Modelling the effects of BLEVE blast on a building spanning an underpass

PSAM 9, Hong Kong

Dr. S.I. Suddle, Dr. Jaap Weerheijm, Dr. A.C. van den Berg, Prof. J.N.J.A. Vambersky

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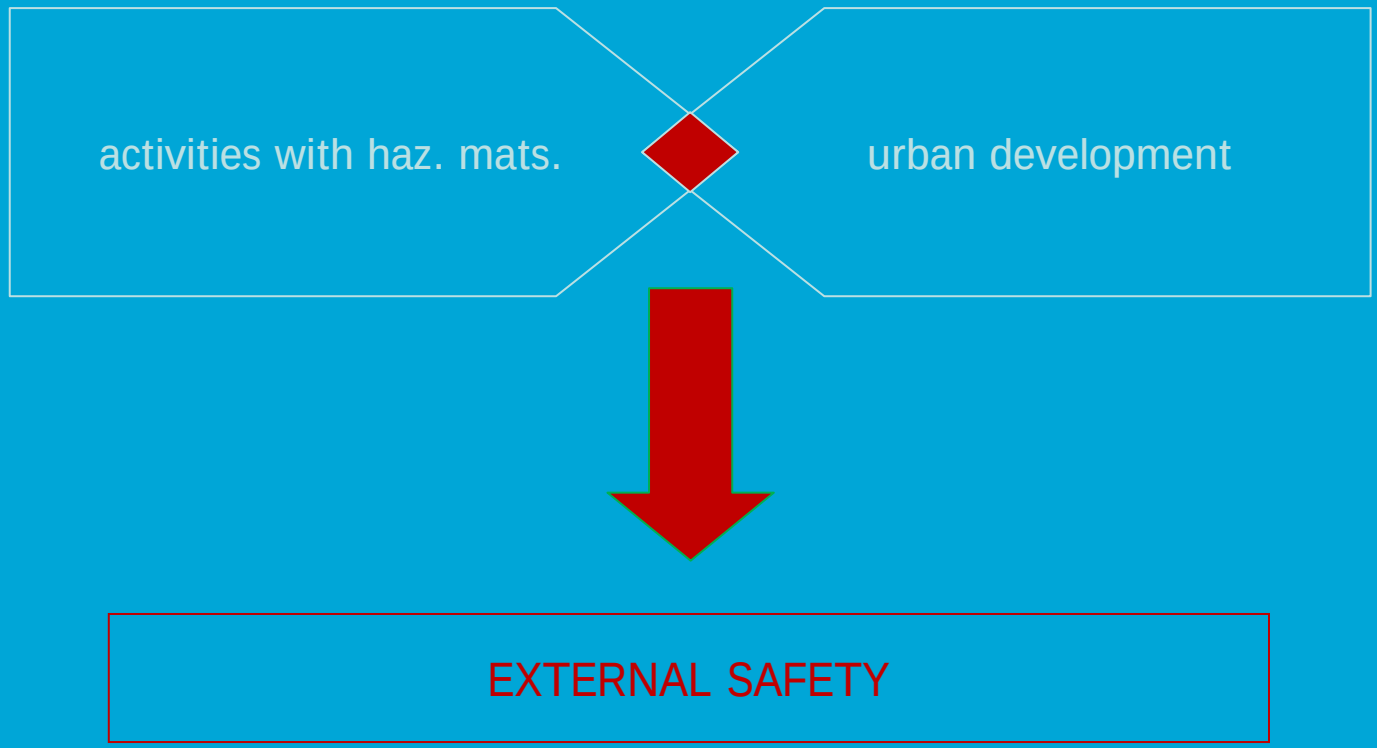
Introduction

Increase of intensive use of space & production, storage and transport of hazardous materials



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Dutch examples…


External safety risks …


FOX
Dan komt het vuur
bij een grote brandstoftank.
KBS

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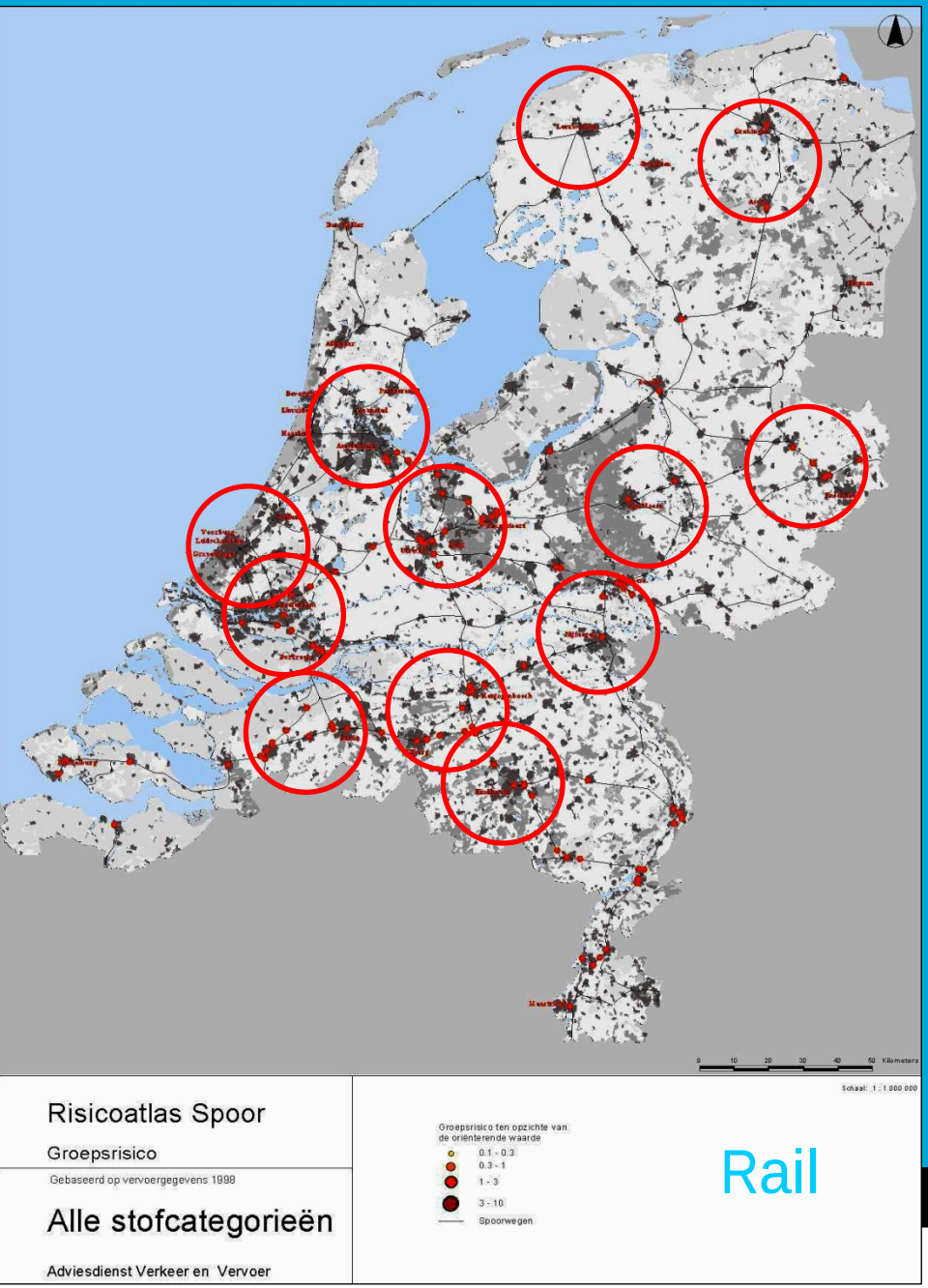

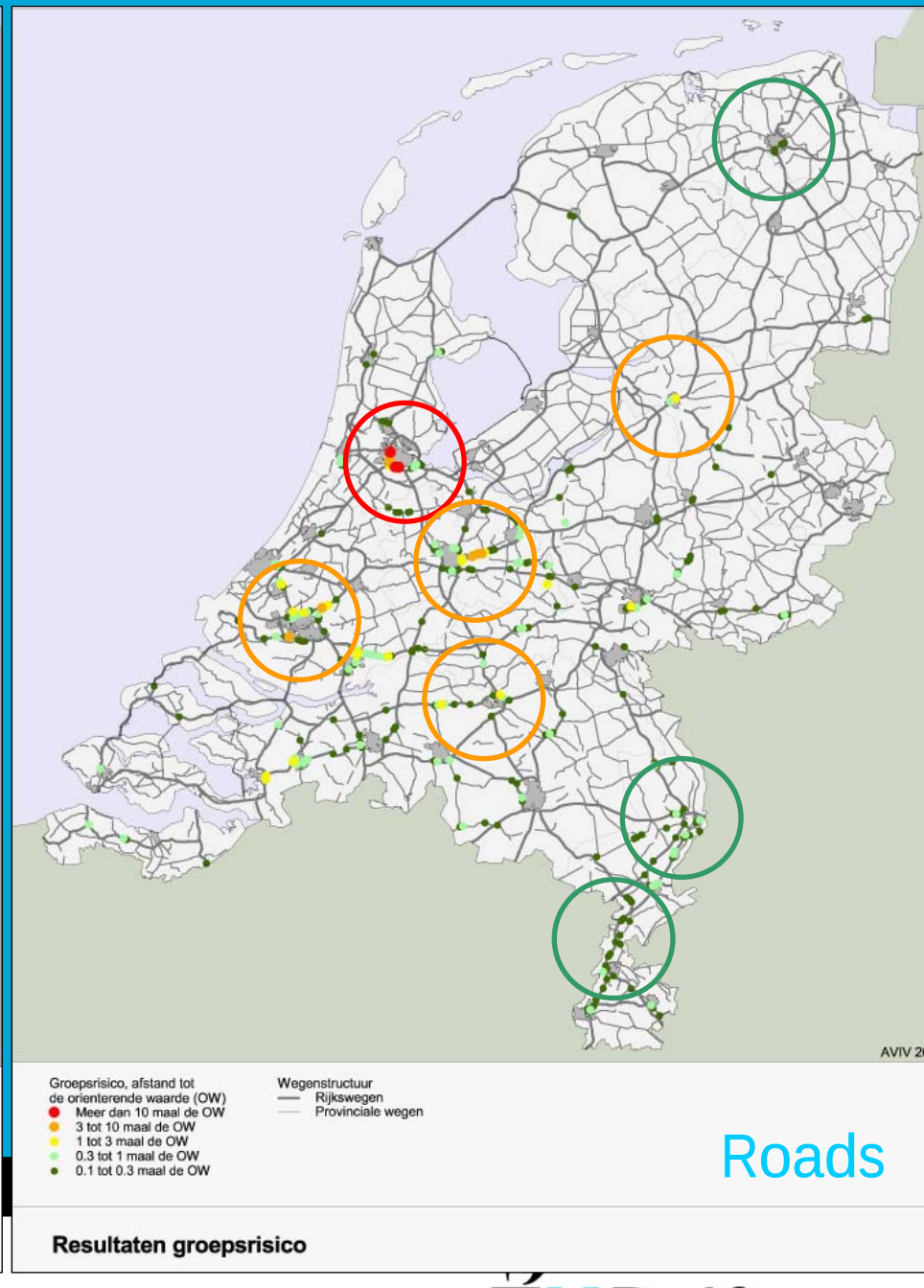

Don't forget: installations, water infrastructure & pipelines

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Literature review

- Suddle (2004): Physical Safety in Multiple Use of Space
- Van den Berg *et al.* (2001): guidelines to assess the blast loading and response of a tunnel structure due to a gas explosion
- Van den Berg *et al.* (2004): developed also a method to quantify the blast load from BLEVE accidents
- Neither Suddle (2004) nor Van den Berg *et al.* (2001,2004) provide specific analyses for structural control of explosion effects of buildings above infrastructure with transport of LPG
  - Van Diermen (2004): analysed some possibilities for the building structure above the infrastructure with the transport of LPG

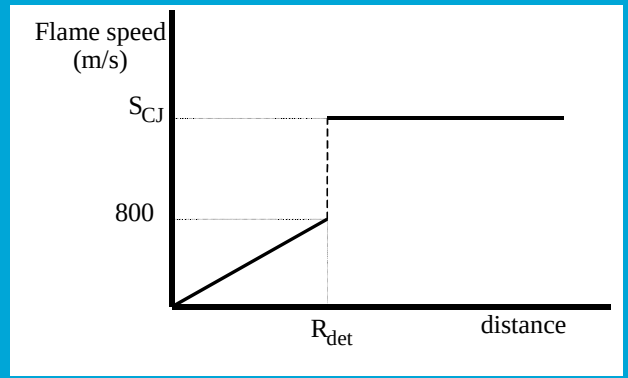
- This paper gives an introduction analysis of possibilities of how to deal with structural control of explosion effects when realizing buildings spanning roads with transport of LPG

Explosion hazards caused by LPG transport

	Consequences			
Frequency	Low	Medium	High	Extremely high
Extremely high	Local traffic accidents and small fires			
High		Fires on the infrastructure		
Medium			Explosions	
Low				Release of toxic gasses

Possible explosion scenarios originating from LPG transport

- Flammable gasses
  a. Gas explosion
  b. BLEVE (Boiling Liquid Expanding Vapour Explosion)

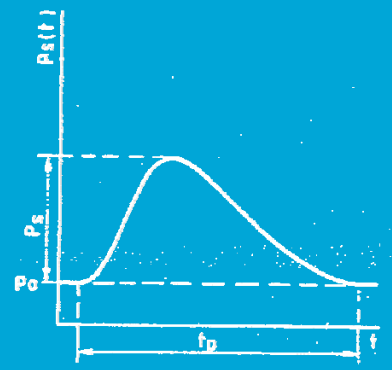


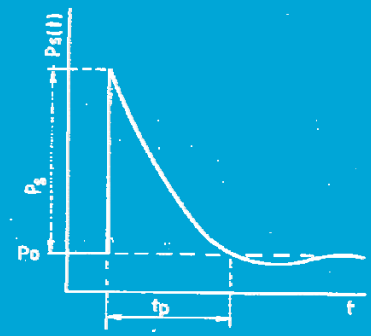
(a) Gas explosion
- Deflagration
- Detonation

(b) BLEVE
- Failure vessel (mechanical)→ physical explosion
- BLEVE due to heating vessel

Physical explosion effects

- Blast wave
- Atmospheric and ground effects
- Fragmentation and missile effects
- Thermal radiation effects





➔ Blast damage

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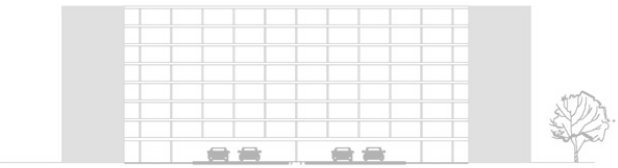
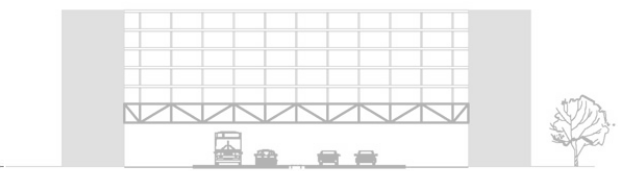
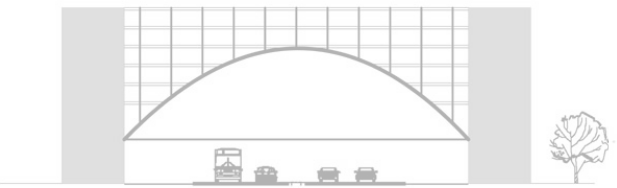
The bearing structure for building above infrastructure

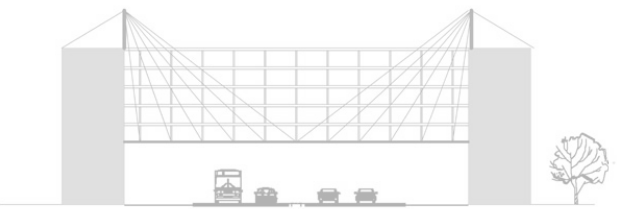
Schemes of span structures

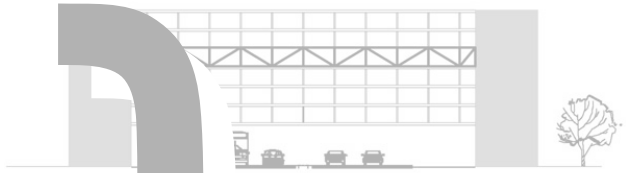


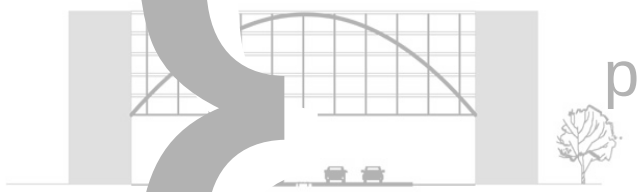
Column-Beam

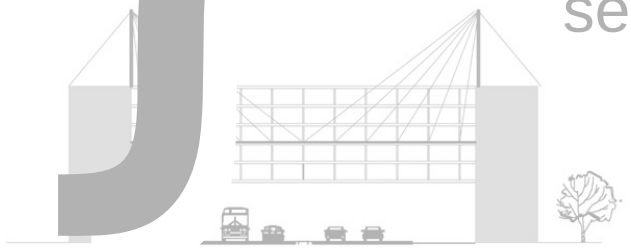


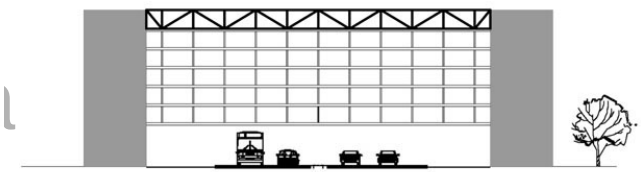


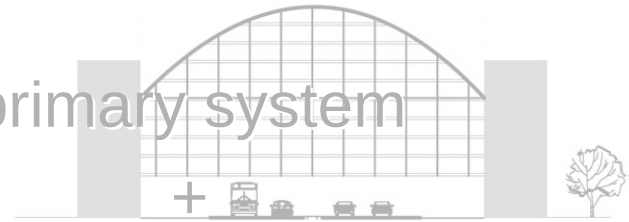








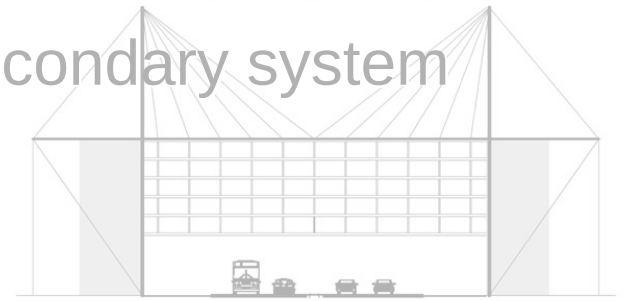




primary system

+

secondary system

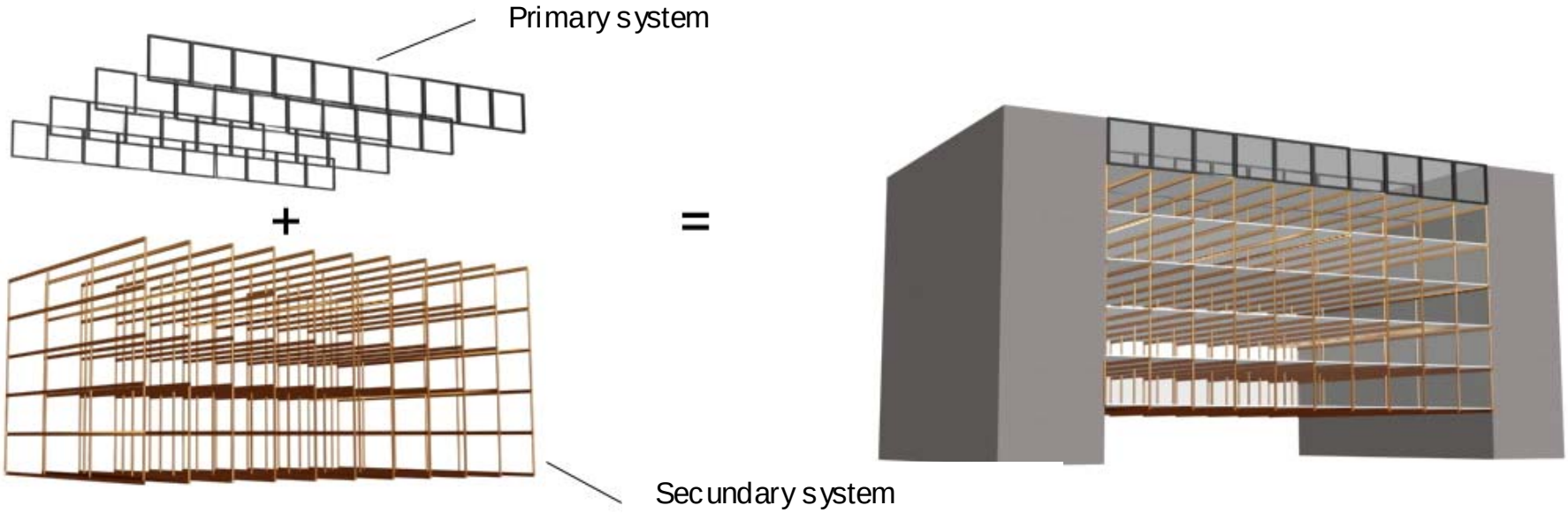


under

middle

top

Bearing system of the building



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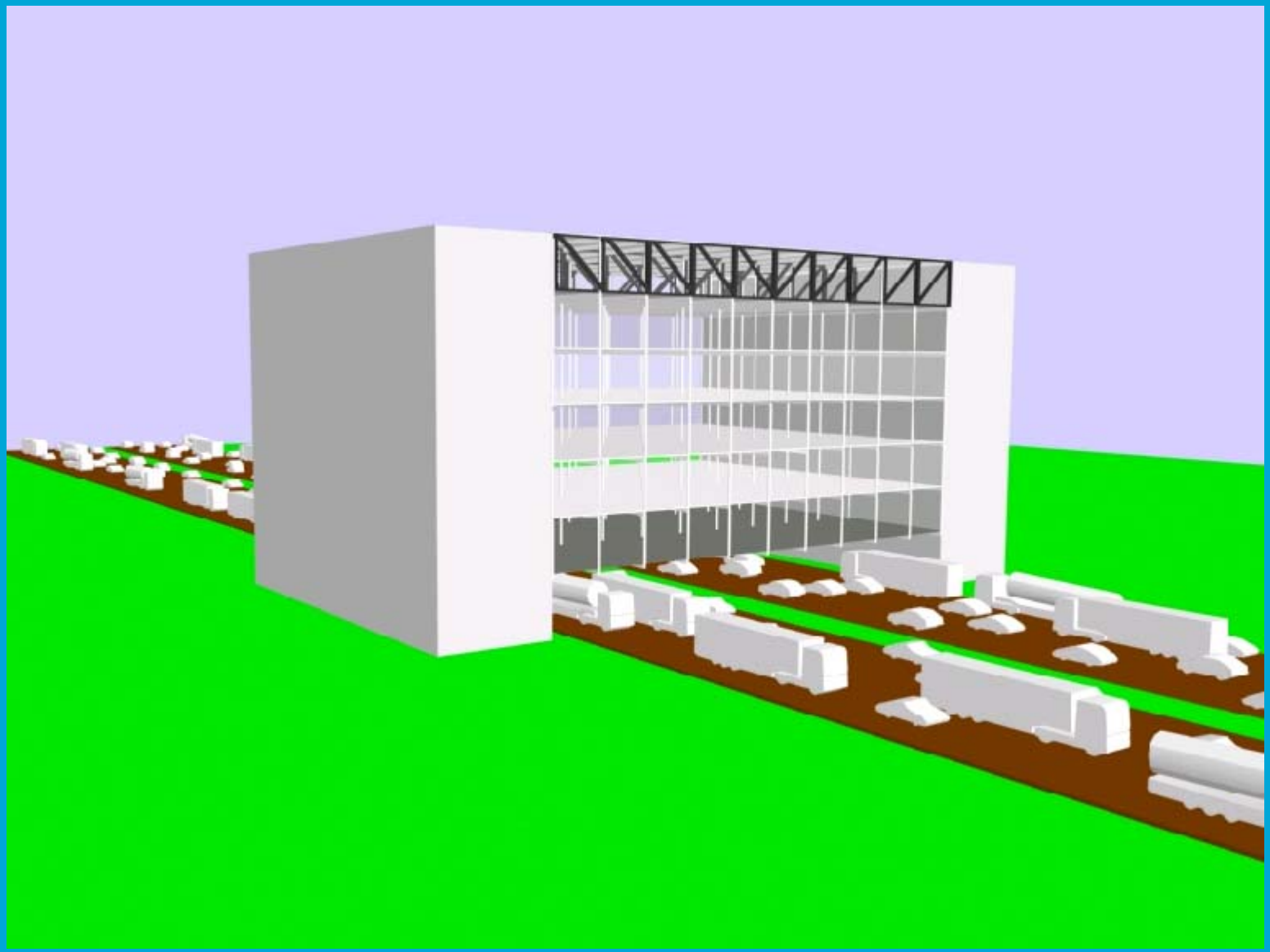
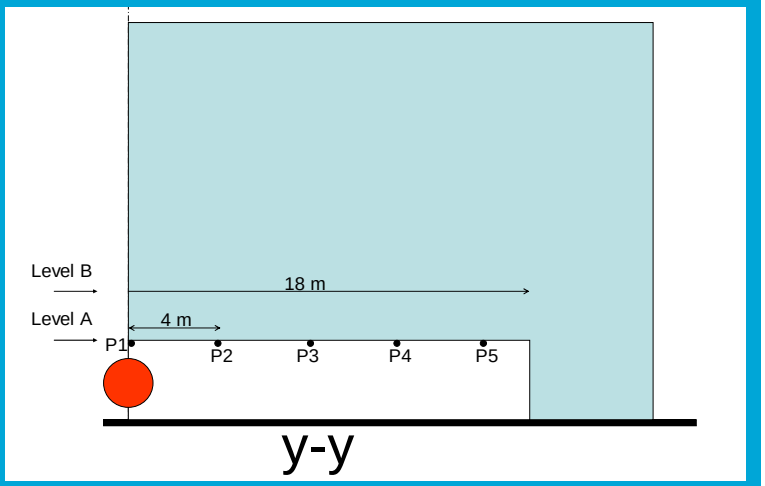
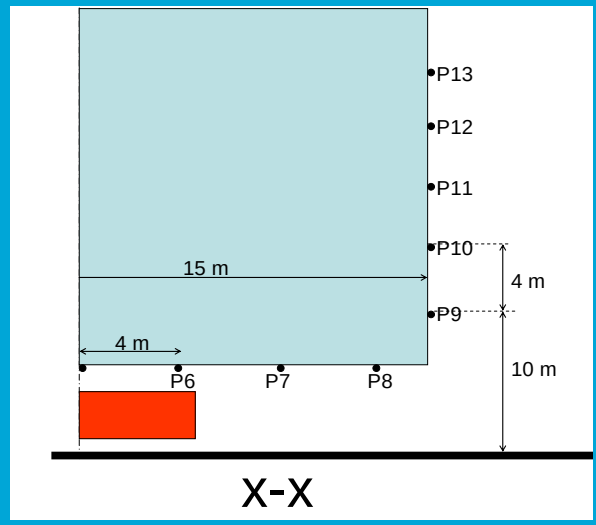
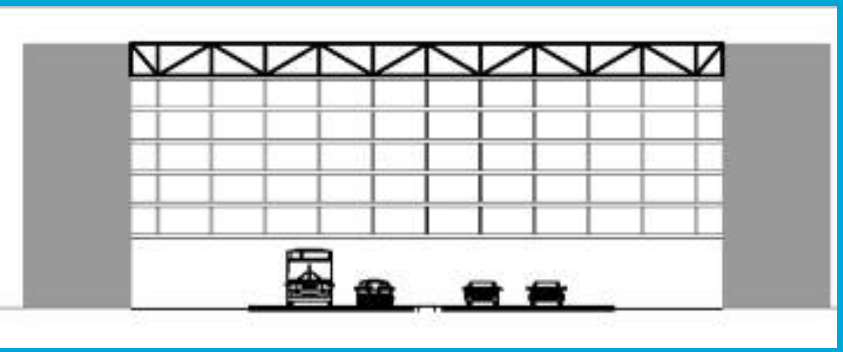
Case study

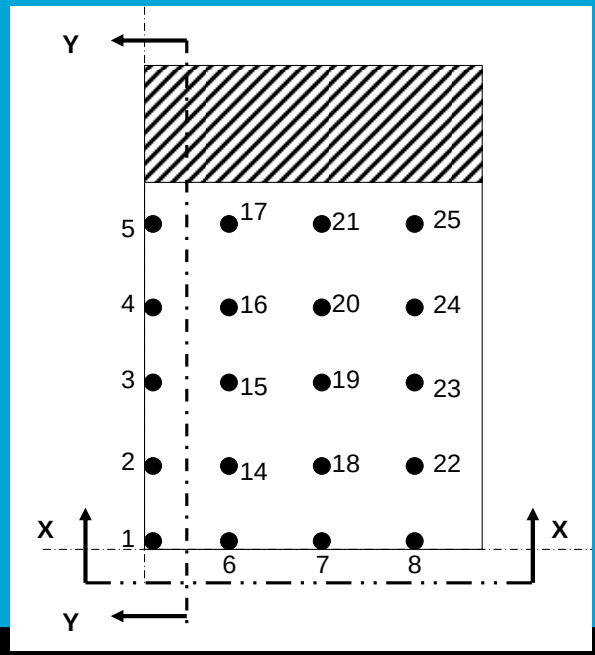
- Geometric model of the building



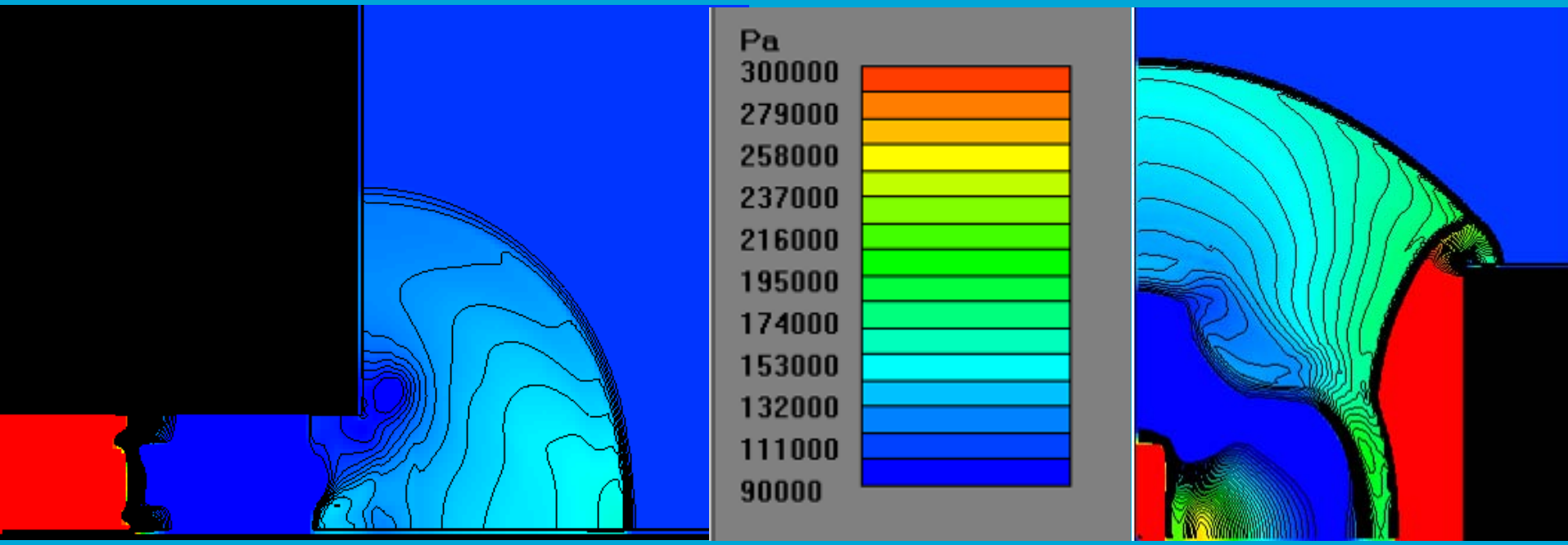

Level B
Level A
18 m
4 m
P1
P2
P3
P4
P5
y-y


P13
P12
P11
P10
P9
15 m
4 m
4 m
10 m
P6
P7
P8
x-x




Y
5
4
3
2
1
17
21
25
16
20
24
15
19
23
14
18
22
6
7
8
X
X
Y

Blast profiles



vertical

horizontal

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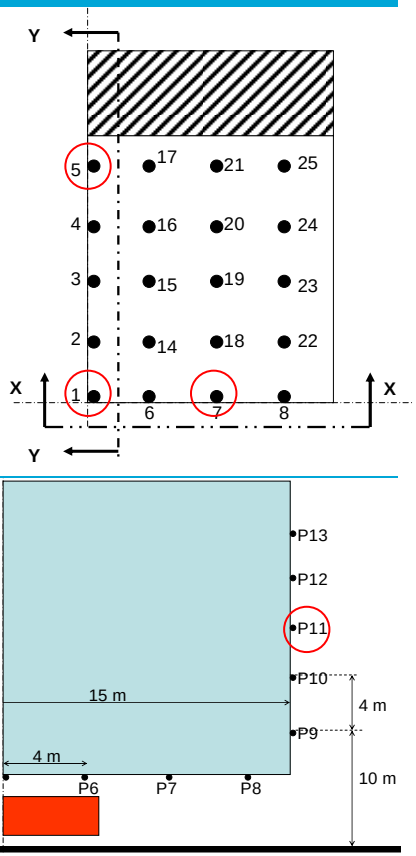
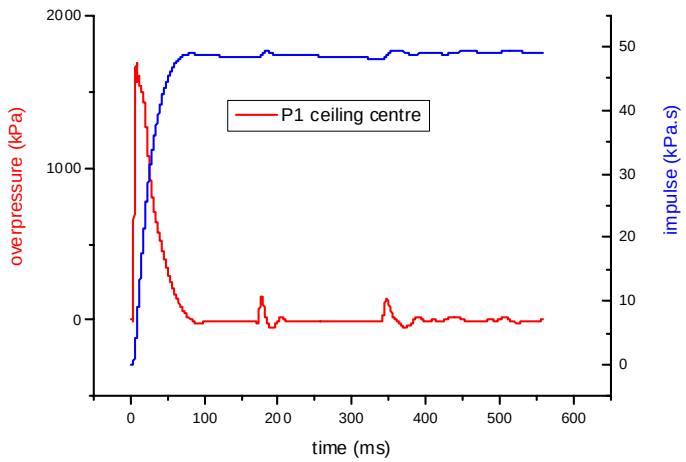
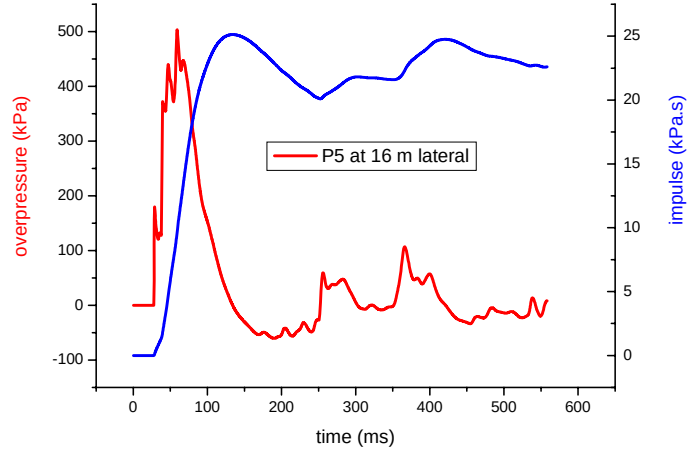
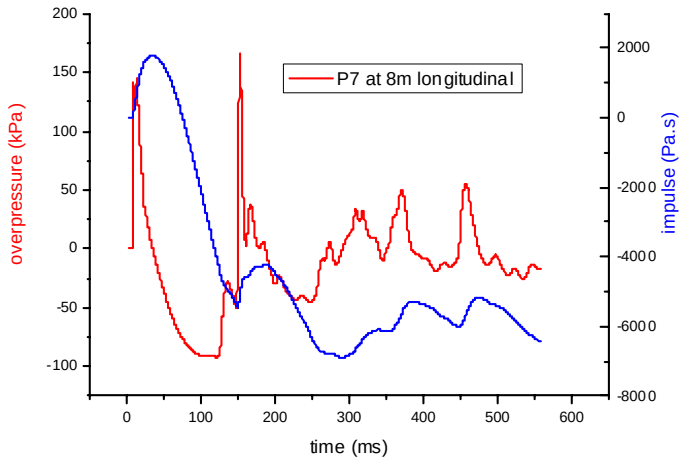
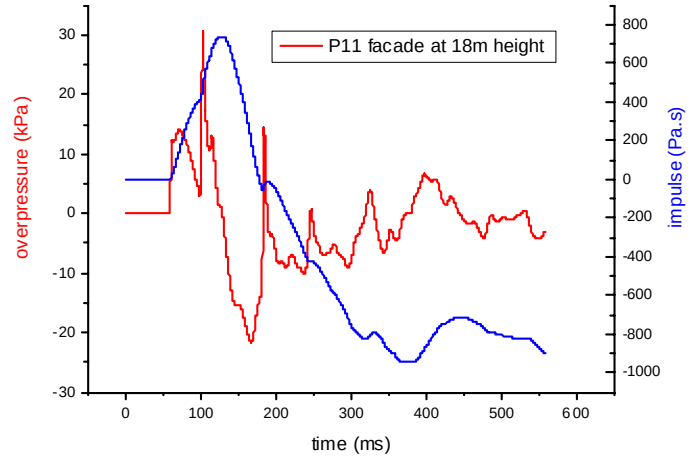
Predicted BLEVE blast loading on building positions 1, 5, 7 and 11











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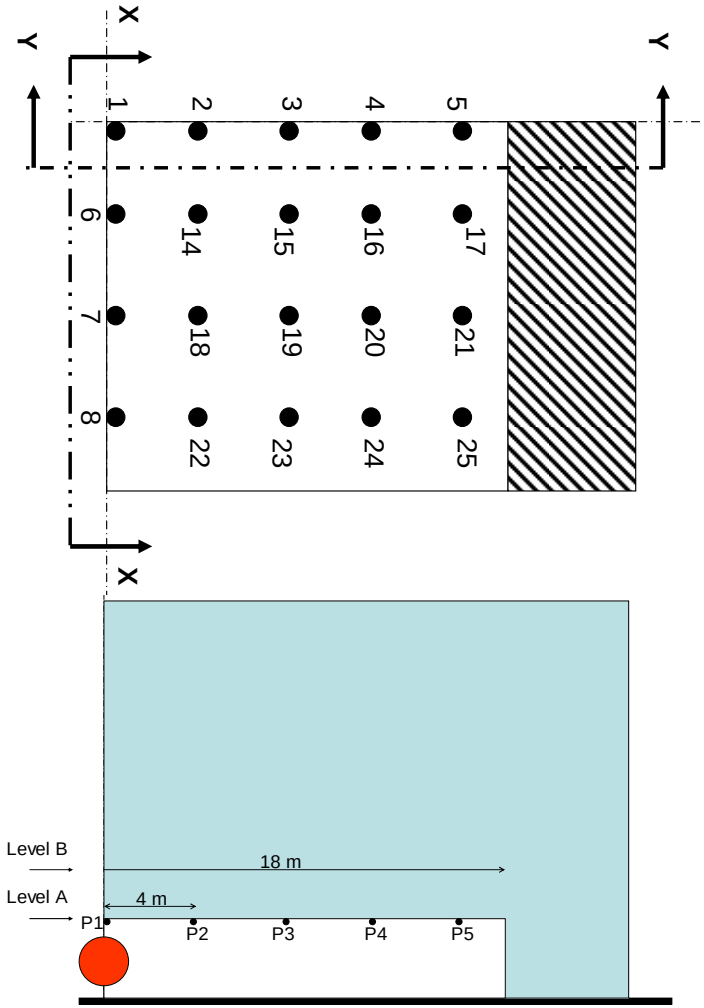
Quantitative results on damage analysis



Red = shear failure

Blue = bending failure

target points floor B	5-L2	17-L2	21-L2	25-L2
5-L2	250	230	200	100
4-L2	250	230	140	50
3-L2	335	165	41	50
2-L2	335	165	83	41
1-L2	667	330	83	83
	1-L2	6-L2	7-L2	8-L2

target points floor A	5	17	21	25
5	500	462	300	233
4	208	172	131	159
3	220	162	113	95
2	350	225	112	88
1	1700	1352	143	100
	1	6	7	8

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Conclusions

- The presented models and approach can be used to estimate the potential consequences of an LPG-accident as an input for risk analysis
- The model enables to identify countermeasures and subsequently to integrate these measures into both structural and building design
- Results of the considered case:
  - no damage to the primary and secondary bearing system
  - Sacrifice the first floor completely (failure)
  - Secondary floor partly fails
  - Windows breakage at all levels
  - Human risks too high at all building levels

Conclusions

- Countermeasures could be:
  - safety integrated design engineering (structural and functional)
  - design the windows for blast loading
  - the lower level should not be used for offices but storage and supporting facilities
  - a balanced design for the floor system at the first level, so that damage is limited to the first level and the dynamic resistance capacity of the bearing system is used

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