Blast effects and risk inside rail transport systems

Dr.-Ing. Martin Larcher

European Laboratory for Structural Assessment (ELSA)
Institute for the Protection and Security of the Citizen
Joint Research Centre, European Commission, Ispra, Italy
Terrorist Attacks against Trains

Madrid, 11 March 2004

London, 7 July 2005

Source: www.bbc.co.uk
Innovative Technologies for Safer and More Secure Land Mass Transport Infrastructures Under Terrorist Attacks

Problems
- Open security architecture
- No measures comparable to those applicable to civil aviation

Main objectives of the project
- Reduce vulnerability of railway and metro stations to explosion effects
- Make available a simulation tool
- Provide a guideline for safer and more secure trains and stations
Terrorist Attack, Madrid, 11 March 2004

Bag bomb (10 kg)

Source: www.spiegel.de
Pressure depends on
• the distance
• the size of the explosive
Parameters for spherical conditions from the literature (e.g. Kingery)

Pressure time curve  Compressed bubble  Solid TNT

Complexity, calculation time
EUROPLEXUS, developed in collaboration with CEA:

• Explicit finite element code for fast dynamic response of structures (explosions, impacts, crashes, etc).

• Specialized in modelling of Fluid-Structure Interaction phenomena.

• Experience in simulation of safety problems.

• Commercial version available (Samtech SA).
Underground Carriage

Model of the simulation

- Frame structure
- 3 mm aluminum sheet welded on the frame structure
- Floor fixed
- Explosive in the centre of the carriage

Dimensions of the carriage using JRC 3D Reconstructor
10 kg TNT, frame structure, laminated glass, displacements
Fluid-Structure Interaction, Charge

Laminated glass, frame structure

0.5 kg TNT

2.0 kg TNT

10.0 kg TNT
Comparison

Fluid-structure interaction

Madrid, 11 March 2004
• Combination of impulse, overpressure
• Different levels of fatal injuries:
  - lung haemorrhage
  - head impact
  - whole body impact
• Non-lethal injuries: Eardrum rupture
• Verified using terrorist attack in Madrid
Risk inside the Carriage

10 kg TNT
- Risk of death

0.5 kg TNT
- Risk of eardrum rupture
Risk in longer trains

- 96 m length, coarser mesh
- Cross section similar to one of the carriage
- Spherical conditions ↔ explosion in a tunnel
- Empty train ↔ train with passengers/chairs
Long train: failure

- 2 kg, free field
- 10 kg, free field
- 10 kg, inside tunnel

2 kg, annealed glass

Free field
Inside tunnel

Risk of death

Free field
Inside tunnel

Risk of eardrum rupture
Influence of Passengers, Chairs

- Simple model with shell elements
- Thickness 10 cm
- Similar weight, density of 1400 kg/m$^3$
- Stiffness $40 \times 10^6$ N/m$^2$
- Failure criterion 20 % strain
- 100/500 persons randomly in the train
- No contact

- Aluminium chairs, thickness 3 mm
<table>
<thead>
<tr>
<th>Chairs</th>
<th>Number of passengers</th>
<th>Length of high death risk zone [m]</th>
<th>Number of affected passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>No chairs</td>
<td>0</td>
<td>27.4</td>
<td>0.0</td>
</tr>
<tr>
<td>No chairs</td>
<td>100</td>
<td>13.2</td>
<td>12.7</td>
</tr>
<tr>
<td>No chairs</td>
<td>500</td>
<td>7.9</td>
<td>41.1</td>
</tr>
<tr>
<td>Chairs</td>
<td>0</td>
<td>17.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Chairs</td>
<td>100</td>
<td>10.0</td>
<td>9.6</td>
</tr>
<tr>
<td>Chairs</td>
<td>500</td>
<td>7.6</td>
<td>36.5</td>
</tr>
</tbody>
</table>
10 kg, including passengers, chairs

- Underground station
- Automatic door system
- Combination train and station
Conclusions

Model
• Allows determination of risk inside structures
• Fluid-structure interaction needed
  → channelling
  → risk

Risk
• Small influence of the structure of the carriage on the risk (frame - sandwich)
• Failure of the structure could reduce the risk due to pressure venting areas.
• Influence of windows (venting areas) is small in case of the failure of the shell.
• Internal walls, windscreens, chairs, passengers have a high influence on the risk, but can become fragments.

Recommendations
• As much material inside as possible
• Reduce the size of the charge!