

# Behaviour of Restrained Columns in Fire

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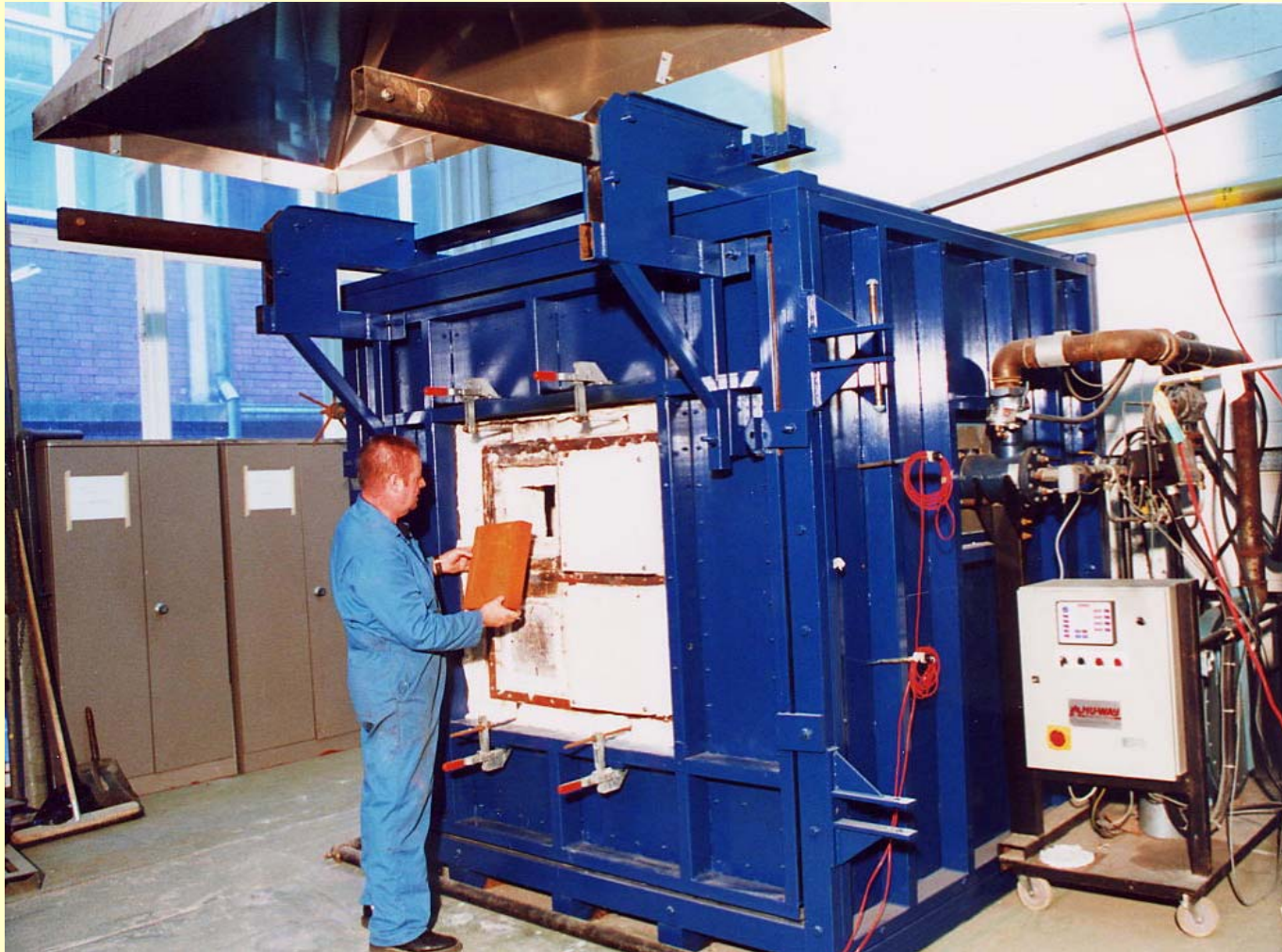
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# Small Furnace





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# Medium Furnace



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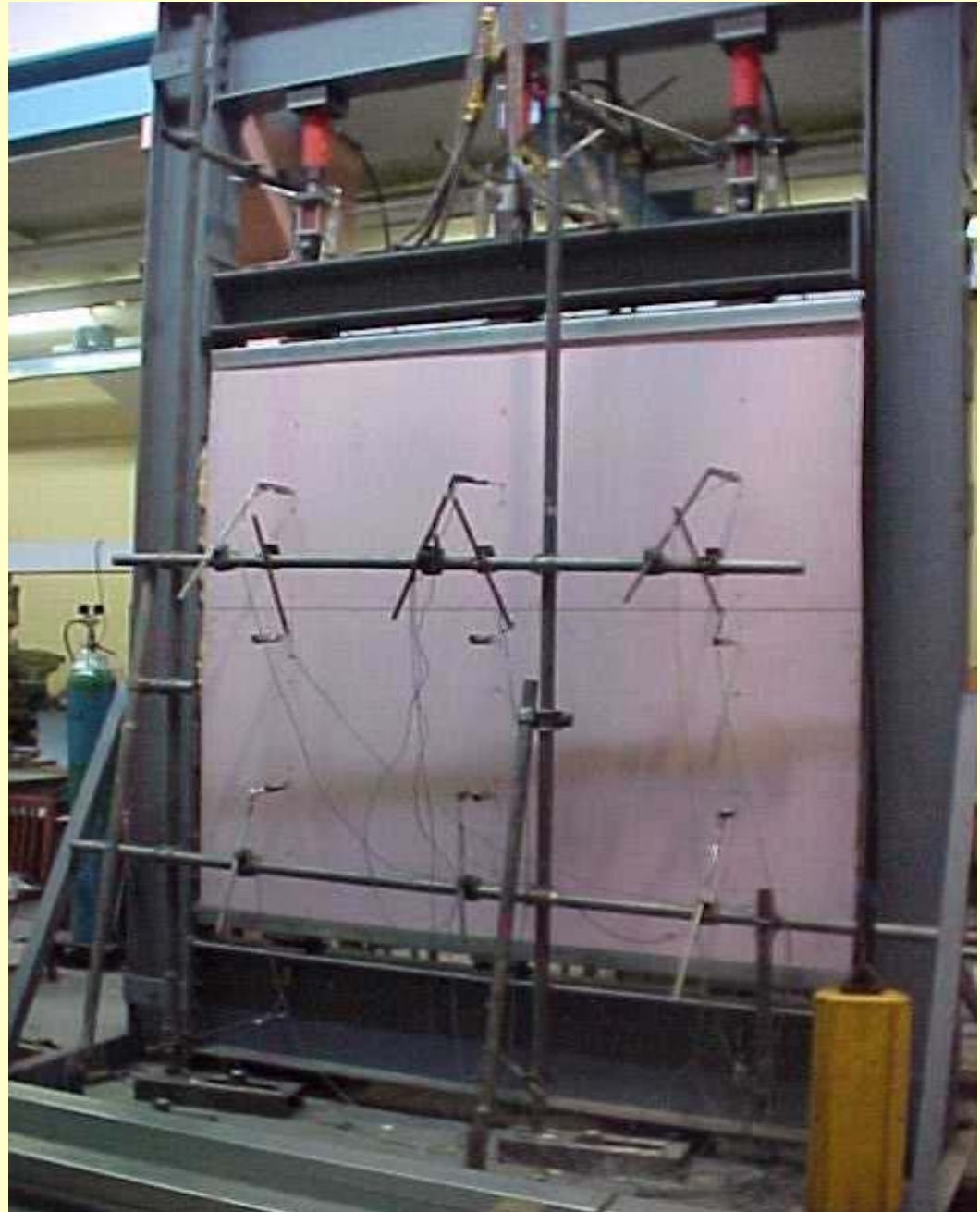
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# Large Furnace



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# Reaction Frame to Large Furnace



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# Objectives

- Bending moment variations in restrained columns in fire
- Effective lengths of restrained columns in fire

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# Test Programme

- 18 restrained steel columns: 9 using fin plate connections, 9 using extended end plate connections, 3 axial load level, 3 bending moment level
- 16 restrained concrete filled columns: 8 using fin plate connections, 8 using extended end plate connections, two tube sizes, two load levels, balanced and unbalanced beam loads



# Restrained Column Arrangement

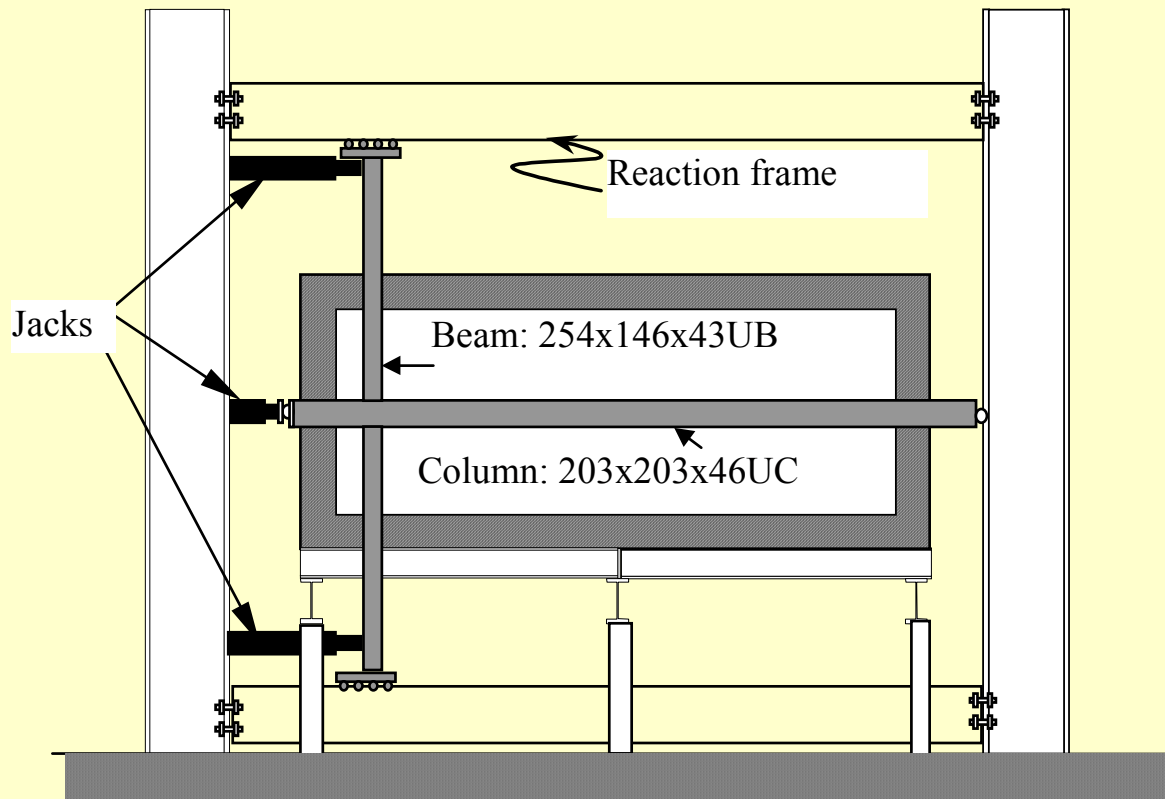


Figure 2: Schematic arrangement

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# Restrained Column Arrangement

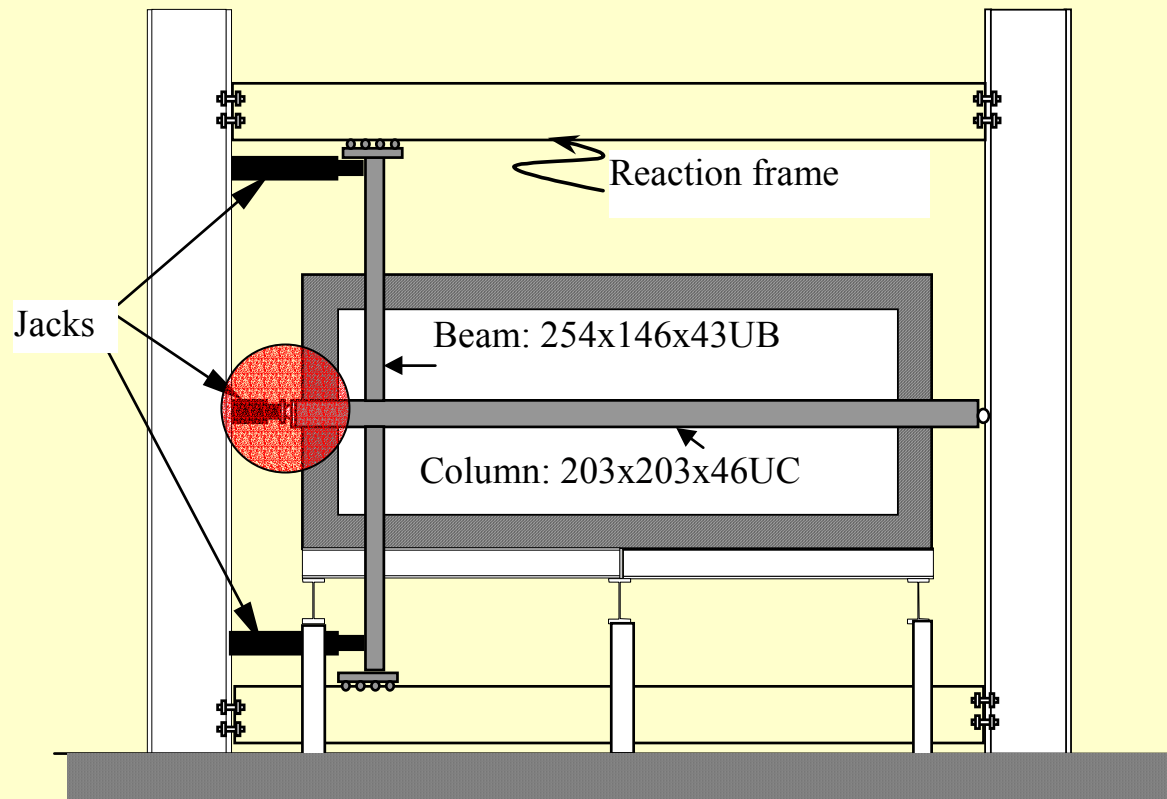


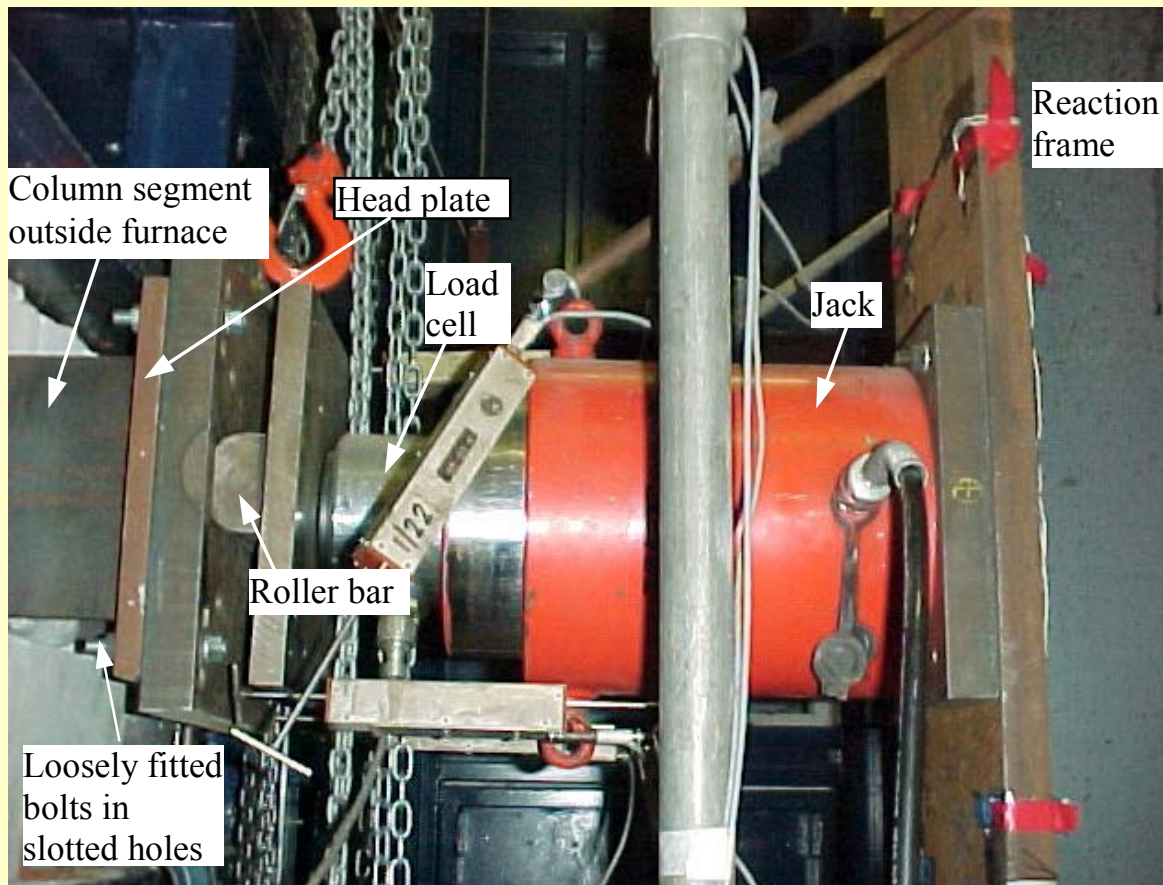
Figure 2: Schematic arrangement

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# Column Head Support



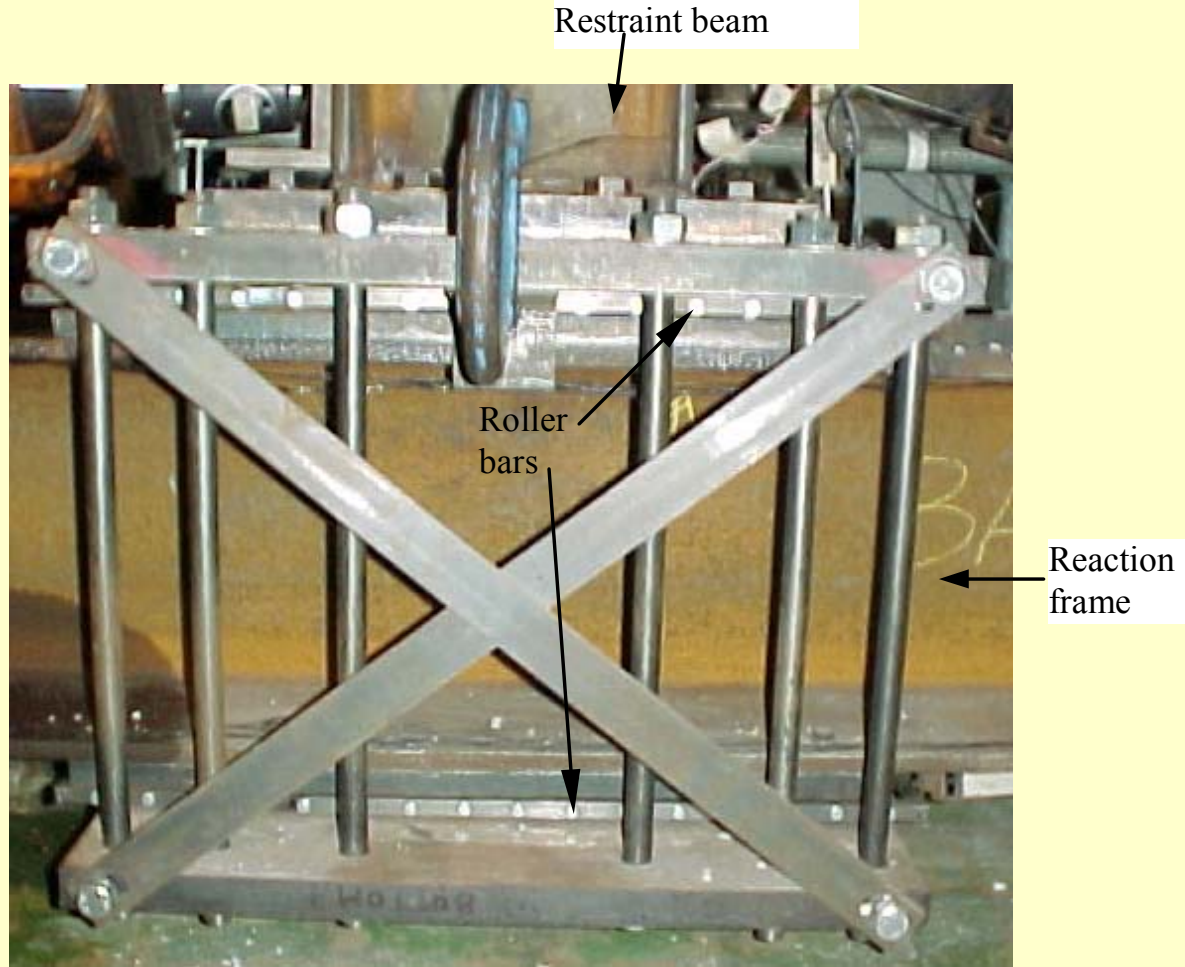
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# Beam End Support



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# Performance of Sliding Joints - Loading Phase

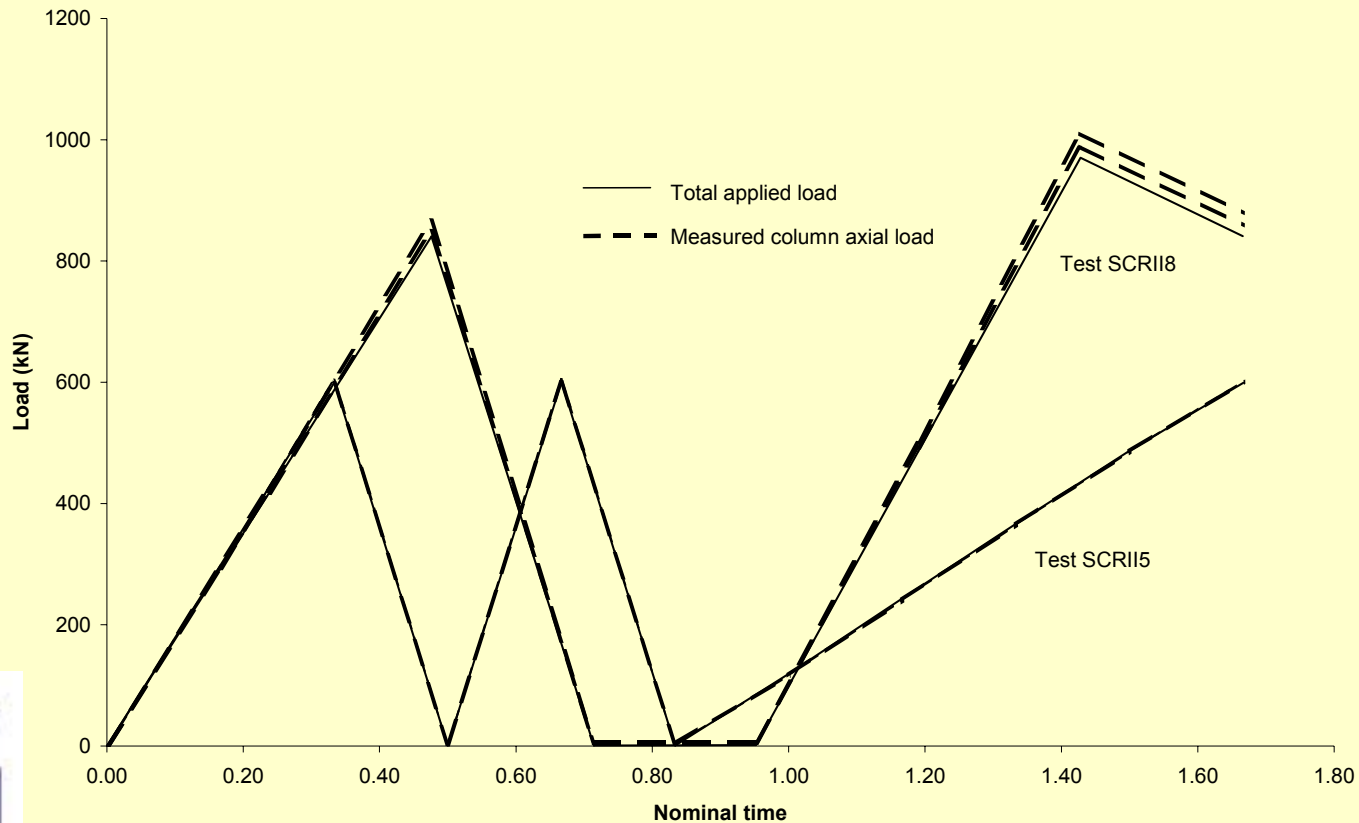


Figure 3: Comparison between measured column axial load and total applied load at ambient temperature



# Performance of Sliding Joints - Fire Exposure Phase

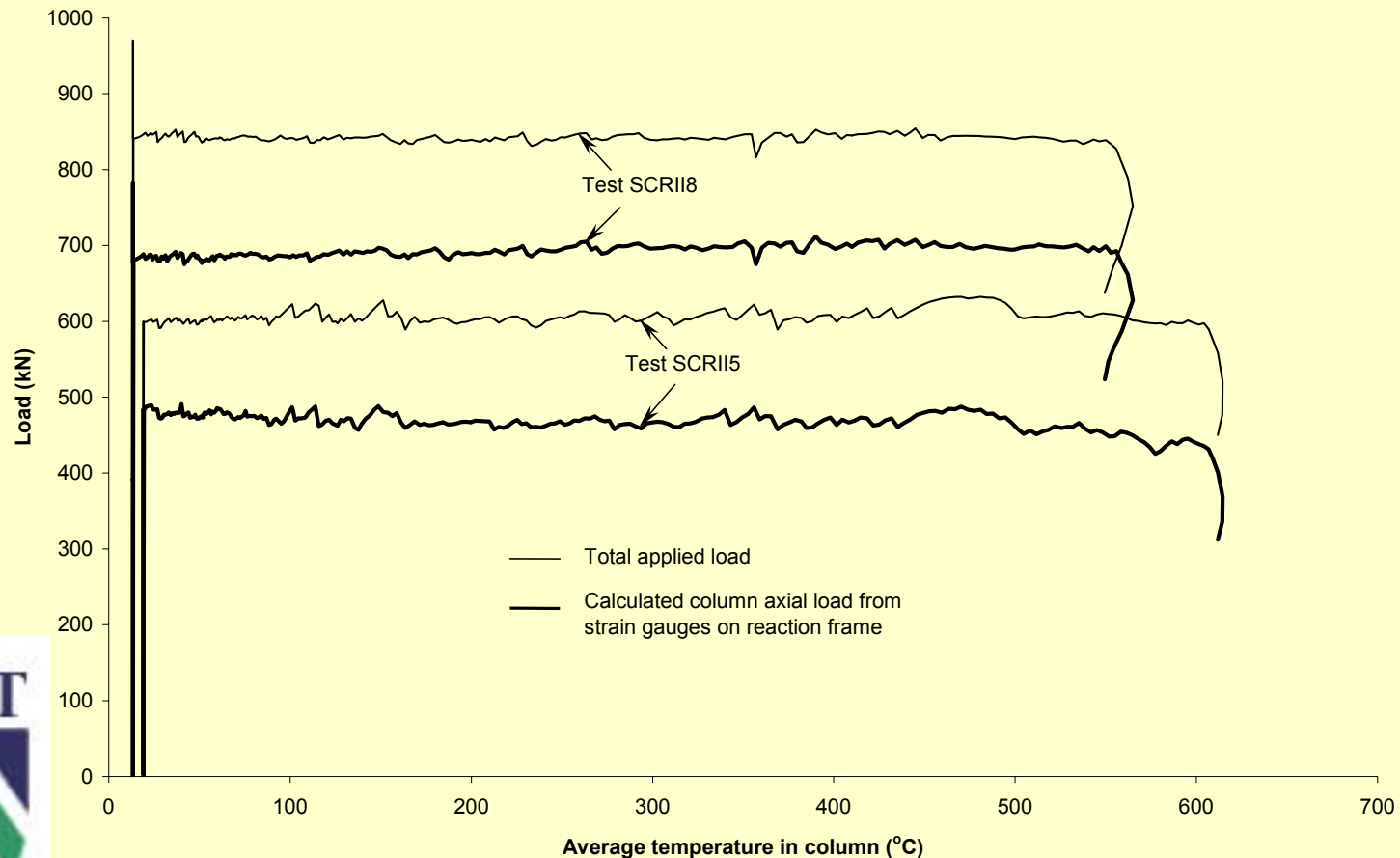


Figure 4: Comparison between calculated column axial load and total applied load





# Bending Moments in Restrained Steel Columns

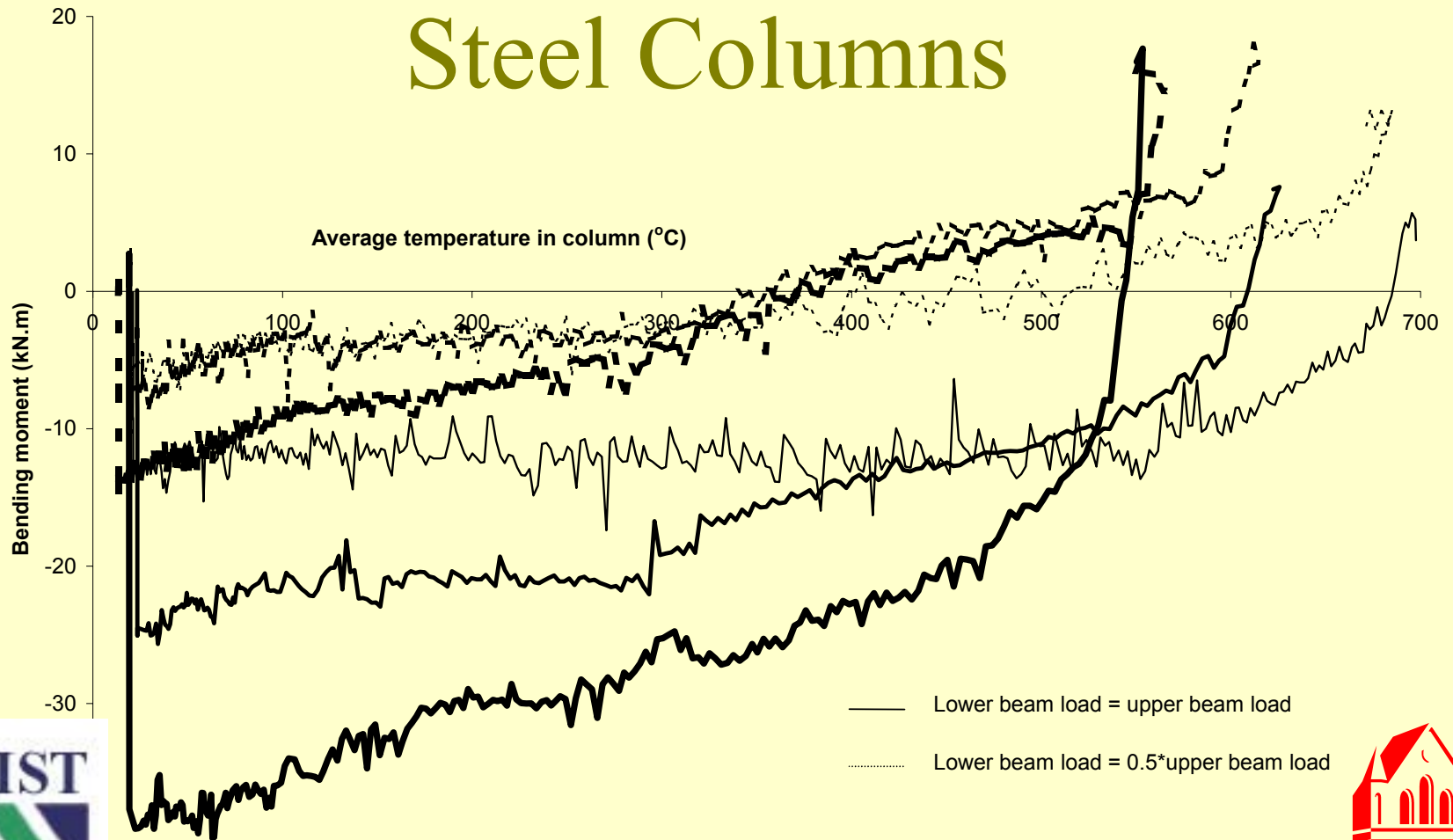
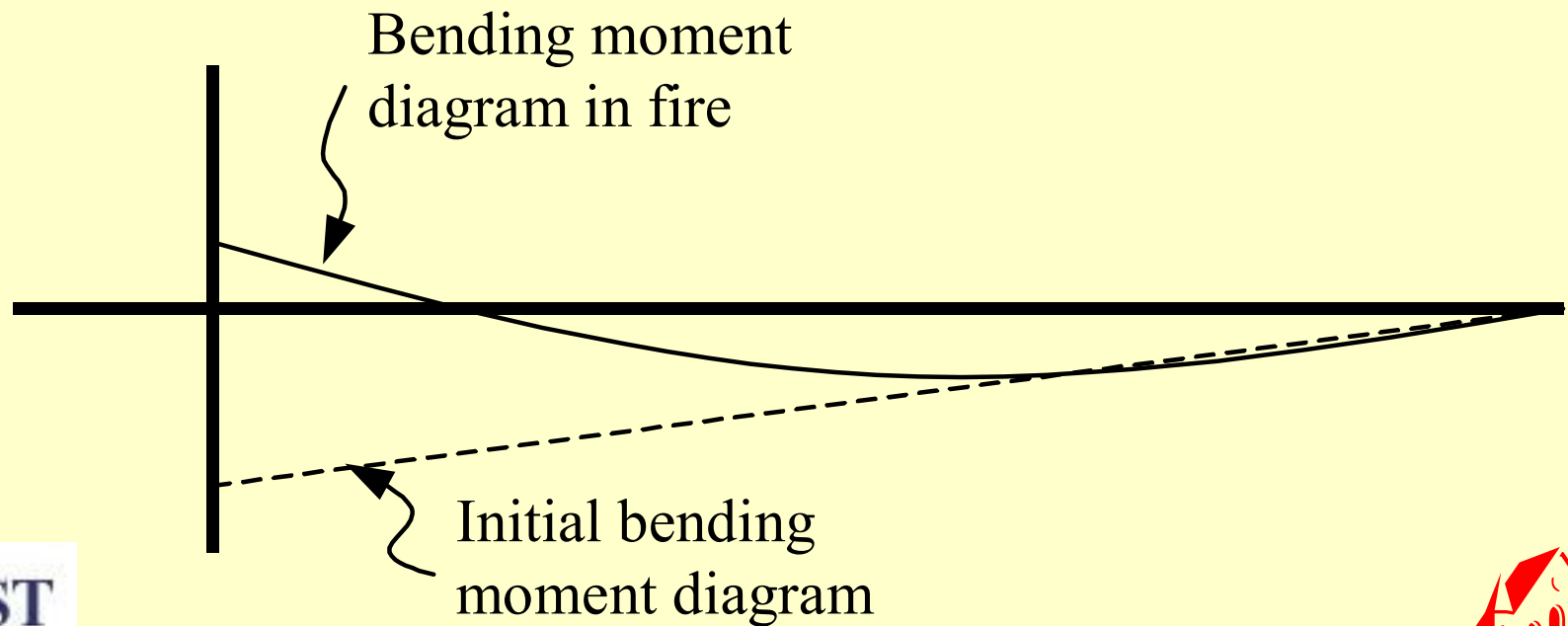


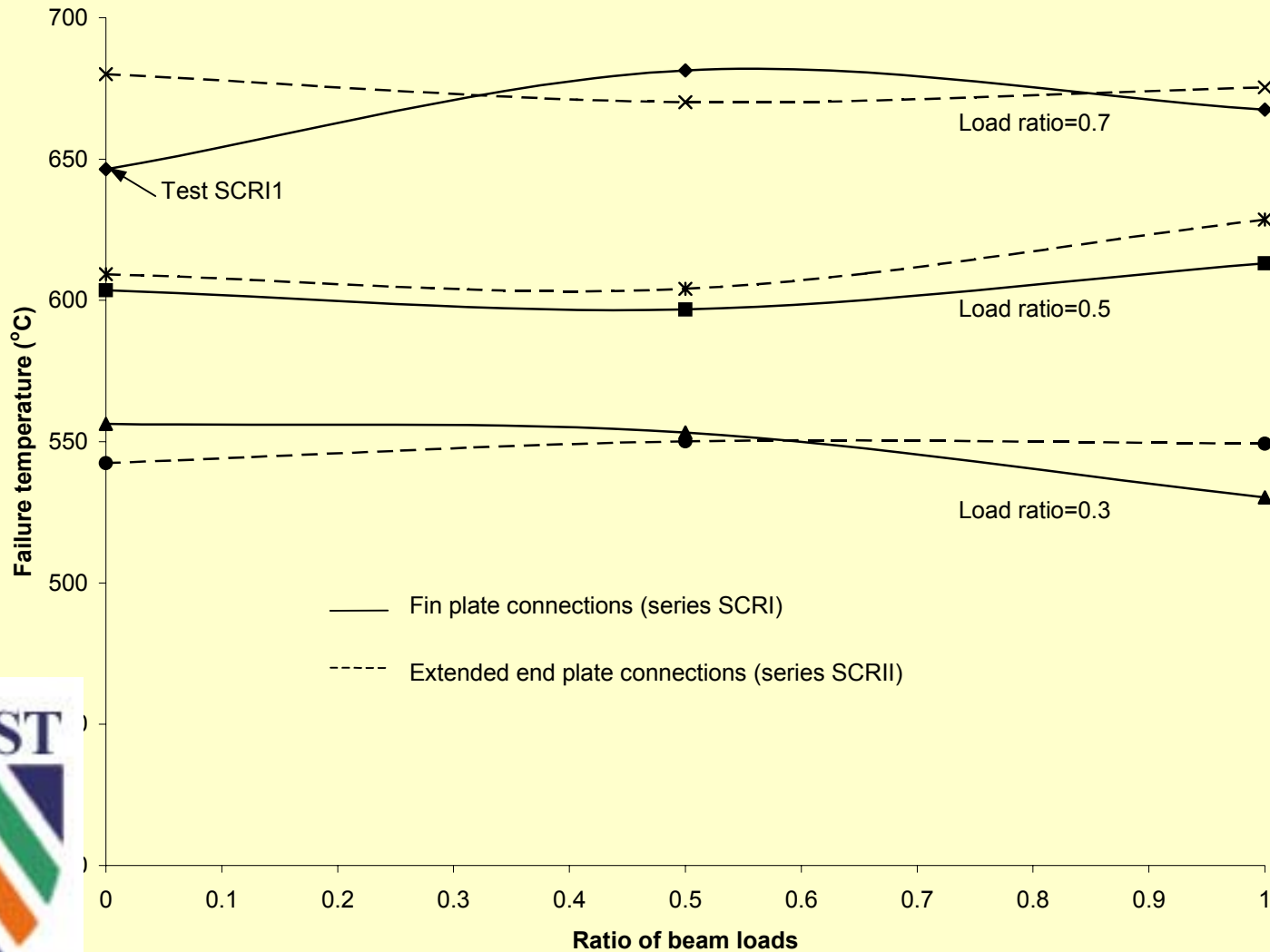
Figure 5: Change of bending moments at column head



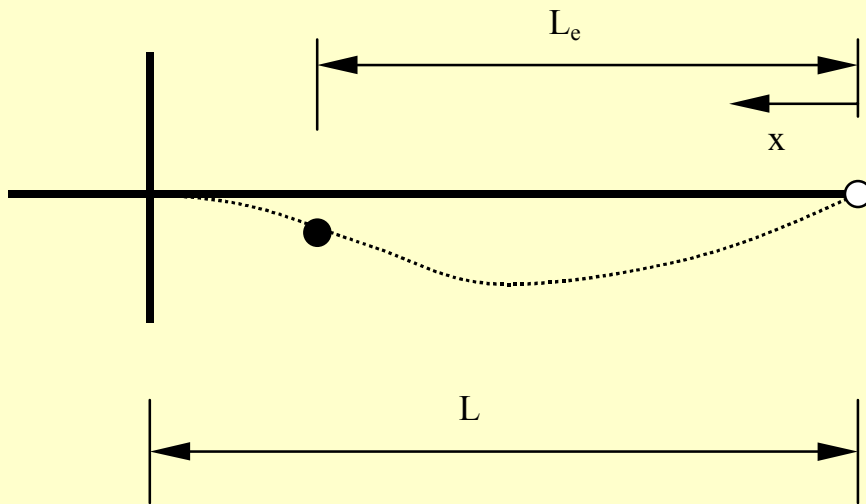
# Bending Moment Distribution at Fire Limit State



# Test Failure Temperatures



# Effective Lengths of Restrained Steel Columns in Fire



$$\delta_x = Ax^5 + Bx^4 + Cx^3 + Dx^2 + Ex + F$$

$$\delta_{x=0} = 0 \Rightarrow F = 0$$

$$\left. \frac{\partial^2 \delta}{\partial x^2} \right|_{x=0} = 0 \Rightarrow D = 0$$

*A, B, C, E to be determined*

*L<sub>e</sub> is effective length, given by:*

$$\left. \frac{\partial^2 \delta_x}{\partial x^2} \right|_{x=L_e} = 0 \Rightarrow AL_e^2 + 0.6BL_e + 0.3C = 0$$

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# Effective Length Ratios

Test series	Test number								
	1	2	3	4	5	6	7	8	9
SCRI	0.8	0.775	0.775	0.825	0.664	0.74	0.809	0.78	0.809
SCRII	0.76	0.768	0.751	0.83	0.777	0.761	0.786	0.786	0.766

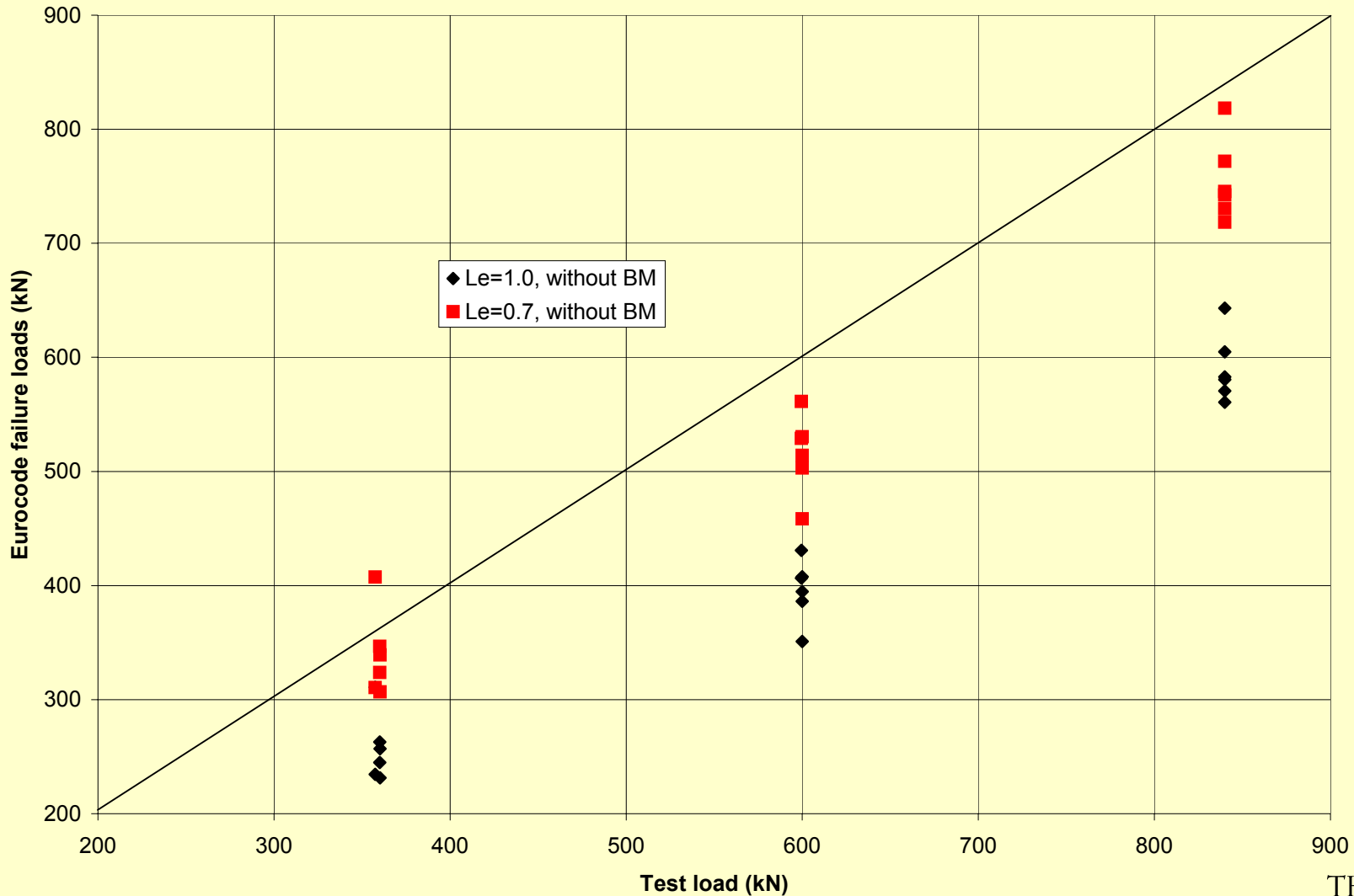
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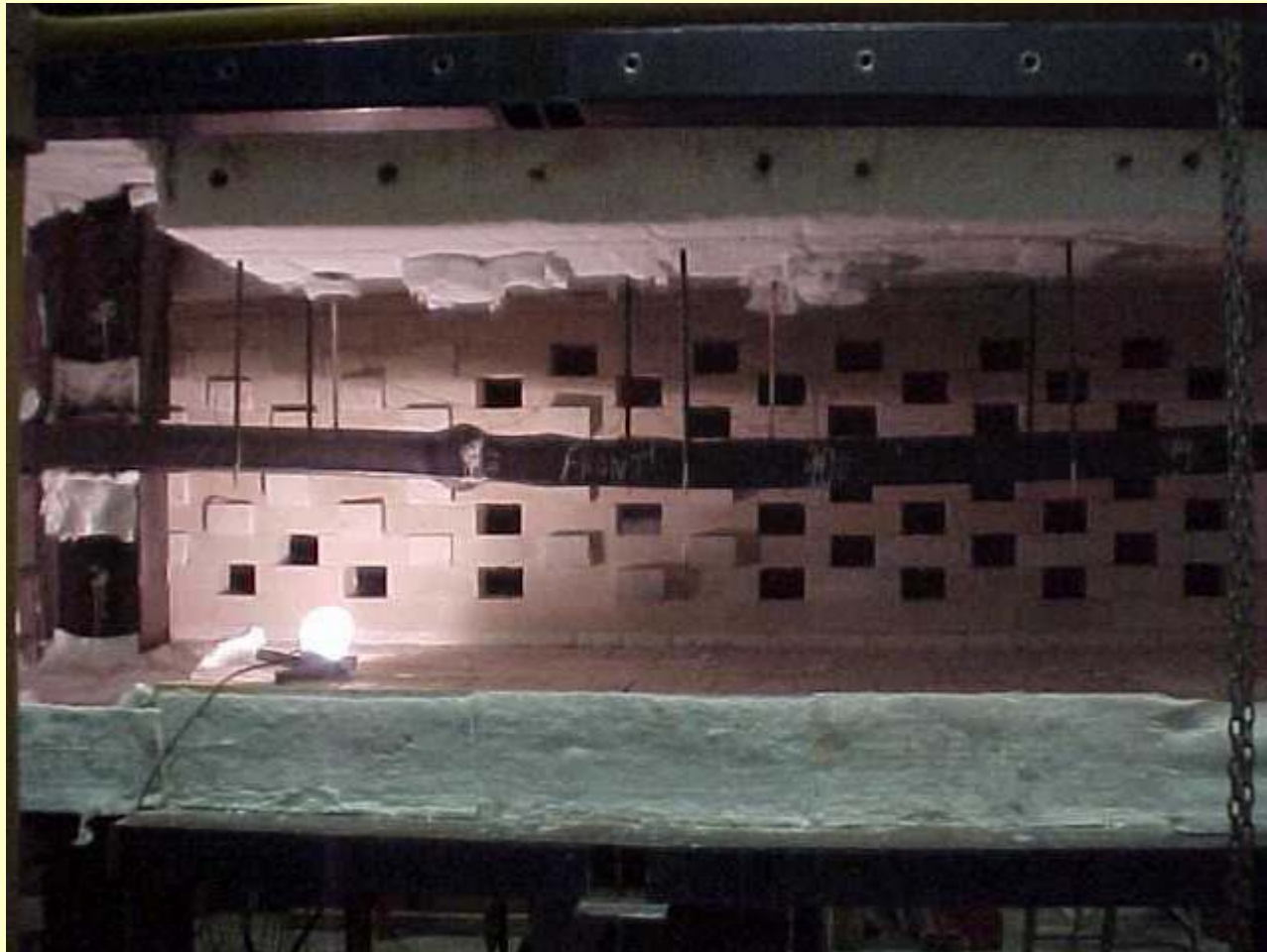
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# Comparison between Test Results and Eurocode Part 1.2



# Effective Length of Restrained Concrete Filled Columns

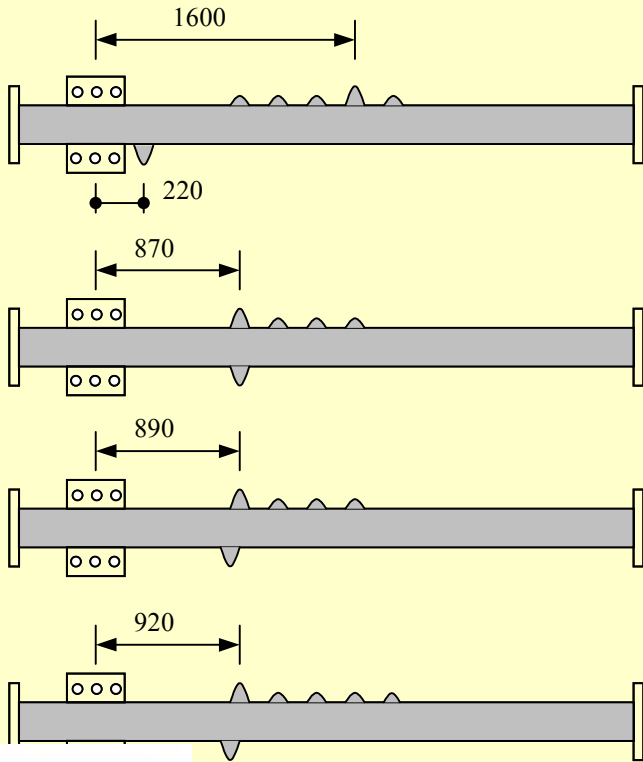


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# Fin Plate Connections

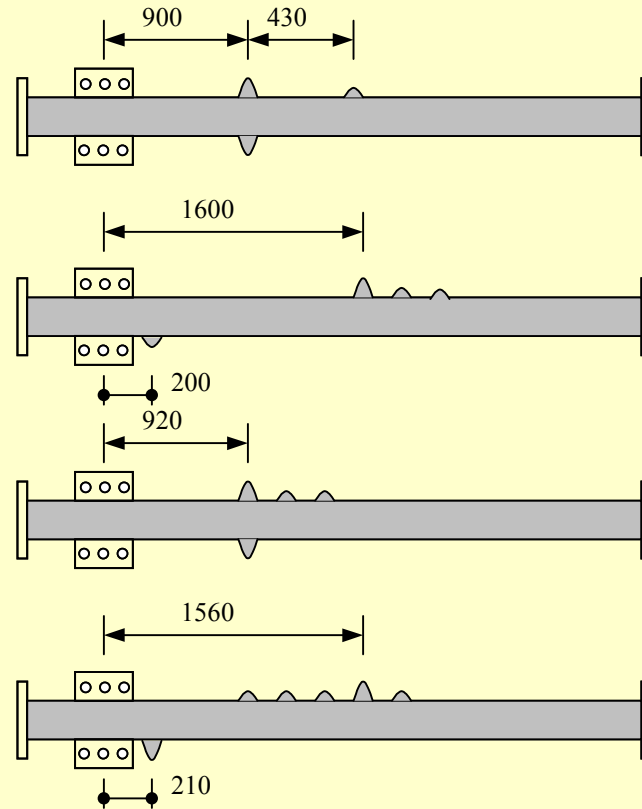


SCR31

SCR32

SCR33

SCR34



SCR35

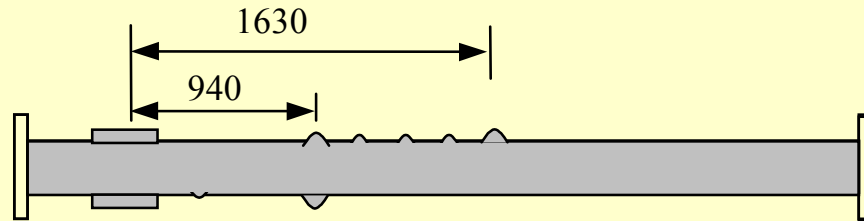
SCR36

SCR37

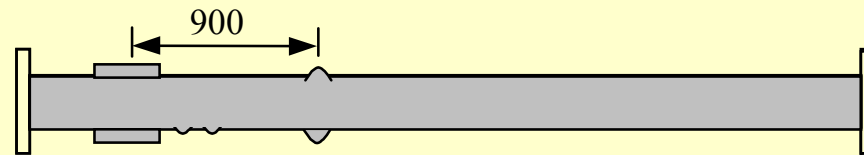
SCR38



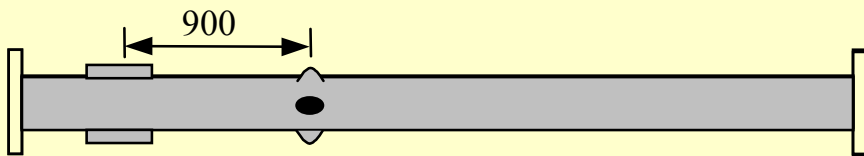
# Extended End Plate Connections



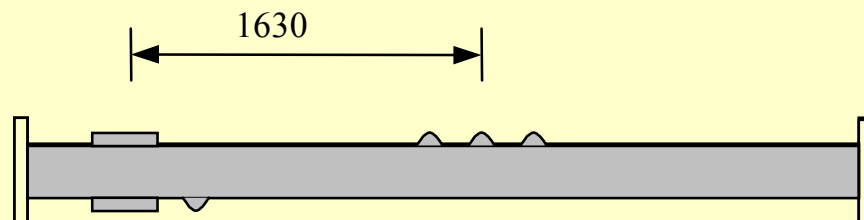
SCR41



SCR42



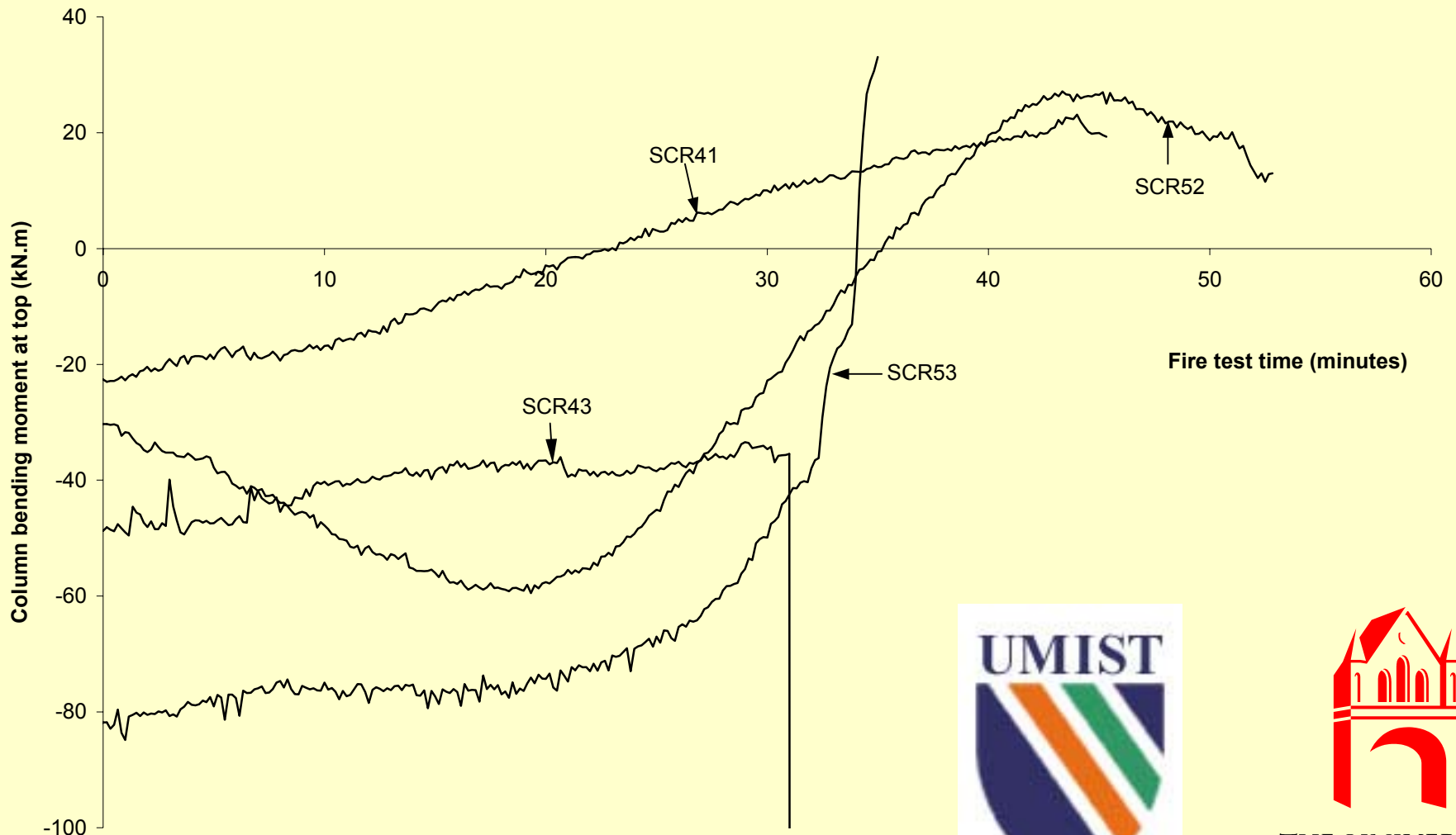
SCR43



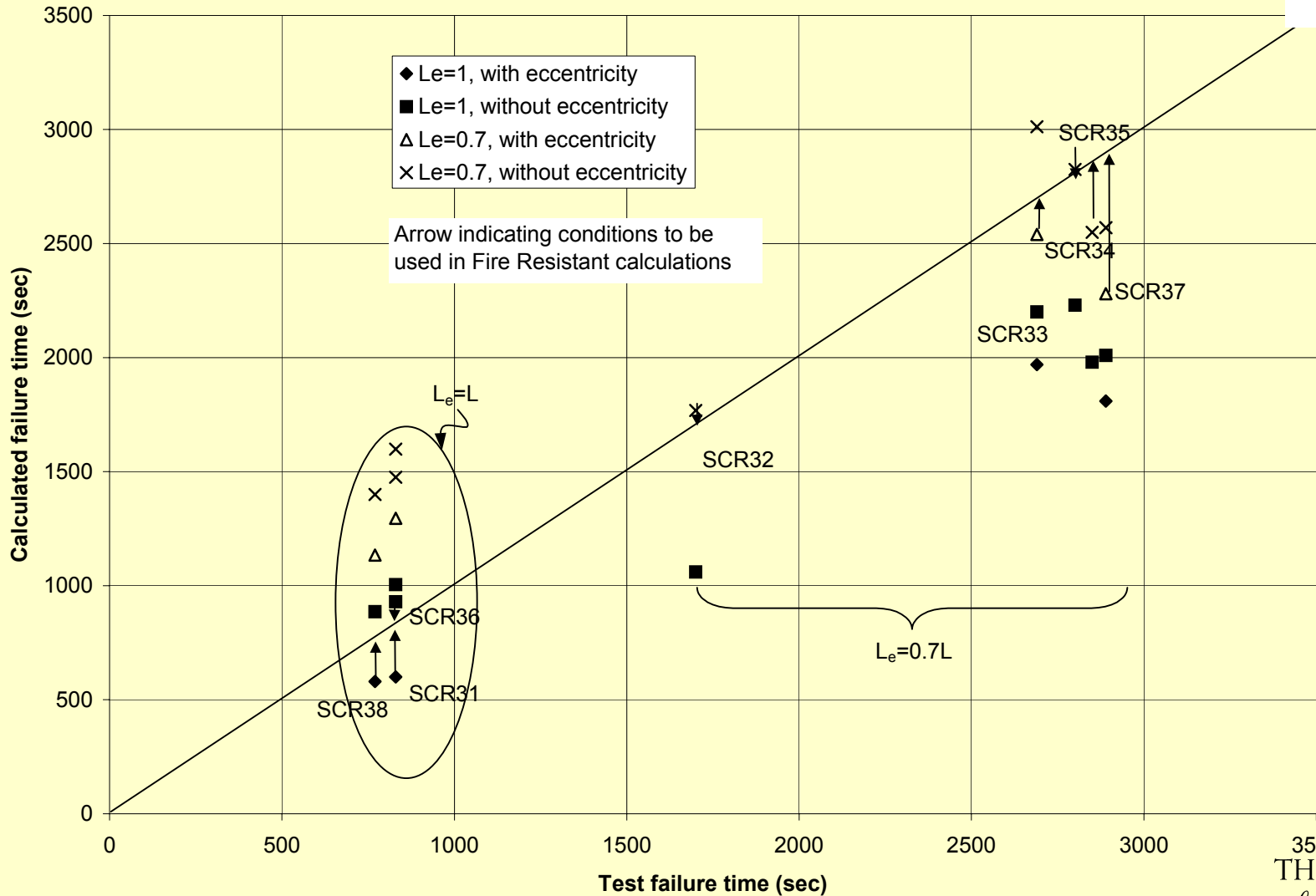
SCR44



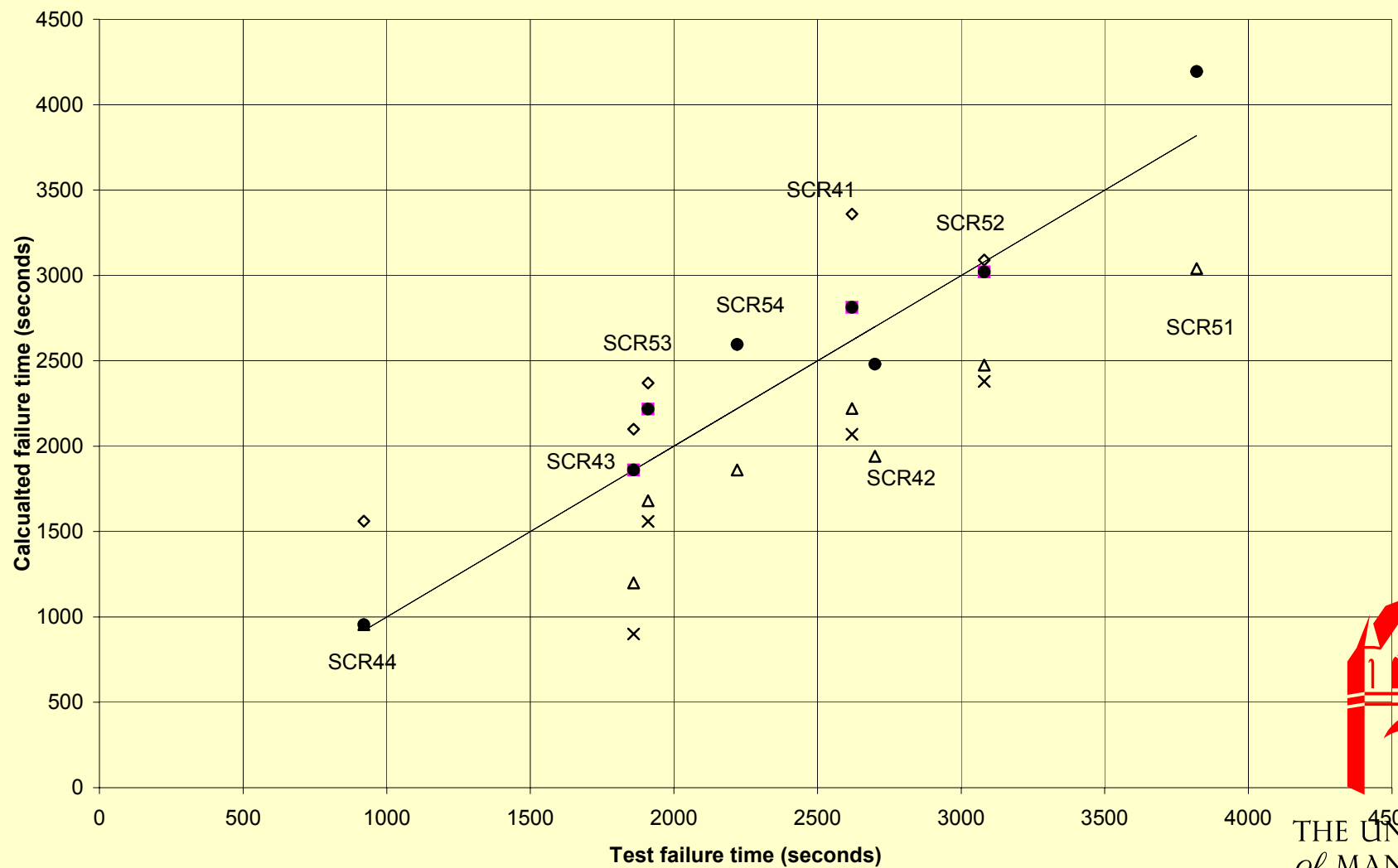
# Bending Moments in Restrained Concrete Filled Columns



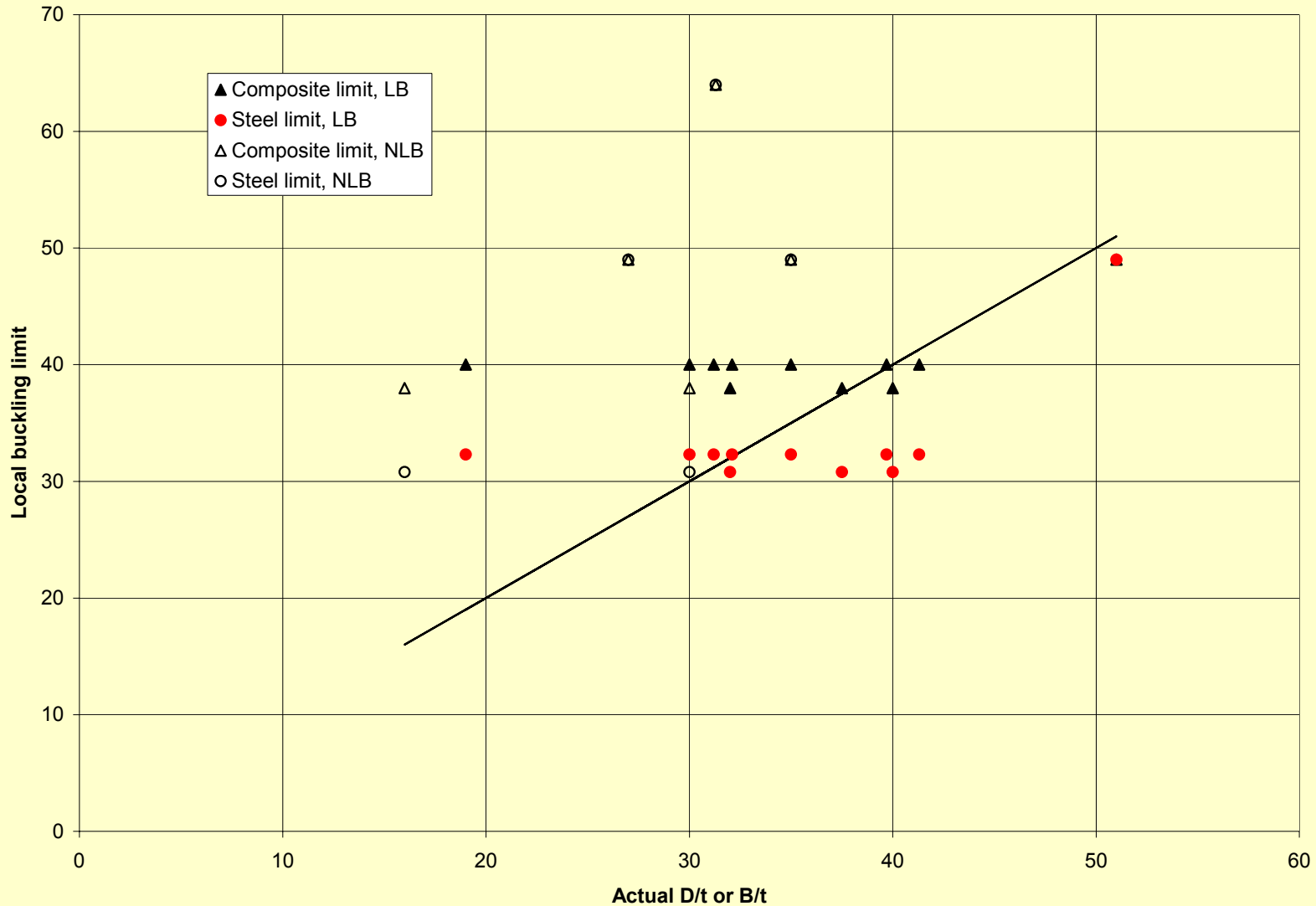
# Comparison of Results: Fin Plate Connections



# Comparison of Results: Extended End Plate Connections



# Occurrence of Local Buckling



# Recommendations for Design

- Bending moments = beam reaction load times eccentricity
- Effective length:
  - (1) Steel columns and concrete filled columns without local buckling: use Eurocode
  - (2) Concrete filled columns with local buckling: column height



# Acknowledgements

EPSRC

Corus



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