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5º CONGRESSO IBERO-LATINO-AMERICANO EM SEGURANÇA CONTRA INCÊNDIOS

5th IBERIAN-LATIN-AMERICAN CONGRESS ON FIRE SAFETY

15-17 /07/ 2019 - Porto, Portugal

Atas dos Artigos
Proceedings (full papers)

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U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
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PREFACE

The Iberian-Latin American Congress on Fire Safety (CILASCI) is held once every two years, with the aim of disseminating scientific and technical knowledge in the field of fire safety, integrating different players involved in this area of knowledge. The first edition of the Iberian-Latin American Congress on Fire Safety (CILASCI 1), was held in Natal (Brazil) between 10-12 March 2011. The second congress (CILASCI 2) was held in Coimbra (Portugal), between May 29 and June 1, 2013. The 3rd and 4th editions took place on the South American continent. The third congress (CILASCI 3) was held in Porto Alegre (Brazil) from November 3 to 6, 2015, while the fourth congress (CILASCI 4) was held in Recife (Brazil) from 9 to 11 October 2017. The CILASCI 5 will take place in the city of Porto (Portugal) from 15 to 17 July 2019, and presents 5 invited lectures and 78 manuscripts (full papers) from researchers around the world (Algeria, Australia, Belgium, Brazil, China, Czech Republic, France, Hong Kong, Italy, Mozambique, Portugal, Spain, United Kingdom and United States).

the 5th Iberian-Latin-American congress on fire safety reflects the new developments achieved on active and passive fire protection, on evacuation and human behaviour under fire, on computational modelling of structures and materials under fire, on explosion and risk management, on architectural issues for fire safety in buildings, on fire dynamics, on the experimental analysis of materials and structures under fire, on fires in special buildings and spaces, on fire-fighting operations and equipments, and on the behaviour of structures and materials under fire.

The Fire Safety is reaching new developments as a result of new research, development and innovation around the world, based on the excellence level of the research, the support of new skilled professionals and due to the existence of advanced training programmes in fire science technology. This development will increase the safety level of people, buildings, and products, but also is going to produce an impact in the economy of each country, with a positive impact on society.

The organizing committee believe that this congress will address to our delegates a wide forum of discussion about the recent developments in Fire Safety, promoting the exchange of ideas and international cooperation.

The organizing Committee would like to thanks to all authors and delegates.

On the behalf of the Organizing Committe
Paulo A. G. Piloto

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BEHAVIOUR OF INDUSTRIAL BUILDINGS WITH STEEL PORTAL FRAMES UNDER FIRE CONDITIONS

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Keywords: industrial buildings; steel portal frames; fire safety, numerical simulations.

1. INTRODUCTION

Pitched roof Steel frame structures are widely used in industrial buildings for practical reasons of exploitation, durability and cost efficiency. However, steel being a ductile material, it remains vulnerable to excessive temperatures. The recent accidents, which occurred in the industrial buildings of Sonatrach (petroleum industry in Algeria), in an urban area in Algiers or in an industrial zone in Skikda, remind us of the real danger and the potential risk of fire.

European standards [1-2] give an overview of simplified design rules, which are common for the evaluation of the fire resistance of steel structural elements. However, for industrial and warehouse buildings, specific requirements defined in terms of structural behaviour have been imposed to meet the safety objectives of occupants and firefighters. In this context, the criteria of non-collapse outward of the structure exposed to fire and non-progressive collapse must be verified. In order to meet these performance criteria, a European project [3] covered the structural behaviour of industrial buildings and warehouses exposed to fire. The project aimed to demonstrate that, given the 3D behaviour of the structure in case of fire, these structures could offer better structural strength. Based on the numerical results, simplified calculation methods

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have been proposed.

The actual behaviour of the industrial buildings in fire situation requires some parameters such as material and geometrical nonlinearities as well as variation in thermal and mechanical behaviour in time. However, only numerical analysis using finite element programs provide a comprehensive analysis of such structures by providing various fire scenarios [4-6].

This work proceeds by numerical simulations to study the behaviour of industrial steel portal frames with haunches under standard fire *ISO834* [7]. A model is developed using ANSYS program [8] to determine the time resistance and the collapse mode considering particularly the effect of fire scenario, haunch length and geometrical dimensions of the portal frames. The parametric study was performed by both shell elements to model the portal frames in 3D and non-uniform temperature within the structural beam-column elements.

2. FIRE MODEL AND THERMAL RESPONSE

Although the governing parameters of a real fire are numerous, the ISO834 standard time-temperature curve [8] is assumed testing purposes and numerical simulations. It represents the action of a fire in a confined compartment of building and the gas temperature evolution given according to the formula of the EC1 [1]:

$$\theta = 20 + 345 \; log_{10}(8t + 1) \tag{1}$$

For thermal response, the governing equation for the three-dimensional non-linear transient heat conduction within the cross section of a structural element takes the following form:

$$\frac{\partial}{\partial x}\left(\lambda_a \frac{\partial \theta_a}{\partial x}\right) + \frac{\partial}{\partial y}\left(\lambda_a \frac{\partial \theta_a}{\partial y}\right) + \frac{\partial}{\partial z}\left(\lambda_a \frac{\partial \theta_a}{\partial z}\right) = \rho_a c_a \frac{\partial \theta_a}{\partial t} \tag{2}$$

Where λ_a and c_a are respectively the thermal conductivity and the specific heat of steel both are expressed as a function of the temperature in EC1 [1], θ_a is the steel temperature in x, y and z directions at time t, ρ_a is the density of steel equal to 7850 kg/m^3.

Since the solution of equation (2) is non-linear, simplified solution for the temperature rise of an unprotected steel member is provided by EC3 [2], assuming a lumped thermal model for non-massive elements, with the following equation:

$$\Delta \theta_a = k_{sh} \frac{A_m / V}{c_a \rho_a} \dot{h}_{net,d} \Delta t \tag{3}$$

Where k_{sh} is the correction factor for the shadow effect, A_m/V is the section factor for unprotected steel elements, $\dot{h}_{net,d}$ is the net heat flux or heat transfer by convection and radiation per unit area, Δt is the time interval in seconds ($\Delta t \leq 5$ s).

3. PARAMETRIC STUDY

A parametric study is conducted using numerical simulations with ANSYS [8]. The industrial portal frame, shown in Fig. 1, is analysed based on the variation of the following parameters: fire scenarios, haunch length and portal frame dimensions.

This structure is illustrated in the CTICM guide [9] where both frame and purlins are checked for 15 minutes of fire exposure. Load combination on the rafter take into account G (dead load, roof, industrial equipment under roof and cladding) equal to 4.16 kN/m and S (snow) equal to 4.4 kN/m. A total uniformly distributed load q in fire situation is calculated using G and 0.2S which gives 5.04 kN/m. Elements are chosen using hot rolled sections with IPE400 for the rafter and IPE500 for both columns. The steel grade is taken as S235 with a density of 7850 kg/m3 and Poisson's ratio equal to 0.3. Haunches, with IPE400 section, are added at the ends of the rafter. Column bases are supposed fully pinned.

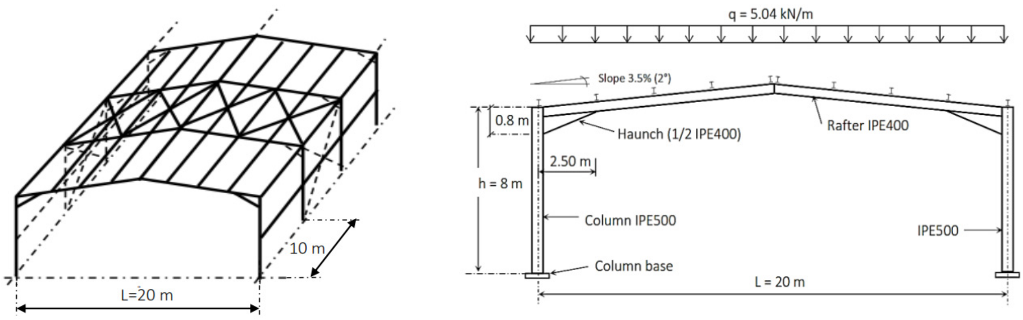

Figure 1: Portal model to be analysed.

3.1 Finite element modelling

The frame model is created using 3D finite elements with SHELL131 for thermal analysis and SHELL181 for mechanical analysis. The task is solved as a combined one using material nonlinear thermal analysis and geometry and material nonlinear static analysis in the ANSYS software [8].

After a convergence test, the columns and beam are subdivided into 60 elements and 86 elements respectively along their lengths. Along the height, the section is subdivided into 12 elements (figure 2). Lateral-torsional buckling of the rafter has been prevented by adding appropriately lateral supports to the flanges.

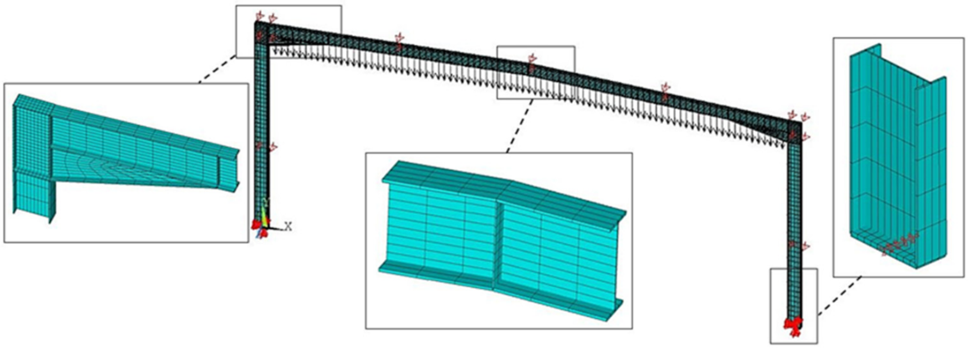

Figure 2: Numerical model, discretization of the portal frame.

3.2 Thermal analysis

The nonlinear transient thermal analysis is performed using the resolution of equation 2. Figure 3 shows the temperature distributions in the portal frame after 15 minutes of a standard ISO834 fire. It is important to note that all the four sides of the elements are under fire load.

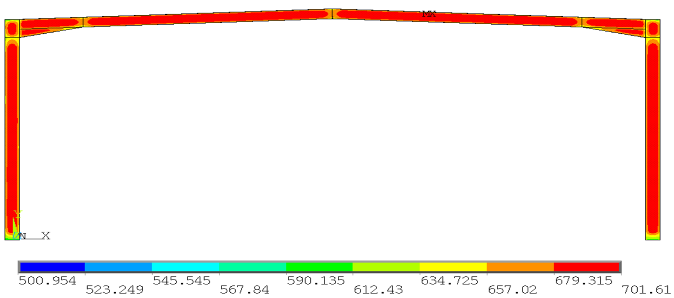

Figure 3: Temperature field in the portal frame at time t = 15 minutes.

The temperature field is recorded for the corresponding resistance class and applied as body load to the mechanical model. The nonlinear material response of steel at elevated temperature is provided by EC3 [2]. The results in term of displacements (vertical and horizontal) of the portal frame, failure time and Von Mises stresses at the developed hinges are illustrated in the next section.

3.3 Mechanical analysis

3.3.1 Effect of fire scenarios

Fire scenarios can have a great influence on the behaviour of the structure and consequently its resistance time and failure mode. In this analysis, as shown in figure 4, four fire scenarios have been considered.

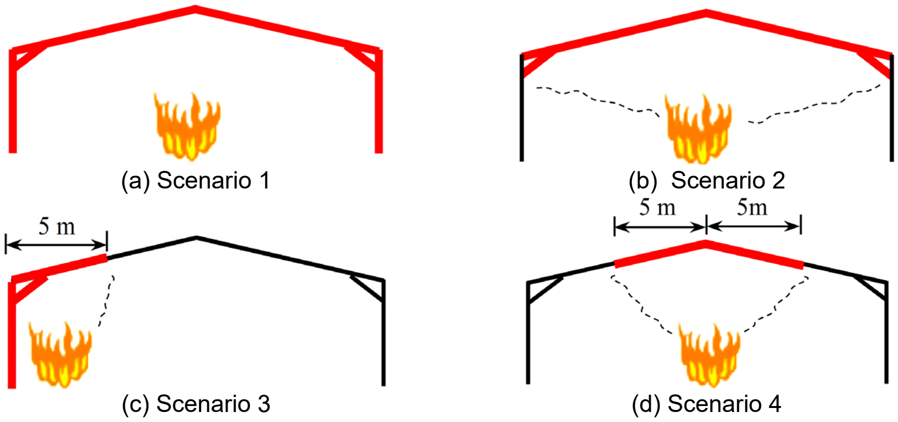

Figure 4: Heating profiles of the frame model.

Figures 5, 6 and 7 show the variations of the vertical (at ¼ and ½ of the rafter) and the horizontal displacements at the top of both columns according to the four scenarios.

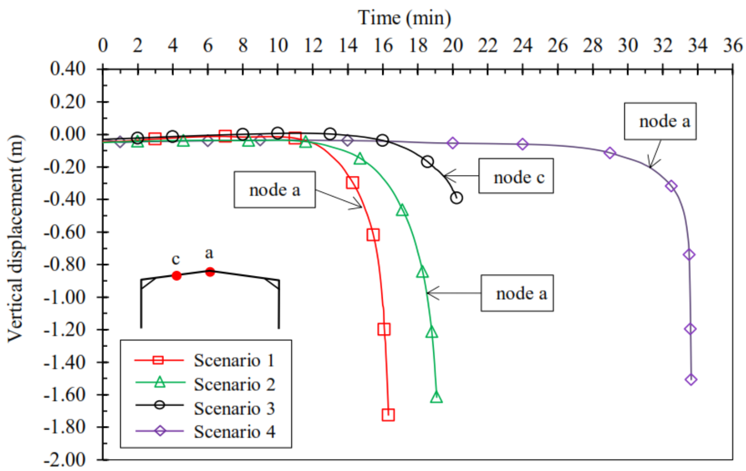

Figure 5: Vertical displacement at node a (fire scenarios 1, 2, 4) and node c (fire scenario 3).

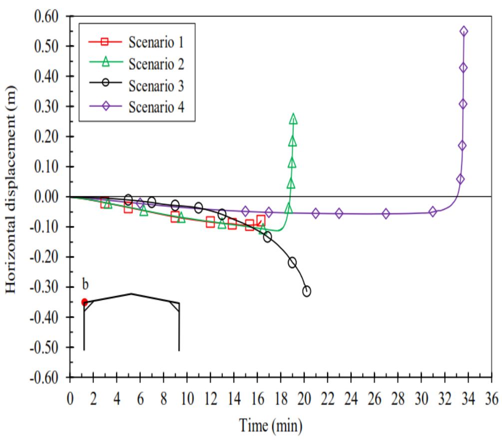

Figure 6: Horizontal displacement of node b.

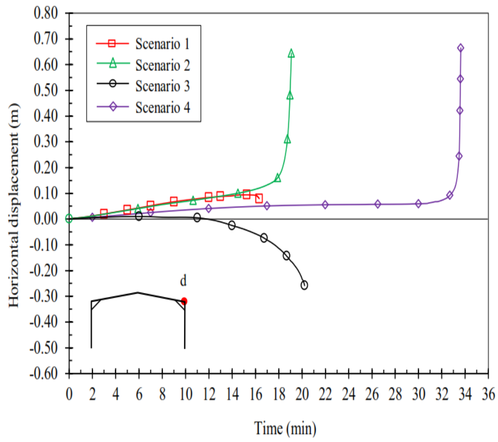

Figure 7: Horizontal displacement of node.

According to the above figures, the failure times are estimated to be 16.32 (min), 19.08 (min), 20.22 (min) and 33.63 (min) respectively for scenarios 1, 2, 3 and 4. This gives an improvement of 16.91%, 23.90% and 106% respectively for scenarios 2, 3 and 4 compared to scenario 1. These results confirm the severity of generalized fires in comparison with localized fires. From the results of the horizontal displacements at the top of both columns, figures 6 and 7, only scenario 1 confirms the beginning of collapse of the structure towards the inside. For the other fire scenarios, the horizontal displacements of the columns do not confirm the collapse modes (inside or outside). The simulations are stopped before the columns come back to the inside of the structure. According to the work of Vassard *et al* [10] and Song [5], only simulations with dynamic approach can go further in the analysis so the collapse mode can be predicted.

3.3.2 Effect of haunch length

To analyse the influence of haunches on the fire resistance of single portal frame, five different lengths are considered: 0 m, 0.5 m, 1 m, 2 m, 3 m and 4 m. The profile section of the haunch is taken constant (1/2 IPE400). The scenario 1 (generalized fire) is considered in this section.

The displacement-time curves presented in figures 8 and 9 show that the use of haunches until one-tenth of the span (2 m) increases the time resistance of the portal frame. With the same rafter profile (IPE400), time resistance without haunches is about 13.81 minutes and with 2 m haunches (one-tenth) time resistance increases to 16 minutes (16% increase). We notice that beyond this distance (2 m), no improvement can be seen. This may be explained by the fact that weakest section can be located at the end of the haunch when shorter haunch is used (less than one-tenth) to rafter end when haunch reached one-tenth and more. Results from figure 9 show that when the lengths of haunches are less than one-tenth of the rafter span, the collapse of the structure tends to happen in the outward direction.

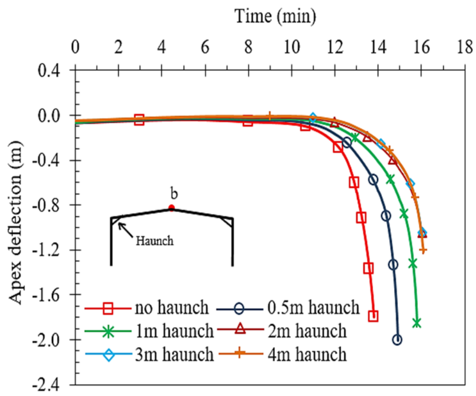

Figure 8: Vertical deflection (node b).

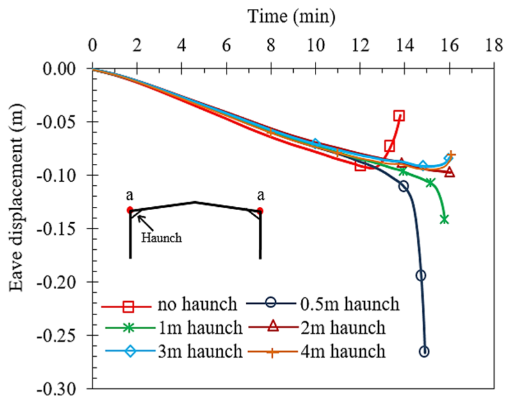

Figure 9: Horizontal displacement (nodes a).

The maximum Von Mises stresses developed in the rafter at different locations (haunch end, rafter ends and rafter mid-span) are shown in figures 10 to 13. From figures 14 and 15, the yielding stresses are obtained at the eaves when haunch length is one-tenth (2 m) and more. For shorter haunches (less than one-tenth), the yielding stresses appear at the ends of the haunches, see figures 10 and 11. This is due to the weakest section on the rafter, which change from the eaves to the ends of the haunches.

As expected, when no haunch is used, maximum stresses are located at the eaves, see figure 13. A value of 250 N/mm² is obtained at 2 minutes heated time, which is greater than the yield stress (235 N/mm²) and this has favourably led to the collapse of the portal frame at early time.

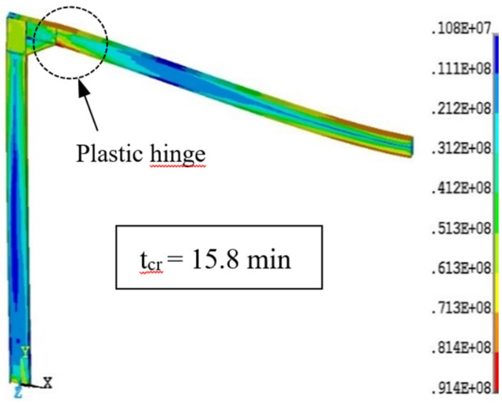

Figure 10: Von Mises stresses in the half portal frame (1m haunch).

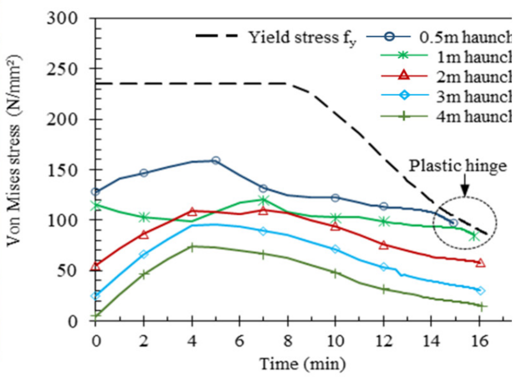

Figure 11: Von Mises stresses at haunch's end for different haunch lengths.

3.3.3 Effect of geometrical dimensions

Different geometries for frames are investigated in this section, see table 1, looking at the influence on failure modes. A series of frames with h/L ratio (h: is column high and L: is rafter span) taken equal to 0.2, 0.3, 0.4, 0.5 and 0.6. The other parameters of the portal frames, such as the haunch length and the rafter slope are taken respectively 1/10 of portal's span and 3.5%. For all portal frames, the haunch's section is the same as the rafter's section. Table 1 summarises the details of these frames.

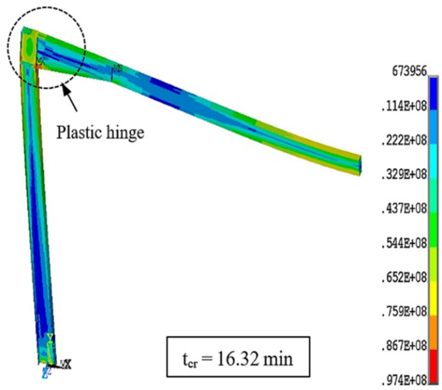

Figure 12: Von Mises stresses in the half portal frame (2.5 m haunch).

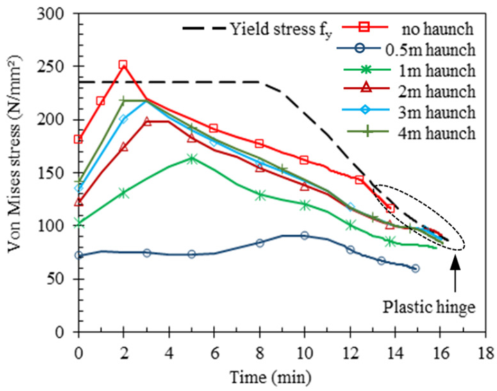

Figure 13: Von Mises stresses at eaves (nodes a) for different haunch lengths.

Table 1: Characteristics of the portal frames.

Portal frame	L (m)	h (m)	h/L	Column section (Grade S235)	Rafter section (Grade S235)	Load ($q_{fi,Ed}$) (kN/m)
(1)	25	5	0.2	IPE 500	IPE 500	3.660
(2)	30	9	0.3	HEA 600	HEA 600	4.230
(3)	20	8	0.4	IPE 500	IPE 400	5.040
(4)	16	8	0.5	IPE 360	IPE 330	4.804
(5)	10	6	0.6	IPE 330	IPE 300	3.180

According to figures 14 and 15, the horizontal displacements at eaves indicate that when the h/L ratio is greater than 0.4 (case of the portal frames 4 and 5), the collapse of the portal frames is developed outwards of the structure. This is confirmed by the positive values of the horizontal displacements of both eaves. For portal frames (1), (2) and (3), with h/L ratio less or equal than 0.4, the horizontal displacements at eaves are developed towards the outside of the structures until the time of collapse when a reversal movement towards the inside of the structure is found. This collapse mode (inward) is considered safe according to the European standards [3].

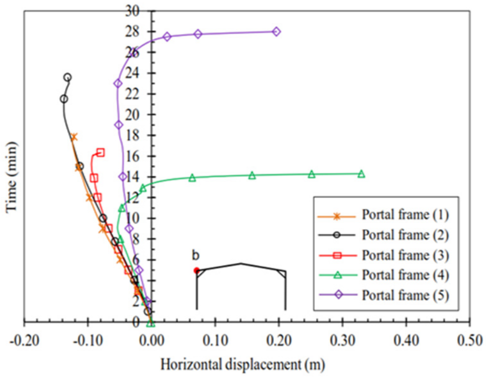

Figure 14: Horizontal displacement node b.

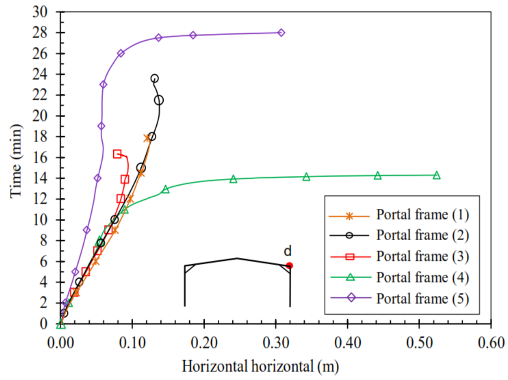

Figure 15: Horizontal displacement node d.

4. COMPARISON OF RESULTS WITH THE SIMPLIFIED METHOD R15

For industrial steel buildings such as warehouses, simplified methods are used to verify frames and purlins for fire stability of 15 minutes [9]. According to these methods, for sections of class 1 and 2, the critical temperature is determined using equation 4 and table 2.

$$k_{y,\theta} \geq \frac{q_{fi,Ed}\, L^2}{14\, W_{pl,y}\, f_y} \tag{4}$$

Table 2: Reduction factor $k_{y,\theta}$ for yield strength at elevated temperatures.

θ (°C)	20 ÷ 400	500	600	700	800	900	1000	1100	1200
$\mathbf{k_{y,\theta}}$	1	0.78	0.47	0.23	0.11	0.06	0.04	0.02	0

Where $q_{fi,Ed}$ is the uniformly distributed load applied to the rafter under fire condition, $k_{y,\theta}$ is the reduction factor for the yield strength f_y, $W_{pl,y}$ plastic modulus and L is the length of the rafter outside haunches.

Critical time t_{cr} of the portal frame can be calculated using equation 3. For the comparison purpose, the correction factor K_{sh} obtained from equation 3 is taken equal to 1.

Tables 3, 4 and 5 present the values of time resistance obtained using this study and those calculated with simplified method R15 [9].

Table 3. Time resistance using different fire scenarios.

Numerical simulation (ANSYS)		**Simplified method (R15)**
Fire Scenarios	**t_{cr} (min)**	**t_{cr} (min)**
1	16.32	15.95
2	19.08	
3	20.22	
4	33.63	

Table 4: Time resistance using different haunch lengths.

Haunch length (m)	**Numerical simulation (ANSYS)** t_{cr} **(min)**	**Simplified method (R15)** t_{cr} **(min)**
0	13.81	12.20
1	15.80	13.61
2	16.04	15.14
3	16.05	16.92
4	16.11	23.49

Table 5: Time resistance using different portal frames.

Portal frame	**Numerical simulation (ANSYS)** t_{cr} **(min)**	**Simplified method (R15)** t_{cr} **(min)**
(1)	17.85	18.90
(2)	23.58	22.33
(3)	16.32	15.95
(4)	14.30	14.28
(5)	28.00	28.85

These results indicate that the fire resistance determined by the simplified method R15 are approximately in agreement with those of the present study when generalized fire (scenario 1) is considered and haunch length varying up to one-eight of the rafter span. Beyond this length, the results are overestimated.

5. CONCLUSIONS

This work investigates the behaviour of industrial steel portal frames under standard ISO834 fire using numerical simulations. The following conclusions can be drawn:

- Fire scenarios can have a great influence on the fire resistance of industrial steel portal frames. An improvement varying from 16% to 106% is observed with localized fire scenarios compared to the generalized fire scenario.

- The use of haunches until one-tenth of the span increases the fire resistance of the portal frame around 16%. Beyond this length, no improvement can be observed.

- The geometrical dimensions of the portal frames have a significant effect on the structural behaviour of industrial buildings. When column height to span length ratio is greater than 0.4, the collapse of the portal frames tends to happen toward the outside of the structure, which is considered unsafe according to the actual codes.

6. REFERENCES

[1] EN 1991-1-2, Eurocode 1 : *Actions on structures Part 1-2 : General actions – Actions on structures exposed to fire*, Brussels : European Committee for Standardization, 2002, 59 p.

[2] EN 1993-1-2, Eurocode 3: *Design of steel structures Part 1-2: General rules-Structural fire design*, Brussels: European Committee for Standardization, 2005, 78 p.

[3] RFCS Research, *Fire safety of industrial halls, Design Guide*, Arcelor Mittal, CTICM, Labein tecnalia, ULG, Directorate-General for research, Research Fund for Coal and Steel Unit, RFS2-CR-2007-00032, Luxembourg, 2007, 140 p.

[4] Wong, YS. *The Structural Response of Industrial Portal Frame Structures in Fire*, Ph.D. thesis, University of Sheffield, Sheffield, UK, 2001, 181 p.

[5] Song, Y.Y., Huang, Z., Burgess, I.W., Plank, R. J. "The behaviour of single-storey industrial steel frames in fire", *International Journal of Advanced Steel Construction*, Vol. 5, 2009, pp. 289-302.

[6] Benlakehal, N., *Comportement des structures industrielles en portiques métalliques sous l'effet de hautes températures d'incendie*, Thèse de Doctorat en Sciences, Université de Chlef, Algérie, 2018, 134 p.

[7] ISO 834-1: *Fire resistance tests - Elements of building construction – Part 1: General requirements for fire resistance testing*, International Organization for Standardization, Switzerland, 1999, 25 p.

[8] ANSYS®, Academic Research, Release 16.2*, Help System, Element reference*, ANSYS, Inc, 2015, 132 p.

[9] Renaud, C., Sakji, S., *Ossatures en acier, Méthode de justification d'une stabilité au feu de ¼ heure (R15)*, rapport CTICM, France, 2009, 46 p..

[10] Vassart, O., Cajot L.G., O'Connor, M., Shenkai, Y., Fraud, C., Zhao, B., De la Quintana, J., Martinez de Aragon, J., Franssen, J. M., Gens, F., "3D simulation of Industrial Hall in case of fire. Benchmark between ABAQUS, ANSYS and SAFIR", *Proceedings of the 10th international conference*, Vol. 2, 2004, pp. 1315-1324.

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