Please note the contents of these documents contain detailed descriptions and diagrams of Grenfell Tower. This could be upsetting for some.

This version of the document has therefore been created with any photographs of fire damage or the interior of the Tower removed to minimise the amount of potentially upsetting or distressing information within it. A copy of the original documents with photographs can be provided on request.

Please take care when reading or circulating these documents.

The Grenfell Health & Wellbeing Service is a free and confidential local NHS service for children and adults affected by Grenfell. To talk to someone, you can get in touch by phone on 020 8637 6279 or by e-mail Grenfell.wellbeingservice@nhs.net.

This document and its contents have been prepared for the Ministry of Housing, Communities, and Local Government. For further information, please contact GrenfellTowerSite@communities.gov.uk

Technical Note

Project:	Grenfell Tower Site Programme
Subject:	Propping risk mitigation study – Part 1: Stage 3 propping from Level 4 upwards
Author:	[redacted]
Date:	03/07/2020
Project No.:	5186875
Note Ref:	5186876-ATK-XX-XX-RP-SE-000004

Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 0.1	Draft issue to MHCLG for discussion	[redacted]				30 Jun 2020
Rev 1.0	Issue	[redacted]				03 Jul 2020
Rev 1.1	Not issued; reference number corrected.	[redacted]				17 Jul 2020
Rev 1.2	Issue with updated reference number	[redacted]				05 Jun 2020

Executive Summary

This Technical Note considers the impact of installing the bulk of the propping system from the suspended slab at Level 4 as opposed to propping from basement (foundation) level.

The purpose of this investigation is to inform the decision-making process as to whether detailed analysis and design work is merited to develop this solution, i.e. this study can be considered as a proof-of-concept only.

The analysis indicates that the less damaged slabs are capable of resisting the applied loads to allow the propping to start at Level 4. The analysis has also highlighted the complex load sharing behaviour between props and slabs over the height of the structure.

Given the age of the structure combined with the structural fire damage, there is a level of uncertainty and risk associated with maintaining the structure in the propped condition. If the intention were to delay the deconstruction of the building, a more robust load path and propping design should be adopted to reflect this uncertainty. Such measures could include sizing the props to provide an increased level of redundancy and extending the props to basement level to avoid relying on the suspended slabs for support.

Given the complexity of observed structural behaviour, and the installation process, it is likely that the detailed design of the modified propping system and detailed validation of the slab resistances would involve a significant amount of work, and associated time, in order to complete. As such, propping to the basement may still represent the quickest, and least risk approach, to providing the next stage of temporary works.

Deconstruction of the building at the earliest possible opportunity is the means to mitigate against the above noted risks irrespective of propping arrangement.

The installation of the new propping system and removal of the old propping arrangement is not considered in this work and would need to be addressed by the Temporary Works Designer to demonstrate the viability of any proposal to replace the existing propping arrangement.

Loading and load redistribution due to deconstruction has not been addressed in this work and would need to be considered by the Deconstruction Contractor as part of designing such works.

1. Introduction

This Technical Note reports on the analysis work carried out for the Ministry of Housing, Communities & Local Government (MHCLG) as a risk mitigation study in relation to the propping within the Grenfell Tower.

The Atkins Final Design Validation (FDV), report ref 5186876-ATK-XX-XX-RP-0003, was based on the assumption that the next stage in the propping works – referred to as Stage 3 – would be installed from basement level to the underside of the roof.

Since the submission of the report the question has been raised that in order to address programme issues, what would be the impact if the propping started at Level 4.

This Note considers the placement of the Stage 3 propping system, as set-out in the FDV, but with the bulk of the props starting at Level 4. The purpose of this investigation is to inform the decision-making process as to where detailed analysis and design work is merited, i.e. this study can be considered as a proof of concept only.

2. Basis of design

The design criteria set out in Atkins report ref. 5186876-ATK-XX-XX-RP-0003 *Grenfell Tower Final Design Validation* is adopted for this work with only variations being addressed in this Note.

2.1. Purpose of the analysis

With the bulk of the props starting at Level 4, the purpose of the analysis is to investigate the load share between primary structure and propping system where the sole variable is the magnitude of dead load that the props are required to support.

As reported in the FDV, it is expected that the propping system is required to carry a proportion of the dead load due to the levels of structural damage to a number of slabs.

The analysis carried out is used to examine both the loading in the propping system and the stresses in the primary structural slabs.

2.2. Methodology

The whole building model from the FDV is used for the purposes of this work but with all propping below Level 4, bar that around columns C10 and C11, having been removed; this is shown in Figure 1.

In order to investigate the load share between the primary structure alone, and the primary structure with propping, a staged construction process is adopted. This is used in conjunction with different levels of dead load being assumed to be shared between each construction stage in order to assess the stress level in the slabs and axial force in the props

2.3. Loading (vertical)

Other than the self-weight of the concrete structure, the only loading considered is as follows:

Superimposed dead load

- 50mm screed @ 24kN/m^3

Live load

The live load arrangement is consistent with that used in the FDV and is based on the Temporary Works Design:

- 1.5kPa applied to the top six floor slabs only
- 0.6kPa applied to all other floor slabs

2.4. Prop types

The prop stiffnesses in the analysis are based on Ischebeck Titan props in accordance with the information supplied during the FDV.

2.5. Assumptions

The following assumptions have been made in carrying out this work:

- All debris on the floor slabs are to be removed prior to changes to the propping system.
- The propping by columns C10 and C11, from basement level to roof, will remain in place until deconstruction of the building.
- The sequencing of prop removal and replacement is not considered in this work but would be required as part of the temporary works design.
- Membrane action is not considered in the steps outlined.
- Where the propping is assumed to support a percentage of the dead load, it is assumed that the propping is prestressed (or similar) in order to relieve the stresses in the slabs.
- The choice of prop types, and associated changes in prop stiffness, has not been investigated as part of this work.

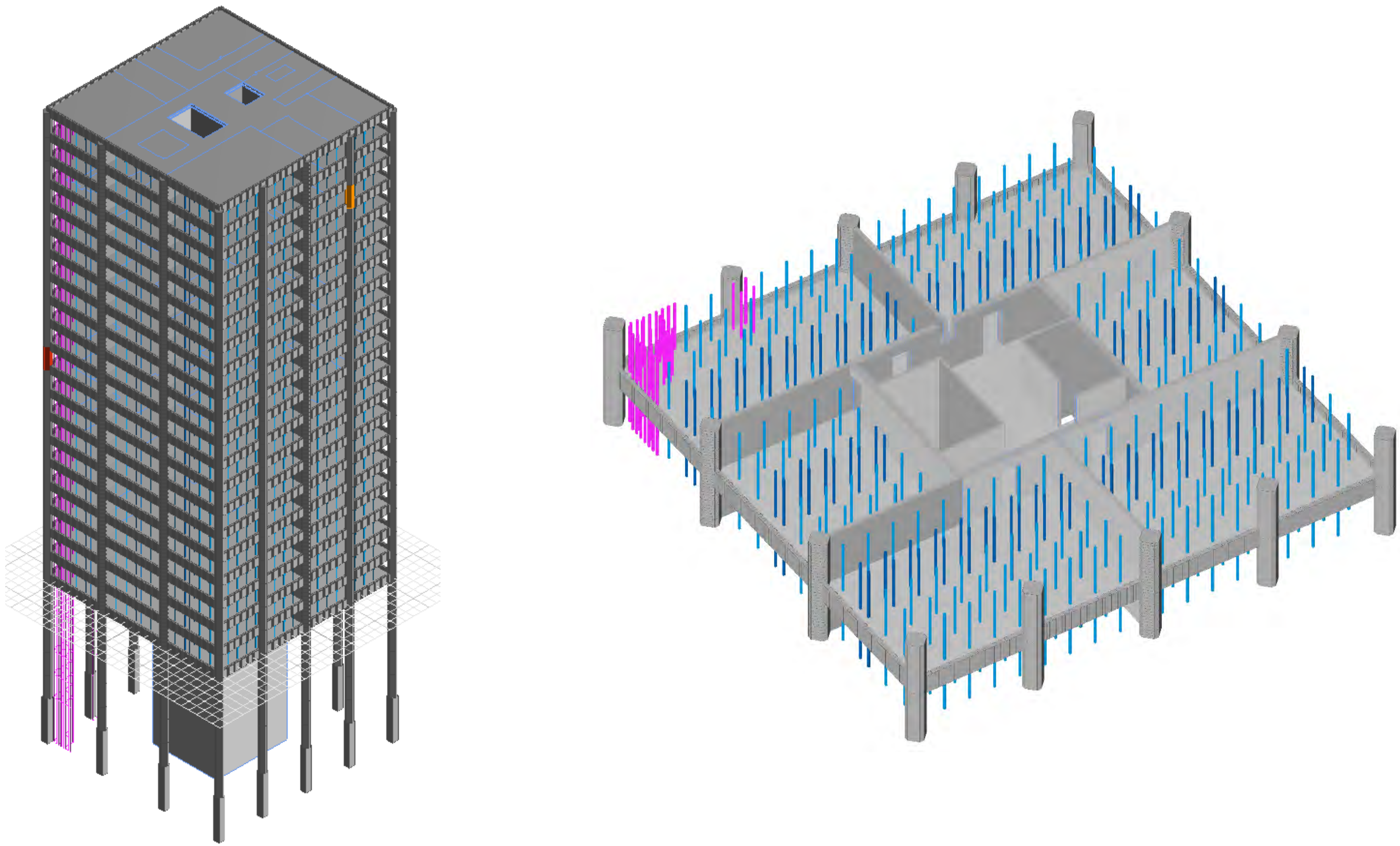

Figure 1 – Whole building model and typical floor showing prop layout

3. Results and interpretation

In investigating the levels of dead load carried by the primary structure and propping, the dead load has been considered in increments of 25% giving load cases for each construction stage as listed in Table 1.

Table 1 - Load cases

Construction stage	Load type	Load case 1	Load case 2	Load case 3
1 (no propping)	Dead	75%	50%	25%
2 (props installed)	Dead	25%	50%	75%
2 (props installed)	Live	100%	100%	100%

3.1. Slab stresses

A visual inspection of the slab stresses at each floor indicate that approximately 50% of the dead load (~3.1kPa) would need to be carried by the propping system to allow the residual being carried by a damaged slab. Whilst there are areas of the floor that would still require additional propping due to the amount of spalling that has occurred, this is not thought likely to be an issue with respect to prop design.

However, the complexity in achieving the sharing of load between the props and the residual structural resistance of a slab is the need to actively support the slab. To mobilise this load path, the current stress in the slabs is relieved and in part transmitted to the props, the props would have to be actively stressed; in effect the load is jacked out of the slabs and transferred in part to the propping system.

The stresses observed in the slabs are also a function of the prop stiffness. Whilst a single prop stiffness has been used in this work, a more detailed investigation of the relationship between prop stiffness and load transfer would be required in the detailed design stage of the propping system.

3.2. Prop loads

For the purposes of discussion, the propping between Level 4 and roof on one vertical slice for Load Case 2 is shown in Figure 2 and is indicative of the behaviour observed. The axial force profile for all props for this load case is provided in Appendix A for reference.

Prop loads

None of the load cases examined indicate that the axial load in the props are beyond that which can be resisted by proprietary propping systems and can could clearly be designed for if structural steelwork sections were used.

Load share between props and slabs

The coloured blocks represent the levels of force in the props; the width of a coloured block also indicates the magnitude of the load at a particular point.

The output illustrates the complicated nature of the load sharing behaviour. If a given vertical line of props were acting similar to a column, the contour would take the form of a stepped pyramid with the load increasing from level-to-level until the base of the prop stack is reached.

What the output shows is an irregular distribution of load in a given vertical line of props with the load being shed into stiffer floors then increasing where the floors have suffered more damage; this is clearly shown in the left half of the output between Level 13 and Level 20.

The issue that this distribution highlights is the complexity of the load path and this is thought likely to pose a significant challenge to a Temporary Works Designer when the three-dimensional behaviour of the structure is considered.

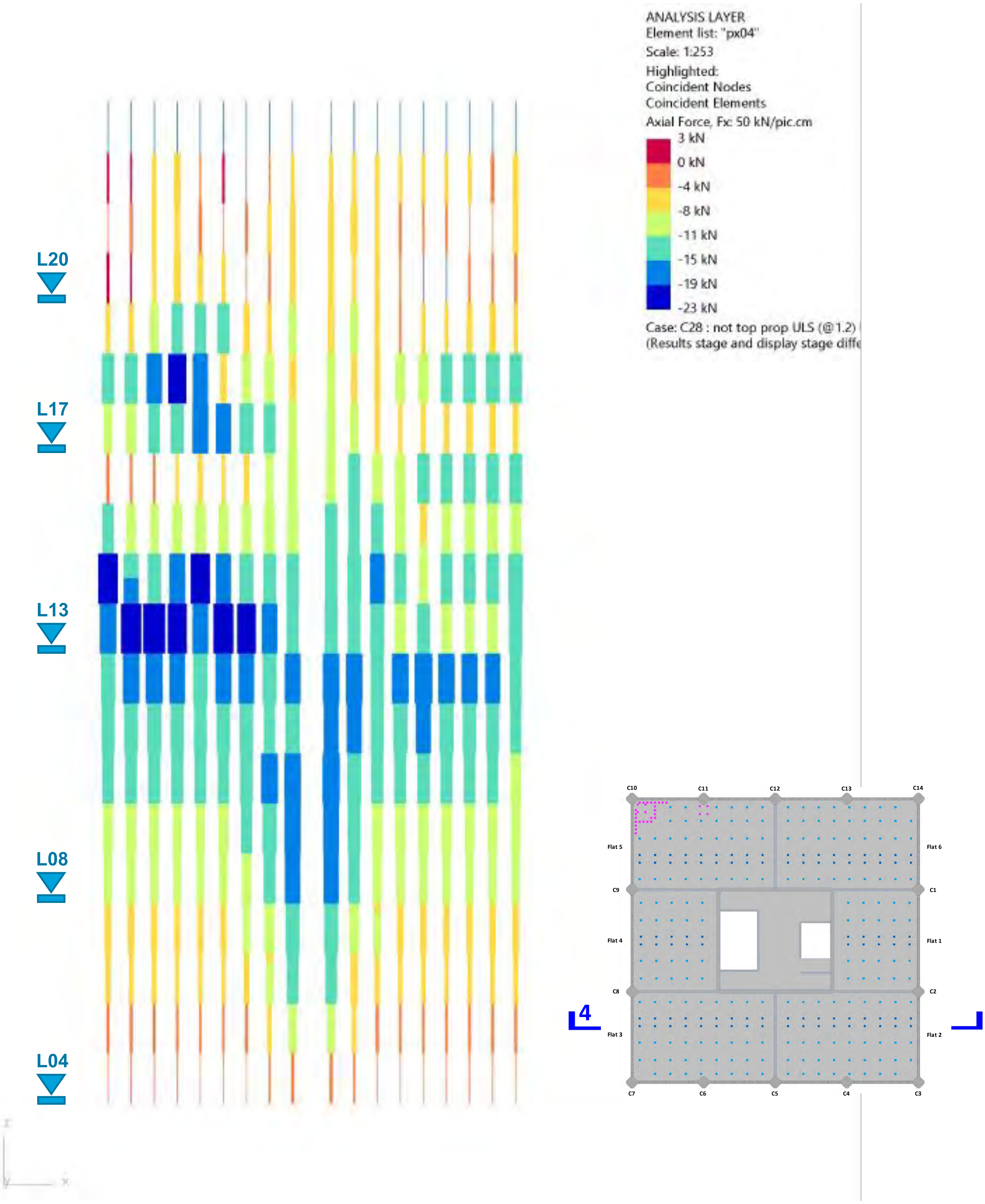

Figure 2 - Axial forces in props from Level 4 to Level 24.

4. Long-term resilience

Associated with the decision on whether to start the propping from Level 4 are issues associated with design life and the risks associated with long-term propping of the structure.

Completed in 1972 the structure is approximately 46 years old. Whilst the design life is not known, the building is likely in the latter part of its design life, if not already past.

The age of the structure combined with the structural damage due to the fire has a detrimental effect on the long-term resilience of the structure. Putting this in terms of risk, the longer the structure is left in-place, risk of the structures condition deteriorating to an unacceptable level, and also risks to the site operatives having to go inside the structure, increase.

Whilst deconstruction of the building at the earliest possible opportunity is the means to mitigate against the above noted risks, a date is yet to be confirmed for any such work. As such the propping system must provide a robust support system.

Whilst this Note has considered the propping starting at Level 4, this is seen as appropriate for the short-term. If the propping were to be left in place for an extended duration, in order to provide adequate redundancy within the propping system to address the ongoing risk of supporting a badly damaged structure, extending the propping to the basement would reduce the uncertainties of propping from suspended slabs.

5. Conclusions

As a proof-of-concept the analysis carried out indicates that there is adequate resistance in the less damaged slabs to allow the load sharing from the propping system to the primary structure. However, the analysis has also highlighted the complexity of this load sharing behaviour.

Should the concept of starting the Stage 3 propping be developed further, a parametric study would be required in order to understand the relationship between prop stiffness and load transfer between slabs.

Given the complexity of the structural behaviour, it is thought likely that the design of the propping and detailed validation of the slab resistances would involve a significant amount of work. Combined with this is the uncertainty on when deconstruction of the building will actually begin. As such propping to the basement still represents the least risk approach to providing the next stage of temporary works.

Appendices

Appendix A. Axial force in props

A.1. Introduction

The axial load profile for all props for Load Case 2 is given in this Appendix. Each vertical slice is given a section number as shown in Figure and is related to the section number shown in the Legend of each page as highlighted in Figure 4.

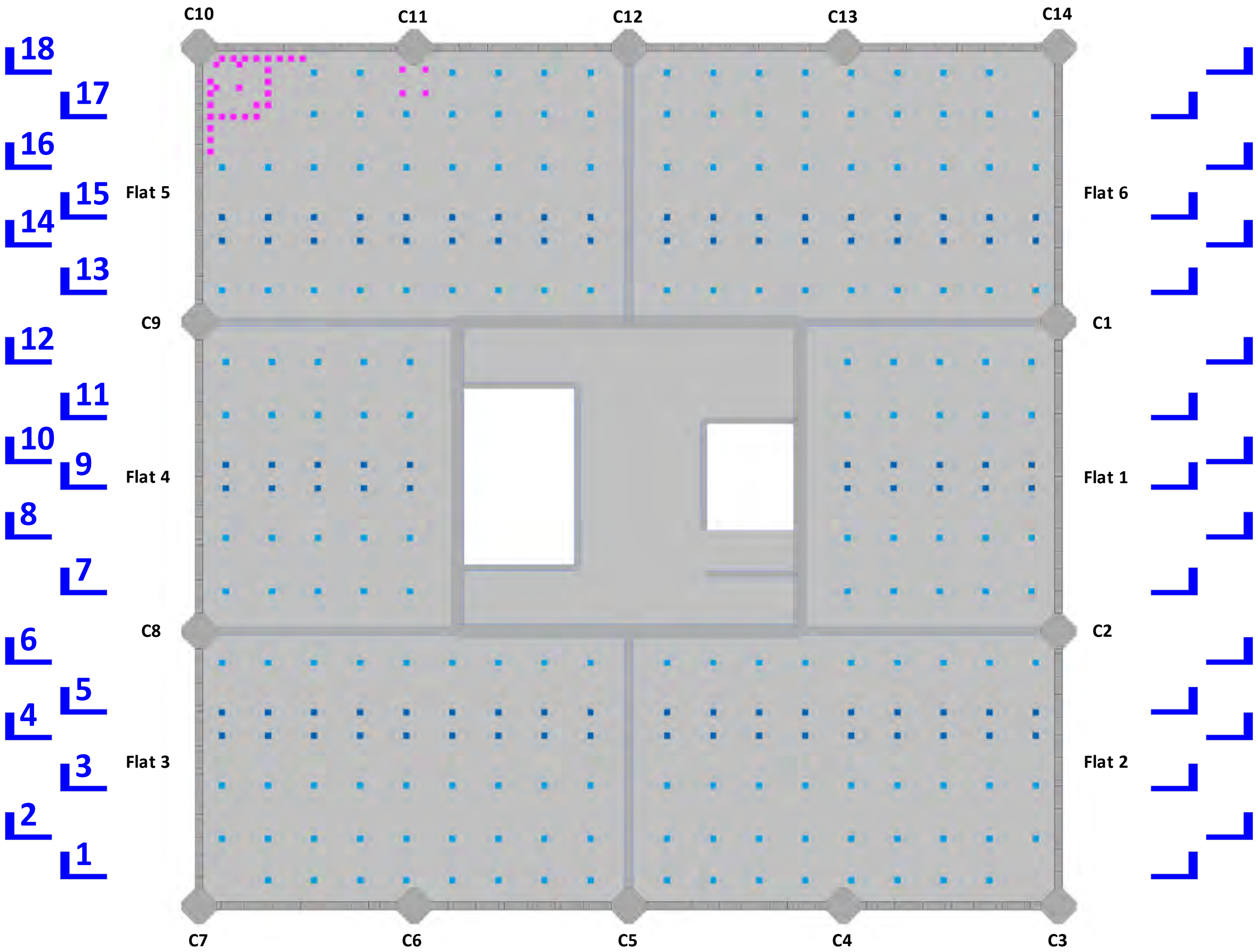

Figure 3 - Key plan for sections

Figure 4 - Section identifier

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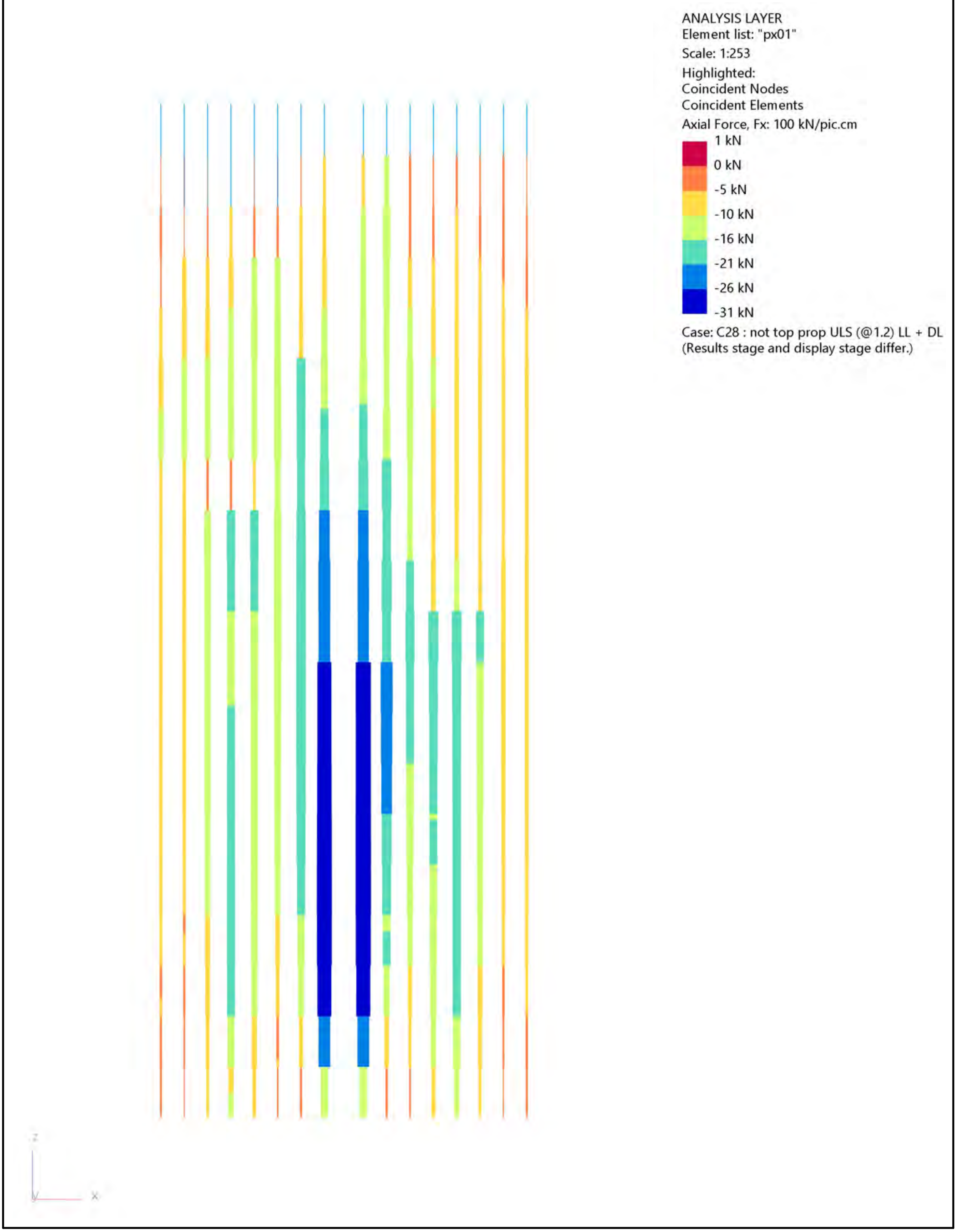

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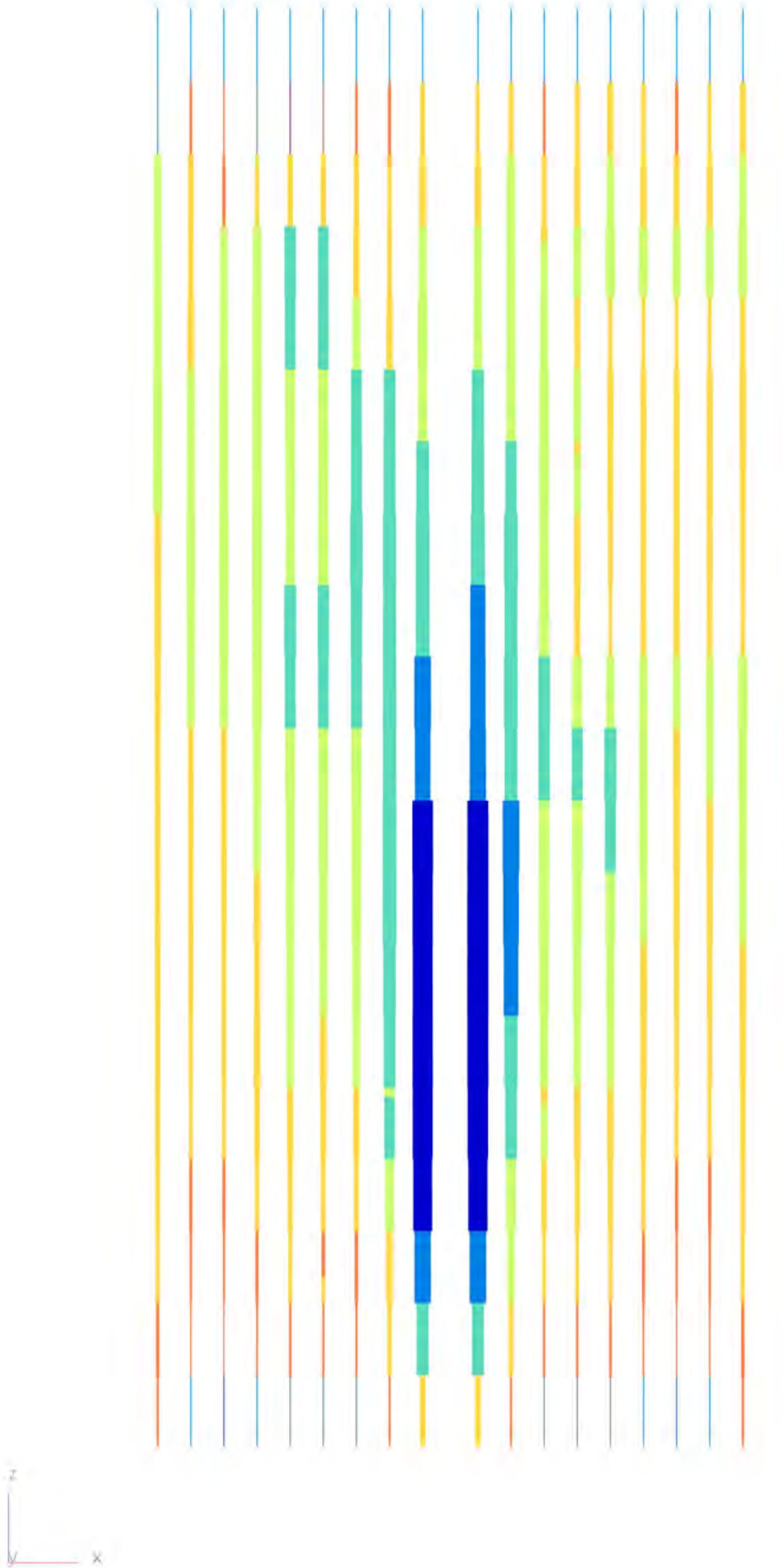
(Results stage and display stage differ.)



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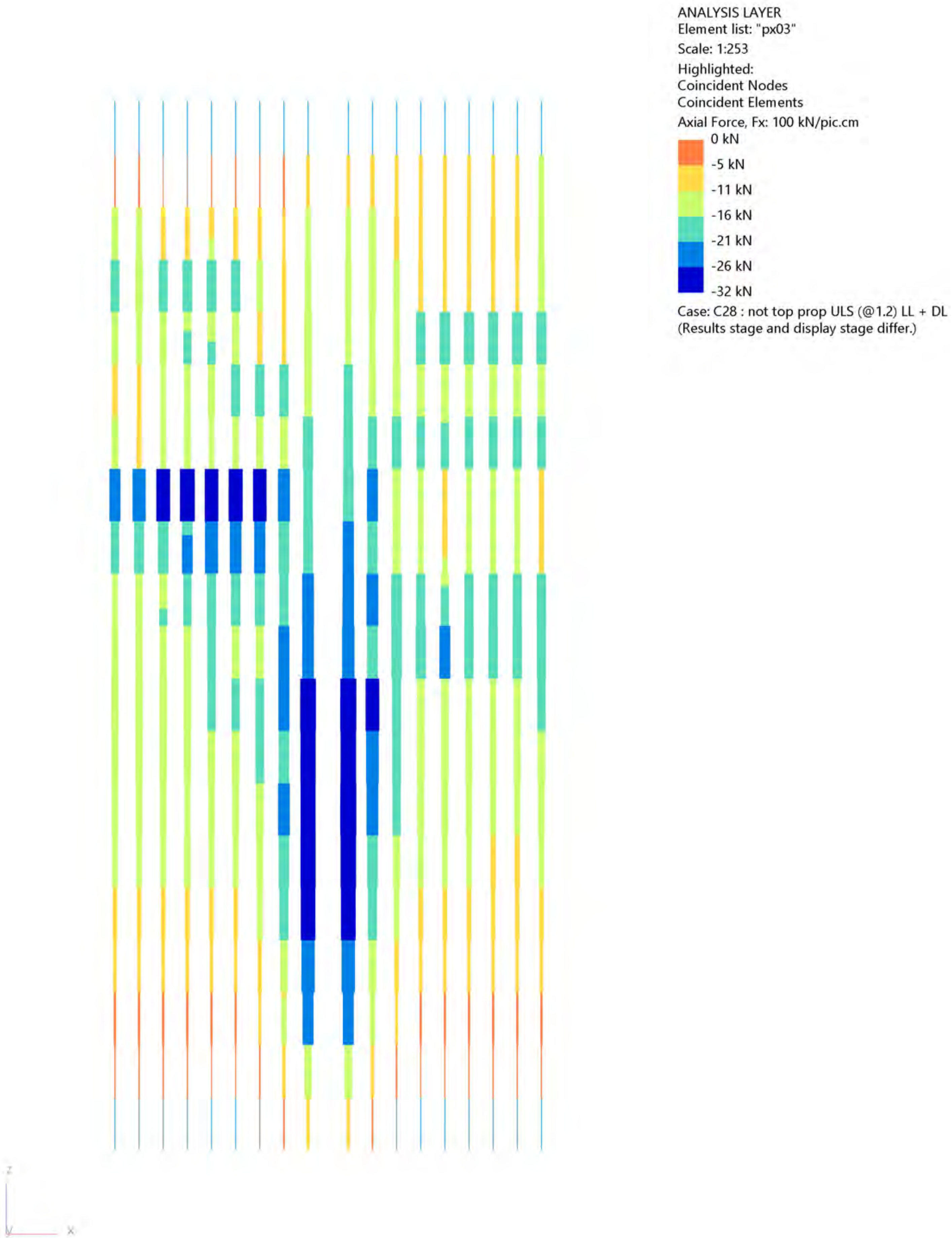

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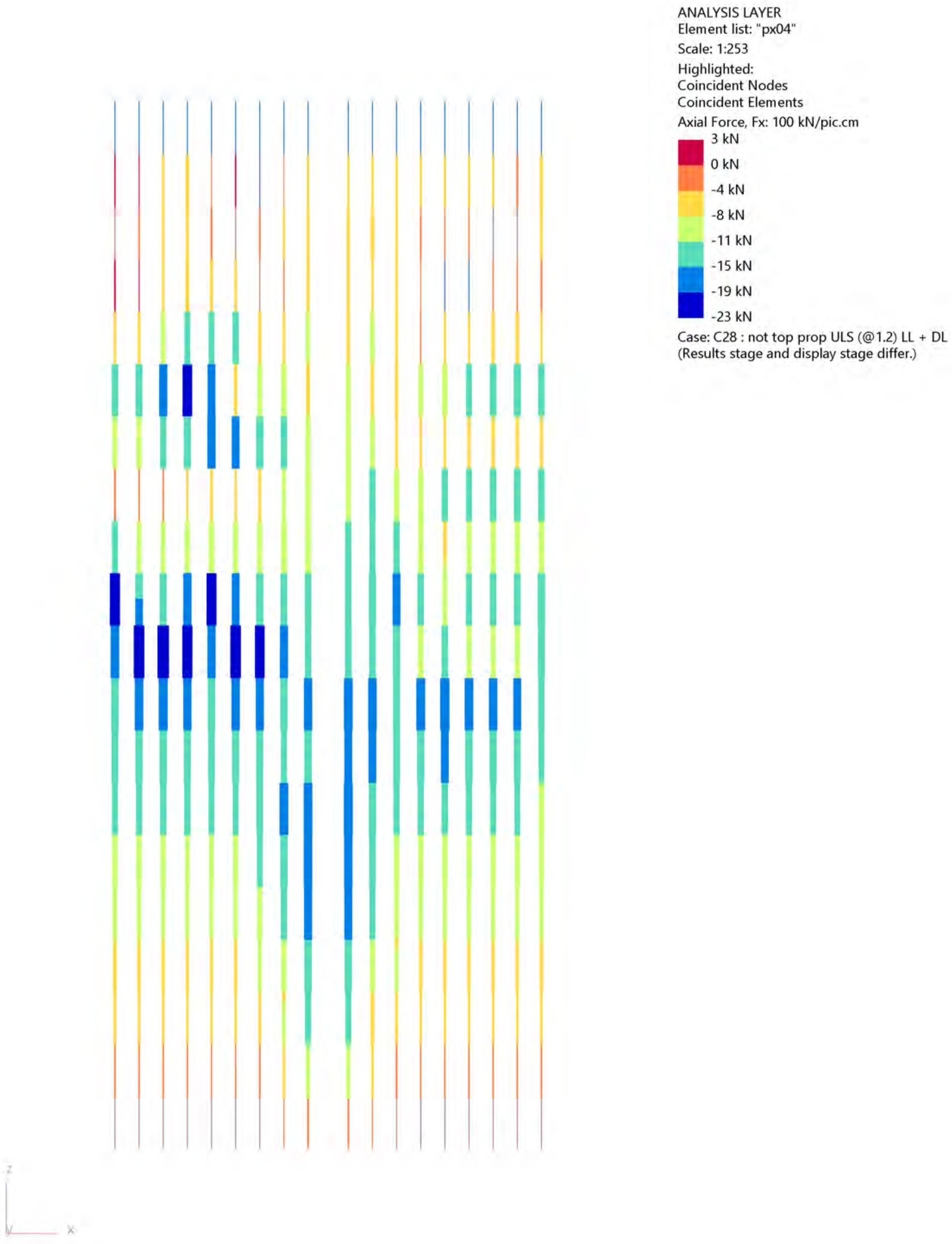

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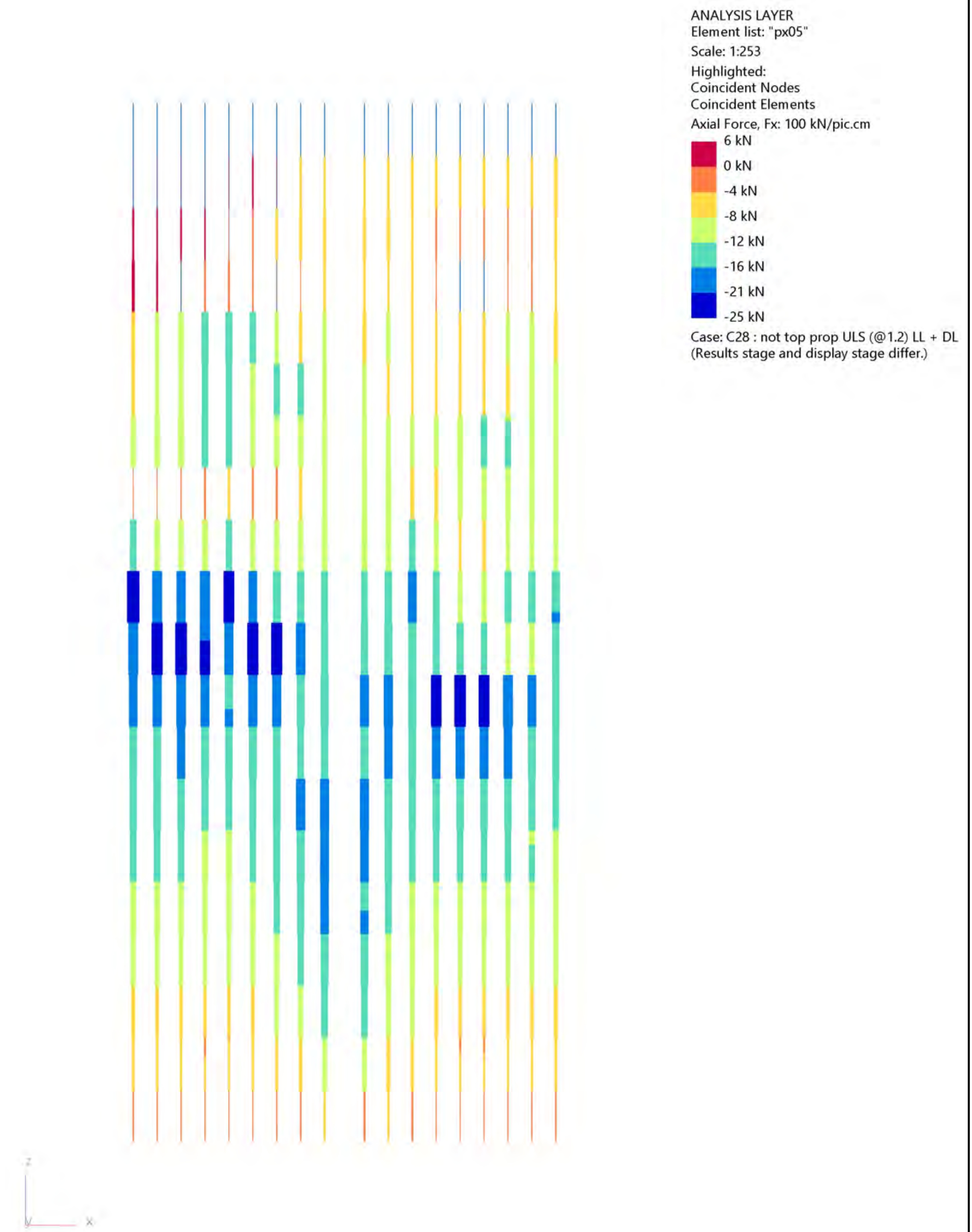

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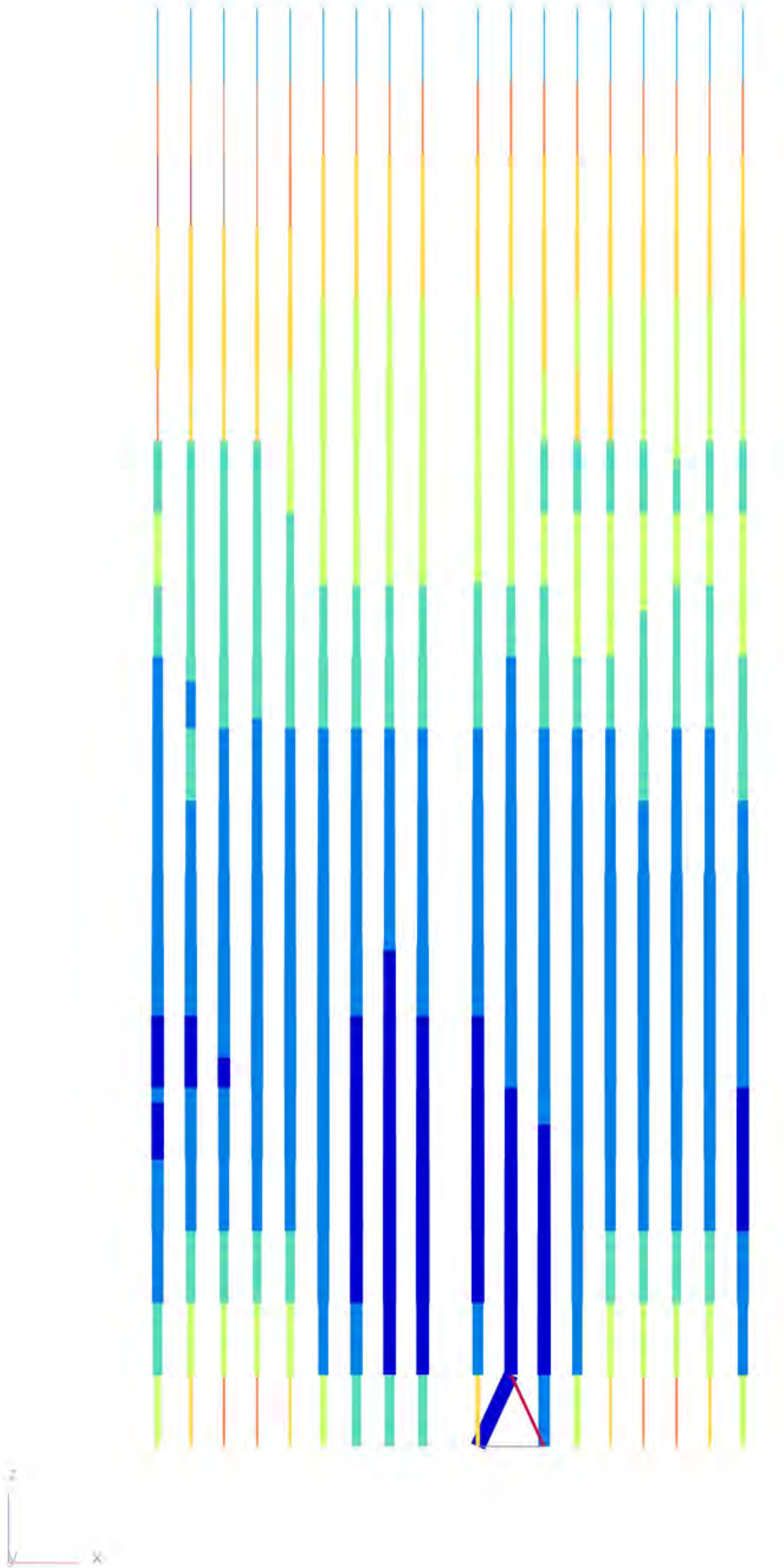
(Results stage and display stage differ.)



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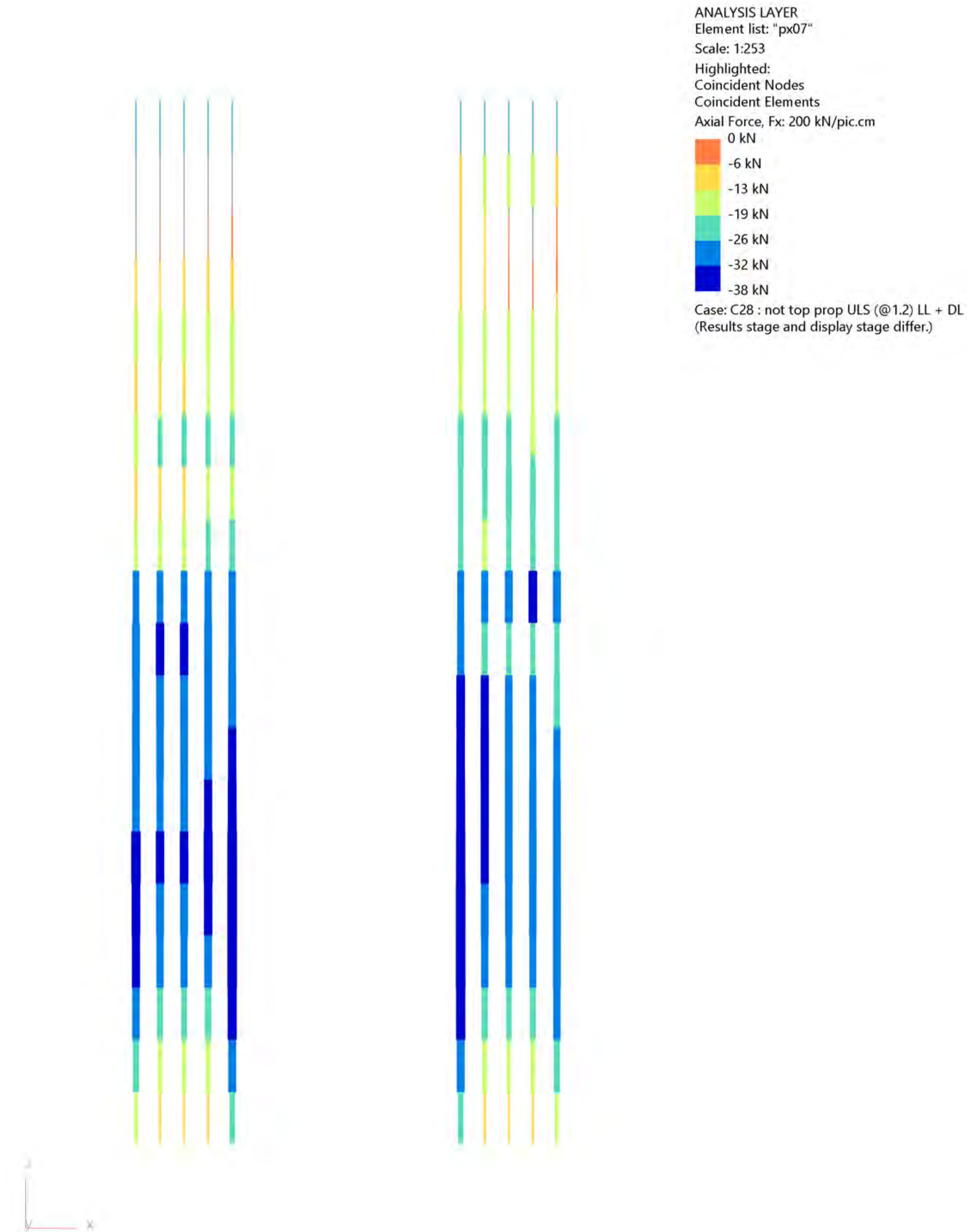

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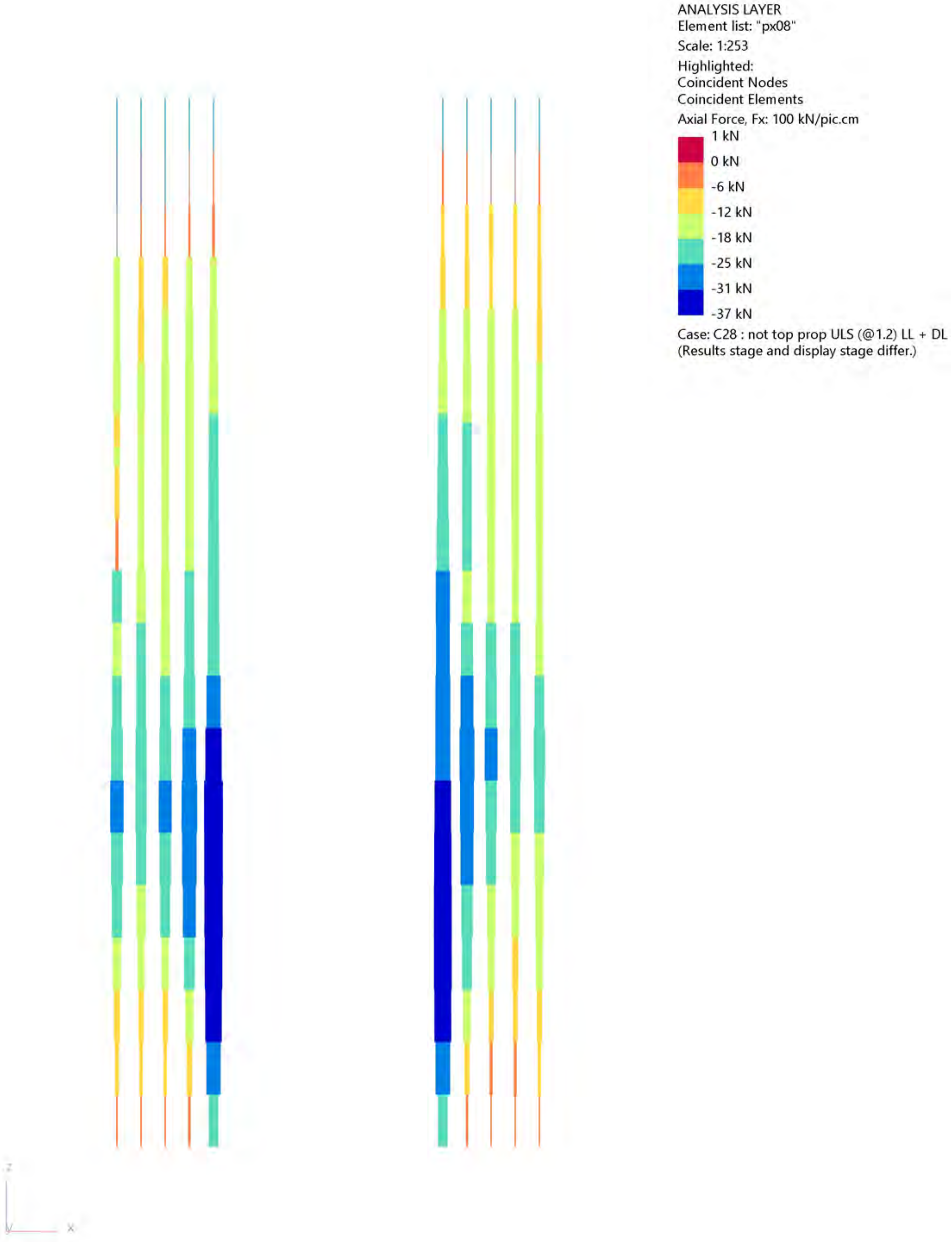

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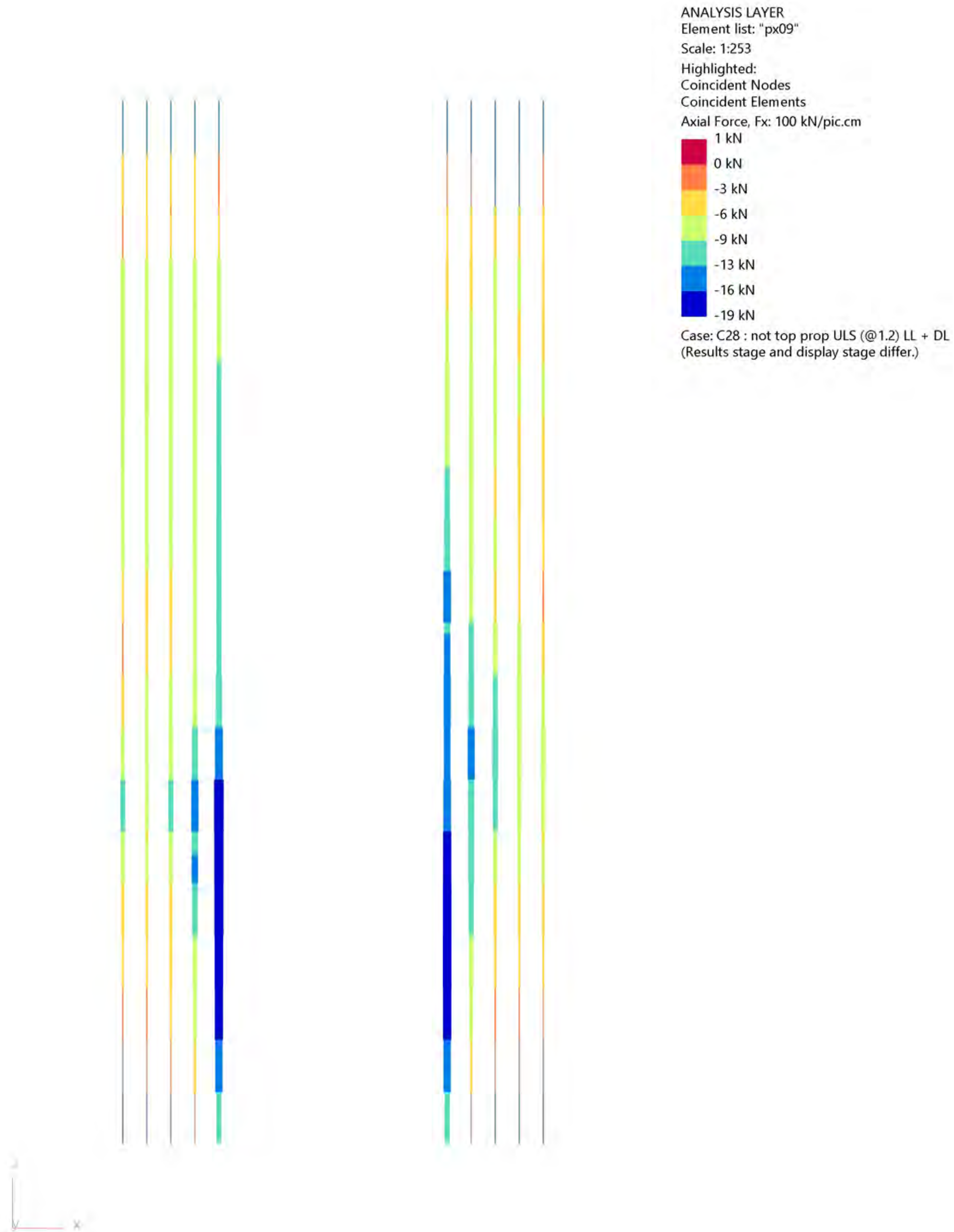

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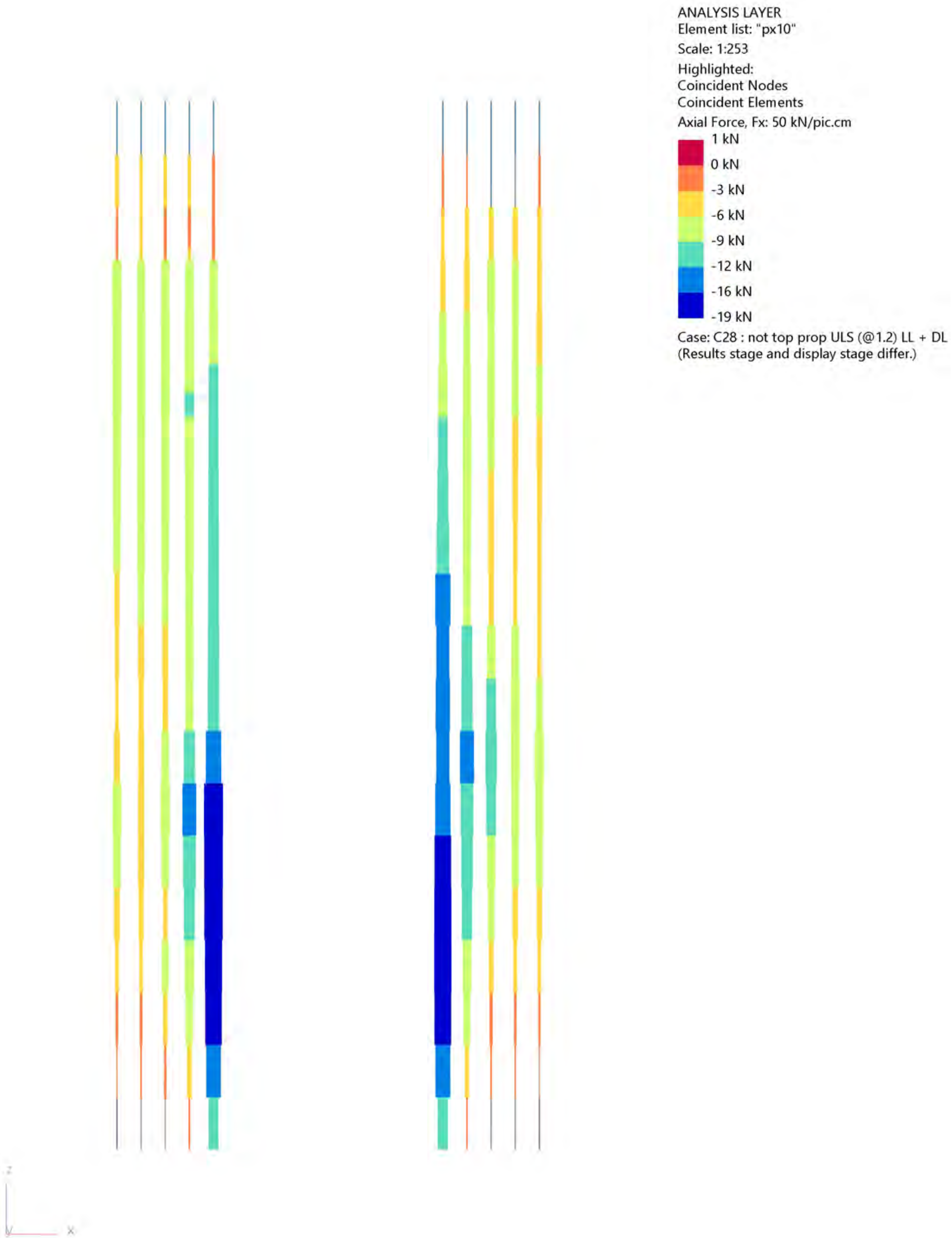

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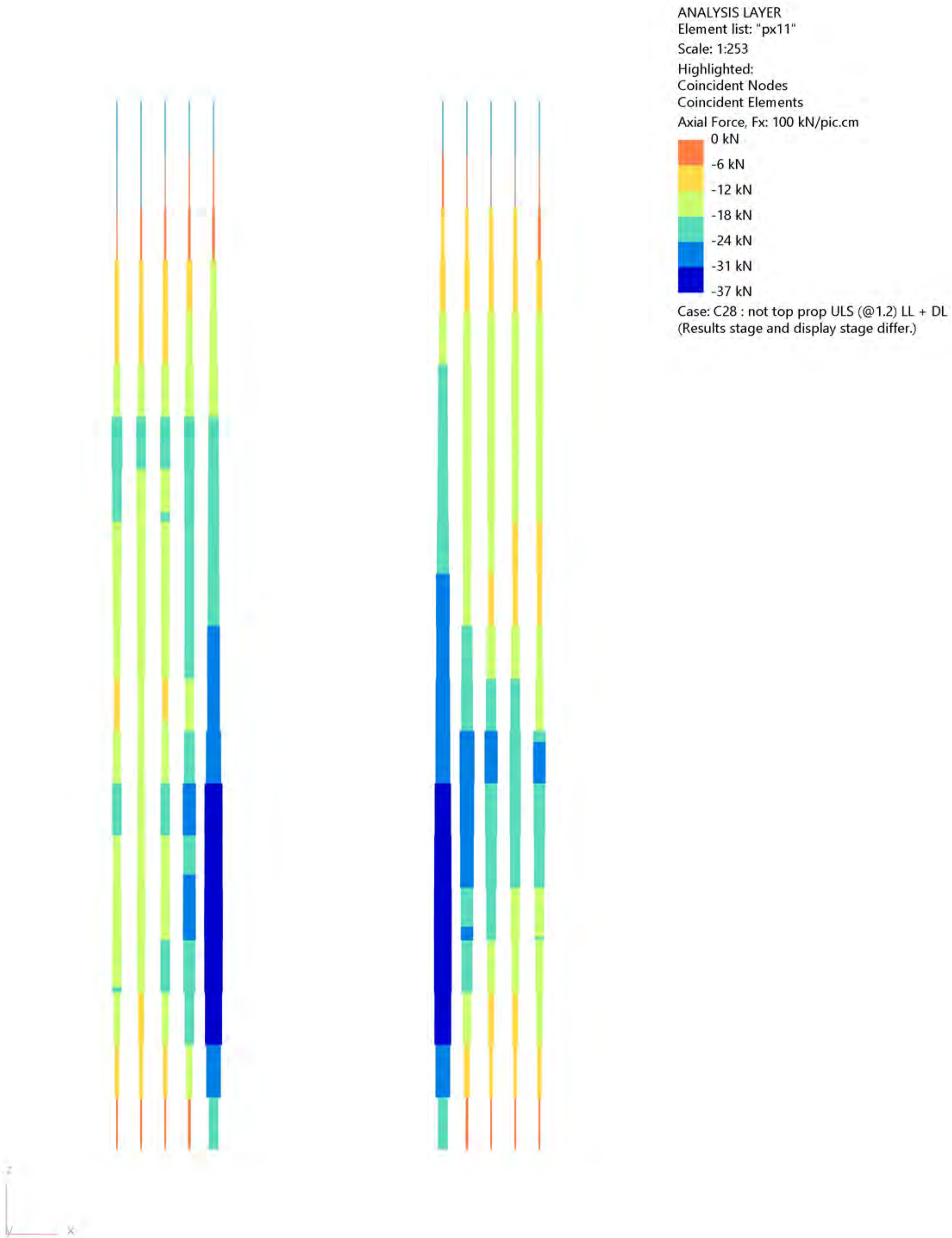

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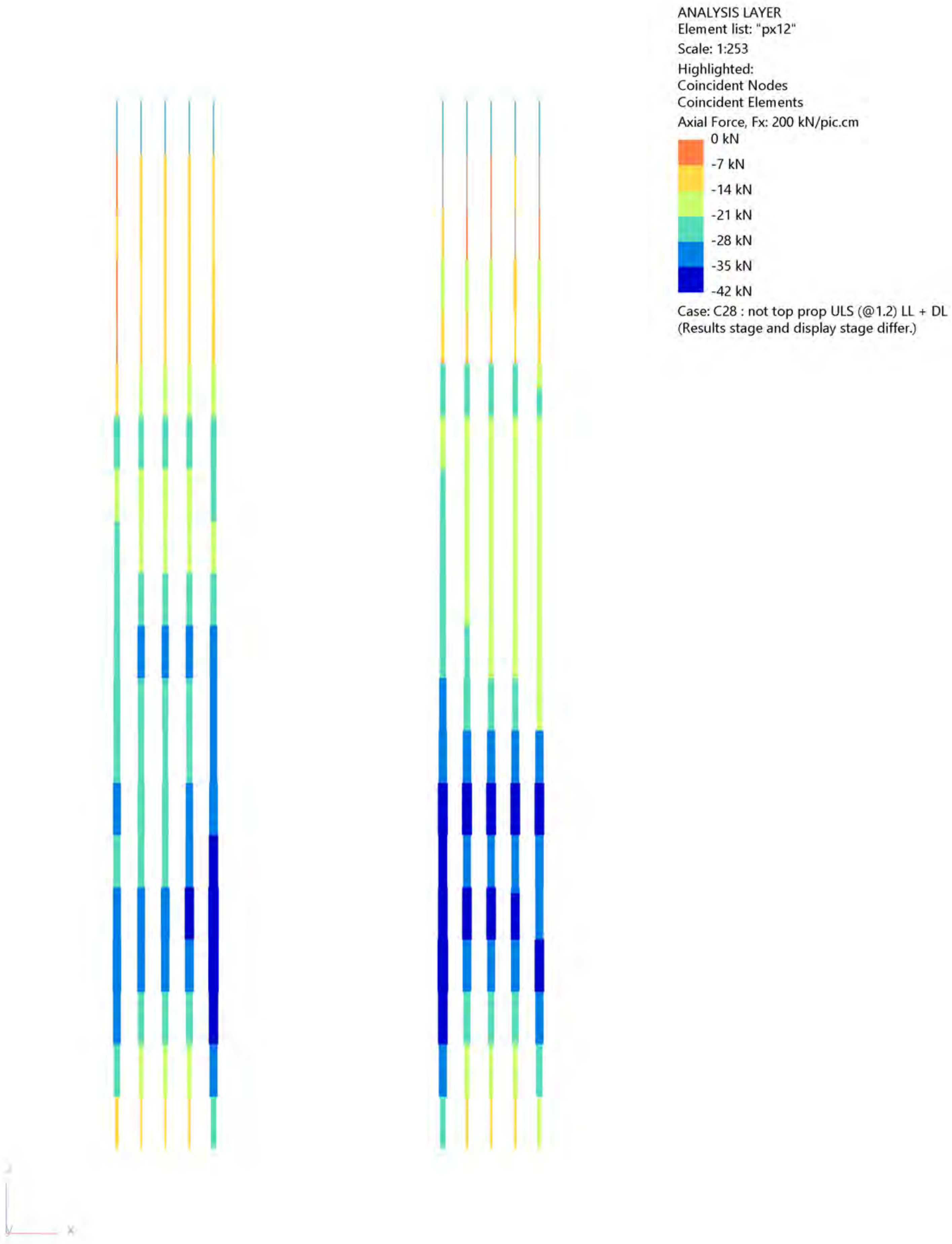

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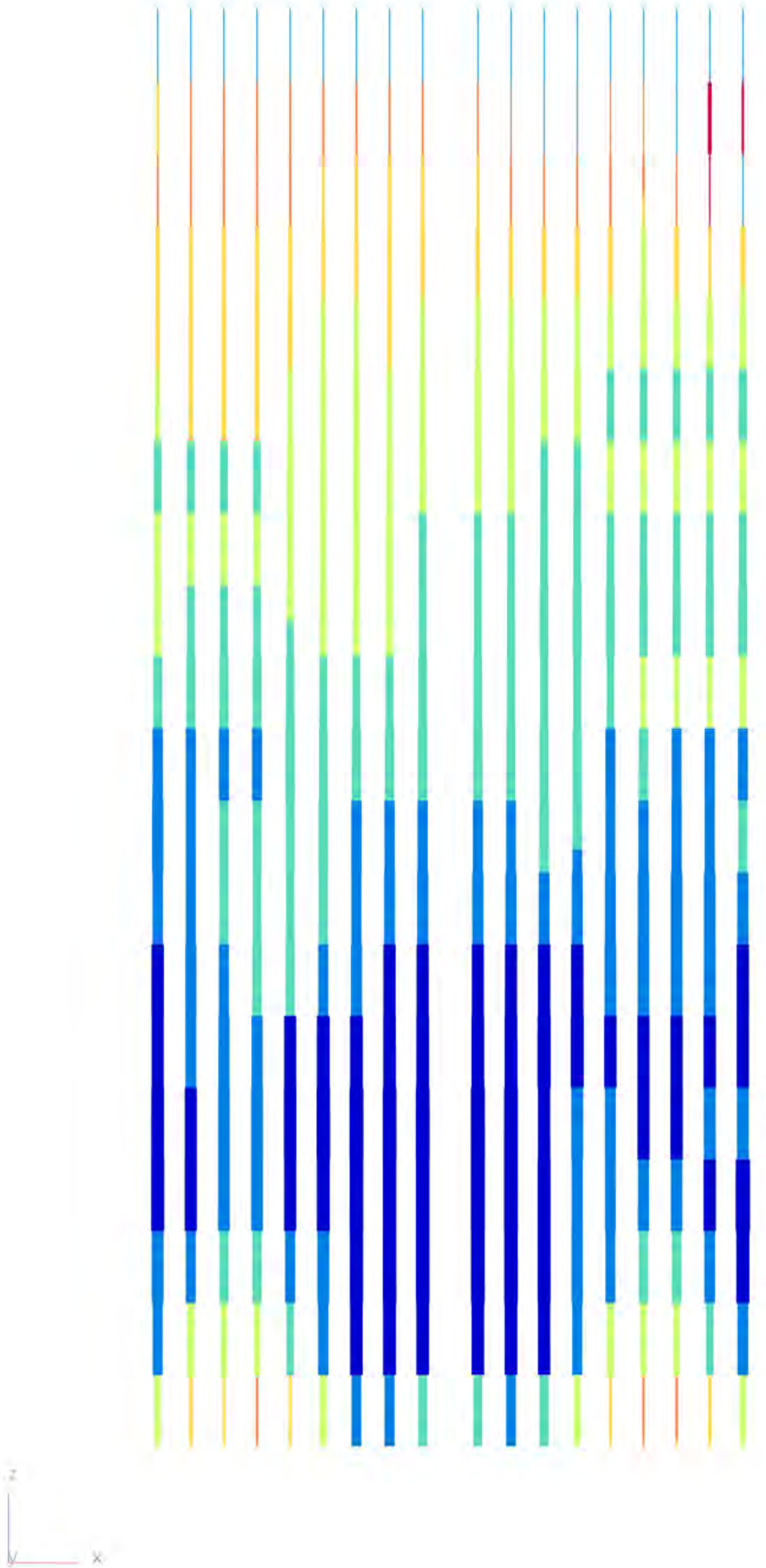

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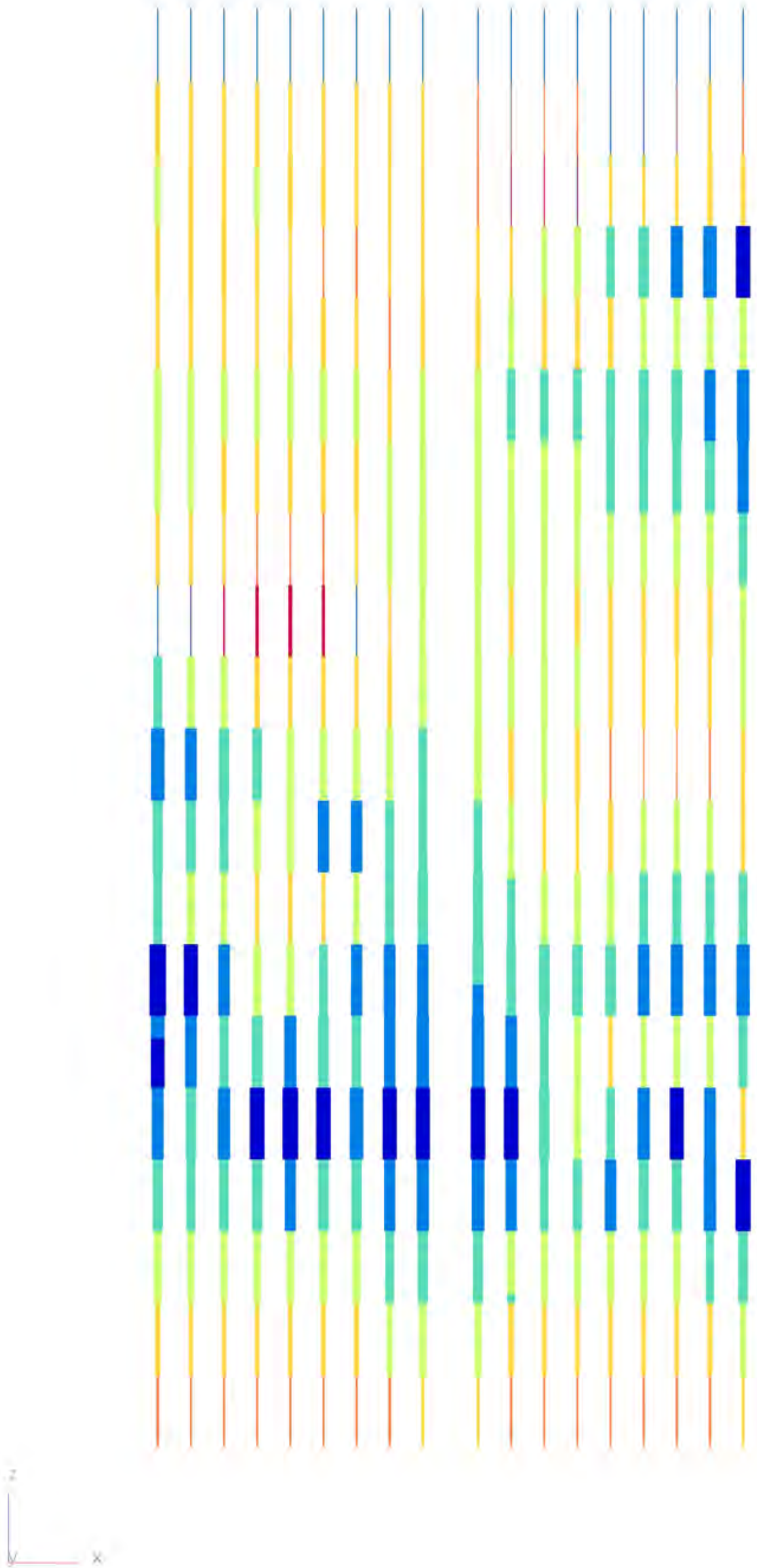

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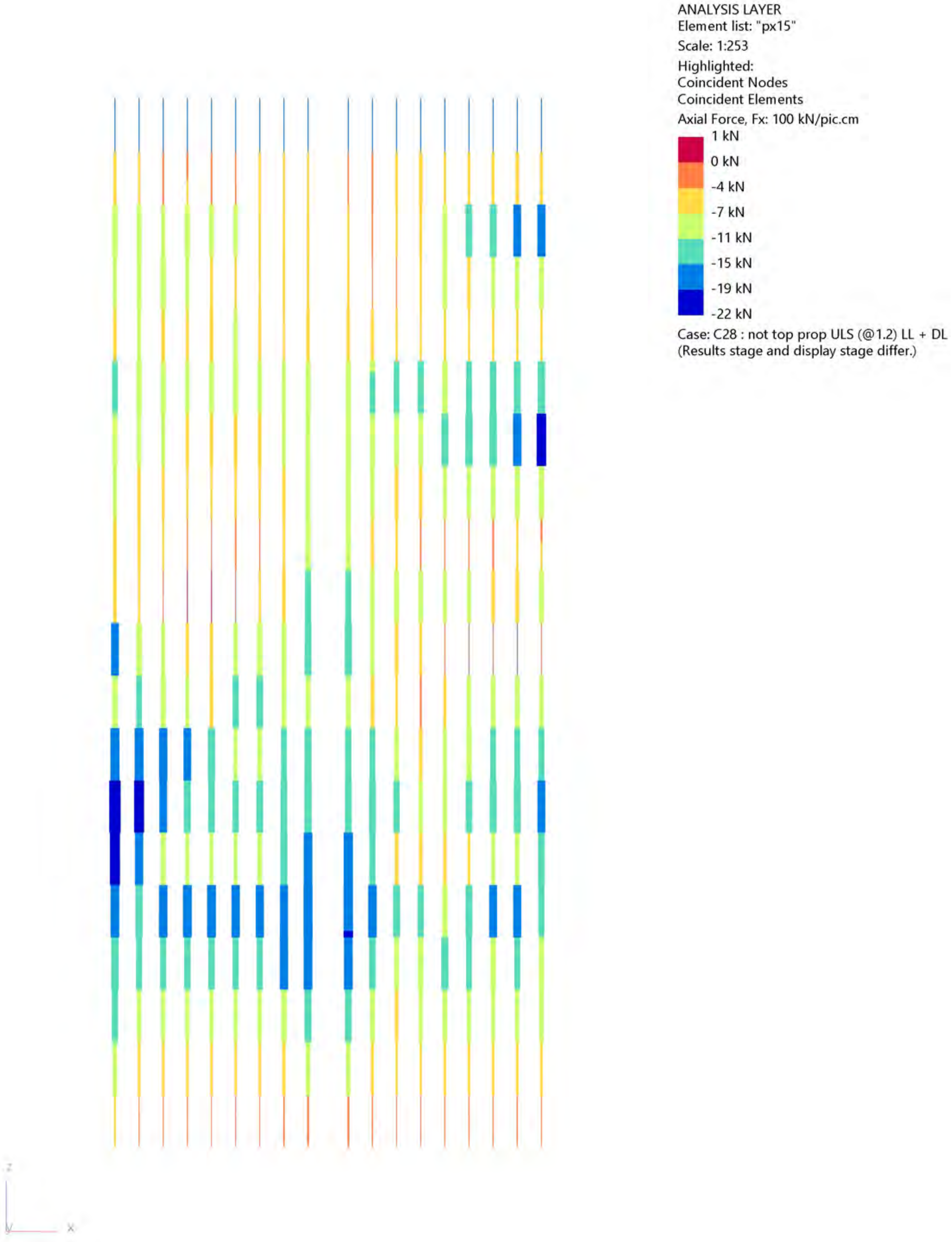

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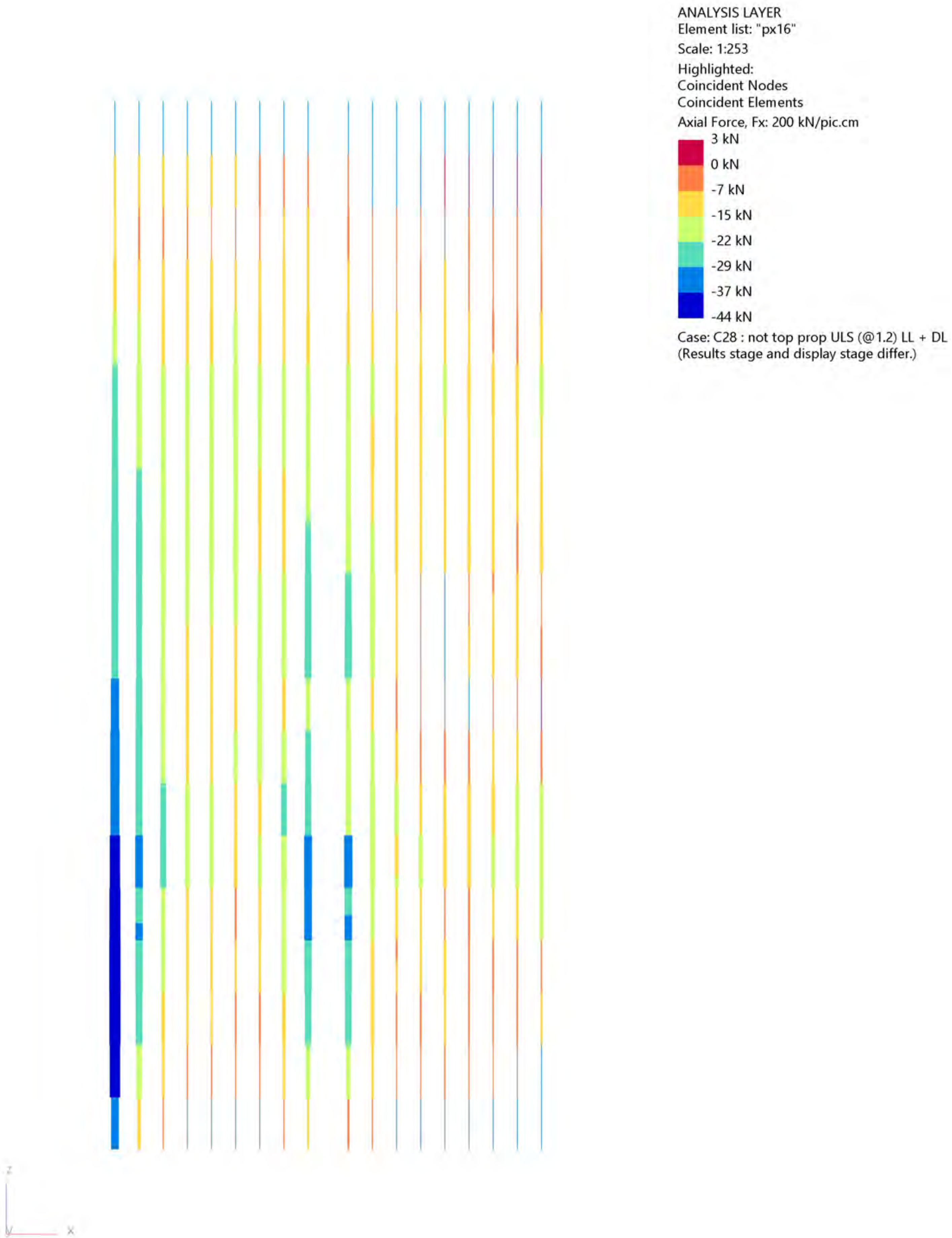

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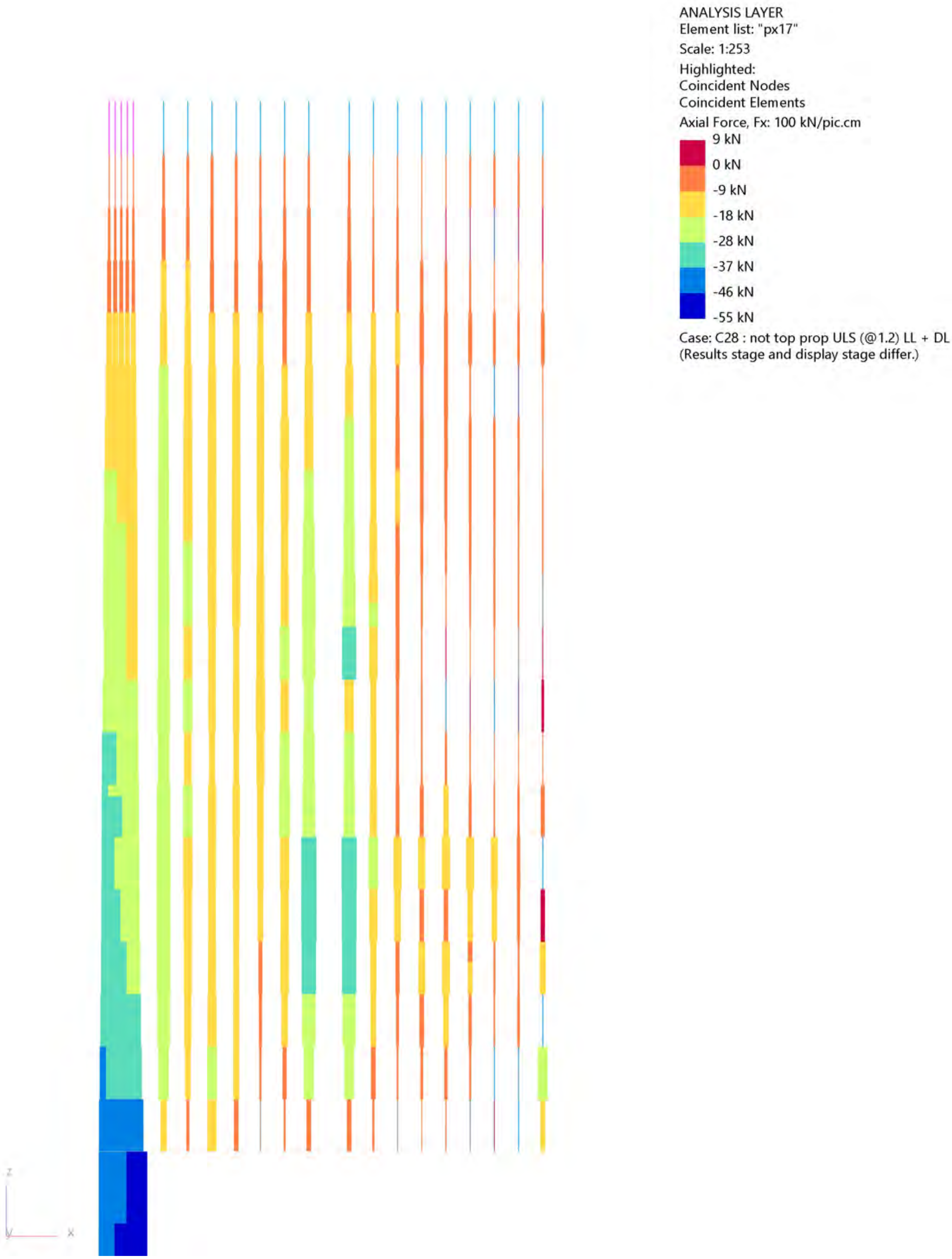

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