Infrastructure for Performance-Based Structural Fire Engineering (PB SFE)

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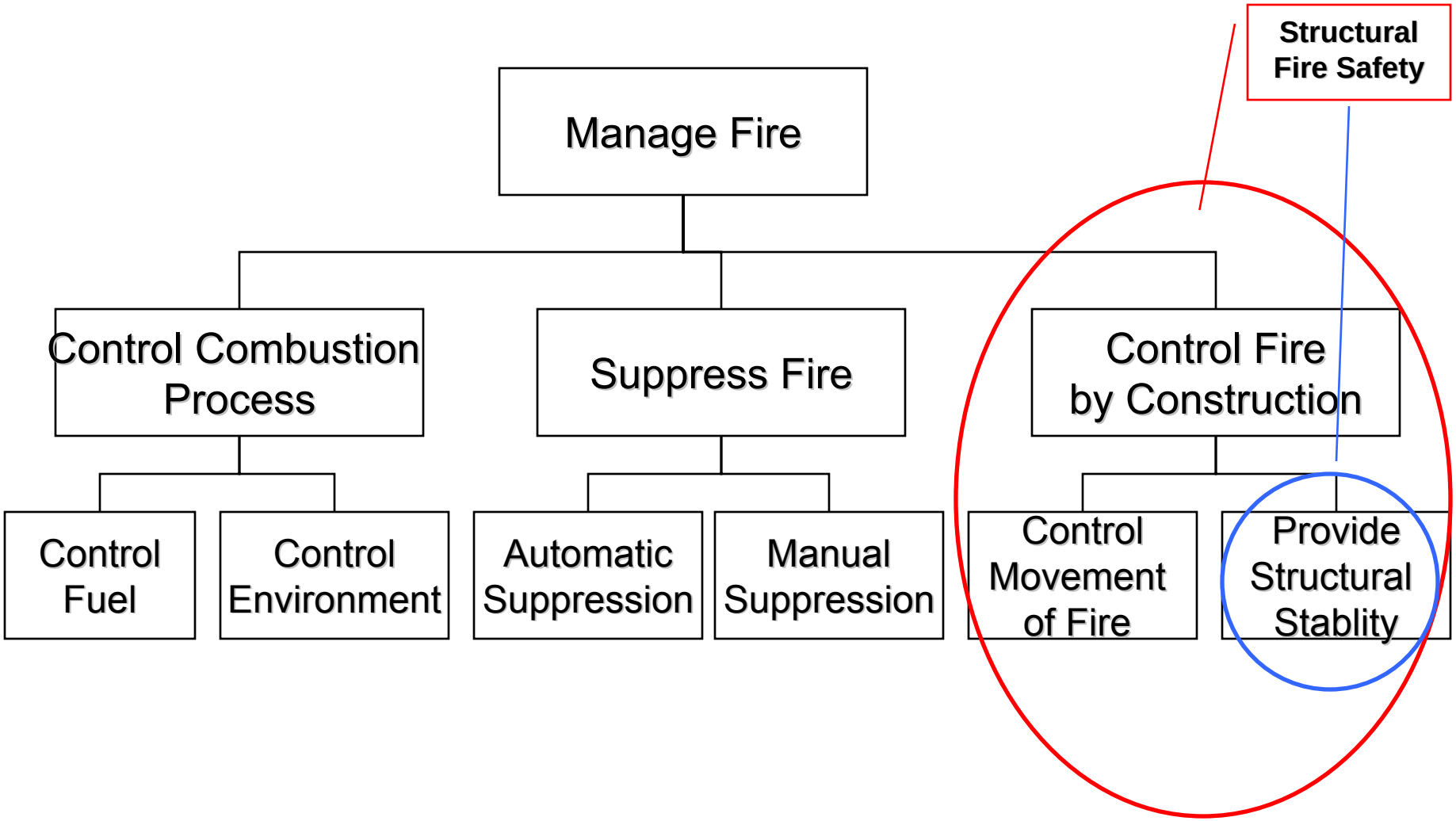
Status of Development of Infrastructure for P-B Structural Fire Engineering (PB SFE)

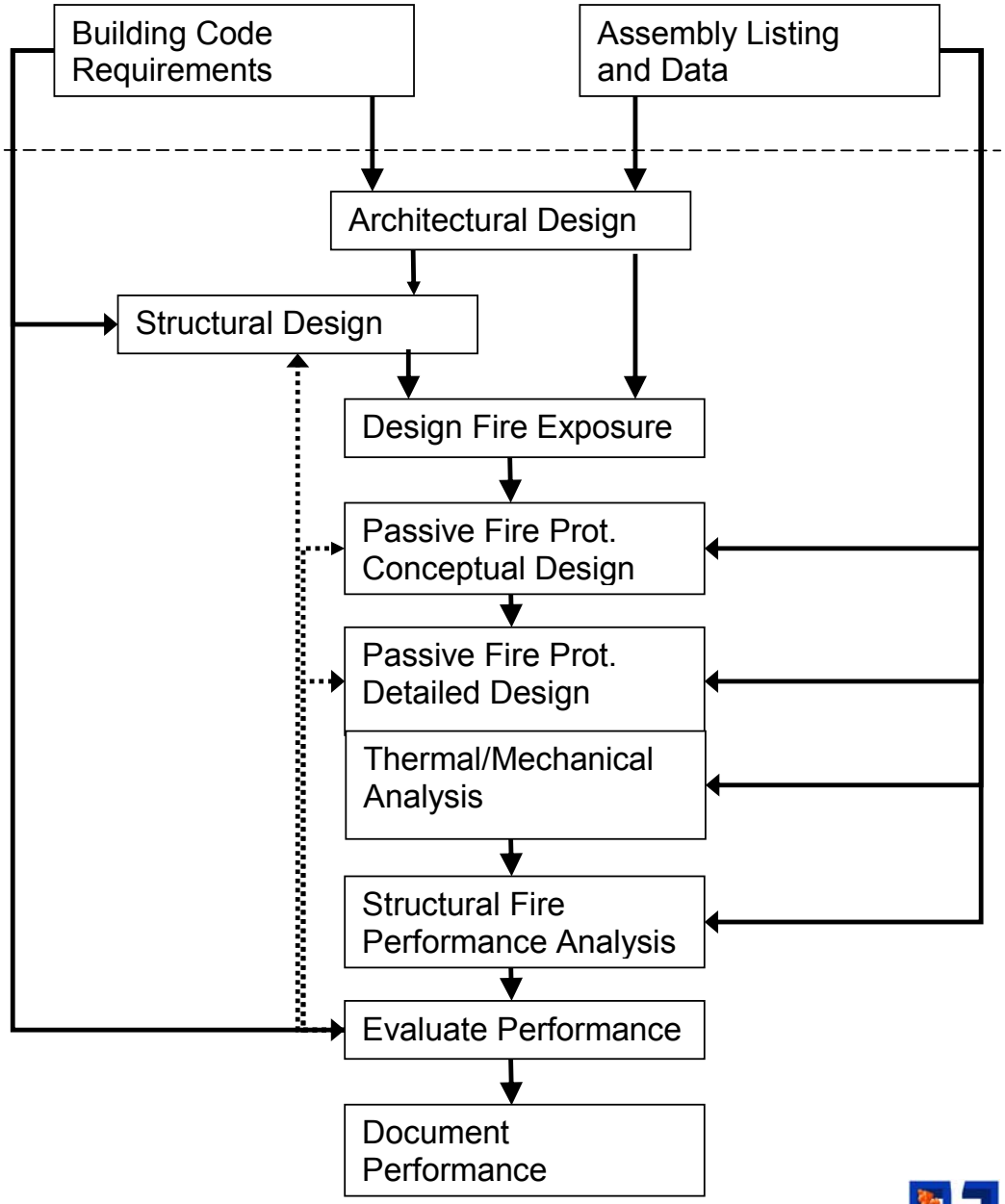
- Design documents for PB SFE
- Test methods to support PB SFE

Manage Fire (Concepts Tree)



Performance-Based Structural Fire Engineering (PB-SFE)

Process Flow Chart



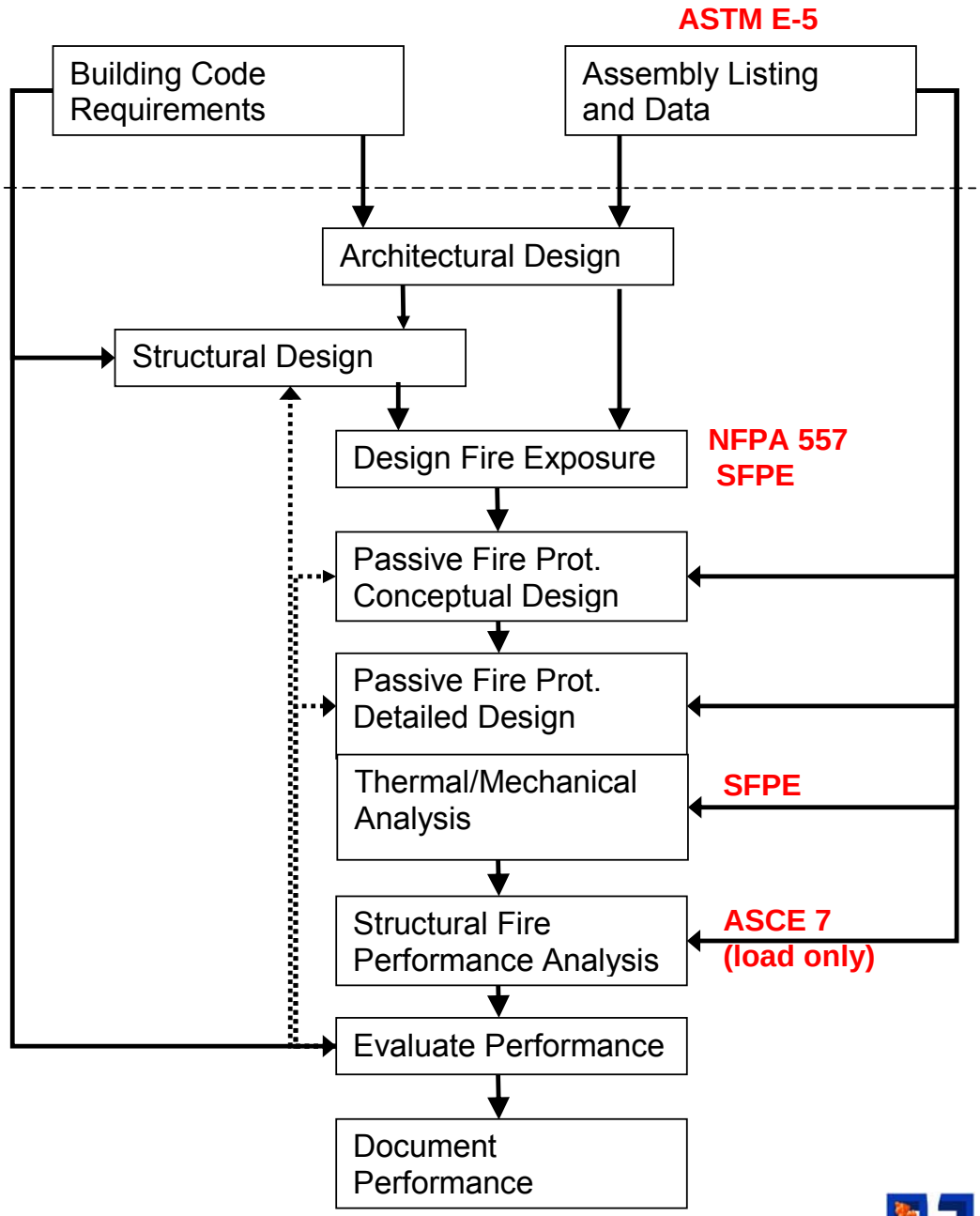
Standards Development Activities for PB-SFE

- Assembly Listings and Data: ASTM E-5
- Design Fire Exposure
  NFPA 557- fire load
  SFPE- thermal exposure
- Thermal-Mechanical Analysis: SFPE
- Structural Fire Performance Analysis:
  ASCE 7 (loading for fire analysis as an extraordinary event only, C2.5)

Red indicates ongoing study or development

Performance-Based Structural Fire Engineering (PB-SFE)

Process Flow Chart



ASCE 7

- Fire exposure is regarded as an extraordinary event and C2.5 provides load guidance
- Structural loading during fire exposure should reflect normal loading only
- Design basis wind loads or earthquakes should not be taken to occur at the time of the fire exposure

NFPA 557: Fire Loads Standard (in development)

- To provide fire load for use in assessing fire exposure
- Fire load distribution can be
  - occupancy-based using existing fire load surveys, or
  - facility specific using special fire load surveys in the facility or exemplar facility
- Design fire load based on a fire load distribution, mitigating features, and design exceedance frequency (e.g. 10^{-6}/yr)

NFPA 557: Fire Loads Standard

Elements of the approach

- Fire load (MJ/m^2) has Gumbel distribution
- Fire frequency is based on fire statistics (e.g. 5 office fires per million square meters per year)
- Mitigation features credited based upon fire statistics (construction type, sprinklers, automatic detection)
- Acceptable risk exceedance criteria is set by code of record, AHJ, or user (nominally set at 10^{-6}/yr)

Effect of Mitigation Features on Probability of a Structurally Significant Fire (Offices)

Type of Construction	No detectors No sprinklers	Detectors No sprinklers	No Detectors Sprinklers	Detectors Sprinklers
Fire resistive	0.13	0.07	0.04	0.03
Protected noncombustible	0.15	0.06	0.05	0.03
Unprotected noncombustible	0.19	0.10	0.07	0.05
Protected ordinary	0.21	0.10	0.03	0.04
Unprotected ordinary	0.30	0.17	0.11	0.07
Protected wood frame	0.30	0.18	0.13	0.08
Unprotected wood frame	0.37	0.20	0.12	0.07

Based upon the likelihood of fire spread beyond room of origin, NFIRS 1989-1998

NFPA 557 Issues

- Existing fire load surveys are highly inconsistent and small in number
- Fire load survey methodologies are poorly documented
- Poor data is pushing the initial drafts toward a very conservative basis and a narrow scope of applicability

SFPE Fire Exposure

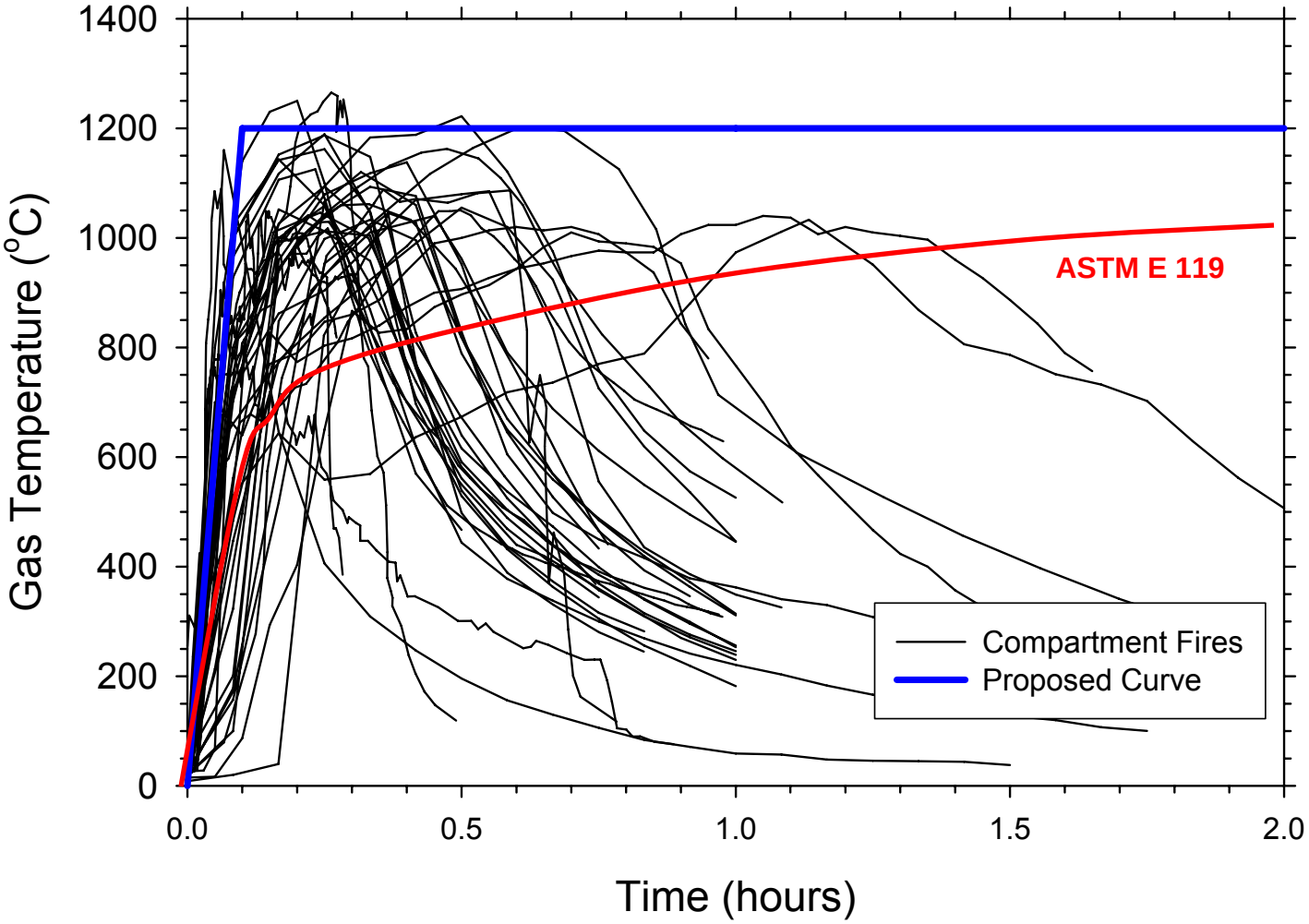
- SFPE Standard on Calculating Fire Exposures to Structures- draft status
- Addresses two types of exposures:
  - * local exposure
  - * enclosure fire exposure
- No consideration for modeling the fire using zone or CFD

SFPE Fire Exposure- Enclosure

- Collected 130 experimental datasets and evaluated 24 methods
- Evaluated the methods based on
  1. bare steel
  2. concrete protected steel
  3. lightweight insulation on steel

  and compared thickness of steel or insulation based on test temperatures vs the methodology
- Two methods adopted: 1200 C constant temperature method and a refined version of Tanaka model
- Issuing document is awaiting journal publication of the methods comparison

SFPE Fire Exposure: Enclosure



SFPE Fire Exposure: Enclosure

Constant Temperature Method

- Steady Burning: 1200 C for duration given by fuel load and vent factor
- Decay: 7 C / minute

Refined Tanaka Method

- Correlation based on
  - opening factor, $A\sqrt{H}/A_T$
  - compartment thermal inertia, $k\rho c$

SFPE Fire Exposure: Local

- Typical application: fire source against a column or fire below a beam
- Simplification of heat flux correlations in the SFPE Handbook

SFPE Thermal/Mechanical Response Standard (in development)

- SFPE Standards Making Committee on Predicting the Thermal Performance of Fire Resistive Assemblies
- Developing a process document to develop and validate methodologies for thermal response prediction

SFPE Thermal/Mechanical Response Standard

Elements of the Standard

- Problem definition and model selection
- Model input data and experimental methods for input data
- Model verification
- Model validation
- Model application methods
- Documentation

ASTM E-5

- "Fire Resistance Testing for Performance-Based Fire Design of Buildings,"
  Beyler, Beitel, Iwankiw, Lattimer for Fire Protection Research Foundation
- Developing guidelines for supplemental testing protocol and studying modification to E119 test method.

Recommendations for Fire Resistance Testing for PB SFE

Types of recommendations:

- Furnace instrumentation (8)
- Furnace operation (10)
- Structural instrumentation (3)
- Structural operation (10)

Recommendations designed to provide V&V data for models and to fully challenge mechanical/structural capabilities of assemblies

ASTM E-5

- Category 1 recommendations will be addressed in Task Group E05.11.26, *Fire Tests Under Exposure Conditions Different from ASTM E 119*, for inclusion in their new Guide for conducting furnace fire-resistance tests.

- Category 2 recommendations will be addressed in Task Group E05.11.01, *ASTM E 119 Update*.
  It is unclear whether the task group will recommend changes to E 119 based on the FPRF report or whether a new task group will be formed to establish a new fire-resistance test method

Furnace Recommendations for Fire Resistance Testing for PB SFE

- Furnace instrumentation- plate thermometer control, positive pressure, velocity, temperature measurements through the thickness of the sample
- Furnace operation- 1200 C exposure temperature, calibration test, furnace lining and depth, burner fuel, secondary air and exhaust control, thermal and physical properties of assembly materials

Structural Recommendations for Fire Resistance Testing for PB SFE

- Structural instrumentation- end restraint load measurement, deflections, strain gauges
- Structural operation- load application, load level, scaling laws, *test to failure*, ambient and elevated temperature strength of materials, eccentric loading of walls and columns, no hose stream

Achieving PB-SFE

- Ongoing development is volunteer work only
- Reveals significant gaps in knowledge
- Requires significant research to support the development of the engineering infrastructure
- Engagement of the structural engineering community is needed

Its still a long road ahead

9th Int. Symposium on Fire Safety Science

- 116 fully peer reviewed papers
- Poster session (with German hospitality) (submission deadline: May 15)
- Sunday workshops, full evening social program
- Interaction with the best of the fire science community

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