Master's Thesis Engineering Technology

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Research into fire stability RF60 (according to Eurocode 3) of modular units

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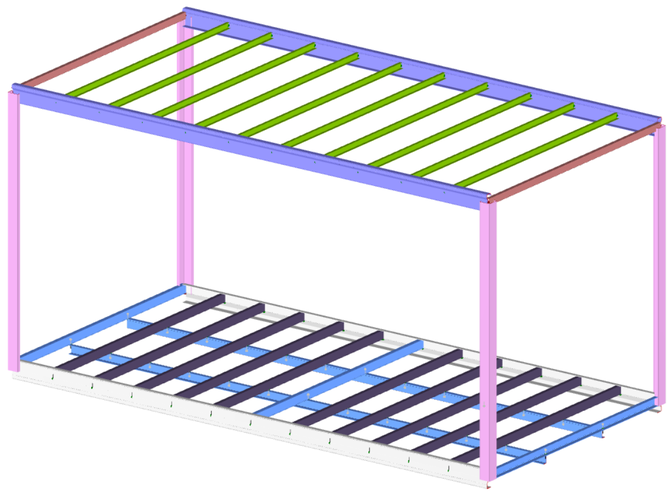
1. OBJECTIVE

The **main objective** of this document is to provide the reader with a better understanding of the current methods used in **structural fire design for steel modular units** according to the European Standard Eurocode, as well as to use this information to gain more insight in the proper use of the **software RFEM** for fire stability calculations.

First of all, a general analysis of a **fire situation** and its conditions is made. As a next step, these conditions are applied on the **modular units used by CBZ** (a construction company from Zutendaal, Belgium) in the RFEM software. One of these basic modular units is analysed in this document for fire stability R60. This in order to provide CBZ with the **calculation methods and results**. By doing so, this document serves as a guide for engineers that use RFEM.



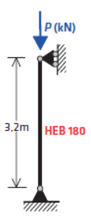
2. METHOD

An analysis of the concept **"fire situation"** is made according to **EN 1993-1-2**. The backgrounds of the calculations are explored before the 3D structural analysis software **RFEM is validated**. This is done by working out three examples, first by hand and then with the calculation software. Once the software is validated, the results, obtained by RFEM, are valid. Finally, the modular units, as constructed by CBZ, are tested for the **fire stability R60** with RFEM.

3. SOFTWARE VALIDATION

The **software RFEM is validated** in order to prove that the results, obtained with the software, are representative. This is done by calculating **three examples** while using the formulas from EN 1993-1-2 and afterwards working out the same examples in RFEM.

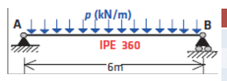
Ex.1: Steel tie [1]



Summary (Tie)	R15 (Manual)	R60 (Manual)	R15 (RFEM)	R60 (RFEM)
Fire load	346.03 kN	346.03 kN	346.05 kN	346.05 kN
Plastic resistance	363.00 kN	363.00 kN	363.28 kN	363.28 kN
Steel temperature	695.00 °C	555.74 °C	700.541 °C	231.65 °C
$k_{y,\theta}$	0.232	1.00	0.229	1.00
Fire resistance	84.216 kN	363.00 kN	83.32 kN	363.28 kN
Validation	NOK	OK	NOK	OK

Table 1: Comparison hand-calculations and RFEM results for a steel tie

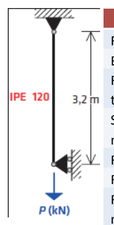
Ex.2: Steel beam [1]



Summary (Beam AB)	R60 (Manual)	R60 (RFEM)
Bending moment	262 kN	259.27 kN
Shear load	175 kN	218.32 kN
Bending resistance	280.5 kNm	280.23 kNm
Shear resistance	557.92 kN	557.89 kN
Critical temperature	602°C	602°C
Steel temperature	597°C	584°C
Reduction factor $k_{y,\theta}$	1	0.454
Fire resistance	280.5 kNm	127.11 kNm
Validation	OK	NOK

Table 2: Comparison hand-calculations and RFEM results for a steel beam

Ex.3: Steel column [1]



Summary	R60 (Manual)	R60 (RFEM)
Fire load	596.08 kN	596.21 kN
Buckling length	2.24 m	2.24 m
Relative slenderness at ambient temperature	0.56	0.565
Steel temperature at 60 minutes	521.9°C	521.946°C
Reduction factor $k_{y,\theta}$	0.712	0.712
Reduction factor $k_{\varepsilon,\theta}$	0.538	0.536
Relative slenderness at 60 minutes	0.66	0.65
Imperfection factor α	0.60	0.601
Reduction factor ϕ	0.92	0.907
Reduction factor χ	0.64	0.65
Fire design resistance	821.142 kN	830.11 kN
Validation	OK	OK

Table 3: Comparison hand-calculations and RFEM results for a steel column

[1] C. –. A. P. d. C. M. e. Mista, Fire Guideline: Design and Examples, Portugal: Joana Albuquerque, 2015.

4. RESULTS & CONCLUSION

The **results** give a perspective on how the **modular units**, as constructed by CBZ, behave in a **fire situation**. Most of the tested configurations have enough fire stability to reach a fire resistance of R60.

When **failures** for the calculation of fire stability R60 do occur, it was attempted to solve the problems. **Two possible solutions are tested**: Improving the steel quality and adding extra supports.

This research also opens the **opportunity for other researches**. The **wall configuration** for the models of the modular units can be further **improved**. This can be done with an analysis of the load dispersion for the wall build-up. Also , it can be useful to explore the **influence of the insulation** on the fire resistance of some of the elements. This was not possible to do for this research, due to the limitations of the software.

Summary	Profiles	Rigid	Orthogonal
Case I	0,48 (6)	0,27 (2)	0,18 (2)
Case II	0,97 (6)	0,27 (2)	0,28 (6)
Case III	2,06 (6)	0,27 (2)	0,45 (6)
Case IV	0,48 (6)	0,27 (2)	0,18 (2)
Case V	0,95 (6)	0,85 (1)	0,40 (1)
Case VI	2,94 (6)	1,51 (1)	0,71 (1)
Case VII	0,46 (6)	0,79 (6)	0,98 (6)
Case VIII	1,46 (6)	0,79 (6)	1,41 (6)
Case IX	0,47 (6)	0,42 (6)	1,03 (6)
Case X	1,49 (6)	1,12 (6)	1,68 (6)

Table 4: Comparison of the result for three types of walls

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