Loadbearing capacity criteria in fire resistance testing

Some simulations on steel beams

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CONFIGURATIONS UNDER STUDY

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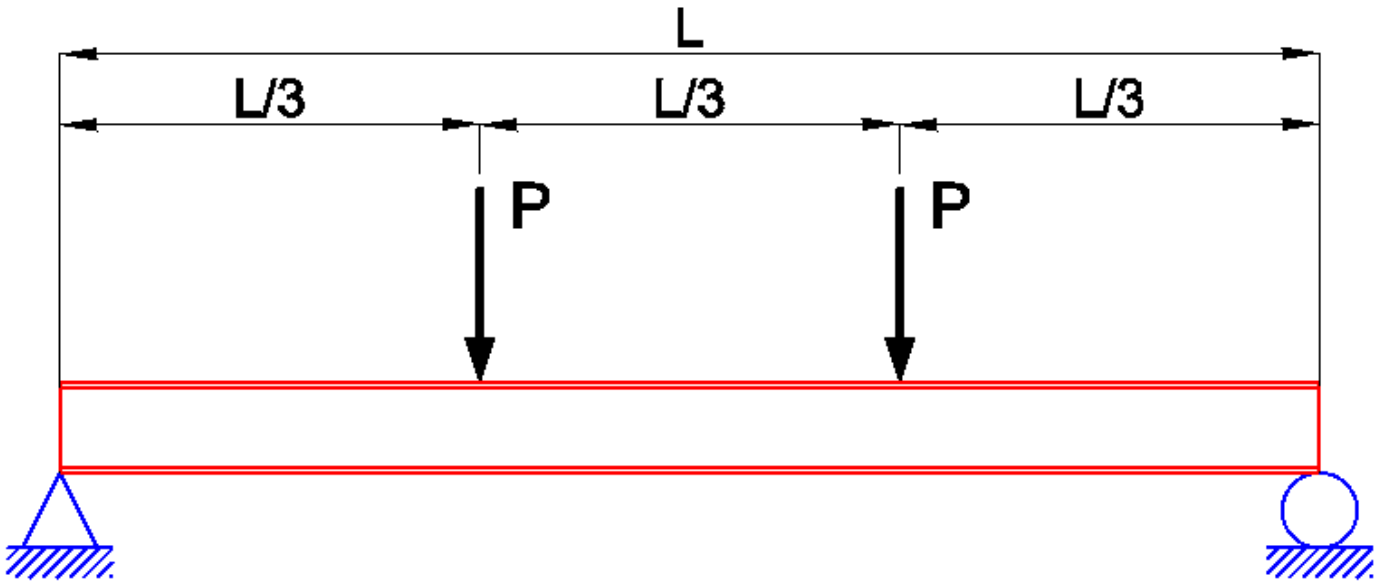
Configurations under study

- Steel beams, grade S355
- Simply supported
- Exposed to ISO834 fire curve
- Loaded in 2 points at 1/3 and 2/3 of the span



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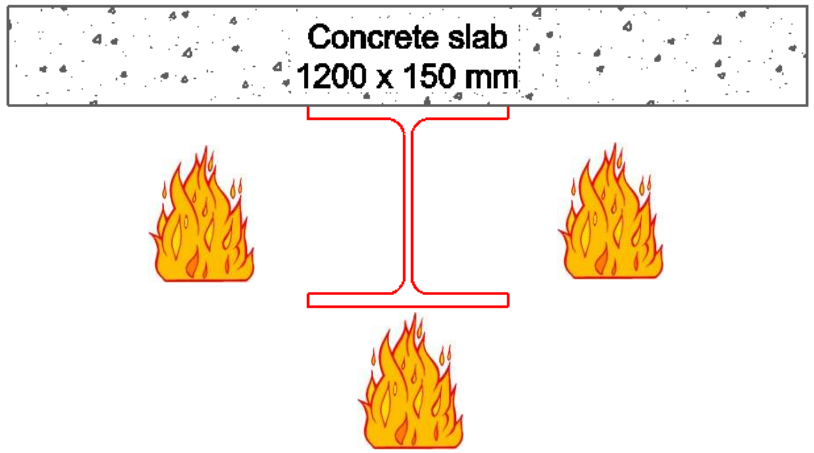
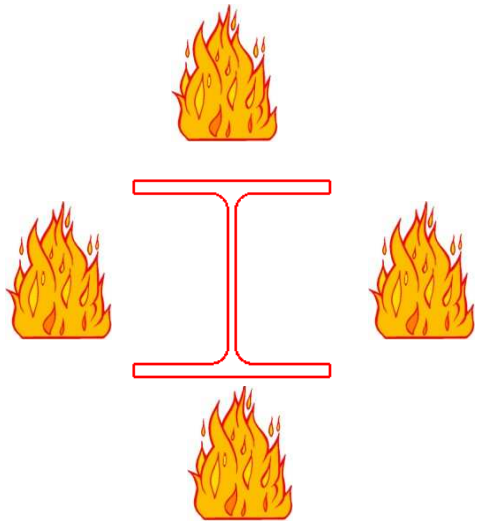
Configurations under study

- 4 sections: HEB200 – HEB 300 – HEB400 – HEB500
- 3 lengths between supports : 4200 mm – 5200 mm – 6200 mm
- 2 expositions to fire: 3 faces – 4 faces





- 4 load ratio (Mmax,test/Mplas,20): 0,2 – 0,35 – 0,5 – 0,65

Total: 4 x 3 x 2 x 4 = **96 scenarios**

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SAFIR®

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SAFIR®

- Software for the simulation of building structures subject to fire
- Capabilities:
  1. Calculation of temperature distributions in structures subject to fire:
     - 2D or 3D thermal calculations
     - Finite elements: triangular, quadrangular, prismatic
     - Transient calculation
  2. Calculation of the behaviour of a structure under varying temperatures:
     - 2D or 3D structural calculations
     - Finite elements: truss, beam, shell, solid
     - Non linear with large displacements
  3. Calculation of the torsional stiffness of a section

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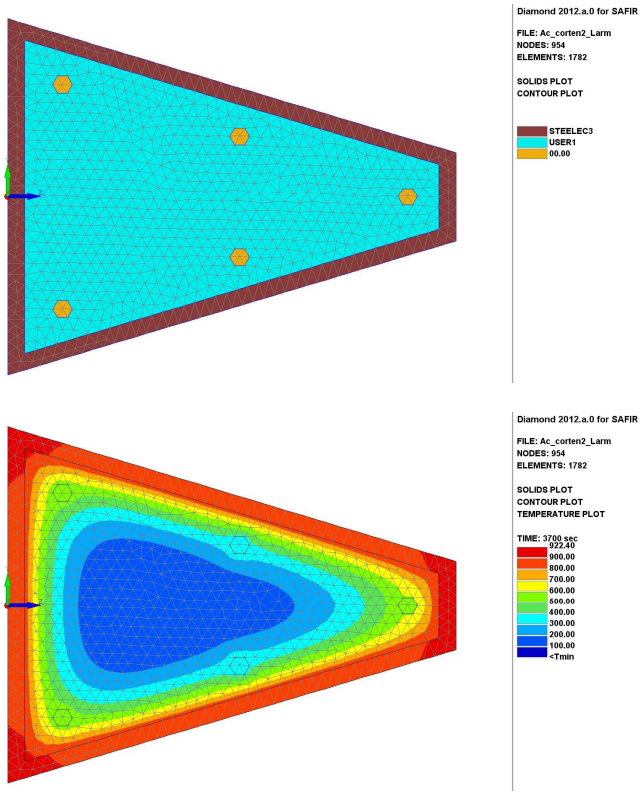
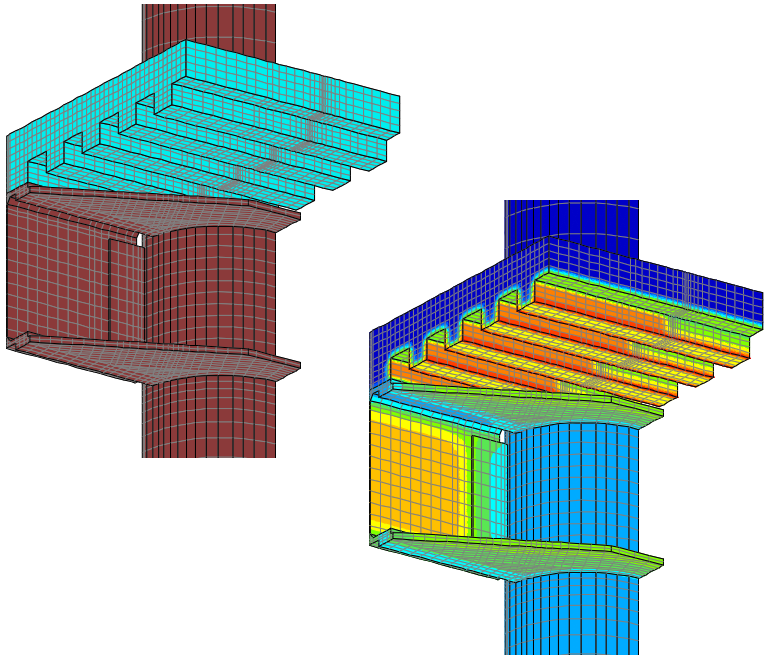
- Thermal calculation: examples

2D – Composite steel-concrete column



3D – Composite steel-concrete joint



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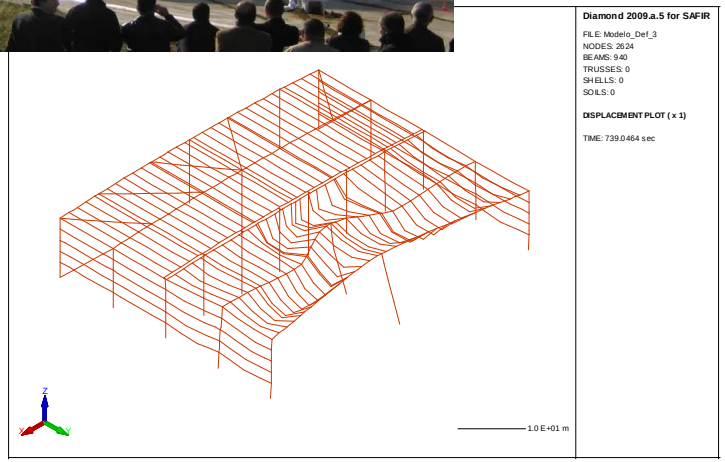
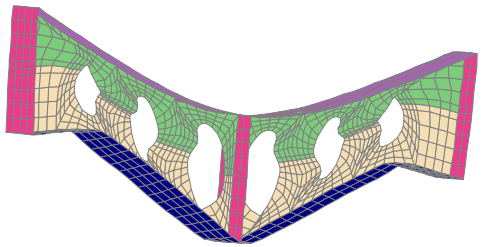
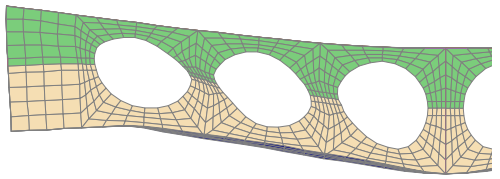
- Structural calculation: examples

Flumilog Test, INERIS France



Cellular beam in fire





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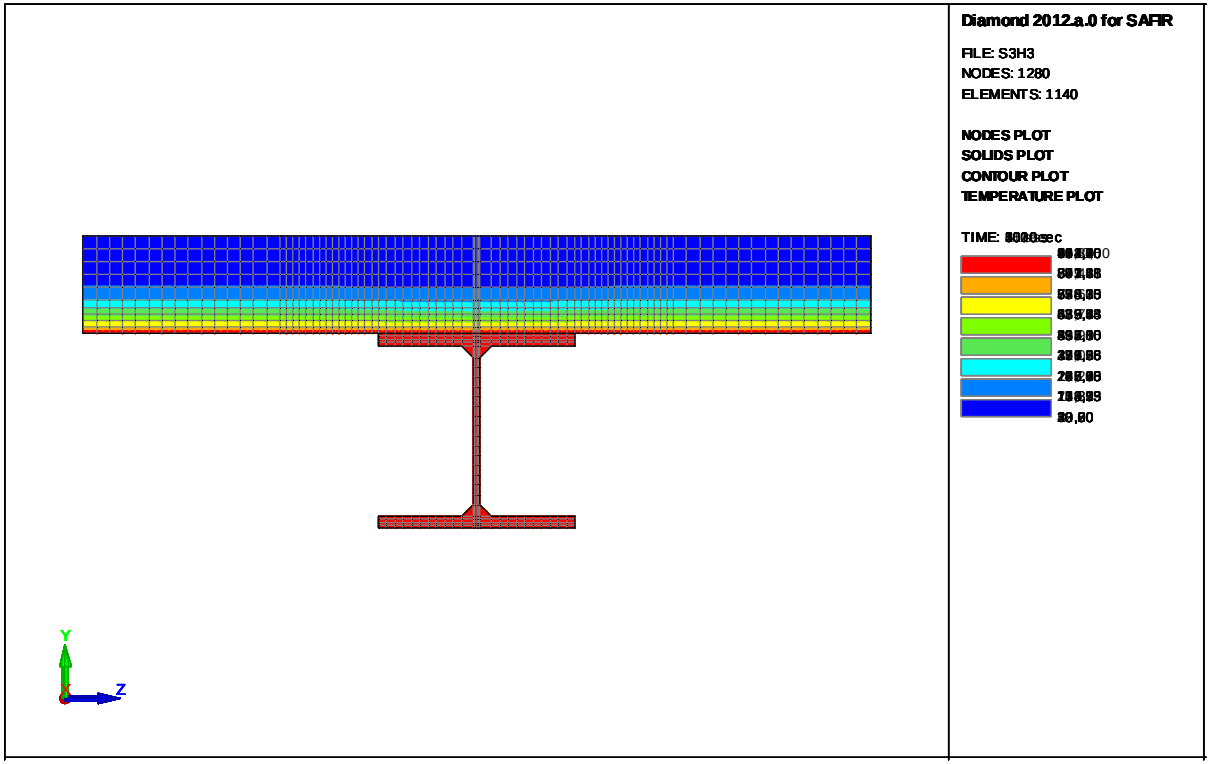
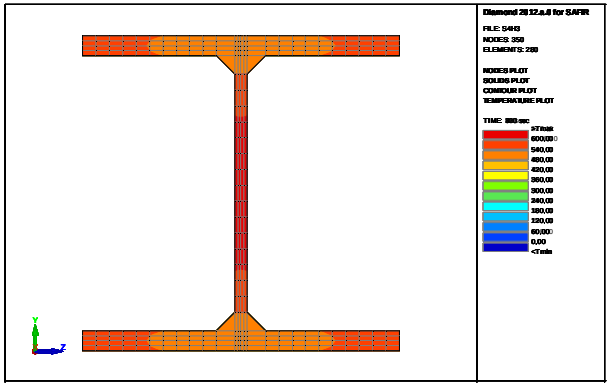
- Thermal calculation

Exposition on 3 faces



Exposition on 4 faces



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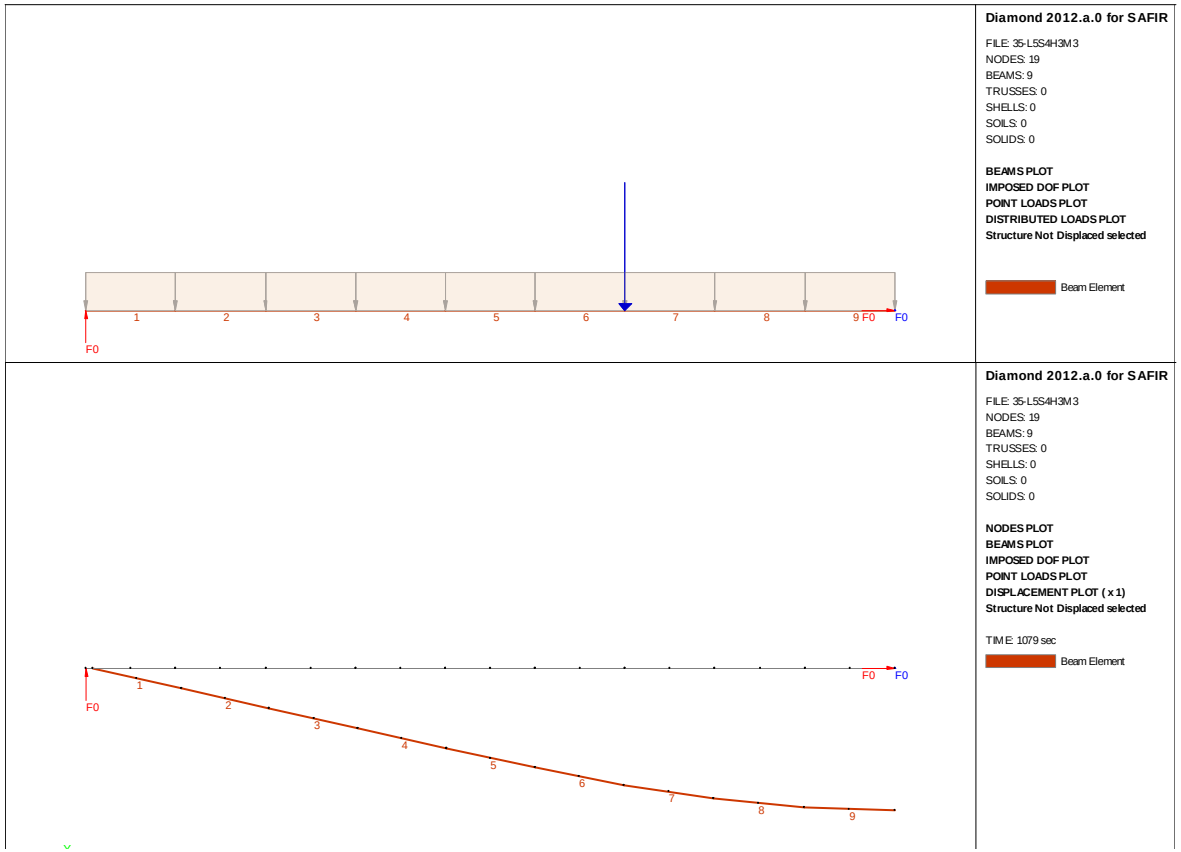
- Structural calculation



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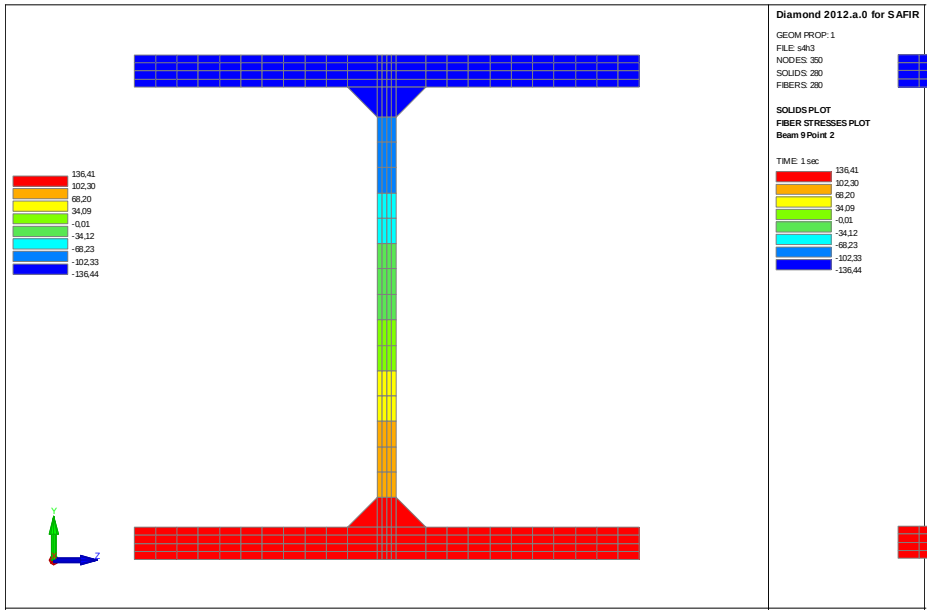
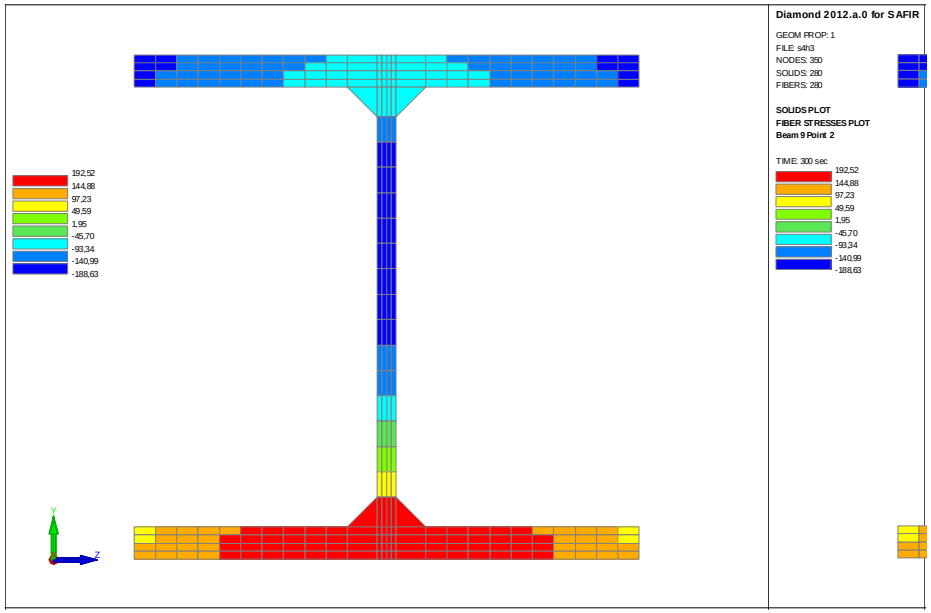
- Stress field calculation





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ANALYSIS

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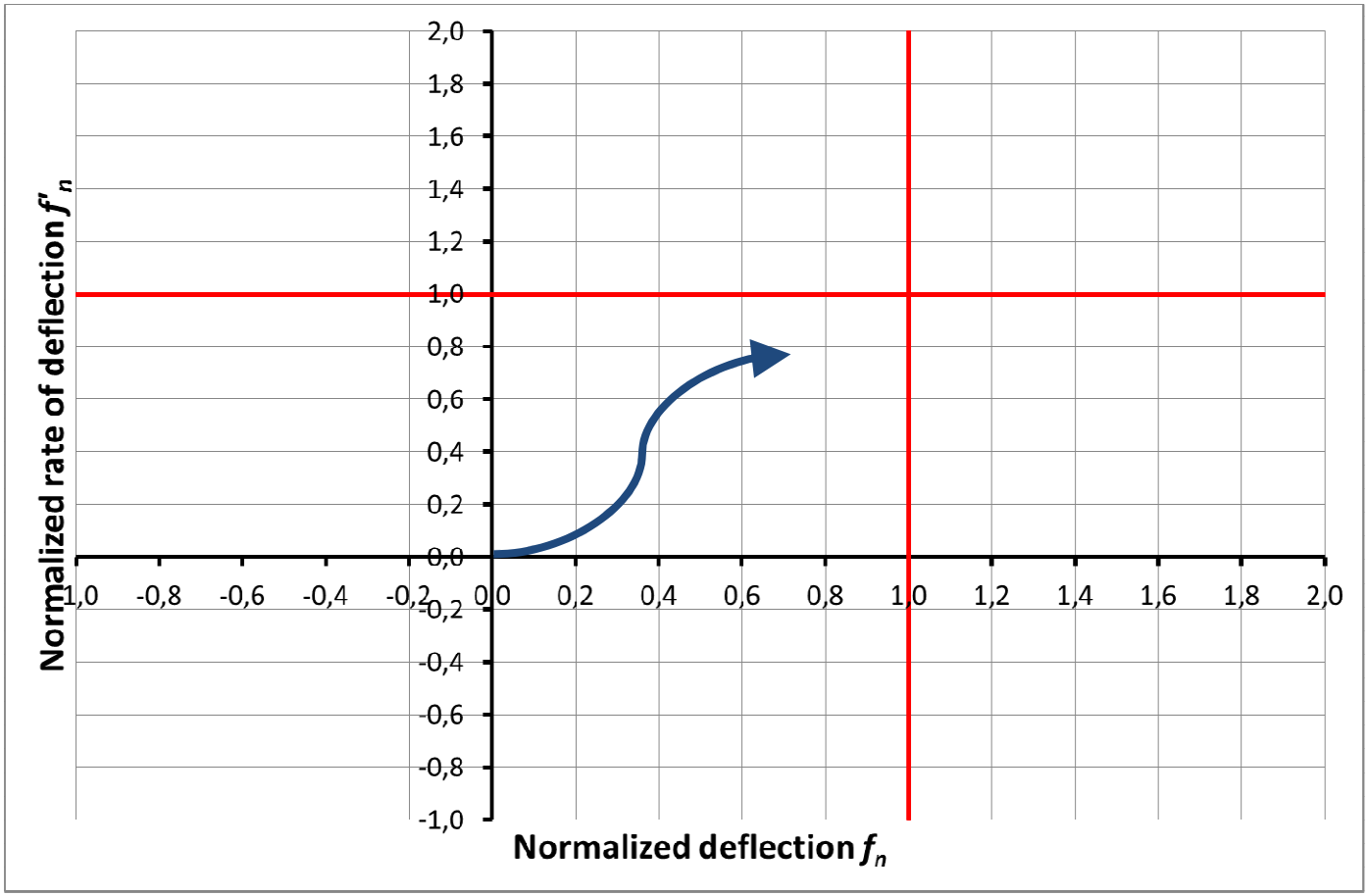
Analysis - Reminder

Normalized rate of deflection f'_n vs. normalized deflection f_n in the **normalized space**



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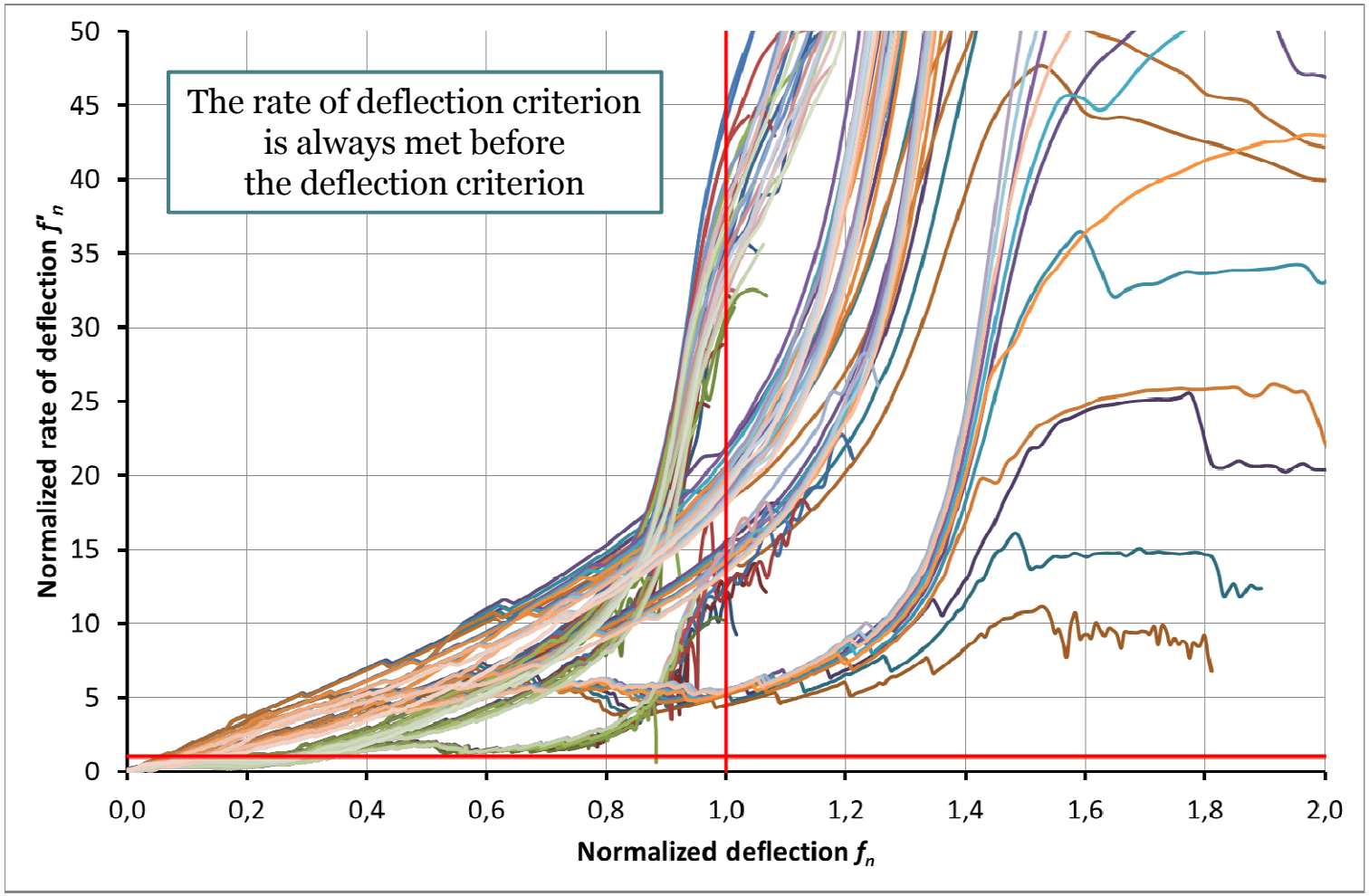
Analysis – 96 curves



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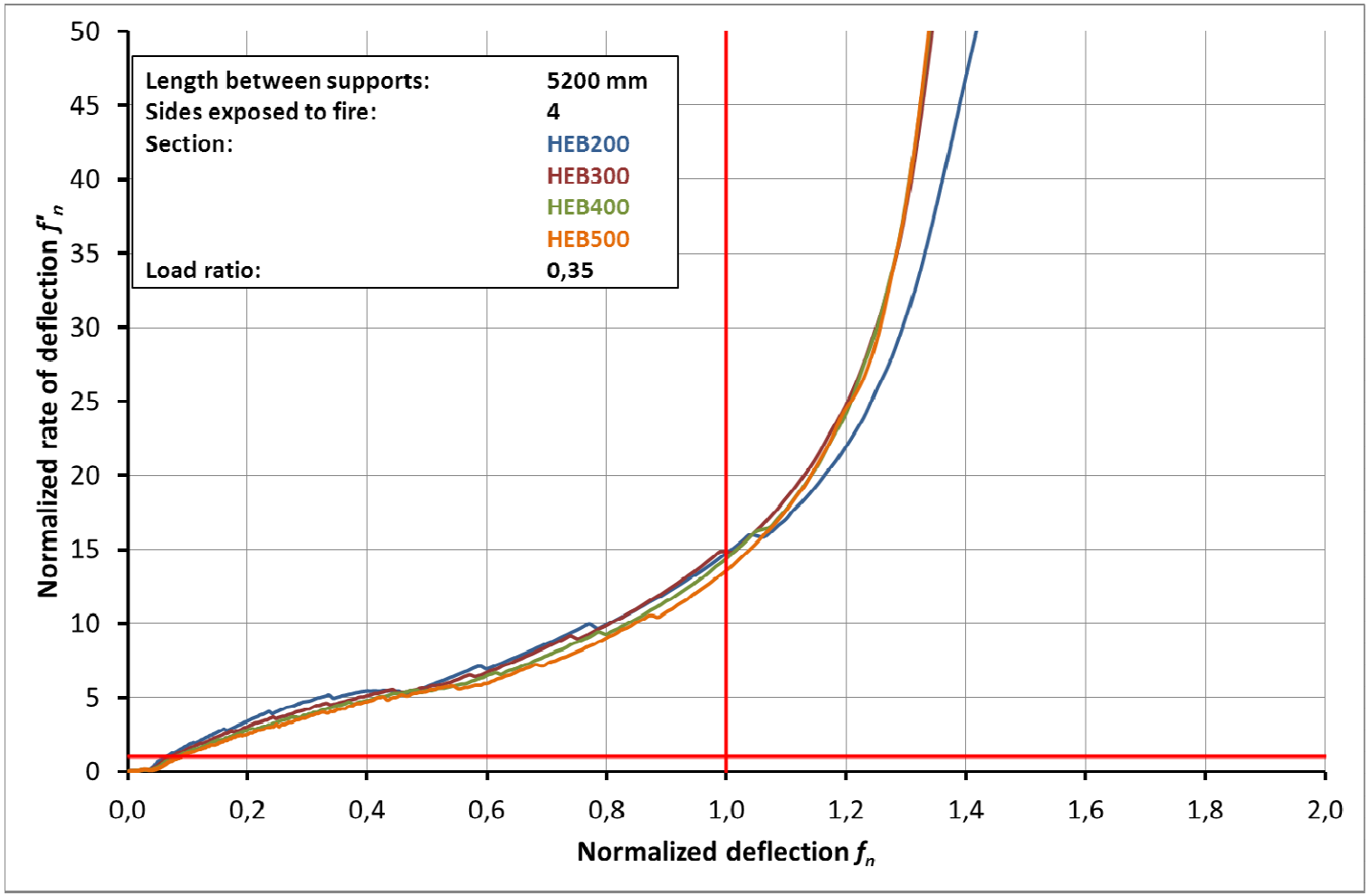
Analysis – Influence of the section



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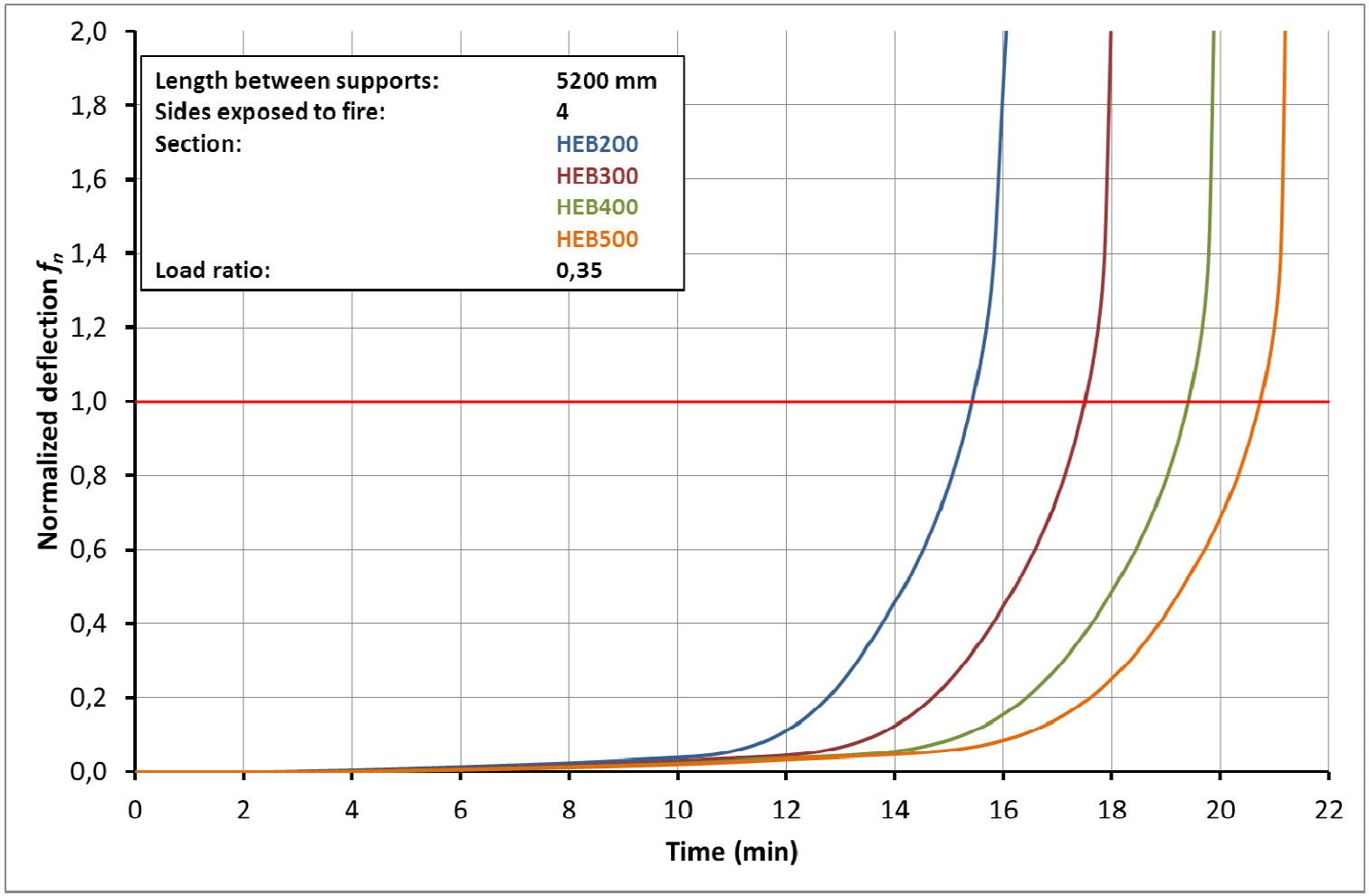

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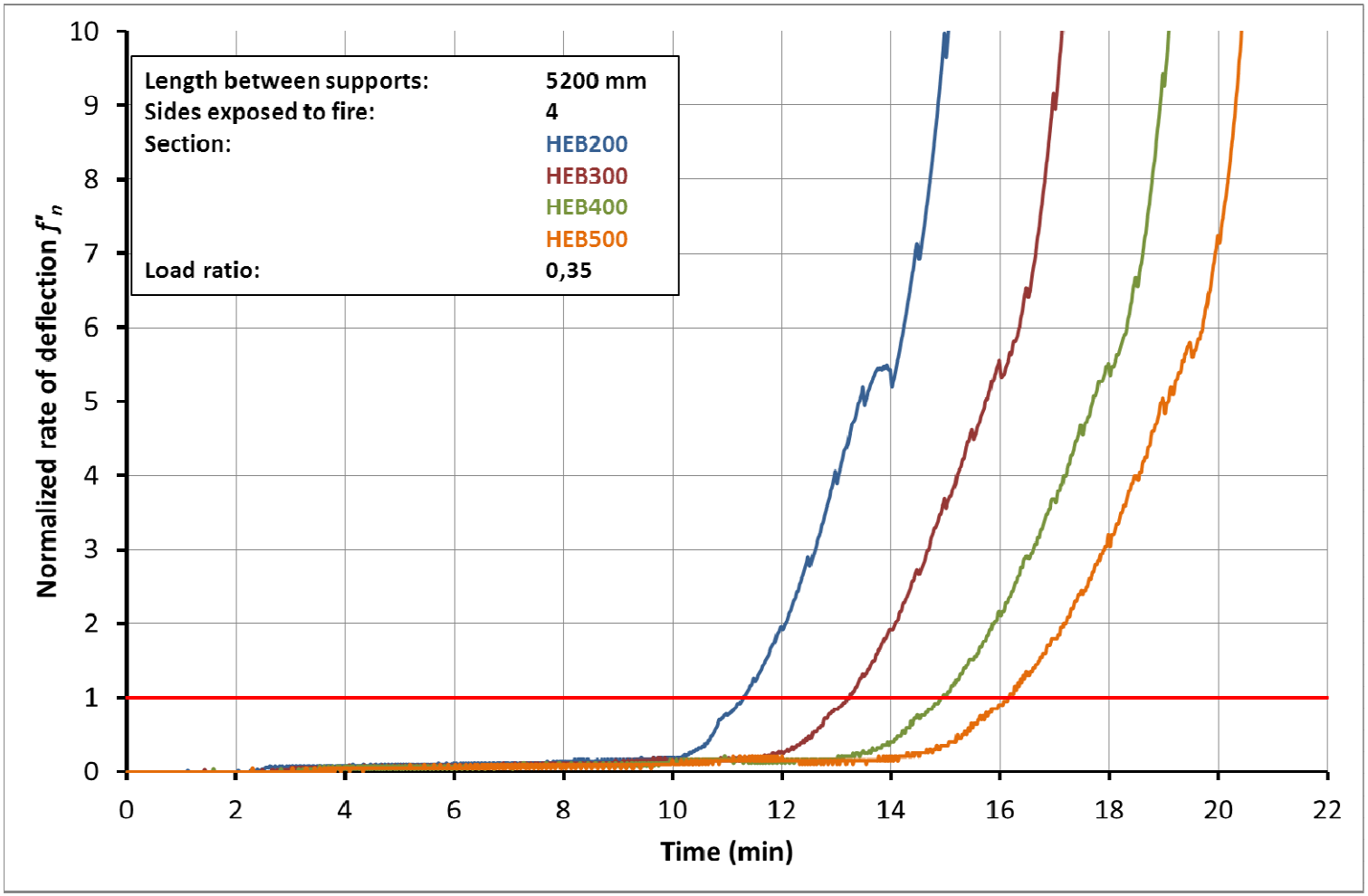

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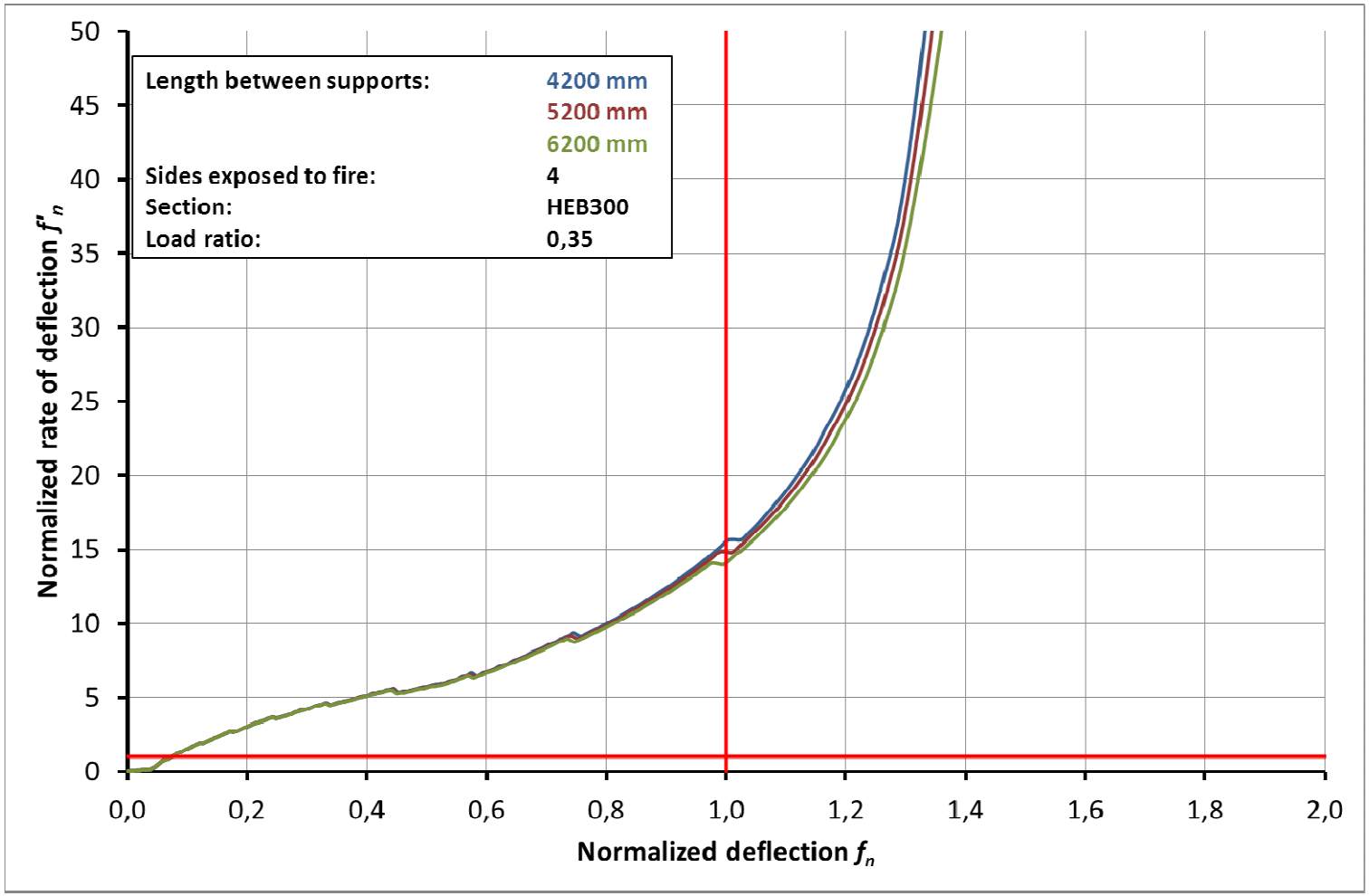
Analysis – Influence of the length



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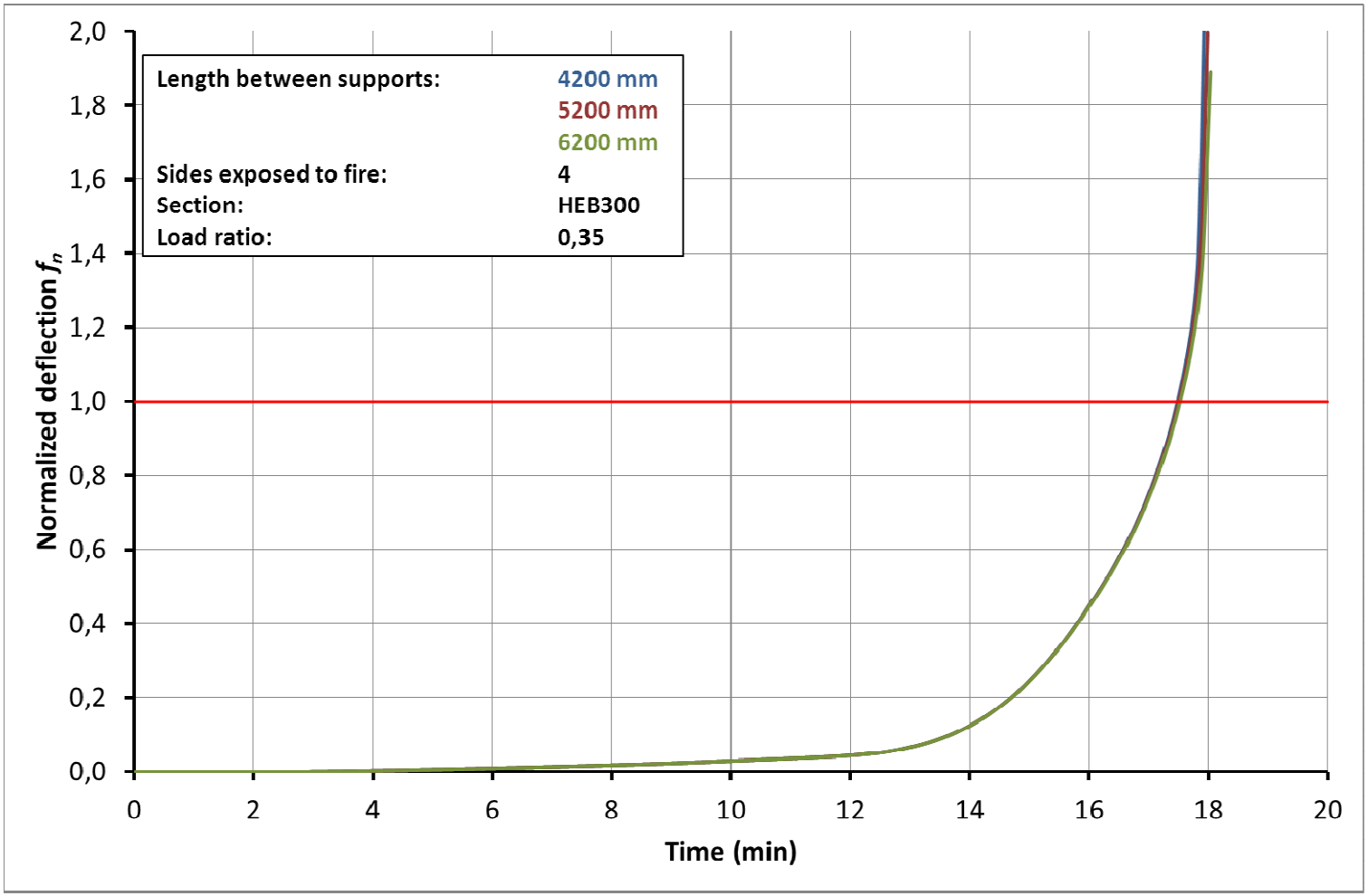

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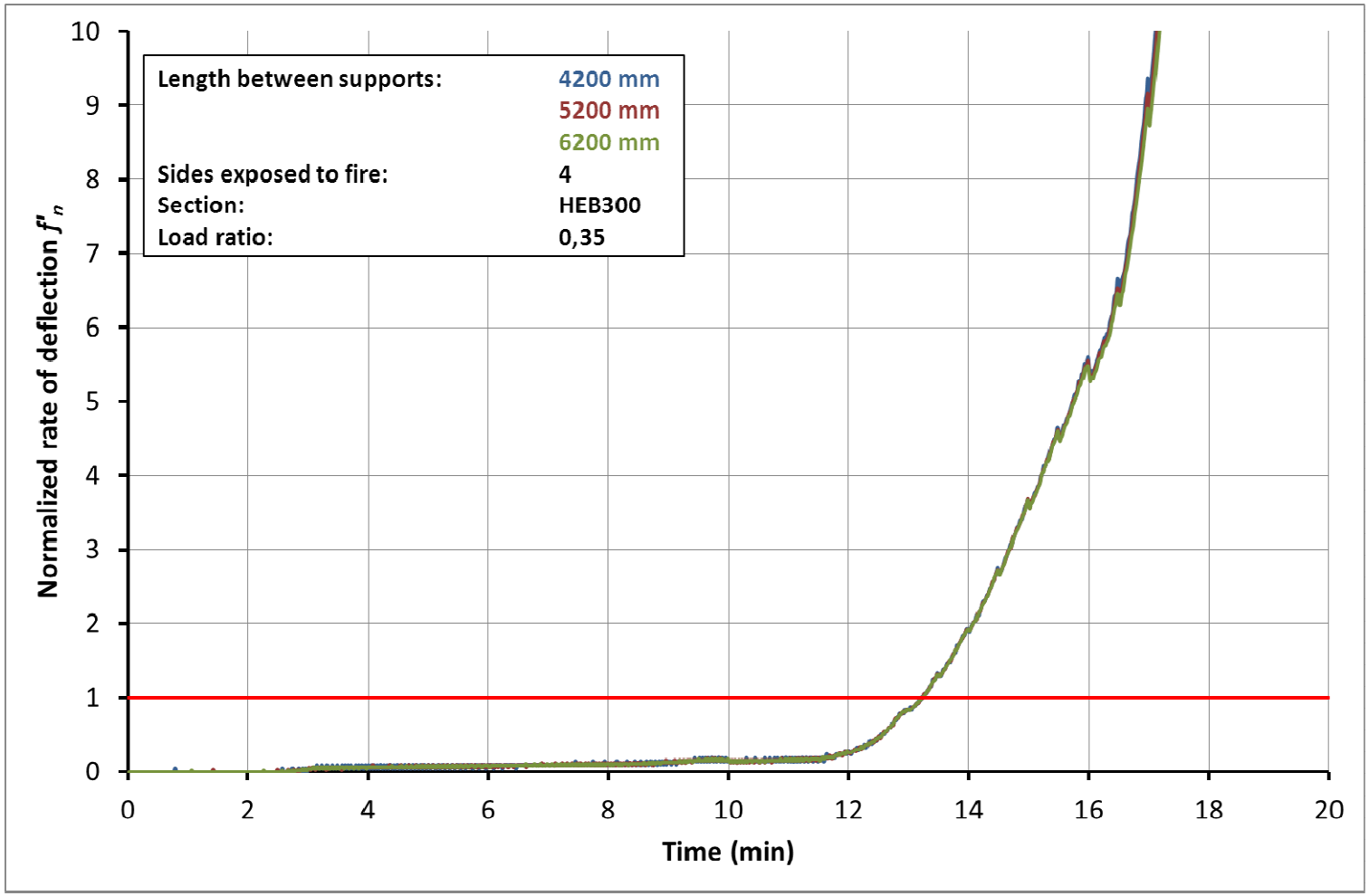
Analysis – Influence of the length



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Analysis – Influence of the length

EGOLF round-robin on HEB300 beams

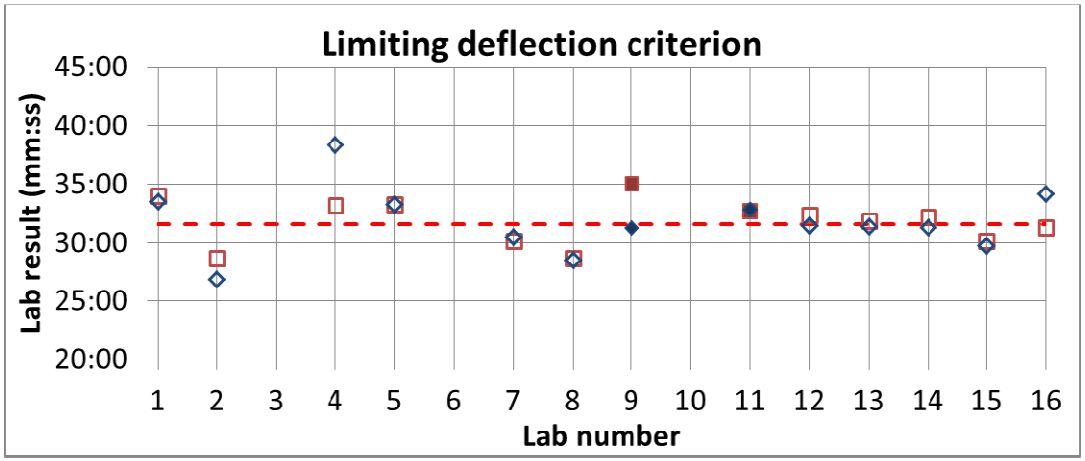
Empty markers:

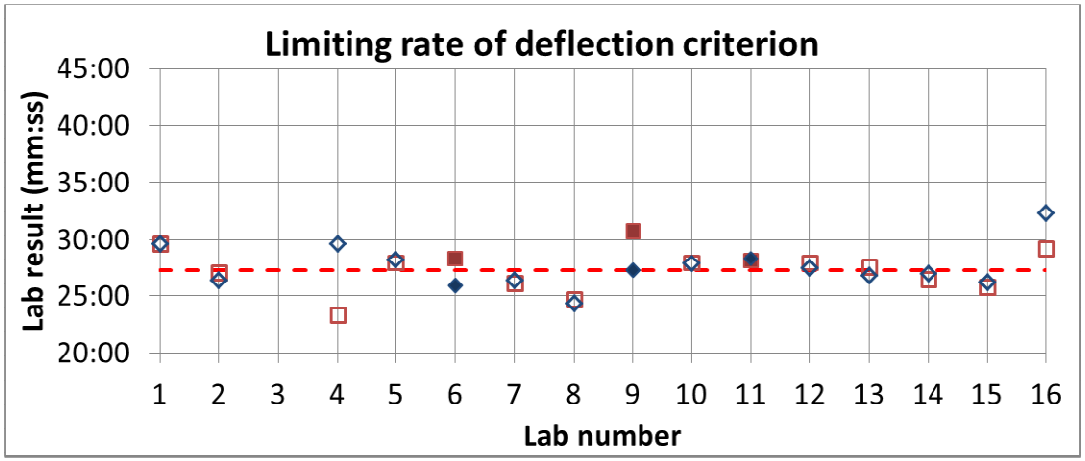
L_{sup}=4200 mm

Filled markers:

L_{sup}=5200 mm

The fact that the length has no influence is confirmed by experimental tests





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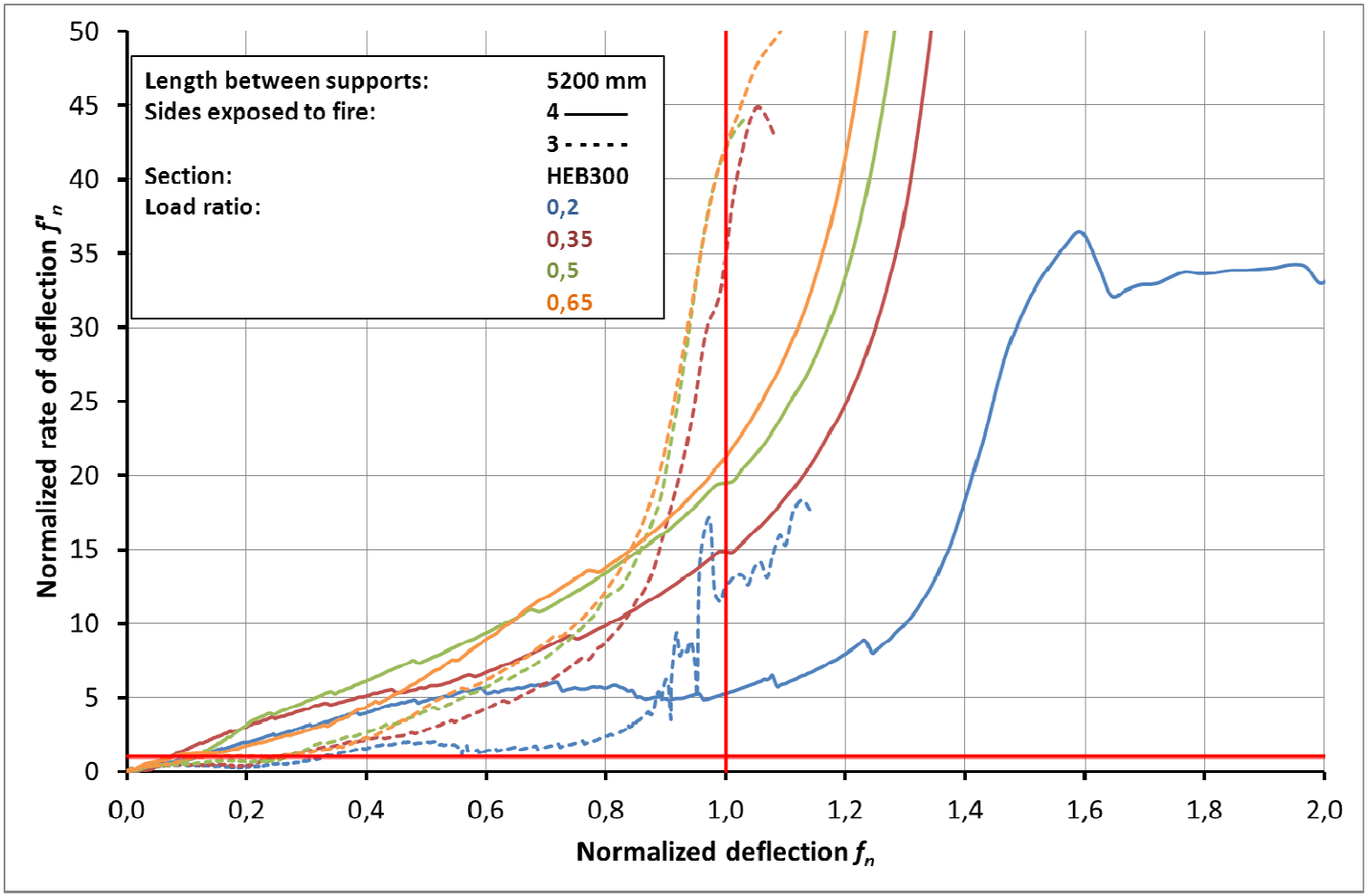
Analysis – Influence of the exposition and load



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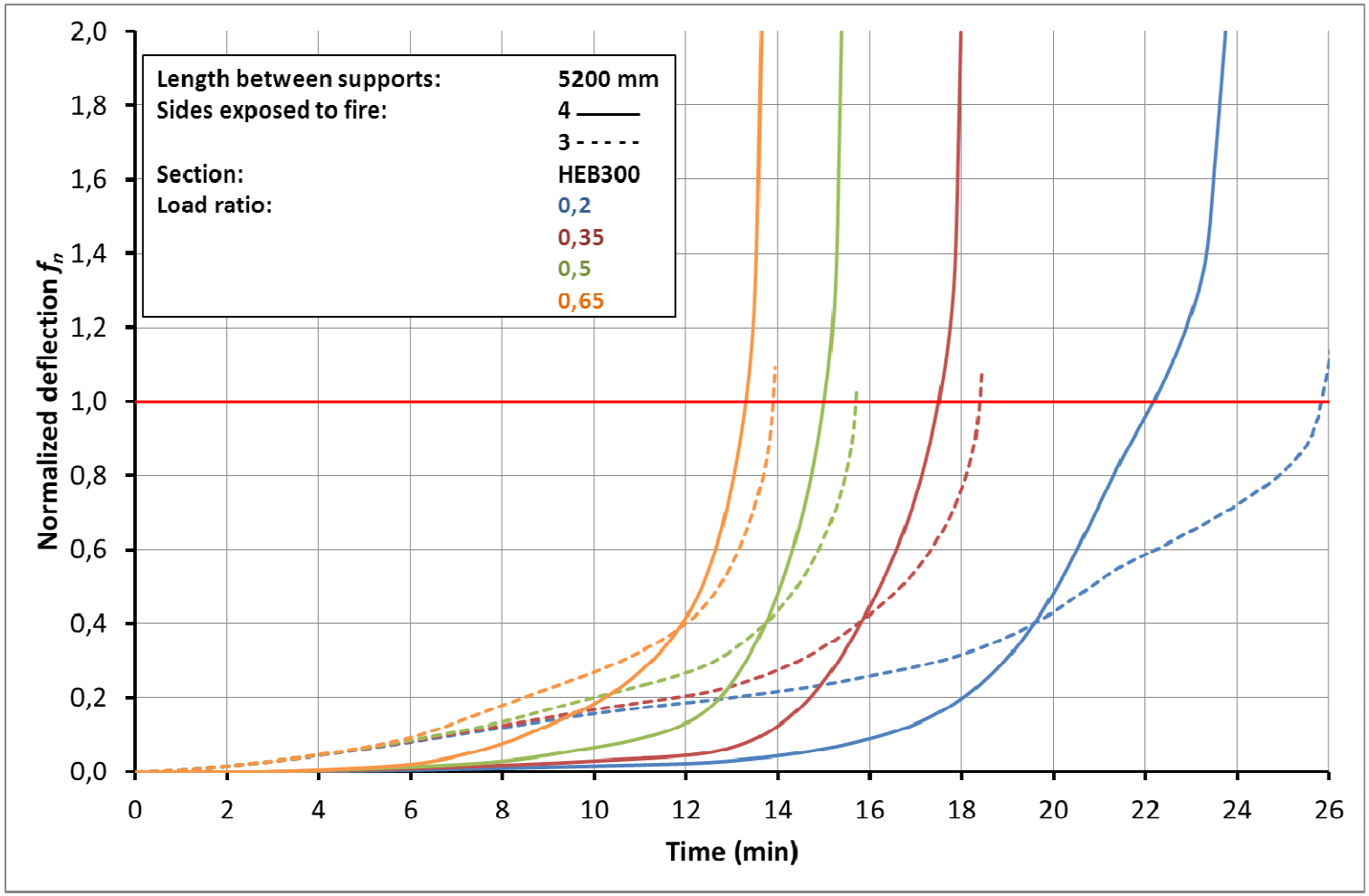

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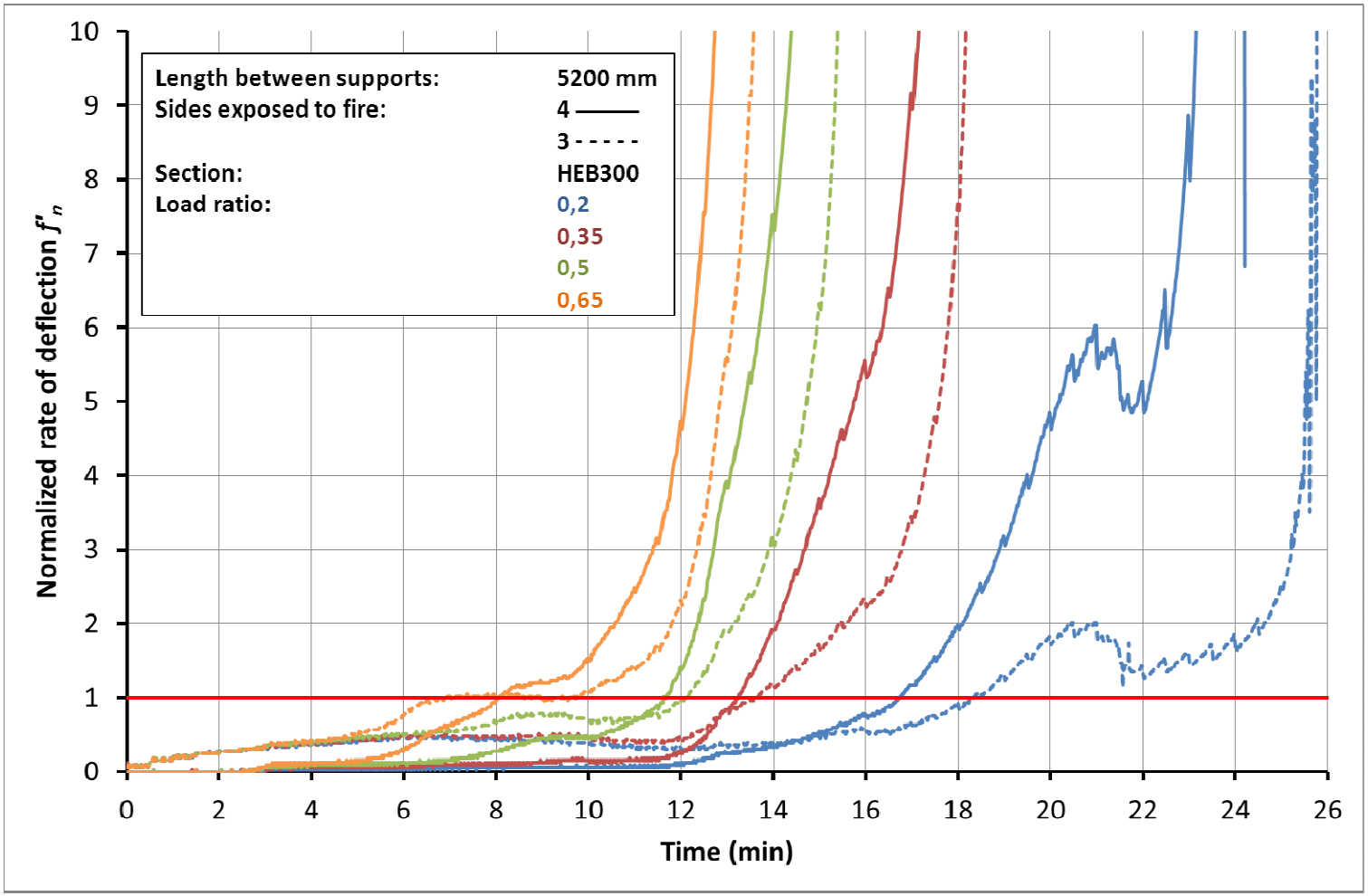

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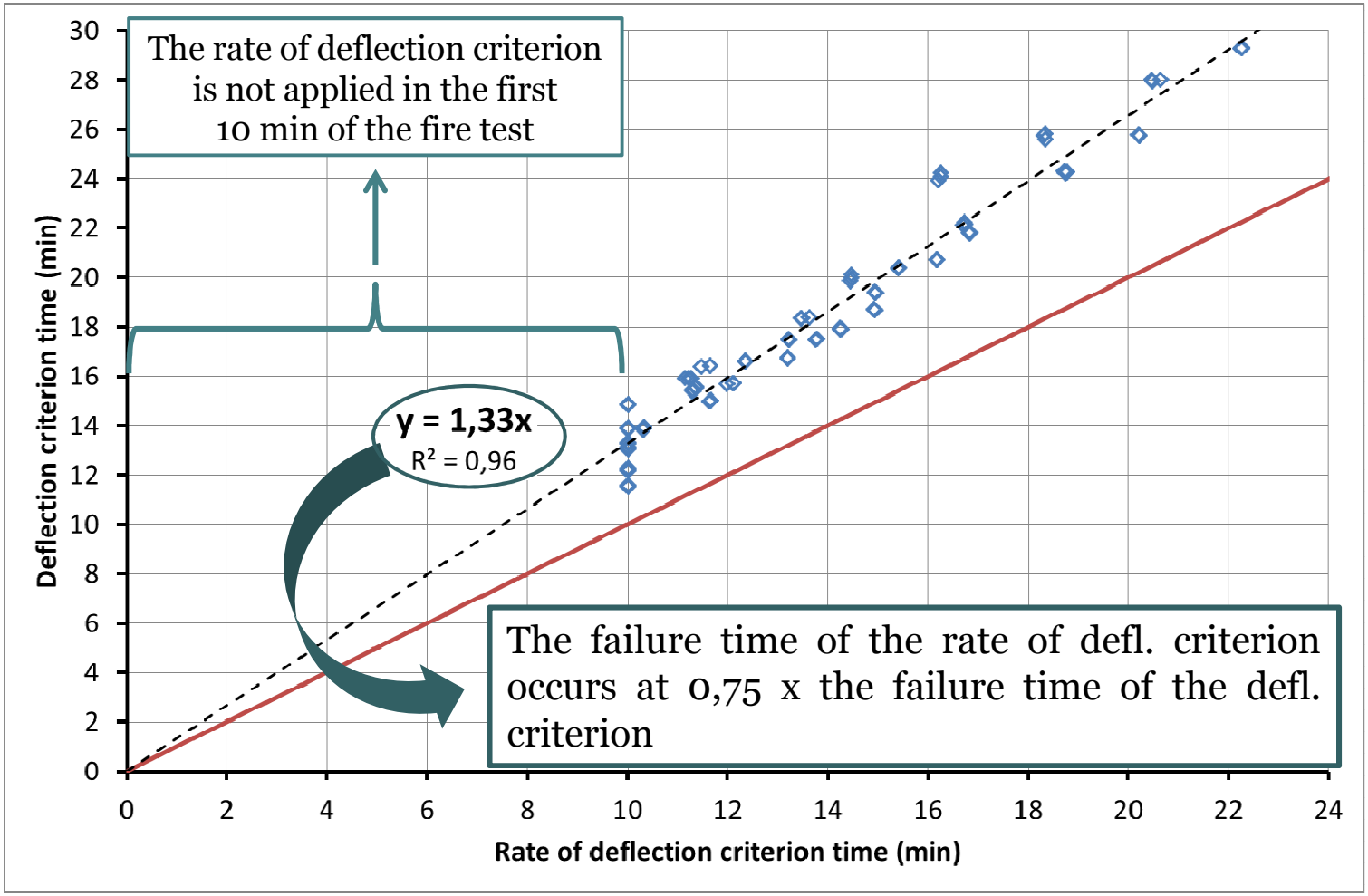
Analysis – Failures times of the criteria



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CONCLUSIONS - PROPOSITION

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Conclusions

- **For flexural loaded elements**

Limiting deflection

$$D = \frac{L^2}{400d}\ mm$$

		Length between supports		
		4200	5200	6200
Section	HEB200	221	338	481
	HEB300	147	225	320
	HEB400	110	169	240
	HEB500	88	135	192

		Length between supports		
		4200	5200	6200
Section	HEB200	L/19	L/15	L/13
	HEB300	L/29	L/23	L/19
	HEB400	L/38	L/31	L/26
	HEB500	L/48	L/38	L/32

Limiting rate of deflection

$$\frac{dD}{dt} = \frac{L^2}{9000d}\ mm/min$$

		Length between supports		
		4200	5200	6200
Section	HEB200	10	15	21
	HEB300	7	10	14
	HEB400	5	8	11
	HEB500	4	6	9

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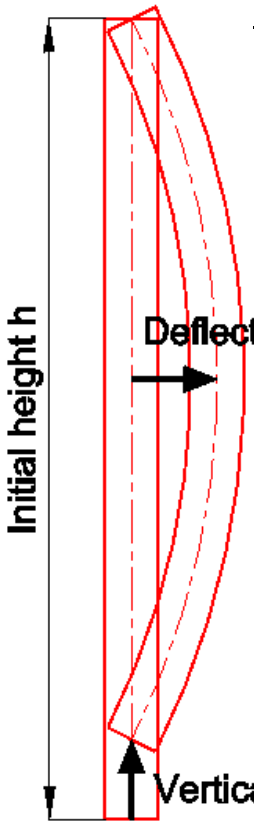
Conclusions

- **For vertically loaded elements**



Limiting vertical contraction

$$C = \frac{h}{100}\ mm$$

		Contraction C	Deflection D
Initial height h	3000	30	183
	4000	40	244
	5000	50	305
	6000	60	366

Huge values

Limiting rate of vertical contraction

$$\frac{dC}{dt} = \frac{3h}{1000}\ mm/min$$

		Rate dC/dt
Initial height h	3000	9
	4000	12
	5000	15
	6000	18

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Proposition

- For flexural loaded elements, both criteria are reachable and the rule could be:

  Limiting deflection criterion AND Limiting rate of deflection criterion

- For vertically loaded elements, the deflection criterion is hazardous for safety/security reasons and the rule could be:

  Limiting rate of deflection criterion only