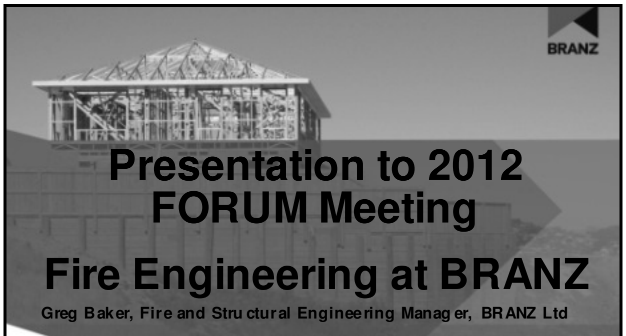
附錄 **2.** 亞太區會員專題簡報

- BRANZ / Craig B. Baker
- NRIFD /Kaoru Wakatsuki
- ABRI / Alec M.Y. Lei(雷明遠)
- SKLFS / Naian Liu(劉乃安)



Presentation to 2012 FORUM Meeting

Fire Engineering at BRANZ

Greg Baker, Fire and Structural Engineering Manager, BRANZ Ltd

INTRODUCTION - BRANZ

- BRANZ came into existence in 1970
- Building Research Levy Act 1969
- Bldg Research Levy
- BRANZ structure
  - Association
  - BRANZ Ltd
- BRANZ is only organisation of its type in New Zealand – sole focus on (NZ) building industry

CURRENT STATUS

- 50% of BRANZ income comes from BRL
- Typical year NZD $10M BRL and $10M from "commercial sources" (note NZD $1 = USD $0.8)
- Last two years BRL 50-70% of typical amount
- Currently running $2M deficit, funded by BRL reserves
- Maintained staff levels at approx. 100 overall

BRANZ SERVICES

- BRANZ Ltd services
  - Research
  - Testing
  - Consultancy
  - Information
  - Education

TECHNICAL AREAS

- Technical Areas
  - Fire
  - Structural Performance
  - Sustainability
  - Bldg Physics
  - Thermal Efficiency
  - Bldg Economics
  - Weathertightness
  - Indoor Air Quality
  - Materials Performance (Durability etc)

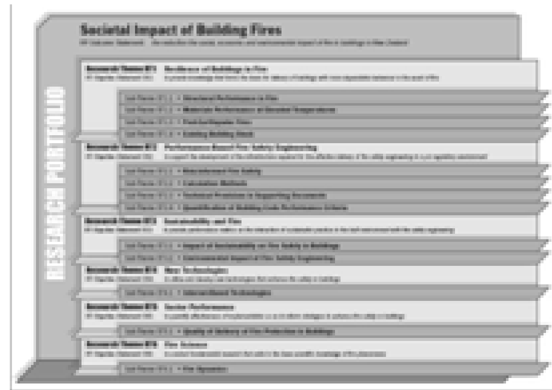
FIRE ENGINEERING

- Fire Engineering
  - Commercial testing & consulting
  - Research
- Staff numbers
  - Commercial testing = 7 FTEs: 4 x engineers, 1 consultant, 2 lab technicians
  - Research = 2.8 FTEs: 2 x fulltime researchers + 1 x part-time researcher
  - Management = ½ FTE, split between fire and balance structures

FIRE RESEARCH FUNDING

- Typical year $0.5-1.0M funding on fire research
- Sources BRL, Government co-funding
- Part of money used to fund collaboration
- Government project co-funding for last 5 years
- Co-funding ends 31 March 2013
- staffing possibly under threat beyond 1 April 2013

FIRE RESEARCH ROADMAP



CURRENT FIRE RESEARCH

- Designing Buildings for Fire
- Risk-Informed Fire Design ✓
- Balcony Spill Plumes
- Model Validation
- Fire Research Search Engine
- Smouldering Ignition Sources
- Post-Earthquake Fire Protection ✓

1. RISK-INFORMED FIRE DESIGN

- 5½ year project ending in March 2013
- Major sponsor is NZ Govt. RS&T funding agency
- Project involves collaboration with University of Canterbury
- Outcome is that project aims to contribute to improved standard of FSE engineering design in NZ

RISK-INFORMED FIRE DESIGN

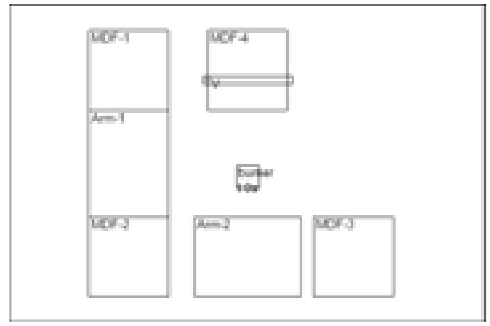
- Regulator developed detailed guidance and acceptance criteria – new C/VM2
- Way to demonstrate compliance with Code for P-B FSE designs
- Previous lack of quantification resulted in widespread subjectivity and inconsistency
- Future-focussed project will produce a probabilistic design tool, called B-RISK

RISK-INFORMED FIRE DESIGN

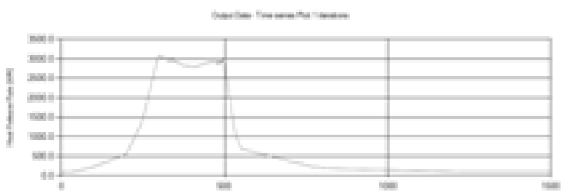
- B-RISK based on deterministic BRANZFIRE two-zone model
- Deals with variability in fire modelling as well as systems reliability
- Functionality:
  - Design fire generator
  - Probability distributions for input parameters and monte-carlo sampling
  - Cumulative distribution functions for tenability outputs

Design Fire Generator

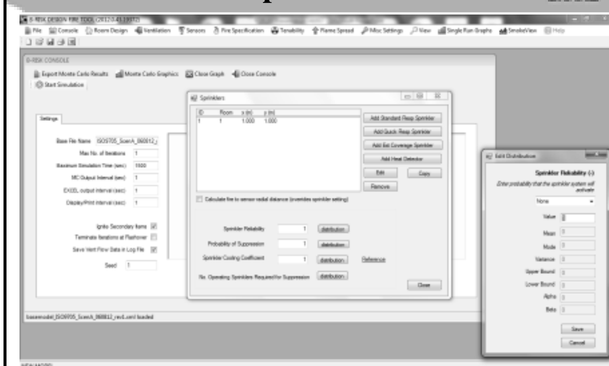
Design Fire Generator



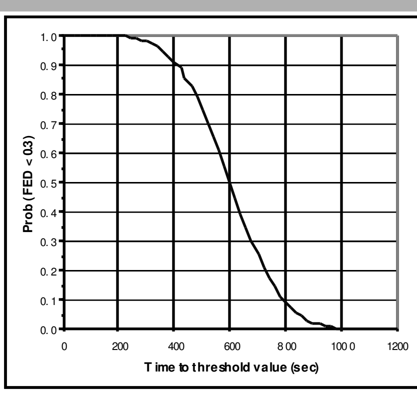
Design Fire Generator



Probabilistic Input & Monte-Carlo



Cumulative Distribution Functions



Cumulative Distribution Functions

- Comparison to risk-informed probabilistic statements of building performance (PSBP)
- PSBP contains a minimum of four elements; probability, performance criteria, threshold value and time (plus location)

RISK-INFORMED FIRE DESIGN

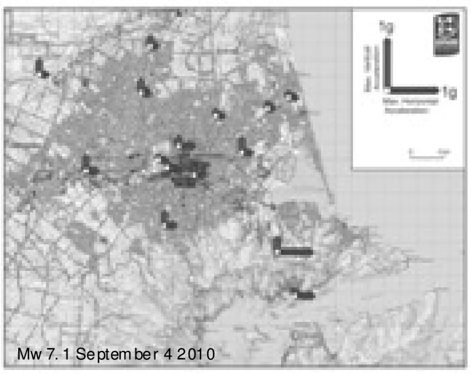
- **An example of a probabilistic statement of performance for life safety is:**

"The design must allow for a 90% probability of the CO FED not exceeding 0.3 for a period of 400 s"

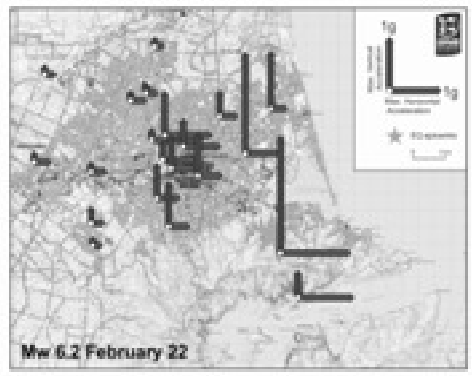
2. Post-EQ Fire Protection

- **Darfield earthquake – 4 Sep 2010** 4:35am
  - Magnitude 7.1
  - 40 km W of Christchurch
  - 10 km depth
- **Christchurch earthquake – 22 Feb 2011** 12:51pm
  - Magnitude 6.3
  - 10 km SE of Christchurch
  - 5 km depth

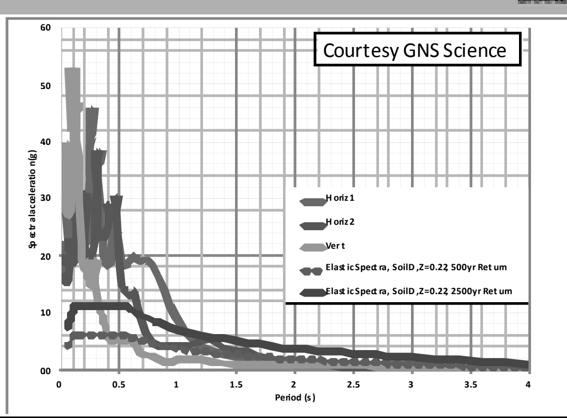
Post-EQ Fire Protection



Post-EQ Fire Protection



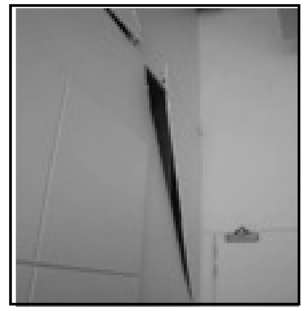
Post-EQ Fire Protection



Post-EQ Fire Protection

Post-EQ Fire Protection

Post-EQ Fire Protection

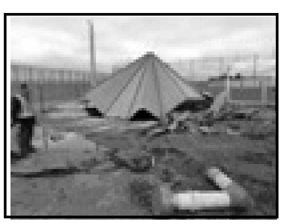
Post-EQ Fire Protection

- Used since the 1980s

Post-EQ Fire Protection

- Significant number of collapses or damage


Post-EQ Fire Protection

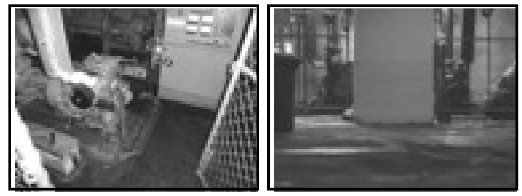



Post-EQ Fire Protection

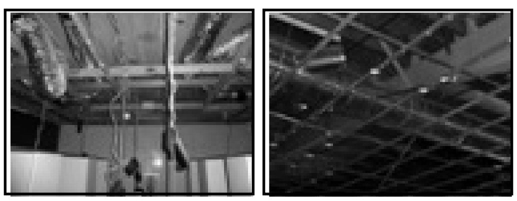
- Used since late 1990s

Post-EQ Fire Protection

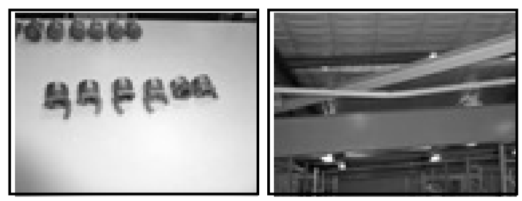
Post-EQ Fire Protection



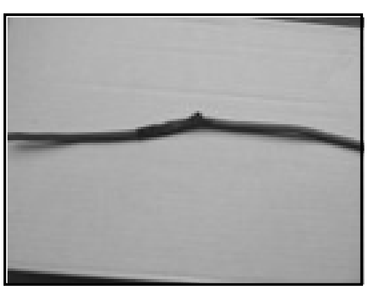
Post-EQ Fire Protection



Post-EQ Fire Protection



Post-EQ Fire Protection



National Research Institute of Fire and Disaster

Fire and Disaster Management Agency, Government of Japan

The NRIFD is the unique institute in Japan engaged in comprehensive research on firefighting and disaster prevention. It continues in the tradition of its predecessor, the Fire Research Institute (FRI) established in 1948, and builds upon results already achieved. Our basic mission is the same as that of the Fire Research Institute when it was established, i.e., to provide scientific and engineering support to assist firefighters in their work and respond to society's demand for safety and security.

Mission

1. Continuous implementation of research and development into fire and disaster prevention based on the long-term vision.
2. The implementation of and support for investigations into the causes of fires and accidents involving the leakage of hazardous materials.
3. Professional support for fire-fighting activities in the event of large-scale or extraordinary disasters.
4. Establishing and maintaining cooperation with people related to science and technology in the field of fire fighting.

Building Fire

Personal Protection

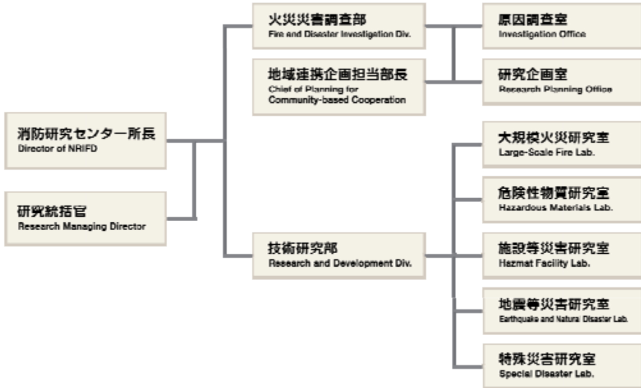
Rescue Robot

Oil Tank Protection

Firefighting Foam

Fire Investigation

Organization Chart



Staffs (excluding general affairs Sec.)

Permanent Staff : 26
Seconded Staff* : 13
Part-time : 18

experienced officers seconded from local fire departments

Budget

'10FY : TOTAL 5.2 M$ (418M¥)

'11FY : TOTAL 4.9 M$ (388M¥)

Research expenditure 2.6 M$ (207M¥)
Administrative cost* 2.0 M$ (158M¥)

This dose not include permanent staff costs.
** Currency Rate 80 (JPY/USD)*

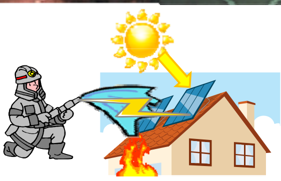
Research Theme (Current)

Fire Research (Building)

Investigation of Fire Smoke in a Building Fire and Fire Whirls cased by Urban Conflagration

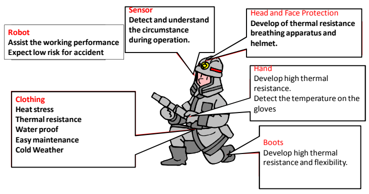
Fire Research (Renewable Energy)

Fire Suppression Technique and Safety Operation on Renewable Energy Facility and Electrical Vehicle



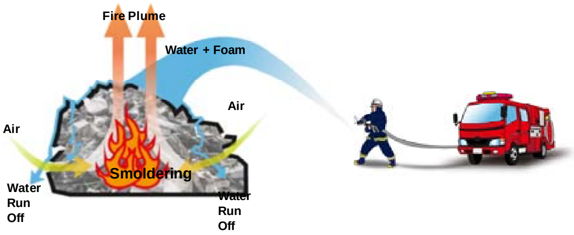
Fire Research (Personal Protection)

Development of Thermal Test and Evaluation Method on Compatibility as a Whole Body



Fire Research (Recyclable Resources)

Effective Fire Suppression Technique against Recyclable Resources



Hazmat Facility Research (Fire and Earthquake)

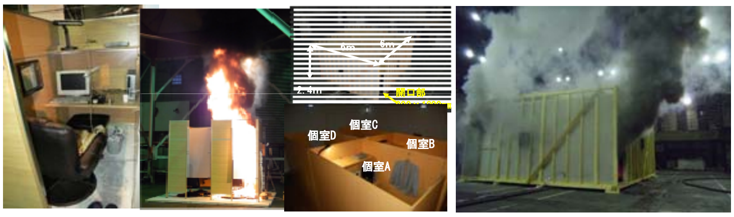
Reinforcement for Oil Tanks Protection against Huge Earthquake and Tsunami

Research Work (Previous)

Fire Research

Provisional housing Fire Test

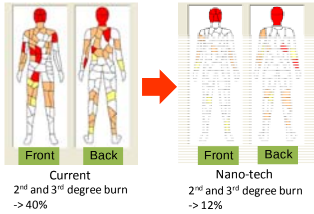
Internet Café Fire Test



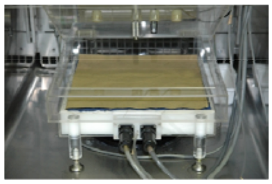
Personal Protective Equipment

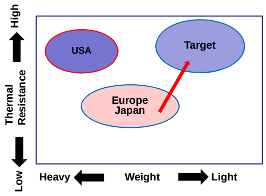
Development of Firefighter Clothing using Nano-Fiber

Manikin Test



Comfort Test





Hazardous Material Facility

"Floating Roof" Experiment in Liquid Sloshing

Actual Tank

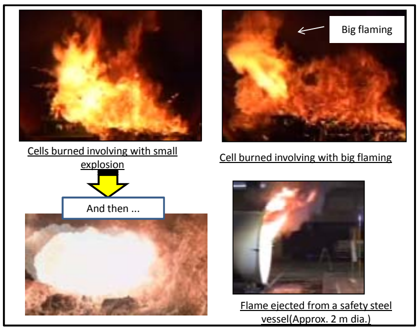
Scale Tank

Hazardous Material

Lithium-ion Batteries Fire Test

Lithium-ion batteries consist of transition metal oxide cathode and carbon material anode. The cylindrical-shaped lithium-ion battery shown below is filled with about 2 ml of flammable-liquid electrolyte. When fire was happened closed to bulk of Li-Ion 2nd batteries, the heat and flame ignited the batteries and started fire. Once the batteries got fire, fire propagated to other batteries with small explosion and made big flame.

Batteries used for Fire Experiment
480 cells of the 18350 type cell (= 95 battery packs of video and other DIY tool) in a plastic container



Research Facility in Mitaka Campus

Large Fire Experiment Building

- Experimental area 24 x 24 x 20 m (W x D x H)

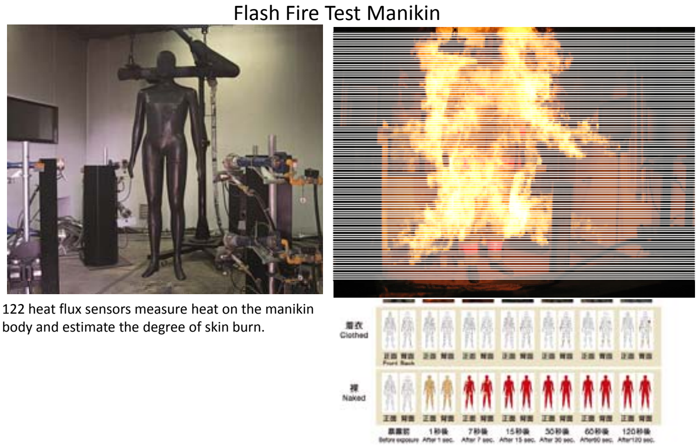
Fire Extinguishing Research Building

- Experimental area 1 25 × 25 × 22 m (W × D × H)
- Experimental area 2 14 × 14 × 12 m (W × D × H)

Exhaust smoke treatment equipment (Exhaust smoke treatment capacity)
Environmentally friendly equipment treats the exhaust smoke generated by fire tests, etc.

- Large fire experiment building : 45,000 m³/h x 4
- Fire extinguishing research building : 90,000 m³/h x 1, 30,000 m³/h x 1

Flash Fire Test Manikin



122 heat flux sensors measure heat on the manikin body and estimate the degree of skin burn.

Furniture Calorimeter

Oxygen Controlled Cone Calorimeter

Steel-made Explosion Proof Vessel

Fire Investigation Mobile

National Research Institute of Fire and Disaster
CONTACT: Kaoru Wakatsuki / NRIFD (kaoruw@fri.go.jp)

2nd US-Japan Fire Research Workshop

Recent Fire Research at ABRI

Dr. M.-Y. (Alec) LEI
Senior Research Officer, Fire Research Program
For
Dr. Ming-Chin HO
Director General, ABRI

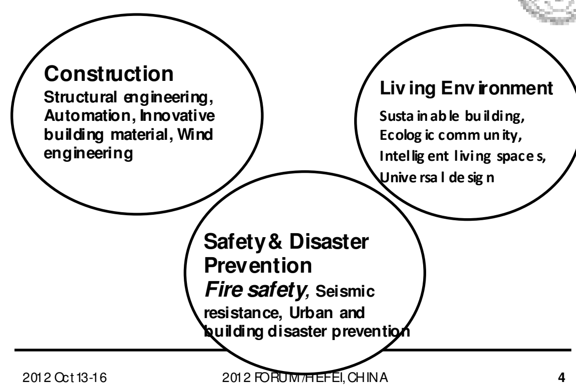
Who we are

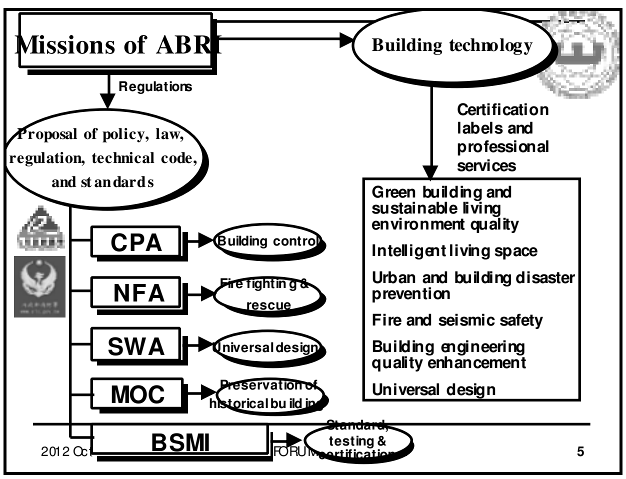
- ABRI established under MOI in 1996(Task Office since 1989)
- *Fire Labs* set up in 1992 and relocated at Tainan in 2002
- Head Office of ABRI relocated at Xindian in 2006
- Around 90 research staffs divided among divisions, such as Planning, *Safety & Disaster Prevention*, Engineering Technology, and Environment Control

Fire Research Team

- Research staff
  - Under the *Safety & Disaster Prevention Division*
  - 13 research staffs, including 10 in fire lab
  - 2 administrative staff
- Research partnership
  - University – Professors
  - Non-government organizations

What we do





Fire Research Program

- Phased research program plan
  - 1995-2000
  - 2001-2006
  - 2007-2010
- ***2011-2014 Plan on Upgrading Fire Safety Design and Engineering Technology***
- ***2011-2014 Plan on Fire Resistant Design of Steel Reinforced Concrete (SRC)***

Fire Research Scope

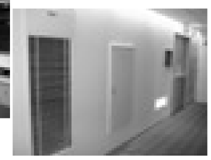
- Countermeasure and Scheme for Enhancing Fire Safety
- Performance Evaluation on Building Material and Equipment
- Compartment Assembly & Structural Fire Resistance
- Evacuation Safety and Smoke Management
- Performance Fire Design & Application of Fire Risk Assessment

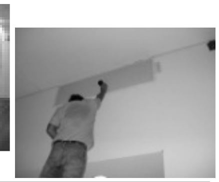
Promotion– Certification Labeling and Application

- Self-directed Fire Safety Certification Scheme for the general public places

Fire Safe Building Label


Taipei 101 Tower





Publications

- Technical guidance for verification of fire and evacuation safety
- Technical guidance for verification of fire resistance performance
- Technical guidance for design of smoke control of large space building

Research– Investigation and Recommendation

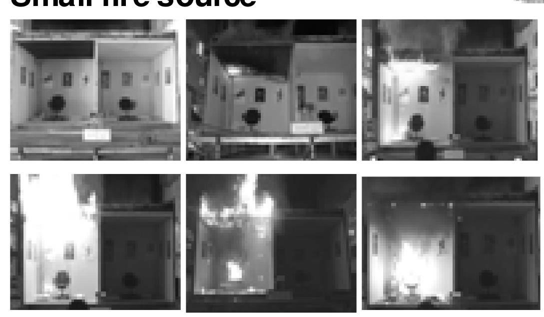
- Jack Daniel's Pub Fire, Taichung, 2011

Corner Tests on Foam Plastics

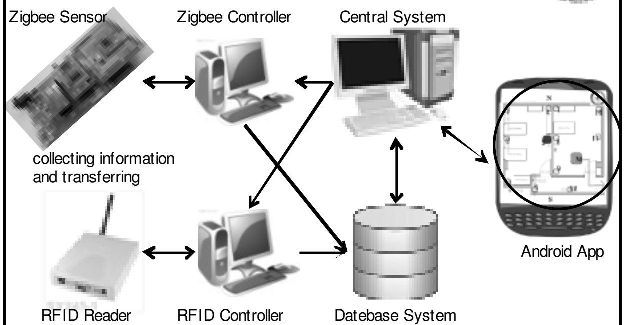
Normal

F.R.

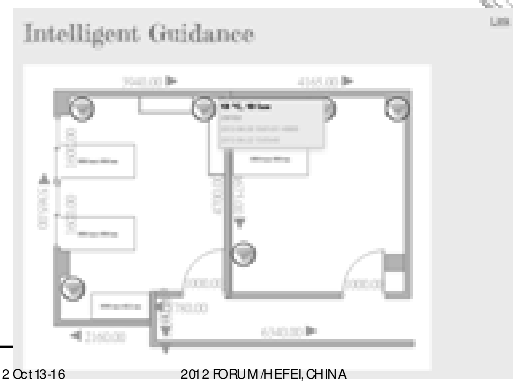
Room Tests for Comparison -Small fire source


16 sec

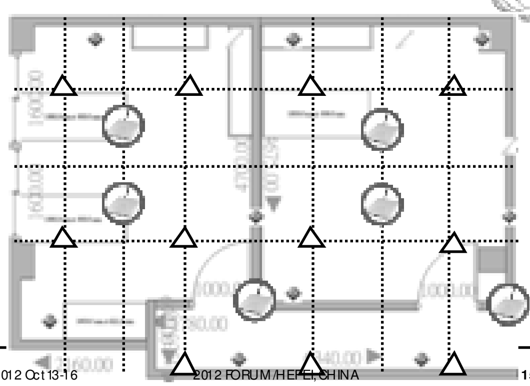
Research– Wireless Sensor Networks for Evacuation Guiding



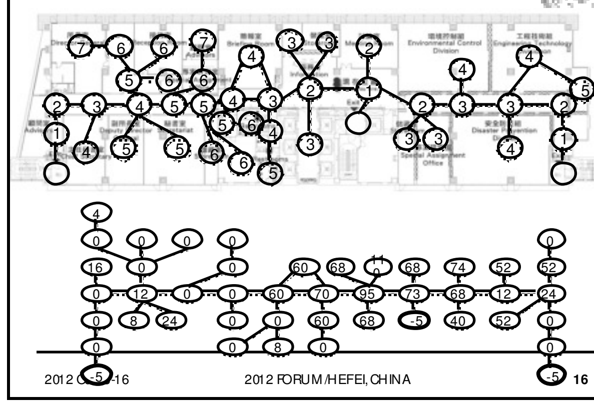
MP Display



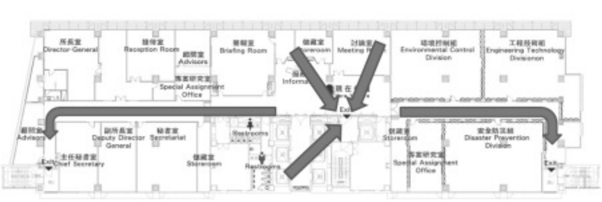
Person Localization



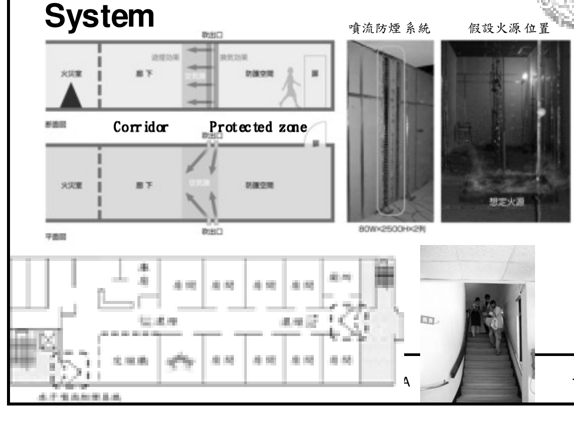
Fire Hazard Index

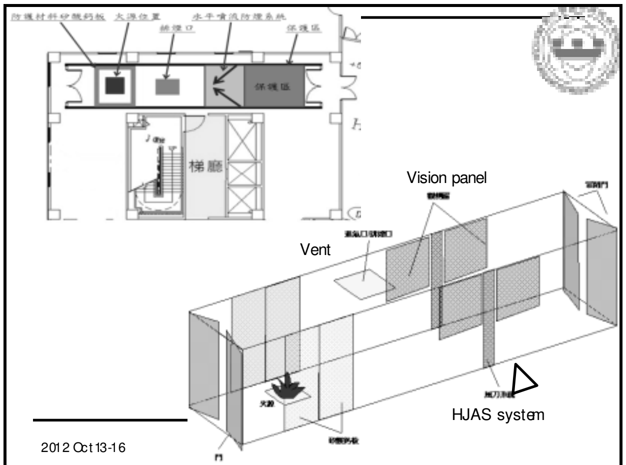


Planning of Route of Escape

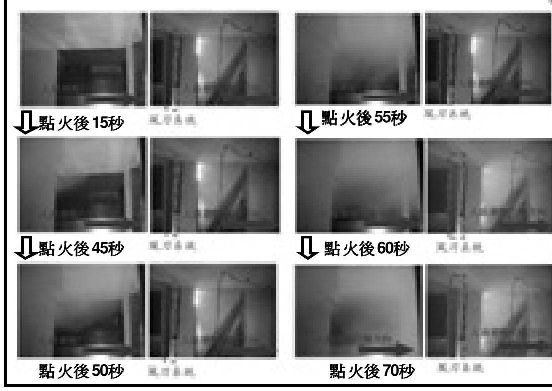


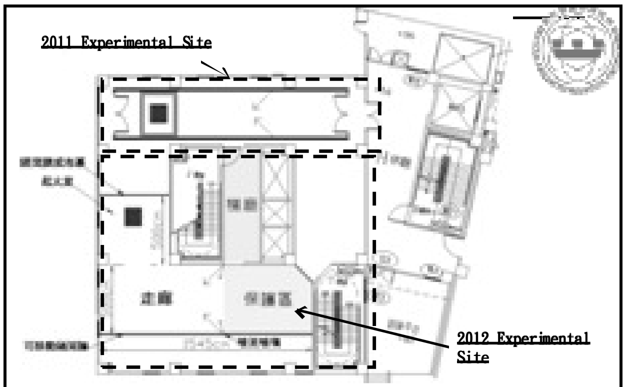
Research– Horizontal Jet Air Screen System



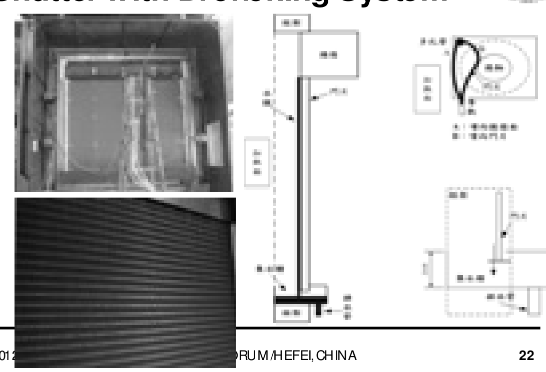


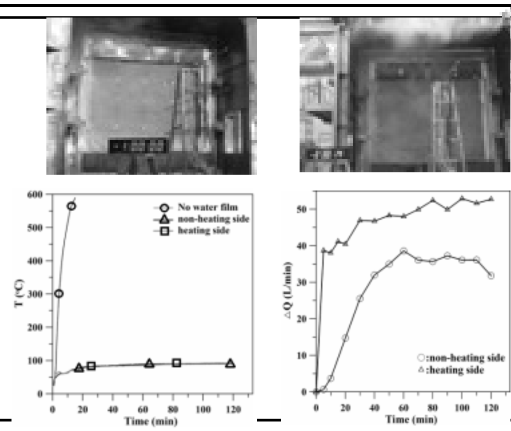
Horizontal Jet Air Screen System



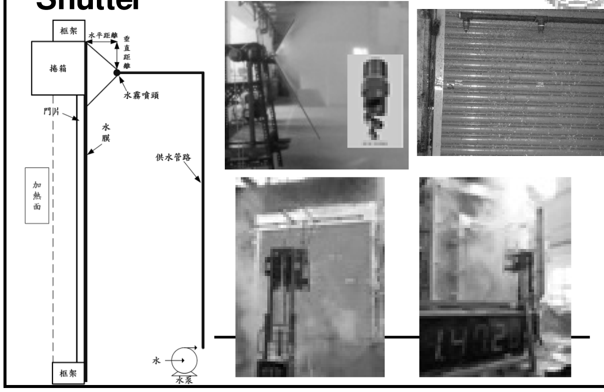


Research—Insulation of Steel Shutter with Drenching System





Application of Water Mist on Steel Shutter



Future Work

- Reliability of fire protection equipments and fire assemblies
- Evaluation of evacuation and development of codes for disabled people (people weak in evacuation ability)
- Integrated intelligent system for fire protection
- Development of code of practices for improvement on fire safety of existed building
- Review and revision of technical guidance used for performance-based design

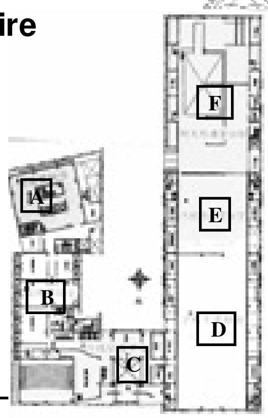
~THANKS FOR YOUR ATTENTION~

QESTIONS?

Website：www.abri.gov.tw
E-mail：alec@abri.gov.tw

Overall Layout of Fire Experiment Center

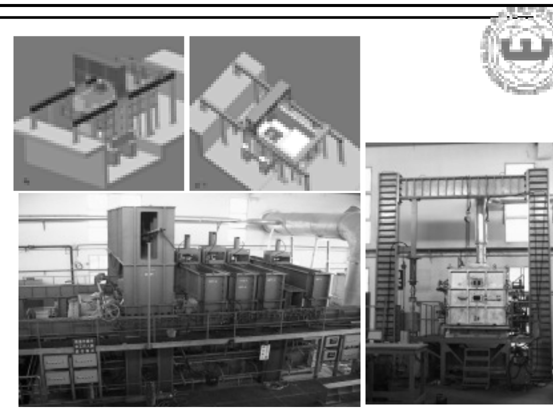
- A: Smoke Control Tower
- B: Fire Fighting Technology
- C: Administration
- D: Full Scale Experimental House
- E: Materials & Assembly Burning Hall
- F: Structure Fire Lab



Fire Laboratory Facilities

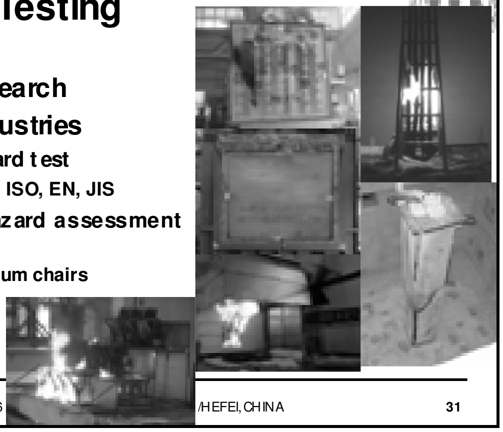
- Reaction to fire
- Fire resistance
  - Structural elements
  - Non-structural assemblies
- Large-scale calorimeter
  - SBI
  - Room/furniture calorimeter
  - 10MW calorimeter
- Facilities for water-based fire suppression system
- Burning hall & smoke tower

Fire Laboratory Facilities



Fire Testing

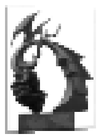
- For research
- For industries
  - Standard test
    - CNS, ISO, EN, JIS
  - Fire hazard assessment test
    - Stadium chairs



The International FORUM of Fire Research Directors
Annual Meeting 2012, Hefei, China

Introduction to State Key Laboratory of Fire Science (SKLFS)

Naian Liu (SKLFS)



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tory of SK

1987 Daxinganling Wildland Fire——
- Fire Area: 13700km^2
- Deaths: 197

Xi Lin Ji

Mo He

---

tory of SK

- 1987 [illegible]
- 1990 [illegible] (SKLFS)
- 1995 [illegible]
- 2003 [illegible]
- 2004 [illegible]
- 2005 [illegible]
- 2007 [illegible]
- 2009 [illegible]
- 2012 [illegible]

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sion and nizatio FS

Aiming at world fire science frontiers, to study fire dynamics & key technologies of fire safety, train qualified personnel and endeavor to cater for the growing national demand in fire science research and make fundamental, strategic and forward-looking contributions to the national fire safety.

Science	• State Key Laboratory of Fire Science
Engineering	• Engineering & Technology Research Center for Thermal Safety, CAS
Education	• Department of Safety Science and Engineering • Bachelor, Master, PhD., Training and Consultation • National Science Education Base

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ector of SK S

Fan Weicheng, Professor, Academician of CAE
- Director of SKLFS
- Director of Research Center for Thermal Safety Engineering of CAS
- Vice-Chairman of the International Forum of Fire Research Director
- Executive Member of International Association for Fire Safety Science (IAFSS)
- Formal and Honorary Chairman of Asia-Oceania Association for Fire Science and Technology (AOAFST)

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searc Te

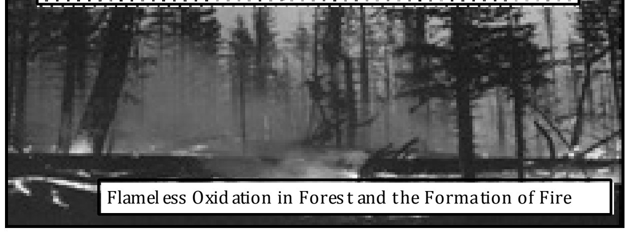
- Faculty members: 56
  - Professor 19
  - Associate Professor 17
  - Ph.D 31
  - Technician 8
- Master students 200
- Ph.D students 60
- Postdoctoral 11
- Visiting professors 4 (from USA, Russia, Japan and UK)
- Research funding: USD $1-4M/year
  - Competitive, 80% from MOST, NSFC, and other government departments
  - 20% from Industry

Research Area of SKLFS

Research Area
- Fire Dynamics
  - Formation and Spread of Fire
  - Fire Smoke and its Toxicity
- Key Technology of Fire Protection
  - Performance-optimized Fire Retardant Materials
  - Multi-signal Sensing and Intelligent Recognition of Early-stage Fires
  - Technology of Clean and High Efficient Fire Suppression
- Theory and Methodology of Fire Safety Engineering
  - Fire Risk Assessment based on Fire Dynamics and Statistics
  - Performance-based Fire Safety Design

①Fire Formation and Its Propagation (a)

Fire Formation Mechanism——
- ■ Pyrolysis Model of Combustibles Under Different Conditions
- ■ Ignition Models of Combustibles
- ■ Mechanism of Smoldering and its Transition to Flame


Flameless Oxidation in Forest and the Formation of Fire

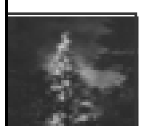
①Fire Formation and Its Propagation (b)

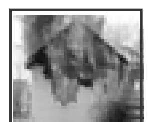
Recognition and Forecasting of Forest Fire——
- ■Satellite Remote-sensing Recognition of Forest Fire
- ■Self-organization Behavior of Forest Fire
- ■Forecasting of Large Forest Fires

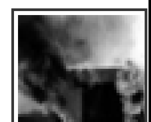
1987 Daxing Anling Fire Satellite Image

①Fire Formation and Its Propagation (c)

Fire Propagation and Its Nonlinear Dynamics——
- ▪Interaction of Pyrolysis, Phase Change, Fluid Flow, Heat Transfer and Chemical Reactions
- ▪Nonlinear Dynamical Models of Fire and Relevant Nonlinear Numerical Methods


Fire whirl


Flashover


Backdraft

②Fire Smoke and Its Toxicity

- ■ Movement of Fire Smoke in Different Kinds of Spaces
- ■ Interaction of Smoke and Fire
- ■ Formation of Toxicity in Smoke
- ■ Effect of Smoke Toxicity to Human Body


Fire Smoke

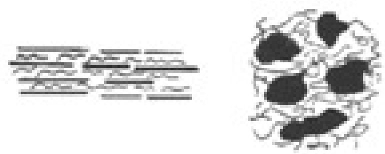
③ Risk Assessment and Performance-based Design

- ■ Method of Evacuation in Fire
- ■ Statistical Theory of Fires
- ■ Method of Risk Assessment and Performance-based Design

Residential Houses Damaged by Fire

④ High Quality Fire Retardant Materials

- Nanometre Fire Retardant Materials
- Fire Retardancy Mechanism of Halogen Free Materials



(a)Nanometer Materials (b) Ordinary Material

⑤ Intelligent Recognition of Fire Signals

- Characteristics of Light, Smoke (heat, gas and solid particles) and Sound in Fire
- Multi-parametric and Multi-criteria Fire Signal Recognition Models

Features in the Early Period of Fire

⑥ Method of Fire Suppression with High Efficiency

- Method to Generate Water Mist and its Characterization
- Effect of Water Mist to Fire and Smoke
- Mechanism of Gaseous Fire Suppression

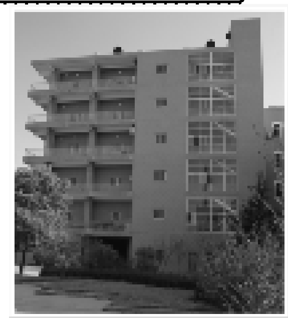
Fire Suppression by Water Mist

13500m², to be in use in end of 2012.

Fire Safety in Plateau

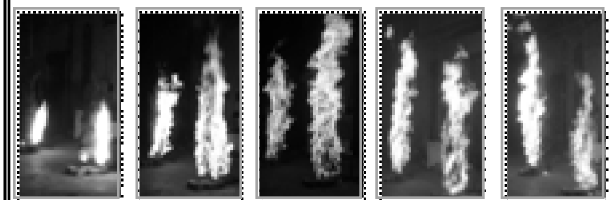
Experimental facilities

USTC/PolyU Fire Test Atrium (22.4mx11.9mx27m)



Experimental facilities

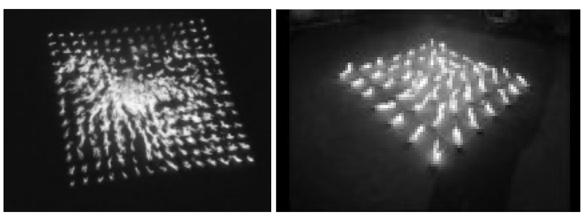
USTC/PolyU Fire Test Atrium (22.4mx11.9mx27m)



Experiments of ignition by radiation in multiple trees

Experimental facilities

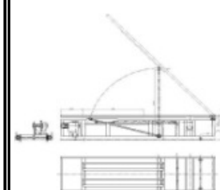
USTC/PolyU Fire Test Atrium (22.4mx11.9mx27m)



Large fire array experiments (Left: 15X15; Right: 7X7)

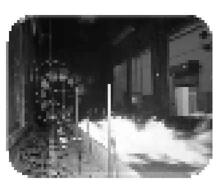
Experimental facilities

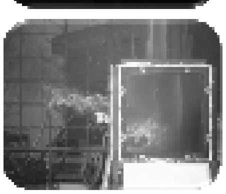
Combustion wind tunnel



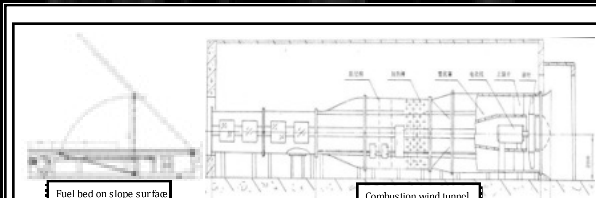
Experimental system of fire spread on slope surface

Experimental facilities





Experimental facilities



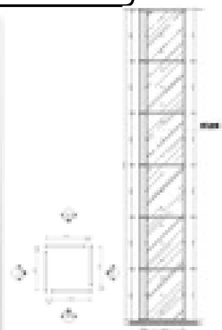
Experimental system for fire spread under wind-slope coupled conditions

- Surface fire propagation experiments
- Transition of surface fire to crown fire
- Wind and slope coupled effect on fire spread
- Fire whirl in fire spread
- Wind effect on enclosure fire dynamics

Experimental facilities

Experimental System of fire whirl

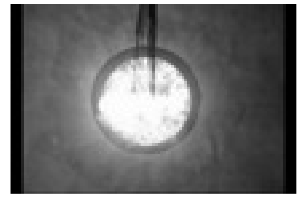
■2m×2m×15m



Top view Side view

Experimental facilities

Side view



Top view

Experiments of fire whirl using the fire whirl modeling facility

Experimental facilities

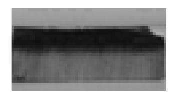
Remote Sensing Platform for Wildland Fire Monitoring

Receiving antenna

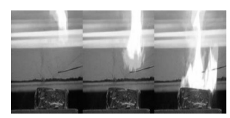
Processing and storage terminal

Experimental facilities

Experimental system for fire characteristics at early stage



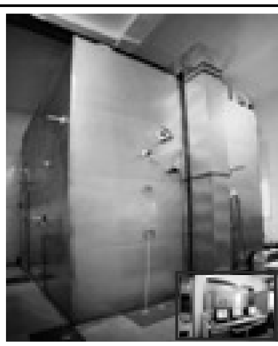
Wood Charring

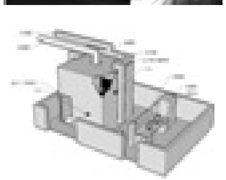


Wood Ignition

Experimental facilities

Experimental system of ship cabin fire





Experimental facilities

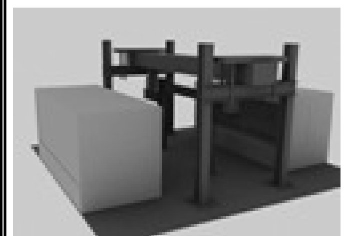
ISO 9705 Calorimeter (2MW)

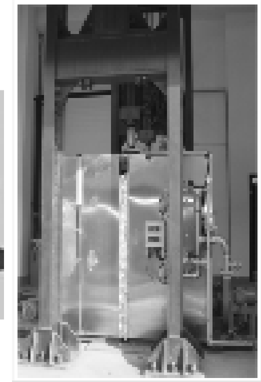
Experimental system of cable fire

Five-floor model building

Backdraft apparatus

Experimental Facility for Coupling Thermal and Mechanical Effect





■ Fire safety in Wildland-Urban Interface (WUI) Regions

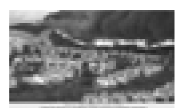
Major International Joint Research Project of NSFC

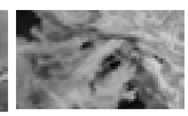
Research on Key Scientific Issues Concerning Wildland-Urban Interface Fire Safety

SKLFS, China

Major partners：*NIST-EL, USA*

Other partners: *ICKC; Russia, BMEL, Japan; RIFEEP, China*





WUI Fires in China

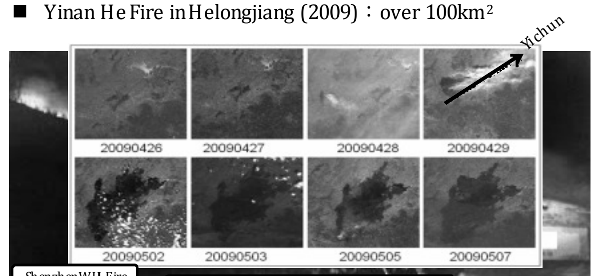
- 1987 DaxingAnling Fire
  - Fire Coverage Area: 13700km²
  - Deaths: 193 persons
  - Tuqiang, Amuer, Xilinji and Mohe, were nearly completed destroyed.

Xilinji

Mohe

WUI Fires in China

- Shenzhen WUI Fire (2005)
- Yunnan Anning Fire (2006)：Spread to Kunming City
- Yinan He Fire in Helongjiang (2009)：over 100km²



Shenzhen WUI Fire

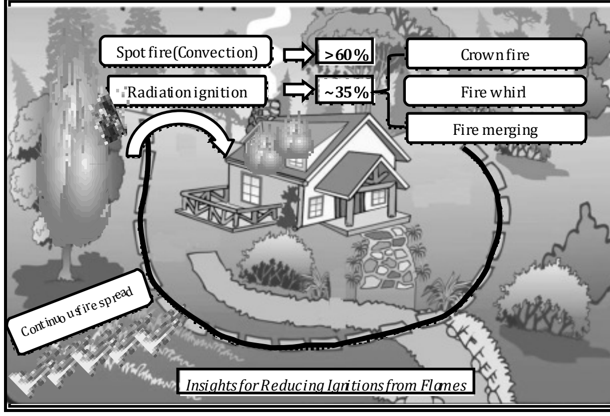
Yinan He Fire in Helongjiang

Project background

- Title: Research on Key Scientific Issues Concerning Wildland-Urban Interface Fire Safety

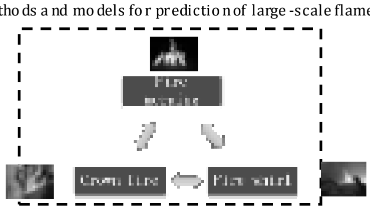
- WUI fire safety in China: currently not so serious as America, Australia and Europe; new and increasing
- Forestry City: one of the major development policy for China urbanization — proposed by Chinese government in 2001
- Recent years:
  —— city and forest have began to become more and more mingled with each other;
  —— more and more WUI fires reported in China
- We judge: WUI fire safety problem is naturally expected to become important with the rapid development of the "Forestry City", due to large number of populations and lack of fire safety instructions in WUI areas.

Special propagation modes of WUI fire



Research contents

1. Heat transportation in large-scale flames of WUI fires
   - Flame radiation spatial distribution of crown fires;
   - Flame height, burning rate, temperature field and heat transportation (especially the flame radiation) of fire whirl under different fuel and ambient circulation conditions;
   - Interactions among multiple fires and flame radiation of fire merging;
   - Methods and models for prediction of large-scale flame radiations.

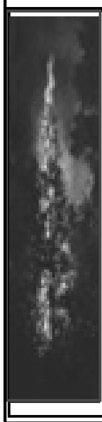


Fire Whirl

Size classification of fire whirl
- Small scale: 0.1-1m
- Medium scale: 1-10m
- Large scale: 10-10^2m

- Snegirev, A. Y.; Marsden, J. A.; Francis, J.; Makhviladze, G. M., Int J Heat Mass Tran 2004, 47, (12-13), 2523-2539.

Fire Whirl



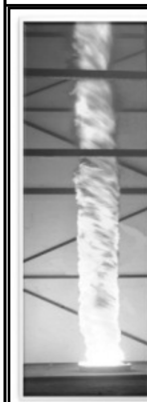
- **Fire whirl: among the most troublesome and erratic phenomena of urban and wildland fire behavior**
  - induced in a violent type of convection which could occur in large WUI fires
  - highly organized flow, most turbulent features of the ordinary convection column are either absent or greatly suppressed.
  - heat transferred upward in a slender vortex, with a much smaller cross section than convection column.

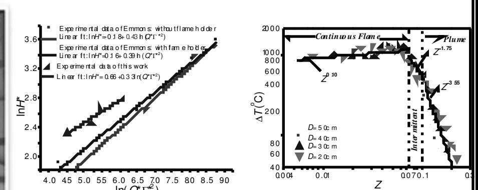
	Pool fire	Fire whirl
Flame height	1-100m	～400m
Flame temperature	～800℃	～1300℃
Vertical velocity	～4m/s	～10m/s
Burning rate	—	3 folds

Data source：Fire whirl experiments by SKLFS

http://www.livescience.com/environment/top10_weird_weather-1.html

Fire Whirl

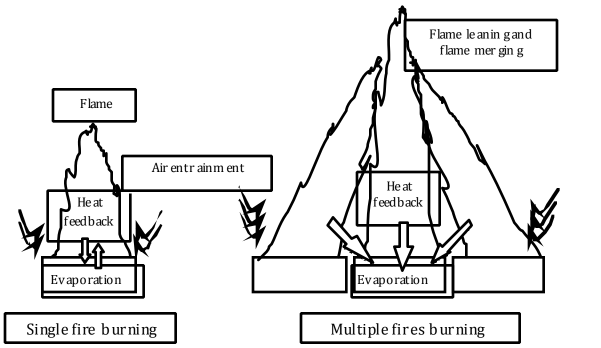




- Effect of flow circulation on combustion dynamics of fire whirl. ***Proceedings of the Combustion Institute***, 2012, 34: in press..
- Experimental research on combustion dynamics of medium-scale fire whirl. ***Proceedings of the Combustion Institute***, 2012, 34: in press..
- Burning rates of liquid fuels in fire whirls. ***Combustion and Flame***, 2012, 159(6):2104-2114.
- Experimental Research on Combustion Dynamics of Medium-scale Fire Whirl. ***Proceedings of the Combustion Institute***, 2011, 33:2407-2415.

Dynamics of multiple fires burning

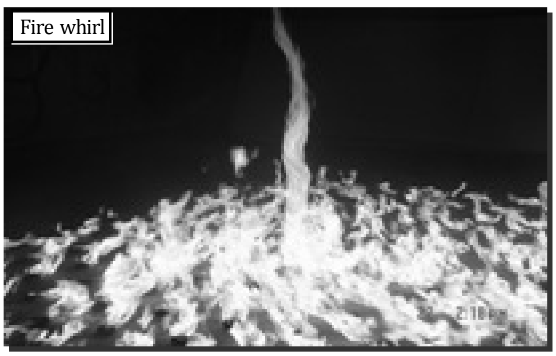
Multifire problem: Complexity of multiple fires burning



Experimental phenomena: Fire merging

Experimental phenomena

Fire whirl: by multiple free burning fires from separate fuel beds



Basic quantity for analysis

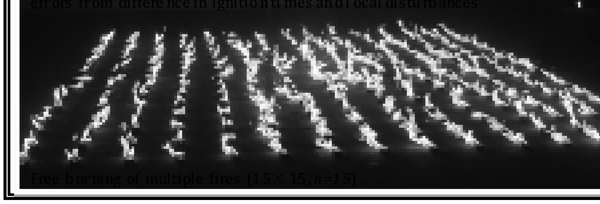
Global average burning rate BR^*

$$BR^* \equiv \frac{BR}{BR_r} = \frac{N \Big/ \sum_{i=1}^{N} BOT(i)}{1 \big/ BOT_r}$$

vs. fire spacing D
vs. fire array size n

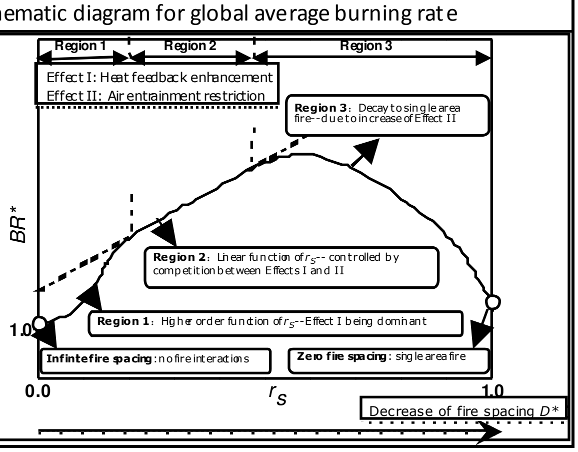
Physical meaning: burning rate enhancement relative to single fire, due to fire interaction effects

Traditional analysis method: puzzled by the limited data available and the errors from difference in ignition times and local disturbances



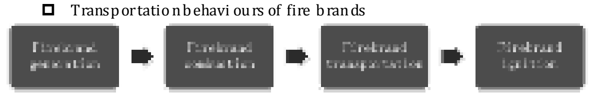
Free burning of multiple fires (15×15, n=15)

Schematic diagram for global average burning rate



Research contents

2. Combustion and transportation behaviours of spot fires in WUI
   - Velocity distribution of fire whirl under different ambient circulation and fuel conditions;
   - Conditions to induce spot fires in crown fires;
   - Combustion kinetics and size variation of fire brands under wind;
   - Transportation behaviours of fire brands



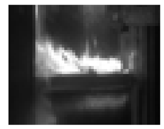
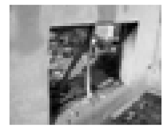
Key problems for spot fire

- Firebra nd ge nera tion: I nitiate d by fire whi rl o r c row n fire-Flow and fuel conditio ns
- Firebra nd t ransp o rtatio n: Physical and c hemical m odels fo r b urning of solid fire b ra nds unde r effect of wi nd
- Ignition of str uctu re mate rials by fi reb ra nds: Effect of mate rial ty pes, moistu re, wi nd spee d a nd b urning be havio rs

Fire location and year	Distance(m)	Reference
Wandilo, SA, 1958	2000	Luke and McArthur
Los Angeles, USA, 1961	2000	NBTC
Hobart, Tasmania, 1967	8000	Wettenhall
Sakata City, Japan, 1976	1800	Babrauskas, p501
Glengower-Creswick, Victoria, 1977	4000-8000	McArthur et al
Melton, Victoria, 1985	250-300	Maynes and Garvey
Avoca/Maryborough, Victoria, 1985	2000-3000	Maynes and Garvey
Oakland Hills, Cal., USA, 1991	1800	Pagni
Cedar, Cal., USA, 2003	1000	Mitchell

Research contents

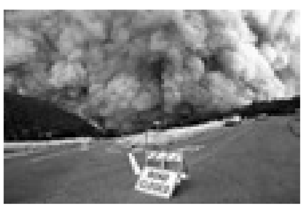
3. Fundamental research on building safety in WUI fires
   - Ignitability of wo ody b uilding mat erials a nd ot her com busti bles in WUI un der th e effect of la rge-scale flame ra diatio n;
   - Proba bility of ignitio n of b uilding mate rials by fire b ran ds;
   - Mechanisms a n d b ehavi ou rs of glass b reakag e u n der th e exte rio r heat sources i n WUI fires;
   - Effect of exte rio r wind on the enclos ure fire dy namics a nd flashove r.


Ignition ⇨ Glass brea kage ⇨ Wind effect on fi re

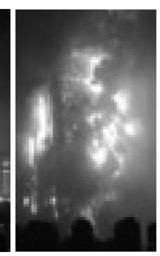
Research contents

4. Fundamental research on human evacu ation safety in WUI fires
   - Cellular aut omat on evol ution met ho ds of WUI fi re sp rea d by combina tion of be haviou rs of fire whi rl a nd spot fires
   - Individu al a nd crowd evacu ation be havio urs in WU I fire
   - Evacua tion mo del by c ombi natio n of WUI fi re dyn amics

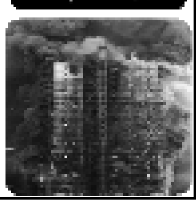



- Fire safety in high-rise buildings





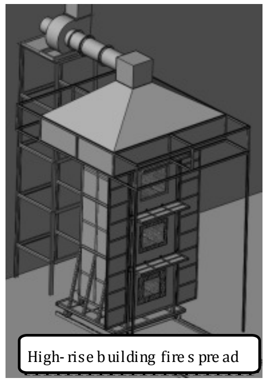
- High-rise building fire safety
  - **2009** CCTV B uilding Fire: 1 d eath, 7 inj ure d, h uge econo mic loss
  - **2010** Shang hai Teac her Apa rt ment Fi re: 58 death， 71 i nju red, h uge econ omic loss
  - **2011** Sheng yang Wan gXi n H otel Fire: huge econo mic loss

- Facade thermal insulation material fire safety
- Building facade fire spread
- Smoke control
- Structure safety in fire
- Human evacuation

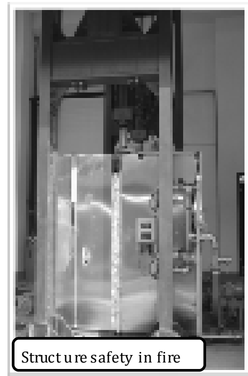
cility

Enclosure façade flame behavior



High-rise building fire spread

cility



Structure safety in fire

Smoke spread and control in staircase

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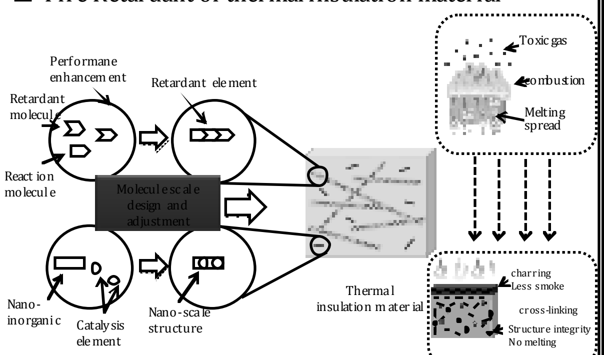
- Fire Retardant of thermal insulation material



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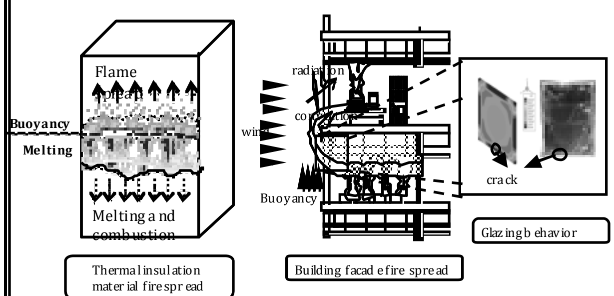
- Facade fire spread behavior



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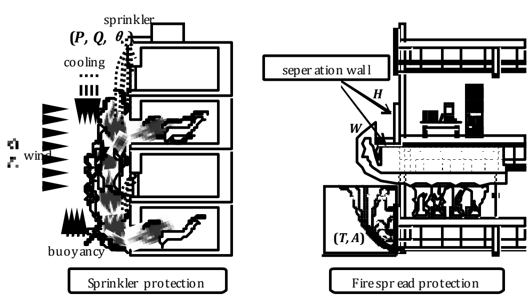
- Facade fire spread behavior



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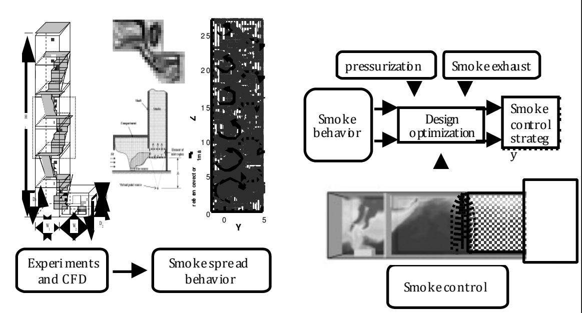
- Smoke spread and control in staircase



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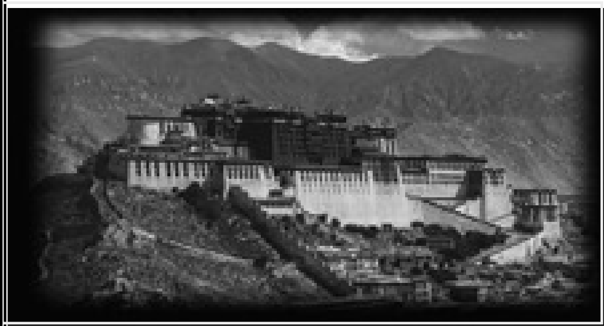
■ Fire safety in plateau and historic buildings



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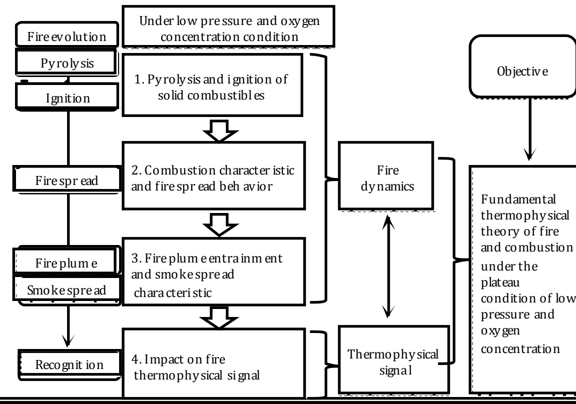

…ernationa… RUM… Research Dir…
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FORUM

Thank you!

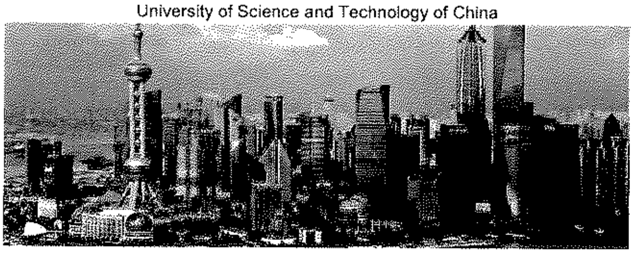
附錄 3. 201 FORUM 會議高層建築物防火安全討論會（Workshop on fire safety of high rise building）簡報資料(英文)

- SKLFS / Jinhua Sun (孫金華)
- SKLFS / Yuan Hu (胡源)
- SKLFS / Weiguo Song (宋衛國)
- TFRI / Peifang Qiu (邱培芳)
- ABRI / Alec M.Y. Lei(雷明遠) & Chi-chung Lee(李其忠)
- TBTL / Tensei Mizukami
- CSTB / Pierre Carlotti
- KICT / Seung-Un Chae

Key fundamental problems in the prevention and control of major fire disaster of high-rise buildings(HRB)

Jinhua Sun

University of Science and Technology of China

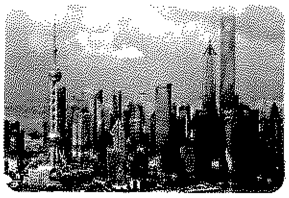


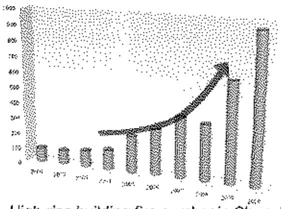
Contents

1. HRB & its fire situation in China

❖More high-rise buildings, more fire hazard

- More than 0.2 Million high-rise buildings and 3,700 super high-rise buildings
- High-rise building fire number grows fast, and many major fire accident occured.





High-rise building fire number in Shanghai

1. HRB & its fire situation in China

❖Serious situation of high-rise building fire in China

- Beijing Jingming building fire, 12 dead, 35 injured, 2004
- Zhejiang Wenfu building fire, 21 dead, 2007
- Urumchi Dehui international plaza fire, 5 dead, more than ¥500 million loss, 2008

Devastating fire in Zhejiang Wenfu building, 2007

High-rise building fire in Urumchi, 2008

1. HRB & its fire situation in China

❖New type high-rise building fire

CCTV building fire, Beijing, in **2009**
1 dead, 7 injured, ¥160 million loss

1. HRB & its fire situation in China

❖New type high-rise building fire

Apartment building fire, in Shanghai, **2010**,
58 dead, 71 injured

1. HRB & its fire situation in China

❖New type high-rise building fire

What new?
Ignition: outside wall
Spread: outside to inside
to both upward
and downward

2011 Wanxin five-star hotel fire, Shenyang, more than ¥100 million loss

2. What are the difficulties in fire prevention and control of HRB?

❖Heat insulation material fire

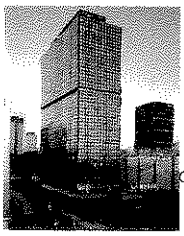
- Fire spread: very fast, highly toxic smoke, downward spreading
- Outside walls：Without any preventive measures

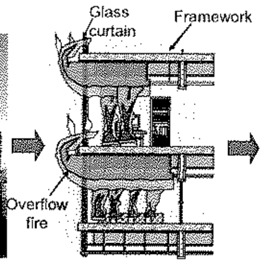
性能和种类	模塑聚苯乙烯	挤塑聚苯乙烯	硬质聚氨酯泡沫	酚醛泡沫
密度（kg/m³）	≤30	≤40	≤50	≤50
导热系数（W/mK）	≤0.04	≤0.03	≤0.02	≤0.03
吸水率（%）	≤4	≤1	≤1	≤1
燃烧等级	B2	B1.B2	B1.B2	A、B1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

2. What are the difficulties in fire prevention and control of HRB?

❖Large-scale three-dimensional fire

- Heat release is much more than the normal building fire
- Outside rescue is usually ineffective

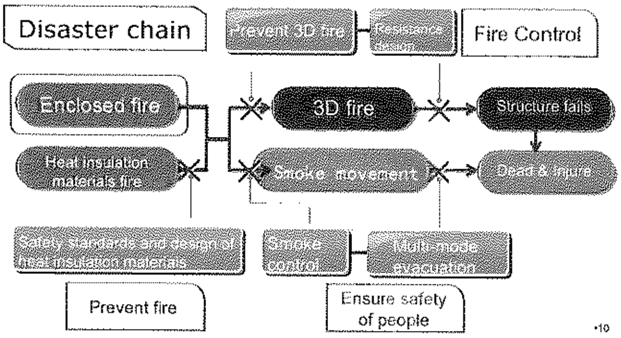




3D large-scale fires

3. Key fundamental problems in prevention and control of HRB fire

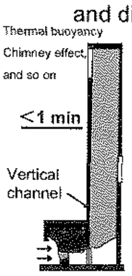
Core problem: promote the self-ability of high-rise buildings to prevent and control fire disaster

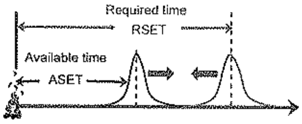


2. What are the difficulties in fire prevention and control of HRB?

❖Smoke moves quickly, evacuation difficulty

- Smoke move: Effected by multi-forces, very fast
- Evacuation: Stairway blocked by smoke? The aged and disabled?



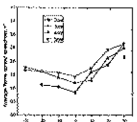


ASET＜RSET
Dangerous !

3. Key fundamental problems in prevention and control of HRB fire

Fire prevention

PS flowing fire formation
JHM, 2009



PS Relationship between flame spread and angle
JHM, 2011

Requirements

- ❑ Fire behavior and hazard ?
- ❑ Safety disign?

PU combustion products HCN et al.

synchrotron radiation diagnostic in combustion
Angew. Chem. Int. Ed, 2010

Requirements

- ❑ HCN et al. formation mechanism?
- ❑ Toxicity control?

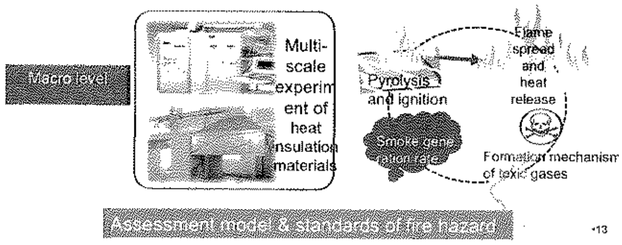
Key fundamental problem 1

Fire behaviors and safety design of heat insulation materials

3. Key fundamental problems in prevention and control of HRB fire

① Fire behavior & safety design of heat insulation materials

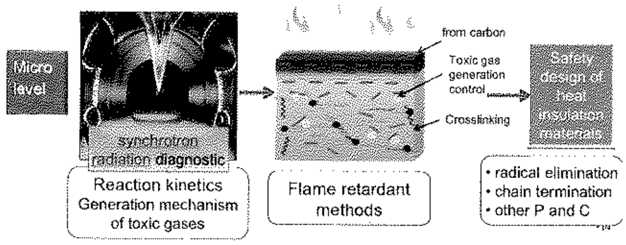
- ❖ Fire behaviors & hazard: assessment methods and standards
- ❖ Safety design：principles and methods



3. Key fundamental problems in prevention and control of HRB fire

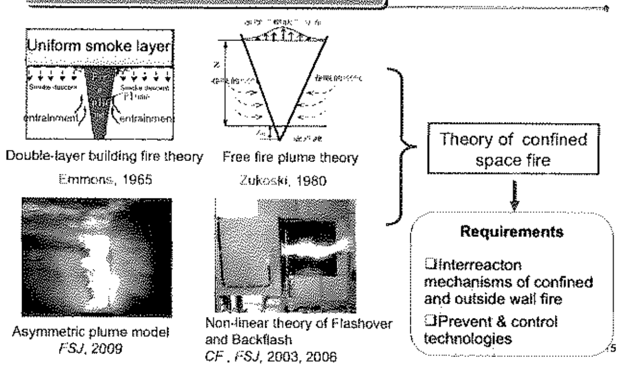
① Fire properties & safety standards of heat insulation materials

- ❖ Fire behaviors & hazard: assessment methods and standards
- ❖ Safety design：principles and methods



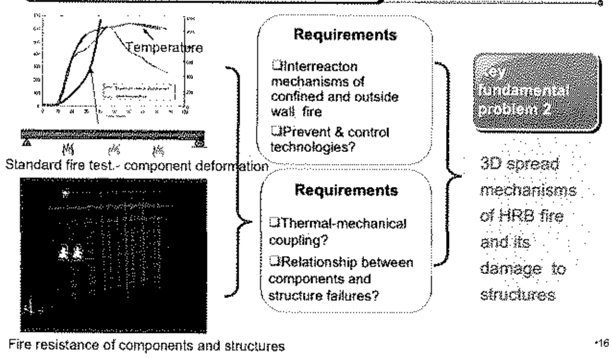
3. Key fundamental problems in prevention and control of HRB fire

Control of fire development



3. Key fundamental problems in prevention and control of HRB fire

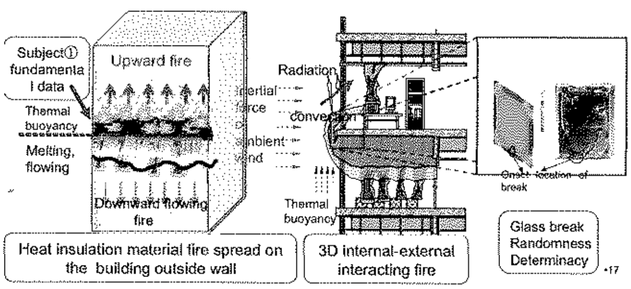
Control of fire development



3. Key fundamental problems in prevention and control of HRB fire

② 3D spread mechanisms and its blocking of HRB fire

- ❖ 3D fire spread behaviors: law and model
- ❖ 3D fire prevention &blocking: mechanism & critical parameters



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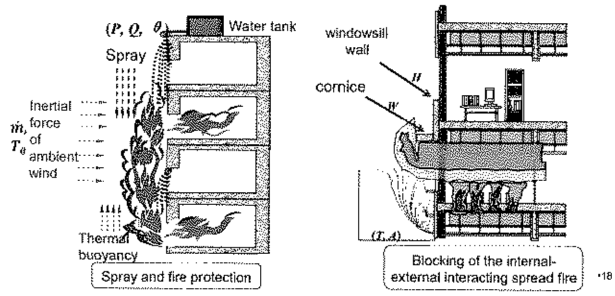
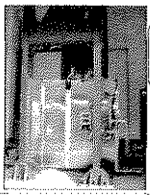


3. Key fundamental problems in prevention and control of HRB fire

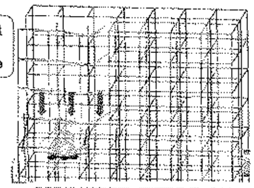
③The damage mechanism and protection of building structural

- Damage mechanism: **key components & joints**
- Components fail to structure fail: **Prediction methods**



Robustness of structure

Heat and force



Experiment of failure mechanism of key components & joints

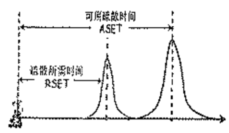
Prediction model of structure fail induced by component fail

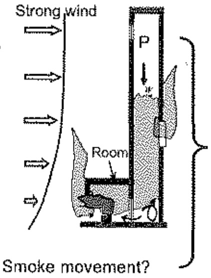
3. Key fundamental problems in prevention and control of HRB fire

Ensure occupant safety

How to ensure people safety?

ASET > RSET





Smoke movement?

Buoyancy, inertial force, chimney effect, ambient wind

Requirements

ASET ↑

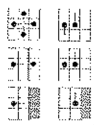
- ❑ Movement behavior of smoke?
- ❑ The best method of smoke control?

3. Key fundamental problems in prevention and control of HRB fire

Ensure occupant safety

How to shorten the required evacuation time?

Social force model *Nature*, 2000



Multi-force CAFÉ model *Build Environ*, 2010

Requirements

ASET ↑

- ❑ Movement behavior of smoke?
- ❑ The best method of smoke control?

Requirements

RSET ↓

- ❑ Influence of smoke?
- ❑ Occupant behavior and dynamic model?
- ❑ multi-mode cooperative evacuation?

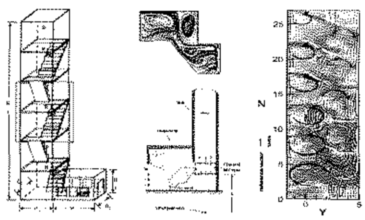
Key fundamental problem 3

Movement behavior of smoke under complex conditions and multi-mode cooperative evacuation

3. Key fundamental problems in prevention and control of HRB fire

④ Smoke movement mechanism and control

- Smoke movement: driven by multi-force
- Smoke control: multi-technique smoke control



Multi-scale experiment and simulation under complex conditions → Smoke movement mechanism and model

3. Key fundamental problems in prevention and control of HRB fire

④ Smoke movement mechanism and control

- Smoke movement: driven by multi-force
- Smoke control: **multi-technique smoke control**

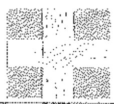
Pressurization air supply | Mechanical exhaust | Natural exhaust

Smoke movement mechanism → Design optimization / decontamination → Integrated control

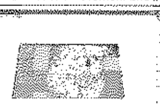
3. Key fundamental problems in prevention and control of HRB fire

⑤ Multi-mode cooperative optimized evacuation

- Crowd behavior: **multi-direction, fire influence**
- Occupant evacuation: **multi-mode evacuation**



Multi-direction movement and interaction



Fire and evavuation

Multi-mode evacuation model

Route capacity model

Game of route choice

Evacuation via of stair & lift

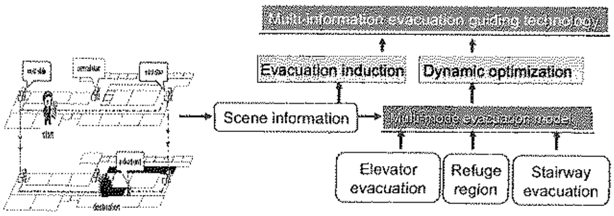
Movement behavior

Fire influence

3. Key fundamental problems in prevention and control of HRB fire

⑤ Multi-mode cooperative optimized evacuation

- ❖ Fire information: place, fire growth, smoke behavior, Evacuation route , ...
- ❖ Evacuation guiding: multi-information, dynamic optimization



4, National research project on HRB fire

Major fundamental research-973 project is established:

- ❖ Key fundamental problems in the prevention and control of major fire disaster of high-rise buildings (¥36 million)

Host institute:

- ❖ University of Science and Technology of China

Partake institutes:

- ❖ Tsinghua university, Tongji university, University of architecture of Anhui
- ❖ Four fire research institutes of Ministry of Public Security
- ❖ China Academy of Building Research

4, National research project on HRB fire

Primary aim: Promote the self-ability of high-rise buildings to prevent and control fire disaster

Theory objectives

- Combust behaviors of heat insulation materials
- 3D fire spread behaviors and structure damage mechanism
- Multi-mode cooperative evacuation model

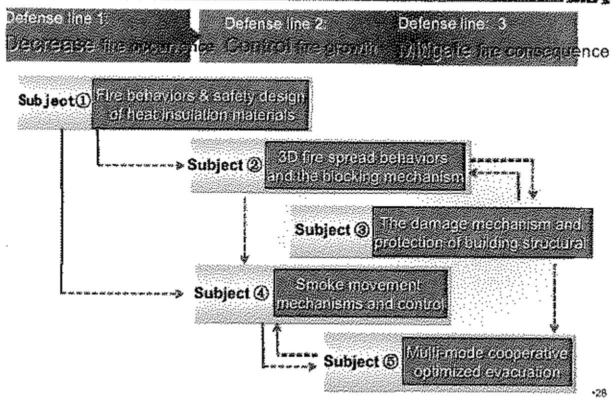
Technique objectives

- Safety standards and design of heat insulation materials
- Standards of 3D fire blocking and structure fire resistance
- Design of crowd evacuation and optimized evacuation technique

- ❑ SCI papers, > 200
- ❑ Top journals, >50
- ❑ Book, 2-3

- ❑ National codes & standards, > 3
- ❑ Patents, > 20

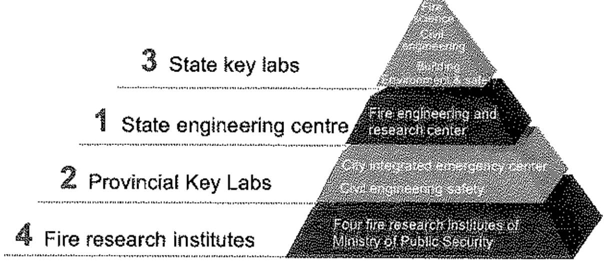
4, National research project on HRB fire



4, National research project on HRB fire

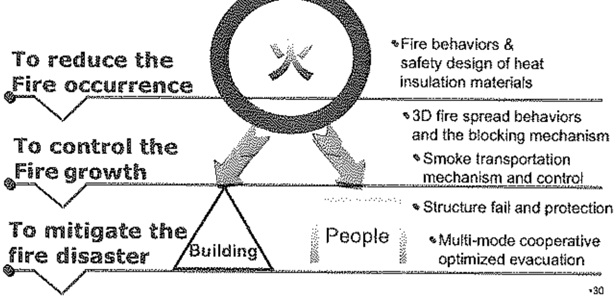
Research team: 17 professors and 13 associate professors

Research institutes:



5, Summary

Promote the self-ability of high-rise buildings to prevent and control fire disaster



Some research progress on thermal decomposition and flame retardant properties of polymeric thermal insulation materials in high-rise buildings

Yuan Hu

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86-551-3601664

State Key Laboratory of Fire Science (SKLFS)
University of Science and Technology of China (USTC)

Outlines

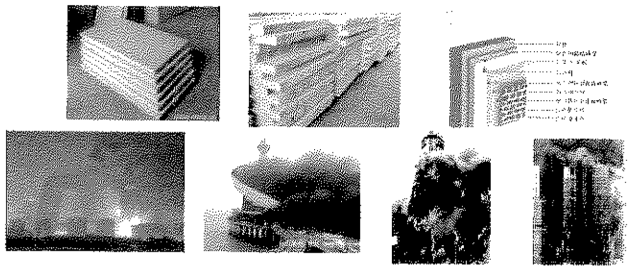
➢**Research Background**
- **Introduction of polymeric thermal insulation materials**

➢**Research Progress**
- **Pyrolysis, combustion& flame retardant properties**
- **Ideas of pyrolysis and flame retardant properties of PS and PU in SKLFS**

➢**Conclusion and Thinking**

Ⅰ. Research Background

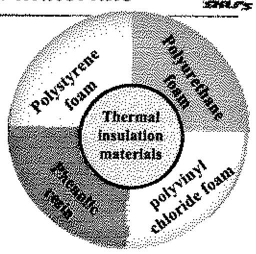
Introduction



- ☐ More and more polymeric foam materials have been used as high-rise building exterior insulation materials.
- ☐ Their flammability and lower thermal stability aroused many fires.

Foams for thermal insulation materials

Thermal insulation materials mainly includes polyurethane foams, polystyrene foams, phenolic resin foams and urea formaldehyde foams.



Materials	Polystyrene foams		Polyurethane foams		Phenolic resin foams	
Classification	Common	Special	Common	Special	Common	Composites
Flammability	≤ B2	B1	≤ B2	B1	B1	Grade A
Smoke Toxicity	Dangerous(WX)		Dangerous(WX)		Safety grade No.3(ZA3)	

Foam properties

1. ThePS foams are extremely high flammability and serious dripping durning burning.
2. PU foams are highly flammable in the air. It burn rapidly and difficult to extinguish once ignited.
3. Phenolic foam (PF) is lightweight and flame retardant, but the drawback are brittle and easily dregs

PS and RPUF are highly flammable materials so that study on the safety of thermal insulation materials is an urgent task.

II. Research progress

Research programs

- Pyrolysis, combustion& Flame Retardant Properties
  - Small-scale Test
  - Medium-Scale Test
  - Full-Scale Test
- Ideas of flame retardant properties of thermal insulation materials of our group
  - Polystyrene foam
  - Polyurethane foam

2.1. Combustion, Pyrolysis & Flame Retardant

Thermal insulation materials → Small-scale / Medium-scale / Full-scale → Combustion, Flame retardant properties, Fire hazard

Understanding the foam combustion and pyrolysis mechanism
Enhancing the application range and supervision of the materials
Establishing the energy saving and fire-proofing systems

2.1.1 Pyrolysis, Combustion & Flame Retardant Properties

-------Small-scale Experiment

- Heat release process
- Smoke density and composition

(1) Thermal decomposition and combustion

LOI and UL-94 of foams

- Rigid polyurethane foam（RPUF）
- flame retardant PU foam（EG/RPUF）
- polystyrene foam（PS）
- phenolic foam（PF）

Sample	LOI (%)	UL-94		
		Rate	t_1 (s)	t_1+t_2 (s)
RPUF	21.5	NR	-[a]	-
EG/RPUF	33	V-0	1.8	4.7
PS	20.5	NR	-	-
PF[b]	47	V-0	1.4	2.7

- **The pure RPUF is highly flammable with the LOI value of 21.5%. After adding 15% expanded graphite, its LOI value is increased to 33% and can pass UL-94 V0 rating test, indicating expanded graphite displays excellent flame retardant effect to RPUF.**
- **The pure PS is highly flammable with the LOI value of 20.5% and shows no rating in UL-94 test. The PF exhibits excellent flame retardant properties with high LOI value of 47%. Moreover, it can pass UL-94 V0 rating test.**

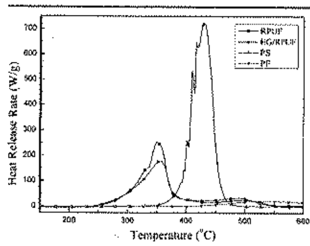
Smoke density for different foams

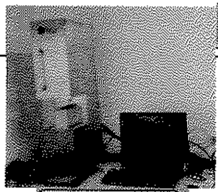
Sample	The maximum smoke density (DM %)	The smoke degree rate (SDR %)
RPUF	70.37	21.39
EG/RPUF	43.67	8.92
PS	52.78	10.79
PF	4.17	0.49

Smoke density instrument

The smoke density for RPUF and PS is very high. The addition of expanded graphite into RPUF can significantly reduce its smoke density. PF exhibits the lowest smoke density, as low as 4.17%.

HRR of thermal insulation materials



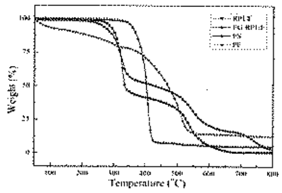


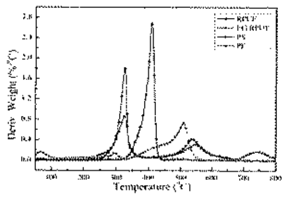
Microscale Combustion Calorimeter (MCC)

Sample	HRC (J/g-K)	PHRR (W/g)	THR (kJ/g)	T_{max} (°C)
RPUF	256	252.4	16.5	350.9
EG/RPUF	183	180.8	15.5	355.9
PS	730	648.9	30.9	416.6
PF	23	17.1	-a	493.4

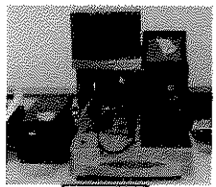
The peak heat release rate and total heat release of EG/RPUF significantly decrease compared to RPUF.

Thermal analysis (air)





Samples	$T_{5wt\%}$ (°C)	T_{max} (°C)			Residue at 650°C (wt %)
		Stage 1	Stage 2	Stage 3	
RPUF	285	325	537		1.8
EG/RPUF	260	325	550	745	17.[illegible]
PS	354	408			5.3
PF	81	67	295	509	14.0

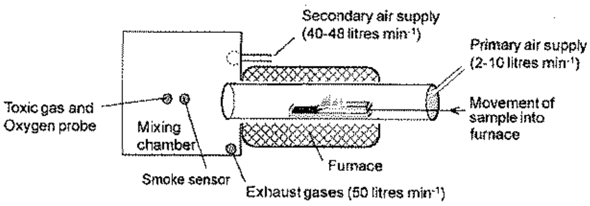


TGA

(2) The fire toxicity of building insulation materials

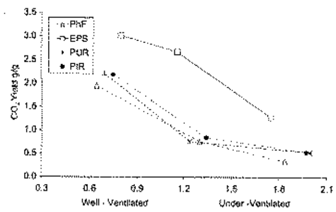
Expanded polystyrene foam(EPS), phenolic foam(PhF), polyurethane foam(PUR) and polyisocyanurate foam(PIR) was investigated under a range of fire conditions.

The steady state tube furnace apparatus (Purser furnace)

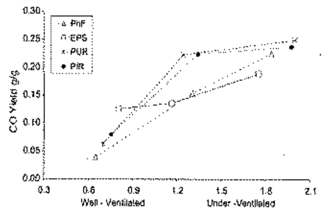


Energy and Buildings 43 (2011) 498–506

The influence of ventilation condition on the toxic product yields

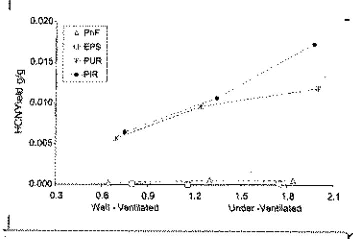


Yield of carbon dioxide during flaming conditions

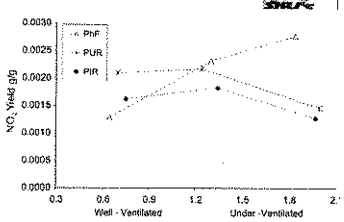


Yield of carbon dioxide during flaming conditions

- The progressive decrease in carbon dioxide yield for decreasing ventilation.
- The increase in carbon monoxide yield as the ventilation changes from well-ventilated to under-ventilated

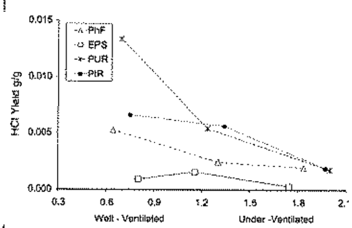


Yield of hydrogen cyanide during flaming conditions.

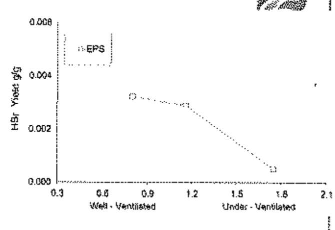


Yield of nitrogen dioxide during flaming conditions

- The variation of the HCN yield
- The variation of NO2 yield with fire conditions for the three materials where it was above the limit of detection



Yield of hydrogen chloride during flaming conditions



Yield of hydrogen bromide during flaming condition

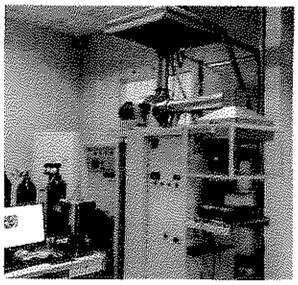
- Similar decreasing yields of hydrogen chloride (HCl) and hydrogen bromide (HBr) with decrease of oxygen

2.1.2 Pyrolysis, Combustion & Flame Retardant Properties
——Medium-Scale Test

Ⅰ. Research the combustion behavior of XPS under different heat flux

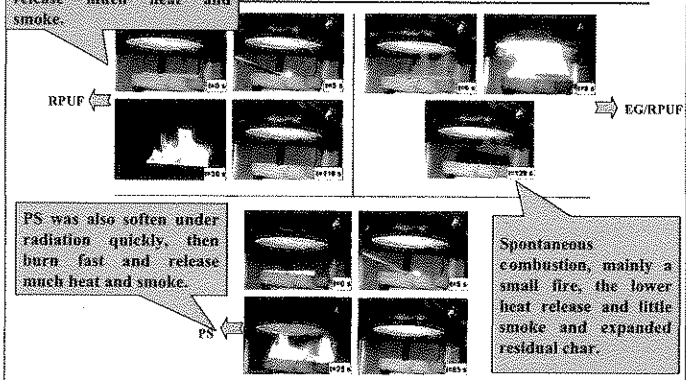
Ⅱ. Research the combustion behavior of PU under different heat flux

Cone calorimeter



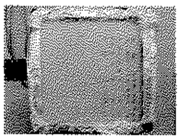
- **100 × 100 × 30 mm³ Foam Material**
- **Samples were placed on cone in different ways: horizontal, vertical and inclined.**
- **Material was ignited under differ thermal radiation Use real-time video camera to record the combustion process**

Horizontal burning behavior at 750 °C

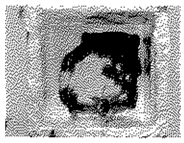


(1) Combustion behavior of XPS under different heat flux

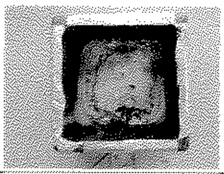
- Experimental material: Flame retardant polystyrene foam—XPS
- Heat flux: 15, 25, 35, 50, 75kW/m²
- Flame retardant---HBCD



XPS before test



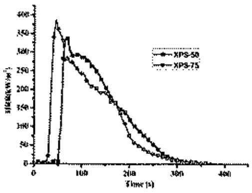
XPS-15

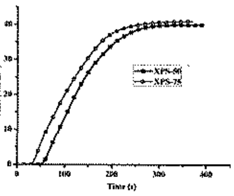


XPS-50

Heat release

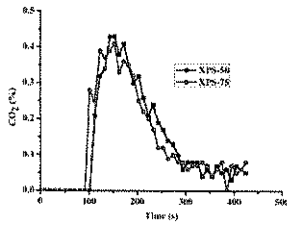
When the heat flux is 15 and 25 kW/m², XPS shrink quickly and is non-combustible; When the heat flux is 35 kW/m², XPS begin to burn after heated 1200s

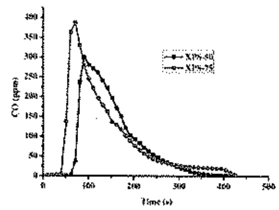




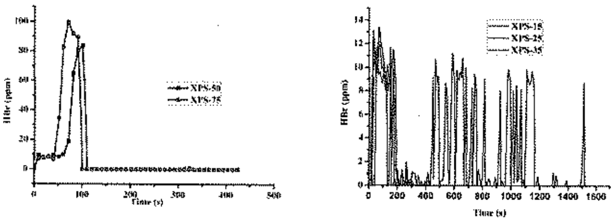
HRR and THR curves of XPS

The toxic gas analysis





CO2 and CO concentration curves of fire effluents of XPS during fire testing



HBr concentration curves of fire effluents of XPS during fire testing

(2) Combustion behavior of PU under different heat flux

- ➢ Experimental materials: rigid polyurethane foam (PU) and flame retardant polyurethane foam (FRPU); Flame retardant: TCPP
- ➢ Heat flux: 15, 25, 35, 50, 75kW/m²

Cone calorimeter data of rigid polyurethane foam

Samples	Heat flux (kW/m²)	TTI (s)	PHRR (kW/m²)	TTPHR (s)	THR (MJ/m²)	TSP (m²/m²)	Mass loss (%)
PU35	35	8	287	30	25.9	6.6	62.0
FRPU35	35	4	181	30	17.2	8.0	61.0
FRPU25	25	11	131	35	8.0	3.8	31.9
FRPU50	50	3	213	25	26.6	10.6	79.7
FRPU75	75	3	260	20	39.7	13.3	94.9

The maximum values of toxic gases concentration of RPUF during fire testing

Samples	CO_2 (%)	CO (ppm)	HCl (ppm)	HCN (ppm)	NO_x (ppm)
PU35	0.93	191.0	50.6	30.6	24.6
FRPU35	2.78	500.0	148.8	107.1	14.1
FRPU25	1.8	192.7	77.4	42.9	6.9
FRPU50	1.1	673.8	186.5	137.6	14.9
FRPU75	0.6	734.5	210.5	157.7	13.4

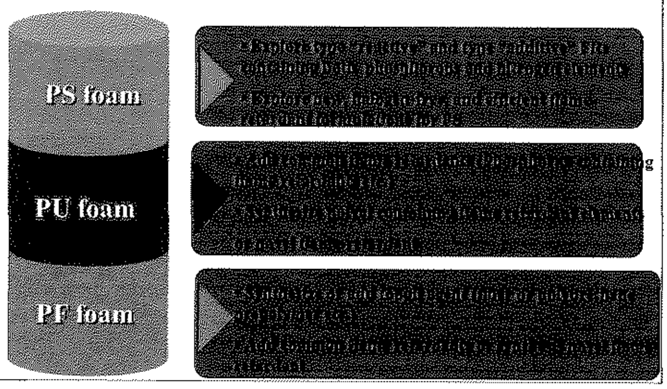
Summary (1)

- **PS and RPUF are highly flammable materials, and their smoke density is very high. The addition of expanded graphite into RPUF can significantly reduce its smoke density. PF exhibits the lowest smoke density.**
- **The main way of improve the thermal insulation materials fire safety is adding effective flame-retardant and forming composite foams on the basis affect the mechanical properties as little as possible.**
- **The amount of fire toxicity of thermal insulation materials vary with different condition of ventilation and heat flux.**
- **From the toxic gas results, the smoke density and toxic gas content of halogen-containing foam are still serious.**

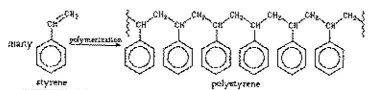
Halogen-free flame retardant

2.2 Some research for flame retarding thermal insulation materials of our research

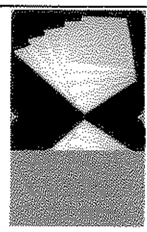
Techniques for flame retardancy and mechnical properties

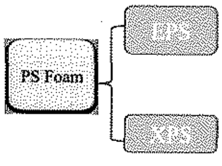


2.2.1 Polystyrene foam



The structure of PS





Key points for flame retarding PS Foam

Enhance the char formation

immobilize the melt, and thus reduce dripping

Combine with new gas-phase FR additives (Non-halogen)

Some Flame retardant methods

A:Synthesize inherently flame-retardant PS foam

Synthesize monomers containing both flame-retardant elements such as P, N, Si, B and polymerizable groups.

↓

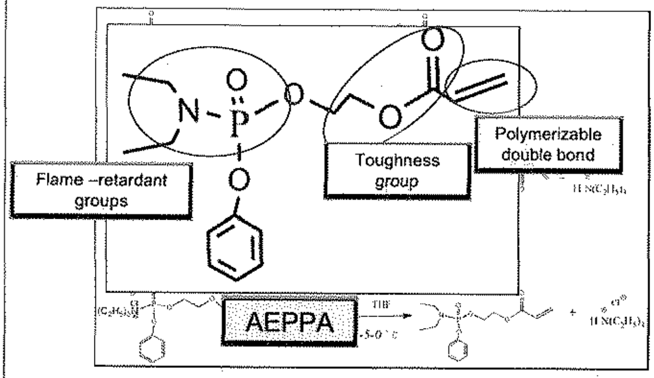
Introduce the monomers into PS backbone via radical polymerization.

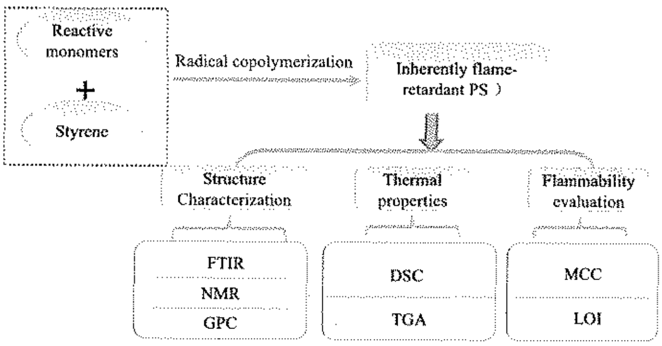
↓

Foam the flame-retardant PS

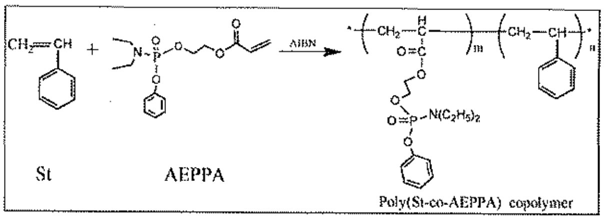
Example

Polymer Degradation and Stability 95 (2010) 830-836



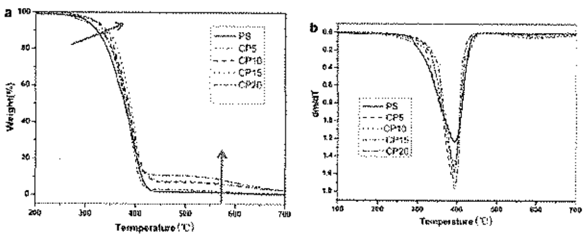


Synthesis of flame-retardant polystyrene



The flame-retardant PS was prepared by the copolymerization of Styrene and AEPPA monomer.

TGA and DTG curves of the samples



- AEPPA changed the decomposition of PS in nitrogen
- Initial decomposition temperature decreased
- Char formation increased

Micro-scale Combustion Calorimeter (MCC) test

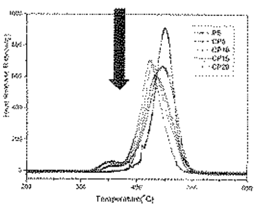


Table 3
MCC data and part of DTG data of the polymers

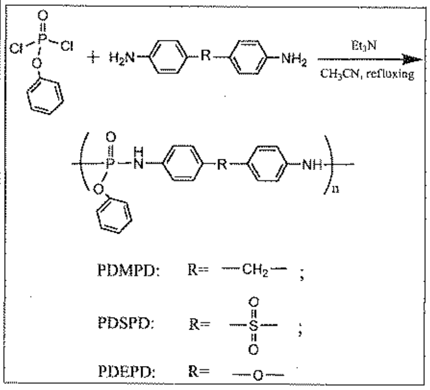
Samples	HRC[a] (J/g K)	Peak HRR[a] (W/g)	Ignition temperature[a] (T_{onset} °C)	Max mass loss rate ($\times 10^2$/s)
PS	915	914	449.6	2.43
CP5	637	635	443.6	1.64
CP10	621	617	433.4	1.57
CP15	690	685	428.3	1.82
CP20	713	709	423.6	1.97

[a] MCC results; max mass loss rate obtained from DTG results under nitrogen.

The introduction of AEPPA can obviously decrease the peak HRR.

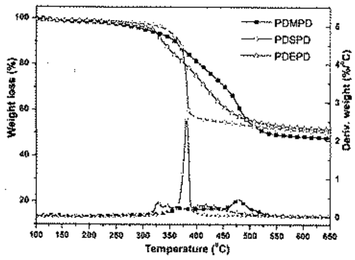
The HRC of all the copolymers are much lower than that of PS. The HRC of CP10 is the lowest among all the copolymers, indicating the lowest flammability.

B. Synthesize novel efficient FR additives with high char formation



@ Phosphorus, nitrogen containing polymeric FRs.

High thermal stability



High thermal stability

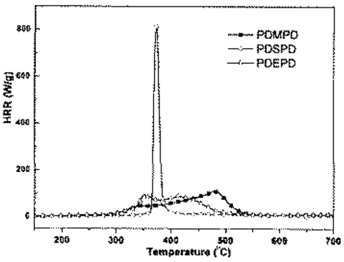
$T_{0.5}$ > 300 °C

High char formation

Char > 45% (650°C)

Good candidate for FRs

MCC results

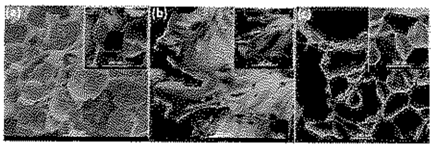


Very low flammability

HRC<100J/g K (PS=927)

Compact char structure

Good candidate for FRs



2.2.2 Polyurethane foam

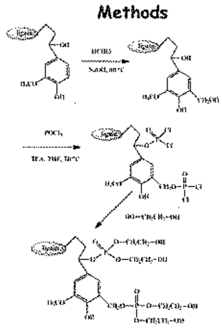
Flame retardant Polyurethane foam

- Additives → Halogen compounds; Phosphorus-containing flame retardants: DMMP, APP, Etc. → Cheap, Efficiency ……
- Reactive → Flame retardant polyol containing flame retardant elements → Good compatibility; No-migration ……

Some Flame retardant methods

Halogen-Free Flame Retardant and Functionalized Lignin-based Rigid Polyurethane Foam

Methods

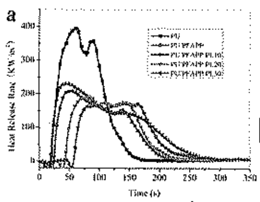


Synthesis of Hydroxypropyl Lignin (Lignin-OH)

Synthesis of Functionalized Lignin (PL)

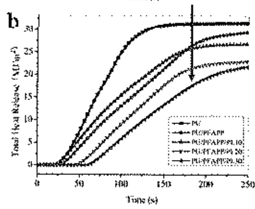
Flammability properties

a



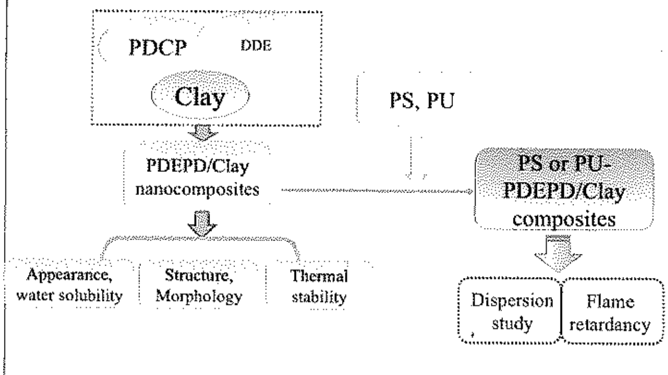
Sample	LOI (%)	Cone calorimetry data of PU foams			
		TTI (s)	Time to PHRR (s)	PHRR	THR
PU	20.0	7	62	403	31.7
PU/PFAPP	23.5	10	53	206	29.9
PU/PFAPP/PL10	23.0	6	50	229	26.9
PU/PFAPP/PL20	23.5	27	84	193	23.4
PU/PFAPP/PL30	23.5	43	96	165	23.1

b



PU/PFAPP/PL foam system gave the excellent flame retardancy property

Polymeric Exfoliated Clay Nanocomposites



Chemical Engineering Journal 183 (2012) 542~ 549

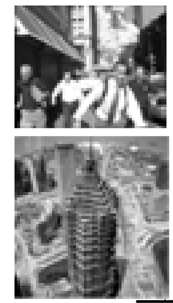
Preparation process

Review of Pedestrian Evacuation from High-rise Building in Fire

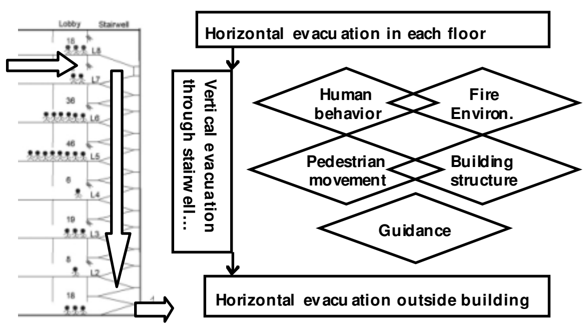
Weiguo Song (Prof. Ph.D)
State key Laboratory of Fire Science,
University of Science and Technology of China
Oct 14, 2012

Introduction -Difficulties

- Human behavior and performance
  - Physical factors
  - Social factors
- Complex building structures
  - Multi-floors
  - Multi-functions
- Integrated evacuation strategies
  - Stairs
  - Elevators, refuge floor…



Introduction



Contents

Human Behavior in High-rise Building Fires

Human Behavior in Highrise Fire

- Survey research
  - Questionnaire survey
  - Telephone interviews
  - Face-to-face interviews
  - Focus group interviews…
- Cases study
  - The World Trade Center explosion (1993, USA)
  - The high-rise building apartments fire (1996, Japan)
  - The World Trade Center (2001, USA)
  - The Chicago Cook Country Building Fire (2003, USA)
  - …

Survey Research---Behavioral Response

- The World Trade Center explosion (RF. Fahy et al, 1998)
  - Initial awareness of the incident
  - Perception of seriousness
  - Reporting the incident or notifying others
  - Movement through smoke
  - Seeking refuge
  - Beginning evacuation

Survey Research---Behavioral Response

- High-rise building apartments fire (A. Sekizawa et al, 1999)
  - Reaction to fire cues
  - Motives for starting evacuation
  - Choice of evacuation route
  - Use of elevators
- Results :
  - Time lag: fire perception ←→ starting evacuation
  - Elevator use is mainly related to floor height
  - People are likely to choose the route they usually use or a safer route rather than a closer route

Survey Research---Behavioral Response

- Evacuation of the World Trade Center 1,2 (JD. Averill et al, 2005)
  - Telephone interviews
  - Face-to-face interviews
  - Focus group interviews
- Research objectives:
  - Sources of evacuation initiation delay (why people did not immediately start to leave the building)
  - Stairs evacuation time (how long the average occupant spend in the stairs per floor)
  - Issues that slow or aid the evacuation process

Survey Research---Behavioral Response

- Evacuation of the World Trade Center (ER. Galea, et al 2007, 2008)
  - Collecting first hand evacuation experiences of survivors from the WTC twin towers evacuation
  - High-rise Evacuation Evaluation Database (HEED)
    - A more open approach to data collection
    - An attempt to understand the social and organizational factors that influence evacuation activity
    - Accessibility of the data

Survey Research---Behavioral Response

- Evacuation of the World Trade Center (RM Robyn et al, 2007)
  - Qualitative data from semi-structured, in-depth interviews and focus groups
  - Influencial factors:
    - Individual level: perception of risk, preparedness training, degree of familiarity with the building, physical condition etc
    - Organizational level: worksite preparedness planning, including the training and education of building occupants, and risk communication
    - Environmental condition: smoke, flames, degree of crowdedness on stairs and communication infrastructure systems

Survey Research---Behavioral Response

- Evacuation of the World Trade Center (NC McConnell et al, 2010)
  - Pre-interview questionnaire and one-to-one interview
  - Survivors' recognition and response phase in WTC1
  - Capture and collate the experiences and behaviors of WTC evacuees
- Results
  - Differences in occupant activities
  - Can be explained in terms of the perception of risk and the nature and extent of cues received by the participants

Survey Research---Behavioral Response

- The Chicago Cook Country Building Fire (G. Proulx et al, 2006)
  - Questionnaire survey
  - Objectives: understand the existing conditions in the building prior to the fire, past training and occupant awareness of the evacuation procedure
- Results
  - Respondents on location at the time of the fire
  - Recognition and response
  - Evacuation movement
  - Total evacuation time

Survey Research---Evacuation Movement in Smoke

- The Chicago Cook Country Building Fire (G. Proulx et al, 2006)
  - Over 40% of the occupants noticing smoke on their floor used an elevator to egress
  - Occupants who did not use elevator to evacuate used one of the two stairs, which were both contaminated with smoke
  - Two thirds of the evacuees saw smoke in the stairs when they opened the stairs door, but they entered anyway and started their journey down
  - Occupants are prepared to move through smoke and some may disobey instructions by using elevators

Human Behavior

- Research purpose
  - First hand evacuation experiences of survivors
  - Existing conditions prior to the fire, past training and occupant awareness of the evacuation procedure
  - Sources of evacuation initiation delay
  - Issues that slow or aid the evacuation process
- Research focus
  - Reaction to fire cues
  - Motives for starting evacuation
  - Choice of evacuation route
  - The use of stairs or elevators
  - Influence of signages or guidance …

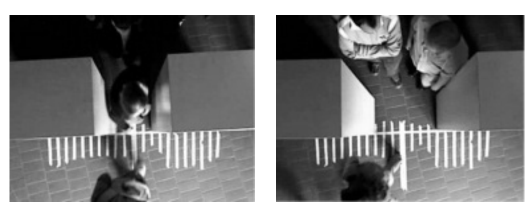
Horizontal Movement inside building

- Movement through building bottleneck
- Movement in building corridor
- Multi-direction movement, counterflow …

Evacuation Models

- Continuous models
  - Social force model
  - Magnetic model
- Discrete models
  - Cellular automaton
  - Queue model
  - Floor field model
- Other models…

Horizontal Movement through bottleneck

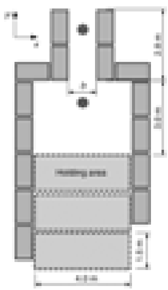


- Total times
- Flux and specific flux
- Time gaps

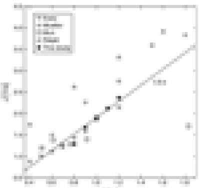
T. Kretz et al, Journal of Statistical Mechanics-Theory and Experiment , (2006)

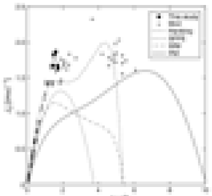
Horizontal Movement through bottleneck

- Influence of bottleneck width
- Fundamental diagram



Experimental Setup

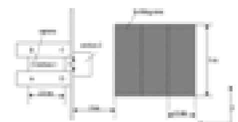


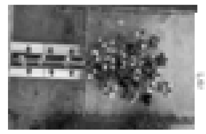


A. Seyfried et al, Transportation Science, (2009)

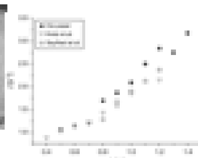
Horizontal Movement through bottleneck

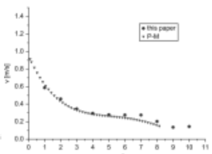
- Flow rate
- Density-velocity relation





Experimental Setup

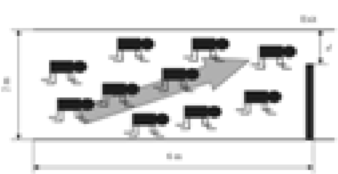




W. Tian et al, Fire Safety Journal, (2012)

Pedestrian movement on building bottleneck

- Experimental research---unidirectional flow

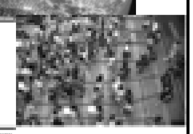


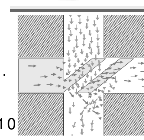
- Evacuation of crawlers where all students go on all fours
- Evacuation of pedestrians where all students go normally by walking

R. Nagai, et al, Physica A, (2006)

Pedestrian movement on building corridor

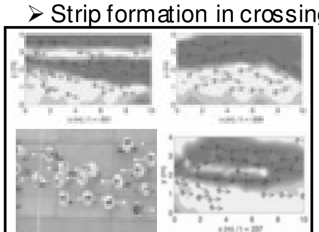
- Unidirectional flow
  - Nakayama et al. 2010
  - Yuen and Lee 2011…
- Counter flow
  - Nagaia et al. 2005
  - Yu and Song. 2007
  - Ma et al. 2010…
- Cross flow
  - Hoogendoorn 2003
  - Gotoh, Harada et al. 2011…
- Group flow
  - Maussaid, Perozo et al. 2010
  - Karamouzas and Overmars. 2010…



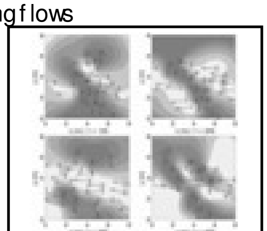


Pedestrian movement on building corridor

- Experimental research---bidirectional flow
- Lane formation in bidirectional pedestrian flows
- Strip formation in crossing flows



Lane formation

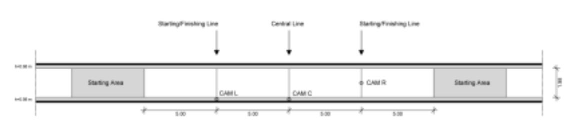


Strip formation

S. Hoogendoorn et al, Traffic and Granular Flow, (2005)

Pedestrian movement on building corridor

- Experimental research---bidirectional flow

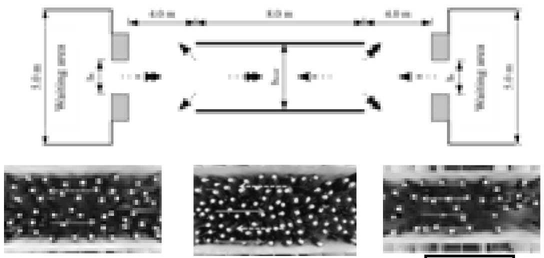


- Passing times
- Walking speeds
- Specific fluxes
- Lane formation

T. Kretz et al, Journal of Statistical Mechanics-Theory and Experiment, (2006)

Pedestrian movement on building corridor

- Experimental research---bidirectional flow



BFR-SSL Flow BFR-DML Flow UFR-DML Flow

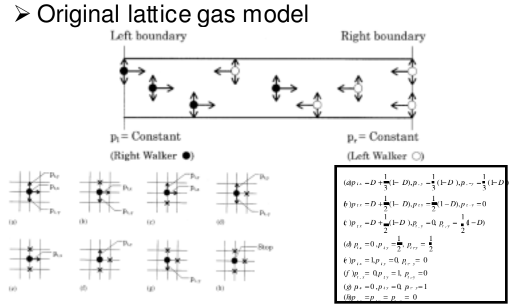
J. Zhang et al, Journal of Statistical Mechanics- Theory and Experiment, (2012)

Pedestrian movement on building corridor

- Modeling research
  - Lattice gas model (M. Muramatsu, 1999)
  - Considering the partition line (K. Takimoto, 2002)
  - Considering the traffic rule breaking behavior (YF. Yu, 2007)
  - Considering the surrounding environment (YF. Yu, 2007; J. Ma, 2010)
  - Considering the prediction behavior (ZY. Wang, 2012)
  - T-shaped corridor (Y. Tajima, 2002; CK. Chen, 2012…)
  - …

Pedestrian movement on building corridor

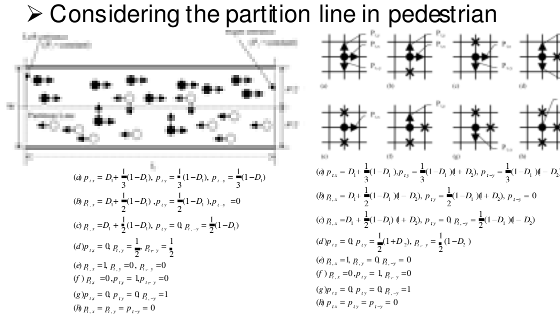
- Model research---bidirectional flow
- Original lattice gas model



M. Muramatsu, et al, Physica A, (1999)

Pedestrian movement on building corridor

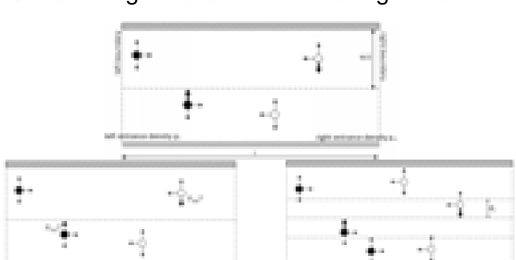
- Model research---bidirectional flow
- Considering the partition line in pedestrian



K. Takimoto et al, Physica A, (2002)

Pedestrian movement on building corridor

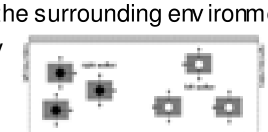
- Model research---bidirectional flow
- Considering the traffic rule breaking behavior

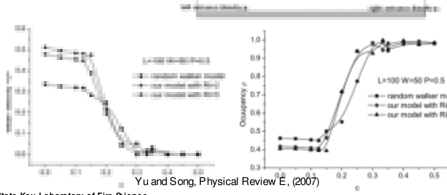


Yu and Song, Physical Review E, (2007)

Pedestrian movement on building corridor

- Case---bidirectional flow model
- Considering the surrounding environment
- Mean velocity
- Occupancy

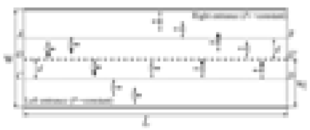




Yu and Song, Physical Review E, (2007)

Pedestrian movement on building corridor

- Model research---bidirectional flow
- Considering the subconscious behavior and different maximum velocities



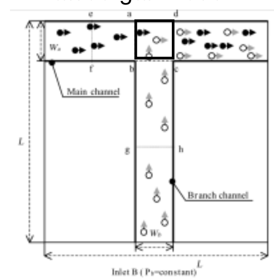
$$(a)\ P_f = D+\frac{1}{3}(1-D),\ P_l = \frac{1}{3}(1-D)(1-D_1),\ P_r = \frac{1}{3}(1-D)(1+D_1)$$
$$(b)\ P_f = D+\frac{1}{2}(1-D)(1-D_1),\ P_l = 0,\ P_r = \frac{1}{2}(1-D)(1+D_1)$$
$$(c)\ P_f = D+\frac{1}{2}(1-D)(1+D_1),\ P_l = \frac{1}{2}(1-D)(1-D_1),\ P_r = 0$$
$$(d)\ P_f = 0,\ P_l = \frac{1}{2}(1-D_1),\ P_r = \frac{1}{2}(1+D_1)$$
$$(e)\ P_f = 0,\ P_l = 0,\ P_r = 1$$
$$(f)\ P_f = 0,\ P_l = 1,\ P_r = 0$$
$$(g)\ P_f = 1,\ P_l = 0,\ P_r = 0$$
$$(h)\ P_f = 0,\ P_l = 0,\ P_r = 0$$

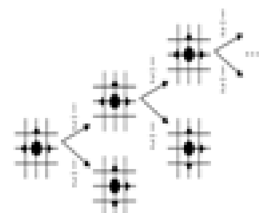
- **Triangles**: the faster walkers
- **Circles**: the slower walkers
- **Subconscious behavior**: the convention of sideways direction preference during their movement in a crowd

H. Kuang et al, Physical Review E, (2008)

Pedestrian movement on building corridor

- Model research---T-shaped corridor
- Lattice gas model





Y. Tajima et al, Physics A, (2002)

Horizontal Movement

- Influencial Factors
  - Width of bottleneck
  - Wall surface
  - Interaction
  - Swaying
  - Dynamic layer formation
  - Layer patterns
  - Ped parameters
  - …
- properties
  - Fundamental diagram
  - Speed
  - Density
  - Flow
  - Jamming
  - Arching distribution
  - Faster is slower
  - Grouping
  - …

Revised from SP. Hoogendoom, Transportation Science, (2005)

Pedestrian Vertical Movement

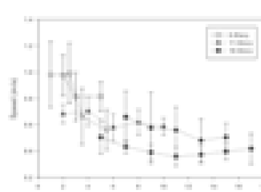
- Staircase
- Elevators
- Refuge floor
- …

Staircase evacuation

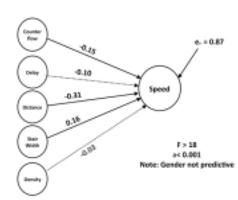
- Fire drill evacuation data collection
  - (RD. Peacock, 2009, 2012……)
- Field observation
  - (CS. Jiang, 2009; T. Fujiyama, 2009; LZ. Yang, 2012……)
- Experimental research
  - (N. Takeichi, 2005; KE. Boyce, 2011; ZM. Fang, 2012; J. Ma, 2012…)
- Modeling research
  - (JD. Averill, 2007; ER. Galea, 2008; X. Xu, 2009; ……)

Staircase evacuation

- Movement speeds on stairs
- Fire drill evacuation data collection(NIST)
- 6,8,11,31-story buildings



- Causal model: the components affecting occupant speeds on stairs



R. D. Peacock et al, NIST Technical Note, (2009)

Staircase evacuation

- Movement speeds on stairs
- Data collection (NIST)
- 10-story office building
- 18-story office building
- 24-story office building
- 31-story office building

Pre-observation time and stairwell movement speeds in several fire drill evacuations.

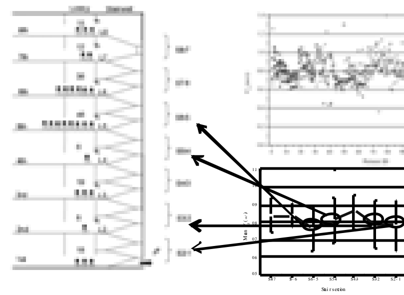
Building	Evacuees[a]	Average pre-observation delay time[c] (s)	Average speed[c] (m/s)
6-Story[b]	273	142 ± 60	0.78 ± 0.23
10-Story	793	171 ± 124	0.44 ± 0.19
11-Story[b]	127	89 ± 54	0.62 ± 0.26
13-Story[b]	226	106 ± 50	0.69 ± 0.09
18-Story	1148	224 ± 146	0.44 ± 0.15
24-Story	593	137 ± 86	0.56 ± 0.12
31-Story	525	149 ± 88	0.52 ± 0.10

[a] Does not include evacuees who did not exit at the lowest camera location.
[b] Data from earlier study (Peacock et al., 2010).
[c] Uncertainty is expressed as one standard deviation.

R, D. Peacock et al, Safety Science, (2012)

Staircase evacuation

- Evacuation process in a stairwell

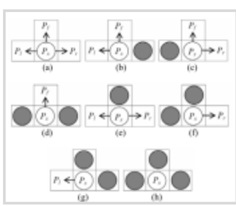


Influencing factors:
- Merging behavior
- Physical strength
- Visibility

Fang and Song et al, Building and Environment, (2012)

Staircase evacuation

- Evacuaiton Model on stairs



$(a) P_f = 0.8, P_l = 0.05, P_r = 0.15, P_s = 0.0$
$(b) P_f = 0.8, P_l = 0.05, P_r = 0.0, P_s = 0.15$
$(c) P_f = 0.8, P_l = 0.0, P_r = 0.15, P_s = 0.05$
$(d) P_f = 0.8, P_l = 0.0, P_r = 0.0, P_s = 0.2$
$(e) P_f = 0.0, P_l = 0.05, P_r = 0.15, P_s = 0.8$
$(f) P_f = 0.0, P_l = 0.0, P_r = 0.15, P_s = 0.85$
$(g) P_f = 0.0, P_l = 0.05, P_r = 0.0, P_s = 0.95$
$(h) P_f = 0.0, P_l = 0.0, P_r = 0.0, P_s = 1.0$

$$P_f + P_l + P_r + P_s = 1.0$$

D——the strength of the drift
P_f——the probability of moving forward
P_l——the probability of moving left
P_r——the probability of moving right

JD. Averill; WG. Song, NISTIR, (2007)

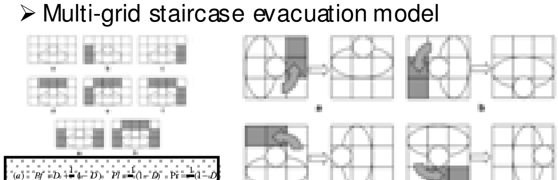
Staircase evacuation

- Modeling scenario
  - 50 story high-rise building with 350 persons per floor
- Two commonly discussed strategies for increasing egress capacity:
  - Adding additional width to existing stairs
  - Adding an additional stair
- Simulation results
  - When comparing equivalent total width, additional stairwells outperform wider stairwells from the perspective of evacuation performance

JD. Averill; WG. Song, NISTIR, (2007)

Staircase evacuation

- Multi-grid staircase evacuation model



$(a)\ Pf = D + \frac{1}{3}(1-D)\quad Pl = \frac{1}{2}(1-D)\quad Pr = \frac{1}{6}(1-D)$
$(b)\ Pf = D + \frac{1}{2}(1-D)\quad Pl = 0\quad Pr = \frac{1}{2}(1-D)$
$(c)\ Pf = D + \frac{1}{2}(1-D)\quad Pl = \frac{1}{2}(1-D)\quad Pr = 0$
$(d)\ Pf = 0\quad Pl = \frac{3}{4}\quad Pr = \frac{1}{4}$
$(e)\ Pf = 0\quad Pl = 0\quad Pr = 1$
$(f)\ Pf = 0\quad Pl = 1\quad Pr = 0$
$(g)\ Pf = 1\quad Pl = 0\quad Pr = 0$
$(h)\ Pf = 0\quad Pl = 0\quad Pr = 0$

⟹

D——the strength of the drift
Pf——the probability of moving forward
Pl——the probability of moving left
Pr——the probability of moving right

Xu and Song et al, Building and Environment, (2009)

Staircase evacuation

- Model Validation through the egress drill
- A four-story student apartment in USTC of China
- 22 dormitories on each floor and the doors of them face the hallway

Floor and tread geometry

Simulation of the evacuation process

Elevators evacuation

- Occupant's response in using elevators
  - (A. Sekizawa, 1999; G. Proulx, 2006; E. Heyes, 2009; G. Proulx, 2009)
- Elevator evacuation strategies
  - (J. Pauls, 1977; NE. Groner, 1992; JH. Klote, 1982, 1993; KHL. Wong, 2005; MJ. Kinsey, 2009, 2012)
- Feasibility analysis of elevator evacuation
  - (A. Sekizawa, 2004; M. Ebihara, 2004; S. Nakahama, 2005)
- …

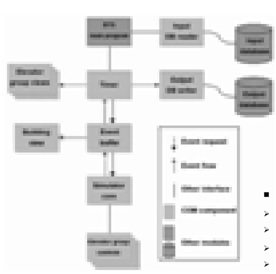
Elevators evacuation

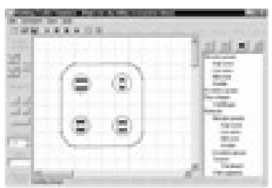
- The use of elevators for egress
  - Factors affecting the use of elevators for evacuation (G. Proulx, 2009)
    - Individual differences between occupants
    - Building or organizational factors
    - Situational factors
  - A primary factor governing evacuation choice between the lift and the stairs (E. Heyes, 2009)
    - An occupant's estimate of the fastest evacuation route

G. Proulx, et al, International symposium on Human Behavior in Fire, (2009)

Elevators evacuation

- Passenger elevator traffic flow simulation
- Building Traffic Simulator (BTS) (R. Leinonen, 1999)





- Parameters to be defined before the simulation:
  - Building parameters
  - Elevator parameters
  - Escalator parameters
  - Passenger traffic parameters

M. Siikonen et al, International Conference on Multi-purpose High-rise Towers and Tall Buildings, (2000)

Elevators evacuation

- Agent based elevator sub-model
  - Agent behavior
  - Elevator representation and attributes
  - Elevator motion control
  - Elevator kinematics
- Simulation scenarios: different evacuation strategies
  - Stairs only
  - 8 elevators
  - …
  - 24 elevators
  - 32 elevators, the lower population using the stairs and the upper using the elevators…
- The most efficient evacuation strategy:
  - Utilizing a combination of elevators and stairs to empty the building and clear the upper half of the building

JK Michael, et al, International Symposium on Human Behavior in Fire, (2009)

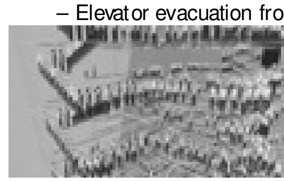
Elevators evacuation

- Elevator messaging strategies (NIST)
  - Issues occurred when the building occupants were instructed to use elevators for evacuation
  - Waiting occupants may wonder when the next elevator will arrive
  - If the elevator are still in service
  - If they should continue waiting for an elevator or use the stairs for evacuation instead
- Emergency messages and signage of elevators can be used to provide evacuation instructions to building occupants during an emergency
- Establishes guidance for emergency message content
- Provides tools and message templates for use by elevator designers

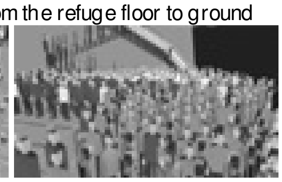
ED. Kuligowski, et al, NIST, (2012)

Elevators evacuation

- A refined concept on emergency total evacuation by elevators
  - Stair evacuation from a group of occupied floors to a refuge floor
  - Elevator evacuation from the refuge floor to ground



Typical floors

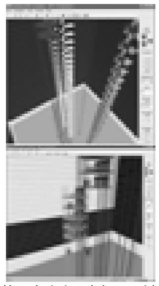


Refuge floor

KHL. Wong, et al, Fire Safety Science-Proceeding of the eighth international symposium, (2005)

Evacuation coupling stairs, elevators and refuge floors

- Building Traffic Simulator for High-rise Building Evacuation
- Vertical transportation models
  - Passenger model
  - Staircase model
  - Elevator model
- human behavior models
  - Macroscopic routing model
  - Microscopic reaction model

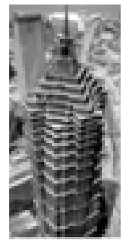


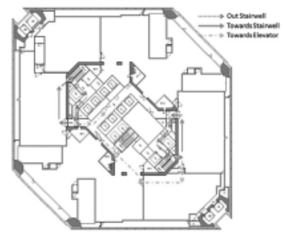
BTS simulation with stairs (up) and elevators (down)

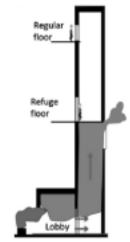
ML Siikonen, et al, Pedestrian and Evacuation Dynamics (2008)

Elevators evacuation

- CA Model for High-rise Building Evacuation
  - Typical building stairwell
  - Elevator equipped refuge floors

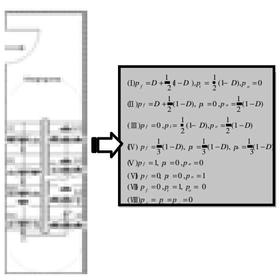


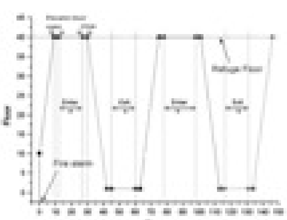




Ma and Song et al, Fire Safety Journal, (2012)

Evacuation coupling the stairs, elevators and refuge floors





Stairs

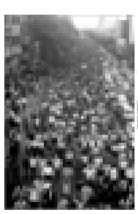
Elevators

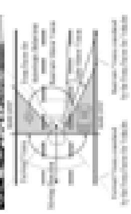
Movement outside building

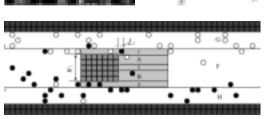
- Pedestrian-vehicle mixed flow

Pedestrian-vehicle evacuation

- Ped-vehicle interaction
  - Blum, Eskandarian. 2004
  - Godara et al. 2007
  - Ma et al. 2008
  - Pretto et al. 2011
  - Zong et al. 2012…
- Ped-vehicle traffic simulation
  - Ma et al. 2011
  - Abdelgawad, et al. 2012
  - Anvari et al. 2012…







Summary

- Human behavior
  - Understanding the characteristics of human behavioral response
  - Indicating the factors that may influence human behavior in emergency situation
  - Providing optimized evacuation inducement methods for high-rise building evacuation
- Pedestrian horizontal movement
  - Capturing microscopic movement characteristics
  - Predicting and analyzing pedestrian movement performance
- Pedestrian vertical movement
  - Obtaining microscopic movement characteristics
  - Proposing appropriate evacuation strategies coupling stairs, elevators and refuge floors
  - Achieving building optimized safety design
- Pedestrian-vehicle

Conclusion

- Further concerns for high-rise building evacuation
  - Collection of appropriate human response data
  - Development of technologies for data collection, experimental analysis, and numerical simulation
  - Progress of a comprehensive theory which predicts human behavior during evacuation movement
  - Combination of the evacuation model with the pedestrian psychological and physical factors in emergency situations
  - Validation of high-rise building evacuation models

Staircase evacuation

- Movement characteristics on stairs
  - Speed
  - Density
  - Flow
- Typical phenomena in staircase movement
  - Bidirectional collision-avoidance behavior
  - Merging behavior at the floor-stair interface
  - Queuing behavior
  - Subgroup behavior
  - Individuals affect crowd

Code for fire protection design of high rise -Current status and future in China

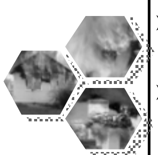
Qiu Peifang

Tianjin Fire Research Institute of MPS

October 14, 2012

Outline

1. System of China building regulation



- History of China building code
- System of China fire codes and standards
- Procedure, organization and management of building fire codes and standards
- Relationship between building fire code and other building regulations

History of China building code

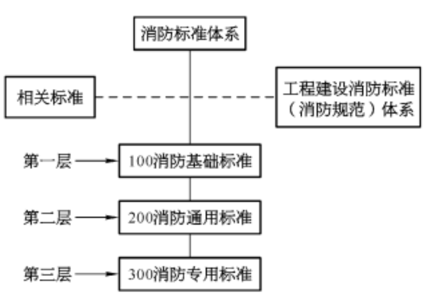
□ Three stages

① 1949～1979（compulsory standard system）

② 1989～2000 （Combination of compulsory and recommended standards）

③ 2001～now （Combination of compulsory and voluntary standards）

System of China fire codes and standards



Structure of standard system

System of China fire codes and standards

① Basic standard—standards for terminology, symbol, measuring units, graphs, basic classification or basic principles. Eg. Terminology of City Planning. (Basis for other standards)

② General standard—standards for some general requirements of safety, sanitation and environmental protection, some common quality insurance, methods of design, construction and test as well as some management requirements. (Basis for specialized standard)

③ Specialized standard—standards for survey, planning, some specified test method, specification of some product etc. It is the supplement or specified requirements for general standard.

Procedure, organization and management of building fire codes and standards

☐ Standards hierarchy

According to Standardization Law of PRC, standards for engineering construction shall be classified as:

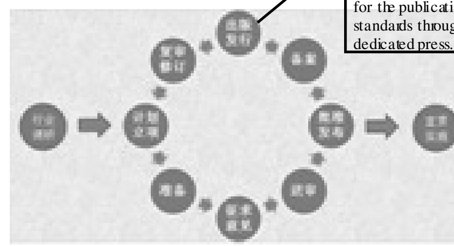
- National standard
- Industrial standard
- Local standard
- Enterprise standard

The total standards of the first three are more than 5000.

Procedure, organization and management of building fire codes and standards

☐ Procedure

The standards approval department is responsible for the publication of the standards through a dedicated press.



procedure for standard development

(closed loop, no ending)

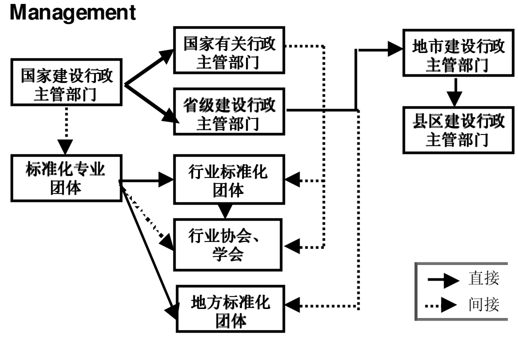
Procedure, organization and management of building fire codes and standards

☐ Organization

- Technical committee formed by experts from different organizations, universities, companies is responsible for the development and review of the standards.
- International standards and advanced standards of other countries are encouraged to be used in China.
- The area of expertise of the main editor shall be corresponding with the professional requirement of the standard.

Procedure, organization and management of building fire codes and standards

☐ Management



Relationship between building fire code and other building regulations

☐ Current codes related to building fire protection:

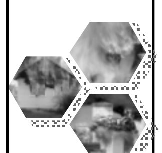
- *Code of design on building fire protection and prevention* (GB50016-2006)
- *Code for fire protection design of tall buildings* (GB 50045-95 2005)

⇩ Merge into

☐ A new code named ***Code for fire protection design of buildings*** (draft for approval)

The newly revised code is the "mother code" of China. The technical requirements of other related codes are based on the requirements of this code.

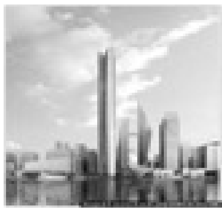
2. Major requirements for high rise



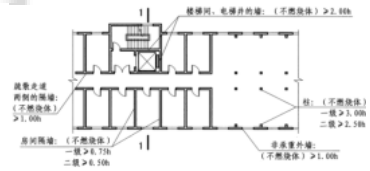
- 2.1 High rise building?
- 2.2 Fire resistance rating
- 2.3 Fire separation distance
- 2.4 Fire compartment
- 2.5 Safe evacuation
- 2.6 Fire protection installations
- 2.7 Refuge
- 2.8 Fire fighting and rescue

2.1 High rise building?

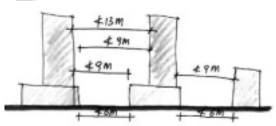
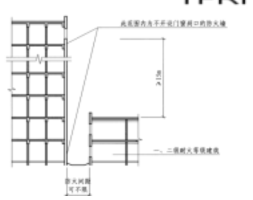
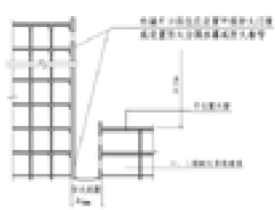
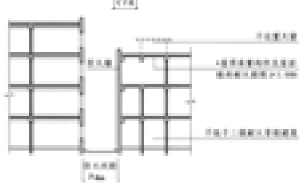
- □ **High rise building:**
  - ➢Public building>24m，Residential> 27m
- □ **Super high:**
  - ➢Building height >250m


2.2 Fire resistance rating

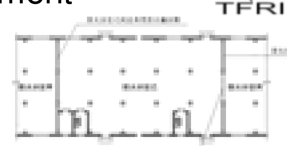
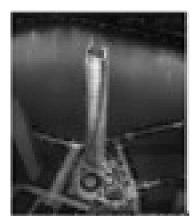
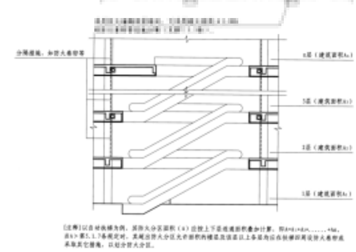



2.3 Fire separation distance

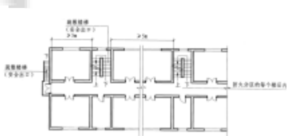
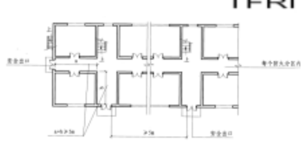





2.4 Fire compartment

Building Class	Area of each fire compartment (m^2)
Class I	1000
Class II	1500
Basement	500

2.5 Safe evacuation

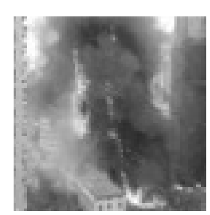



High-rise building		Max. distance between room door or entrance door to the nearest exit or staircase（m）	
		Rooms between two exits	Room at the both sides or end of a dead end passageway
Hospital	Inpatient	24	12
	Other	30	15
Hotel, exhibition and teaching building		30	15
Others		40	20

2.6 Fire protection equipment

① Sprinkler and automatic fire alarm system:

- ➢ Public building>50m;
- ➢ residential> 100m;
- ➢ Important locations for public building that is higher than 24m but less than 50m.

2.7 Refuge

□Refuge：

- ➢Refuge floor shall be provided for building more than100m high. One every 15 storeys or 45m.
- ➢ Refuge room shall be provided within every family if the building is more than 27m high.
- ➢Refuge room shall be provided in high-rise inpatient building from the second floor.

2.8 Fire fighting and rescue

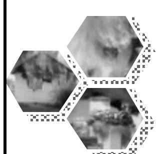
① Fire vehicle access

- ➢ Clear height: 4m   width:4m

② Rescue opening

- ➢ No less than 0.8m ×1.0m.
- ➢ The inside height: no more than 1.2m.
- ➢ Spacing of the openings: no more than 20m.
- ➢ At least two openings shall be provided for each fire compartment.

3. Researches related to high rise building



3.1 Fire performance test of double-skin breathing-type glass curtain wall

3.2 Fire performance of large commercial complex

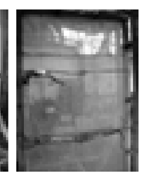
3.3 Household sprinklers

3.1 Fire performance test of double-skin breathing-type glass curtain wall

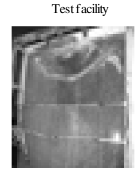
① Breakage test of glass curtain wall：

- ➢ Sample：double skin insulating tempered glass （1.8m×0.9m）
- ➢ Burner：1.6m（length）×1.6m（width）×2.6m（height）
- ➢ Fuel and fire size：1MW propane
- ➢ Result：
  - • Breakage temperature：exposed side：800℃，unexposed side：600～700℃
  - • Breakage time：exposed side：2min, unexposed side：12min

Test facility



Break



Softening

Burning through

3.1 Fire performance test of double-skin breathing-type glass curtain wall

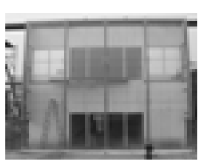
② Full scale fire test：

- ➢ Test facility：2 storeys; 9m(length)×4m(width)×3.3m(height)
- ➢ Glass：

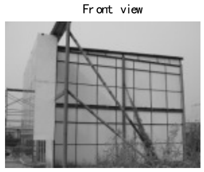
  Inside: double skin insulating tempered glass

  Outside: double tempered laminated glass

  Distance between: 860mm
- ➢ Fuel：propane and wood crib
- ➢ Fire size：0.7MW，1MW，2MW
- ➢ Objective：breaking temperature and time



Front view



Side view

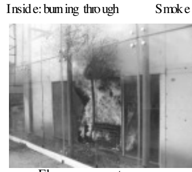
3.1 Fire performance test of double-skin breathing-type glass curtain wall

② Full scale fire test：

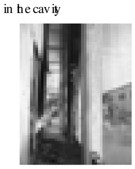
Inside: burning through

Smoke spread in the cavity

Inside: break



Flame comes out



Outside: ignited

outside: break

3.1 Fire performance test of double-skin breathing-type glass curtain wall

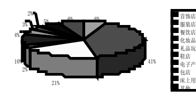
④ Recommendations:

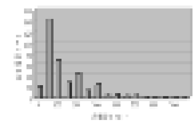
- The vertical distance between two windows of upper and lower story in the inside curtain wall should not be less than 0.8m.（1.2m ）and the gaps between the curtain wall and floors, partitions should be fire stopped.
- The width of the extended part of each floor should not be less than 0.5m. (to prevent vertical spread of fire)
- The fire resistance performance of the inside curtain wall should be better than that of the outside.
- Rescue openings shall be provided in the outside curtain wall, the spacing should be 20m.

3.2 Fire performance of large commercial complex

① Fire load survey

Type	Number of shops	Area（m^2）	Fire load density（MJ/m^2）: Range	Tantile 80%	Tantile 90%	Tantile 95%	average	MSE
Clothes	147	43～425	142～742	472	523	565	375	116
Restaurant	75	15～711	84～541	307	348	382	228	94
Shoes	15	70～106	211～420	369	380	396	342	104
Bags	7	61～128	153～230	224	225	—	203	49
Toys	36	55～96	126～265	229	238	247	207	98
Clothes for kids	19	70～117	251～447	383	397	415	367	123
Books	2	52～86	970～1680	—	—	—	1325	502
Cosmetics	9	165～209	362～547	467	483	516	437	121
Jewelry	21	80～156	112～167	152	157	161	143	32



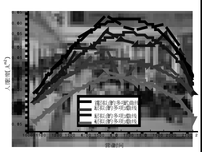


3.2 Fire performance of large commercial complex

② Occupant density (OD) survey

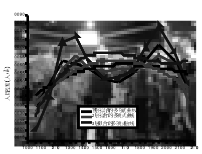
summary of OD of department store（person/m^2）

Floor	北京	上海	南京	西安	成都	石家庄		调研最大值	规范规定	规范要求与调研的比值	Recommend value
-1	0.03	—	0.04	0.25	—	—	—	0.25	0.595	2.38~238	0.6
1	0.08	0.04	0.05	0.08	0.16	0.15	0.25	0.25	0.425~0.595	1.7～238	0.6
2	0.06	0.04	0.03	0.04	0.13	0.25	0.19	0.25	0.425~0.595	1.7～238	0.45
3	0.07	0.03	0.03	0.06	0.13	0.16	0.16	0.28	0.385~0.539	1.38~193	0.4
4	0.05	0.02	0.03	0.03	0.13	0.16	0.14	0.26	0.3~0.42	1.15～1.62	0.3
5	—	0.02	—	—	—	0.17	0.13	0.26	0.3~0.42	1.15～1.62	0.3
6	—	—	—	—	—	0.19	0.14	0.19	0.3~0.42	1.58～2.21	0.3
7	—	—	—	—	—	—	0.19	0.19	0.3~0.42	1.58～2.21	0.3



OD of walking street（person/m^2）

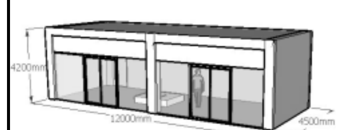
Locaton	Floor	北京	上海	南京	西安	成都	OD（人/m^2）: 调研最大值	OD（人/m^2）: 规范规定	调研与规范要求的比值	Recommend value
Shop	1	0.11	0.08	0.06	0.07	0.06	0.11	0.425～0595	3.86~541	0.6
	2	0.08	0.09	0.08	0.08	0.06	0.09	0.425～0595	4.72~661	0.45
	3	0.23	0.11	0.12	0.16	0.12	0.23	0.385～0539	1.67~234	0.4
Walking street	1	0.14	0.04	0.06	0.08	0.06	0.14	0.425～0595	3.04~425	0.2
	2	0.08	0.04	0.05	0.16	0.07	0.16	0.425～0595	4.54~496	0.25
	3	0.18	0.08	0.09	0.14	0.09	0.18	0.385～0539	2.14~299	0.3

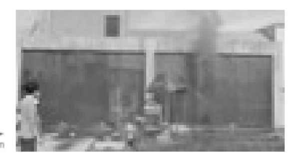


3.2 Fire performance of large commercial complex

③ Full scale test: sprinkler protected tempered glass

- Test room：12.0m×4.5m×4.2m
- Glass：with metal frame or without
- Sprinkler： window type and side wall type
- Fire source：2.5MW(wood crib）, 5.3MW(gasoline, clothes)
- Measuring parameters：inside temperature, surface temperature (both sides) of the glass, heat flux of outside, activation temperature of sprinkler and glass breaking time

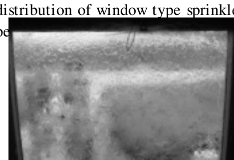




3.2 Fire performance of large commercial complex

③ Full scale test: sprinkler protected tempered glass

- Water distribution of sprinklers
  - The higher the pressure, the better effect. When pressure reached 0.1MPa, water can cover the whole piece of glass quite evenly.
  - When the deflector is at the same level with the top end of the glass, water from the sprinklers can cover the glass; when it is 100mm lower to the top end of the glass, there is areas without covered by water.
  - Water distribution of window type sprinkler is better than that of the side wall type

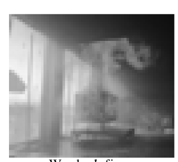


Window type

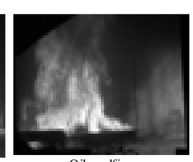
Sidewall type

3.2 Fire performance of large commercial complex

③ Full scale test: sprinkler protected tempered glass

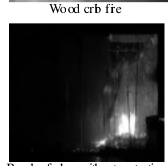


Wood crib fire

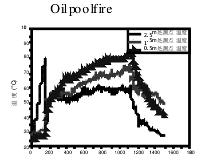


Oil pool fire

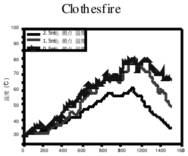
Clothes fire



Break of glass without protection



Temperature of exposed side



T of unexposed side

3.2 Fire performance of large commercial complex

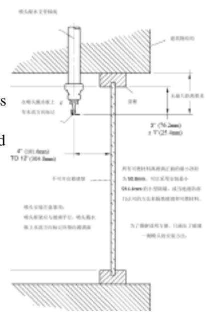
③ Full scale test: sprinkler protected tempered glass

- Conclusions:

a) The working pressure of the sprinkler shall not be less than 0.1MPa, water discharge intensity shall not be less than 0.5L/s·m；deflector shall be at the same level with the top end of the glass and 150mm~300mm away from the ceiling；spacing of the sprinkler shall be 1.8m~2.0m and the horizontal distance to the glass shall not be more than 0.3m。

b) Window type sprinkler is recommended;

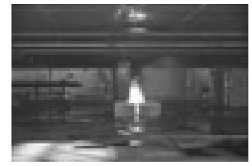
c) Thickness of the glass shall not be less than 12mm and height shall not be more than 4m；



3.3 Household sprinkler

① Full scale test

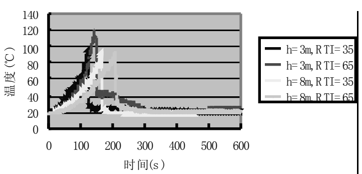
- Fast response（RTI＝35）
  special response（RTI＝65）
- Mounting height：3m,8m
- Number：16（4×4）
- Pressure : 0.1MPa
- Water intensity：8.9min/m^2
- Fire source：16 carton boxes full of plastic cups



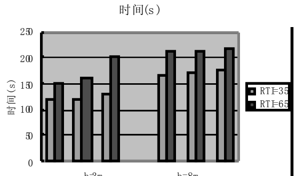
3.3 Household sprinkler

① Full scale test

Activation temperature



Activation time



3.3 Household sprinkler

② Result

- Activation time of fast response sprinkler is about 20% earlier;
- When mounting height is 3m, the max. ambient temperature, max. T of the structure and burning loss of the fuel of the fast response sprinkler has been reduced 25.0%、37.9% and 62.5% respectively；when mounting height is 8m, reduction of the three parameters is 8.2%, 7.8% and 20.0% respectively.
- Therefore, fast response sprinkler is recommended for high rise buildings and public assembly buildings.

4. Future considerations

4 Future considerations

① Feasibility study of using lift as a means of evacuation in high-rise building (mainly focus on some technical requirements)

② Fire water supply system for high-rise buildings

③ Technology for safe use of curtain wall system in high-rise buildings

④ Smoke control technology for large space atrium

The End

Thank you for your attention

Fire Safety of High-Rise Building in Taiwan
– Application of Research in Building Regulations

Dr. M.-Y. (Alec) LEI
Senior Research Officer, Fire Research Program
For
Dr. Ming-Chin HO
Director General, ABRI

Outlines

- Characteristics of High-Rise Fires
- Major Fires in Taiwan
- Reforming of BTR (Building Technical Regulations)
- Specific Research

Characteristics of High-Rise Fires

- Construction & Space features
  - Strong & durable structure
  - Huge floor area
  - Complex interior finishes
  - Numerous routes & openings
  - Various shafts & ducting
  - Atrium design


Characteristics of High-Rise Fires

- Features of Fire Disaster
  - clouding smoke & changeful flow
  - Fast fire spread & various means of spread
  - High temperature & uncontrolled fire severity
  - Difficult evacuation & high risk of casualty
  - Difficult rescue & high challenge for fire-fighting

Major High-Rise Fires in Taiwan

- 1995 Commercial Complex Fire
- 1996 Department Building Fire
- 2003 Office Building Fire

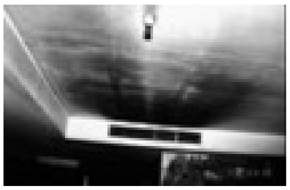
1995 Fortune World Building Fire /Chiayi

Issue - Smoke spread through shaft to the tall storey and projected out of shaft through the access door

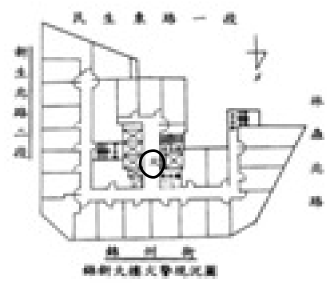


1995 Fortune World Building Fire /Chiayi

Issue – Smoke diffused into HVAC system and spread to all of guest room



1996 JinXin Department Building Fire /Taipei



1996 JinXin Department Building Fire /Taipei

Issue – Fire spread throughout the corridor because of combustible finish material and spread into duct shaft

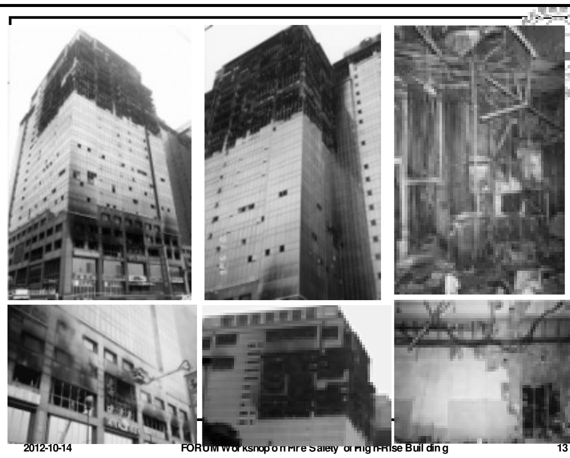
1996 JinXin Department Building Fire /Taipei

Issue – Smoke spread throughout the corridor and through the door into the suites

2003 Eastern Science Park Building Fire/ Xizie

- **The longest fire-fighting time, largest damaged area, the highest property loss and also the most numerous fire fighters joined the operation**
- **Issues – fire spread inside the service shaft, failure of sprinkler system, failure of internal fire compartment, lack of fire protection on curtain wall, poor management and maintenance**

Phases of Fire Spread：Lower Fire(3F-5F)→Incubation(spread inside shaft)→High-rise Fire(16F-26F)→ Neighbourhood Building Fire



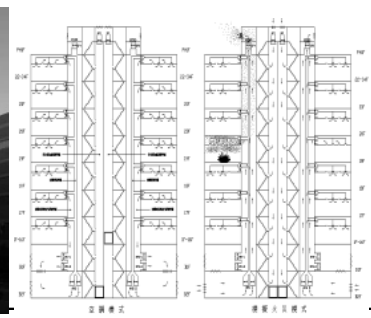
Reforming of BTR (Building Technical Regulations)

- Requirements on fire compartment
  - Shaft (access door)
  - Fire assembly (door, shutter, damper)
  - Spandrel of curtain wall system (Perimeter fire barrier system)
- Requirements on means of egress

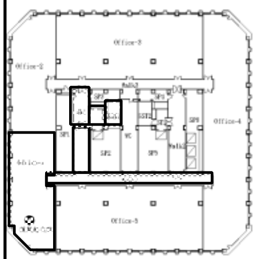
Specific Research

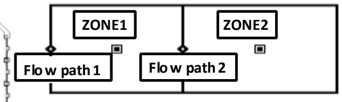
- Structural Fire Resistance
- Smoke Management Strategy
- Evacuation Analysis

Zoned Smoke Control and Validation

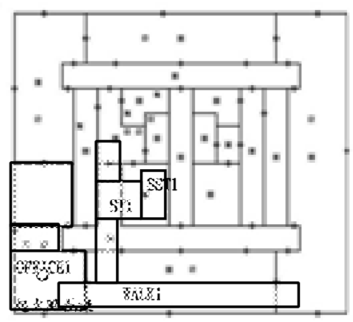


CONTAMW Airflow Model Setup





ITB Plan view model

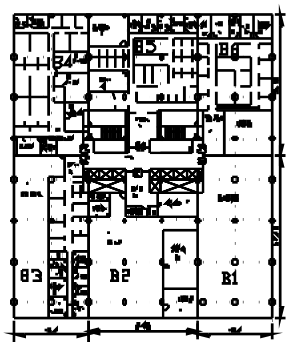


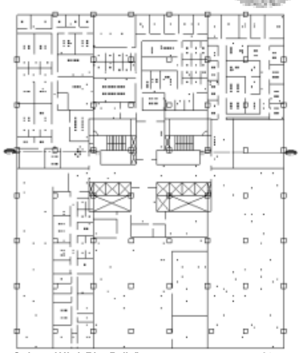
calculated vs. measured

Location	measured (Pa)	Calculated (Pa)
Office1 vs Walk1	0	0.9
Walk1 vs ST1	13	13.2
SST1 vs ST1	30	28.4

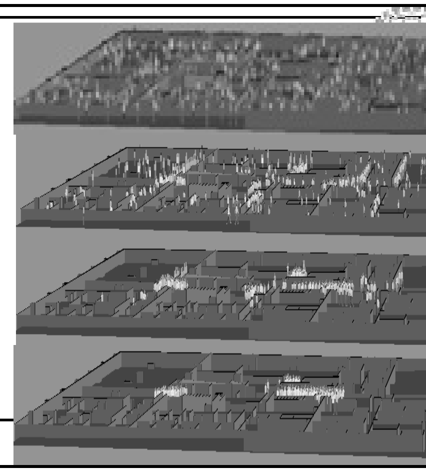
Evacuation Analysis of High-Rise Building

-Comparison between EXODUS & Guidance

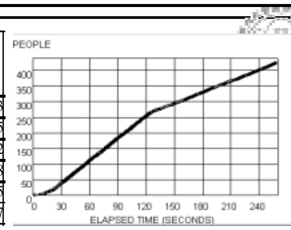




Evacuation Simulation Using building-EXODUS



居室別	避難人數 Number Out （人）	第一個通過時間 First exit (sec)	最後一個通過時間 Last exit (sec)
B1	84	2.1	80.53
B2	94	15.98	227.85
B3	50	16.49	105.2
B4	99	8.09	241.8
B5	53	7.21	60.85
B6	44	5.99	99.97



居室別	手冊人數	EXODUS 人數	手冊時間(s) t_{reach}	EXODUS first exit （s）	手冊時間（s） t_{escape}	EXODUS last exit （sec）
B1	73	84	88.2	2.1	115.24	80.53
B2	81	94	85.2	15.98	115.2	227.85
B3	71	50	88.2	16.49	114.5	105.2
B4	69	99	80.4	8.09	105.96	241.8
B5	74	53	80.4	7.21	107.81	60.85
B6	56	44	76.2	5.99	96.94	99.97

Thank you for your attention.

Contact us:

- **ABRI: http://www.abri.gov.tw**
- **Fire Experiment Center: http://firelab.abri.gov.tw**

Behaviors of Structural Assemblies of Building under Fire

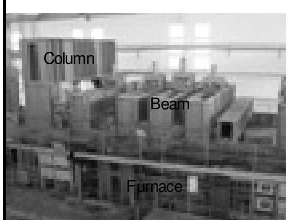
Chi-Chung Lee , Ming-Chin Ho, Ming-Yuan Lei

Architecture and Building Research Institute
Ministry of the Interior, Taiwan

Structure Catalogue

- Reinforced concrete
  - Fire resistance of beam-column subassemblage
- Steel structure
  - Structural behaviors of steel building beam-column connections in fire
- Steel reinforced concrete
  - Behavior of axially loaded concrete-filled steel box columns in fire

Test Facility
specification and function

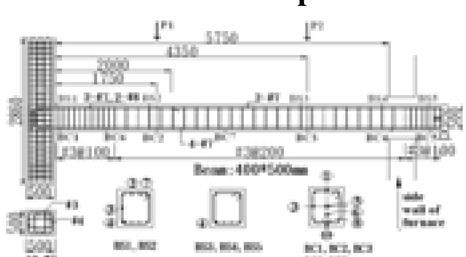


Dimensions:
(1)Column furnace - height 3.3 m, area 4 m*4 m, (2)Beam furnace - depth 2.3 m, area 4 m*8 m.
Heating: ISO 834, ASTM E119, BS 476...etc.
Loading:
(1)Column: 2000 tons.
(2)Beams: 100 tons.
(3)Distributed loading: 50 tons on 4 test subjects.
Loading control mode:
(1)Column and beam loading: force/displacement control.
(2)Uniform distribution loading: force control.

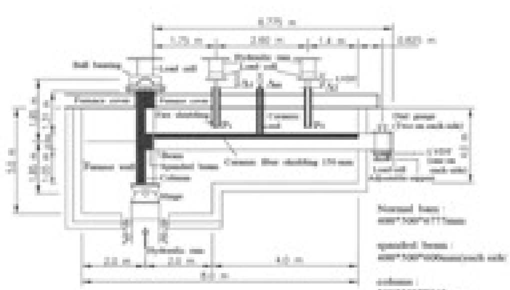
Fire resistance of beam-column subassemblage

- **Fire resistance of beam-column sub-assemblage designed based on seismic provisions**
- **Possible differences between ordinary and self-compacting concrete components under fire**
- **Establish the data base for future fire-performance based design**

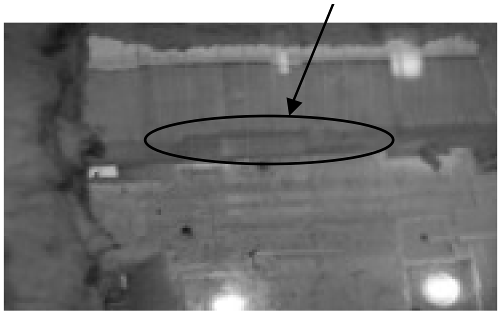
Reinforcement details and locations of thermocouples

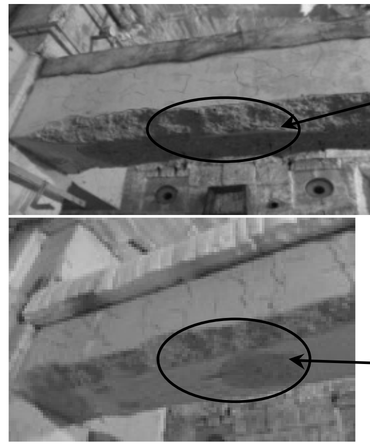


Schematic of installation

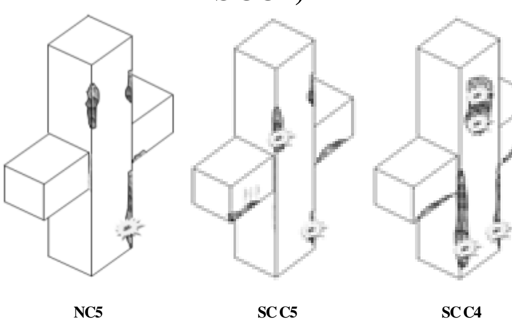


Spalling occurred along the bottom edge of beam during early stage of heating

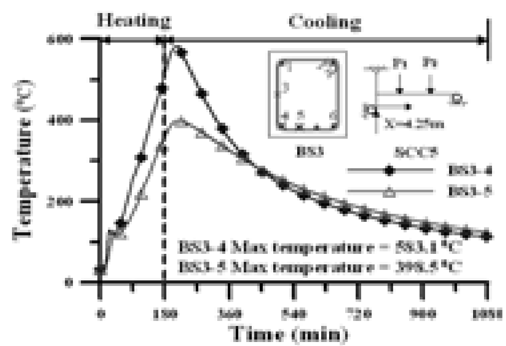




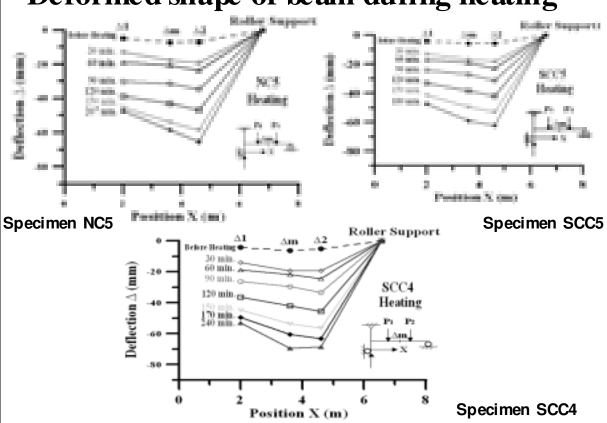
Spalling of column (NC5, SCC5, SCC4)



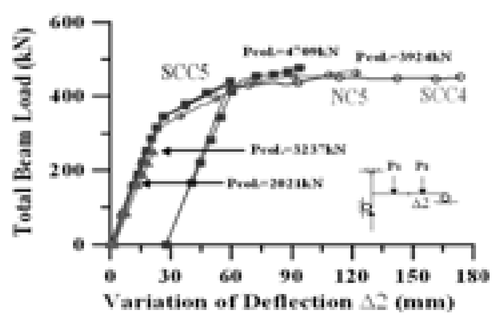
Variations of temperature of rebar in beam



Deformed shape of beam during heating



Total beam load vs. deflection at P2 (Residual strength test)



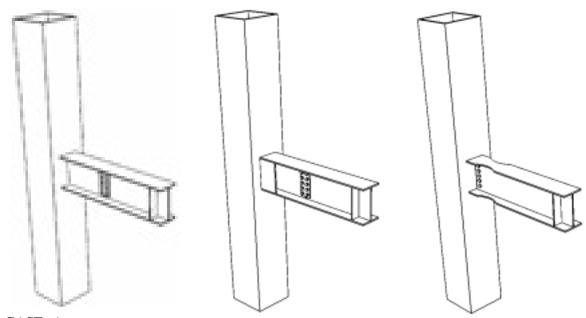
Flexural failure near P2 (Residual strength test, Specimen NC5)

Shear failure at P1 (Residual strength test, Specimen SCC5)

Structural behaviors of steel building beam-column connections in fire

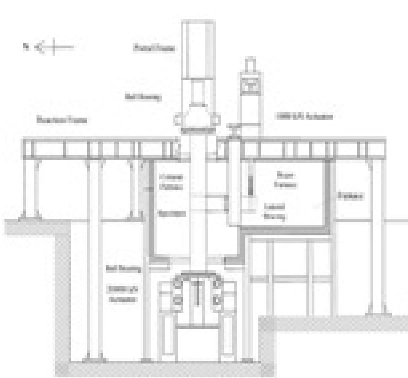
- At elevated temperatures the strength and stiffness of steel weakens, and the ability of the connections to withstand force during fire directly affects the redistributed stress from the beams to other structural members.
- This research presented a series test of steel beam-column moment connections in fires.
- Three full-scale beam-column moment connection specimens were tested at elevated temperatures according to the standard ISO-834 fire.
- The test result showed that the critical temperatures of beam-column sub frames depended on the type of the connections when subjected to fire.

Ordinary Beam Section (OBS)	Increase Beam Section (IBS)	Reduced Beam Section (RBS)

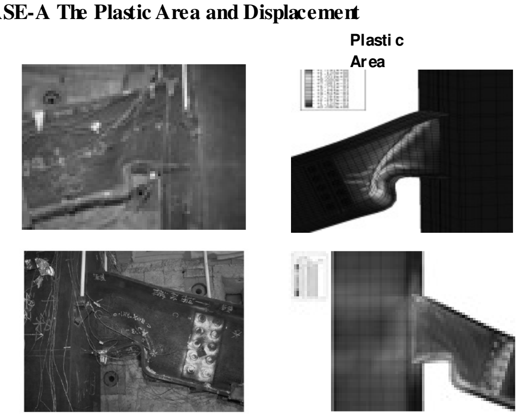


CASE-A Ordinary Moment Connection	CASE-B Side Plated Moment Connection	CASE-C Dogbone Moment Connection

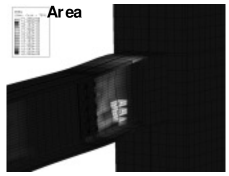
Schematic of installation

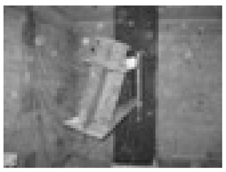


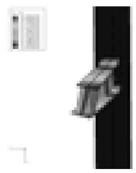
CASE-A The Plastic Area and Displacement



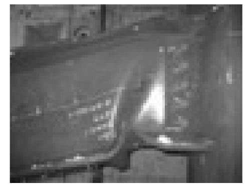
CASE-B The Plastic Area and Deformation

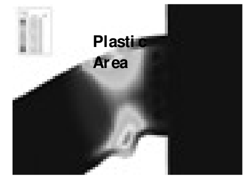


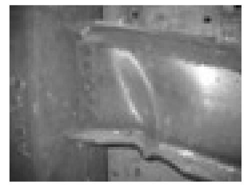


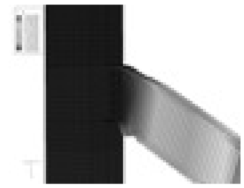


CASE-C The Plastic Area and Deformation









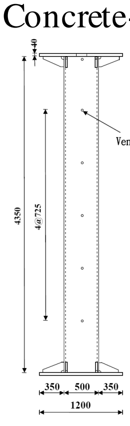
The Comparisons of Test and Simulation Result of the Three Moment Connections

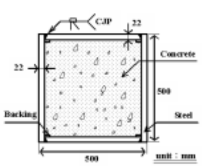
Type	CASE-A	CASE-B	CASE-C
Critical Temperature (Test)	587 °C	597 °C	586 °C
Critical Temperature (Analysis)	587 °C	596 °C	585 °C
Deviation(%)	0	-0.17	-0.17

Behavior of axially loaded concrete-filled steel box columns in fire

- The concrete-filled box columns (CFBCs) are frequently used for medium- and high-rise buildings. The CFBCs must be subjected to axial compression, and the structural behavior is complex under elevated temperature. Moreover, the study for large-scale specimens is still very lacking.
- The purpose of this study is to investigate experimentally and numerically the behavior of the large-scale concrete-filled box columns subjected to axial compression under fire.

Concrete-filled box columns specimen





CJP :Complete Joint Penetration Weld

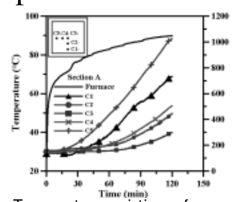
Specimen No.	Size	Steel	self-compacting concrete (fc')	fire proof
CFBC-1	□ 500x500 x22x22x4350 mm	CNS 13812 SN 490B	420 kgf/cm²	12 mm(2hr)
CFBC-2			700 kgf/cm²	12 mm(2hr)
CFBC-3			700 kgf/cm²	No

Note:CNS 13812 Rolled steels for building structure

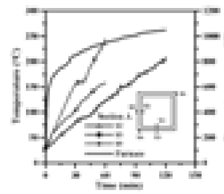
Test data

Specimen No.	Test time(min)	Maximum steel plate temperature (℃)	Applied load
CFBC-1	120	287	Pn（1550 tons）
CFBC-2	179	512	Pn（1600 tons）
CFBC-3	43	847	0.56Pn（900 tons）

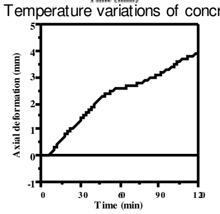
Specimen CFBC-1



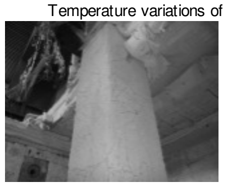
Temperature variations of concrete



Temperature variations of steel

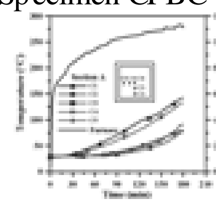


Axial deformation of column during heating

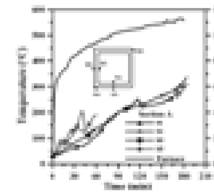


Failure modes of specimens

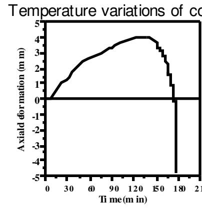
Specimen CFBC-2



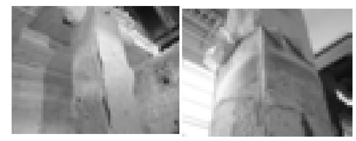
Temperature variations of concrete



Temperature variations of steel

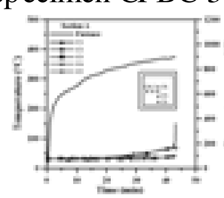


Axial deformation of column during heating

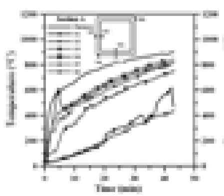


Failure modes of specimens

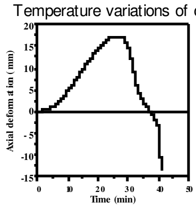
Specimen CFBC-3



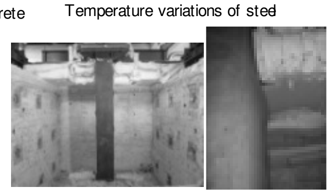
Temperature variations of concrete



Temperature variations of steel



Axial deformation of column during heating



Failure modes of specimens

Proficiency testing program on horizontal furnace and the fire resistant performance of insulated steel beam under different loads

Tensei Mizukami（水上　点睛）
The Center for Better Living

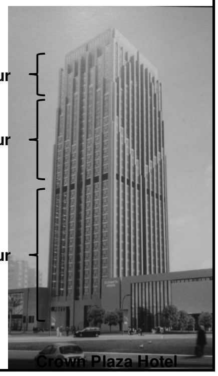
Back ground

Required Fire Resistance Time

	Top floor & 2~4F from the top	5~14F from the top	15F over from the top
Column	1hour	2hour	3hour
Beam	1hour	2hour	3hour
Wall	1hour	2hour	2hour
Floor	1hour	2hour	2hour
Ceiling	0.5hour		
Stair	0.5hour		

Maximum and Average temperature limit (Unloaded)

Steel Structure	Beam	Floor, Roof, Wall
Max. limit (℃)	450	500
Ave. limit (℃)	350	400



Objective and method

Objective 1: Assess reproducibility of horizontal furnace test

Method 1: Round robin test for insulated steel beam

Objective 2: Assess proposed calculation method for evaluating the fire resistance of structural steel under different loading conditions

Method 2: Full-scale furnace test under different loading conditions and high-temperature tensile test using the portion of the steel beam

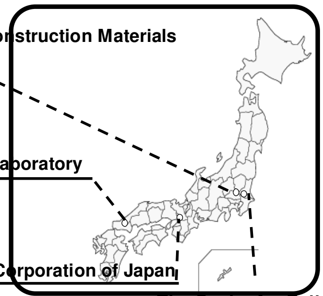
Japanese Fire Testing Laboratories

Japan Testing Center For Construction Materials

・Central laboratory
Souka, Saitama
Tel: 048-935-1995
Fax: 048-931-8684

・Western Japanese laboratory
Sanyo-Onoda, Yamaguchi
Tel: 0836-72-1223
Fax: 0836-72-1960

General Building Research Corporation of Japan
Suita, Osaka
Tel: 06-6834-0157
Fax: 06-6872-8170



The Center for Better Living
Tsukuba, Ibaraki
Tel: 029-864-1745
Fax: 029-877-0050

Principle of selecting the materials

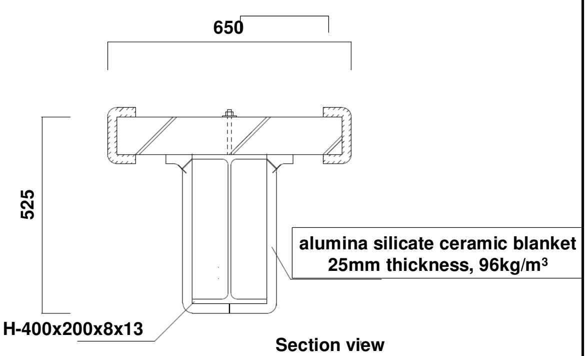
The variety and errors of products and construction procedure should be minimized.

・Base material: Structural rolled steel, SN class, same lot number – minimize production tolerance

・Insulation: Ceramic fiber blanket, seamless
– low skilled and less hand commission construction
– unaffected by furnace oxygen concentration

・Target time to failure: about 2 hours – mitigate the effect of accepting error for early stage of heating

Specimen

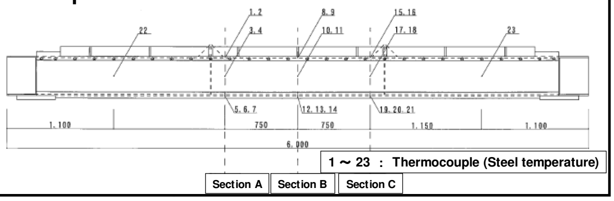


Section view

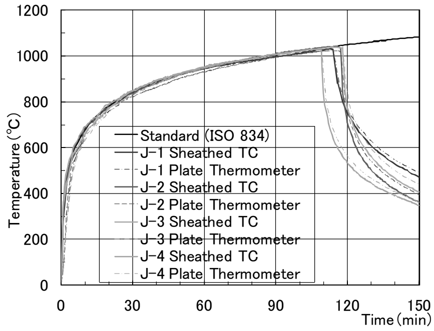
Failure criteria

- The maximum deflection reaches $L^2 / 400d$
- The maximum deflection speed reaches $L^2 / 9000d$
  (Range of application:
  The maximum deflection > L / 30)

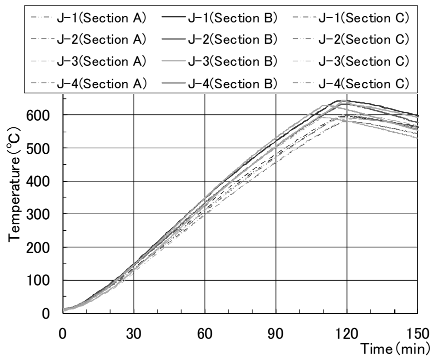
L: The support span
d: The distance between the edge of tension and compression in the section



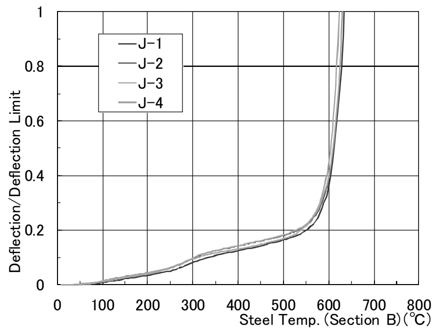
Results: Average furnace temperature



Steel temperature measurement



Deflection vs. Steel temperature measurement



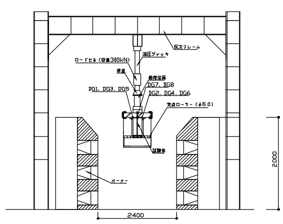
Summary 1

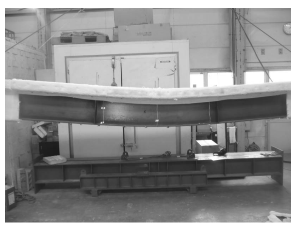
Time to failure and Steel temperature limit

	J-1	J-2	J-3	Average	J-4
Time to failure (min)	114	117	116	115.7±1.2	109
Critical Steel temp. (°C)	636	631	631	632.7±2.4	625

- Reproducibility of horizontal furnace test using standard steel beam structure was reasonable.

The performance of insulated steel beam under different loading condition





Steel beam structure after ripping off the insulation

Test procedure

Loading calculation

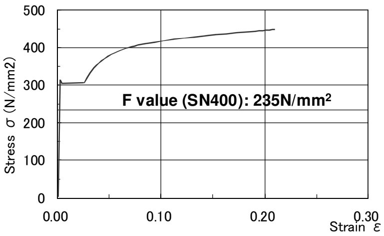
$\sigma = F/1.5$ **(standard)**

Long-term loading

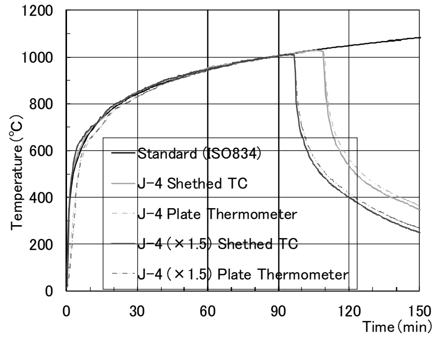
(Maximum design value)

$\sigma_{(1.5)} = 1.5\times\sigma = F$ **(this test)**

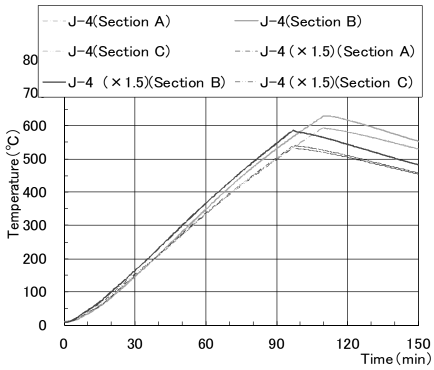
1.5 times larger loading



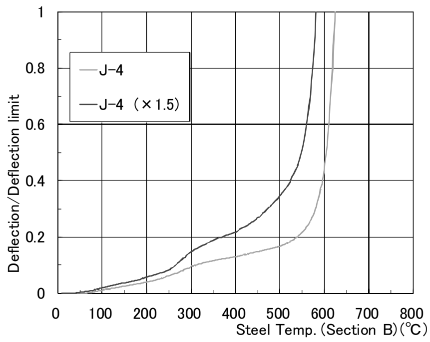
Results: Average furnace temperature



Steel temperature measurement



Deflection vs. Steel temperature measurement



Summary 2

Time to failure and Steel temperature limit

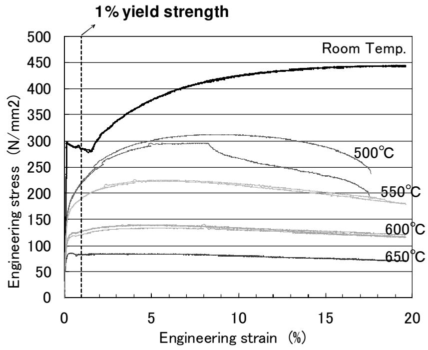
	J-4	J-4 (×1.5)
Time to failure (min)	109	96.5
Critical Steel temp. (°C)	625	548

- **The temperature increase rate was not changed until the time to failure and not different from standard loading condition.**
- **The deflection speed depends on the loading conditions.**

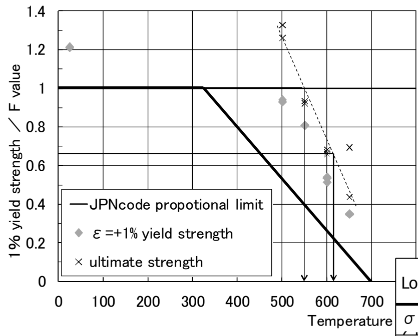
High-temperature tensile test

- Samples were obtained from steel beam specimen
- Tested at room temp, 500, 550, 600, 650C
- Tensile speed:
  0.3% / min by 19.6%
  3.75mm / min
  by fracture point

High-temperature stress-strain behavior



High-temperature tensile behavior



Furnace test results

Loading condition	Critical temp.
σ=F/1.5	625℃
σ=F (x1.5)	548℃

Conclusions

- All Japanese testing laboratories conducted proficiency furnace testing for load-bearing insulated steel beam structure. And the reproducibility has been checked.
- High temperature stress-strain relationships were obtained both load-bearing furnace test and high-temperature tensile test. And the proposed calculation method was checked to be conservative compared with these data.

Fire safety in French high rise buildings

Pierre Carlotti

Safety in high rise building: enforced by law

➔Code de la construction et de l'habitation
➔2 parts:
  ➔Law (voted by the parliament)
  ➔Regulations (decided by the government)

➔ applies to all building on technical criteria
➔ whoever the owner is
➔ whatever the insurer may wish

Early high rise buildings in France

➔ Haussmannian Paris (1870-1920) : a uniform 8-storey design – no specific dispositions
➔ « Gratte ciel » disctrict in Villeurbanne (near Lyon): accomodation blocks
  ➔built 1927-30
  ➔19 storeys
  ➔Reinforced concrete structure
  ➔Central heating, electric stoves (no gaz in the building)
  ➔Nearly no other specific design choice

Early high rise buildings in France

➔Le Corbusier : designs for Paris (plan Voisin, 1922-25) and Alger, not built
➔Cité radieuse: 20 storeys

February 2012
Propagation through the floors
20 flats concerned

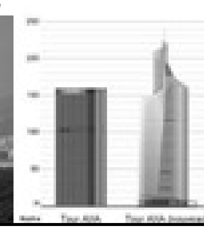
1958: La Défense district

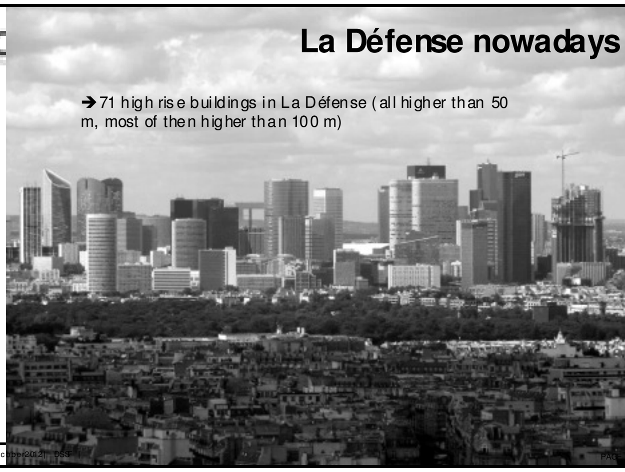
➔1958: creation of the special district « La Défense »
➔1963 : « Esso Tower » (now destroyed)
➔1964 : Plannig allows 100 m buildings
➔1966 : Nobel tower, refurbished 2003

New constructive system ➔ curtain walls
Starting point of the (then) new High Rise Building Regulation

High rise buildings in France nowadays

➔less than 100 in total in France
➔ France is the European country with the most numerous high rise buildings
➔Highest high rise building « First tower » 231 m, 1974, refurbished 2007-2011
➔Projects : twin Hermitage towers, 330 m
➔CMA-CGM Tower, Marseille





La Défense nowadays

➔71 high rise buildings in La Défense (all higher than 50 m, most of then higher than 100 m)

High rise buildings regulations in France (1)

➔1967: First High rise building regulations
➔1977: Second High rise building regulations
➔2011: Third High rise building regulations
➔Apply to new buildings only, but a heavily refurbished building are seen as « new »

➔Safety principles:
1. Fire resistant compartiments (2 hours) and limitation of calorific potential per compartiment
2. Evacuation
3. Active safety equipments
4. Lift service in case of a fire
5. Prevention of smoke motion out of the fire compartiment
6. Separation of the building from other buildings

2 types of buildings :
➔Accomodation buildings higher than 50 m (other texts for lower accomodation buildings)
➔ Other buildings (offices, hotels, etc.) higher than 28 m

Nota : constructive consequence of Safety principles: all buildings have a central concrete core

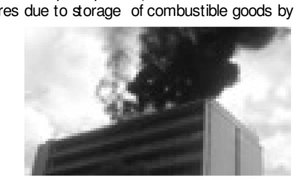
High rise buildings regulations in France (2)

New regulation → 30th December 2011 – 86 pages (in French)
http://www.legifrance.gouv.fr/jopdf//jopdf/2012/0118/joe_20120118_0019.pdf

High buildings which are not high rise buildings

➔France has a lot of accomodation buildings between 28 and 50 m
➔This is the case of the 2 historical examples quoted (Villeurbanne, Cité Radieuse)
➔A few recent and spectacular fires due to storage of combustible goods by residents

Roubaix



Annecy

➔Very different safety principle: no self-evacuation but assisted evacuation ; no limitation of combustible mass
➔Staircase fire (L'Hay Les Roses 2006– mailbox fire), 18 victimes

Fire propagation through façade plumes

➔Problem analysed for the first (1967) regulation due to the (then) new curtain wall system
➔Design of a special test (LEPIR2) after an international benchmarking and a study travel in Japan
➔Renewed interest in view of the use of wood in construction

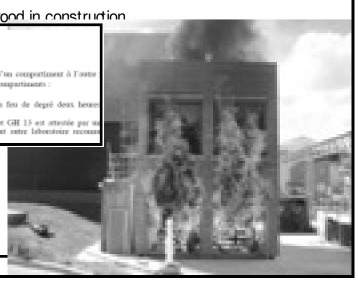
Article GH 12

Généralités relatives aux façades

Les façades sont conçues et réalisées de façon à limiter la propagation du feu d'un compartiment à l'autre
– par les jonctions des façades avec les structures et parois aux limites des compartiments ;
– par l'extérieur.

Les façades ou parties de façades ayant une fonction porteuse sont stables au feu de degré deux heures ou R. 120.

La conformité des façades aux dispositions réglementaires des articles GH 12 et GH 13 est attestée par un avis du Centre scientifique et technique du bâtiment, d'Efectis France ou de tout autre laboratoire reconnu compétent par la commission centrale de sécurité.

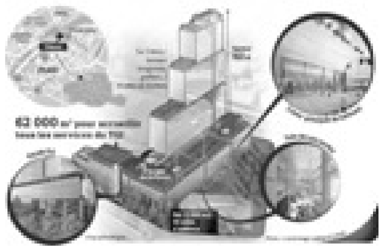


Main changes in the new regulations

➔New class of « Very high » buildings (above 200 m)
➔Fire mitigation system compulsory (sprinkler, water mist, …)
➔Fire resistant (structural stability) 3 hours (instead of 2 hours)
➔At least 3 lifts able to reach the highest level in less than 60 s
➔2 safety central offices + safety officer located at 2/3 of the height
➔Simplification for accommodation buildings with limited public spaces
➔Simplification of regulation interpretation for multi-activity building
➔Integrated safety system better taken into account
➔More stringent smoke removal
➔One evacuation exercise per compartment per year
➔Leave the compartment with stairs to the adjacent one
➔Then use of the lifts

Separation of the building: may seem easy, but..

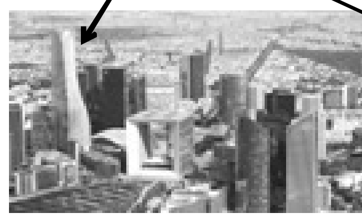
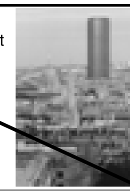
Difficulties with complex buildings, or building with several uses
e.g. future Paris tribunal (Renzo Piano)
- justice court (with public)
- magistrate offices
- Prison space



➔ Commission centrale de sécurité (CCS) in charge of approving derogations / interpretations

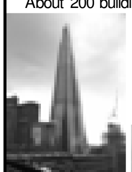
Do « very high » high rise buildings exist in France?

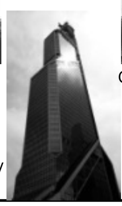
Today: Tour Maine-Montparnasse (1974) and Tour First
Projects: tours Phare (297m) and Hermitage (323m)

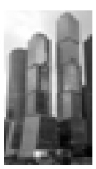



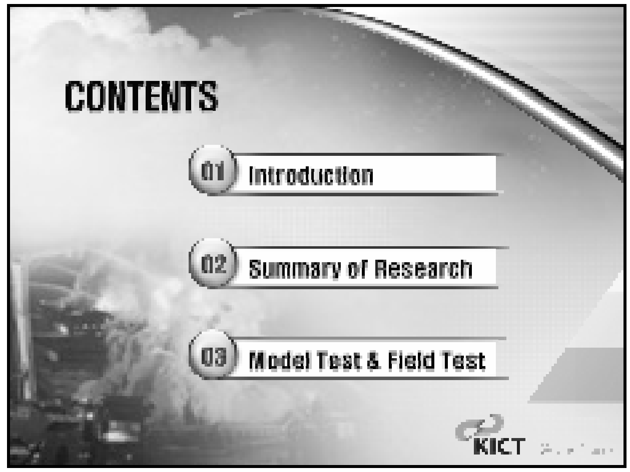
And in Europe?

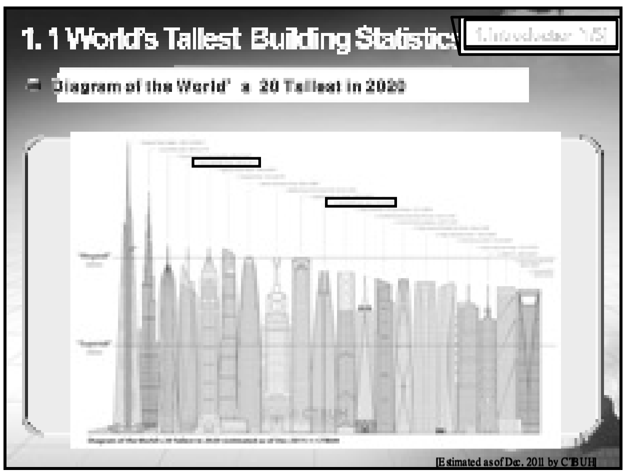
23 Buildings higher than 200 m
About 200 buildings higher than 100 m

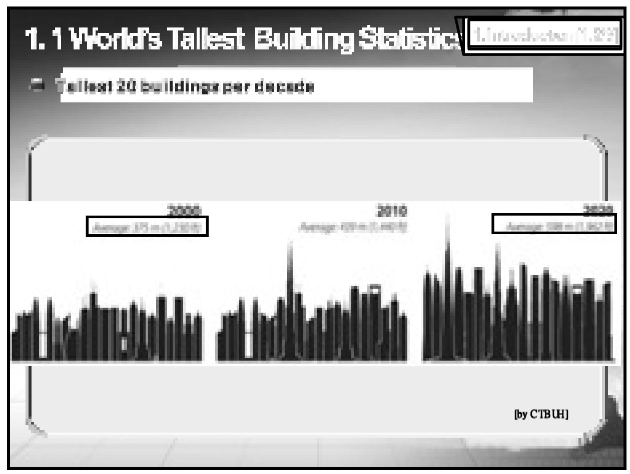

London Shard

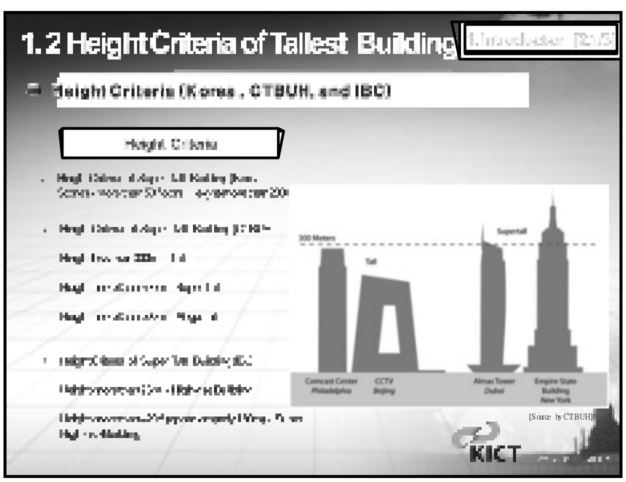

Mercury City (end 2012)

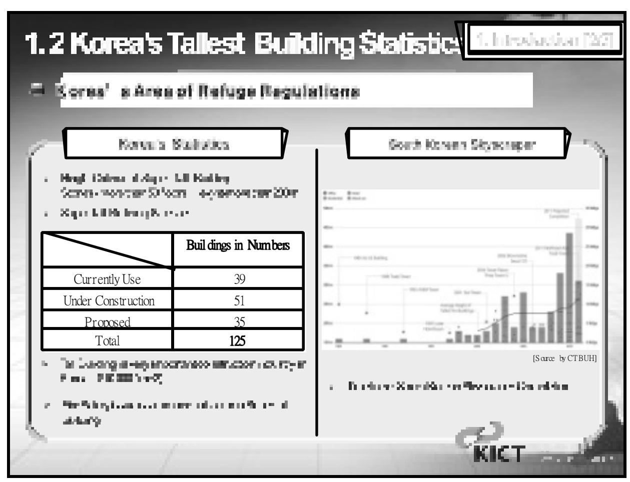

City of Capitals



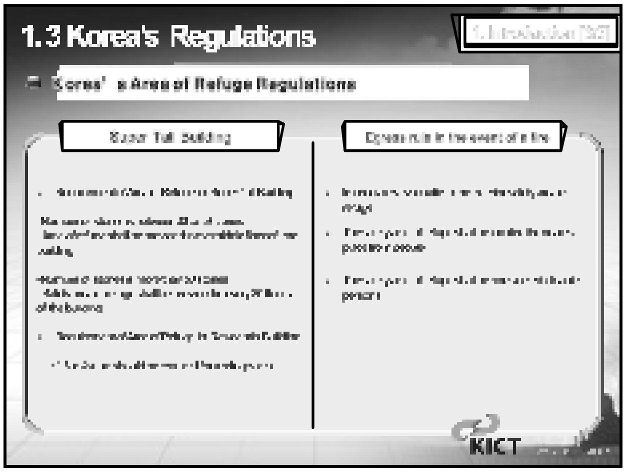


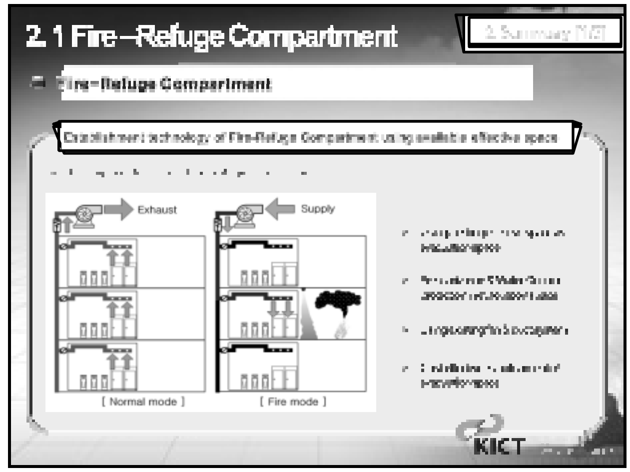


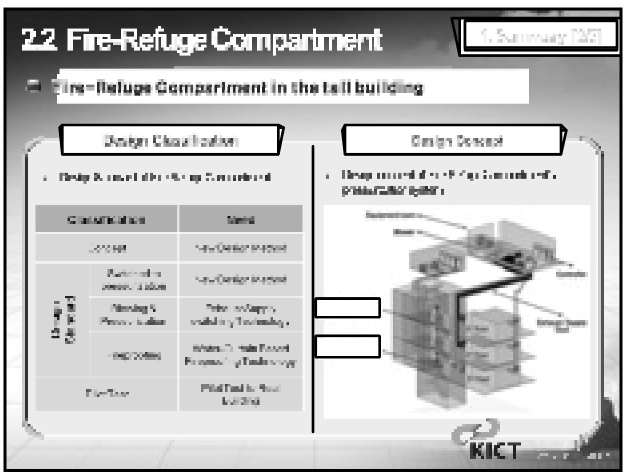


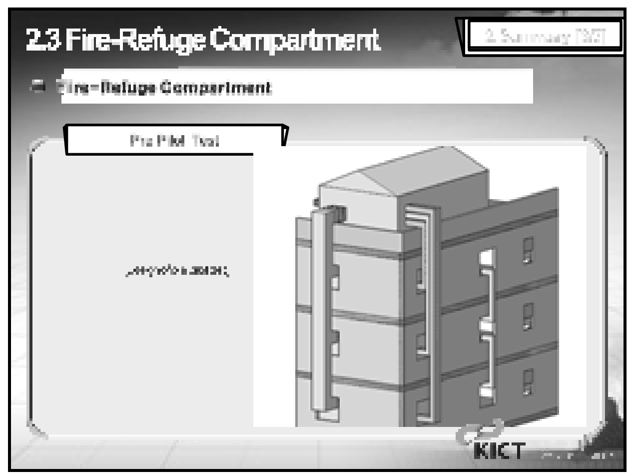


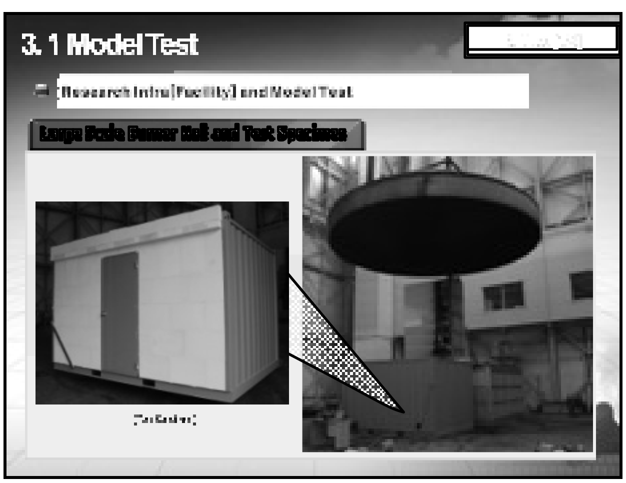
	Buildings in Numbers
Currently Use	39
Under Construction	51
Proposed	35
Total	125

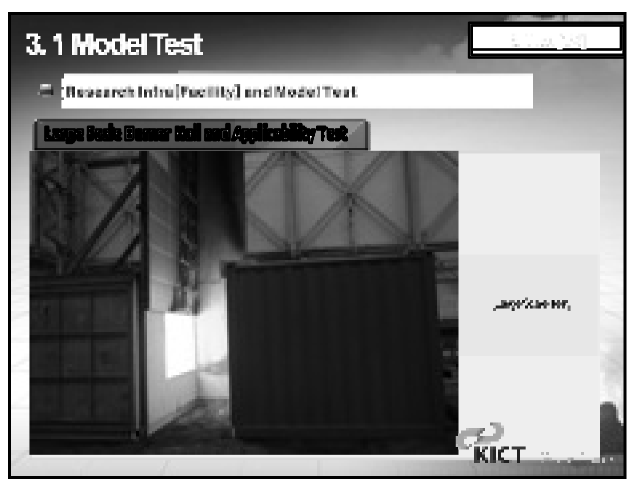

1.3 Korea's Regulations
Super Tall Building
KICT

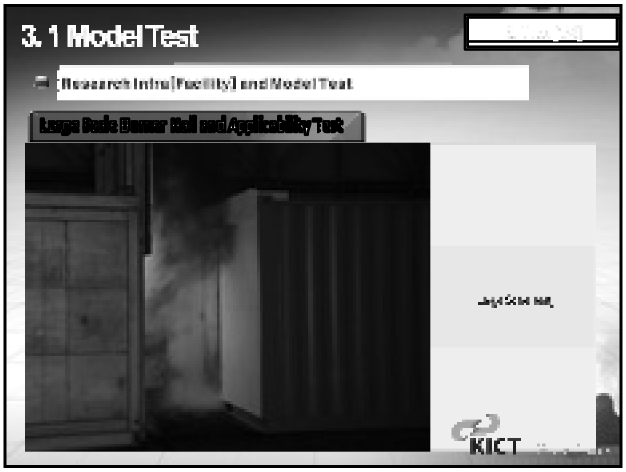

2. 1 Fire –Refuge Compartment
Fire-Refuge Compartment
Exhaust
Supply
[Normal mode]
[Fire mode]
KICT

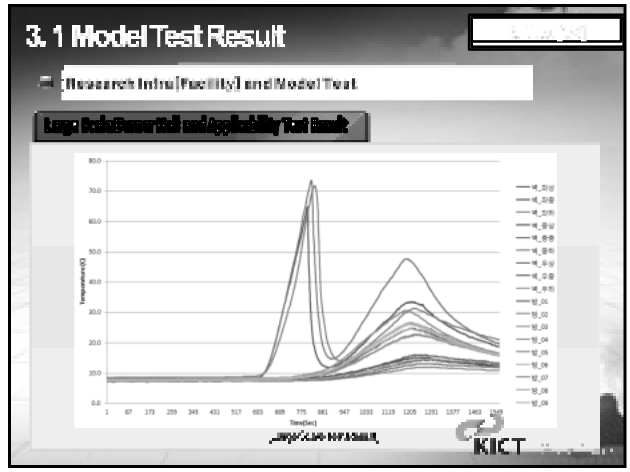

2.2 Fire-Refuge Compartment
Fire-Refuge Compartment in the tall building
Design Classification
Design Concept
KICT

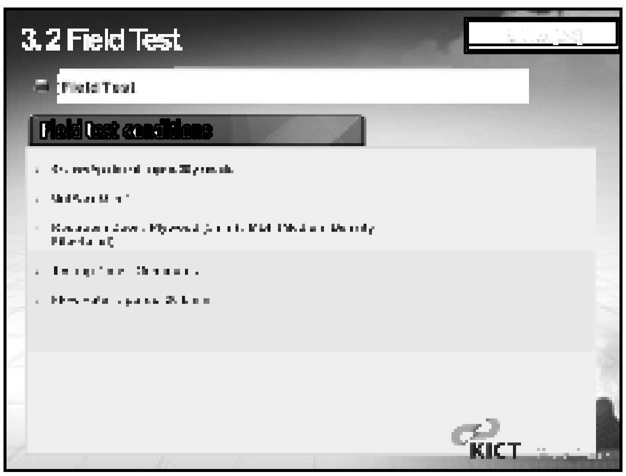

2.3 Fire-Refuge Compartment
Fire-Refuge Compartment
KICT

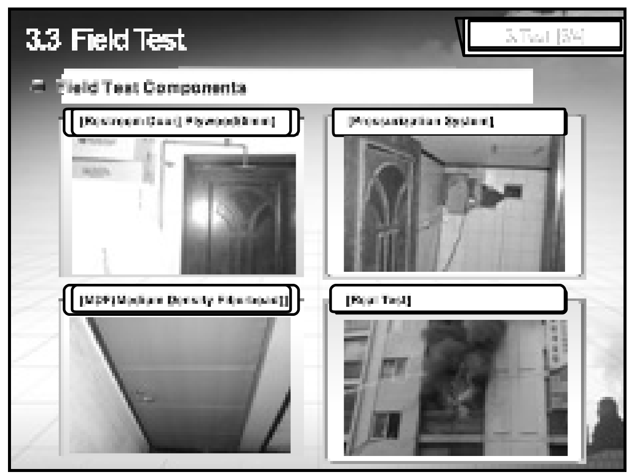

3. 1 Model Test
[Research Infra(Facility)] and Model Test
Large Scale Burner Hall and Test Specimen

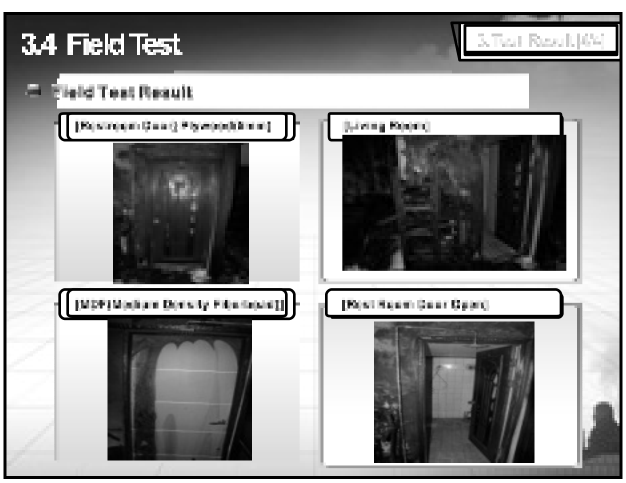

3. 1 Model Test
[Research Infra(Facility)] and Model Test
Large Scale Burner Hall and Applicability Test
KICT

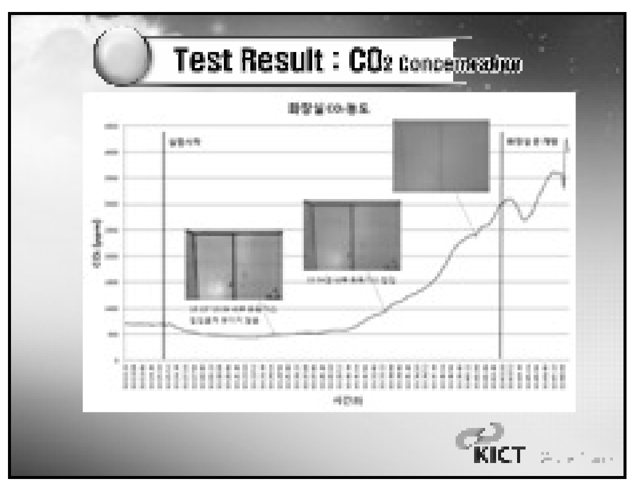

3. 1 Model Test
Research Infra(Facility) and Model Test
KICT


3. 1 Model Test Result
Research Infra(Facility) and Model Test
KICT


3.2 Field Test
Field Test
Field test conditions
KICT


3.3 Field Test
Field Test Components
[MDF(Medium Density Fiberboard)]
[Real Test]
KICT


3.4 Field Test
Field Test Result
[Living Room]
[MDF(Medium Density Fiberboard)]
[Rest Room Door Open]


Test Result : CO2 Concentration
KICT

Analysis & Future Process

■ Result

– To ensure the applicability of using a restroom as an area of refuge (2hr ~3hr)

– Wetted Normal door using a water curtain system can be have a fire-resistance rating

■ Future Plan

– Running simulation and real scale test to ensure the reliability
- Research Period : 2012. 11~2013. 12
- Test facility : KICT Smoke Control Tower

KICT

Suggestions

■ International co-project with FORUM members

: Applicability of the Fire-Refuge Compartment in case of a fire of high-rise building

:Life safety Standards for a restroom as the Fire-Refuge Compartment

–Mechanical Systems/Emergency Power System etc

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Alternative

Fire-Refuge Compartment

using a Restroom

Thank You!!

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附錄 4. 大陸文化古蹟及歷史建築防火保護相關手冊及規範

- 棲霞寺古建築物保護消防宣導手冊
- 古建築消防管理規則（1984.2.28）
- 北京市地方標準 DB 11/791-2011 文物建築消防設施設置規範（2011.4.28）
- 北京市古建築消防管理規定（1983.3.28）
- 北京市文物建築裝修暫行標準及管理規定（2006.4.3）
- 河南省地方標準 DB 41/T 692-2011 文物建築消防安全管理規範
- 山西省文物建築消防安全管理規定（2007.1.5）