Fire load density

How to reliably estimate and describe it for fire engineering calculations?

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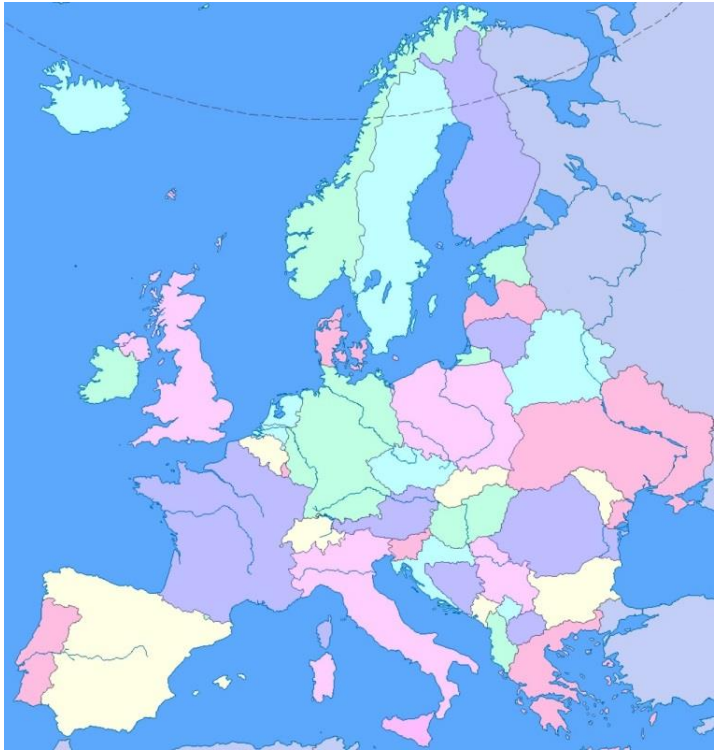
Scope of presentation

- Why is fire load density (FLD) important as a design parameter?
- Are the fire load density data provided in EN 1991-1-2 / PD 6688-1-2 still representative of modern buildings?
- Why is it difficult to asses fire load density for actual buildings?

Fire load density in structural fire design

- Fire load density in a compartment is relevant to the potential severity of the fire i.e. the maximum temperature attained and the duration of the fire
- Ventilation conditions, thermal properties of the enclosure and fire protection systems used are also relevant
- In the Eurocodes FLD is an input parameter for calculation of parametric fire curves and the equivalent time of fire exposure

Fire load density in European fire safety regulations



- Fire load density is used as a design criterion in several European countries e.g. Poland, Germany, Italy, Czech Republic, Spain
- Fire load density is expressed in MJ/m^2 or in some cases as an equivalent of fire load in kg of wood $/m^2$

Fire load density as a parameter for industrial & storage buildings

Table 12 Maximum dimensions of building or compartment (non-residential buildings)

Purpose Group of building or part	Height of floor of top storey above ground level (m)	Floor area of any one storey in the building or any one storey in a compartment (m^2)	
		In multi-storey buildings	In single-storey buildings
Office	No limit	No limit	No limit
Assembly and recreation Shop and commercial:			
a. Shops – not sprinklered	No limit	2000	2000
Shops – sprinklered [1]	No limit	4000	No limit
b. Elsewhere – not sprinklered	No limit	2000	No limit
Elsewhere – sprinklered [1]	No limit	4000	No limit
Industrial [2]			
Not sprinklered	Not more than 18 More than 18	7000 2000 [3]	No limit N/A
Sprinklered [1]	Not more than 18 More than 18	14,000 4000 [3]	No limit N/A

	Height of floor of top storey above ground level (m)	maximum compartment volume m^3	maximum floor area (m^2)	maximum height (m) [4]
		multi-storey buildings	single-storey buildings	
Storage [2] and other non-residential:				
a. Car park for light vehicles	No limit	No limit	No limit	No limit
b. Any other building or part:				
Not sprinklered	Not more than 18 More than 18	20,000 4000[3]	20,000 N/A	18 N/A
Sprinklered [1]	Not more than 18 More than 18	40,000 8000[3]	No limit	No limit

Notes:

1. 'Sprinklered' means that the building is fitted throughout with an automatic sprinkler in accordance with paragraph 0.16.
2. There may be additional limitations on floor area and/or sprinkler provisions in certain industrial and storage uses under other legislation, for example in respect of storage of LPG and certain chemicals.
3. This reduced limit applies only to storeys that are more than 18m above ground level. Below this height the higher limit applies.
4. Compartment height is measured from finished floor level to underside of roof or ceiling.

Table A2 Minimum periods of fire resistance

Purpose group of building	Minimum periods of fire resistance (minutes) in a:					
	Basement storey [5] including floor over		Ground or upper storey			
	Depth (m) of a lowest basement		Height (m) of top floor above ground, in a building or separated part of a building			
	More than 10	Not more than 10	Not more than 5	Not more than 18	Not more than 30	More than 30
1. Residential:						
a. Block of flats – not sprinklered – sprinklered	90 90	60 60	30* 30*	60**† 60**†	90** 90**	Not permitted 120**
b. Institutional	90	60	30*	60	90	120#
c. Other residential	90	60	30*	60	90	120#
2. Office:						
– not sprinklered – sprinklered [2]	90 60	60 60	30* 30*	60 30*	90 60	Not permitted 120#
3. Shop and commercial:						
– not sprinklered – sprinklered [2]	90 60	60 60	60 30*	60 60	90 60	Not permitted 120#
4. Assembly and recreation:						
– not sprinklered – sprinklered [2]	90 60	60 60	60 30*	60 60	90 60	Not permitted 120#
5. Industrial:						
– not sprinklered – sprinklered [2]	120 90	90 60	60 30*	90 60	120 90	Not permitted 120#
6. Storage and other non-residential:						
a. any building or part not described elsewhere: – not sprinklered – sprinklered [2]	120 90	90 60	60 30*	90 60	120 90	Not permitted 120#
b. car park for light vehicles:						
i. open sided car park [3] ii. any other car park	Not applicable 90	Not applicable 60	15*+ 30*	15*+ [4] 60	15*+ [4] 90	60 120#

Fire load density as a parameter for industrial & storage buildings

In Poland fire load density is a design parameter for industrial and storage buildings, which impacts on:

- Requirements for means of escape
- Fire resistance class
- Maximum allowed area of a fire zone (compartment)
- Indirectly also on the need for sprinklers and/or smoke vents
- Requirements for fire hose reels and fire extinguishers
- Provisions of fire-fighting water supply and fire brigade access
- Fire separation distances

Fire load densities – Annex E of EN 1991-1-2

Table E.4 — Fire load densities $q_{f,k}$ [MJ/m²] for different occupancies

Occupancy	Average	80% Fractile
Dwelling	780	948
Hospital (room)	230	280
Hotel (room)	310	377
Library	1 500	1 824
Office	420	511
Classroom of a school	285	347
Shopping centre	600	730
Theatre (cinema)	300	365
Transport (public space)	100	122
NOTE Gumbel distribution is assumed for the 80 % fractile.		

Fire load densities – Annex E of EN 1991-1-2

Table A.2 **Fire load densities $q_{f,k}$ for different occupancies** [a)]

Occupancy	Fire load density $q_{f,k}$			
	Average MJ/m²	Fractile [b)] MJ/m²		
		80%	90%	95%
Dwelling	780	870	948	920	970
Hospital	230	350	280	440	520
Hospital storage	2 000	3 000		3 700	4 400
Hotel bedroom	310	400	377	460	510
Offices	420	570	511	670	760
Shops	600	900	730	1 100	1 300
Manufacturing	300	470		590	720
Manufacturing and storage [c)]	1 180	1 800		2 240	2 690
Libraries	1 500	2 250	1824	2 550	–
Schools	285	360	347	410	450

a) This table is reproduced from PD 7974-1.

b) The 80% fractile is the value that is not exceeded in 80% of the rooms or occupancy of the survey data. Typically this value may be used in design.

c) Storage of combustible materials at less than 150 kg/m².

Fire load density data available from the literature

Type of occupancy	Fabrication (MJ/m^2)	Storage ($MJ/m^2/m$)
Vegetable, dehydrating	1000	400
Vehicle mfg, assembly	400	
Veneering	500	2900
Veneer mfg	800	4200
Vinegar mfg	80	100
Vulcanising plant (without storage)	1000	
Waffle mfg	300	1700
Warping department	250	
Washing agent mfg	300	200
Washing machine mfg	300	40
Watch assembling	300	40
Watch mechanism mfg	40	
Watch repair shop	300	
Watch sales	300	
Water closets	~0	
Wax products forwarding	2100	
Wax products mfg	1300	2100
Weaving mill (without carpets)	300	
Welding shop (metal)	80	
Winding room	400	
Winding, textile fibres	600	
Window glass mfg	700	
Window mfg (wood)	800	
Wine cellar	20	
Wine merchant's shop	200	
Wire drawing	80	
Wire factory	800	
Wood carving	700	
Wood drying plant	800	
Wood grinding	200	
Wood pattern making shop	600	
Wood preserving plant	3000	
Youth hostel	300	

Source: A. Buchanan, Structural design for fire safety, Wiley, 2001 (Appendix B)

Are the available FLD values still representative?

Factors potentially impacting on actual fire load densities in modern buildings:

- Different materials used for furniture? (in most occupancies)
- Different make and fuels of modern cars (for car parks)
- Smaller reliance on paper documentation
- Different fit-out trends
  (e.g. co-working in offices)
- Different retail practices

What are the main problems in calculating / estimating FLD?

- How to account for variations of FLD in time? (e.g. in logistics, car parks)
- How to account for spatial non-uniformity (e.g. production and storage in one fire compartment)?
- Accurate calculation of FLD is only feasible in case of well-defined storage of homogenous goods, preferably of known composition and type of packaging
- How to include combustible elements of structure and/or thermal insulation?

NFPA 557:2016

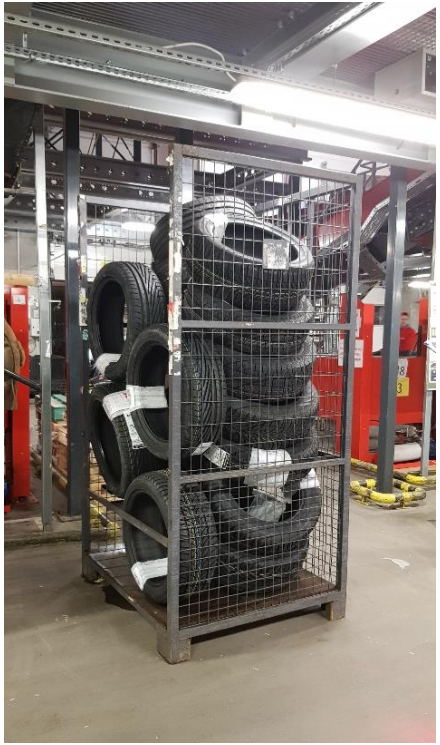
NFPA 557 Standard for determination of fire loads for use in structural fire protection design

- The code refers to: fire load (expressed in MJ), fire load density (expressed in MJ/m^2) and fuel load (expressed in kg of wood)
- Average fire load density = average fixed fire load density + average contents fire load density
- Where concentrations of combustible materials exist which are larger than 2.57 times the established distributed fire load density, **localized fire loads** are calculated
- For offices, average content fire load is give as 600 MJ/m2 (σ=500 MJ/m2)
- For buildings of non-combustible construction the average fixed fire load density is given as 130 MJ/m2 (σ=40 MJ/m2)
- Fire load surveys can be carried out using the weighing technique, the inventory technique or a combination of both
- Design fire load takes into account – besides FLD - the fire initiation frequency and the effectiveness and reliability of the fire protection

Case study 1 – Sorting centres of a courier company

- Two buildings analysed, with floor areas of 13300 m^2 and 11200 m^2 respectively
- Non-combustible construction
- Automated + manual sorting
- Maximum sorting capacity of approx. 390 000 parcels / day (for the larger facility)
- Goods delivered include letters, books, clothing, home appliances and consumer electronics, tyres

Case study 1 – Sorting centres of a delivery company



Case study 1 – Sorting centres of a courier company

- Analysis carried out based on visual survey and data from the IT system tracking the individual parcels
- Weight of each parcel recorded by the system
- Exact total mass of parcels at any given time not known (estimated from assumed time an average parcel spends in the facility)
- Actual content of individual parcels not known
- Average value of 30 MJ/kg assumed for generic „parcels”
- Timber pallets and plastic containers for smaller parcels included in the calculation

Case study 1 – Sorting centres of a courier company

- The purpose of the analysis was to verify if the design fire load of 500 MJ/m^2 assumed in the original design was exceeded
- Average fire load densities calculated in the study:
  - For facility #1: 402 MJ/m^2 (estimated range 350 to 450 MJ/m^2)
  - For facility #2: 324 MJ/m^2 (estimated range 300 to 400 MJ/m^2)

Case study 2 – logistics warehouse

- Warehouse of a commercial deliveries and logistics company, area approx. 7700 m^2
- Non-combustible construction
- Manual sorting only
- Two distinctive zones: cross dock and high-rack storage
- Goods delivered include building materials, sanitary ware, furniture, clothing, home appliances and consumer electronics, metal parts, paints, tyres etc.

Case study 2 – logistics warehouse




Case study 2 – logistics warehouse

- Analysis based on visual survey and data from the IT system
- Total weight of the goods processed available for each day
- Actual content of individual packages not known
- Average value of 30 MJ/kg assumed for generic content
- Timber pallets included in the calculation
- Only approx. 50% of the high-rack storage area used, goods stored in this area at the time of survey included high portion of non-combustible materials (steel)

Case study 2 – logistics warehouse

- The purpose of the analysis was to verify if the design fire load of 4000 MJ/m^2 assumed in the original design was exceeded
- Average fire load densities calculated in the study:
  - For the cross dock area: 7787780 / 2914 = 2670 MJ/m^2
  - For the high-rack storage area: 3384639 / 4760 = 710 MJ/m^2
  - Average for the facility: approx. 1460 MJ/m^2

Conclusions

- Average fire load densities for different occupancy types differ between codes and standards
- In many cases it is not clear what exactly do they refer too
- Fire load densities based on historical surveys. Not clear if they are still representative as nature of fit-outs, furniture, goods sold etc. changes with time
- Advanced IT systems used in retail, logistics, car parks etc. combined with detailed characteristics of products such as furniture, electronics, cars may one day make more accurate FLD assessments possible
- Consumer goods such as cars, furniture, large electronics etc. should have their combustible energy load stated by their producers!


THANK YOU
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