Stress-Laminated Timber Bridge Decks: Non-linear Effects in Ultimate and Serviceability Limit States

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Background

-SLTB decks are strong, easy to produce, easy to erect

-Large spans and widths are possible to construct

-Eurocode 5 should be used to determine appropiate thicknesses (in Europe that is)

-Eurocode 5 does not explicitly specify calculation methods

-nonlinear finite element calculations have shown that local slip and gaps between glulam beams may appear at relatively low loads

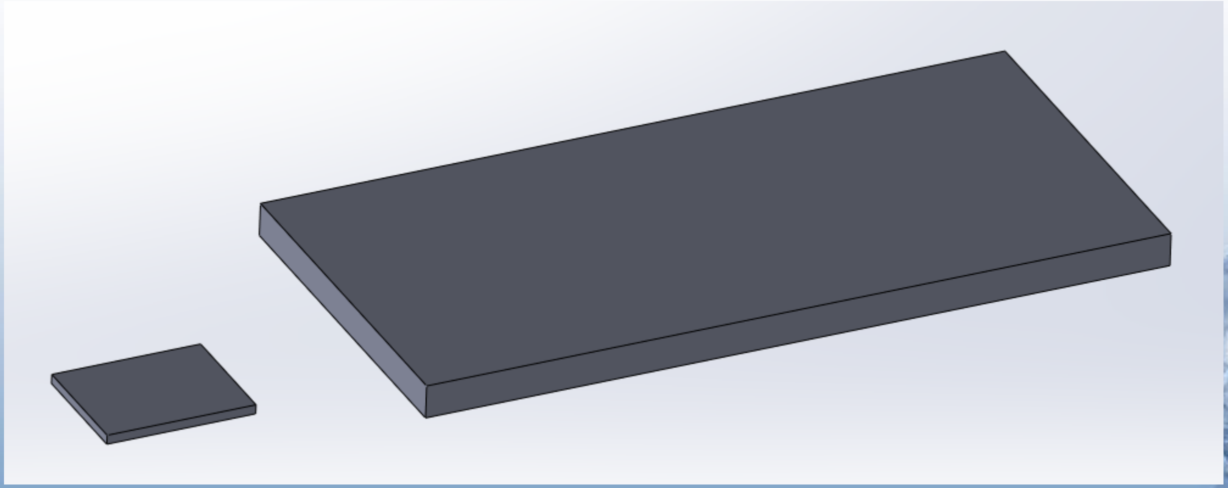
Ekevad M.; Jacobsson P.; Forsberg G. (2011). Slip between glulam beams in stress-laminated timber bridges: finite element model and full-scale destructive test. *Journal of Bridge Engineering* 16:188-196.

Research questions

- What are the differences between results from nonlinear calculations (including gaps and slip) and linear results when using EC5?
- Are the differences negligible?
- Do we need to perform non-linear calculations for ”ordinary” SLTB decks?

Two test geometries

Span l (m)	Width b (m)	Thickness t (mm)	b/l	t/l	t/b	
5	4	315	0.80	0.16	0.079	short
25	12	1125	0.48	0.045	0.094	long



Eurocode 5, check 2 separate ”states”

- SLS= serviceability limit state, check for ”deformation limit”
- ULS= ultimate limit state, check for ”strength limit”
- Separate load cases and separate material data must be used in each state, i.e. a comparison between SLS and ULS is difficult to do in general

Simplification used in this study

- The same one load case is studied for both SLS and ULS: a combination of gravity load, distributed load and a double axle load in the middle section but laterally close to the edge

- The same material data was used for both SLS and ULS: E=12000, 240, 720 and 72 MPa in fiber, crossfiber, shear and rolling shear directions, respectively. Design stress values 22.2, 1.9, 2.5, 0.6 MPa for bending stress, transverse compressive stress, bending shear stress and rolling shear stress, respectively.

- Supports are stiff, prestress 0.35 MPa, friction coefficients between beams 0.29 and 0.34 in the fiber and crossfiber directions, respectively.

Relative loads

- Relative load 1.0 is the ULS load for both bridge geometries
- Relative load 0.44 is the SLS load for the 5x4m deck
- Relative load 0.22 is the SLS load for the 25x12m deck

Nonlinear finite element calculation method

- Slip between glulam beams are taken into account, both vertical and horizontal slip might occur if shear stresses are high enough
- Gaps are taken into account, may occur if transverse stress tries to become >0
- Three-dimensional, orthotropic
- No limits for strength are set in the programme and loads are increased proportionally from 0 up to 2.3

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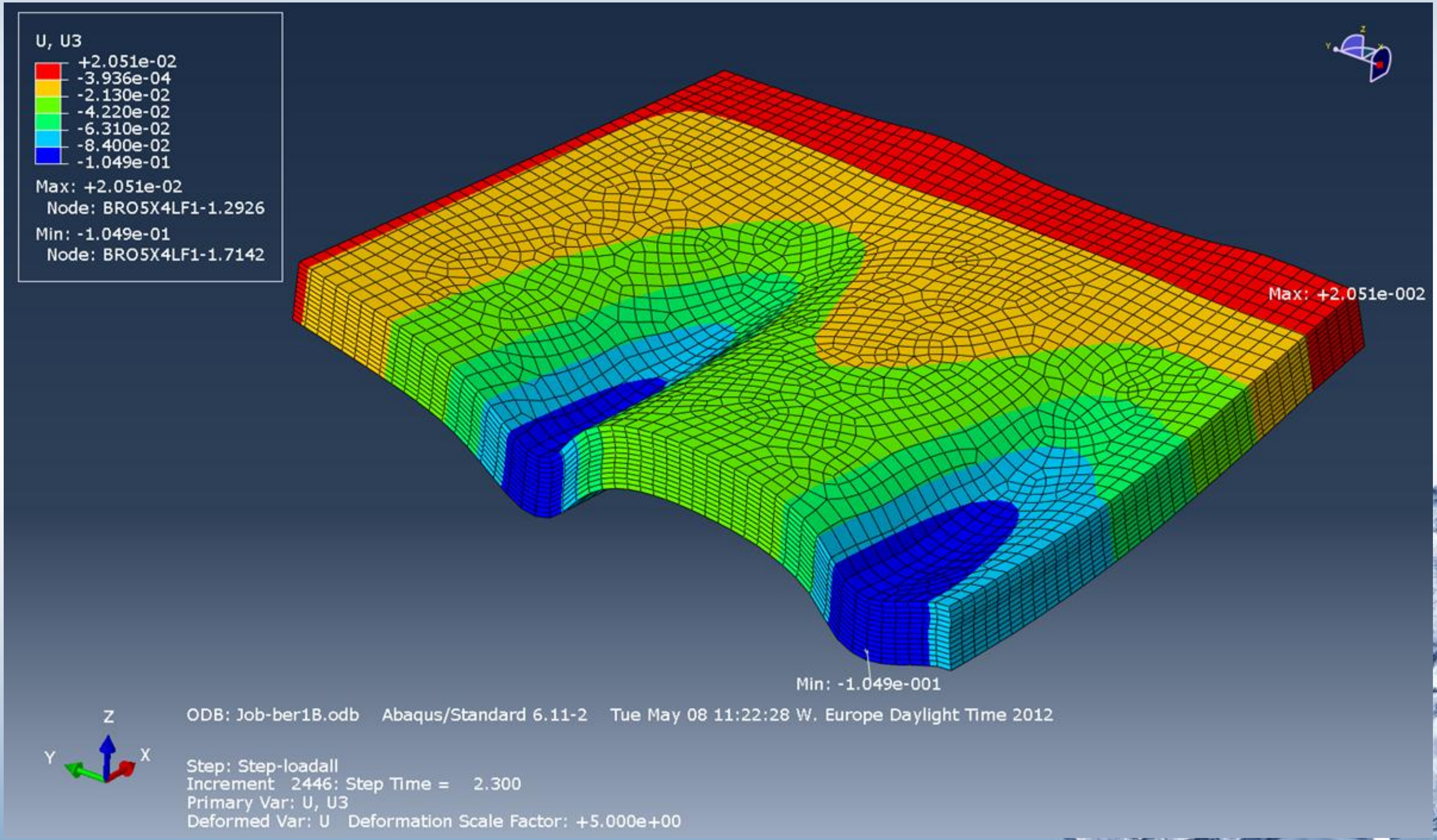
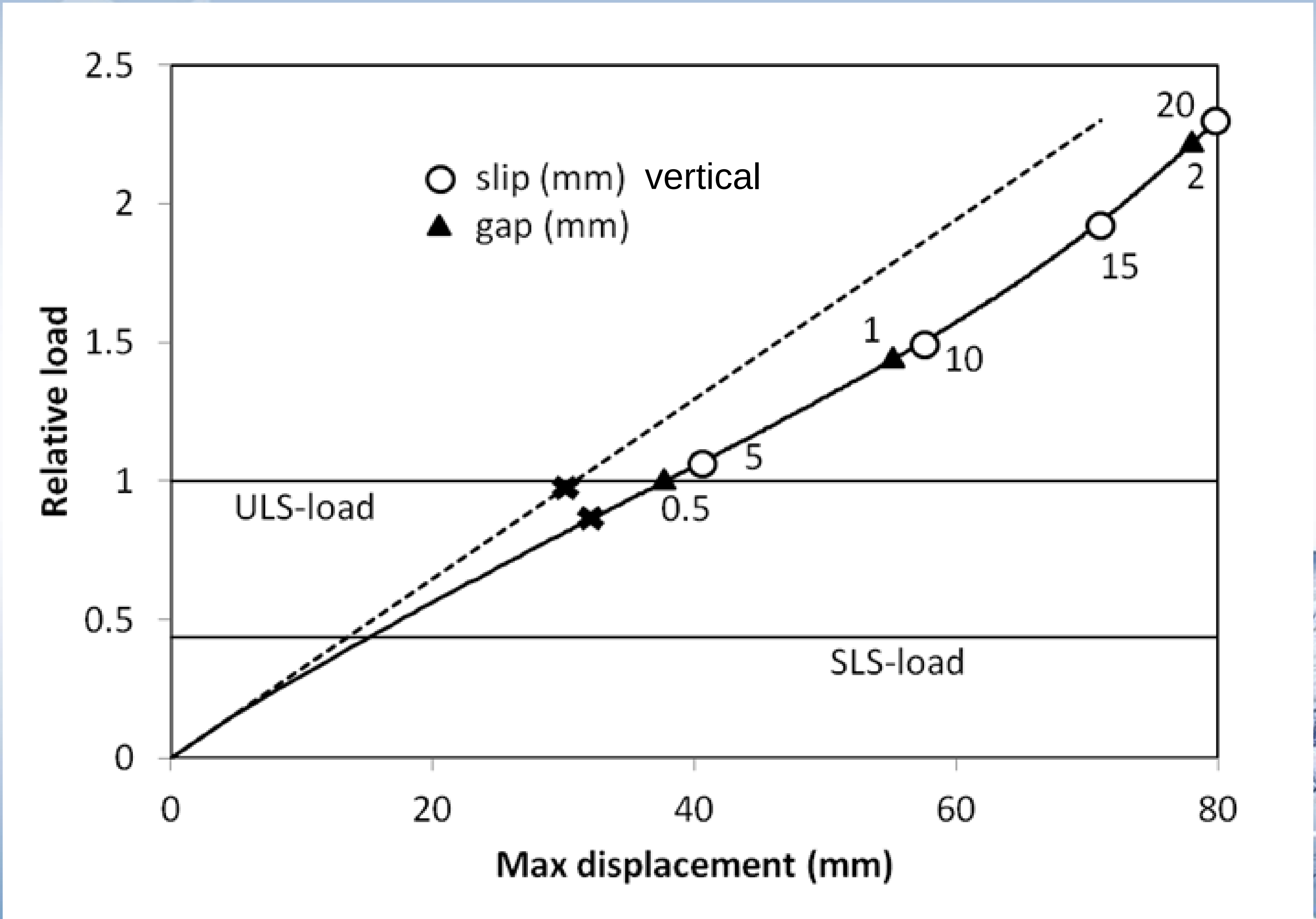
Results 5x4 m deck

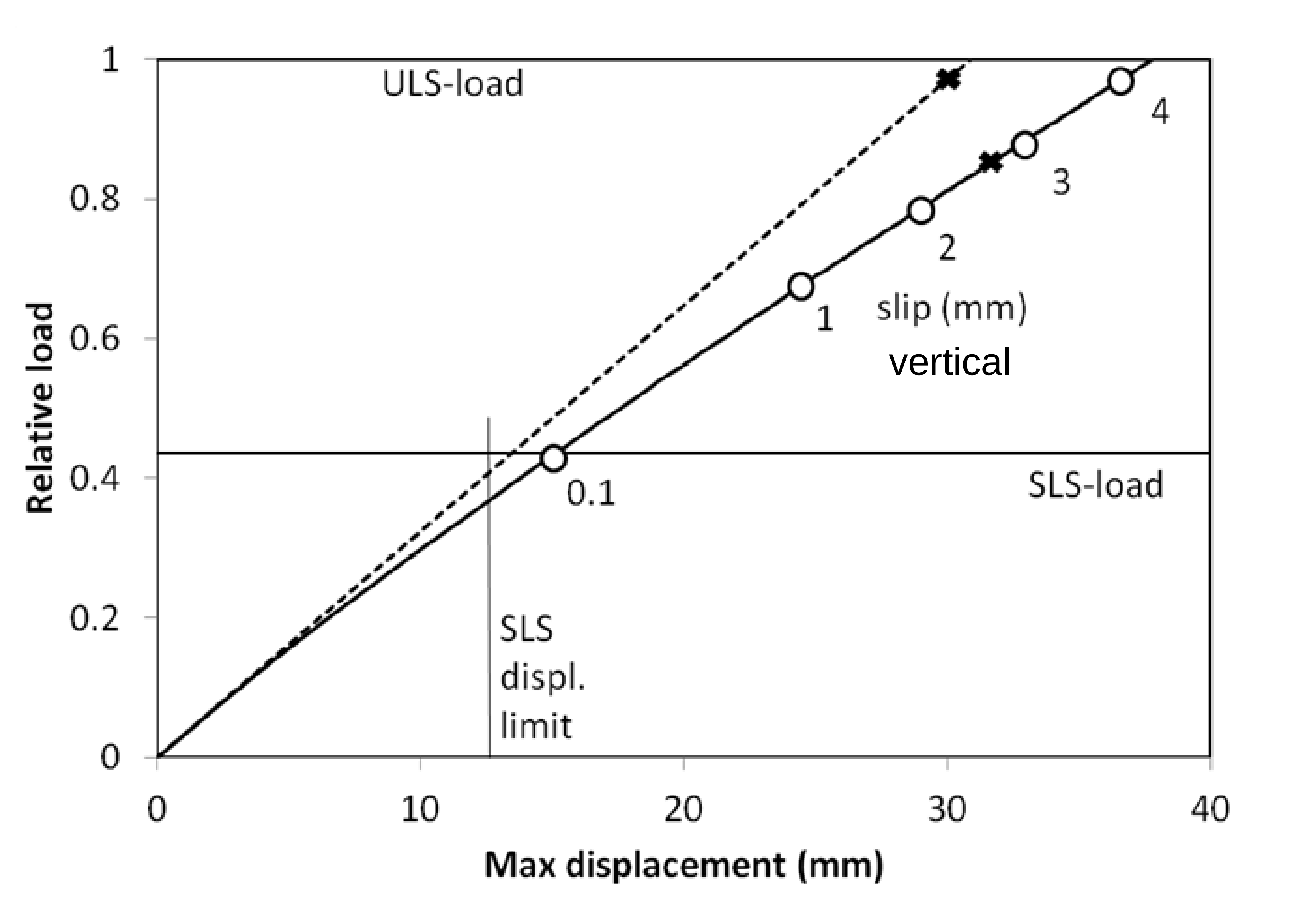


5x4 m deck

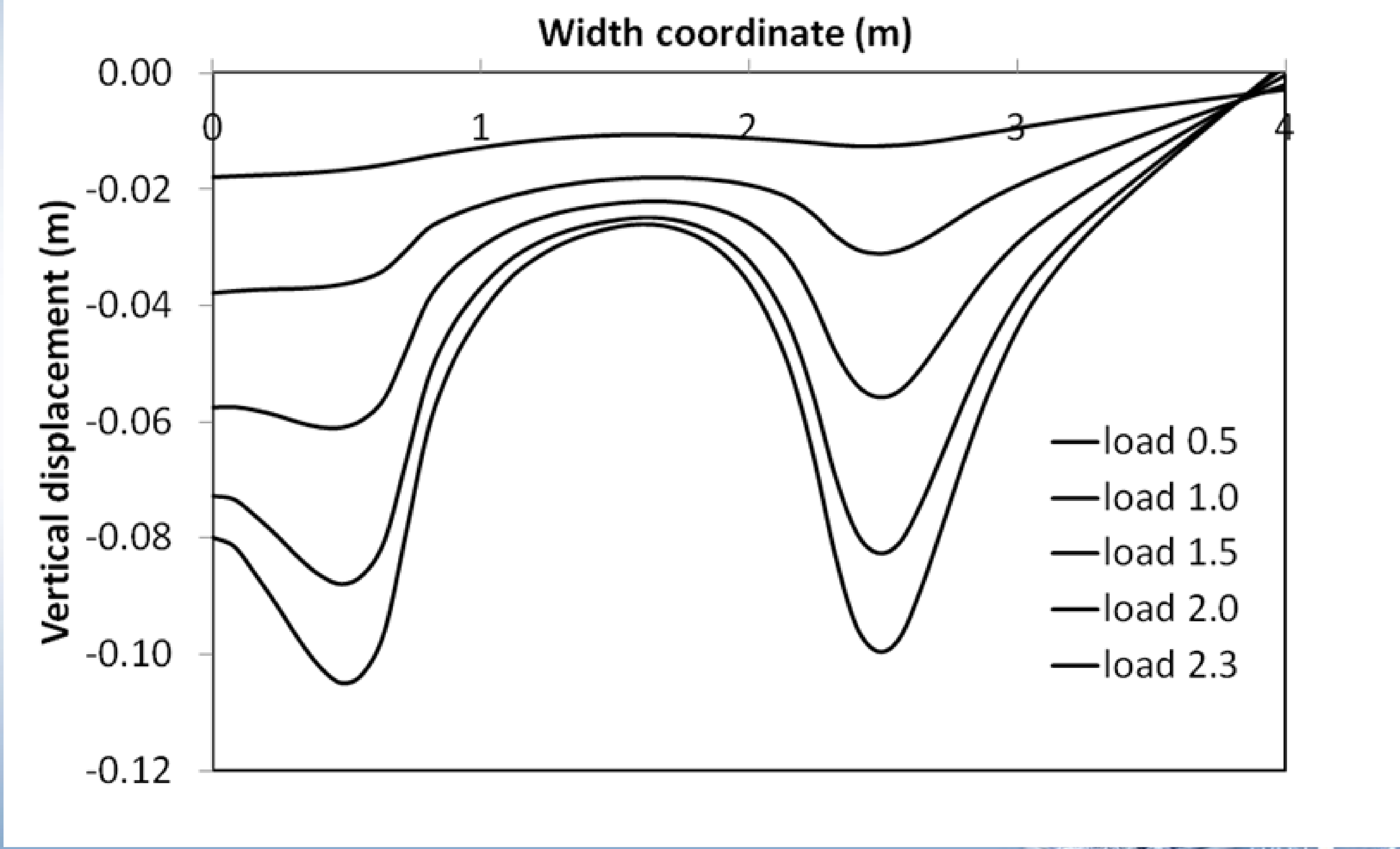


2.5
2
1.5
1
0.5
0
Relative load
slip (mm)
vertical
gap (mm)
20
2
15
1
10
5
0.5
ULS-load
SLS-load
0
20
40
60
80
Max displacement (mm)

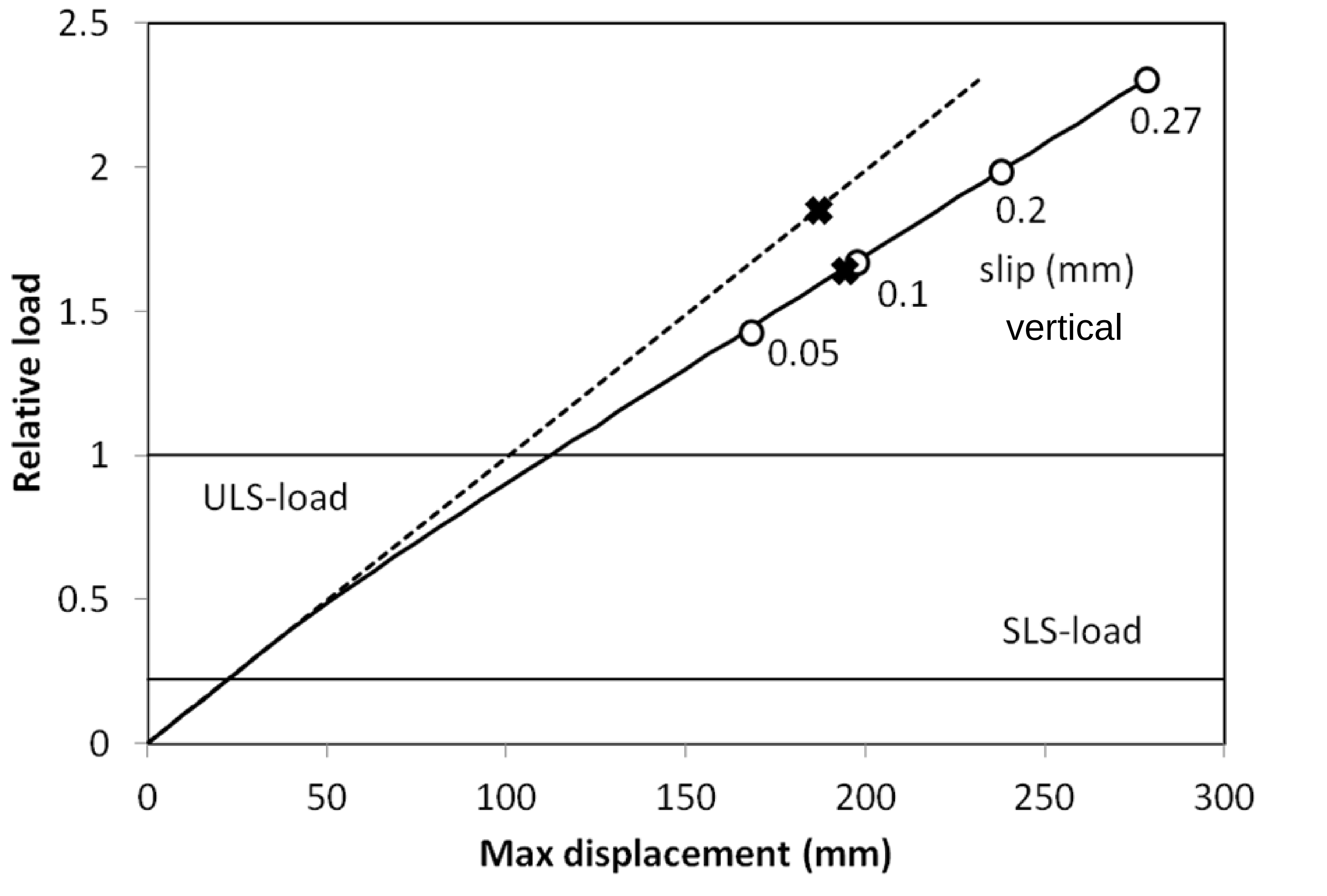
5x4 m deck zoom-in



5x4 m deck

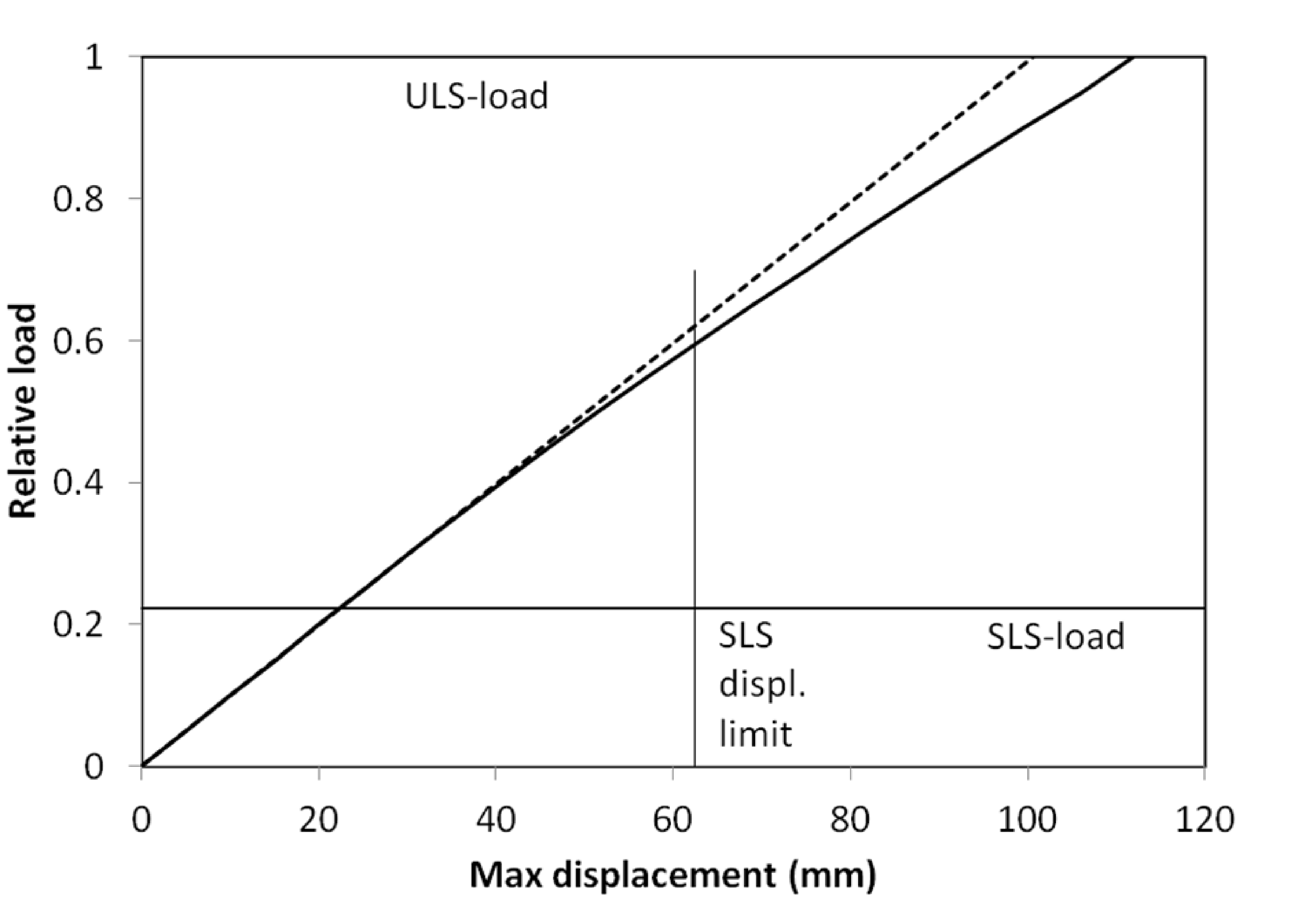

Width coordinate (m)
Vertical displacement (m)
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
0
1
2
3
4
load 0.5
load 1.0
load 1.5
load 2.0
load 2.3

25x12 m deck



2.5
2
1.5
1
0.5
0
Relative load
0.27
0.2
slip (mm)
0.1
vertical
0.05
ULS-load
SLS-load
0
50
100
150
200
250
300
Max displacement (mm)

25x12 m deck zoom-in



Conclusions from linear calculation and EC5

- 315 mm thickness was approved for 5x4 m deck
- 1125 mm can be reduced for the 25x12 m deck

Conclusions linear vs. nonlinear

-Nonlinear calculations give higher deformation (due to slip and gaps). Linear calculations were non-conservative (give lower stresses for the same load)

-For 5x4 deck: vertical slip in ULS is high (4 to 5 mm), gaps are small in ULS (<0.5 mm)

-For 25x12 deck: since the thickness was unnecessarily large the gaps and slips were small in ULS. A reduction of thickness would lead to more slip and gaps.

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