

2.17 Overview of the structural verification of buildings under fire in Spain

Marimon F., Spain

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Overview of the structural verification of buildings under fire in Spain

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Spanish Technical Building Code CTE (2006)

Residential, commercial and administrative buildings

a) PERFORMANCE-BASED CODE
b) PRESCRIPTIVE RULES

- EUROCODES (ENV's)
- The Equivalent Time Method

Concrete Structures
Steel Structures
Masonry Structures
Timber Structures
Composite Structures

In practice, the prescriptive rules are the most utilized for the Fire Officers
Additional rules are in some cities and lands around Spain

Documento Básico SI
Seguridad en caso de incendio

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Spanish Security Code against the Fire in Industrial Activities RSCIEI (2005)

The classification of industrial buildings is according to:

- Type of activity or load fire density
- Distance near other building
- Structural system; light roof, number of levels, mezzanine
- Active measures; automatic sprinklers, colt's ...

GUÍA TÉCNICA DE APLICACIÓN:
REGlamento de SEGURIDAD CONTRA INCENDIOS EN LOS ESTABLECIMIENTOS INDUSTRIALES
REAL DECRETO 2287/2006, de 7 de diciembre

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Administrative Building (Spain)

A. Arteaga; L. Rodríguez
Eduardo Torroja Institute (CSIC) (2005)

• Medium building for administrative purpose
• Concrete structure in conventional rigid frame

PRESCRIPTIVE RULES

Direct use of table from Spanish Technical Code DB-SI 6

Tabla 3.1 Resistencia al fuego suficiente

Uso del sector de incendio considerado⁽¹⁾

R90 standard fire ISO834

	<15 m	<28 m	≥28 m
Vivienda unifamiliar ⁽²⁾	R 30	R 30	-
Residencial Vivienda, Residencial Público, Docente, Administrativo	R 120	R 60	R 120
Comercial, Pública Concurrencia, Hospitalario	R 120 ⁽³⁾	R 90	R 120
Aparcamiento (edificio de uso exclusivo o situado sobre otro uso)	-	R 90	R 120
Aparcamiento (situado bajo un uso distinto)	-	-	R 120 ⁽⁴⁾

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The Spanish Technical Building Code has the Equivalent Time of Fire Exposure Method (same Annex F EN 1991 1-2)

PERFORMANCE-BASED METHOD

Equivalent time of fire exposure
 $t_{e,d} = (q_{f,d} \cdot k_s \cdot W) \cdot k_s$

Design fire load density, $q_{f,d}$	625 MJ/m ²
k_s	0.07

Parameters of scenario:

- Density fire load $q_{f,d} = 625$ MJ/m²
- Floor area $A_f = 420$ m²
- Area of vertical openings $A_v = 60$ m²
- Without horizontal openings $A_h = 0$
- Height $H = 2,8$ m

Result:

R60 standard fire ISO834 ✓

Floor area, A_f	420	m ²
vertical openings, A_v	60	m ²
horizontal openings, A_h	0	m ²
Height of the compartment, H	2,8	m
$q_v = A_v/A_f$	0,143	
$q_h = A_h/A_f$	0	
$bv = 12,5 \cdot (1 + 10 \cdot q_v - q_v^2)$	30,12	
$W = (6,0 \cdot H)^2 \cdot 10,82 - 90 \cdot (0,4 \cdot q_v)^4$	1,273	
$t_{e,d} = (1 + b \cdot q_v)$	56	min

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R60 standard (ISO 834)

Verification by Isothermal 500°

Verification by tables

Tabla C.2. Elementos a compresión

Resistencia al fuego	Lado menor o espesor b_{eq} / Distancia mínima equivalente al eje a_{eq} (mm) ⁽¹⁾
Soportes	Muro de carga expuesto por una cara
	Muro de carga expuesto por ambas caras
R 30	150 / 15 ⁽²⁾ / 120 / 15
R 60	200 / 20 ⁽²⁾ / 140 / 15
R 90	250 / 30 ⁽²⁾ / 160 / 20 ⁽²⁾
R 120	250 / 40 ⁽²⁾ / 180 / 35 ⁽²⁾
R 180	350 / 45 ⁽²⁾ / 250 / 45 ⁽²⁾
R 240	400 / 50 ⁽²⁾ / 300 / 50 ⁽²⁾

Los requisitos por exigencias de durabilidad pueden requerir valores superiores.
Los soportes ejecutados en obra deben tener, de acuerdo con la Instrucción EHE, una dimensión mínima de 250 mm.
La resistencia al fuego aportada se puede considerar (R1).

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Caja Madrid Tower (2009)

A specific Fire Prevention Rules in Madrid for this Four Towers project

PRESCRIPTIVE RULES

Height	250 m
Number of levels	56+(-5)
Floors	38+(-5)

R180

R120 Parkings

Building Construction:
- FFC Construcción
- Dragados

Architects:
- Norman Foster and Partners

Structural Engineering:
- Halvorson and Partners (Chicago)
- GMS

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R180 Composite columns

REI 180 Composite slabs with vermiculite spray. It was tested in Barcelona

R180 Beams with near 75 mm of vermiculite spray

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Industrial Biodiesel Plant (Huesca) (2009)

Structure fire resistance

F. Marimon; F. Juan

A. Jiménez **construsoft**

- The industrial plant produce biodiesel from vegetables oils and cooking oils with an annual production capacity of 100.000 tons
- It is a steel structure inside a concrete structure. This is only an envelope for climatic loads and lateral protect explosions

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PRESCRIPTIVE RULES

Spanish Security Code against the Fire in Industrial Activities - RSCIEI (2005)

CALCULATIONS OF FIRE LOAD DENSITY

$$\frac{\sum(Q_i)}{\text{TotalArea}} = \frac{168.891,081 \text{ MJ}}{792,11 \text{ m}^2} = 213,216 \text{ MJ/m}^2$$

Risk of Activation R_2 → 426,316 MJ/m²
RSCIEI → High Level 8

TYPE OF BUILDING CONFIGURATION ==> TYPE C

TPO C

REQUIREMENTS OF STRUCTURAL RESISTANCE

- High Level 8
- Type of building C
- Automatic Sprinklers

Nivel de riesgo	Sistema de almacenamiento independiente o autoportante operado manualmente					
	Tipo A		Tipo B		Tipo C	
	Rotadores automáticos de agua		Rotadores automáticos de agua		Rotadores automáticos de agua	
	NO	SI	NO	SI	NO	SI
Riesgo bajo	R0(EF-30)	R15(EF-15)	R15(EF-15)	No se exige	No se exige	No se exige
Riesgo medio	R0(EF-30)	R30(EF-30)	R30(EF-30)	R15(EF-15)	R15(EF-15)	No se exige
Riesgo alto	R0(EF-30)	R0(EF-30)	R30(EF-30)	R30(EF-30)	R30(EF-30)	R15(EF-15)

→ **R15 ✓**

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- Mechanical Loads (in Spain, mandatory ψ_1)
- Global Structural Analysis without indirect actions (software PowerFrame V5.6.11)
- Thermal analysis for individual members under standard fire ISO834 until $t_{\leq 115 \text{ min}}$
- Simple calculation model for individual members at $t \leq 15 \text{ min}$ in the resistance domain

Spanish Code RSCIEI allows the use of EN 1993-1-2

$$N_{Ed,fire} = \gamma_{0,fire} N_{k,fire} / \gamma_{M,fire}$$

$$M_{Ed,fire} = \gamma_{0,fire} M_{k,fire} / \gamma_{M,fire}$$

$$E_{b,d,fire} \leq R_{b,d,fire}$$

Several members of horizontal bracing system are changed for R15 requirements ✓

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CONCLUSIONS

- In Spain there are excellent codes based in modern concepts of Fire Engineering
- The basic Eurocodes rules are incorporated in Spanish Codes
- But in practice the Officers of Fire Prevention Service use the Prescriptive Rules and only for exceptional projects the Performance-Based Code is allowed

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