Behaviour of Restrained Columns in Fire

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Small Furnace
Medium Furnace
Large Furnace
Reaction Frame to Large Furnace
Objectives

• Bending moment variations in restrained columns in fire
• Effective lengths of restrained columns in fire
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
Restrained Column Arrangement

Figure 2: Schematic arrangement
Column Head Support

Column segment outside furnace
Load cell
Head plate
Roller bar
Jack
Loosely fitted bolts in slotted holes
Reaction frame
Restrained Column Arrangement

Figure 2: Schematic arrangement
Beam End Support

- Restraint beam
- Roller bars
- Reaction frame
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

- Test SCRII8
- Test SCRII5

Load (kN)

Average temperature in column (°C)

Total applied load
Calculated column axial load from strain gauges on reaction frame

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

Figure 2: Schematic arrangement

Column: 203x203x46UC
Beam: 254x146x43UB
Jacks
Reaction frame
Bending Moments in Restrained Steel Columns

Figure 5: Change of bending moments at column head

- Lower beam load = upper beam load
- Lower beam load = 0.5*upper beam load
Bending Moment Distribution at Fire Limit State

Bending moment diagram in fire

Initial bending moment diagram
Test Failure Temperatures

- **Test SCRI1**
  - Load ratio = 0.3
  - Load ratio = 0.5
  - Load ratio = 0.7

- Fin plate connections (series SCRI)
- Extended end plate connections (series SCRII)
Effective Lengths of Restrained Steel Columns in Fire

\[ \delta_x = Ax^5 + Bx^4 + Cx^3 + Dx^2 + Ex + F \]
\[ \delta_{x=0} = 0 \Rightarrow F = 0 \]
\[ \frac{\partial^2 \delta_x}{\partial x^2} \bigg|_{x=0} = 0 \Rightarrow D = 0 \]

A, B, C, E to be determined

\( L_e \) is effective length, given by:

\[ \frac{\partial^2 \delta_x}{\partial x^2} \bigg|_{x=L_e} = 0 \Rightarrow A L_e^2 + 0.6 B L_e + 0.3 C = 0 \]
## Effective Length Ratios

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<th>3</th>
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Comparison between Test Results and BS 5950 Part 8

Graph showing the comparison between test results and calculated limiting temperatures. The graph includes data points for different values of $Le$ with and without BM, indicating a close alignment with the theoretical limiting temperature line.
Comparison between Test Results and Eurocode Part 1.2

![Graph showing comparison between test loads and Eurocode failure loads for different Le values.](image)
Effective Length of Restrained Concrete Filled Columns
Fin Plate Connections

SCR31

SCR32

SCR33

SCR34

SCR35

SCR36

SCR37

SCR38
Extended End Plate Connections

- SCR41: 1630
- SCR42: 940
- SCR43: 900
- SCR44: 1630
Bending Moments in Restrained Concrete Filled Columns

[Graph showing column bending moment at top (kN.m) against fire test time (minutes).]

- SCR41
- SCR43
- SCR51
- SCR52
- SCR53

[Handwritten notes on graph:]

- Fire test time (minutes)
Comparison of Results: Fin Plate Connections

- Le=1, with eccentricity
- Le=1, without eccentricity
- Le=0.7, with eccentricity
- Le=0.7, without eccentricity

Arrow indicating conditions to be used in Fire Resistant calculations
Comparison of Results: Extended End Plate Connections

![Graph showing comparison between test failure times and calculated failure times for SCR41, SCR42, SCR43, SCR44, SCR51, SCR52, SCR53, and SCR54. The graph plots test failure time (seconds) on the x-axis and calculated failure time (seconds) on the y-axis.]
Occurrence of Local Buckling

![Graph showing the occurrence of local buckling with different markers for composite and steel limits.]
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

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