



ProtaStructure Design Guide

3D Effects of Continuous Primary & Secondary Beams Analysis

Version 1.0

23rd June 2021

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Introduction

Traditionally, continuous beam lines are analysed and designed in isolation. The modelling of the support conditions in such cases is often unsophisticated or simplified. For example, in the analysis of secondary beams supported by primary beams, the traditional method is to perform 2 analyses independently & separately :

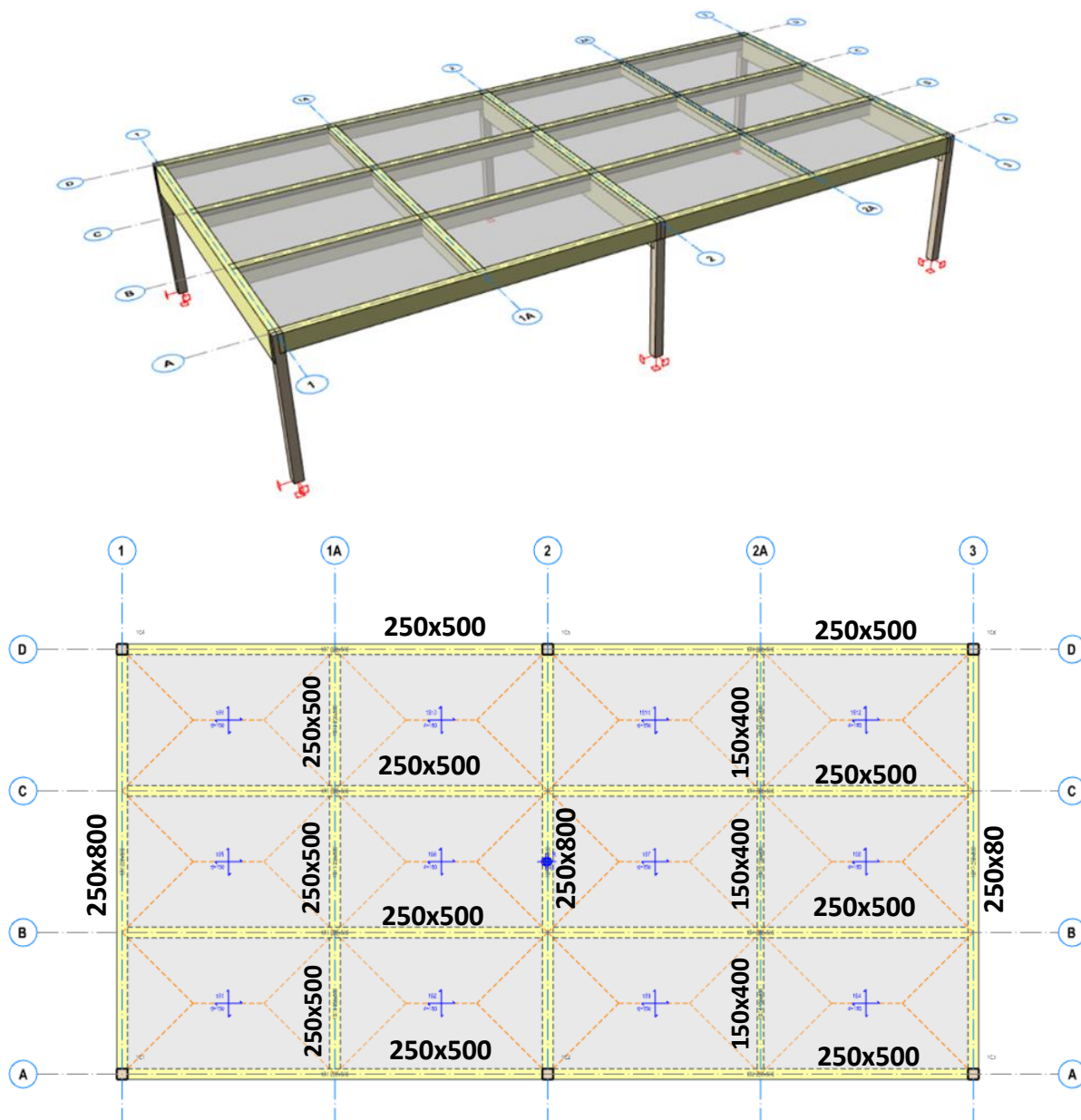
- Firstly, the secondary beams frame line is analysed as simplified 2D frame, with primary beam as knife edge support, that cannot move (translation in all direction restrained).
- The reaction of this knife edge support is obtained via simple 2D equilibrium equations.
- The primary beam frame is then analysed, again as 2D frame, with the reactions of the secondary beam applied as external point load.
- In short, the deflection of primary beams as support, is not considered in the analysis of secondary beam.

In a 3D analysis program such as ProtaStructure, the analysis method is different :

- The entire 3D model is analysed and solved simultaneously as an indeterminate structure.
- Primary & secondary beam will act together, in unison, to support the slab loading simultaneously.
- The proportion of loading sustained by primary & secondary beams will depend on its size and relative layout.
- Deflections of primary beams affects secondary beams; vice versa, as they are connected together – i.e. there is compatibility in deflections of common joints.

3D Example Model

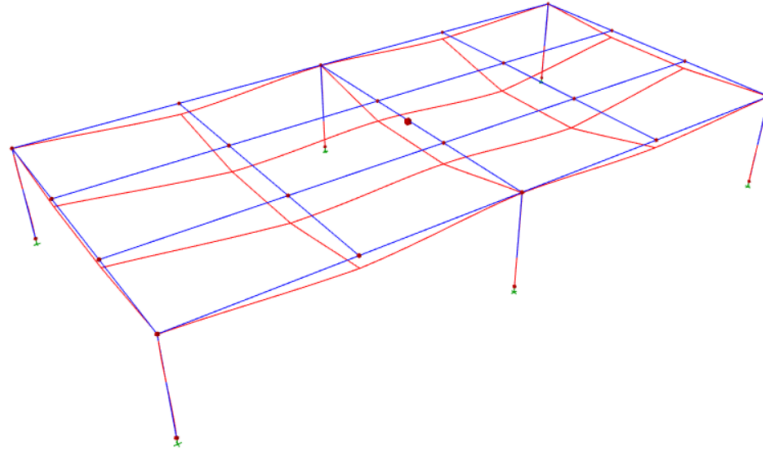
We will use a simple 1 storey model to illustrate this 3D behaviour, as shown below.



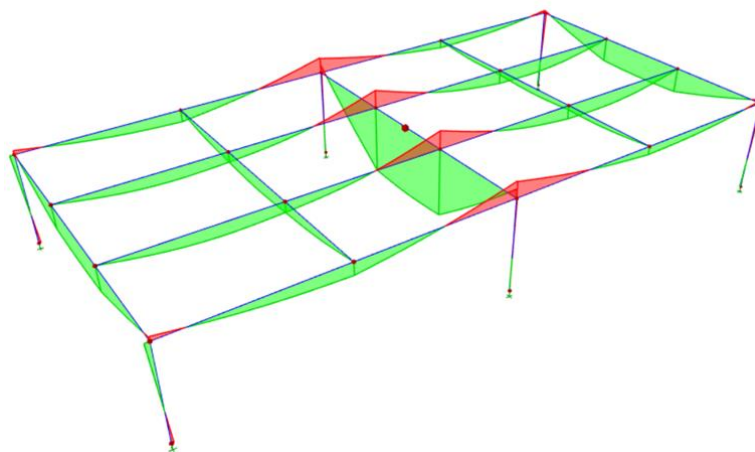
- Grid 1, 2, 3 : Beam size 250 x 800
- Grid A, B, C, D : Beam size 250 x 500
- Grid 1A : Beam size 250 x 500
- Grid 2A : Beam size 150 x 400

3D Analysis Result Discussion

The structure is analysed in ProtaStructure. The analytical model is shown in blue lines and the deflected shape is shown in red lines, due to ultimate load combination.



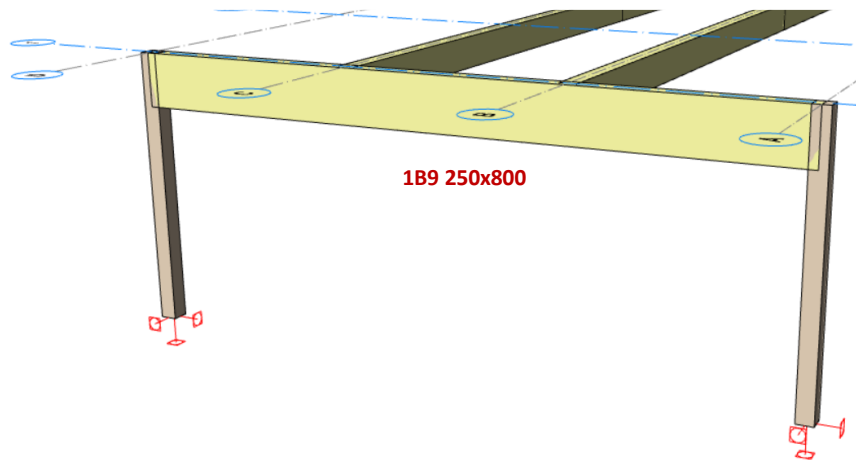
The major bending moment diagram (M33) due to ultimate load combination is as shown below.



It is evident that analysis is based on 3D connected frame and there is 3D deflection. This results in a 3D bending moments which is reflective of the 3D deflection. When beams join together at a common node, there is a single common deflection. This means all the beams are acting together simultaneously to support the slab loads & each other.

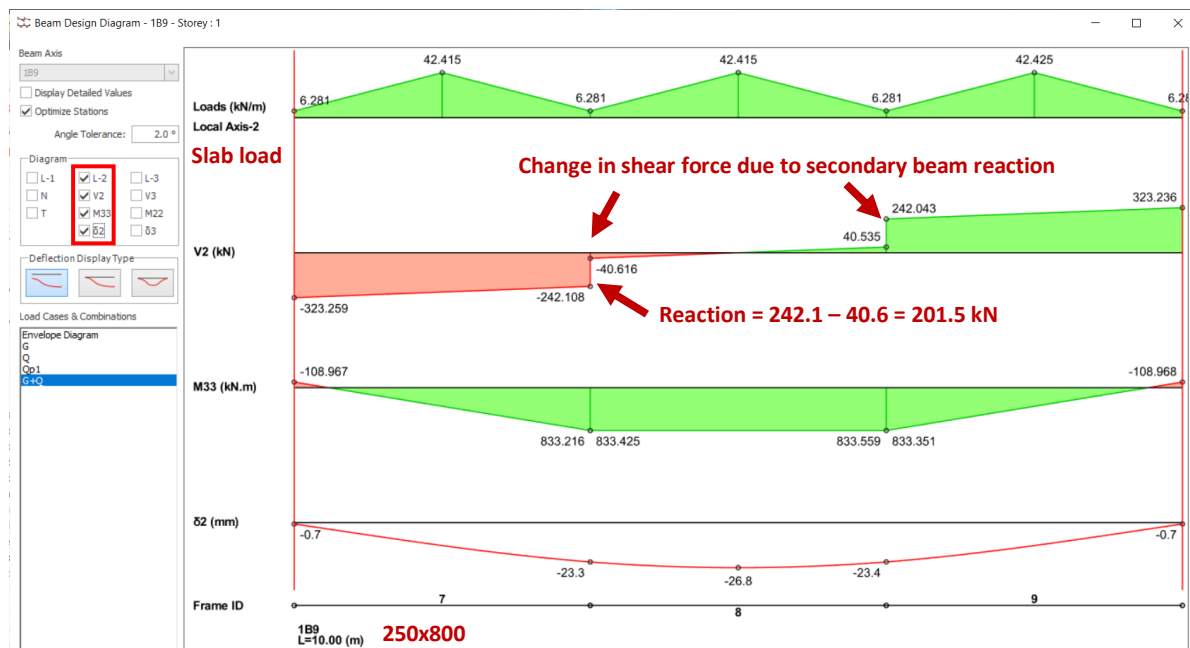
Analysis Results along Grid 1 (primary beam supported by columns)

Let us look at the result of the analysis along grid 1. The filtered frame view is as shown below.



To thoroughly examine the result along each grid, we can access the **Analysis Result Diagram** (select a beam on plan, right-click).

The result along grid 1 with slab loads, major shear, major bending moment & absolute deflection turned on, is as shown below.

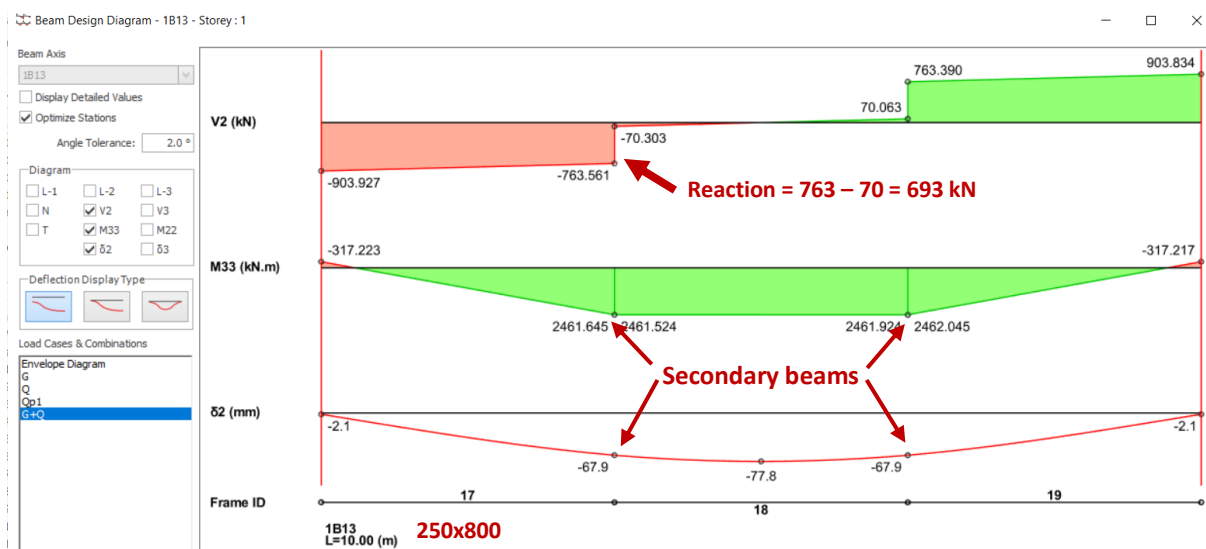
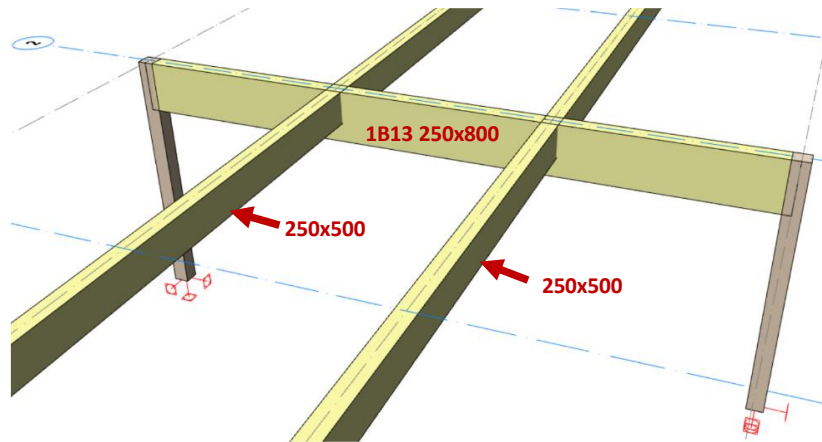


The result of this primary beam is expected & similar to a traditional 2D analysis (similar to primary beam @ grid 1).

- Being the internal primary beam, both the bending moment and deflection are much higher, as it is carrying much larger secondary beams loads.
- The change in shear force diagram, equivalent to the secondary beams' reactions, is also much larger compared to the beam @ grid 1.

Analysis Results along Grid 2 (primary beam supported by columns)

Similarly, the filtered view & results of primary beam along grid 2 is as shown below.

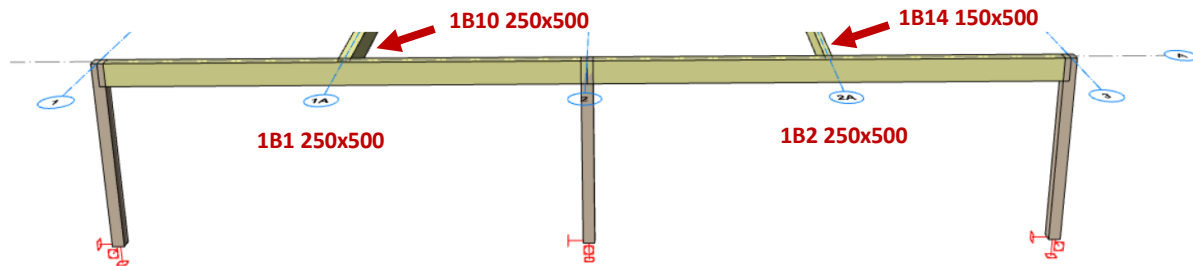


The result of this primary beam is expected & similar to a traditional 2D analysis (similar to primary beam @ grid 1).

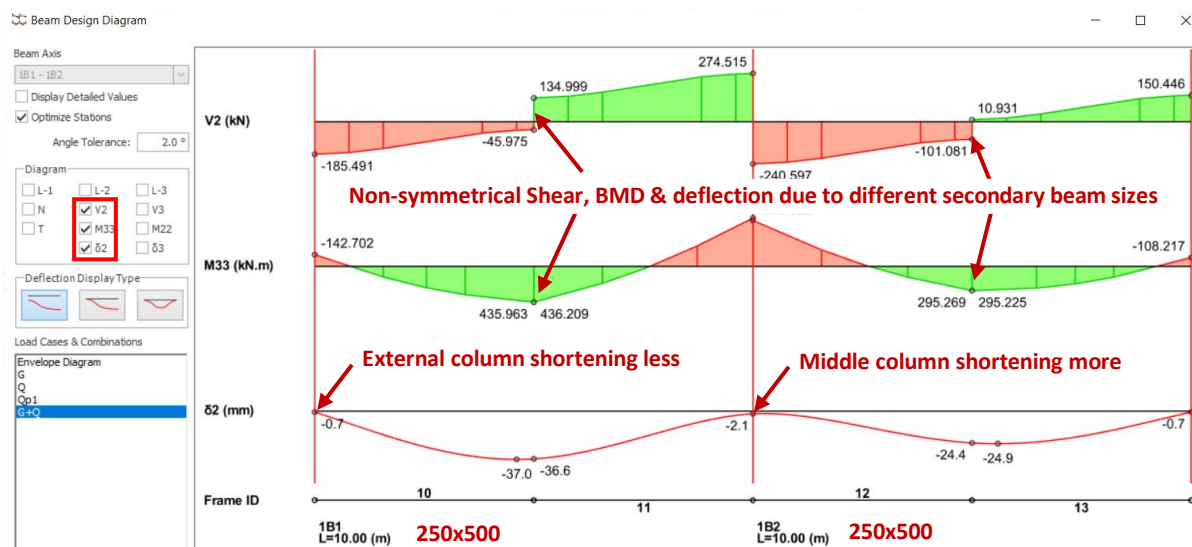
- Being the internal primary beam, both the bending moment and deflection are much higher, as it is carrying much larger secondary beams loads.
- The change in shear force diagram, equivalent to the secondary beams' reactions, is also much larger compared to the beam @ grid 1.

Analysis Results along Grid A (primary beams supported by columns, with incoming secondary beams)

Let us look at the result of the analysis along grid A. The filtered frame view is as shown below.



The analysis result along grid A, with major shear, bending moment & absolute deflection turned on is as shown below.

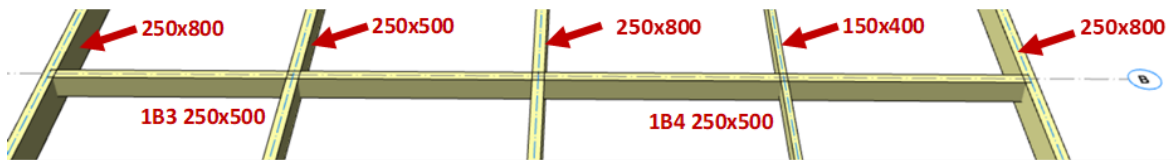


The above result is as expected and comparable to a 2D frame analysis.

- The middle supporting column is shortening more than the external column, due to higher axial load. However, since the shortening of the columns is small, it has negligible impact on the forces in the beams.
- The shear, bending moment diagrams & deflection is non-symmetrical due to different secondary beam sizes.
- The secondary beam on **1B1** is 250 x 500 (larger) while that on **1B2** is 150 x 400 (smaller).
- The larger secondary beam will attract more load in a 3D analysis. as compared to smaller beam (in addition to larger self-weight), giving rise to higher bending moment & deflection.

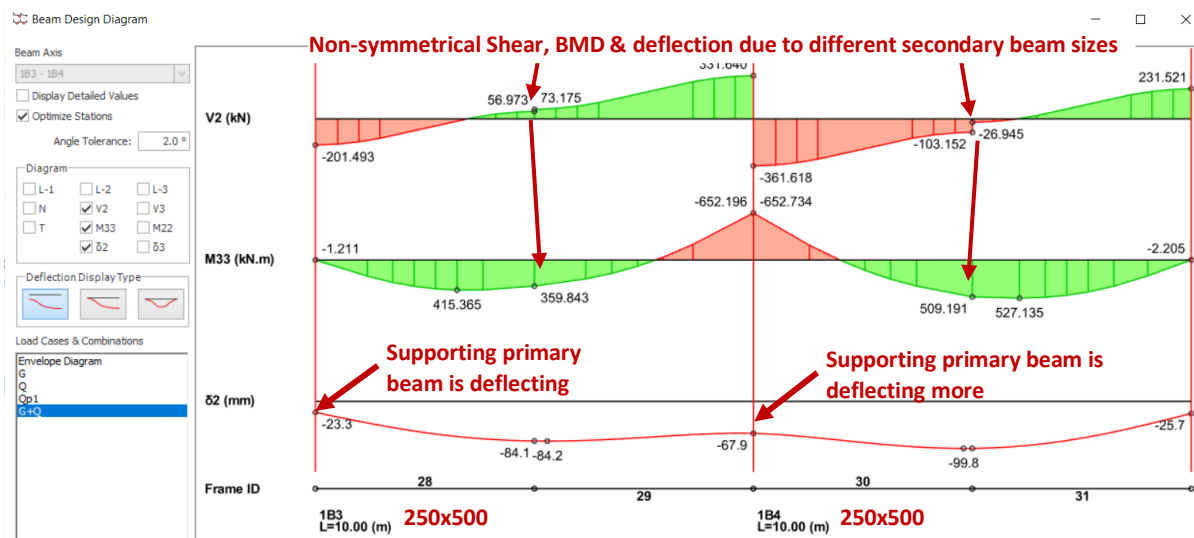
Analysis Results along Grid B (beams supported by primary beams, with incoming secondary beams)

Let us look at the result of the analysis along grid **B**. The filtered frame view is as shown below.



All beams along this grid are supported by primary beams (250 x 800), with 2 incoming secondary beams at mid span (250 x 500 & 150 x 400).

The analysis result along grid B is as shown below.

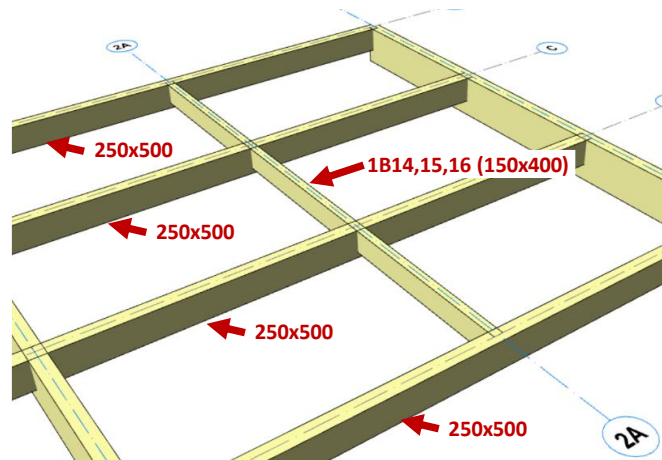


The above result is different from traditional 2D analysis.

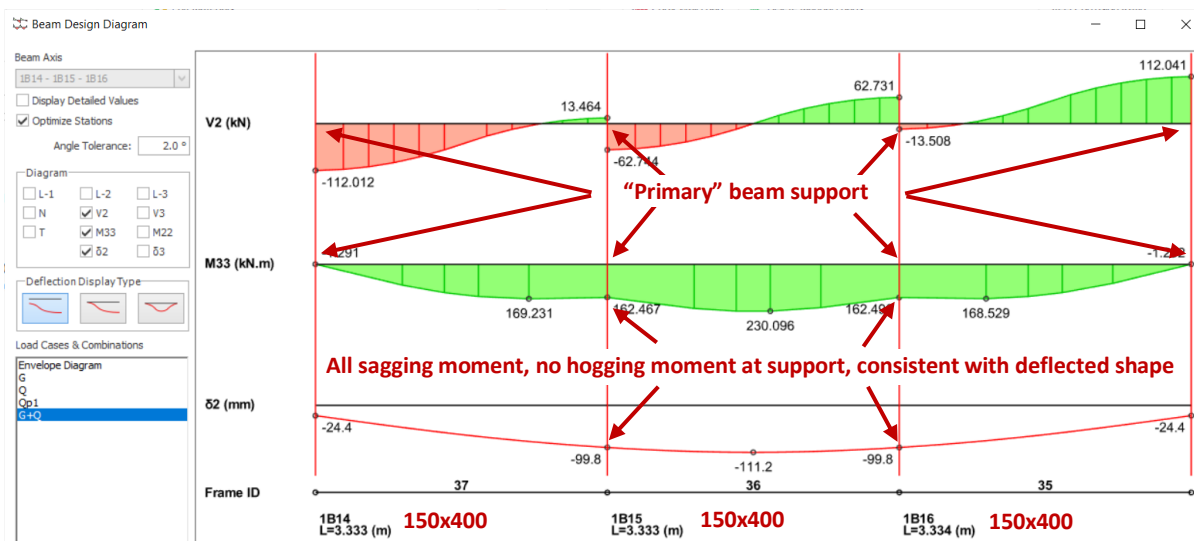
- These beams (**1B3 & 1B4**) are supported by 3 primary beams along Grid **1, 2 & 3**.
- All the supporting primary beams are deflecting, with the middle deflecting the most, 67.9 mm. The deflection value at this position matches exactly the deflection value of the primary beam **1B13** along grid **2**, i.e. deflection at a common joint is exactly the same.
- The net effect is that the resultant hogging moment is not as high as a traditional analysis, where the supporting beam is fixed (prevented from deflecting). This means that whenever there is relative support deflection (moving downwards in this case), the bending moment will be reduced. The more the support movement (downwards), the larger the reduction.
- In this example, the maximum hogging moment is 652 kNm at the middle support, which is only slightly larger than external beams **1B1-1B2** along grid **A** (587 kNm), despite carrying double the loads.
- Notice that the mid span deflection of beam **1B3 & 1B4** is not symmetrical. This is because the size of the secondary connected beams along **GL 1A** and **2A** are different (250 x 500 & 150 x 400). This is further explained below.

Analysis Results along Grid 2A (secondary beams supported by primary beams)

Let us look at the result of the analysis along grid **2A**. The filtered frame view is as shown below.



The result along grid **2A**, with major bending moment & absolute deflection turned on, is as shown below.

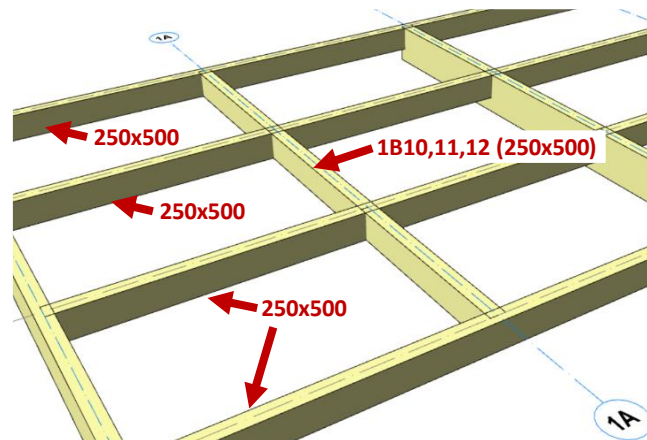


The above results deviate significantly from traditional analysis.

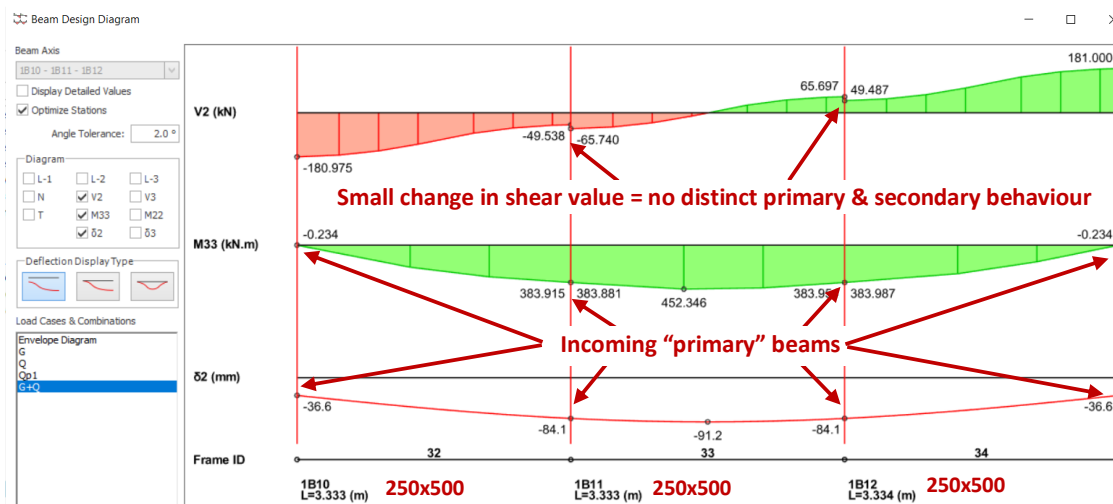
- In this case, the above beams are supported by 4 nos. of “primary” beams (250 x 500).
- However, the deflection of these “primary” beams are so excessive in this case, there is sagging moment along the entire beam line & no hogging moment at the primary support, even though these beams are sized smaller (150 x 400).
- The only indication there is a primary beam support is the small kink in the bending moment diagram.
- The deflection of the beams is consistent with the sagging bending moment diagram.
- To summarize, the traditional distinction of “primary” and “secondary” beam is irrelevant, due to 3D stiffness analysis.

Analysis Results along Grid 1A (primary & secondary beams of same sizes)

Let us look at the result of the analysis along symmetrical grid **1A**. The filtered frame view is as shown below.



The result along grid **1A**, with major bending moment & absolute deflection turned on, is as shown below.



Similar to grid **2A**, the above results deviate significantly from traditional analysis.

- The deflections of the support "primary" beams are also very large, as there is no longer noticeable distinction between primary & secondary beam behavior.
- This is because both the "primary" & "secondary" beams are the same size (250 x 500) & supporting similar slab loads.
- The result is a 3D grillage effect where loads are shared equally by all beams.
- This is evident as there is a very small change in shear force diagram at the common joints.
- Further, there is no noticeable kink in the bending moment diagram as compared with similar beams along grid **2A**.
- To summarize, the traditional distinction of "primary" and "secondary" beams is irrelevant, due to 3D stiffness analysis.

Summary & Conclusion

The continuous beam analysis using ProtaStructure 3D stiffness analysis is different from a traditional 2D analysis.

- The key difference is in 3D analysis, the connected beams, both primary and secondary are analyzed & solved simultaneously as indeterminate structure.
- Bigger and hence stiffer beams will naturally behave like primary beams, vice versa. There is no way & no need to force a particular beam to be primary or secondary beam, the user should just size beams appropriately.
- All connected beams must have the same deflection at the common joint.
- Traditional assumption where there must be hogging moment at the primary beam support is no longer valid.
- The 3D stiffness analysis result is not unique to ProtaStructure. Any 3D general analysis program will give similar results given the same model. You can export ProtaStructure model to SAP or ETABS for further verification if desired.

The resultant 3D moment is best viewed by accessing the 3D analytical model and reviewing the 3D deflection, as the deflections are direct reflection of the forces in the beams.

Thank You...

Thank you for choosing the ProtaStructure Suite product family.

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The Prota Team

