Egress

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Joelma fire, Sao Paulo, Brazil,
Friday, February 1\textsuperscript{st}, 1974

Lecture – 2
How do I get everyone out?
Objectives

\[ t_e << t_f \quad \text{RSET} << \text{ASET} \]

\[ t_e << t_s \]

\[ t_s \rightarrow \infty \]

Fire Safety Strategy
Prescriptive Design

- If codes are followed RSET <<<<< ASET
  - by definition
Performance Based Design

- It has to be demonstrated: RSET <<<< ASET
A.S.E.T.: Available Safe Egress Time ($t_f$)
- Models can be used for the definition of the evolution of the fire ($t_f$)
Or ... Congregation Spaces (Theatres)

- **Successful evacuation**
- **Empire Palace Theatre**
  - 9 May 1911
  - Disastrous fire on stage
  - 3000 audience evacuated in 2.5 minutes
  - 11 deaths backstage

- **Post-war building studies report**
  - Fire grading of buildings, HMSO, 1952
  - 2.5 minute clearing time for a space!
The Great Lafayette and God Save the King
RSET

- We need to establish egress times ($t_e$)
- R.S.E.T. ($t_e$) – Required Safe Egress Time
Egress Time \((t_e)\)

\[ t_e = t_{de} + t_{pre} + t_{mov} \]

- \(t_e\) – Egress time
- \(t_{de}\) – Detection time
- \(t_{pre}\) – Pre-Movement time
- \(t_{mov}\) – Displacement time
Detection time \( (t_{de}) \)

- Depends on the technology used but it is generally much smaller than all other times \( (t_{de} \approx 0) \)

\[
t_e = t_{pre} + t_{mov}
\]
Luna Club
Rhode Island Night Club
Choice of Materials

- The growth of the fire needs to be limited to enable egress to occur under ideal conditions.
- If flames spread too fast then panic is induced.
  - Egress is unpredictable.
- If flames spread too fast there is not enough time to evacuate before reaching $t_f$. 


Pre-Movement Time ($t_{pre}$)

- Purely statistical – can be very long and brings great uncertainty
Principles of Egress

- Avoid panic behaviour
  - Reduces uncertainty
- Guide people to behave like an ensemble
  - Signalling
  - Illumination

![Diagram showing the relationship between V (m/sec) and D (people/m²). The graph has a curve peaking at a certain point and then decreasing. The y-axis is labeled V (m/sec) and the x-axis is labeled D (people/m²). A horizontal line at 1 m/sec on the y-axis indicates a threshold.]
Corridor
Displacement time \( (t_{\text{mov}}) \)

- Based on experiments
Velocities

- Allow to calculate displacement times and times to flow through doors \( t_{mov} = \frac{d}{V_e} \)
Doors

Fixed Density

Variable Density
Compatibility

Width of stairs

- Time to fully evacuate a floor ($t_{ff}$)
- Time to displace down a floor ($t_{df}$)

$$t_{df} \approx t_{ff}$$
Egress Exercise
**Code Requirements**

- **Untenable conditions** $(t_f)$
  - If the space is standardized then $t_f$ can be assumed constant

- $t_e < t_f \approx 0$

- $t_f > \frac{d_{max}}{V_e} + \frac{N}{W_p} + t_{pm}$

- Maximum egress distances are defined so $t_{mov}$ can be neglected
Hand Calculations

- Hand calculation of displacement times $t_{\text{mov}}$
  - Simple geometry
  - Precision is a function of available data and $t_{\text{pre}}$
- Ideal application: tall buildings, train stations, stadia with limited egress options, no cross-flows, etc.
Software

- Commercial Codes: Simulex, Exodus, etc.
- Freeware: FDS-(evac), etc.
○ Computations of $t_{mov}$
  ○ Complex geometry
  ○ Precision also depends of available data and $t_{pre}$

○ Ideal application:
  ○ Shopping centres, infrastructure with very large surface area and multiple egress paths, cross flow, etc.
**Example**

<table>
<thead>
<tr>
<th>Evacuation trail</th>
<th>ASERI</th>
<th>buildingEXODUS</th>
<th>PedGo</th>
<th>Simulex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total building</td>
<td>ca. 9 min</td>
<td>ca. 8.5 min</td>
<td>ca. 8 min</td>
<td>ca. 8 min</td>
</tr>
<tr>
<td>2nd floor</td>
<td>50–149 s</td>
<td>40–82 s</td>
<td>38–74 s</td>
<td>44–94 s</td>
</tr>
<tr>
<td>4th floor</td>
<td>45–75 s</td>
<td>35–86 s</td>
<td>49–73 s</td>
<td>50–82 s</td>
</tr>
<tr>
<td>5th floor</td>
<td>61–101 s</td>
<td>36–87 s</td>
<td>35–83 s</td>
<td>42–89 s</td>
</tr>
<tr>
<td>6th floor</td>
<td>31–102 s</td>
<td>42–82 s</td>
<td>35–78 s</td>
<td>41–95 s</td>
</tr>
<tr>
<td>7th floor</td>
<td>67–132 s</td>
<td>43–96 s</td>
<td>37–77 s</td>
<td>39–96 s</td>
</tr>
<tr>
<td>10th floor</td>
<td>51–102 s</td>
<td>33–117 s</td>
<td>41–83 s</td>
<td>39–92 s</td>
</tr>
<tr>
<td>15th floor</td>
<td>48–155 s</td>
<td>38–83 s</td>
<td>38–81 s</td>
<td>45–88 s</td>
</tr>
</tbody>
</table>

Hand calculations

- Very similar results
Egress Calculations

- Precision is given by the experimental data not by the complexity of the model
  - Hand calculations for simple geometries
  - Computations (software) for complex geometries
Timeline

- 1st floor: 10 sec
- 3 floors: 30 sec
- 8 floors: 60 sec
- 16 floors: 120 sec
- 25 floors: 180 sec
- Building: 240 sec
How does this change egress?