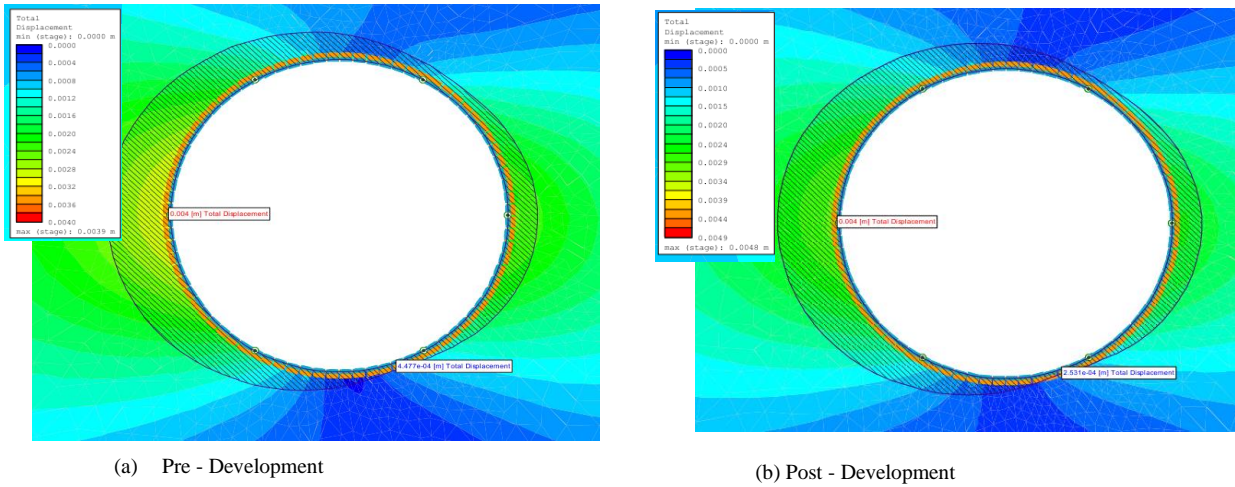


Figure 2: Tunnel lining movement – post development

The total tunnel movement before and after the proposed development is 3.9 mm and 4.8 mm, respectively. Both values are within the allowable total movement limit of 10 mm in any direction, as specified in the Guideline. Differential movement in transverse plan is less than 1 mm.

3.4 Crack assessment

Analysis was conducted to assess the cracking potential due to the induced structural actions by the proposed development. An M – N interaction diagram was developed for 0.2 mm crack width and using the long-term Young’s modulus as per Australian Standard AS5100.5-2017.

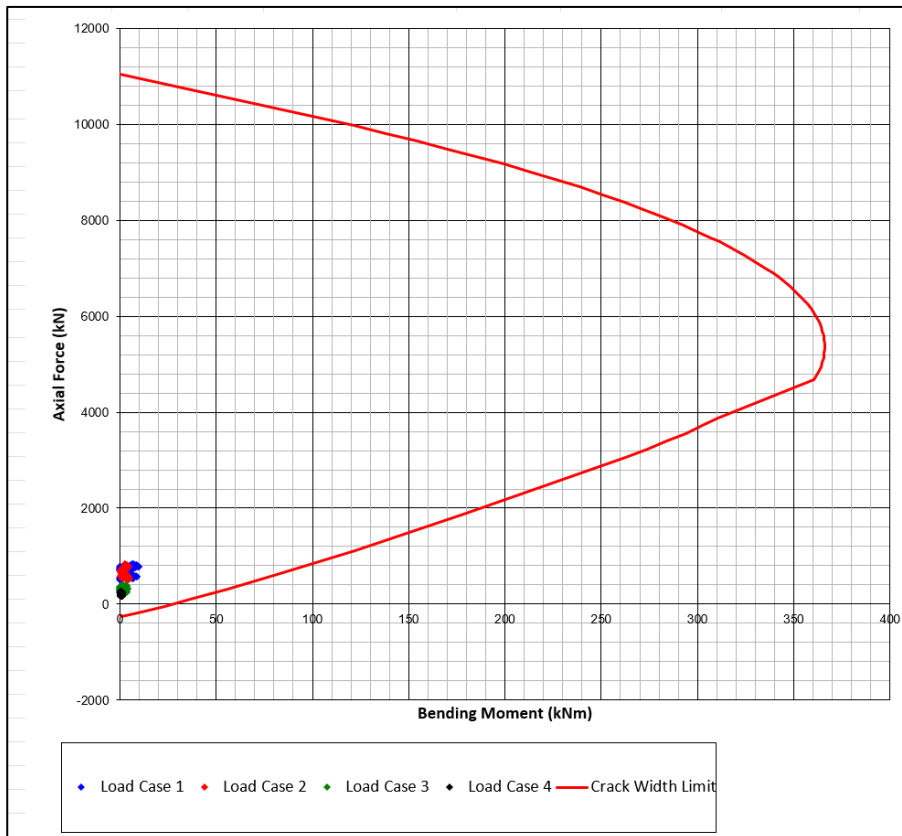


Figure 3: M-N interaction diagram for limiting crack width of 0.2 mm

The structural actions were provided by DP, and the assessment was conducted using the parameters presented in Table 1. A load factor of 1.0 was adopted for this assessment. As shown in Figure 3, the induced structural actions remain within the limit corresponding to a maximum crack width of 0.2 mm. Furthermore, the axial force in the tunnel lining remains consistently compressive, indicating that the potential for crack development in the segmental lining is minimal.

3.5 Summary

Based on the above assessment, the following observations are made:

- Total movement of tunnel lining after the proposed development is 4.8 mm and differential movement is less than 1 mm, indicating that the tunnel lining movement is within the 10 mm tolerable limit.
- Structural actions developed within the lining are always within the capacity for ULS and SLS conditions.
- Axial force developed within the lining is always compressive, indicating that potential for tensile crack development is minimal.

4. Instrumentation and monitoring

An Instrumentation and Monitoring (I&M) Plan will be developed to support the basement excavation and construction works. The plan will include the installation of monitoring instruments along the site boundary to measure ground movements. These will include inclinometers, displacement markers on the shoring wall, settlement points behind the excavation zone and vibration sensors. Appropriate alert, action, and alarm levels will be established in accordance with the Sydney Metro Underground Corridor Protection Technical Guideline.

5. Risk assessment

A preliminary risk assessment register has been produced to identify potential risks of adversely impacting Sydney Metro assets (Attachment B).

The potential impact of the proposed development on the metro tunnel is substantially mitigated by the distance (approximately 24 m perpendicular dimension), and the relatively small depth of additional excavation proposed (< 4m – 5m), which is reflected by the negligible movements at the tunnel lining predicted by the 2D numerical analysis. As such material risk to the metro tunnel structure and operations is also considered to be negligible.

The main risk identified results from ground movement caused during construction by excavation or excessive movement of the site retention system including catastrophic collapse. Other risks relate to excessive ground borne vibration. The table in Attachment B identifies risks, possible causes and consequences and provides mitigation measures to minimise the risks and the impact of those risks eventuating.

Risks impacting the Sydney Metro tunnel are considered to be negligible.

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revenue, loss of opportunity to earn profit, loss of production, loss of contract, increased operational costs, loss of business opportunity, site deprecation costs, business interruption or economic loss) of any kind whatsoever, suffered on incurred by a third party.

Yours sincerely

A handwritten signature in black ink, appearing to read 'N. Sasiharan', with a circled initial 'N'.

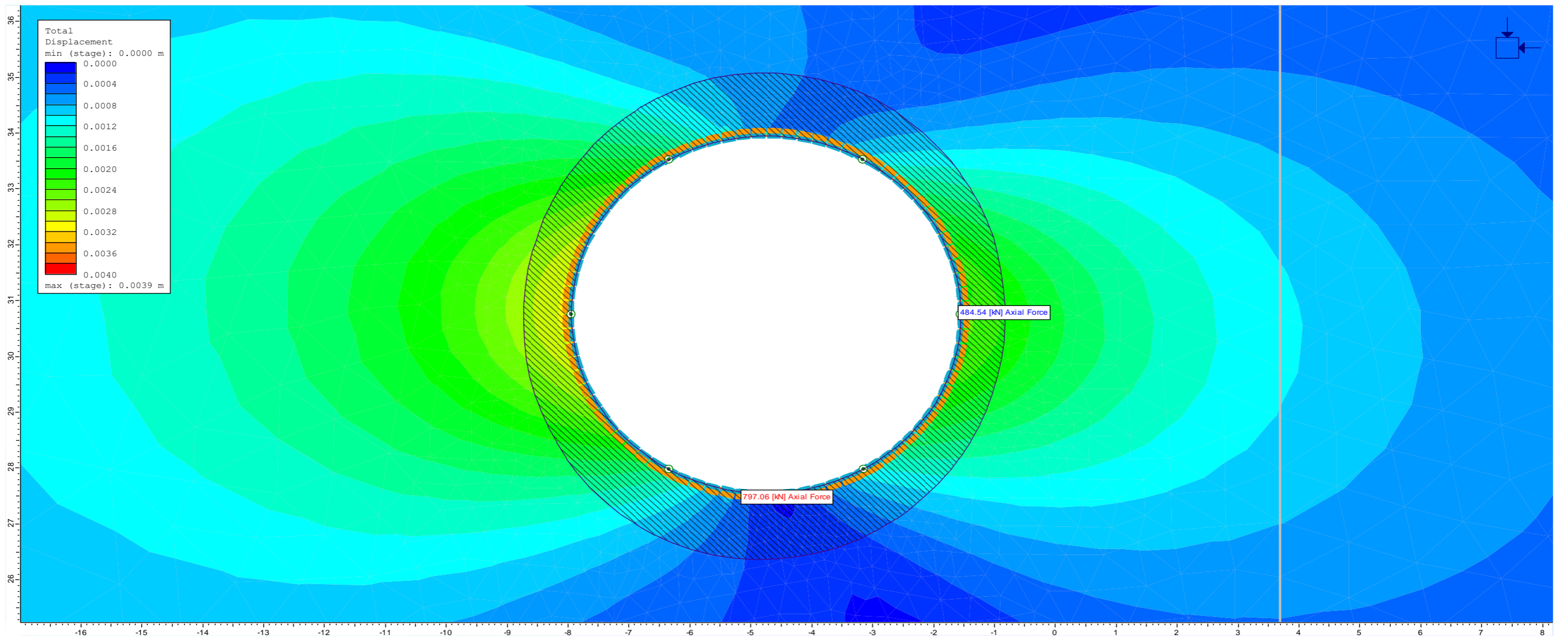
Sasi Sasiharan
Technical Executive

List of attachments

Attachment A - Numerical Analysis Output from DP

Attachment B - Sydney Metro related risk register

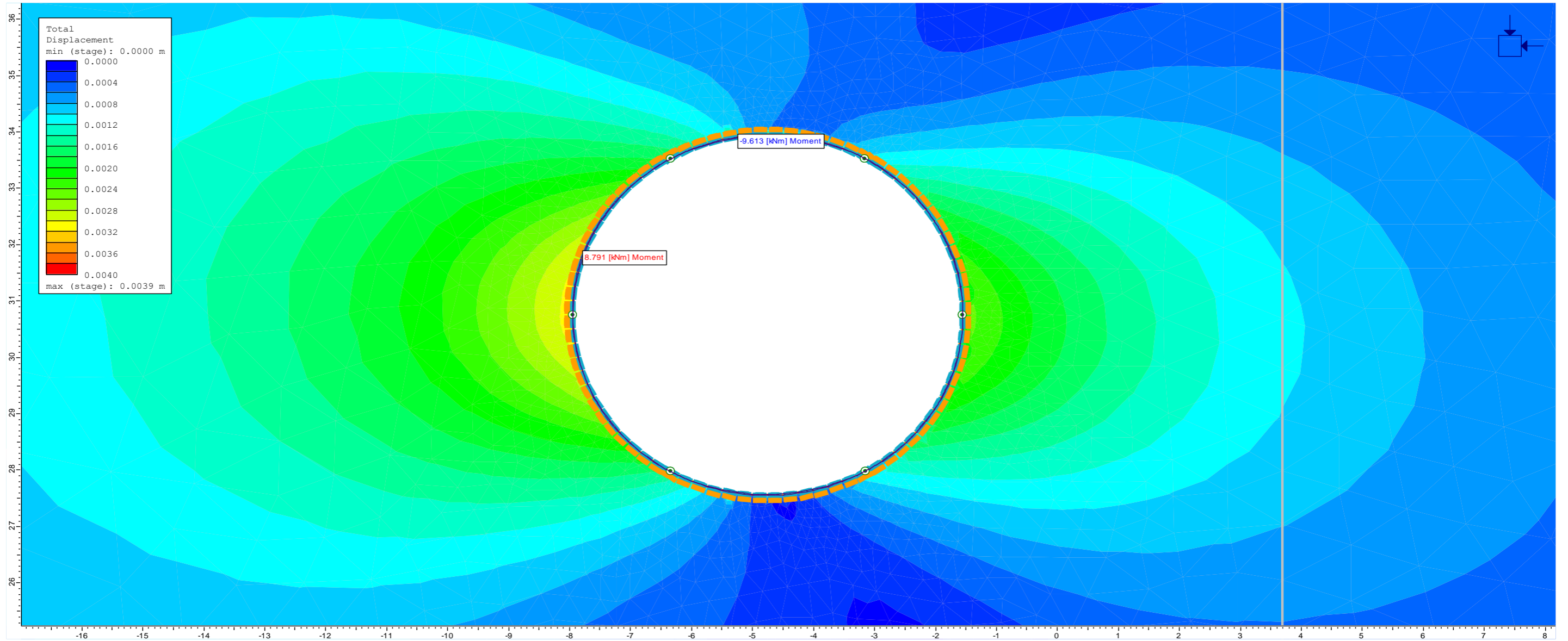
Attachment A
Numerical Analysis Output from DP



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OFFICE: Sydney	DRAWN BY: RMM
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Proposed Redevelopment
105 Miller Street, North Sydney

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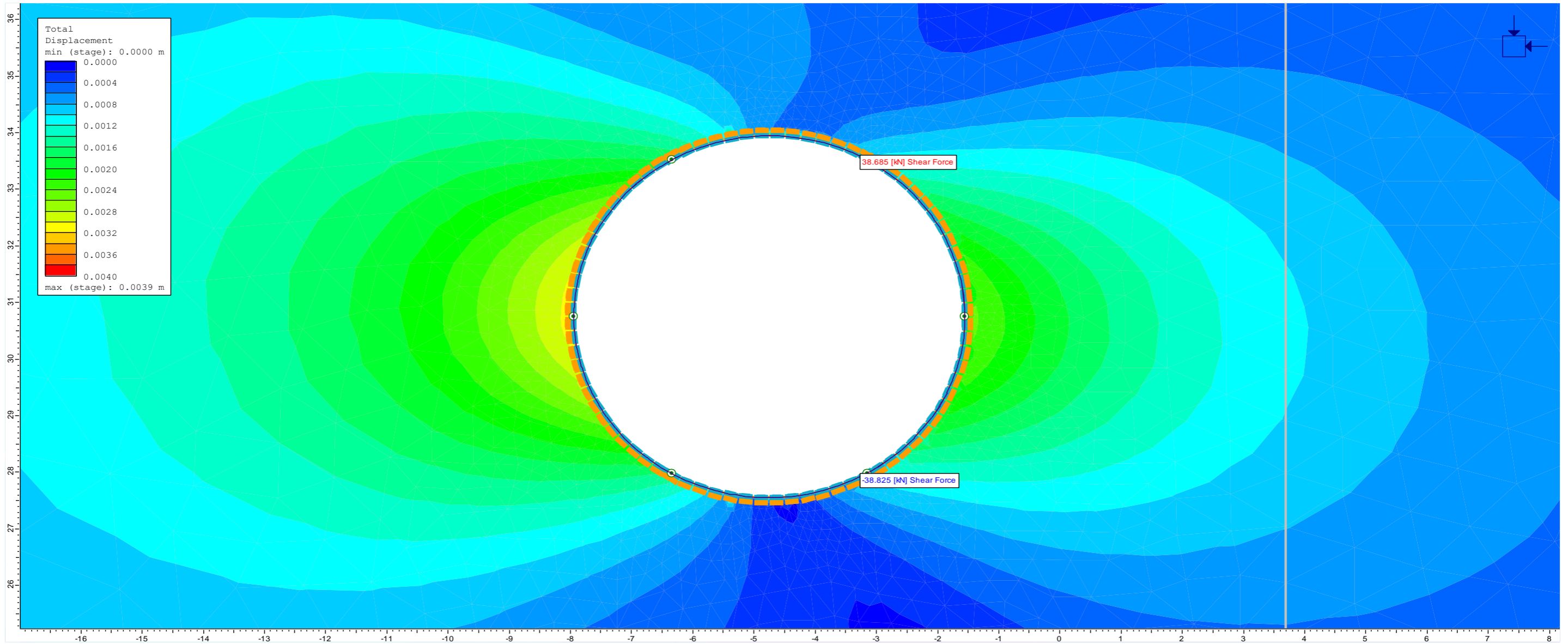


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105 Miller Street, North Sydney

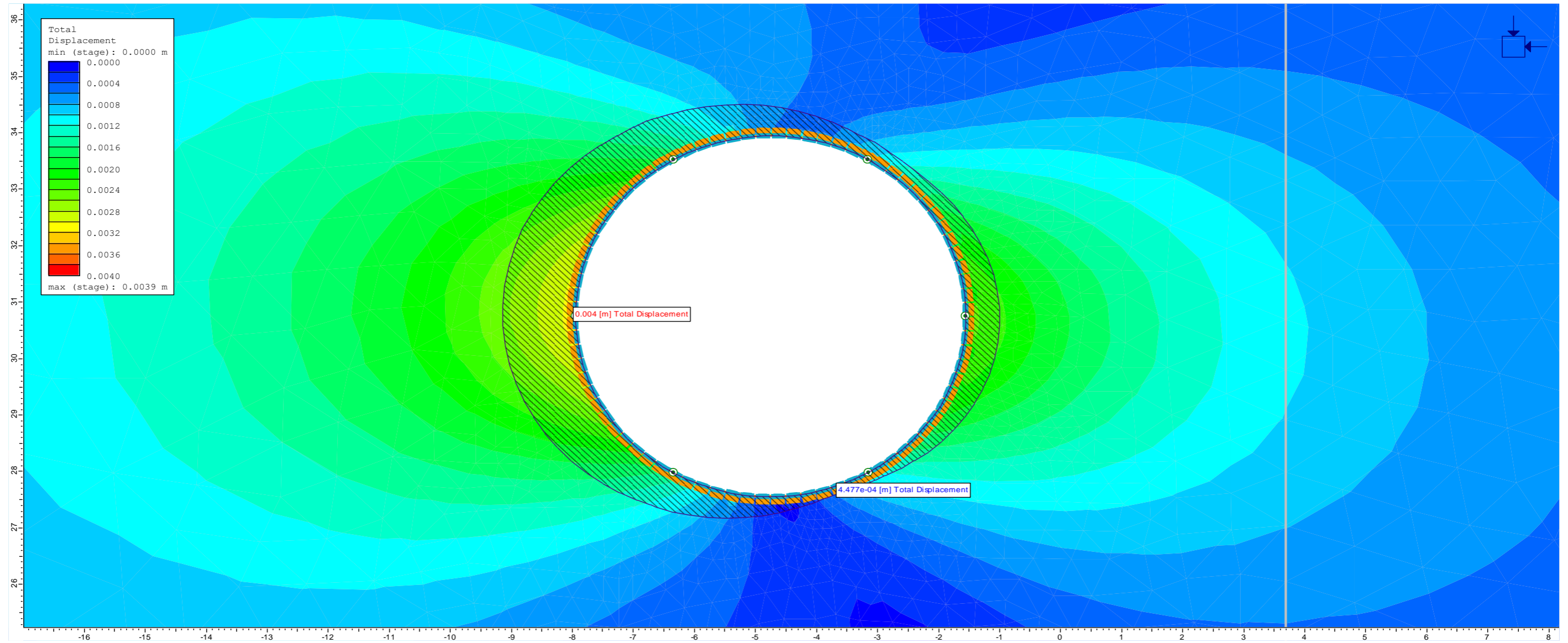
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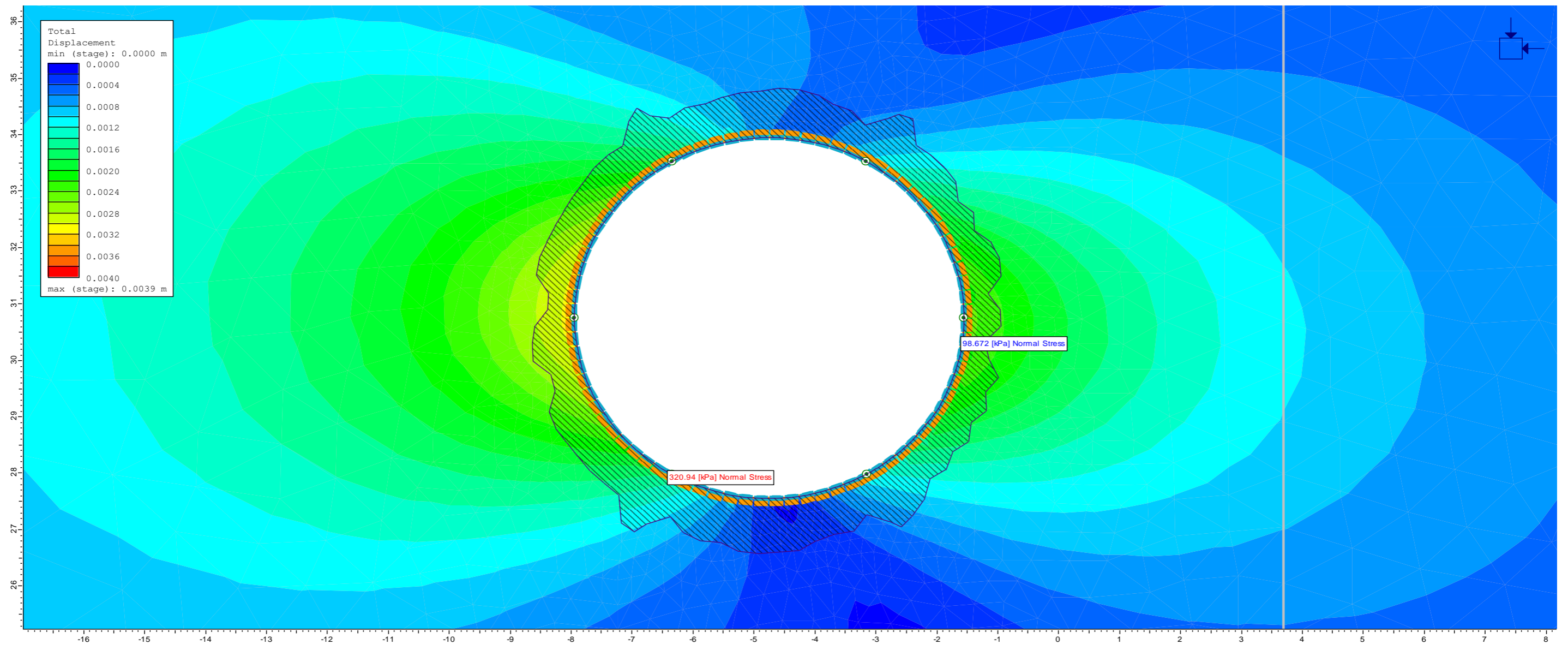
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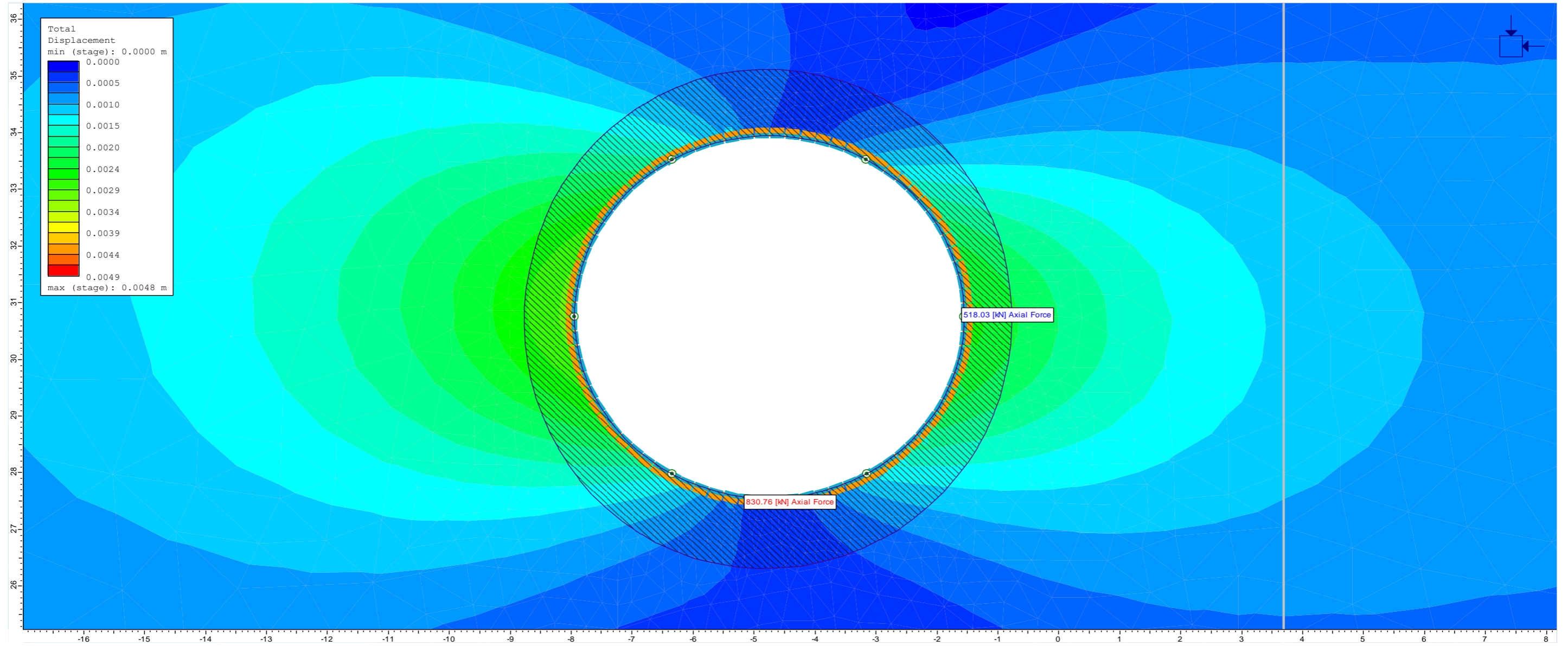
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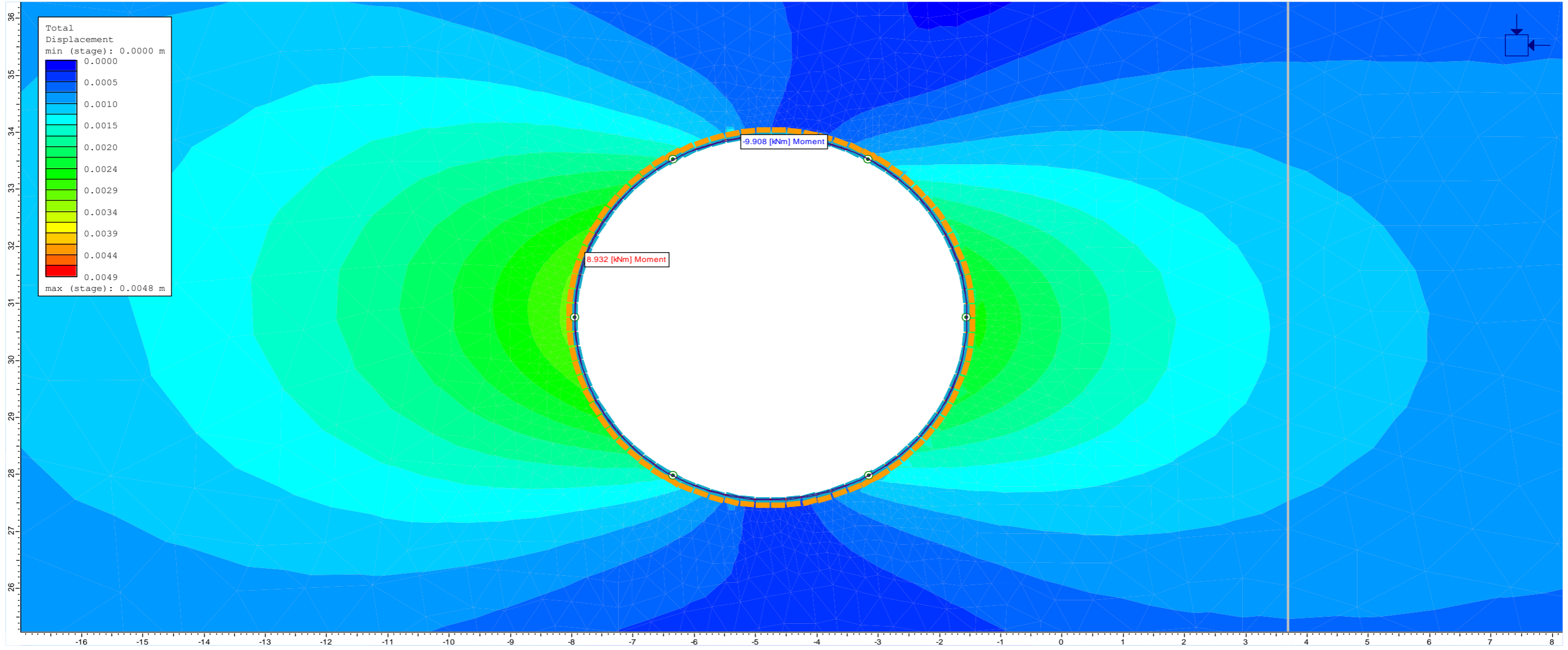
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105 Miller Street, North Sydney

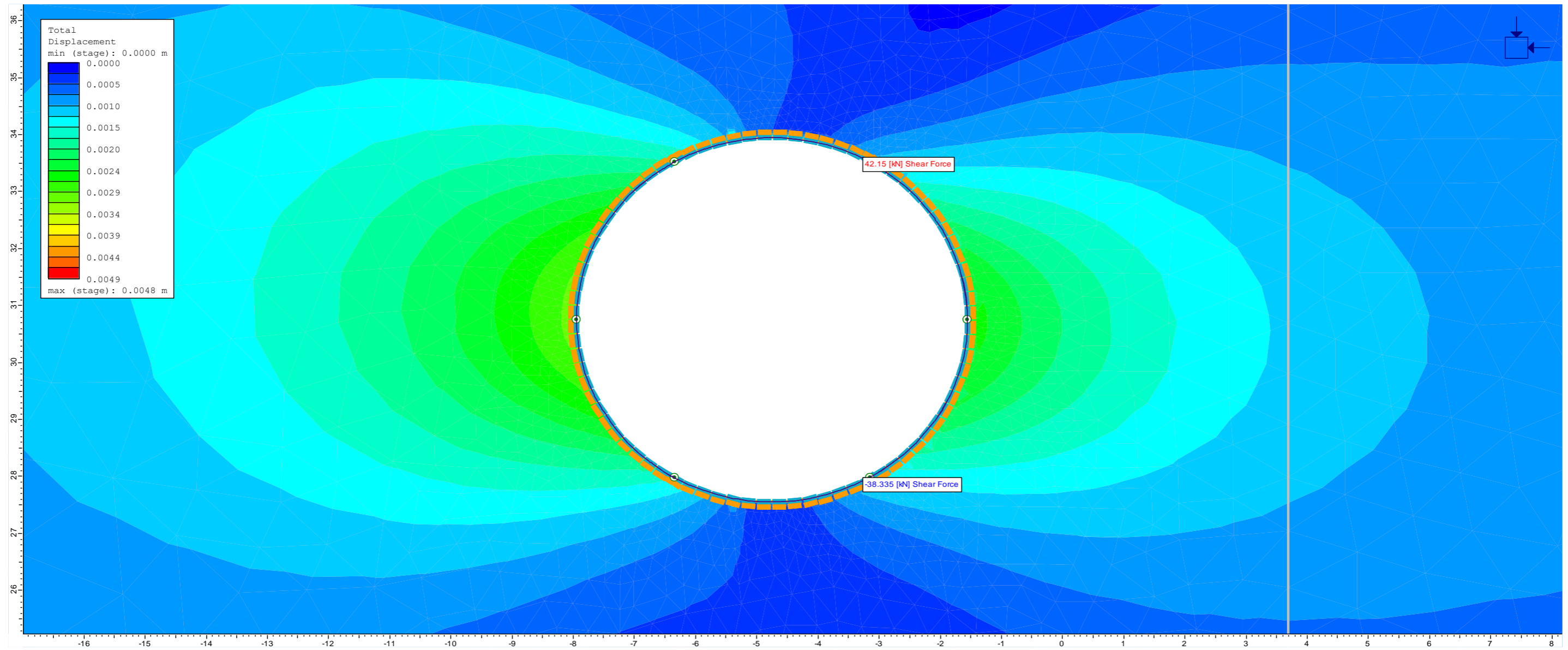
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105 Miller Street, North Sydney

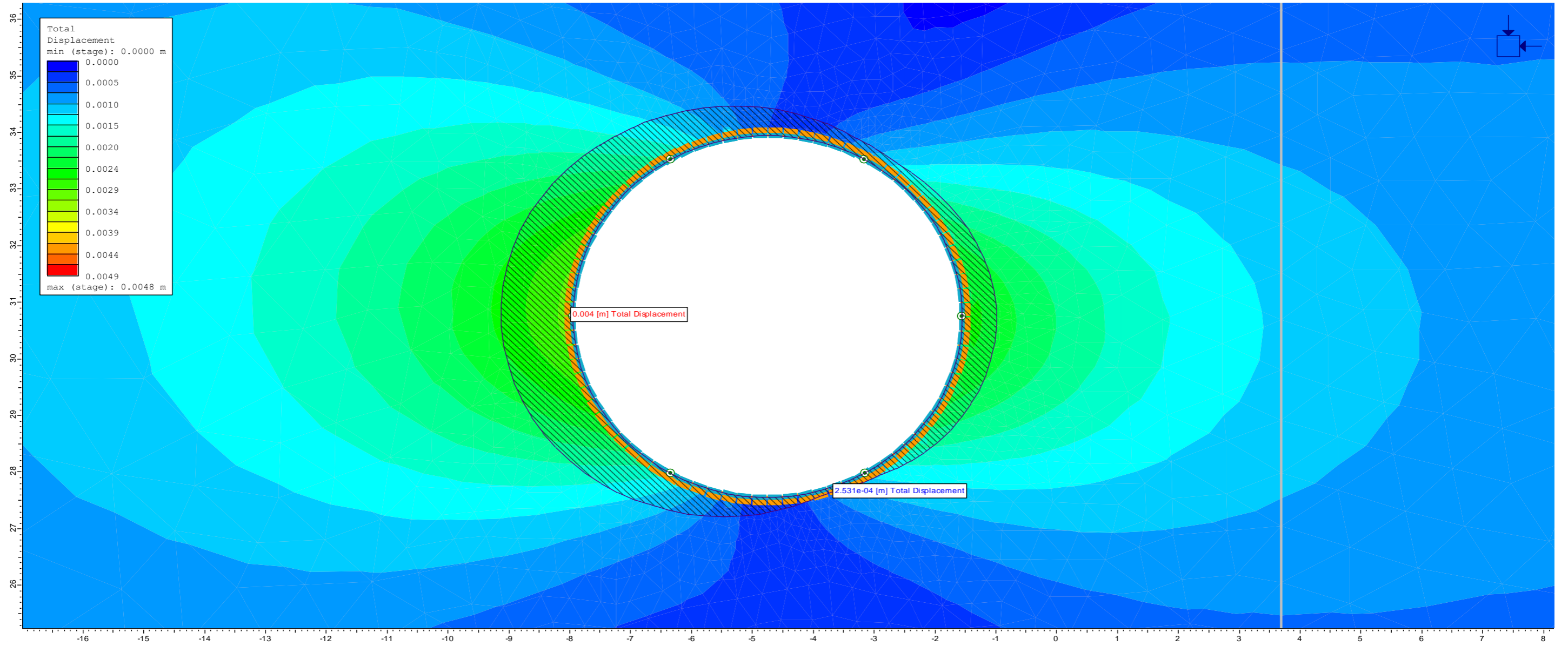
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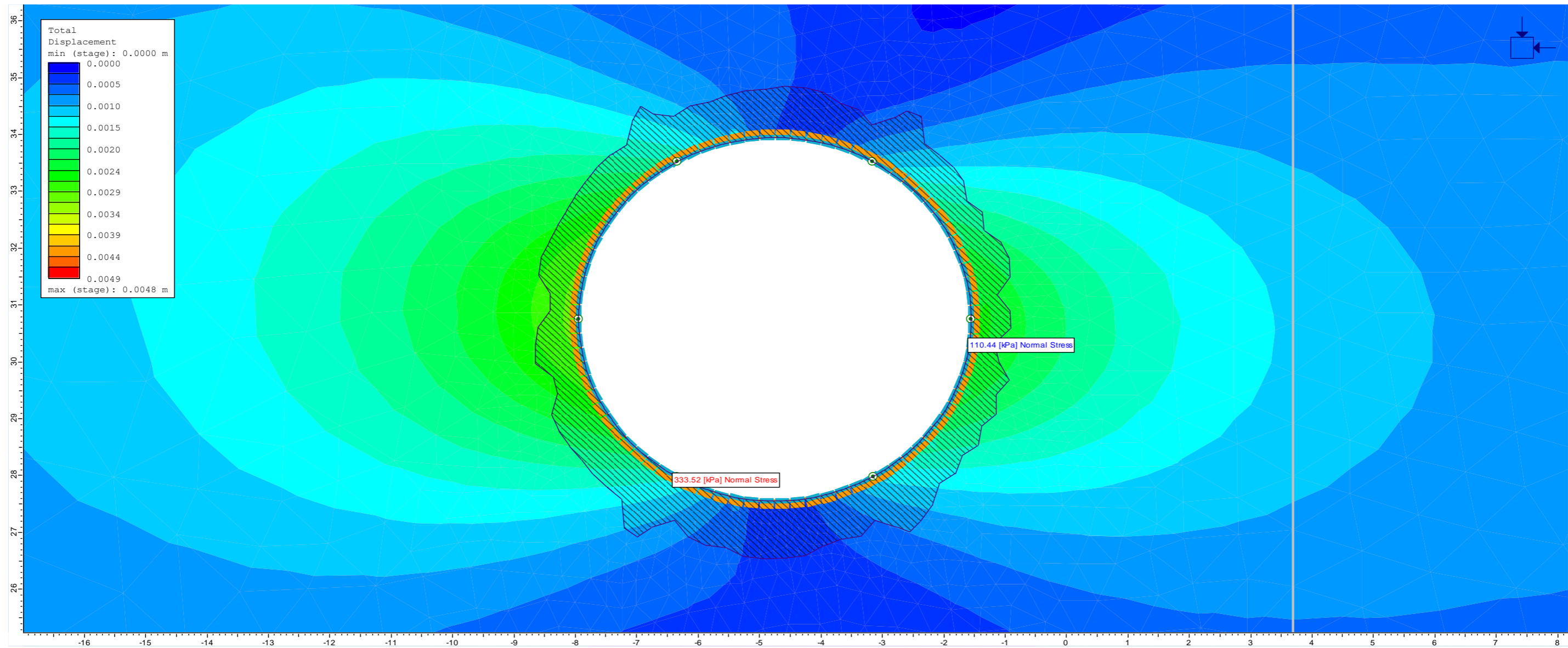
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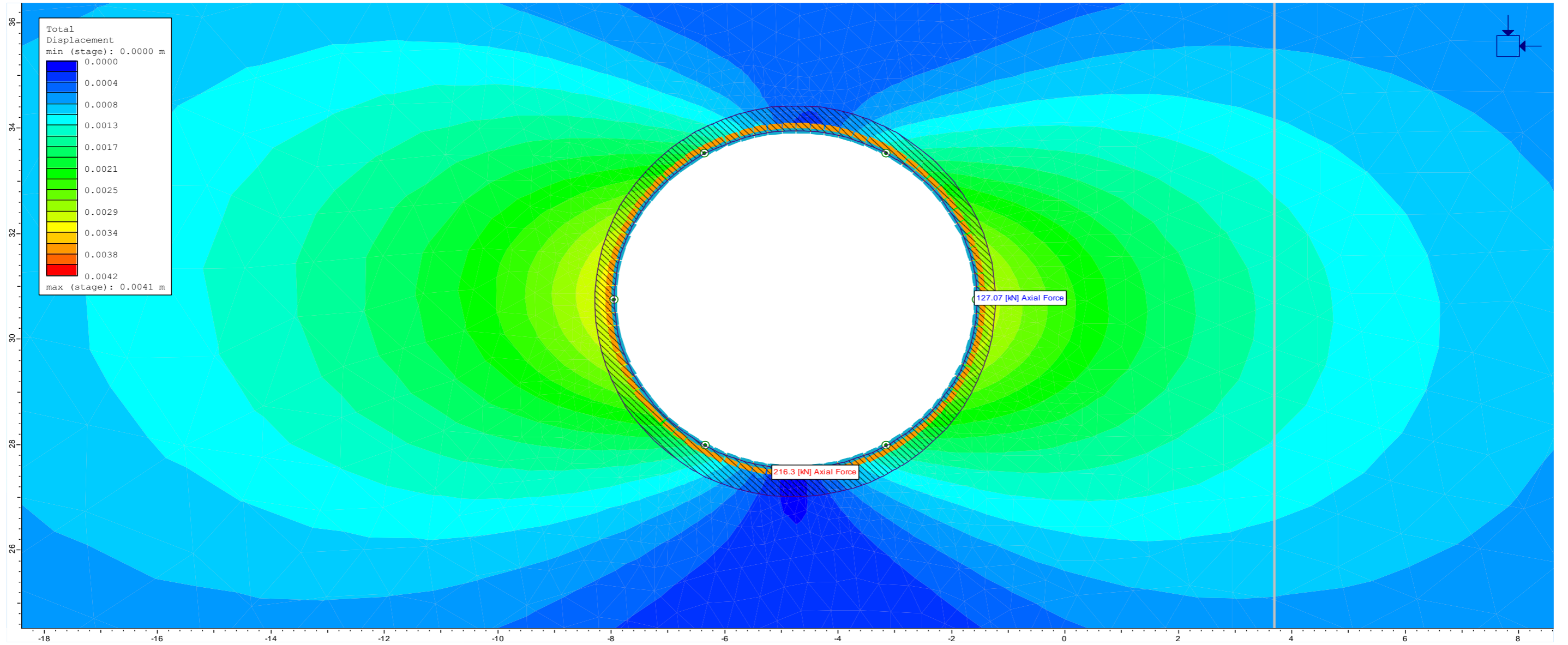
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Proposed Redevelopment
105 Miller Street, North Sydney

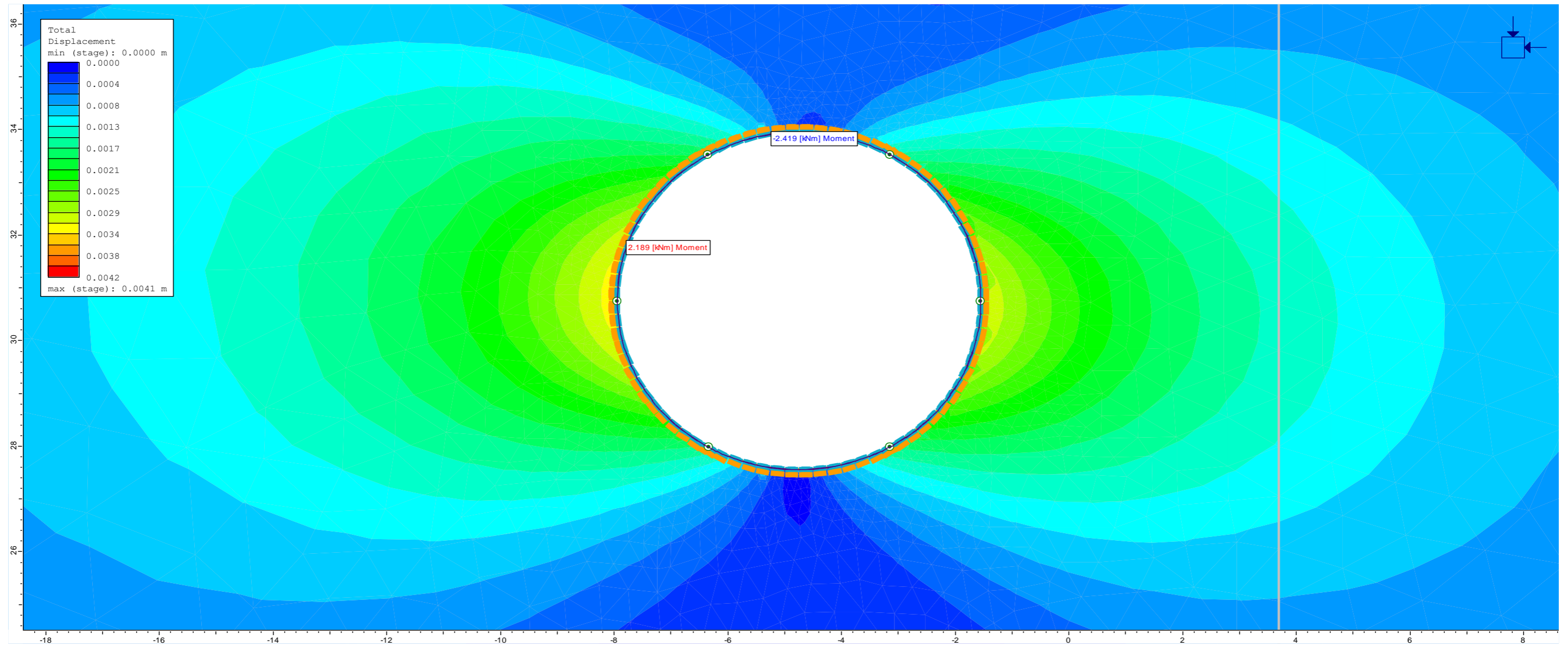
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Proposed Redevelopment
105 Miller Street, North Sydney

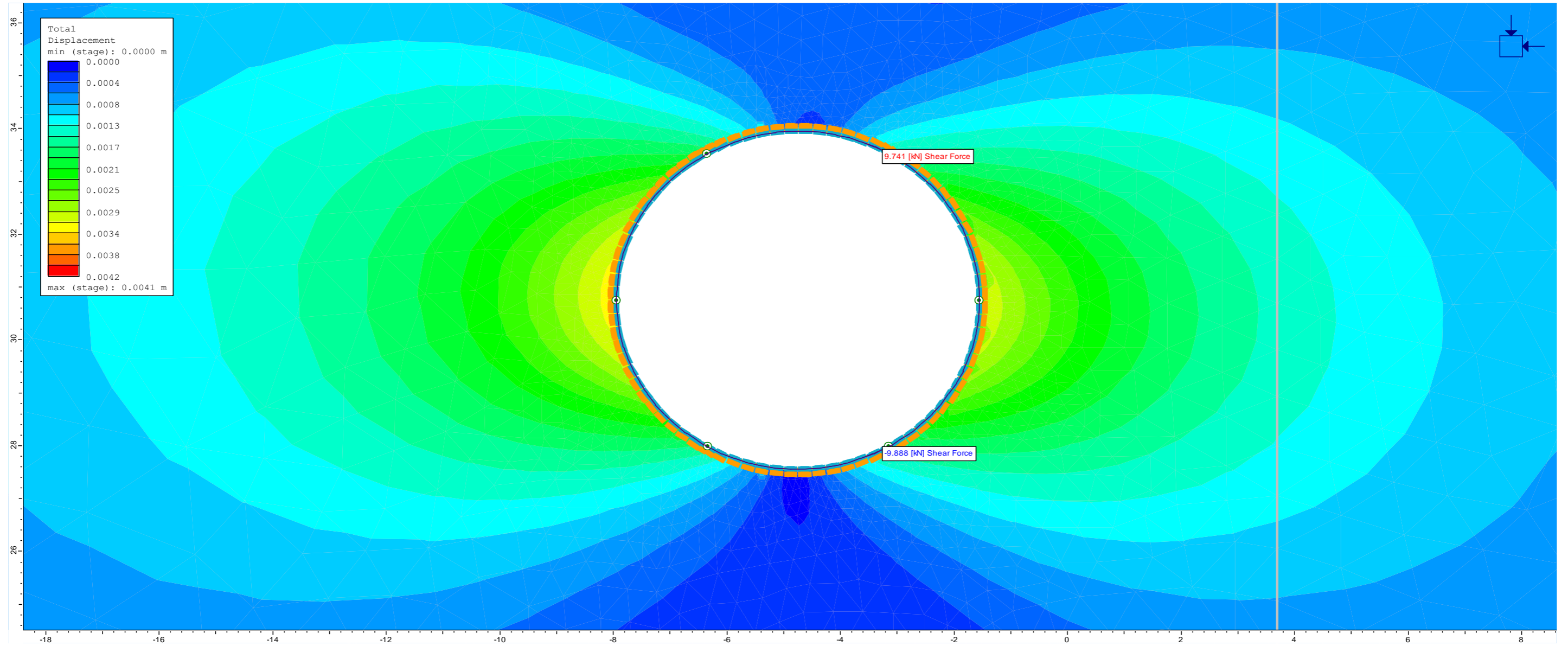
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Proposed Redevelopment
105 Miller Street, North Sydney

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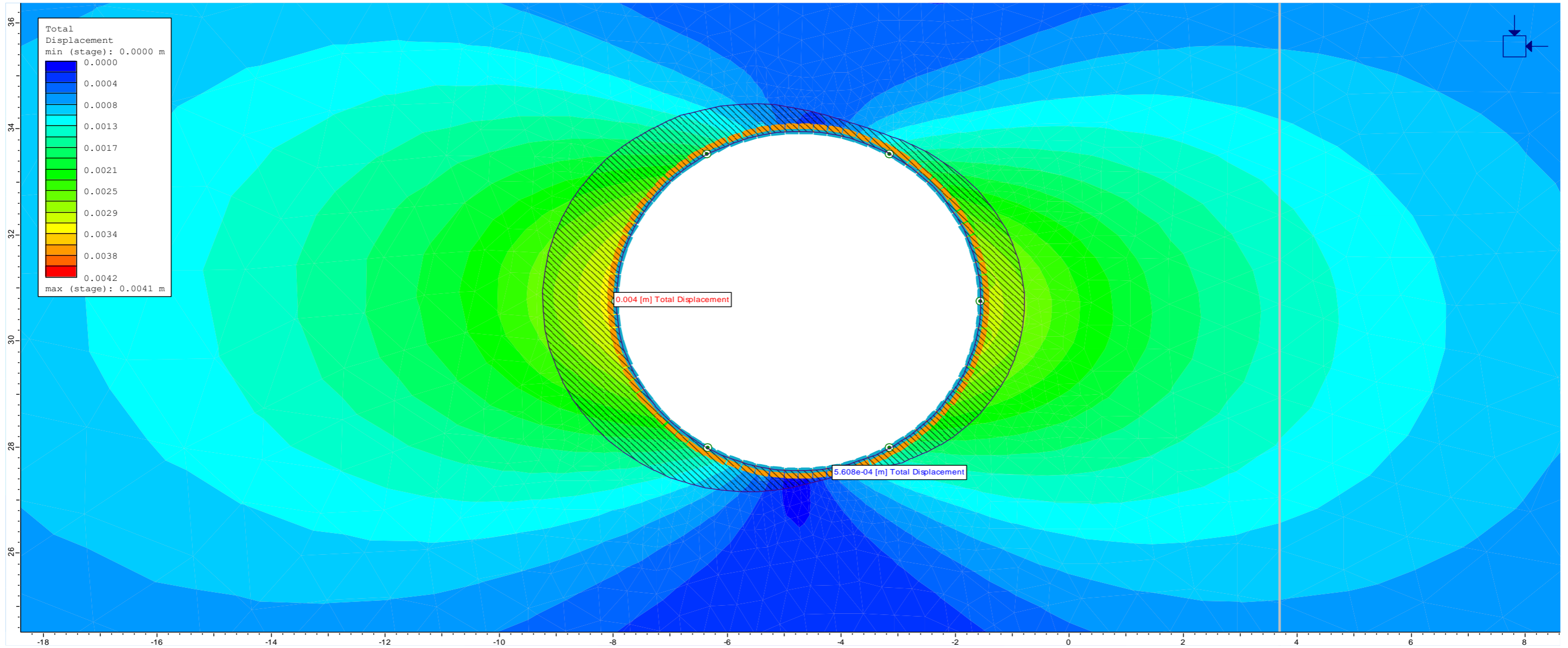


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Proposed Redevelopment
105 Miller Street, North Sydney

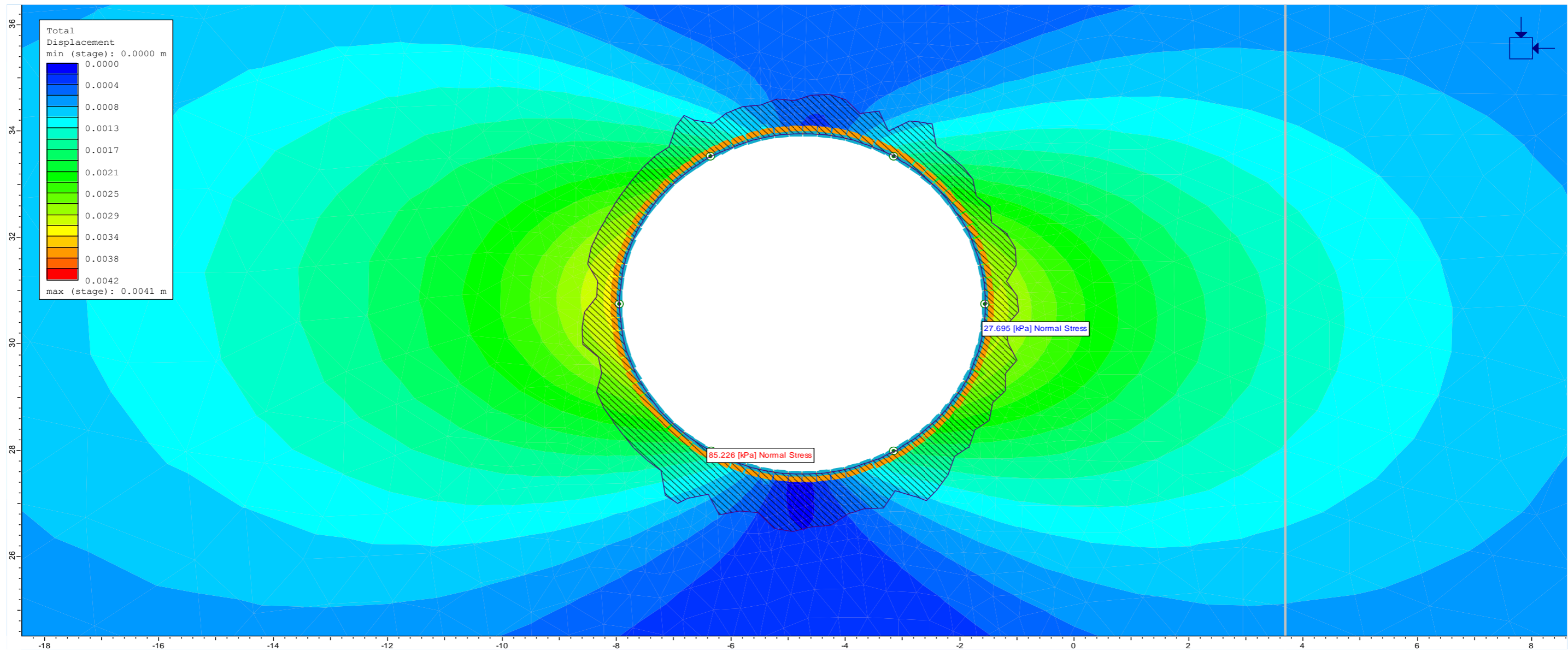
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105 Miller Street, North Sydney

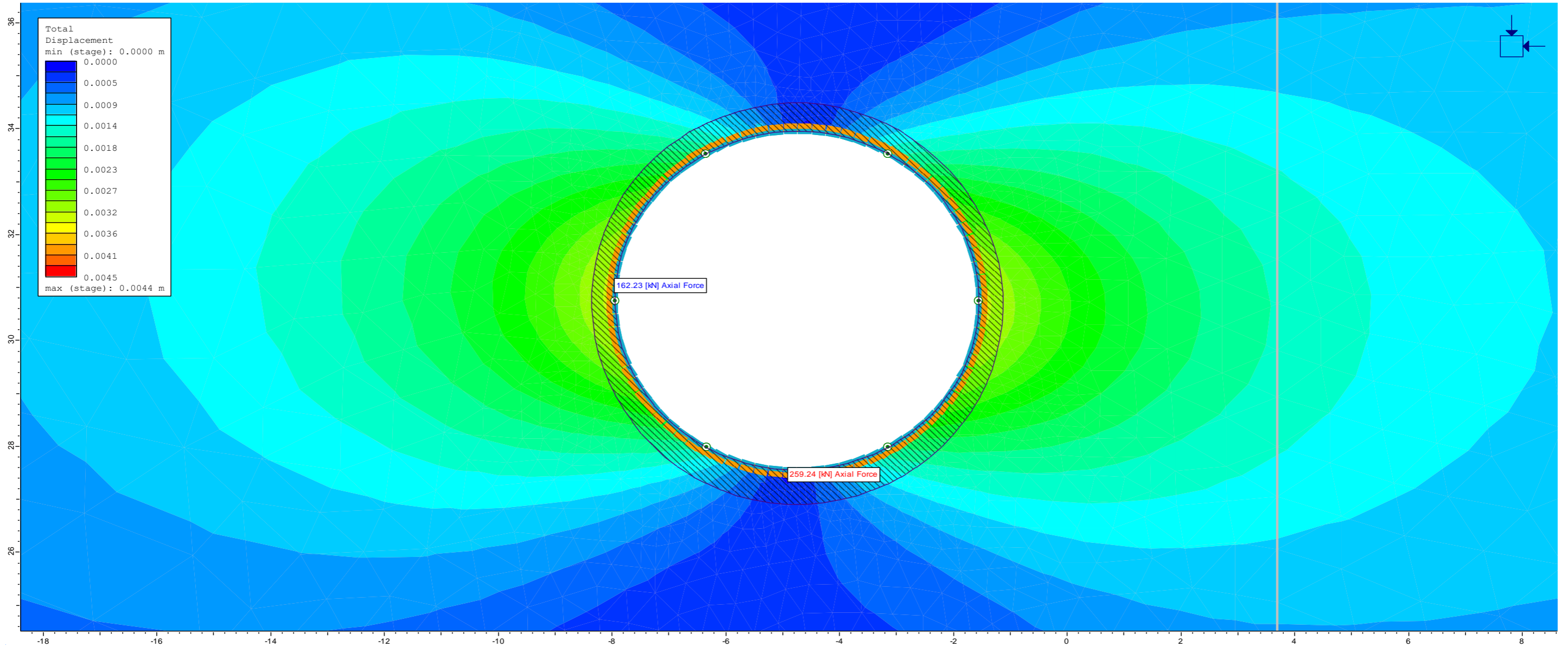
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Proposed Redevelopment
105 Miller Street, North Sydney

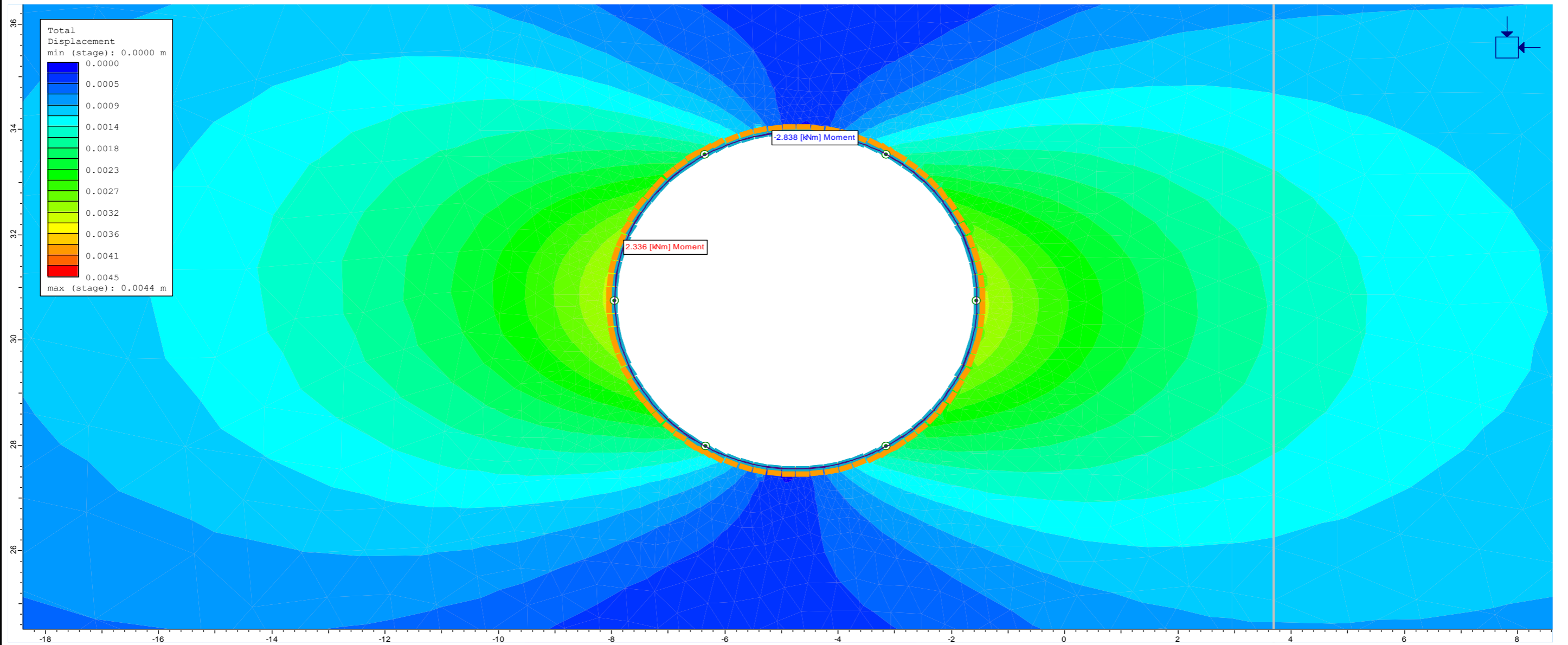
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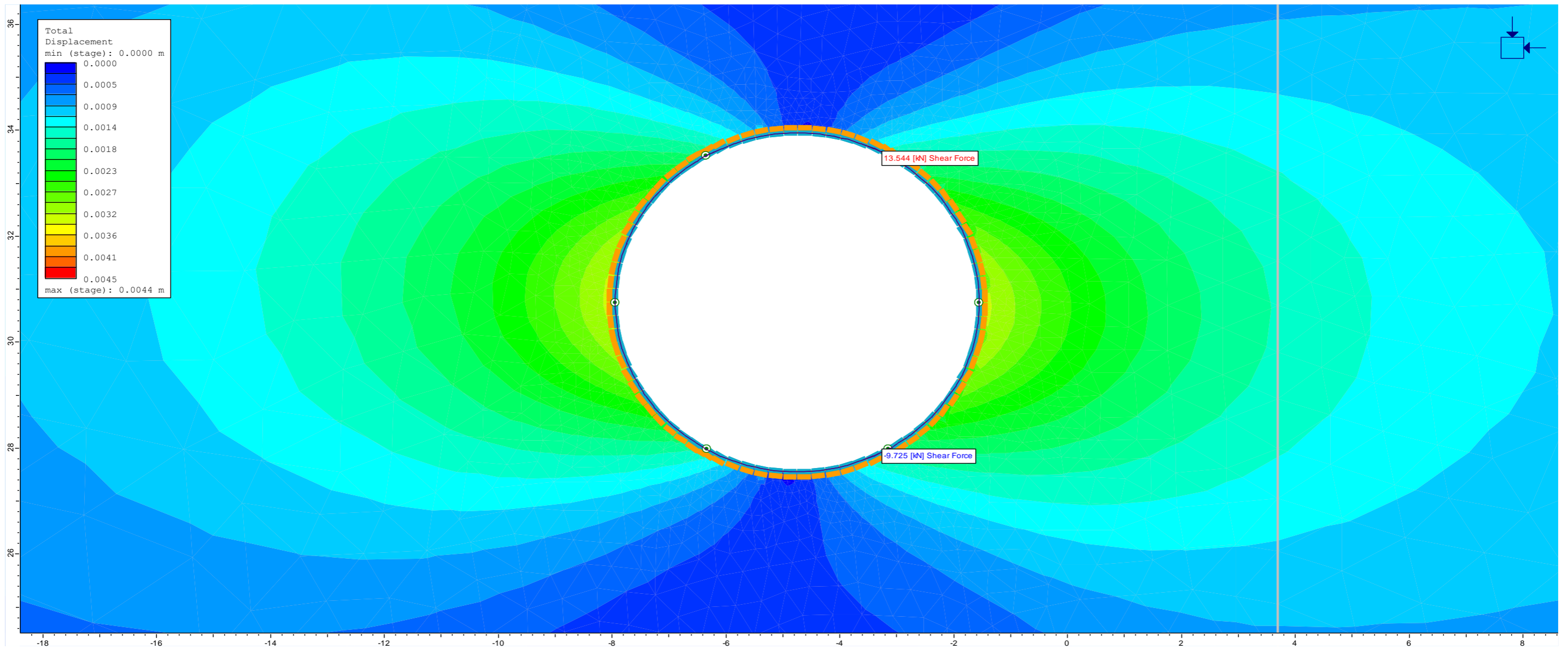
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Proposed Redevelopment
105 Miller Street, North Sydney

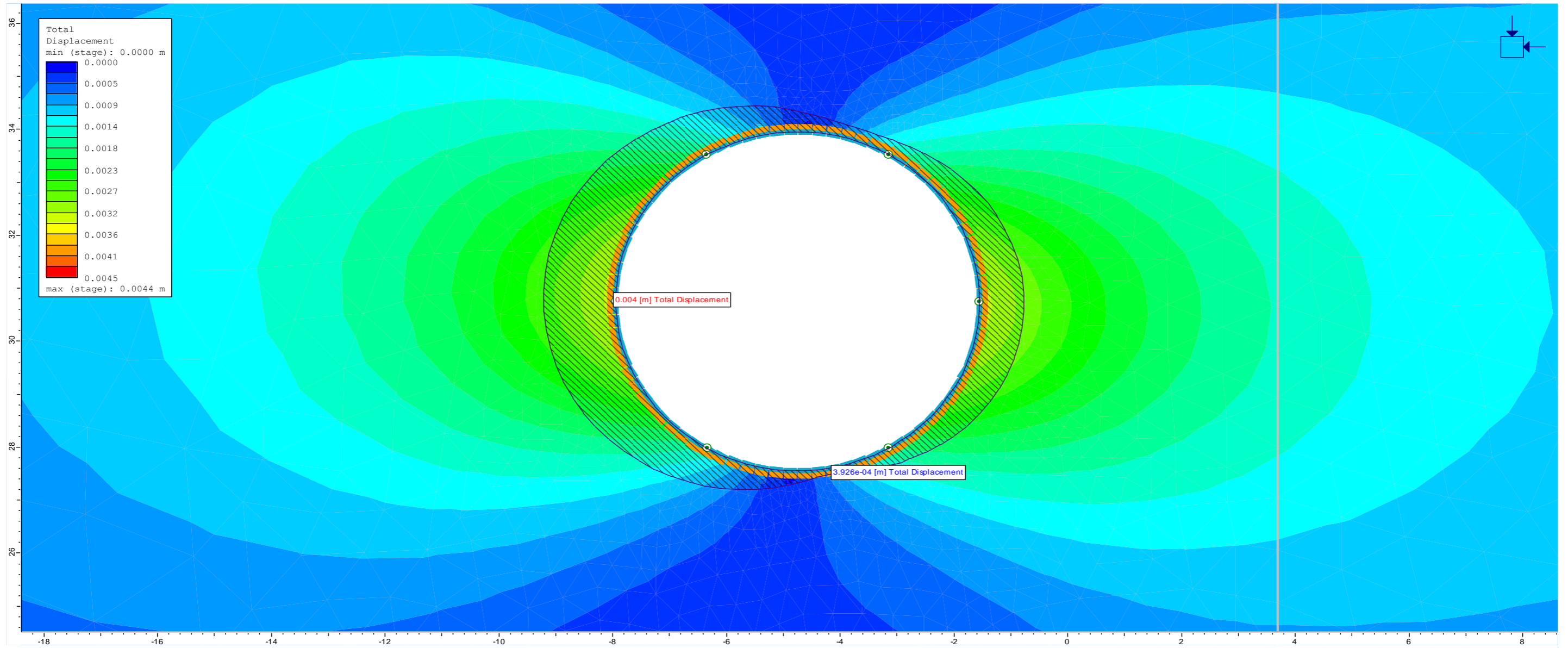
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Proposed Redevelopment
105 Miller Street, North Sydney

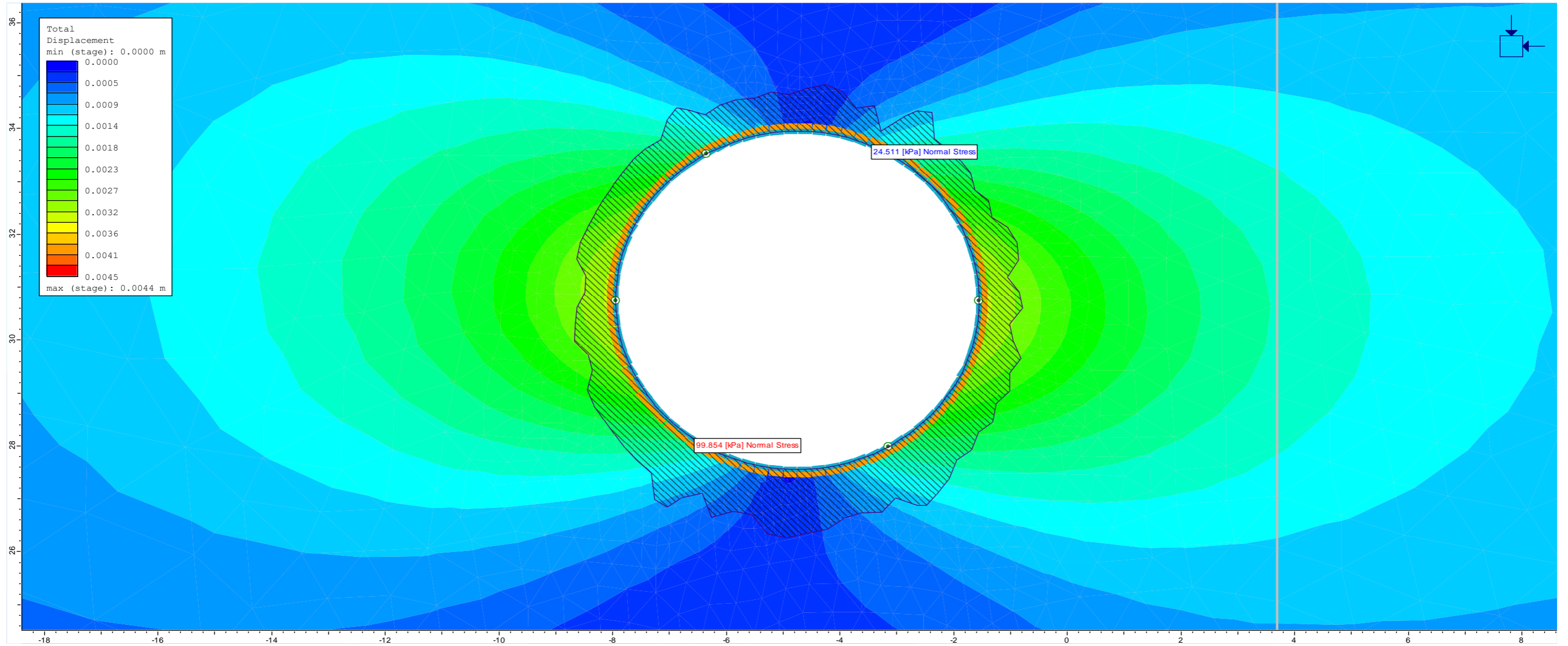
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Proposed Redevelopment
105 Miller Street, North Sydney

PROJECT No:	86964.03
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TITLE: **Post-Development - Tunnel Liner Interface Pressure - 90% Relief**
Proposed Redevelopment
105 Miller Street, North Sydney

PROJECT No:	86964.03
DRAWING No:	D20
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Attachment B
Sydney Metro related risk register

Rail Related Risk Register

Identification				Analysis including Current Controls		Risk Rating				Treatment	Residual Risk Rating			
Risk ID	Risk Name	Status	Risk Owner	Cause(s)	Effect / Consequence	C	L	Calc	Risk Rating	Planned or additional tasks required to further Reduce Risk	C	L	Calc	Residual Risk Rating
1	Excessive vibration during excavation causing damage to the tunnel	Open	Contractor	Size of rock breaking equipment and excavation methodology	Damage and/or disruption to Sydney Metro infrastructure	C4	L4	11	C	Undertake a detailed vibration impact assessment If required, use rock saw to minimise transference of vibrations through the ground Consideration of weight of rock hammer (reduce size if vibrations are excessive) Follow Geotechnical Instrumentation and Monitoring Plan, including provision of vibration monitors around the site and boundary	C4	L5	8	D
3	Ground displacement within the tunnel greater than predicted, adversely impacting on concrete segment waterproofing gaskets	Open	Owner's Engineer	Ground conditions differ from those assumed in geotechnical impact assessment	Damage and/or disruption to Sydney Metro infrastructure	C4	L4	11	C	Carry out sensitivity check during design on material parameters to assess potential impacts and ensure a robust design Supervision by a geotechnical engineer / engineering geologist during construction Follow Geotechnical Instrumentation and Monitoring Plan, including routine monitoring of inclinometers, retaining wall survey target, surface settlement points, etc Excavation to stop if a displacement in excess of the predicted value is encountered <u>Re-assess geotechnical model based on observed displacements</u>	C4	L5	8	D
4	Quality of construction	Open	Contractor	Poorly executed work and/or materials leads to collapse of the retaining wall resulting in stress changes in the ground	Damage and/or disruption to Sydney Metro infrastructure	C4	L5	8	D	Ensure contractor's quality system and construction methodology is adequate and applied on site. Carry out daily toolbox talks and adequate training and supervision of site personnel Monitor contractors work to check it is following design	C4	L6	2	D
5	Stray currents and electrolysis	Open	Owner's Engineer	Affect of stray currents not adequately considered in design	Reduced durability of reinforced concrete elements within the proposed building	C4	L4	11	C	Electrolysis to be considered in design and measures implemented, if required, to prevent stray currents from impacting on RC elements	C4	L6	5	D
6	Severe collapse of excavation	Open	Owner's Engineer	Adverse and unforeseen geological conditions leading to collapse of the retaining wall and changes in stress in the ground	Damage and disruption to rail infrastructure	C5	L4	7	D	Supervision by a geotechnical engineer / engineering geologist during excavation Adequate design of rock support including rock bolts Geotechnical investigation and carry out Impact Assessment Report Follow Geotechnical Instrumentation and Monitoring Plan, including routine monitoring of inclinometers, retaining wall survey target, surface settlement points, etc Excavation to stop if a displacement in excess of the predicted value is encountered <u>Re-assess geotechnical model based on observed displacements</u>	C5	L6	2	D
7	Temporary over excavation within easements adjacent to Victoria Cross clashing the ground anchors	Open	Owner's Engineer	Over excavation for new footing's	the ground anchors may be damaged and retaining structure lose lateral support and collapse	C5	L4	7	D	Excavation in easement should be closely monitored with foundation levels being checked as the excavation advances Locate the ground anchors if possible and mark their locations on the surface or on the retaining wall	C5	L6	2	D

Risk tolerance and responses

Risk rating	Risk description	Response
A	Very high - generally intolerable	Very high risks are generally intolerable and should be avoided except in extraordinary circumstances. A very high risk would not be acceptable when related to the operation or maintenance of a new or altered asset as the activity would not be permitted. An alternative solution shall be found and all necessary steps shall be taken to reduce the risk below this level.
B	High – undesirable	High risks are undesirable. It is highly unlikely that an undesirable risk would be accepted when related to the operation or maintenance of a new or altered asset. They can only be tolerated if it is not reasonably practicable to reduce the risk further, that is that SFAIRP is demonstrated and the risk is agreed as acceptable to TfNSW. High risks are considered to be on the verge of being unacceptable and all credible options to reduce or eliminate the risk shall be explicitly considered.
C	Medium – tolerable	Medium risks are tolerable if it is not reasonably practicable to reduce the risk further. It is essential that where a risk has health, safety or environmental consequences the activity should be reviewed to determine if the risk can be reduced further and whether all reasonable and practicable controls have been considered or applied, or both and a demonstration of SFAIRP is provided. Additional treatment measures should be sought if significant benefit can be demonstrated and/or there is an additional treatment measure which is recognised as good practice in other like environments.
D	Low – broadly acceptable	Low risks are considered to be broadly acceptable. Where the risk has health, safety or environmental consequences control measures should be effective, reliable and subject to appropriate monitoring. If options for further risk reduction exist and costs are proportionate to the benefits, then implementation of such measures should be considered. The risk and its treatments should be subject to appropriate degrees and forms of monitoring to ensure that it remains at this level.

Risk Rating: A - Very High B - High C - Medium D - Low		CONSEQUENCE					
		Insignificant C6	Minor C5	Moderate C4	Major C3	Severe C2	Catastrophic C1
LIKELIHOOD	Almost certain L1	20	22	29	32	34	36
	Very likely L2	14	18	23	28	31	35
	Likely L3	9	12	16	24	27	33
	Unlikely L4	6	7	11	17	25	30
	Very unlikely L5	3	4	8	13	19	26
	Almost impossible L6	1	2	5	10	15	21