Investigation of the Overload Response of Flatbars to Ice Loads

International Conference on Ships and Offshore Structures
Hamburg, Germany
31 August – 2 September 2016

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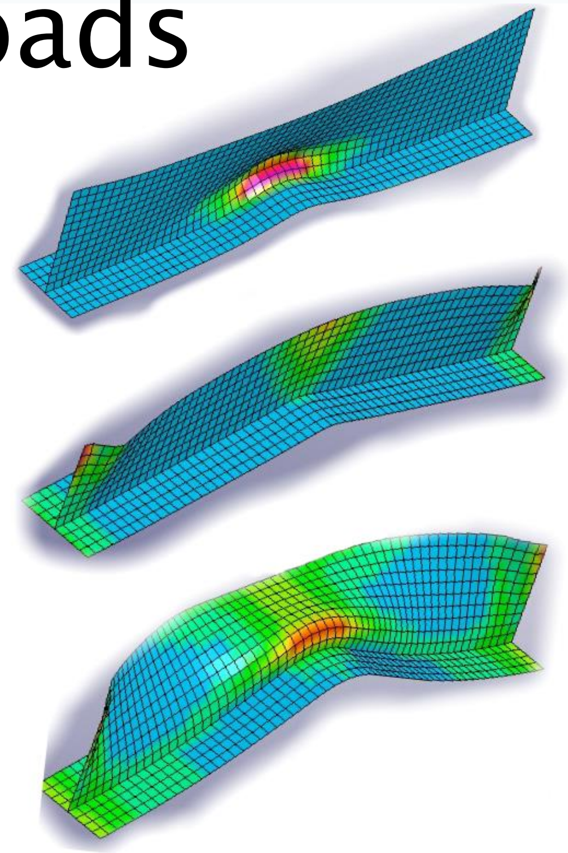
Presented By
Katherine Daley

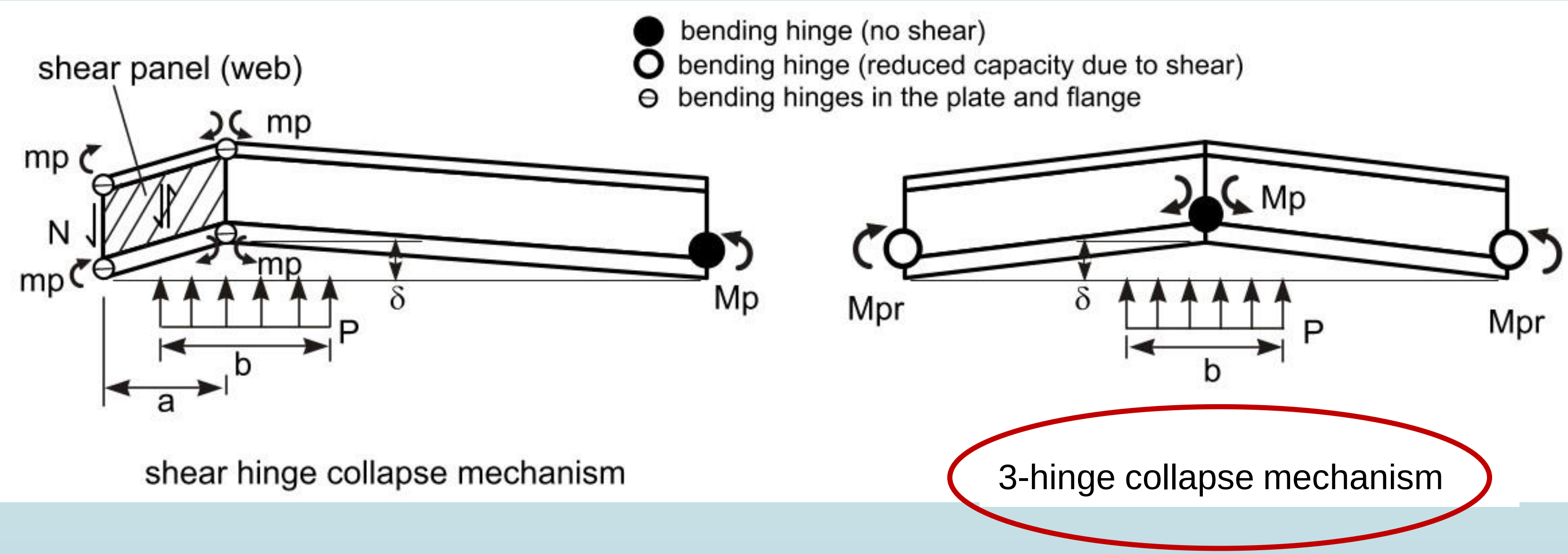


Background

- IACS Polar Class Rules check a plastic limit state that is the onset of significant deformation
- Intention of PC rules was to improve overload performance without specifically requiring an overload check

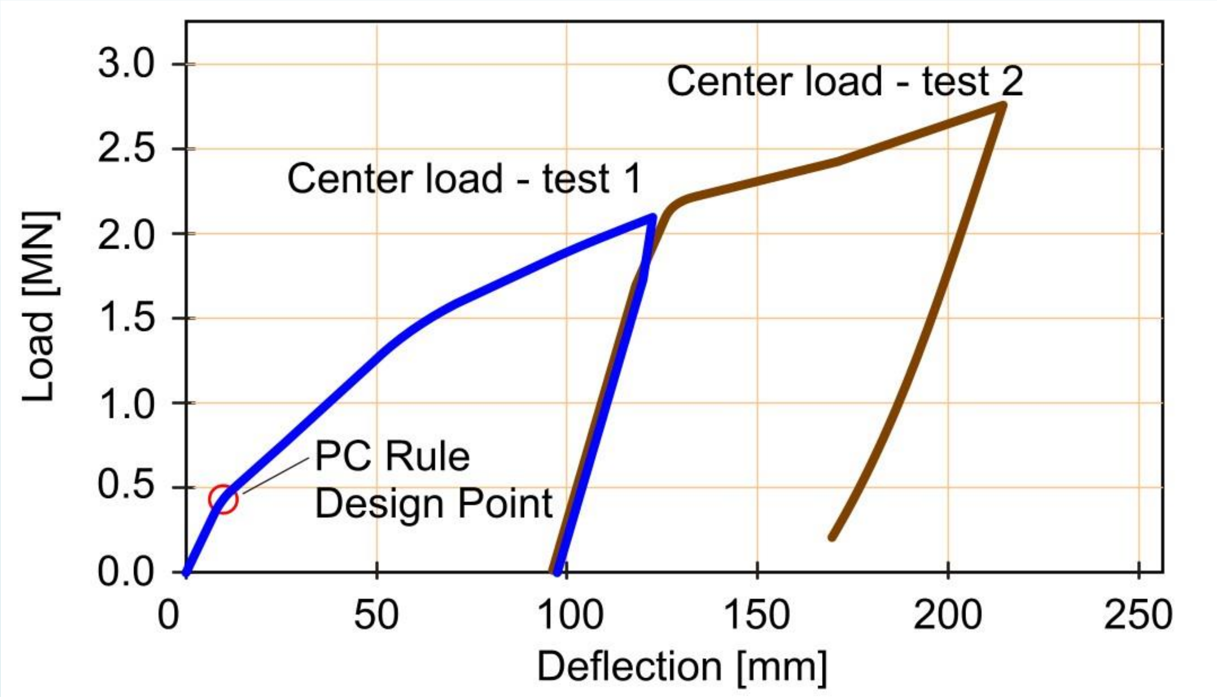
Background

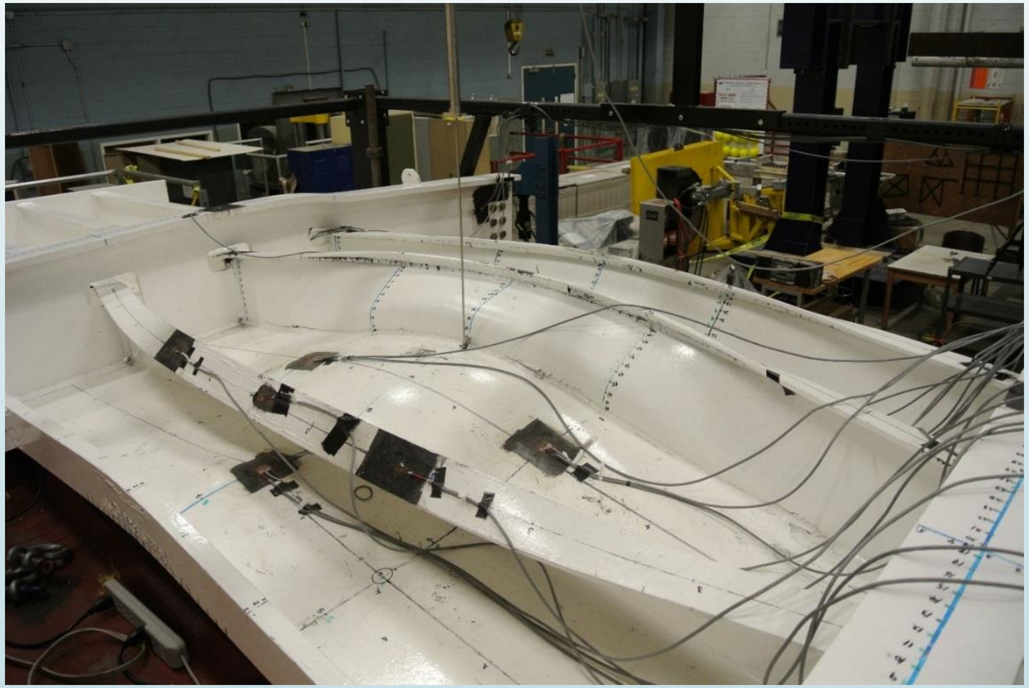
- A method of evaluating overload capacity will lead eventually to rules that make sure that we have good initial and overload capacity
- Encourage better design – not necessarily at more cost



Background

- We know that significant overload capacity can often be achieved but we don't know why

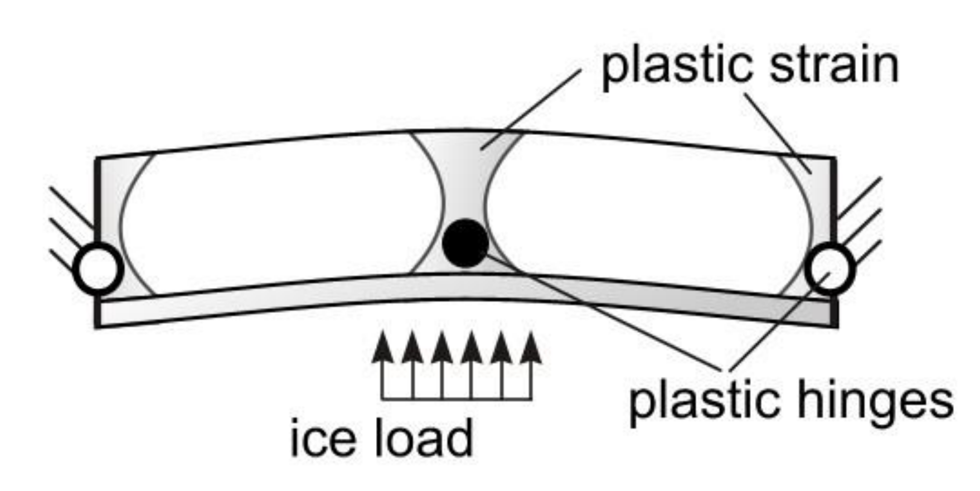


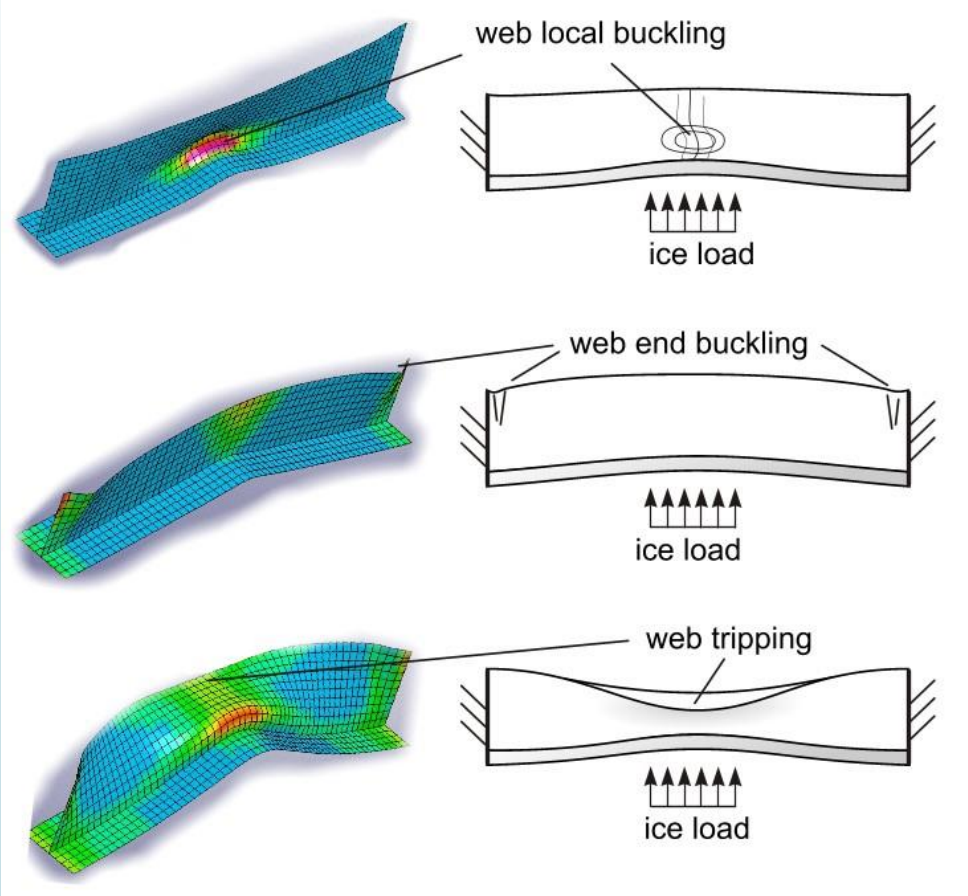


Kim, H., (2014), "An Experimental Study of the Overload Capacity of Grillages Subject To Ice Loads"

Aims

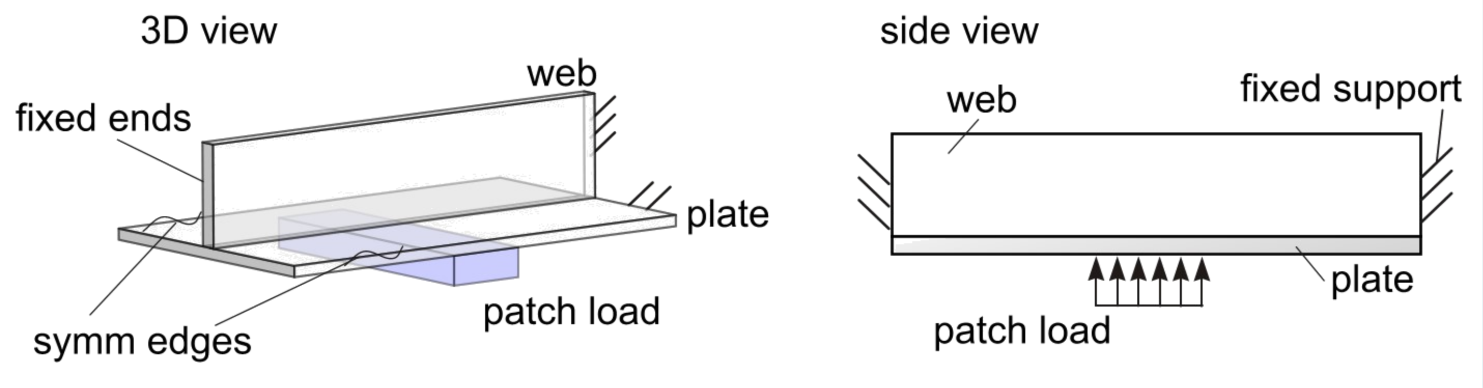
- Explore the overload capacity of flatbar frames as one step towards a general improvement in overload design
  - Nature of overload behaviour
  - Modelling techniques (LS-DYNA)





Standard Load Application Methods:

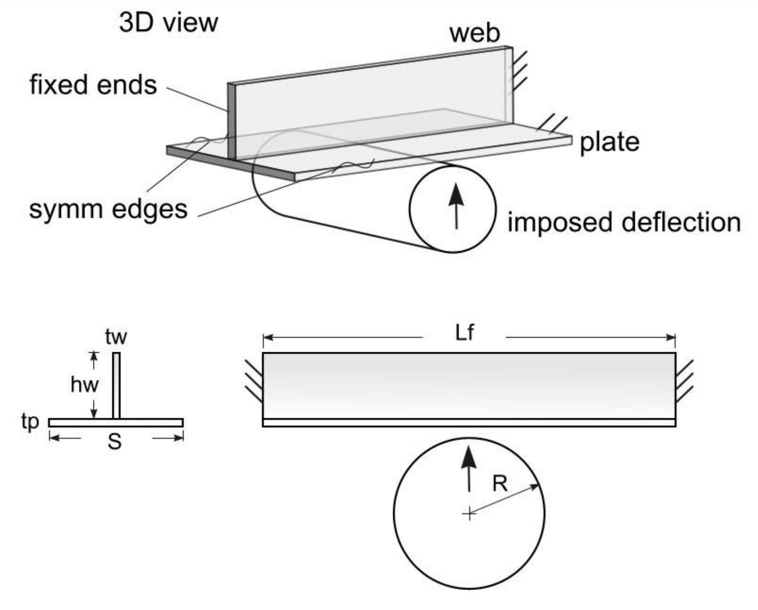
- IACS Polar Rules used rectangular design load patch with a uniform pressure
  - Does not account for change in force once the elasto-plastic buckling mechanism is formed

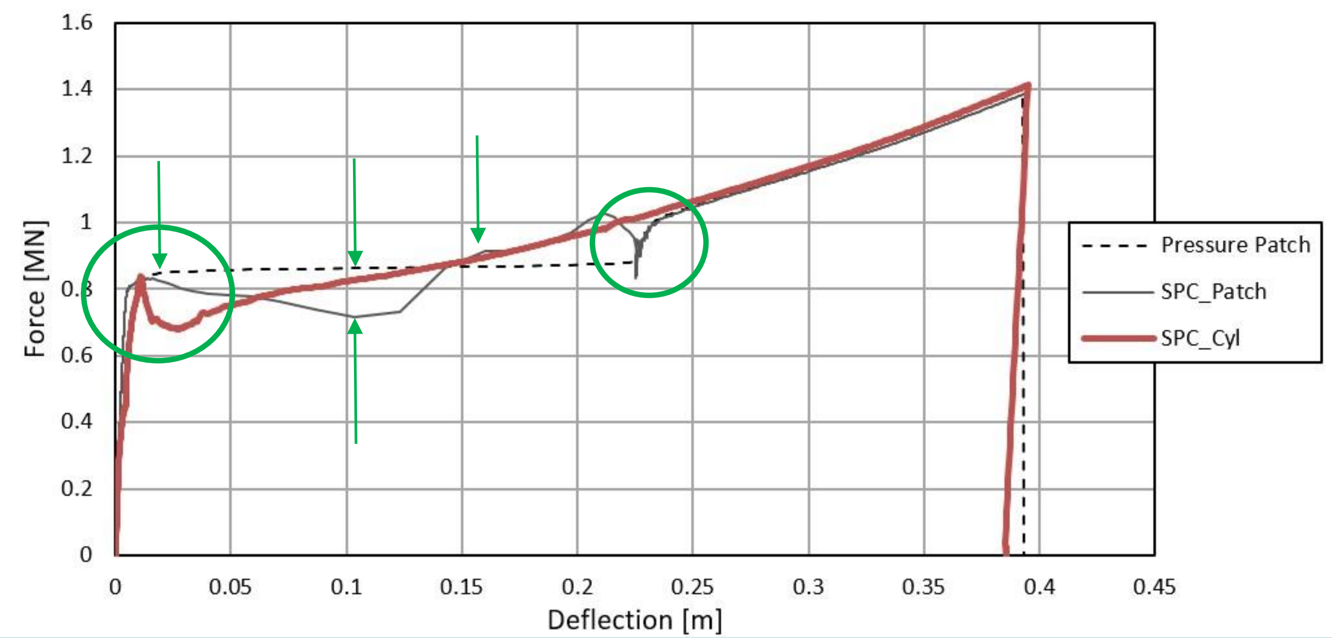


- Accurate modelling of ice material is dependent on many factors, very complicated analysis

Proposed Load Application Method:

- Imposed deflection with cylindrical rigid object

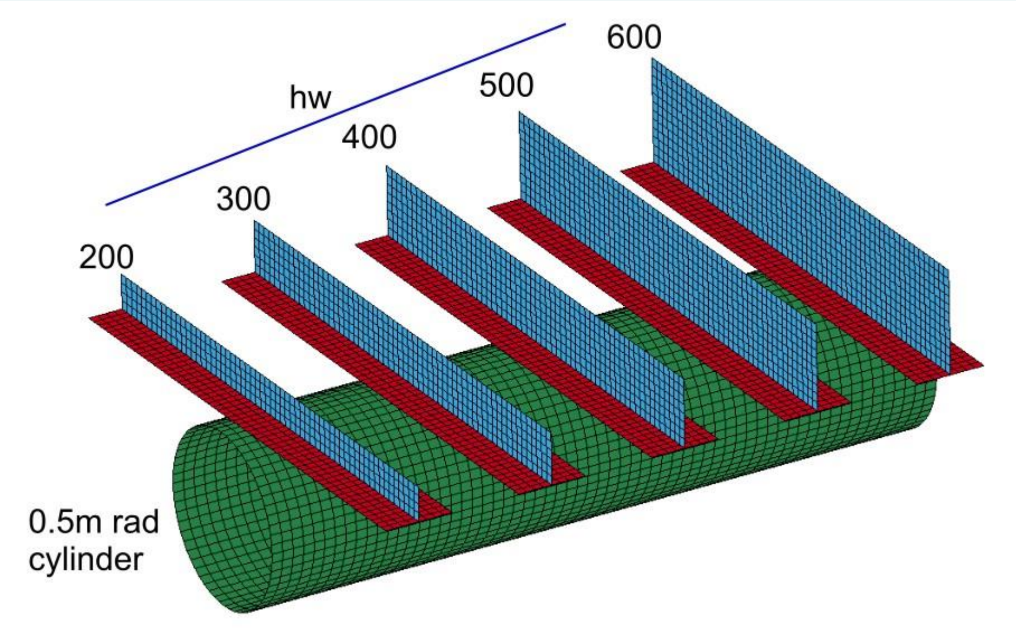




- Response stays quasi-static, stress concentrations at the edge of the loaded region are avoided
  - Allows for a consistent representation of the overload behavior

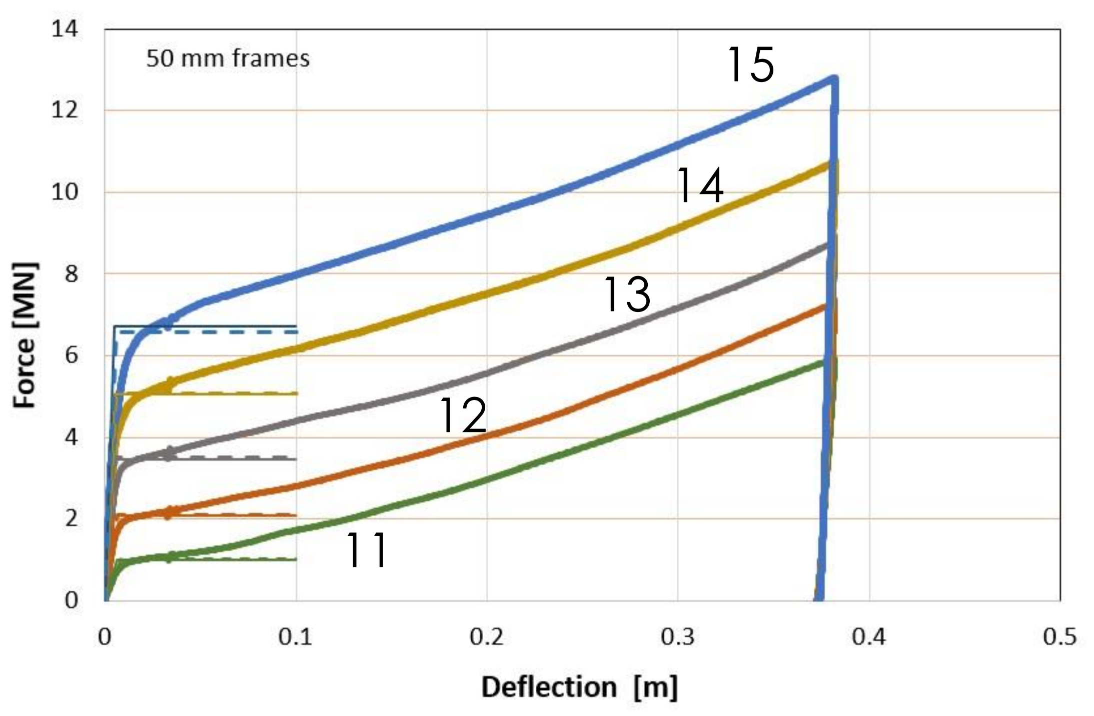
Inputs

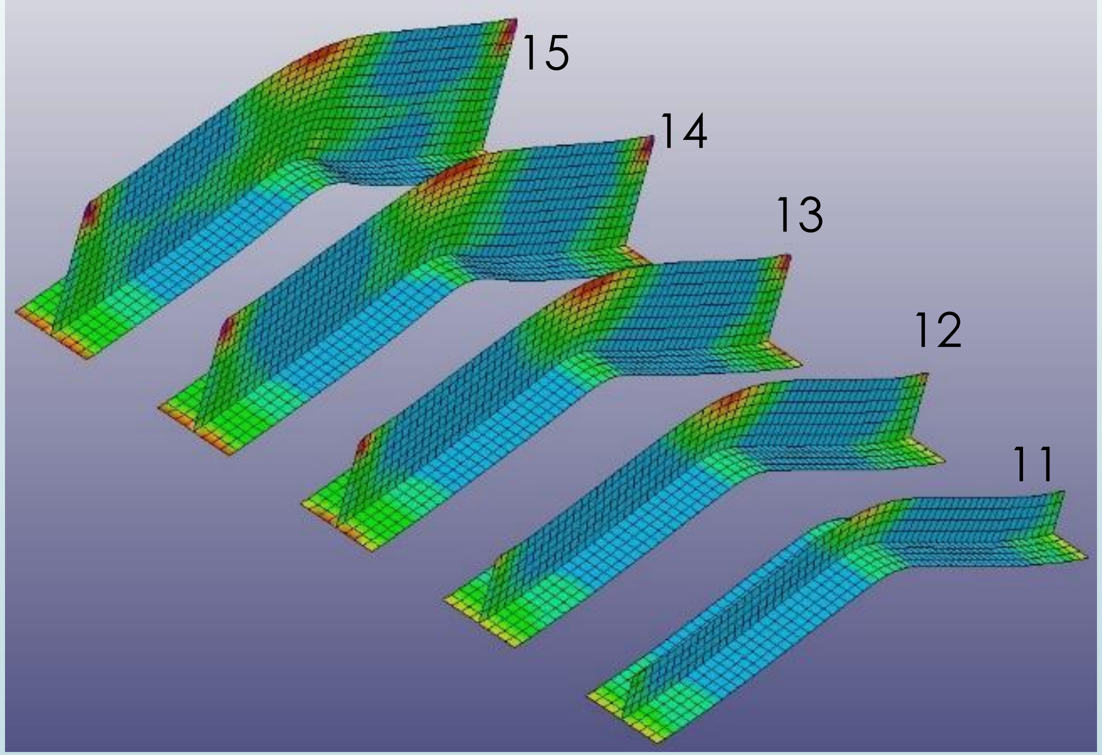
- Initial set (15 cases) - 3 metre long frame
  - Web height: 200 – 600 mm
  - Web and plate thicknesses: 10mm, 20mm, 50mm
  - Frame spacing: 400 mm
  - Imposed deflection of 0.4 m

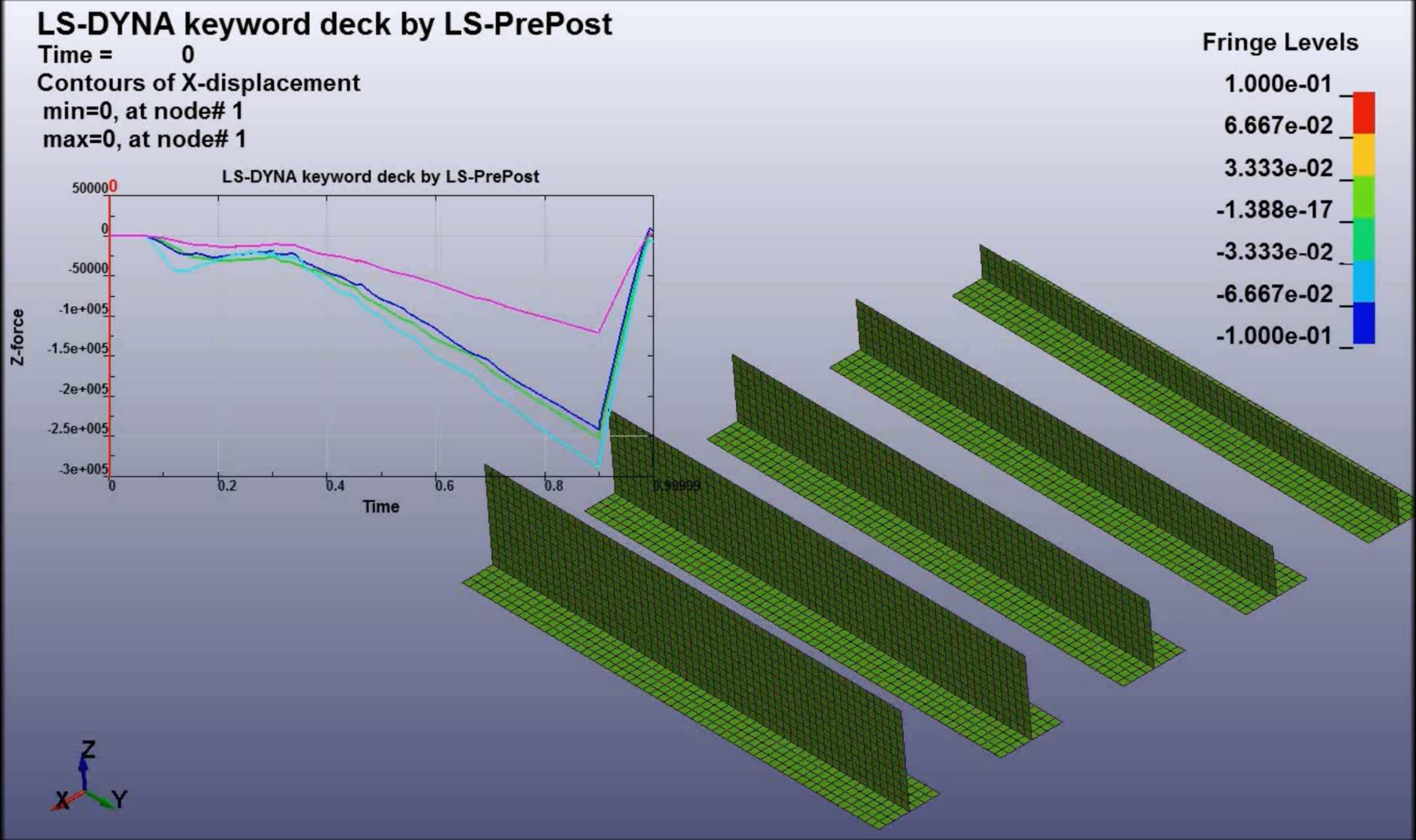


Results

- Initial set - 50 mm thick plate (3 metre frame)
  - Stable bending behaviour
  - Large overload capacity



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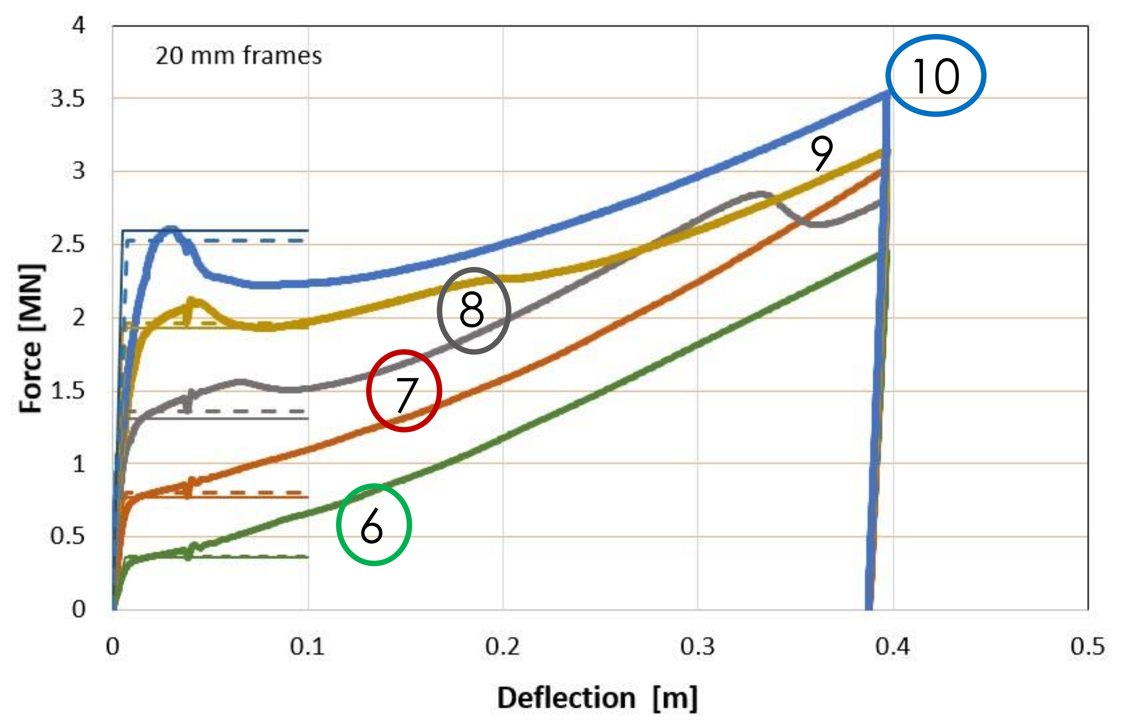
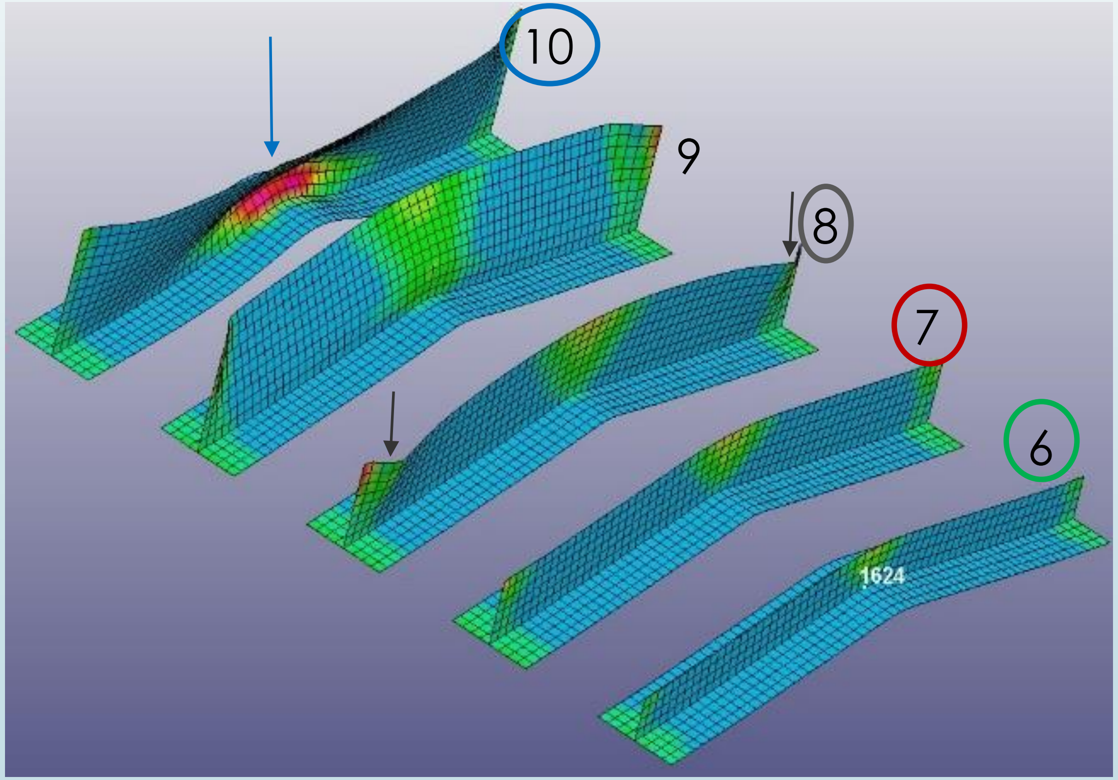
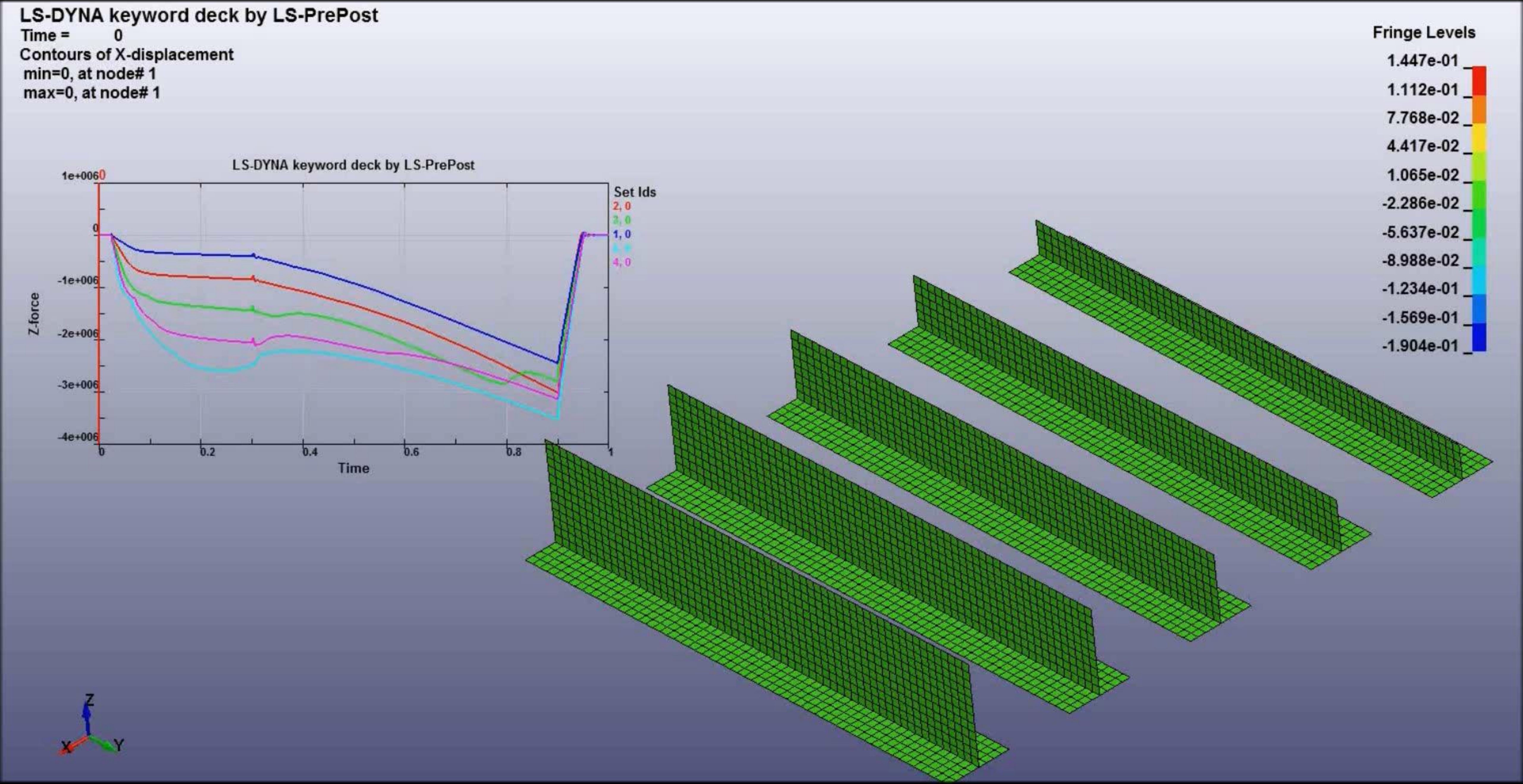
3.333e-02
-1.388e-17
-3.333e-02
-6.667e-02
-1.000e-01
LS-DYNA keyword deck by LS-PrePost
Z-force
500000
0
-50000
-1e+005
-1.5e+005
-2e+005
-2.5e+005
-3e+005
0
0.2
0.4
0.6
0.8
0.99999
Time
Z
X
Y

Results

- Initial set - 20 mm (3 metre frame)
  - Taller frames start to exhibit buckling
  - Overload capacity is similar for all frames



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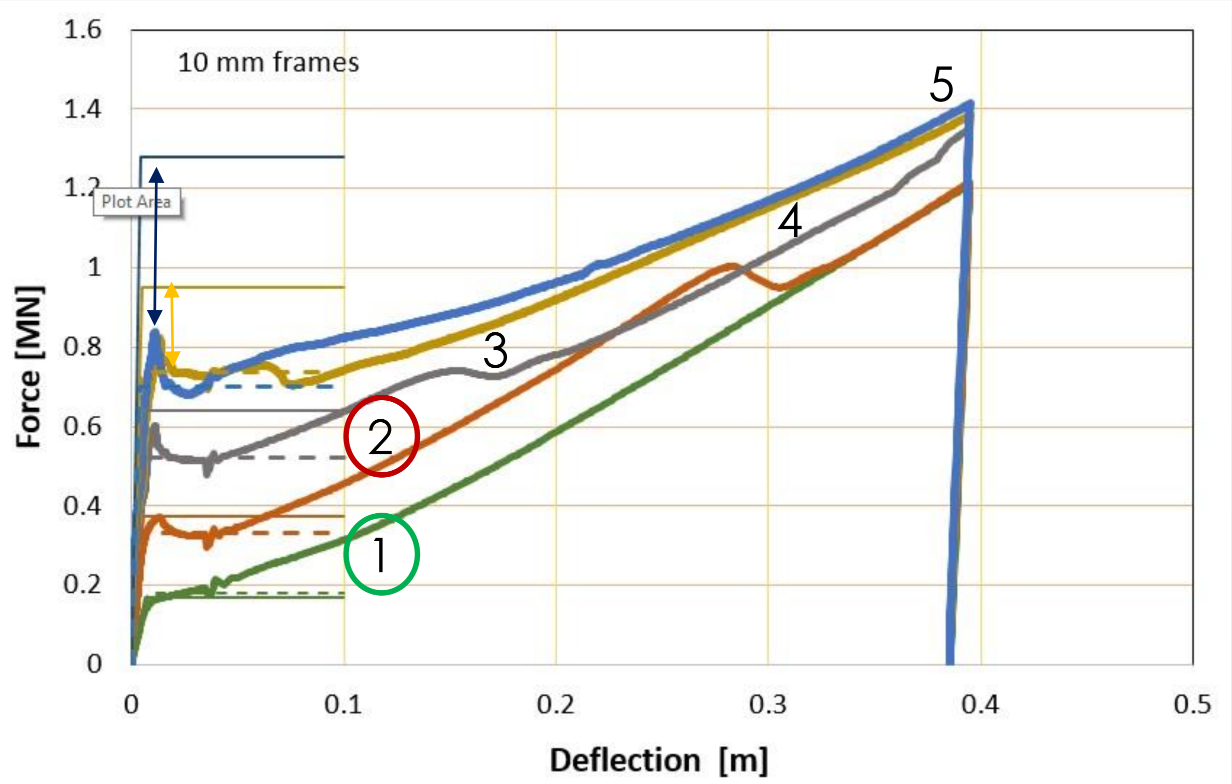
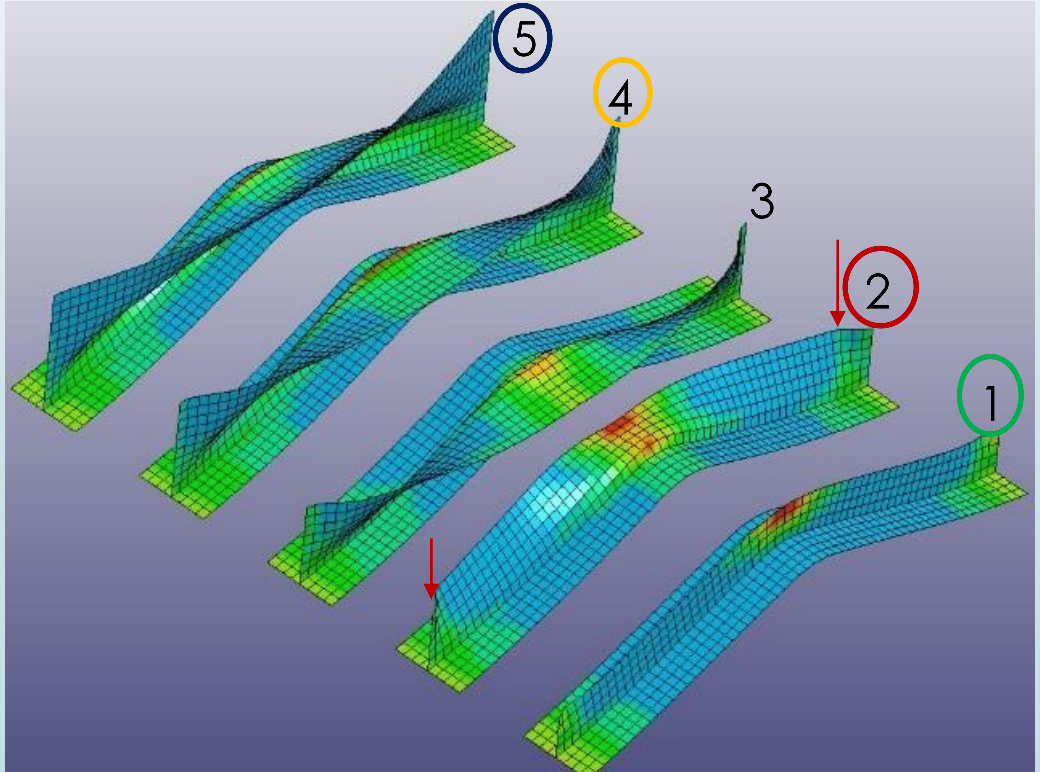
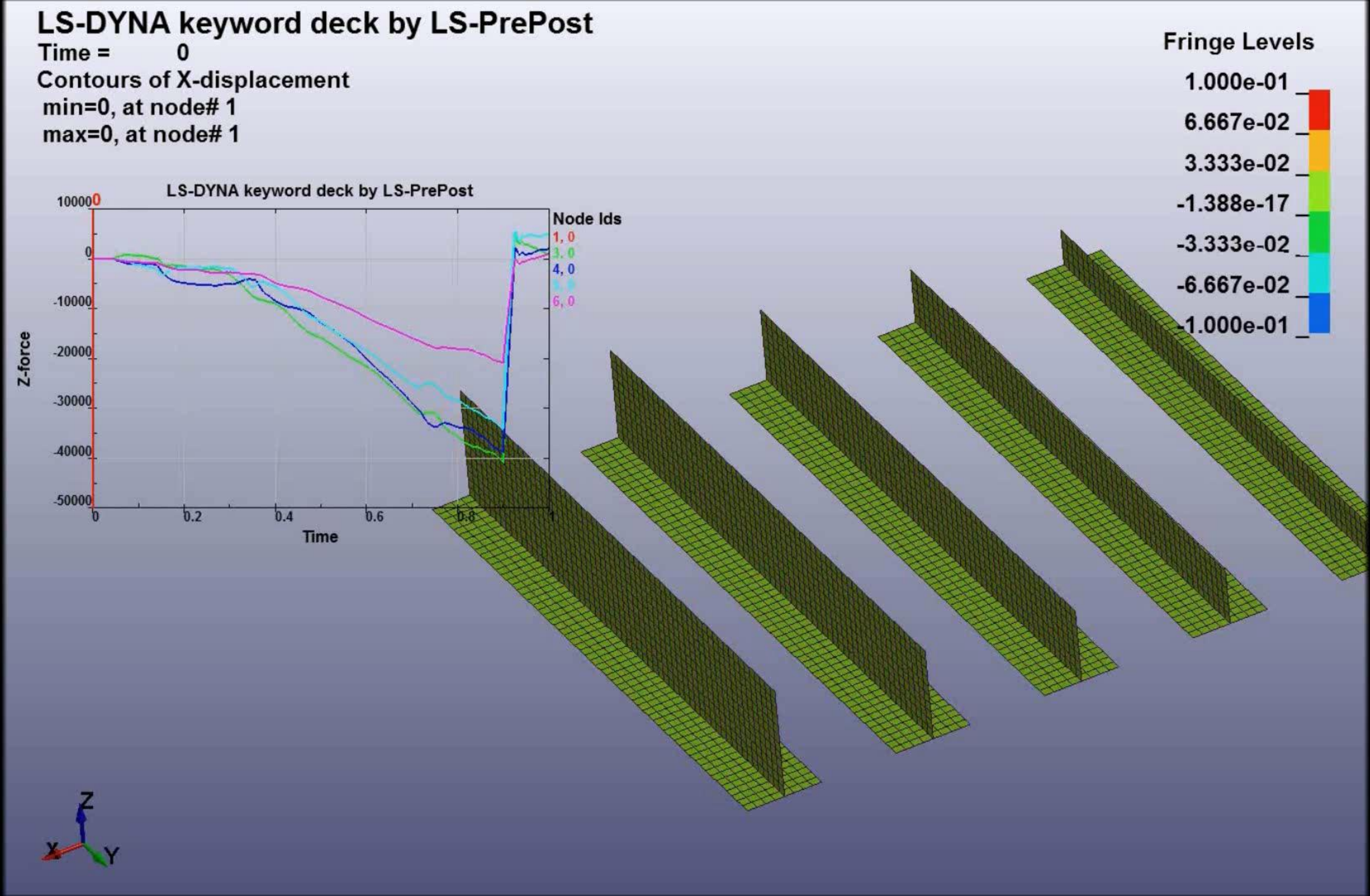
-5.637e-02
-8.988e-02
-1.234e-01
-1.569e-01
-1.904e-01
LS-DYNA keyword deck by LS-PrePost
1e+006
0
-1e+006
-2e+006
-3e+006
-4e+006
Z-force
0
0.2
0.4
0.6
0.8
1
Time
Set Ids
2, 0
3, 0
1, 0
4, 0
Z
X
Y

Results

- Initial set - 10 mm (3 metre frame)
  - Only shortest frame is stable
  - End buckling, local bucking, overall folding increase as frames become more and more slender






LS-DYNA keyword deck by LS-PrePost
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Contours of X-displacement
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max=0, at node# 1
Fringe Levels
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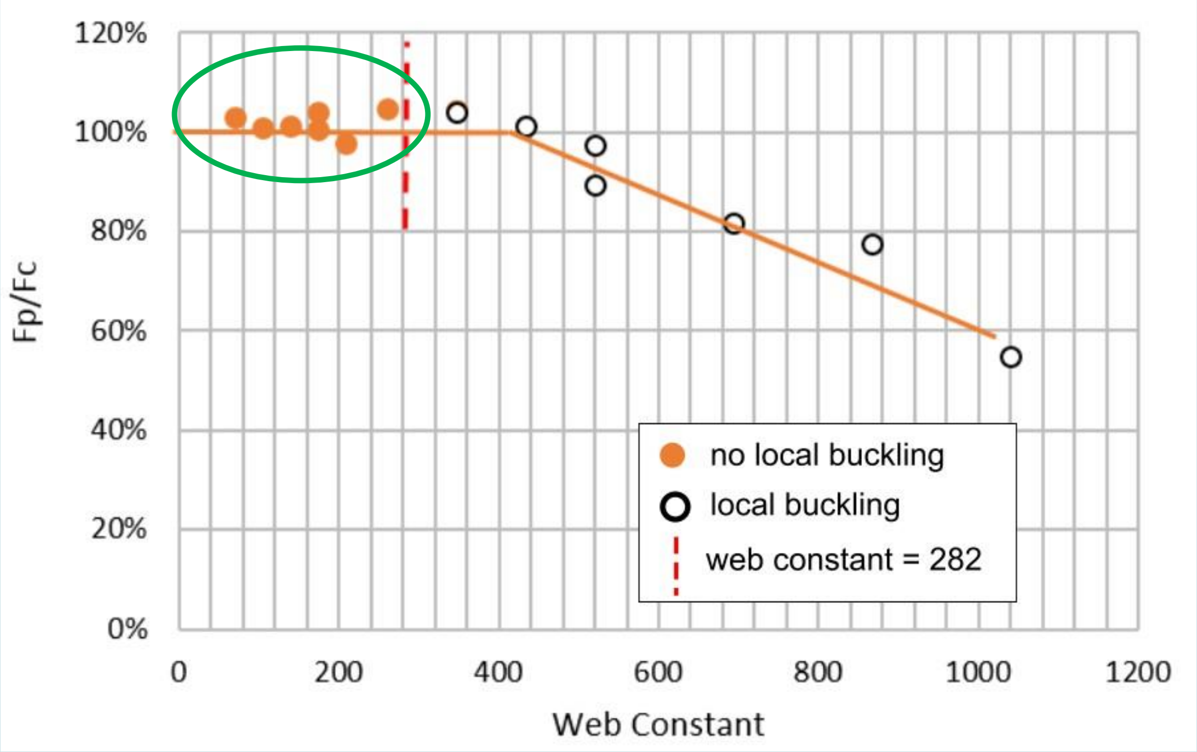
6.667e-02
3.333e-02
-1.388e-17
-3.333e-02
-6.667e-02
-1.000e-01
LS-DYNA keyword deck by LS-PrePost
Z-force
Time
Node Ids
1, 0
3, 0
4, 0
6, 0
10000
0
-10000
-20000
-30000
-40000
-50000
0
0.2
0.4
0.6
0.8
1
Z
X
Y

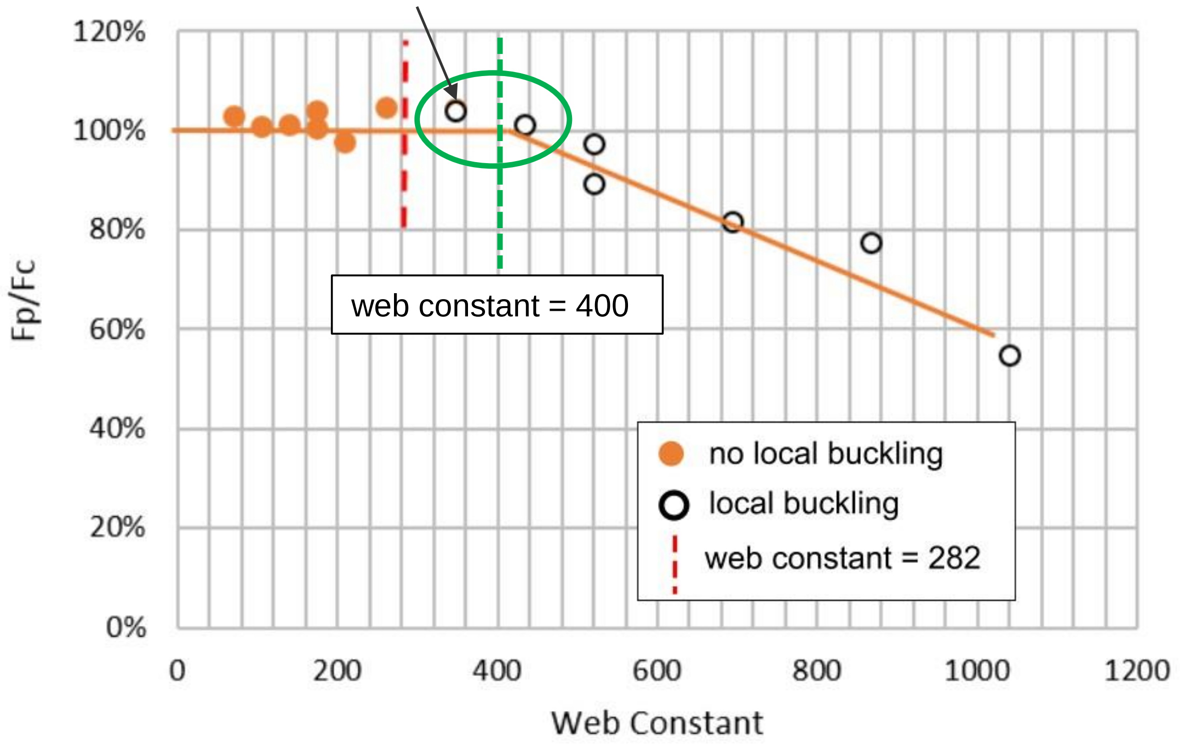
Analysis

- Web Constant = $\frac{hw}{tw}\sqrt{\sigma_y}$
  - only frames with Web Constant below 282 (Polar Rules) are able to avoid the local buckling that causes a temporary loss of capacity



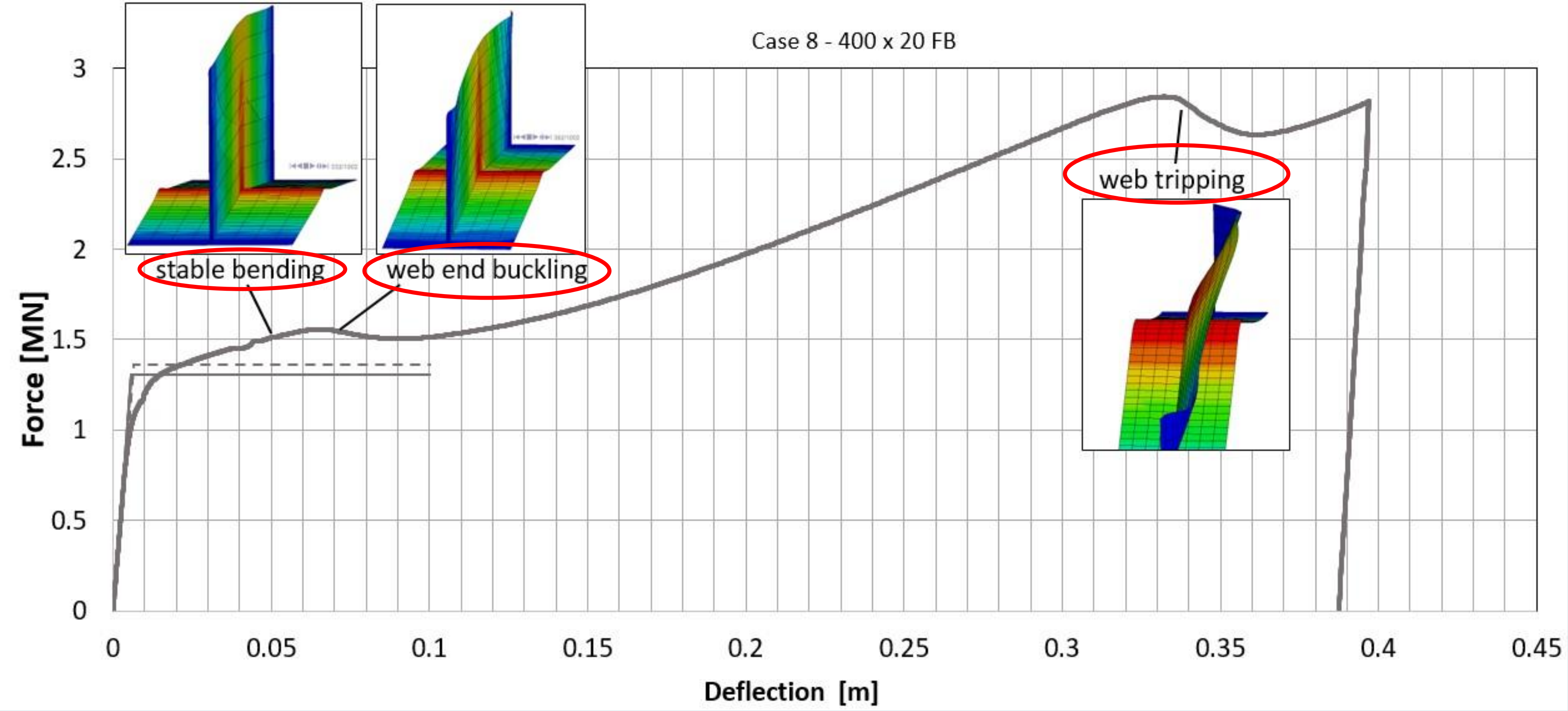
Analysis

- Web Constant of up to 433 are capable of developing the full nominal bending capacity
  - Polar Rules may be too conservative
  - Boundary conditions may effect buckling



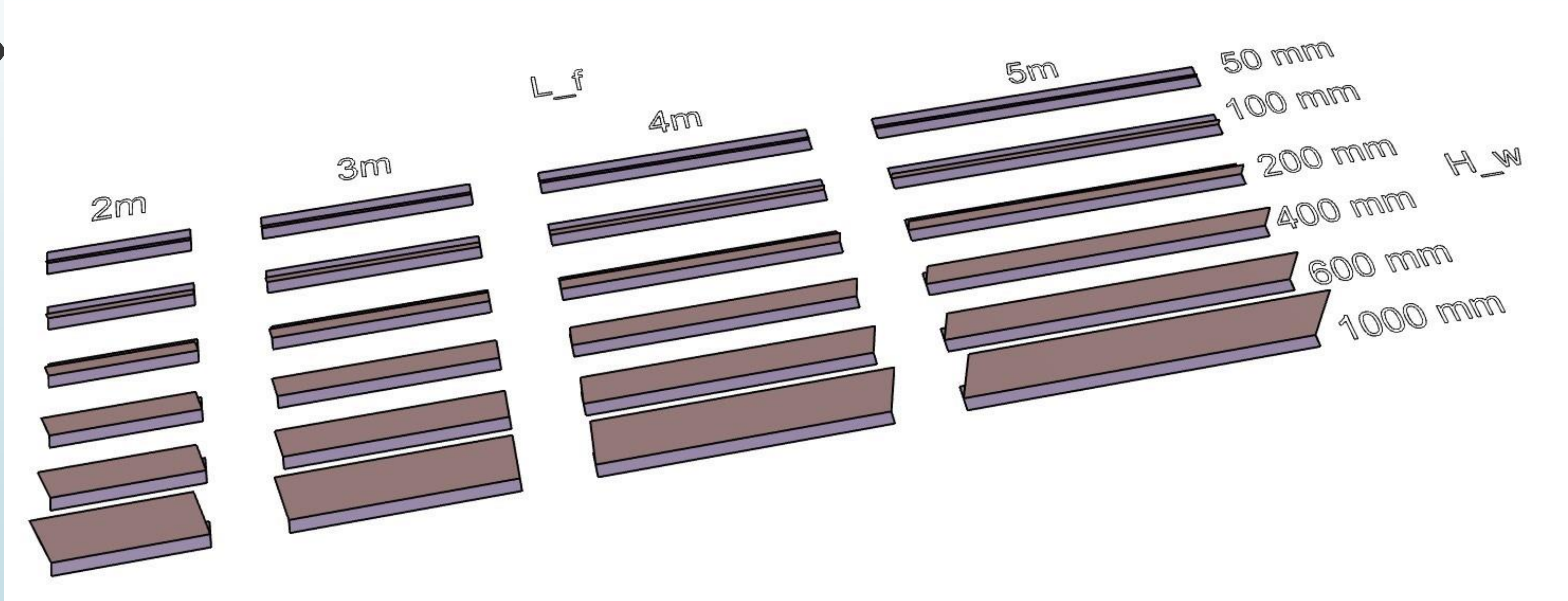
Analysis

- Multiple instability mechanisms



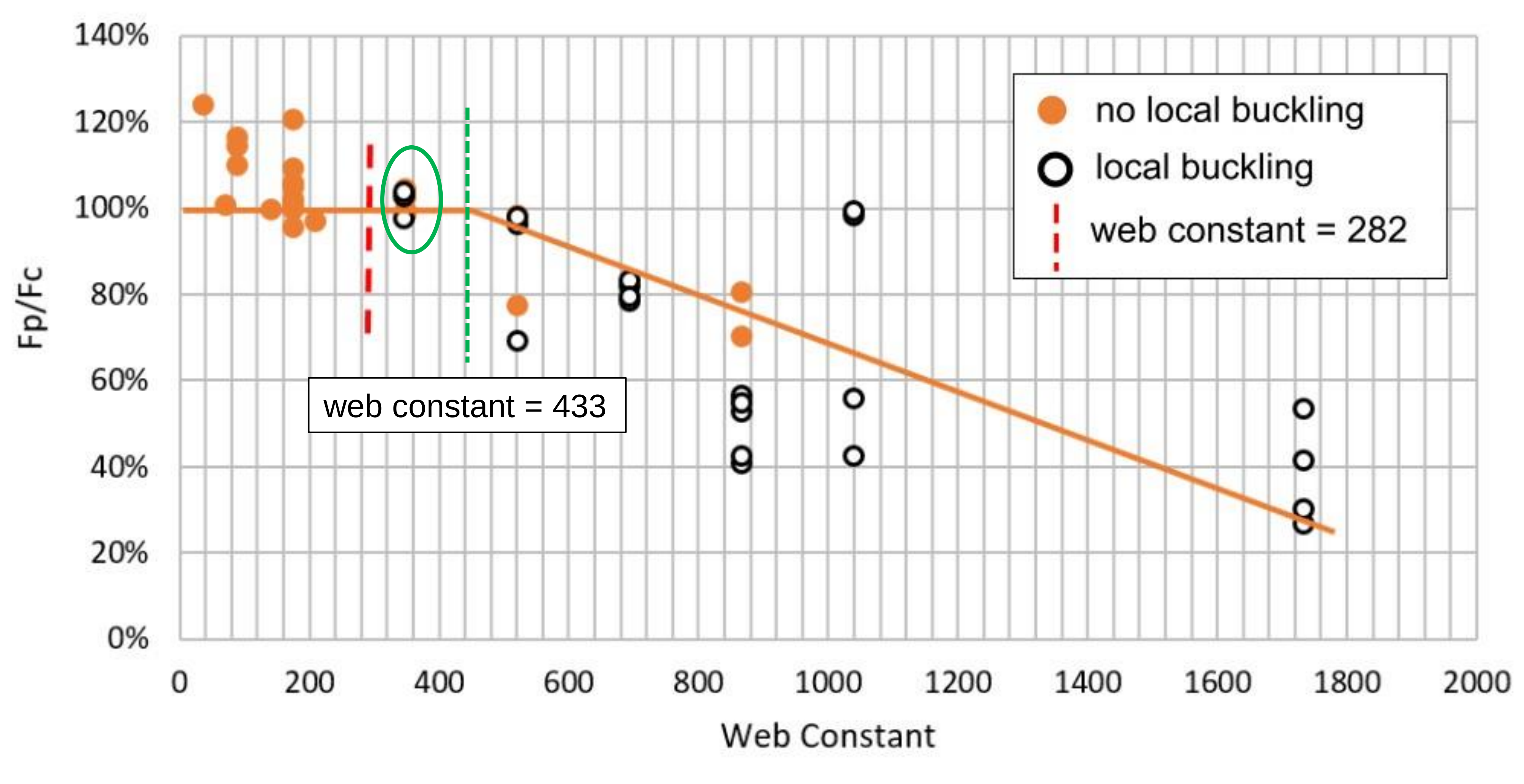
Additional Inputs

- 72 frame matrix
  - Further exploration and confirmation of previous results



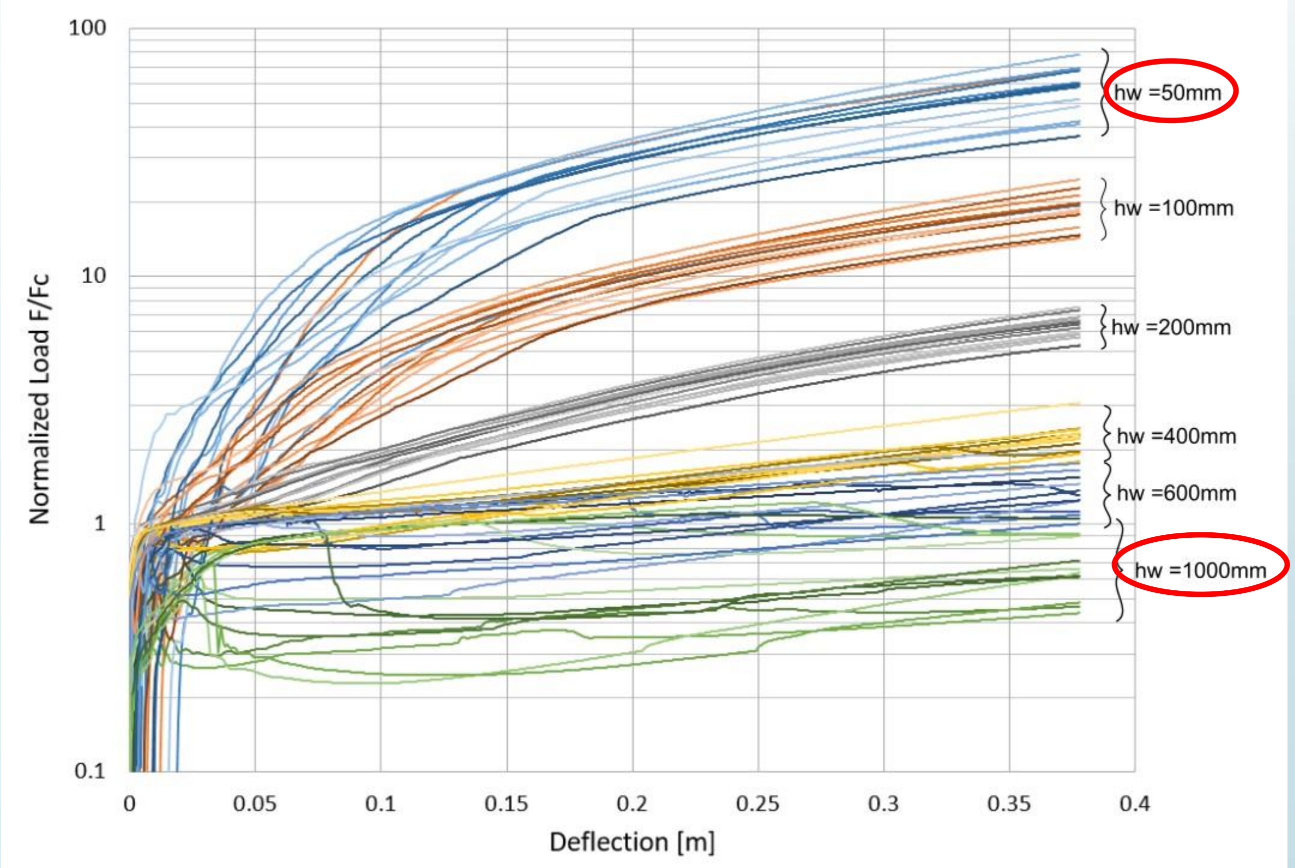
Analysis

- 72 frame normalized force vs web constant



Analysis

- 72 frame force vs deflection curve
  - The taller the web, the greater the initial capacity but less reserve



Conclusions and Future Work

- By using a cylinder to impose the deflection, we avoid stress concentrations at the edge of the loaded region
  - Simple and repeatable
- The web constant of 282 used in the Polar rules has the effect of ensuring stable overload behavior for flatbar frames
  - A value such as 400 would allow for more efficient structure, more use of flatbars
- Overload response is a sequence of plastic mechanisms

Conclusions and Future Work

- As web height increases, the relative overload capacity falls - deep webs tend to exhibit out of plane plastic buckling (folding) mechanisms.
- Influence of factors can be explored:
  - asymmetrical loading, web tilt, and different frame shapes on the load and overload behaviour
- A study and development of overload capacity of large members would be a significant contribution to the safety of ice class vessels, especially those of low ice class

Thank You!

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