Smoke ventilation in common areas of single stair residential buildings

Some on-going issues and analysis

Stewart Miles
International Fire Consultants

The study and results reported are part on-going, personal academic work, and do not necessarily represent the views of any organisation
Smoke control in common areas

• Compartmentation is most important element
• Suppression may be significant
• Ventilation generally also required
  • Can assist means of escape
  • Can assist fire service operations
Smoke ventilation in single stair buildings

- To help protect stair enclosure
  - Limit smoke ingress before fire service arrival and during firefighting
- Where there are ‘extended’ corridor travel distances
  - Purge smoke that enters corridor prior to fire service arrival
  - Reduce severity of conditions in corridor during firefighting
Current ventilation practice

• Natural ventilation from corridor; or
• Mechanical extract ventilation from corridor
  • Sometimes augmented with mechanical supply too
  • Or sometimes open vents for inlet air
• Open vent at top of stair enclosure (with either of above)
• Air supply / pressurisation in stair enclosure not common
Some concerns

• Fire sizes considered are generally restricted to fuel-bed limited condition
  • i.e. contained fuel area and associated heat release rate
  • But, can post-flashover fires actually be more severe?
    • (and take smoke ventilation system beyond designed capability?)

• Can too much depressurisation in the corridor lead to hazards that are not generally considered?
  • e.g. smoke drawn under door threshold
  • Propensity for ‘backdraught’ conditions during firefighting?
Building geometry modelled
Apartment and common corridor
Smoke ventilation methods analysed

• External wall AOV in corridor
  • (plus top of stair AOV)
Smoke ventilation methods analysed

• Natural smoke shaft to corridor
  • (plus top of stair AOV)
Smoke ventilation methods analysed

• Mechanical extract from corridor
  • (plus top of stair AOV)
Smoke ventilation methods analysed

• Mechanical ‘push/pull’ in corridor
  • supply & extract in corridor
  • (plus top of stair AOV)
Smoke ventilation methods analysed

- Mechanical supply to stair
  - Fresh air into stair
  - Pressure-relief damper
  - (top of stair AOV omitted)
Smoke ventilation methods analysed

• Mechanical supply to stair, plus either:
  • External wall AOV in corridor, or
  • Mechanical ‘push/pull’ in corridor
Post-flashover fire scenario

• Steady-state condition
• Fire distributed across whole floor
• Assume:
  • Hot gas layer at 800°C & emissivity ~1
  • Fuel heat of gasification = 4 000 kJ kg⁻¹
    • (ranges from 1 000 to 5000 kJ kg⁻¹ for most fuels)
  • Heat of combustion = 20 000 kJ kg⁻¹
• Then
  • Energy (heat) release rate associated with fuel pyrolysis = 375 kW m⁻²
    • (would be higher if lower heat of gasification adopted)
Post-flashover fire scenario

- Fire spread across entire floor area in room of origin
  - $24m^2 \rightarrow 9 \text{ MW heat release}$
    - (assuming all fuel combusts)
- Window/vent 3m by 1.4m
  - From empirical correlation $\sim7.5\text{MW}$ heat release rate can be supported within room
    - (excess fuel can combust in flames outside window)
Illustration of fire from CFD model
Illustration of fire from CFD model
Comparison with a real fire

• Flame and smoke dynamics similar to the CFD model
Illustration of fire from CFD model – apartment door open
Modelling using Fire Dynamics Simulator

• 10cm mesh throughout

• Eddy dissipation combustion
  • Heat combustion 20 000 kJ kg$^{-1}$
  • 10% soot yield

• ‘Finite volume’ ray-tracing radiation model
  • 100 rays
  • Grey gas absorption sub-model
  • 0.35 radiative fraction (from combustion process)

• HVAC sub-model
  • For mechanical supply & extract boundary conditions
Simulations (scenarios) at fire service intervention stage

- Steady (post-flashover) fire source
- Ventilation system running
- Apartment door open
- Stair door (on fire floor) open to 20° angle
- Stair bottom (entrance) door open
- Simulations conducted for two to three minutes or until quasi-steady state reached
Simulations (scenarios) prior to fire service arrival

- Steady (post-flashover) fire source
- Ventilation system running
- Apartment door closed
  - 3mm threshold gap modelled using FDS ‘leak vent’ capability
- Stair door (on fire floor) closed
  - Unless ‘pulled-open’ as part of ventilation operation
- Stair bottom (entrance) door open
- Simulations conducted for two to three minutes or until quasi-steady state reached
Smoke transport at firefighting stage

- No corridor ventilation
Smoke transport at firefighting stage

- ADB corridor AOV
  - ~1m² aerodynamic free area
    - (equivalent to 1.5m² unobstructed rectangular opening)
Smoke transport at firefighting stage

- ADB natural smoke shaft
Smoke transport at firefighting stage

- Mechanical extract at 2 m\(^3\)s\(^{-1}\)
Smoke transport at firefighting stage

- Mechanical extract at 4 m$^3$s$^{-1}$
Smoke transport at firefighting stage

- Mechanical extract at 6 m$^3$s$^{-1}$
Smoke transport at firefighting stage

- Mechanical ‘push/pull’ at 2 m$^3$s$^{-1}$
Smoke transport at firefighting stage

- Stair supply at 2 $\text{m}^3\text{s}^{-1}$
- No vent in corridor
Smoke transport at firefighting stage

- Stair supply at 2 m³s⁻¹
- Wall vent in corridor
Smoke transport at firefighting stage

• Stair supply at 4 m$^3$s$^{-1}$
• No vent in corridor
Smoke transport at firefighting stage

- Stair supply at 4 m$^3$s$^{-1}$
- Wall vent in corridor
Smoke transport at firefighting stage

- Mechanical ‘push/pull’ at 2 m$^3$s$^{-1}$
- Stair supply at 2 m$^3$s$^{-1}$
Smoke transport at firefighting stage

- Mechanical ‘push/pull’ at 2 m$^3$s$^{-1}$
- Stair supply at 4 m$^3$s$^{-1}$
Smoke transport prior to fire service arrival

- Mechanical ‘push/pull’ at 2 m$^3$s$^{-1}$
Smoke transport prior to fire service arrival

- Low level mechanical extract
  - Air leakage into corridor
Smoke transport prior to fire service arrival

- Mechanical extract at 2 m$^3$s$^{-1}$
  - ‘Reverse-hung’ stair door part-opening at ∼10Pa
To conclude

• Various issues relating to smoke ventilation in residential buildings warrants further investigation
  • Impact of post-flashover apartment fires
  • Potential for smoke and fire gases to be drawn into the corridor
  • Possible benefit of supplying air mechanically into the stair is being missed
  • For ‘extended corridors’ a combination of mechanical corridor smoke clearance (e.g. ‘push/pull’) and mechanical air supply into the stair may prove productive
• Work reported is very much ‘work in progress’ open for discussion
Thank you for your attention