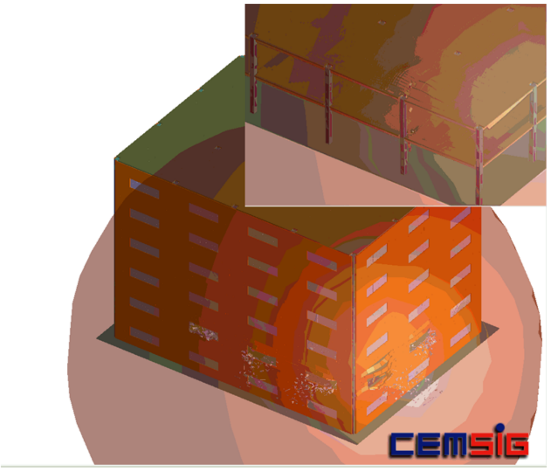
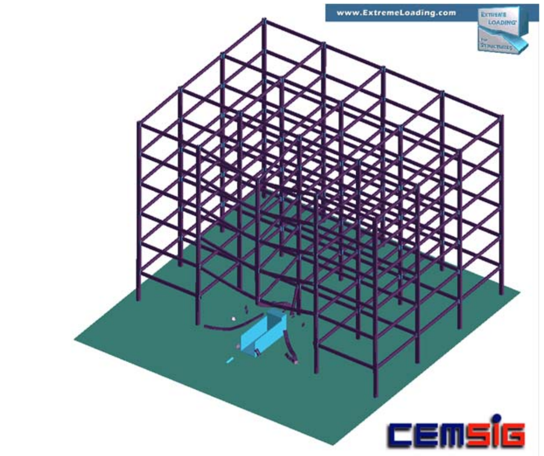
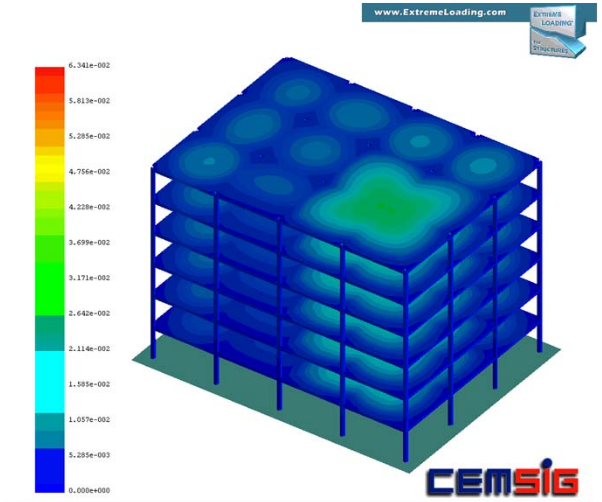
Robustness of structures. Scenarios







Florea Dinu

Lecture 6: 02/04/2014

European Erasmus Mundus Master Course

Sustainable Constructions
under Natural Hazards and Catastrophic Events

520121-1-2011-1-CZ-ERA MUNDUS-EMMC

Requirements

Eurocode EN 1990 « Basis of structural design »

(P) A structure shall be designed and executed in such a way that it will not be damaged by events such as :

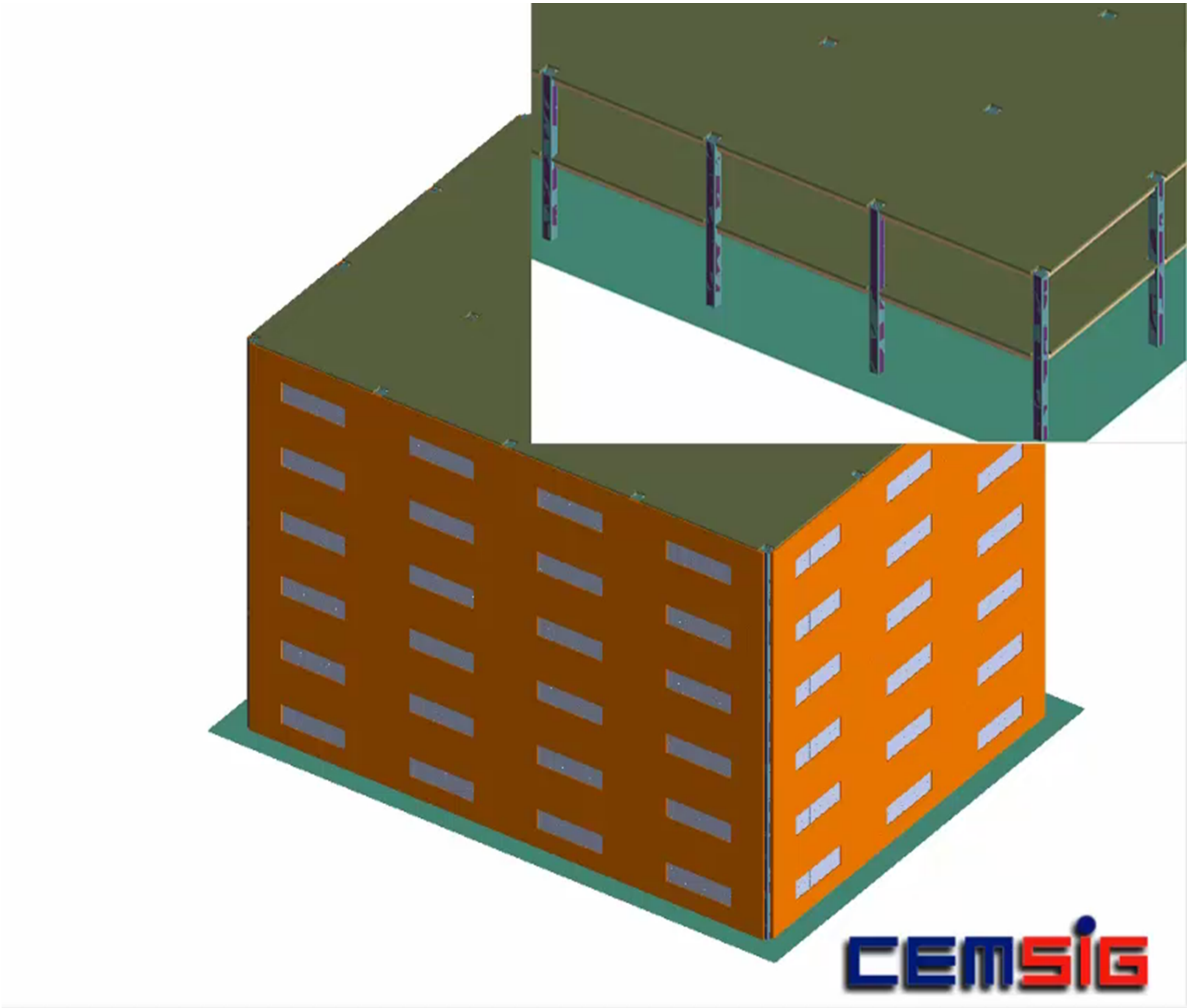
– explosion,
– impact, and
– the consequences of human errors, to an extent disproportionate to the original cause.

NOTE 1 The events to be taken into account are those agreed for an individual project with the client and the relevant authority.

NOTE 2 Further information is given in EN 1991-1-7.

Additional information specific to EN 1991-1-7

- EN 1991-1-7 describes Principles and Application rules for the assessment of accidental actions on buildings.
- The following actions are included:
  - impact forces from vehicles, rail traffic, ships and helicopters
  - actions due to internal explosions
  - actions due to local failure from an unspecified cause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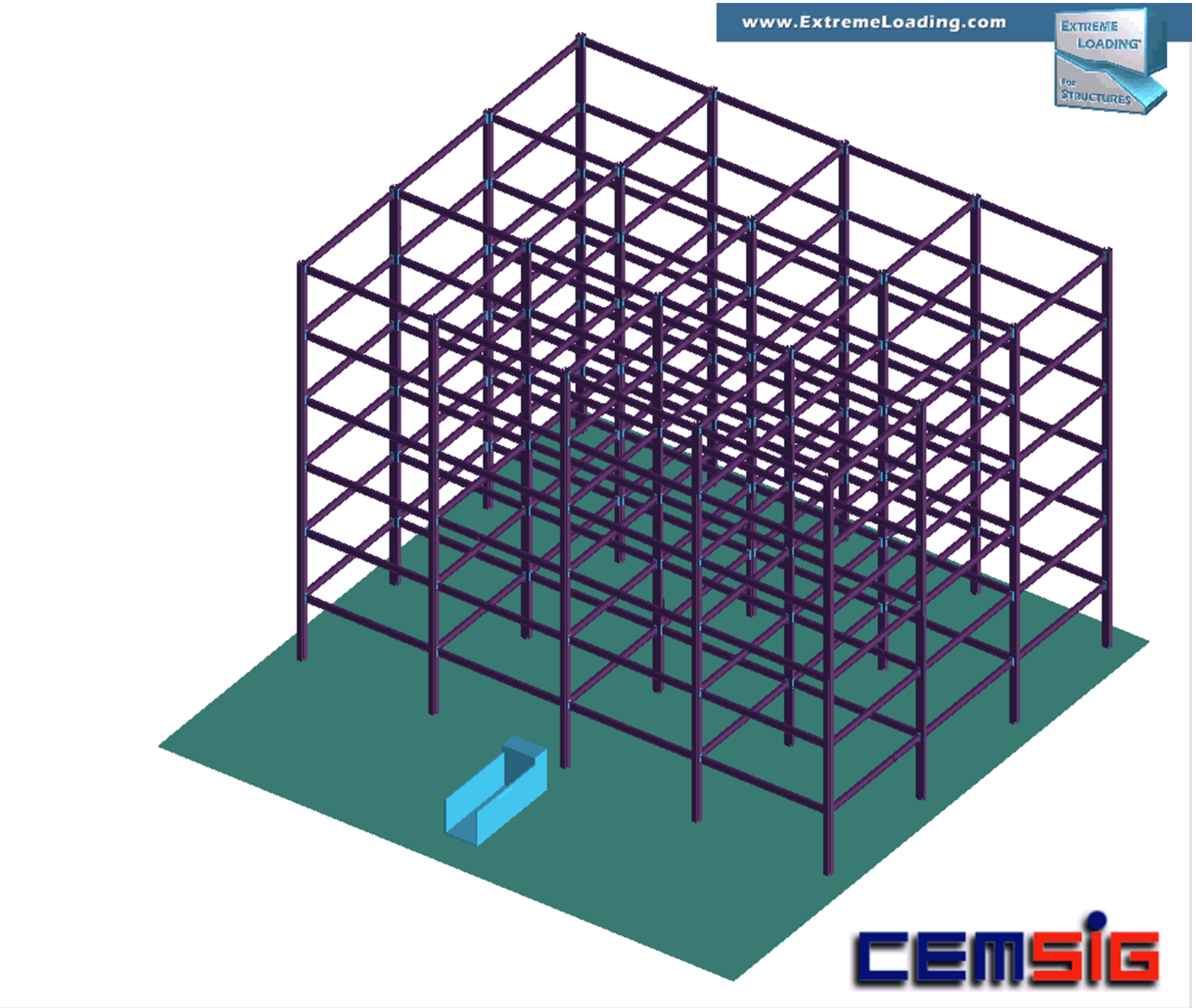
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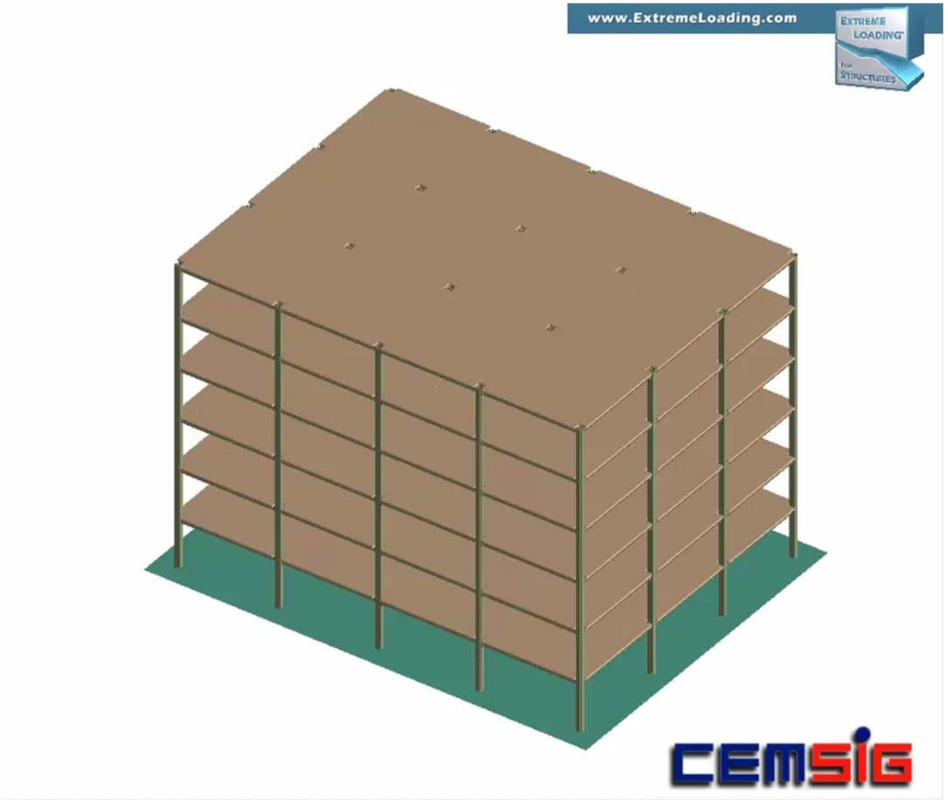
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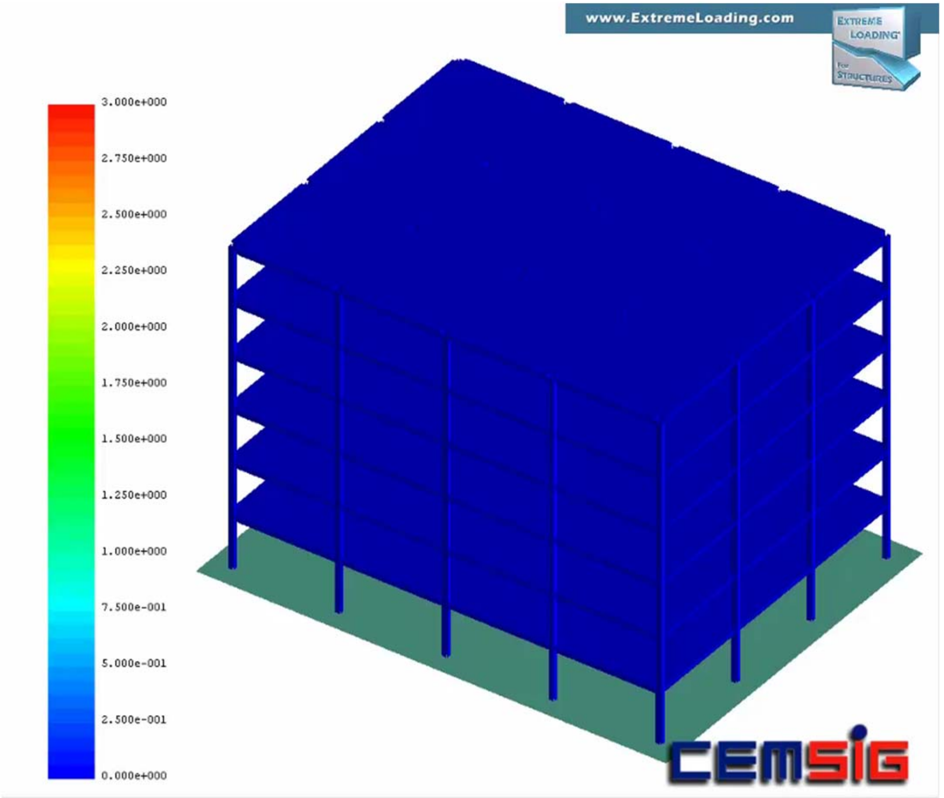
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7.500e-001
5.000e-001
2.500e-001
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CEMSIG

Explosions:

- Terrorist attack?
- Quantity of explosive?
- Where may be placed the explosive?
- Gas?
- Container or pipe?
- Place of the explosion?

Natural gas explosions (EN 1991-1-7)

- For buildings provided for having natural gas installed, the structure may be designed to withstand the effects of an internal natural gas explosion using a nominal equivalent static pressure given by expressions:

$$P_d = 3 + P_{stat}$$

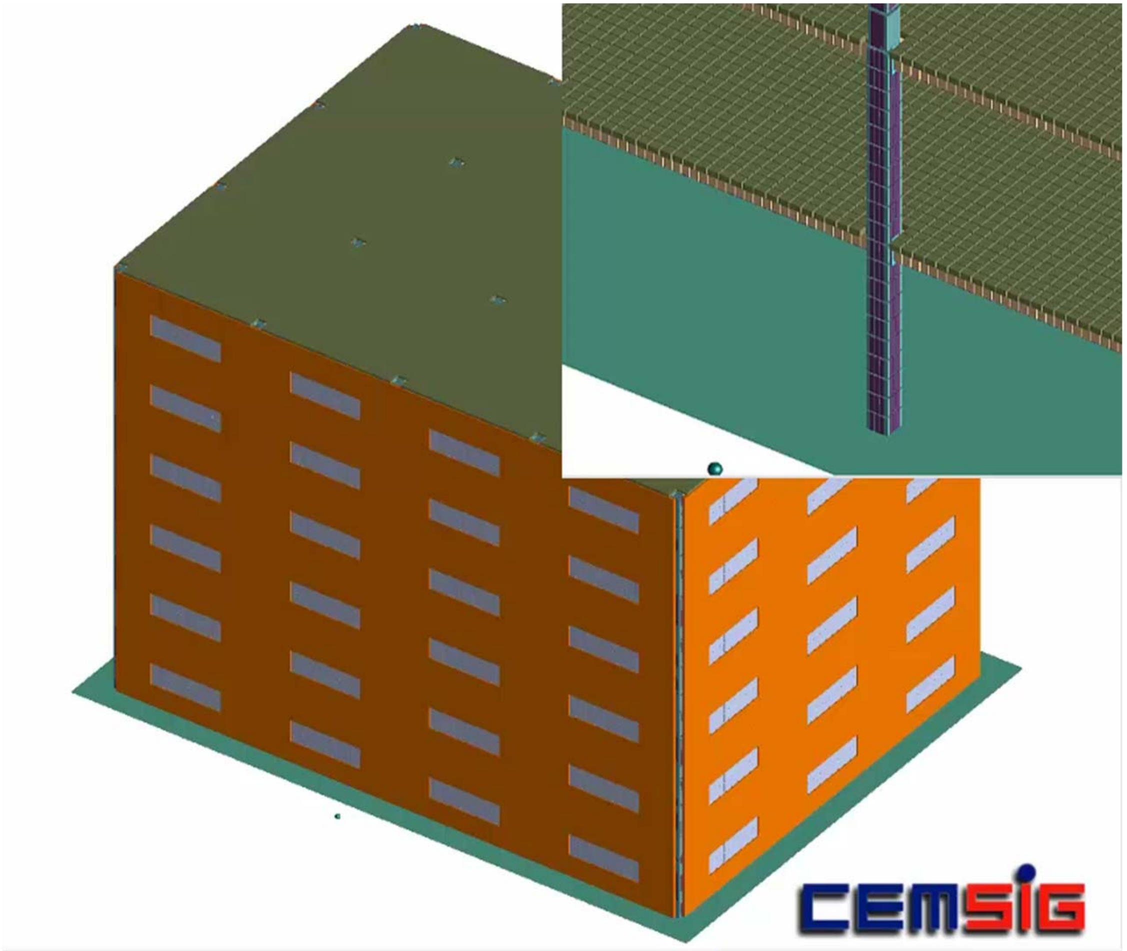
or

$$\mathrm{P_d} = 3 + \mathrm{P_{stat}}/2 + 0{,}04/(\mathrm{A_v}/\mathrm{V})^2$$

whichever is the greater

where:
P_{stat} is the uniformly distributed static pressure at which venting components will fail, in (kN/m^2);
Av is the area of venting components, in m^2
V is the volume of rectangular enclosure [m^3].

No provisions in EN 1991-1-7 regarding external explosions!



Impacts:

- Car or truck?
    - At which place?
    - Speed and mass?
- Plane?
    - At which place?
    - Speed and mass?
- …

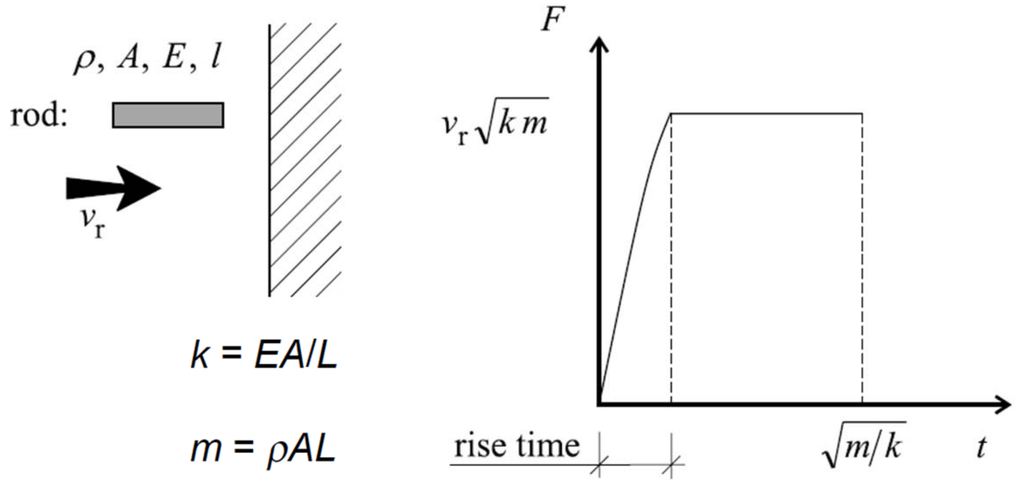
Dynamic design for impact(EN 1991-1-7)

Impact is characterized as either *hard impact*, when the energy is mainly dissipated by the impacting body, or *soft impact*, when the structure is designed to deform in order to absorb the impact energy.

Hard impact

If the structure is rigid and immovable and the colliding object deforms linearly, during the impact phase and remains rigid during unloading, the maximum resulting dynamic interaction force is given by expression (1):

$$F = v_r \sqrt{k\, m} \quad (1)$$



$k = EA/L$

$m = \rho AL$

Impact model, F = dynamic interaction force

Soft impact

- If the structure is assumed elastic and the colliding object rigid, the expressions given in (1) still apply and should be used with *k* being the stiffness of the structure.
- If the structure is designed to absorb the impact energy by plastic deformations, it should be ensured that its ductility is sufficient to absorb the total kinetic energy $\frac{1}{2} m v_r^2$ of the colliding object.
- In the limit case of rigid-plastic response of the structure, the above requirement is satisfied by the condition of expression:

$$\frac{1}{2} m v_r^2 \leq F_o y_o$$

where
F_o is the plastic strength of the structure, i.e. the quasi-static limit value of the force F;
y_o is its deformation capacity, i.e. the displacement of the point of impact that the structure can undergo.

Human errors:

- Collapse of a dam?
- Bad use of the equipment?
    - fire?
    - explosion?
- Underdesign?

Natural events:

- Tsunami? Hurricanee, typhoon…?
- Unexpected earthquake?
- Ground settlement?
- …?

seems to have been forgotten in the Eurocodes

- Actions due to local failure from an unspecified cause may be used
- The amount of local damage that should be accommodated must be defined - two alternatives are "notional" removal of one major load-bearing element at the perimeter of the building or stipulating a certain extent of damage by floor area or by volume.

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Scenarios

- Their definition is made on the basis of:
  - The class of consequences
  - The specific conditions (country, region, location of the building, political or social context, …)
  - The cost aspects
  - …

Fictive example

Construction of a new US ambassy in Bagdad

Fictive example

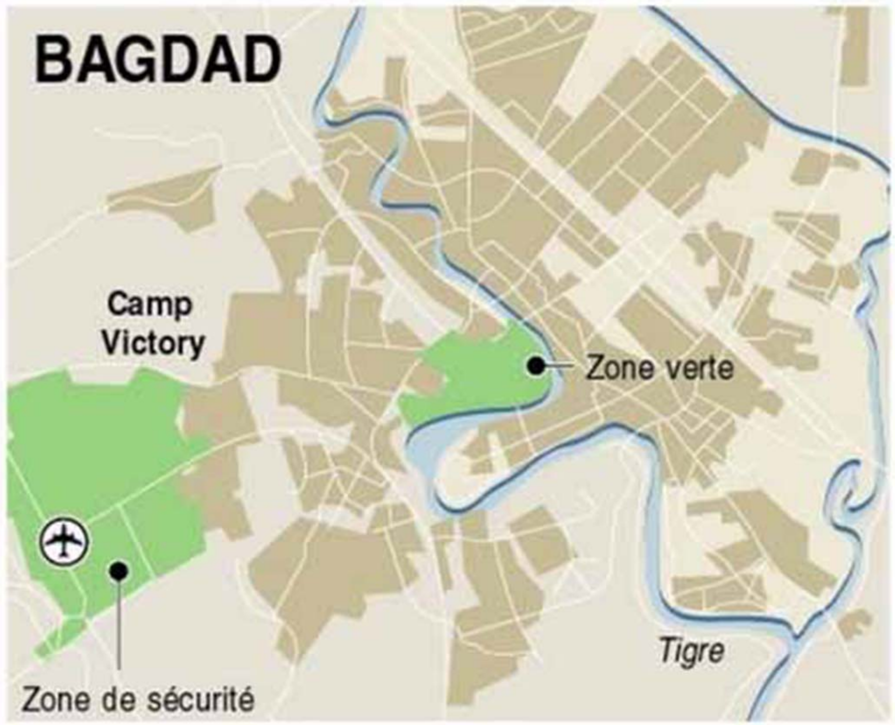
- Elevated consequence class considering the number of persons working in this building
- Difficult political context with permanent risks
- Decision to install it in the city centre
- Aspects of cost important but are not a priority (not often the case in practice)

Fictive example

- Potential risks to be considered:
  - Nuclear attack or through “conventional” weapons
  - Impacts of planes, trucks and cars …
  - Blasting ==> explosion (explosives or impacts with explosives)
- …

Fictive example

- First decision: location in the «green» zone



Risks of attacks

- This location allows to limit the risks of ground attacks.
- Attacks through the air can be prevented only if the airspace is under controlled
- The risk of a nuclear attack is not considered (weapon not available for the enemy (very low probability), strategic importance of the building not sufficient, class of consequences does not justify it)
- A ground attack has not to be fully excluded, but the localisation limits the means which could be used by the enemy

Risks of impact (with or without explosive)

- The impact of a plane is not considered (the airspace is under control)
- Impact of a truck has a limited probability of occurrence due to the localization of the embassy and of the controls at the entrances of the green zone
- The impact of a lightweight vehicle could be considered in case of problem with the safety system

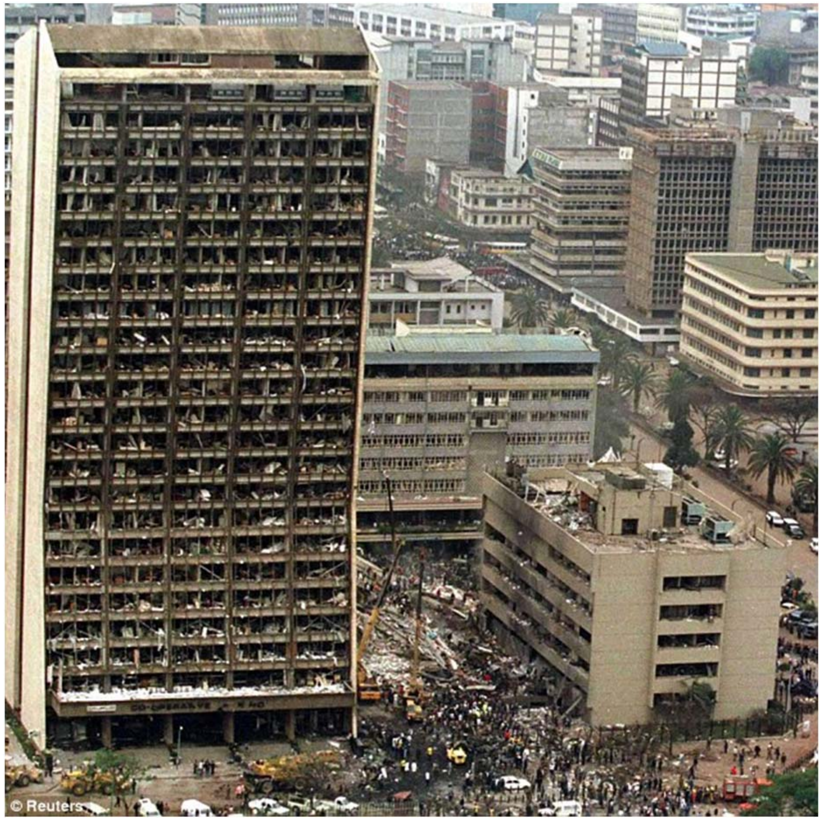
Risks of blast

- Explosion of a vehicle parked close to the embassy not possible as it is considered that anti-blast walls are placed around the embassy

Reinforced concrete barrier wall with artwork at the Scottish Parliament, Edinburgh

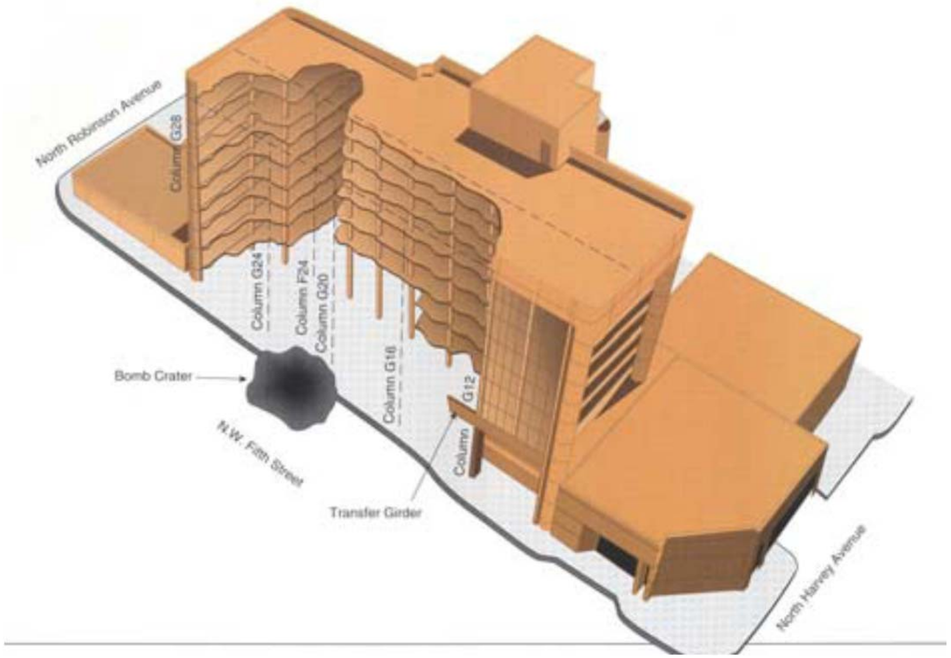
Bombings of the US Embassies in Nairobi, Kenya, on August 7, 1998

- *Six months before the attack, a report by State Department revealed embassy's extreme vulnerability due to lack of standoff (min. 100 ft standoff)*



Attacks on embassies: An aerial view shows the damage after the American embassy in Nairobi was bombed in 1998

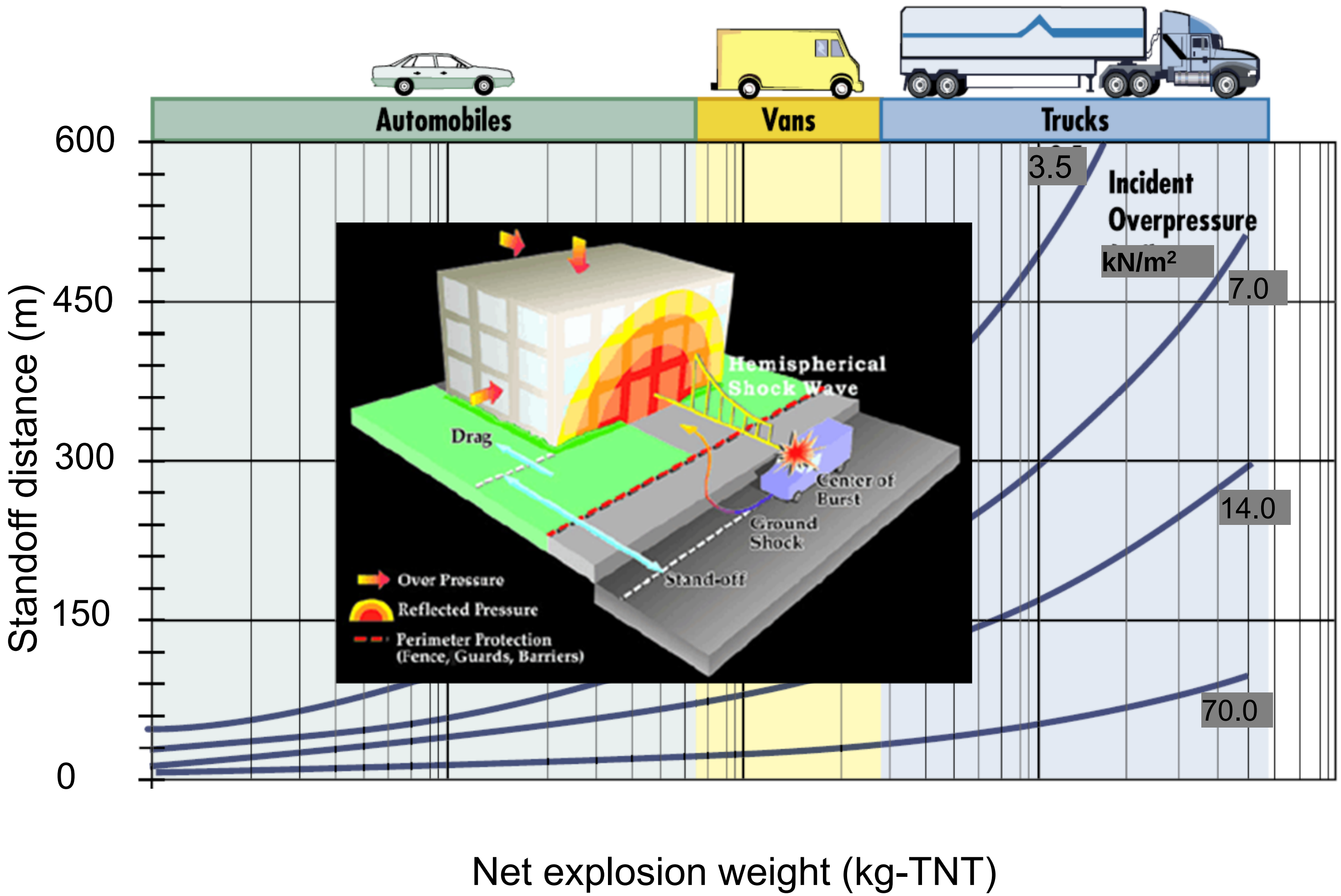
- The building setback is a fundamental requirement of design
- In many cases not meeting this setback will translate into more severe design requirements for the exterior envelope



Alfred P. Murrah
Building,Oklahoma City

Stand-off distance: 1.5m

Equivalent TNT weight:
1814 kg



Vehicle Bomb Sizes, Standoffs and Overpressures

Risks of blast

Suitcase with explosive close to the building: has to be considered, but the explosion would be limited

- Identified risks:
  - Type
  - Degree of intensity
  - Places where the impacts or the explosions could take place
  - …

==> Capacity to establish possible scenarios

Criteria of localization to be considered in case of more classical building

- Localization
  - Position of the gas pipes
  - Not in front of an inclined road
  - Outside floodplains
  - Outside critical zones in case of dam ruptures
  - Outside zones sensitive to ground settlements
  - …

Scenarios to be transformed in situations of verification of the robustness

- Consequences at local level
  - Placement of local protections, at identified locations, in order to limit the damages around the impact zone or the explosion

Scenarios to be transformed in situations of verification of the robustness

- Consequences at local level
  - Verification of the robustness of the structure partially damage (local level)

This lecture was prepared for the 1st Edition of SUSCOS (2012/14) by J.-F. Demonceau & J.-P. Jaspart, ULg

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