Preliminary FEA Results

PH-DT Engineering Office, CERN

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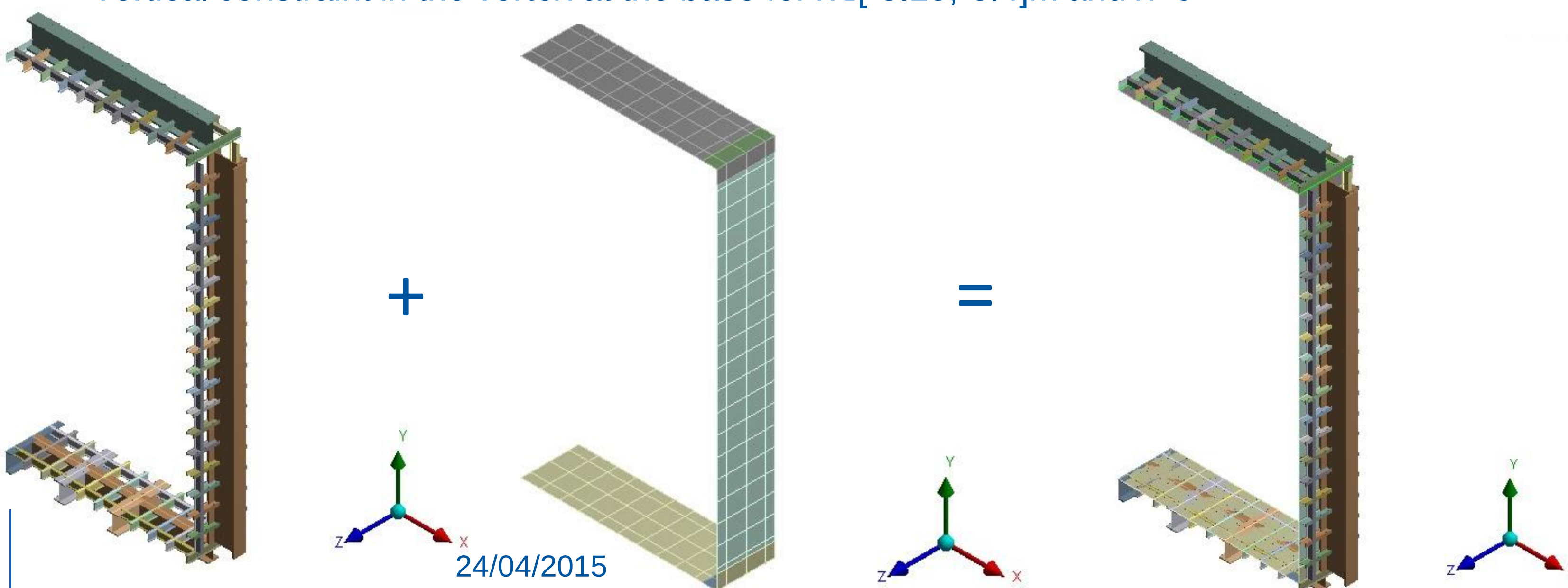
Maximum Beam Stresses

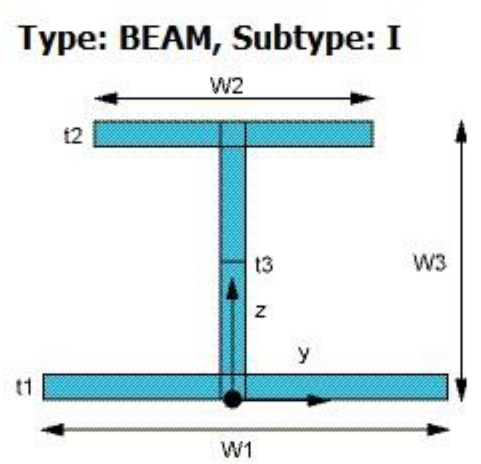
Maximum Beam Stresses: FEA Model Details

- Half Frame Unit (2.4m in length)
  - Beam elements (with offsets) to simulate the main frame and the grid
  - Shells to represent the warm vessel (6mm thick)
  - Joint (MPC184) at the bottom and top connections of the main frame to study the effect of torsional stiffness (i.e. K_{bot} and K_{top} respectively)
  - BCs
    - Symmetry BCs + Periodic BCs (via CPs) to simulate unit cell behaviour
    - **Nominal** pressure loads acting on the shells (P_0=350mbar and ρ_{LAr}=1400kg/m^3) taking into account the presence of the insulation ~ 600mm thick)
    - Vertical constraint in the vertex at the base for x∈[-8.15,-3.4]m and x=0



Baseline Configuration

- Main frame composed by three large beams with the same cross section



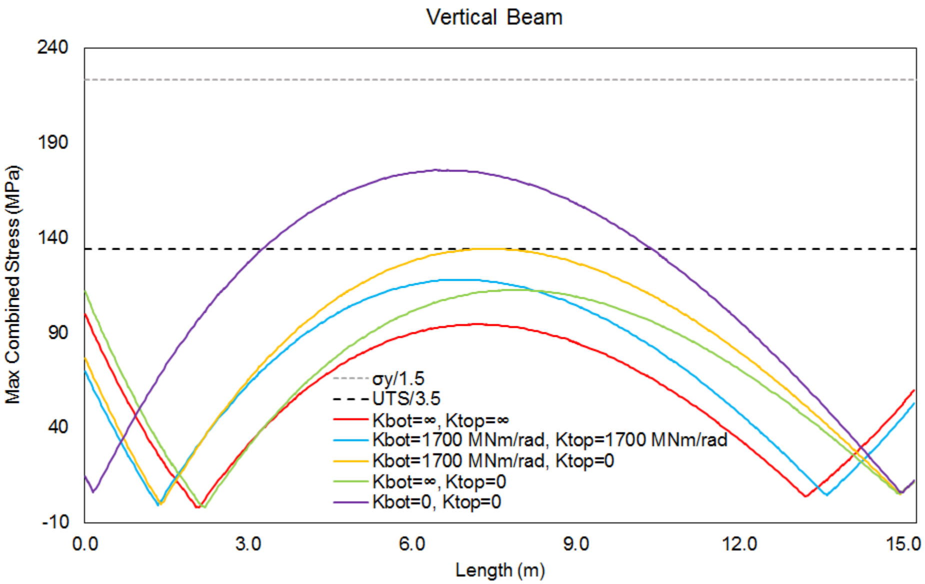
	Section Grid	Section Vertical	Section Floor	Section Roof
W1 (m)	0.15	0.55	0.55	0.55
W2 (m)	0.15	0.55	0.55	0.55
W3 (m)	0.3	1.2	1.2	1.2
t1 (m)	0.015	0.075	0.075	0.075
t2 (m)	0.015	0.075	0.075	0.075
t3 (m)	0.01	0.04	0.04	0.04
Mass/m (kg/m)	56.52	977.325	977.325	977.325

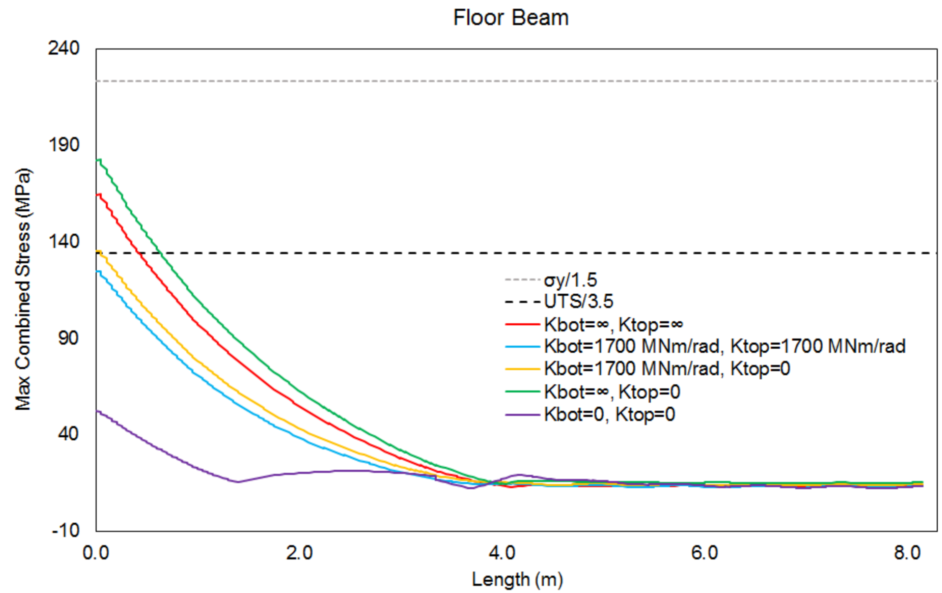
- Steel S355 (EC properties for t>40mm)
  - σ_y=335 MPa $\rightarrow$ σ_y/1.5=223 MPa
  - UTS=470 MPa $\rightarrow$ UTS/3.5=134 MPa

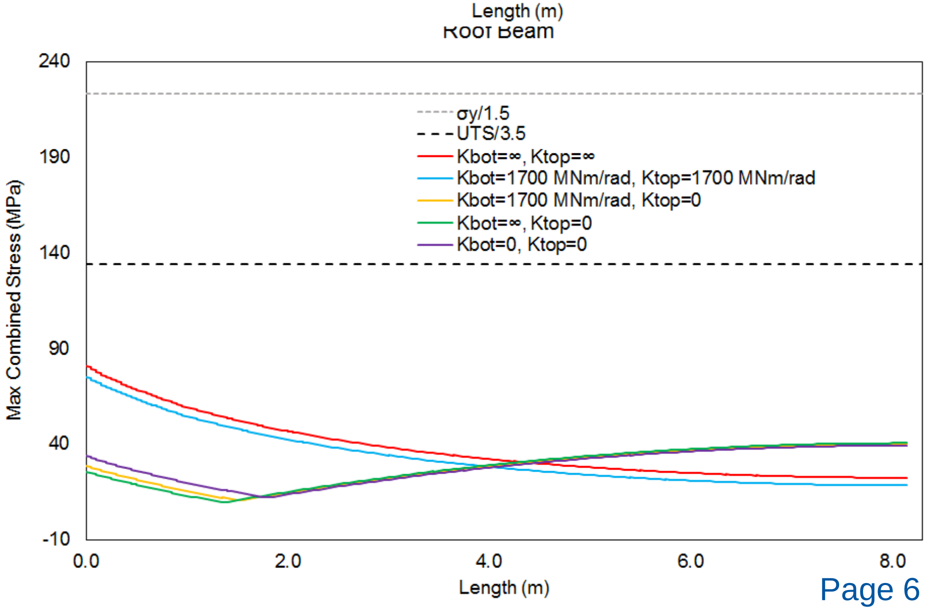
- K=1700 MNm/rad $\rightarrow$ Stiffness estimated via FEA for a bolted joint between two of the large beams used in the main frame

Baseline Configuration: Effect of Joint Stiffness

- Effect of the Joint Stiffness on the maximum combined stress for the main vertical, floor and roof beams





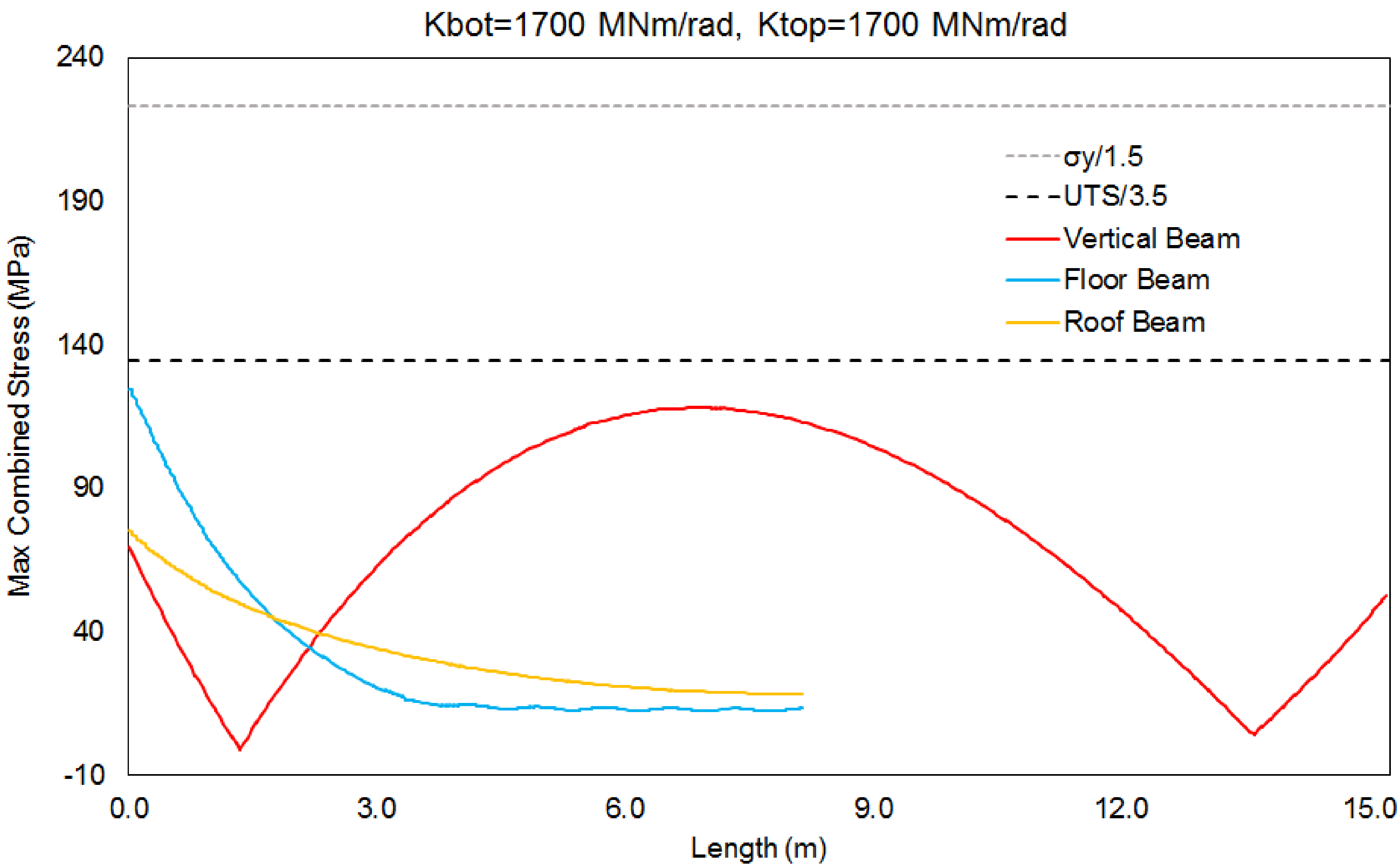


Only two configurations seems to be acceptable:

- $K_{bot}=K_{top}=1700$MNm/rad
- $K_{bot}=1700$MNm/rad, $K_{top}=0$

(Although the second one would be at the very limit in the vertical and floor beams).

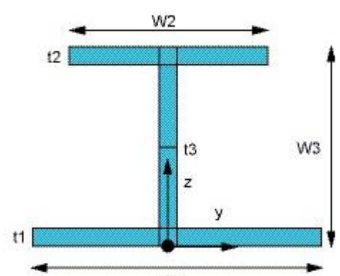
Baseline Configuration: Imperfect Joint



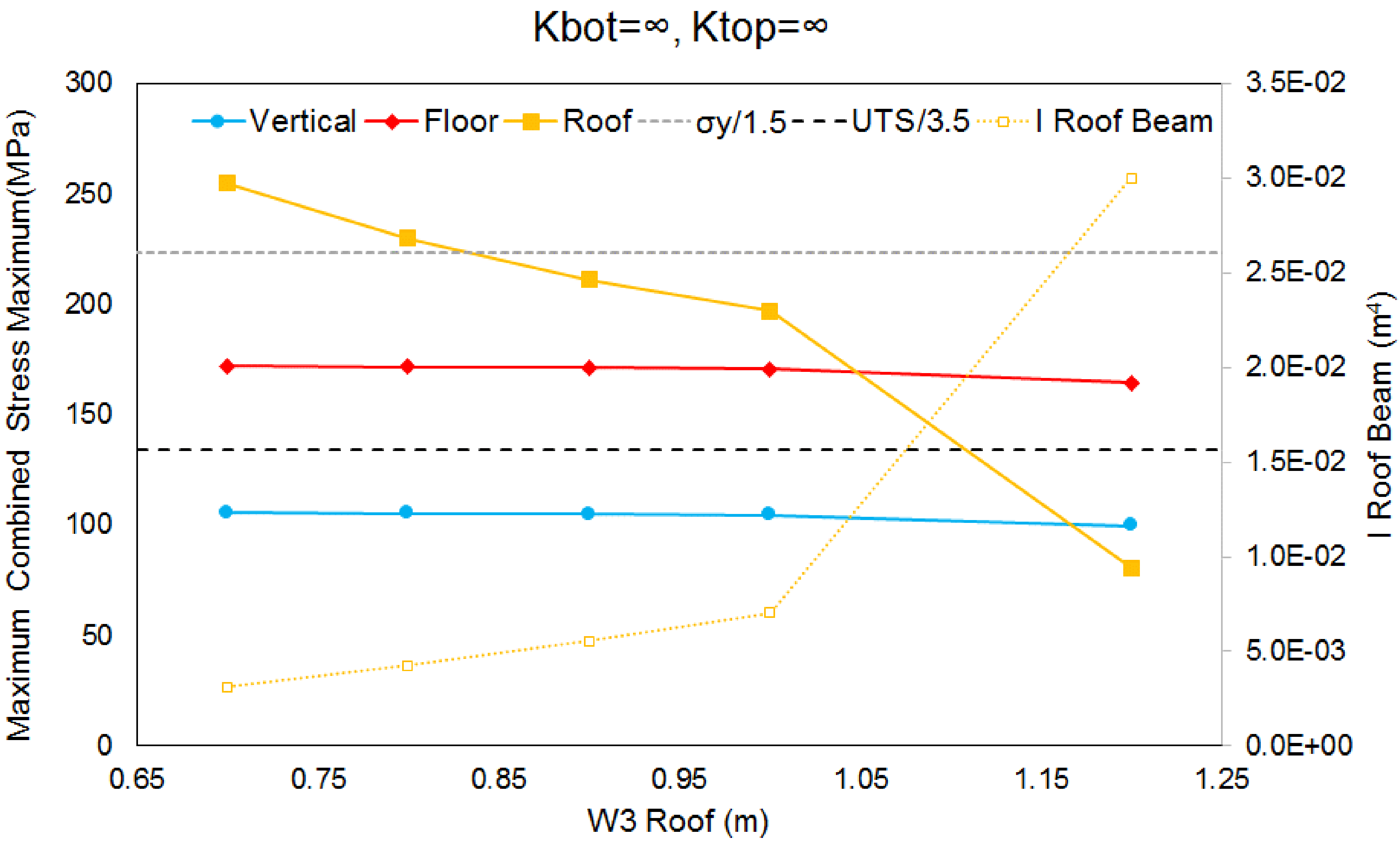
Smaller Roof Beam: Parametric Study

- Parametric study varying the cross section of the large beam used at the roof (floor and vertical beams remain unchanged):
  - Dimitar's original roof beam taken as the starting point
  - Progressive increase of the web length (i.e. W3)
  - Effect of the joint stiffness on the maximum values of the maximum combined stress for the different cross sections

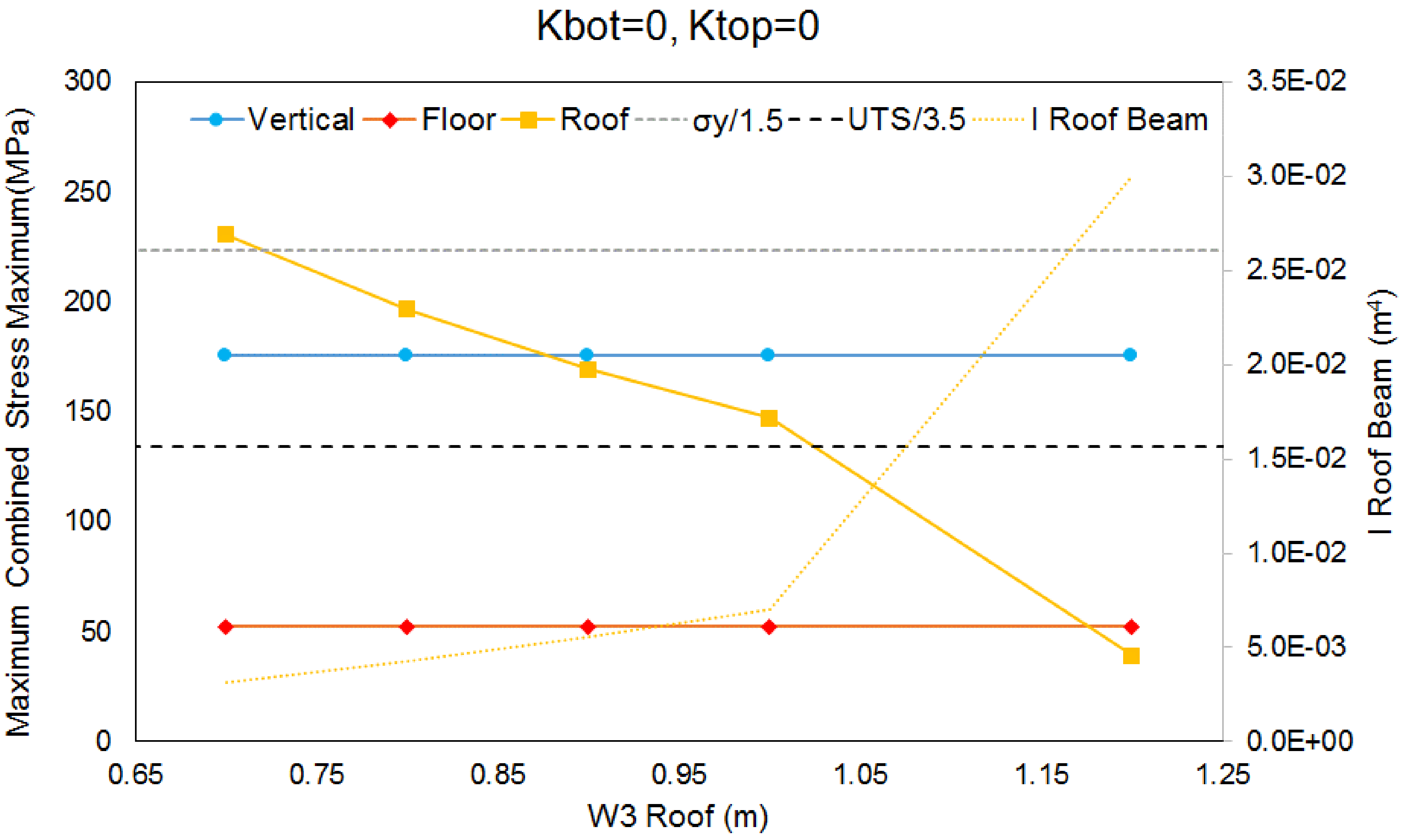
Characteristics of the I-beam sections considered for the large roof beam					
	Case 1	**Case 2**	**Case 3**	**Case 4**	**Baseline**
W1 (m)	0.35	0.35	0.35	0.35	0.55
W2 (m)	0.35	0.35	0.35	0.35	0.55
W3 (m)	0.7	0.8	0.9	1	1.2
t1 (m)	0.035	0.035	0.035	0.035	0.075
t2 (m)	0.035	0.035	0.035	0.035	0.075
t3 (m)	0.02	0.02	0.02	0.02	0.04
I (m4)	0.003128	0.004235	0.005538	0.007047	0.030001
Mass/m (kg/m)	291.235	306.935	322.635	338.335	977.325



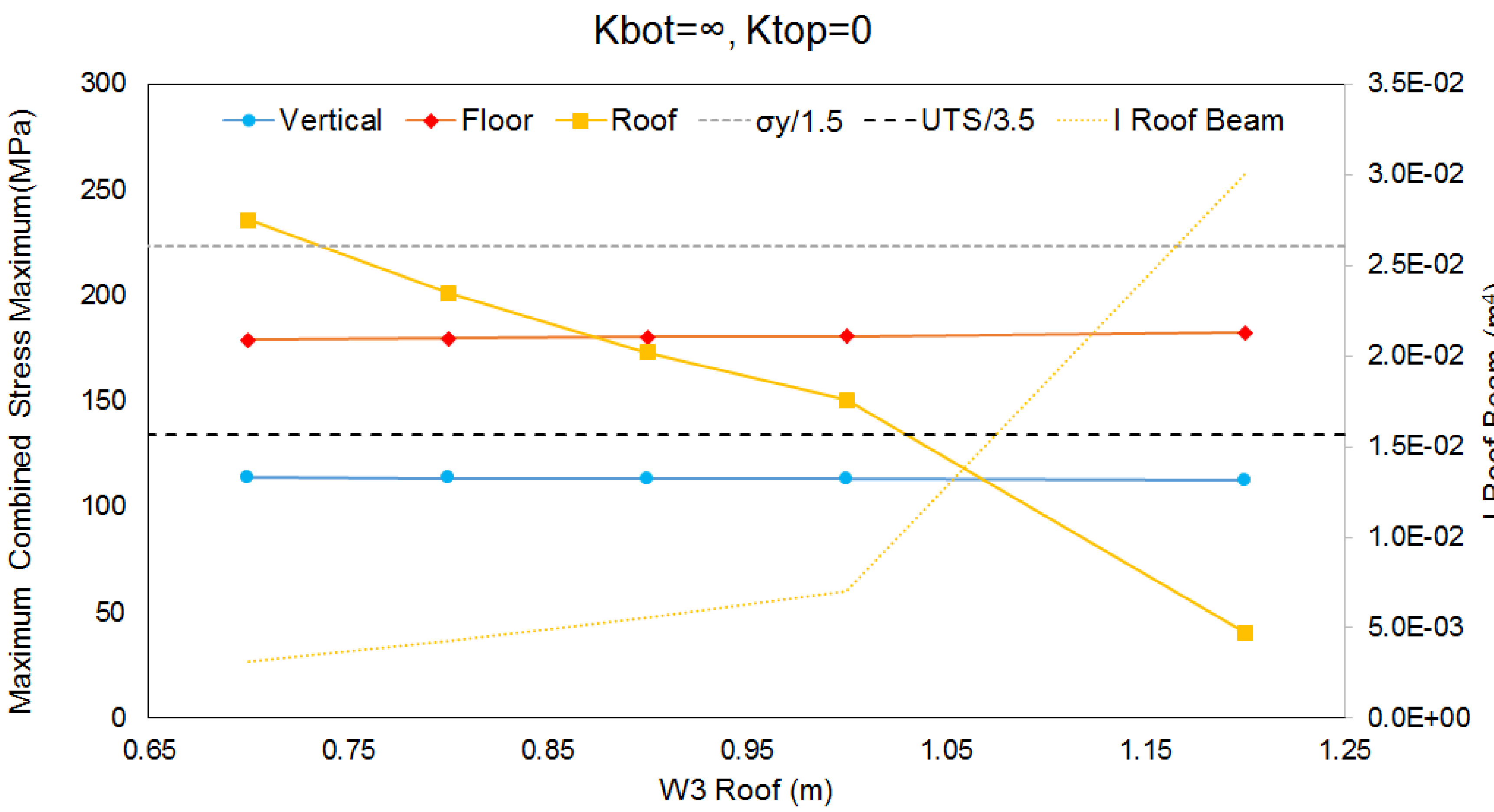
Small Roof Beam: Perfect Moment Connections



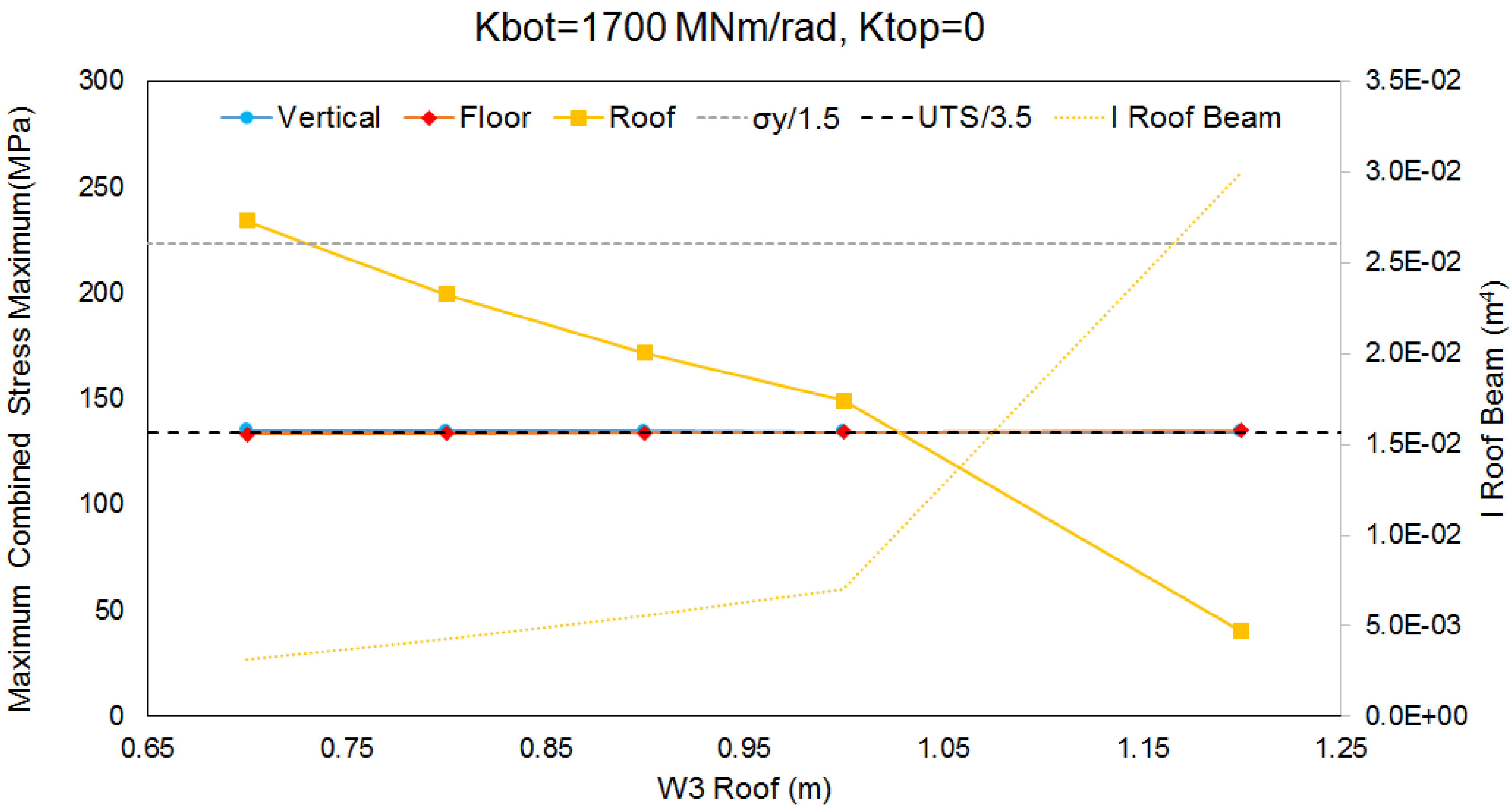
Small Roof Beam: Pinned Connections



Small Roof Beam: $K_{bot}=\infty$, $K_{top}=0$



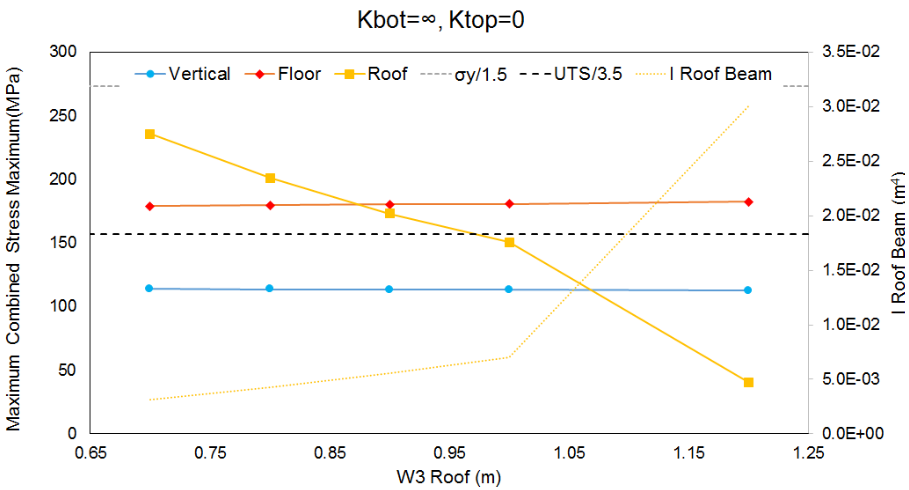
Small Roof Beam: K_{bot}=1700 MNm/rad, K_{top}=0

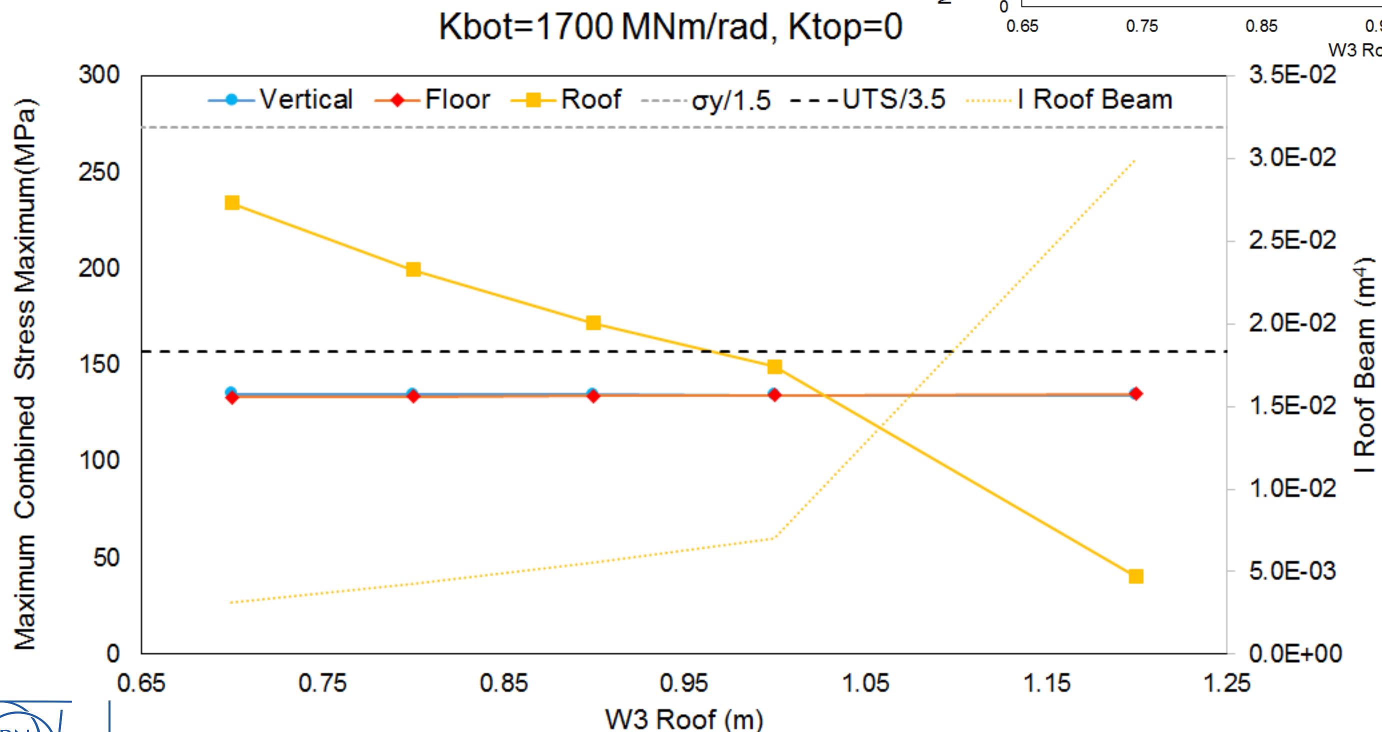


Change is Steel Grade?

- Small Improvements by moving to S450 (EC properties for t>40mm):
  - σ_y=410 MPa → σ_y/1.5=273.3 MPa
  - UTS=550 MPa → UTS/3.5=157 MPa

K_{bot}=1700MNm/rad + K_{top}=0 could work for I_{roof} > 7050·10^6 mm^4



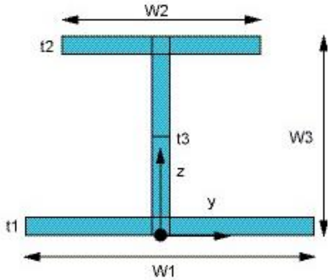


Smaller Floor Beam: Parametric Study

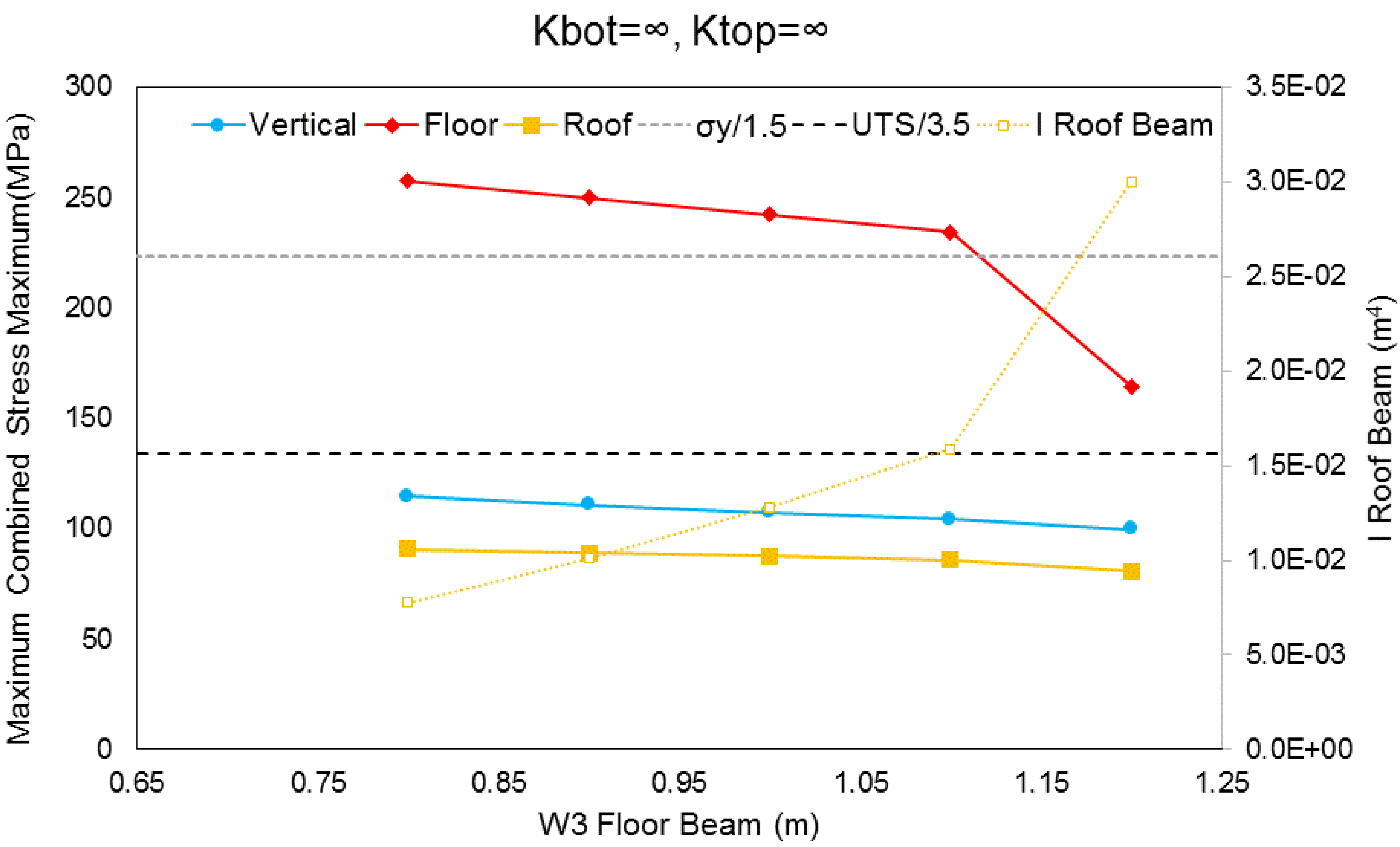
- Parametric study varying the cross section of the large beam used at the floor (roof and vertical beams remain unchanged):
  - Dimitar's original roof beam taken as the starting point
  - Progressive increase of the web length (i.e. W3)
  - Effect of the joint stiffness on the maximum values of the maximum combined stress for the different cross sections

Characteristics of the I-beam sections considered for the large roof beam					
	Case 1	**Case 2**	**Case 3**	**Case 4**	**Baseline**
W1 (m)	0.5	0.5	0.5	0.5	0.55
W2 (m)	0.5	0.5	0.5	0.5	0.55
W3 (m)	0.8	0.9	1	1.1	1.2
t1 (m)	0.05	0.05	0.05	0.05	0.075
t2 (m)	0.05	0.05	0.05	0.05	0.075
t3 (m)	0.025	0.025	0.025	0.025	0.04
I (m4)	0.007756	0.010108	0.01281	0.015875	0.030001
Mass/m (kg/m)	529.875	549.5	569.125	588.75	977.325

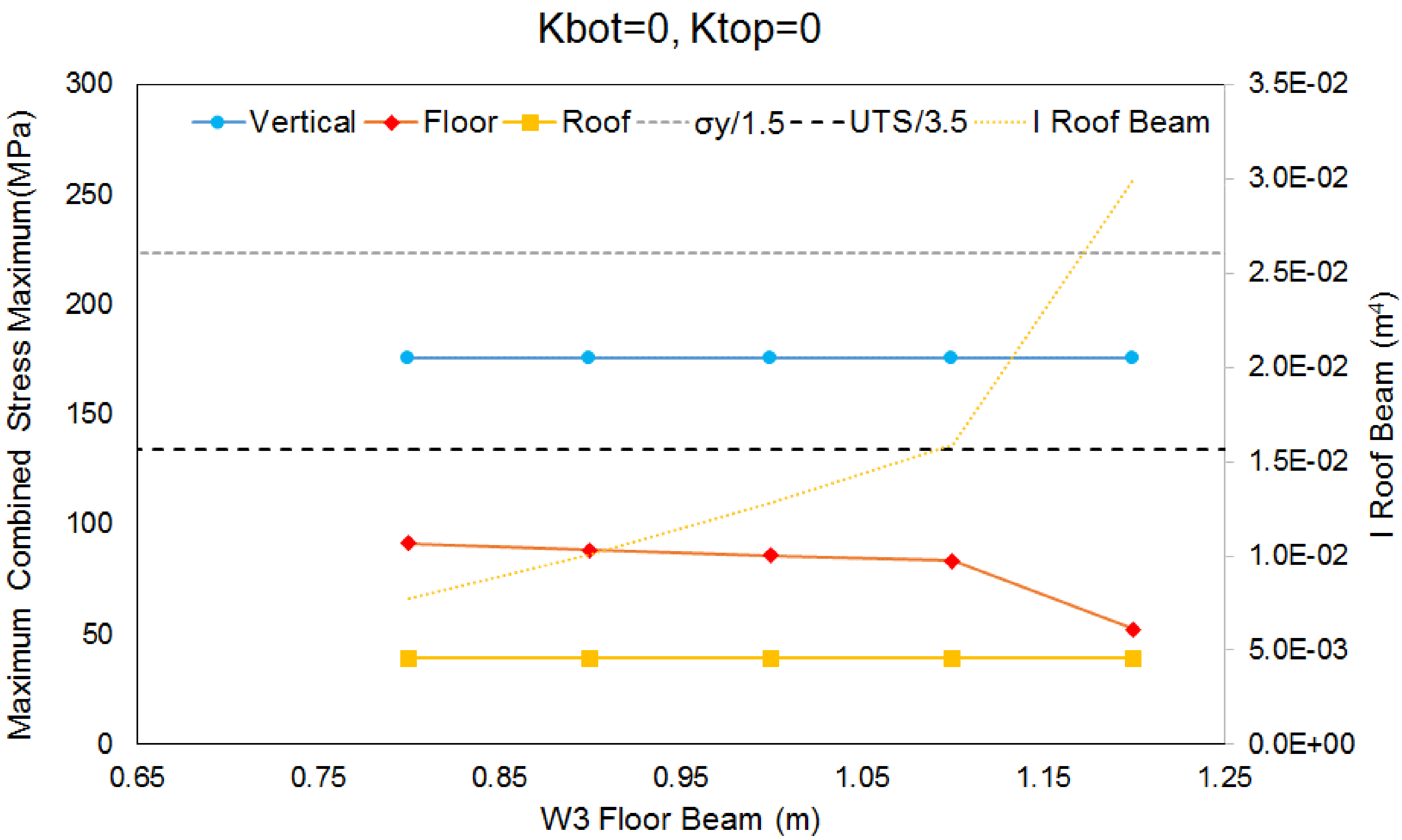
- Initially S355 is considered



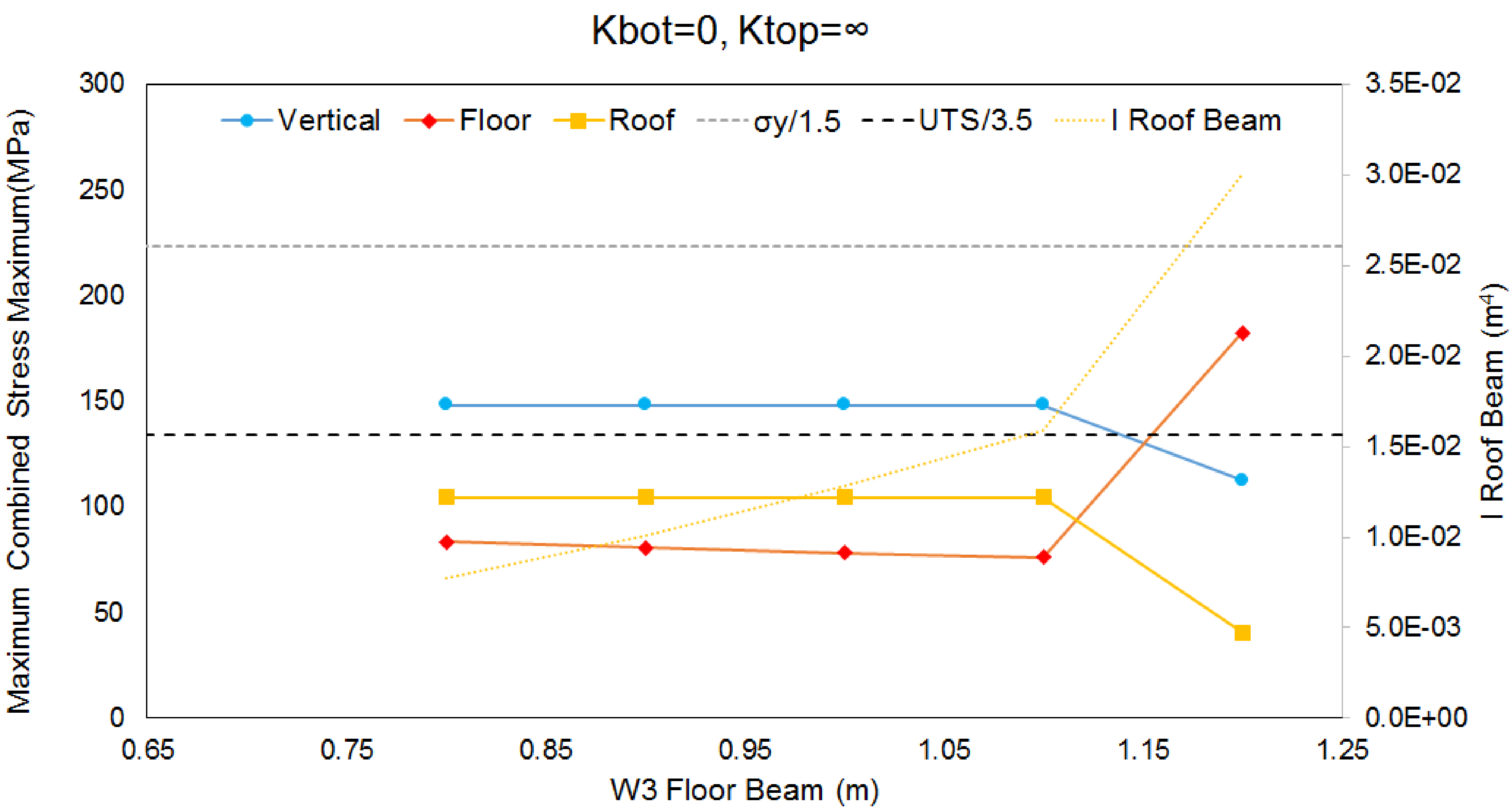
Small Floor Beam: Perfect Moment Connections



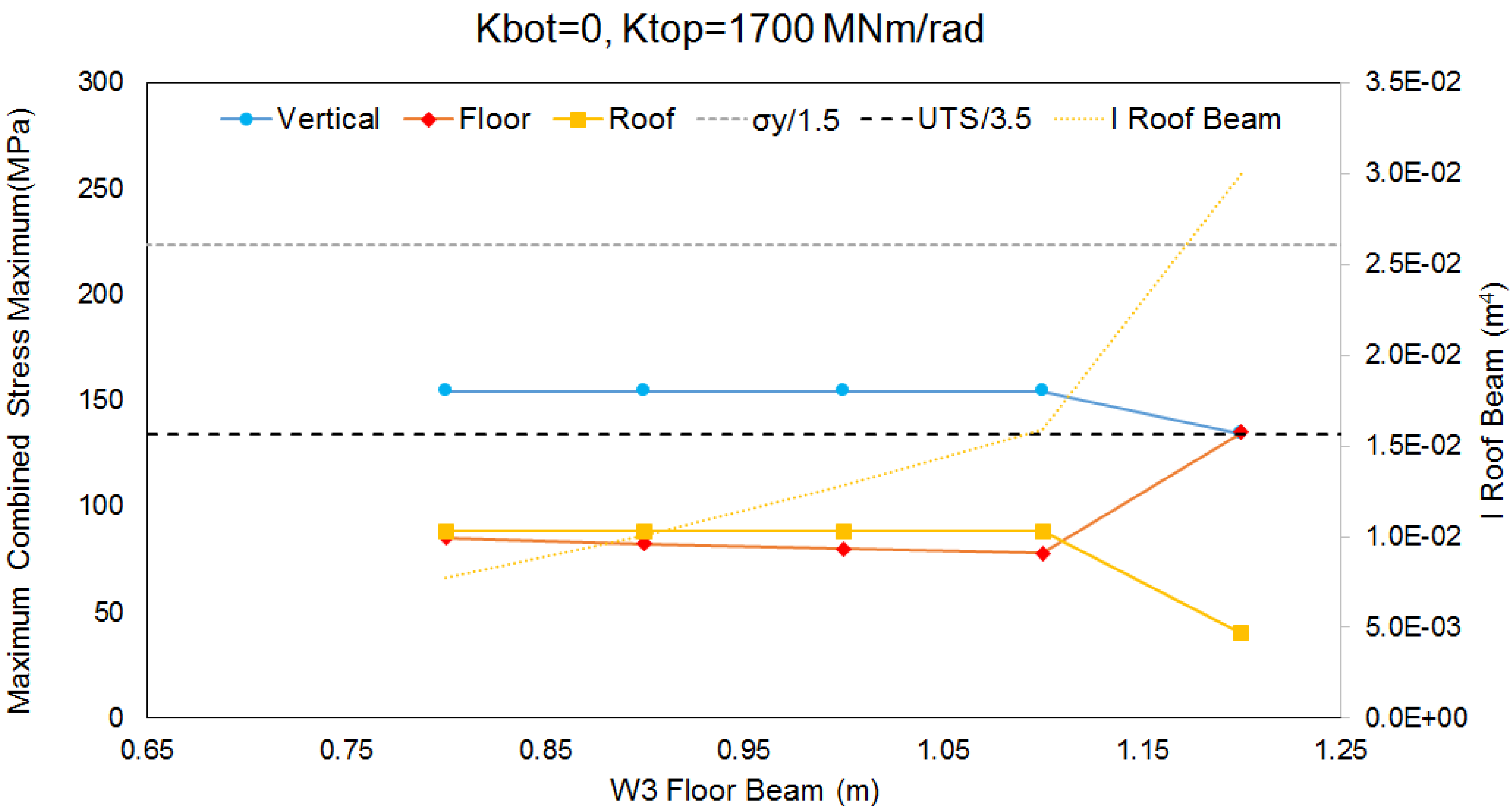
Small Floor Beam: Pinned Connections



Small Floor Beam: K_{bot}=0, K_{top}=∞

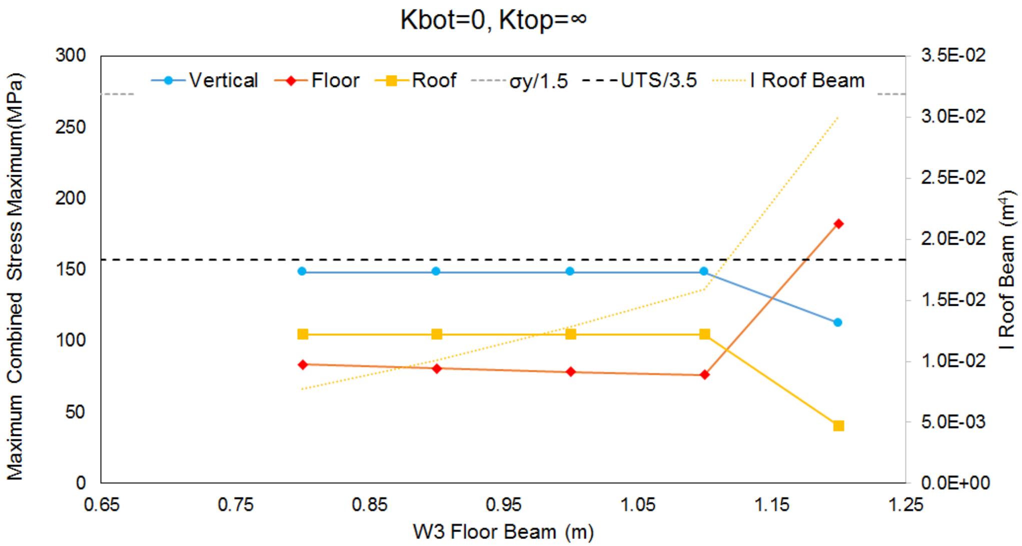


Small Roof Beam: K_{bot}=0, K_{top}=1700 MNm/rad

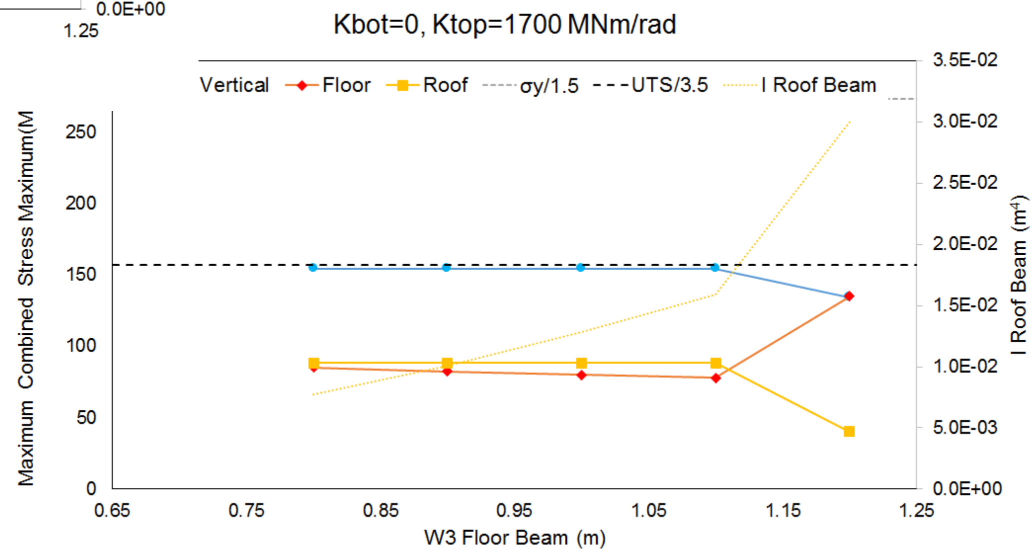


Change is Steel Grade?

- Small Improvements by moving to S450 (EC properties for t>40mm):
  - σ_y=410 MPa $\rightarrow$ σ_y/1.5=273.3 MPa
  - UTS=550 MPa $\rightarrow$ UTS/3.5=157 MPa



Moment connection at the top and a pinned joint at the bottom could work, but just marginally.



Summary

- Initial FEA results suggest that the stresses in the main frame would make it difficult to reduce the size of the roof beam substantially.
  - This is even worse taking into account that the nominal loads were considered for the previous analysis
  - Moving to higher grade steels (e.g. S450 instead S355) should make things a bit easier

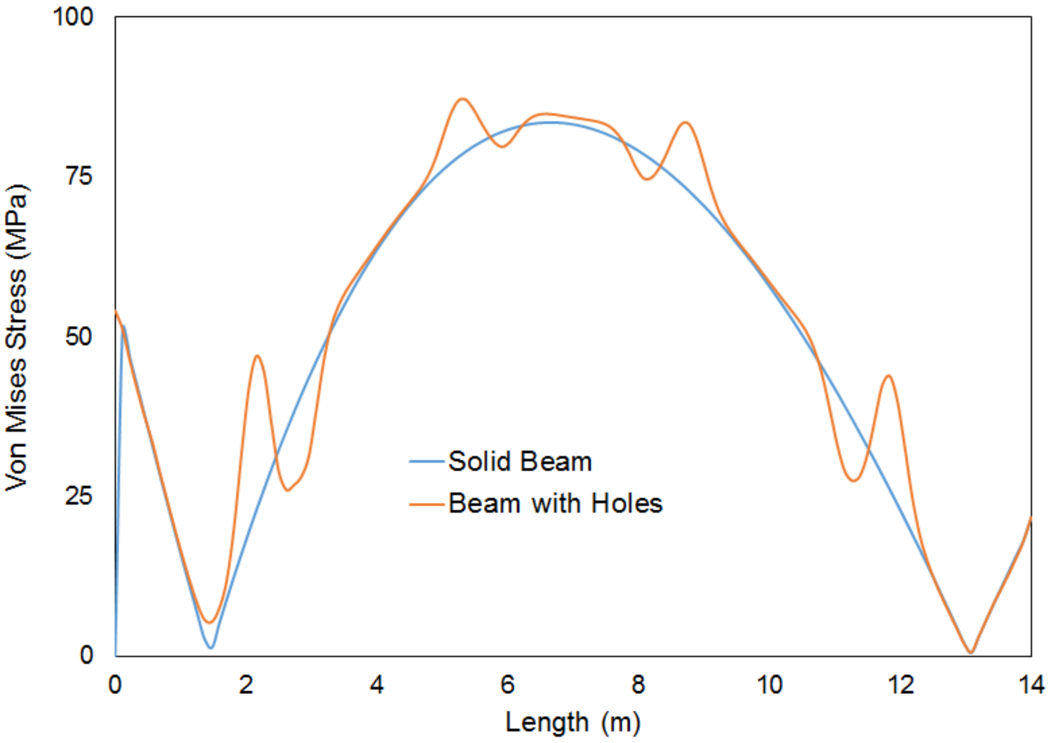
- Moving to a hinged connection at the top also seems difficult (even for the baseline configuration).

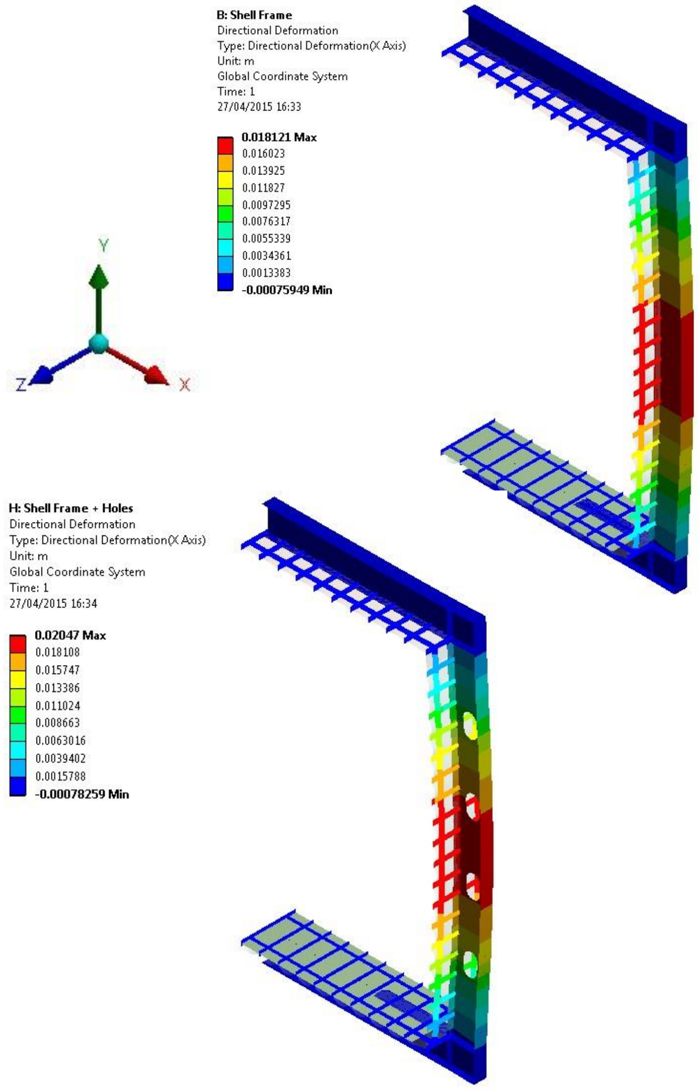
- Reducing the dimensions of the floor beam also seems very problematic (with the vertical beam becoming the critical element).

- From a mass standpoint, a truss structure would appear a much more suitable solution for the main frame.

Note: Access Holes in the Vertical Beams

- The holes to be included in the web of the vertical beams for access purposes were neglected in the previous analysis.

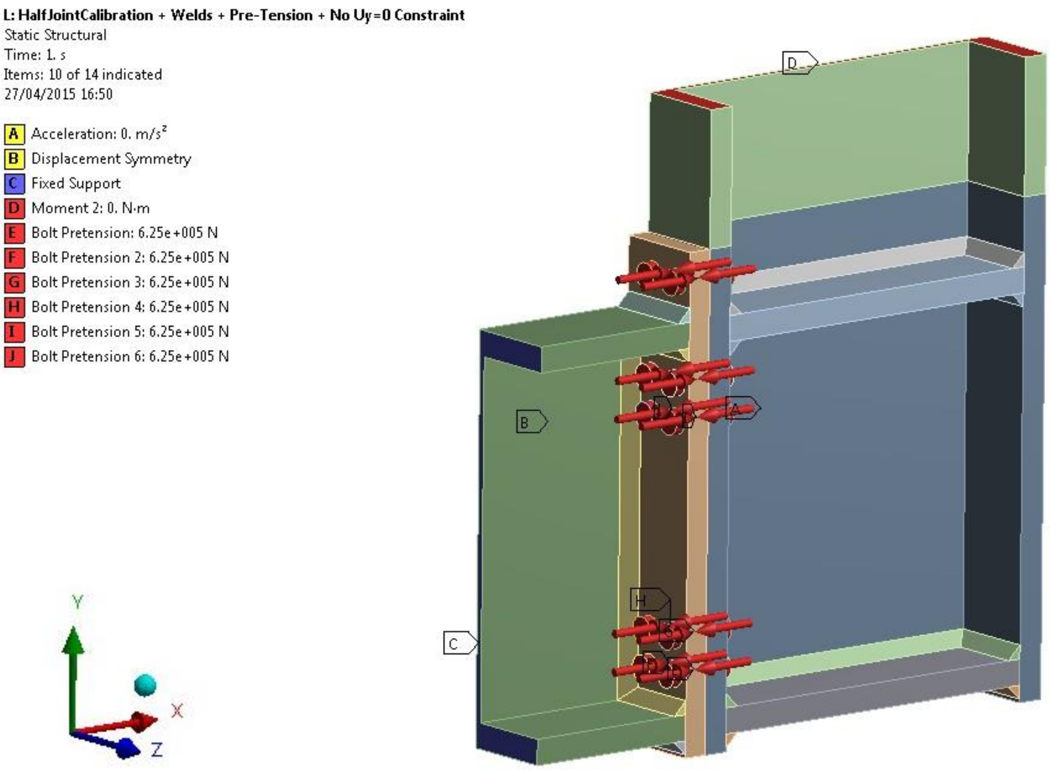




FEA of Moment Connection

Moment Connection: FEA Model Details

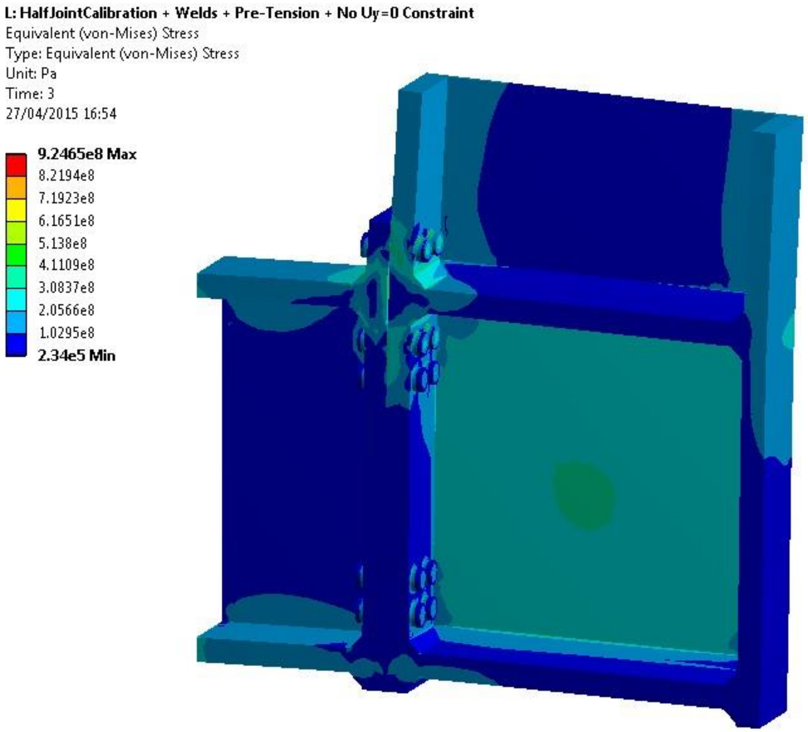
- Half Joint (each beam extending 0.6m from intersection)
  - M48 x 10 bolts with pre-tension (625kN)
  - Frictional contacts (μ=0.25)
  - Welds (40mm)
  - Non-linear materials (S355 for beams, 10.9 for bolts)

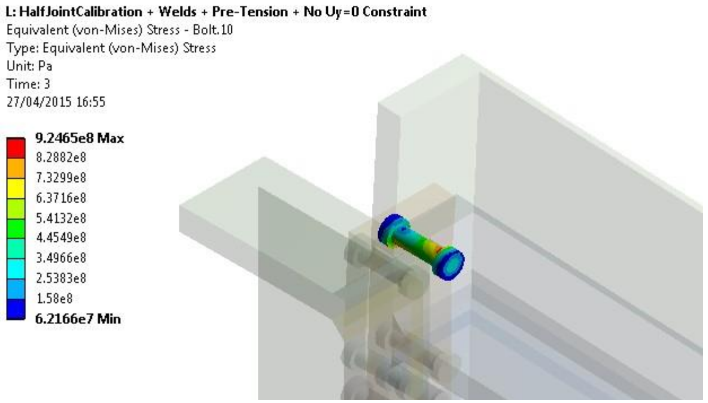


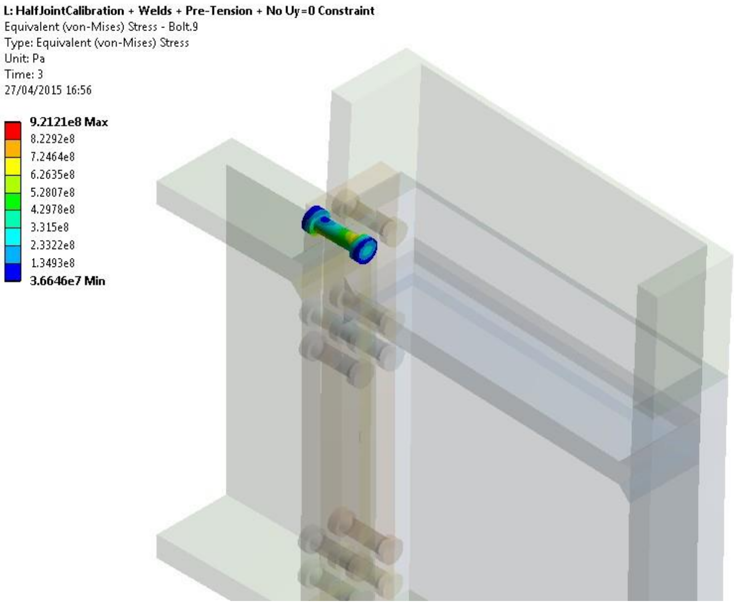
- Stiffness as a function of the applied moment?

Moment Connection: FEA Model Results

- For applied moment M=8MNm







- K=1600-2100 MNm/rad (depending on corner support