超高層火災時の煙避難事例を通した日本の安全対策

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Outline of presentation

- Safe evacuation requirements of the Building Standard Law (BSL) in Japan
- Past large-scale fire incidents in Japan
- Issues for fire safety and evacuation in high-rise buildings
- Fire incidents of super high-rise buildings in USA

Safe evacuation requirements of the Building Standard Law (BSL) in Japan

Basic concepts of fire safety in BSL

- Fire protection
  - Preventing buildings from catching fire from outside
  - Preventing fire outbreak, fire spread, etc. in buildings
- Fire evacuation
  - Ensuring safe evacuation of occupants in each building

Chapters of the BSL pertaining to evacuation safety

- Chapter IV
  - Fire-resistive construction, quasi-fire-resistive construction, fire preventive construction, fire compartments, etc.
- Chapter V
  - Evacuation facilities, etc.
- Chapter V-2
  - Interior finish of special buildings, etc.

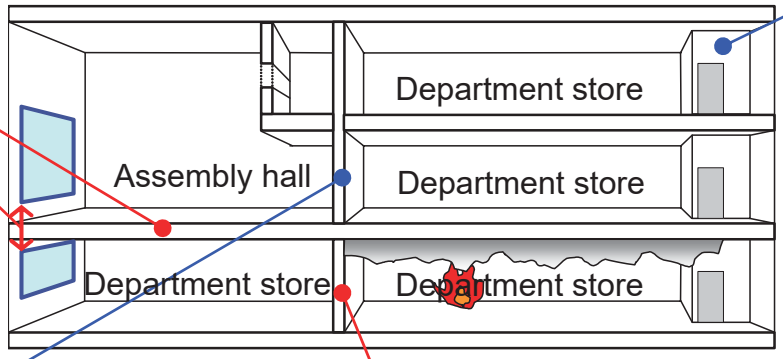
Overview of fire compartmentation

- *To divide the space such that each compartment is <1500 m^2 (3000 m^2 if fire sprinklers installed)*
- *To divide the space such that each compartment is <100 m^2 on the 11th floor or higher (200 m^2 if the interior surface is finished with quasi-noncombustible materials, and 500 m^2 if finished with non-combustible materials)*
- *To divide **vertical spaces** (atrium, stairwell, elevator shaft, duct space, and other similar parts) from other parts*
- *To divide the parts for use as schools, theaters, public halls, markets, automobile garages, department stores, apartment houses, hospitals, warehouses, and the like from parts for another use*

Fire compartments to divide into areas <100 m^2 (11th floor or higher)

Fire compartments of vertical shaft

Fire compartments of spandrels and floors



Fire compartments to divide into areas <1500 m^2

Fire compartments to prevent fire from affecting an adjacent area for another use

Provision of evacuation facilities

- *Corridors, escape stairs, and entrances/exits*
  - *Width of corridors*
  - *Through stairs to evacuation floor*
  - *Two or more through stairs*
  - *Escape stairs and special escape stairs*
  - *Width of escape stairs, etc. in stores*
  - *Exits to outside*
  - *Rooftop plaza (buildings for department store use on the 5th floor or higher)*

Provision of evacuation facilities

- Smoke ventilation equipment
- Lighting apparatus for emergency use
- Entrances for emergency use (for firefighters)
- Passageways, etc. within building sites necessary for evacuation and fire service

Outline of interior finishing

- Interior finishing of special buildings, etc.

Past large-scale fire incidents in Japan

History of BSL amendments on evacuation safety and major fire incidents

Year	Major amendment of BSL on evacuation safety requirements
1950	(Enactment of BSL)
1959	- Fire compartments (except for vertical shaft)
1964	- Fire compartment and evacuation facilities in high-rise building
1969	- Fire compartment of vertical shaft
1970	- Smoke ventilation equipment - Lighting apparatus and entrances for emergency use - Width of escape stairs, etc. in stores
1998	- Introduction of performance-based code

Building fires since 1950 (>30 deaths)

Oohara Theater (1951) ------39 dead
Seibo-no-Sono Elderly Home (1955) ----------99 dead

Kikufuji Hotel (1966) -------30 dead
Ikenobo Mangetsujo (1968) 30 dead

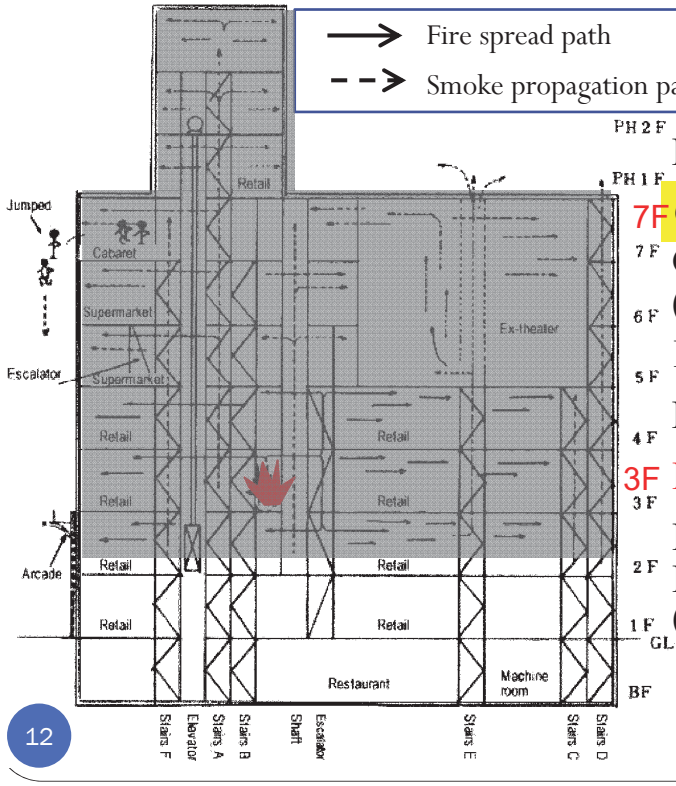
Banko Hotel (1969) ---------30 dead

Sen'nichi Department Store (1972) ----------118 dead
Taiyo Department Store (1973) ---------- 103 dead

Kawaji Prince Hotel (1980) 45 dead
Hotel New Japan (1982) ----32 dead

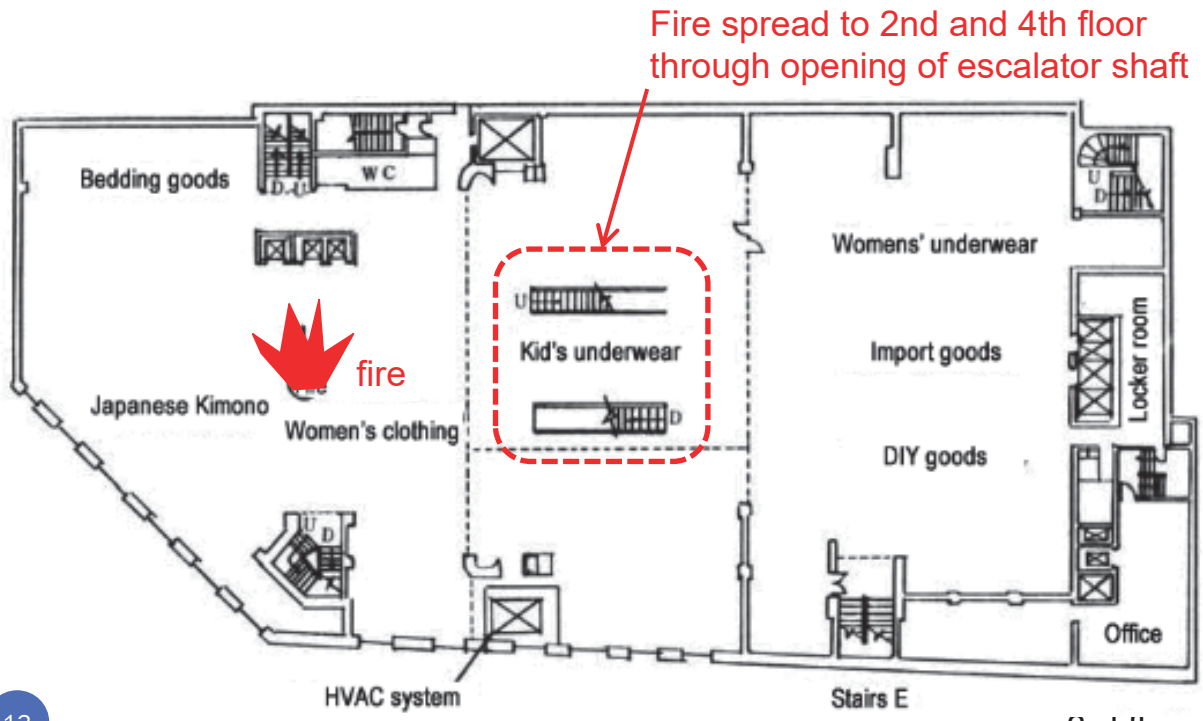
Meisei 56 Bldg. (2001) ------44 dead

Sen'nichi Department Store Fire



Department
7F Cabaret (181 occupants→118 dead)
7 F Game corner (6 occupants →0 dead)
6 F Dept. store
5 F Dept. store (2 occupants →0 dead)
4 F
3F Dept. store (5 occupants →0 dead)
3 F
2 F Dept. store
Dept. store, guard's room (14 occupants →0 dead)
1 F
GL
BF Restaurant, machinery room (2 occupants →0 dead)

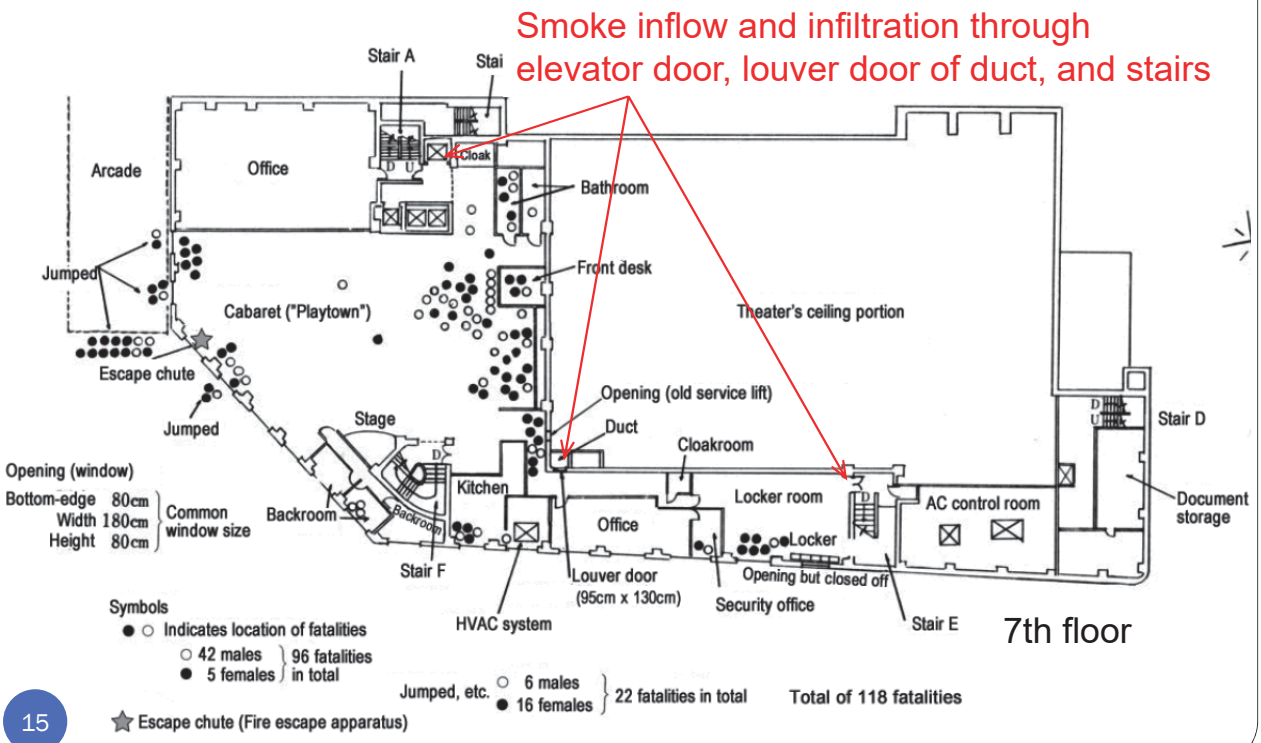
Sen'nichi Department Store Fire



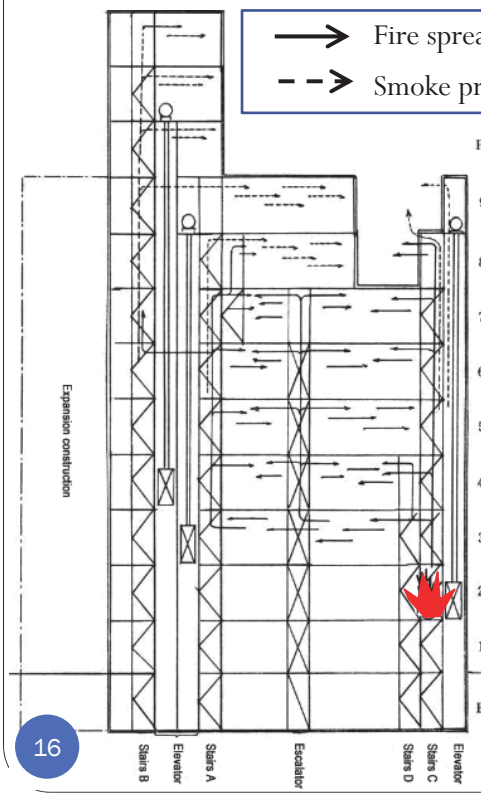
3rd floor

Sen'nichi Department Store Fire

Sen'nichi Department Store Fire



Taiyo Department Store Fire



PH F PH1-4: Machinery room (18 occupants→0 dead)

9 F 9F: Hall* (10 occupants→0 dead)

8 F 8F: Office* (51 occupants→1 dead)

7 F 7F: Restaurant, etc.(257 occupants→29 dead)

6 F 6F: Dept. store (69 occupants→31 dead)

5 F 5F: Dept. store (114 occupants→1 dead)

4 F 4F: Dept. store (82 occupants→40 dead)

3 F 3F: Dept. store (103 occupants→1 dead)

2 F 2F: Dept. store (137 occupants→0 dead)

1 F 1F: Dept. store (137 occupants→0 dead)

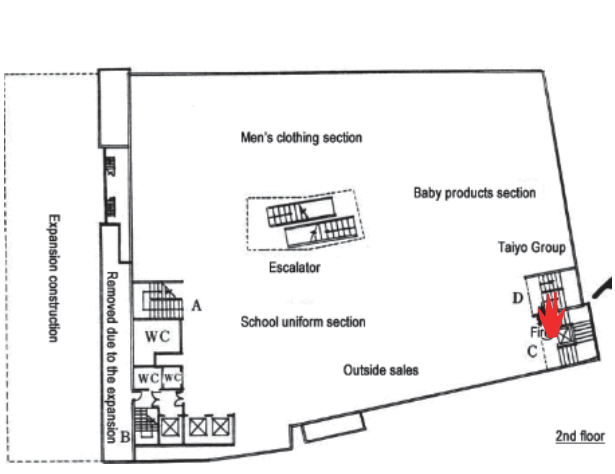
GL

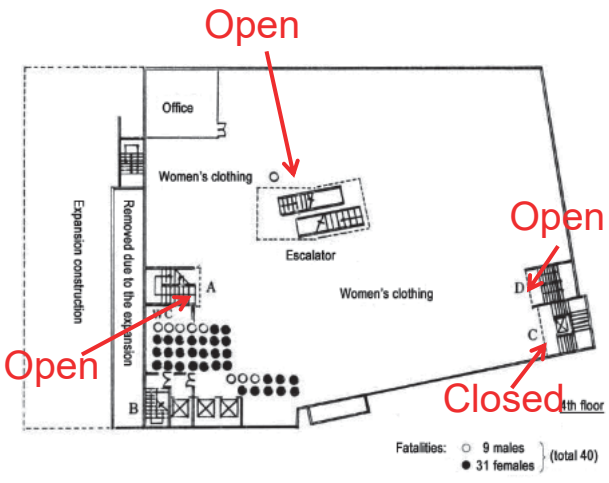
B F B1F: Dept. store (169 occupants→0 dead)

*Under renovation

Taiyo Department Store Fire

Taiyo Department Store Fire

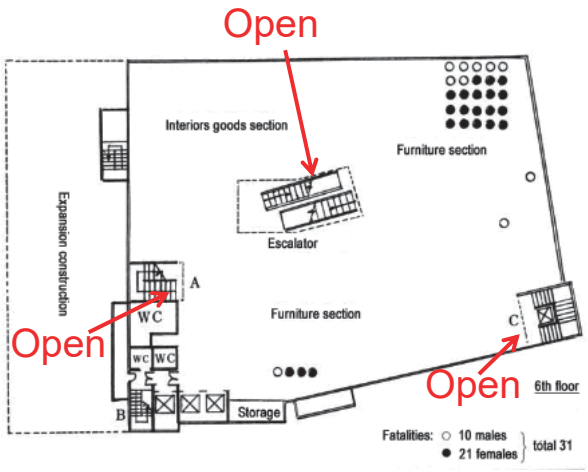




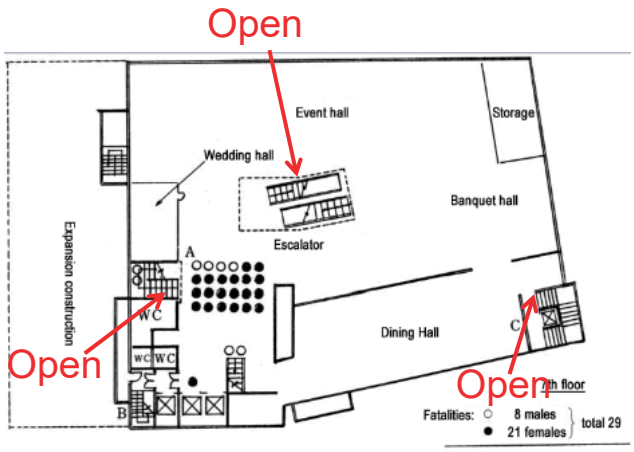
2nd floor

4th floor

Taiyo Department Store Fire



6th floor



7th floor

Issues for Fire Safety and Evacuation in High-rise Buildings

高層ビルにおける防火と避難の課題
Issues for Fire Safety and Evacuation in High-rise Buildings

A) Measures to confine a fire within the floor that the fire started and prevent fire spread to upper and lower floors.

B) Measures to prevent the smoke diffusion by fire to upper and lower floors.

C) Fire resistive performance to prevent structural failure.

D) Plan for prompt and safe evacuation in a high-rise building.

E) Facilities for prompt access for fire-fighters to upper floors.

F) The issues for evacuation by elevators, while in many cases elevators were used for evacuation in the past.

G) Measures of evacuations for disaster-vulnerable people, such as aged , handicapped people, etc.

Issues for Fire Safety and Evacuation in High-rise Buildings

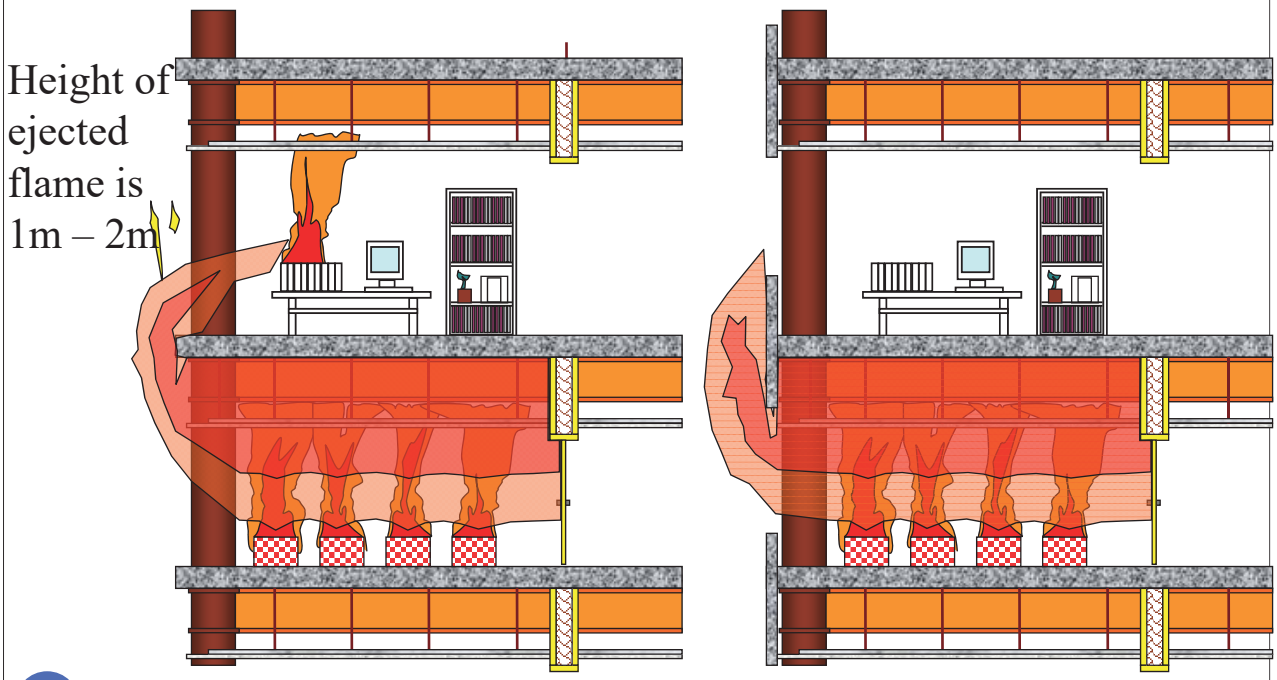
A) Measures to confine a fire within the floor that the fire started and prevent fire spread to upper and lower floors.

B) Measures to prevent the smoke diffusion by fire to upper and lower floors.

① Spandrel (to prevent fire spread through openings on the exterior walls) and compartmentaion of vertical space (to prevent fire spread and smoke diffusion inside a building) must be saved. Especially compartmentalization of stair space, EV shaft, EPS shaft, and pass-through space of pipes/cables must be well protected.

② Smoke control plan (by mechanical system, by pressurization, and natural vent through an atrium etc.) and actuation sequence in the case of a fire must be known to everybody.

What is "spandrel" and for what purpose?



For spandrel, the height of 90 cm or more is required.

C) Fire resistive performance to prevent structural failure.

1. Design to localize the fire impact to structural elements by preventing fire spread over fire compartmentation.

2. Fire safety structural design for assuring fire resistive performance by giving appropriate and sufficient fireproofing protection.

Issues for Fire Safety and Evacuation in High-rise Buildings

D) Plan for prompt and safe evacuation in a high-rise building.
E) Facilities for prompt access for fire-fighters to upper floors.

1. Installation of the fire and smoke proof stairs with vestibule space between the stairs and hall way (it is called as special egress stairs for evacuation and designated in Building Standard Law in Japan).
2. The access of fire-fighters (upward) and the evacuation routes of occupants (downward) do not cross each other, in other wards installation of stairs and EV exclusively used by fire brigades is required. The EV for fire-fighters is called as emergency-use EV and is also designated in Building Standard Law in Japan) and this EV should be located next to the vestibule space that is shared by the egress stairs.

Issues for Fire Safety and Evacuation in High-rise Buildings

Requirement and Features of Special Egress Stairs in High-rise buildings Japan

- All stairs that connect to 15th and higher floors are required to be "Special Egress Stairs".
- It should connect directly to the ground floor.
- It should be compartmentalized with fire rated walls.
- It should be attached with a vestibule with smoke control system in front of the entrance door of stairs.
- It is mainly used for evacuation of occupants, but after then it may be used by fire brigades.

Issues for Fire Safety and Evacuation in High-rise Buildings

Requirement and Features of Emergency-use Elevator in high-rise buildings in Japan

- Buildings with 31m height or higher are required to be installed with "Emergency Elevators".
- Required number of emergency elevators is depending on the maximum floor area among floors over 31m height. (Within 1500 m^2 : 1, over 1500 m^2 : +1 by 3000 m2)
- Compartmentation with fire rated walls is required around the elevator shaft.
- Smoke control system is required in the lobby.
- Compartmentation with fire resistance door is required in the lobby.
- Mainly used for rescue and firefighting by fire brigades.

Issues for Fire Safety and Evacuation in High-rise Buildings

F) The issues for evacuation by elevators, while in many cases elevators were used for evacuation in the past.

1. Elevators for evacuation, if needed, should be fire and smoke proof and have buck-up power like emergency-use elevators for fire-fighters in Japan.
2. Fundamental principles of evacuation by elevators, for example which floor and/or who has priority for evacuation in relation to fire floor, physical/mental conditions as aged, child, disaster-vulnerable people have to be softwarily inquired.
3. To begin with, if we compare by evacuation completion time for all evacuees, which is more efficient evacuation by stairs or elevators? Also, we have to study how to allocate the evacuees by stairs and elevators.

Issues for Fire Safety and Evacuation in High-rise Buildings

G) Measures of evacuations for disaster-vulnerable people, such as aged , handicapped people, etc.

1. In some facilities such as hospitals and nursing-homes, where some have difficulties in walking or some are bedridden, the plan for evacuation by elevators is adopted in Japan.
2. The concept of safe 'Besieged evacuation' is required for untransferable patients in ICU, CCU, but in the hospital etc. the concept of horizontal evacuation is generally the most actual as the measure for safety evacuation.
3. As measures for people who can not use the stairs such as wheelchair-users, the assistance of fire-fighters or the use Evac-Chair etc. are available.

Fire incidents of super high-rise buildings in USA

Introduction of two fire incidents in super high-rise buildings in USA

- WTC bombing (New York, 1993)
  - 110 stories above ground and 6 underground stories (Approx. 435 m tall and typical floor Approx. 4000 m^2)
  - Explosion and fire in the parking space on underground floor
  - Smoke movement through EV shafts and stairs
- First Interstate Tower fire (Los Angeles, 1998)
  - 62 stories above ground and 4 underground stories (Approx. 260 m tall and typical floor Approx. 2050 m^2)
  - Fire in the workstation of bank office on the 12th floor

WTC bombing

- Outline of building members breaking by explosion

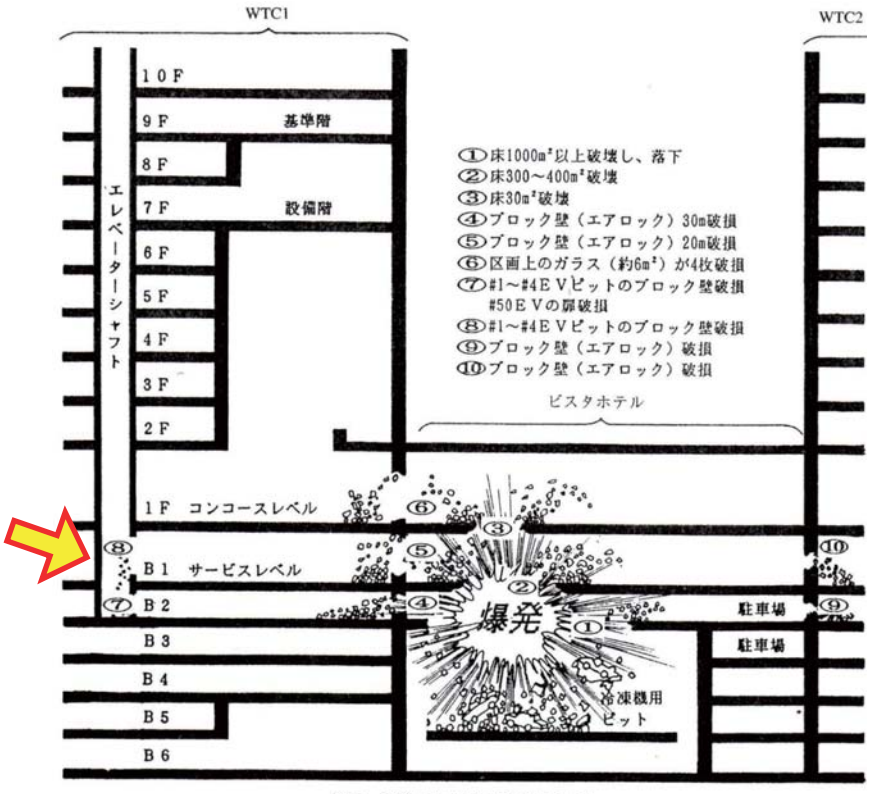
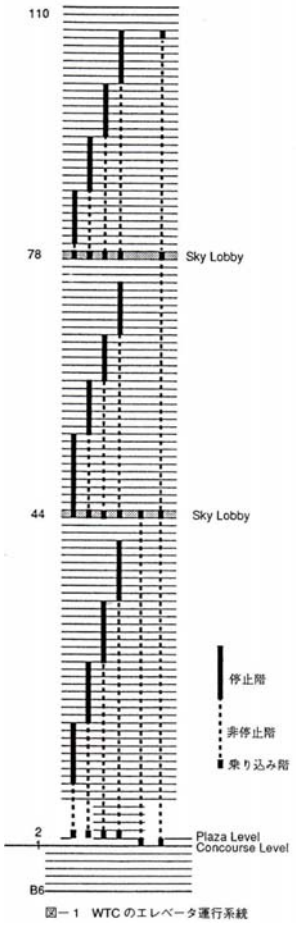


図2 爆発による区画の破壊の概略

WTC bombing

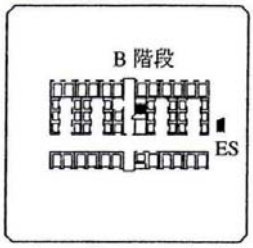
- Outline of elevator system
  - Sky lobbies: 44th and 78th floors
  - 3 zones divided by sky lobbies
  - Sky lobbies connected through shuttle/express EVs
  - Each zone looks like a high-rise building and has several EVs that can reach to designated floors.



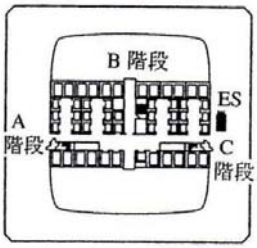
図－1 WTC のエレベータ運行系統

WTC bombing

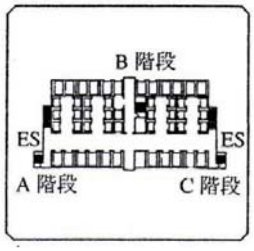
- Outline of ***Egress Staircase***
  - 3 staircases (A, B and C) reach to ground level
  - Every Egress Stair had "transfer" of the horizontal route to keep from EV lobbies in the vertical section and change the location on the floor
  - Each Transfer was located on the above and under the sky lobby floors and had doors, which may prevent from propagating smoke into upstairs more and reduce the stack effect in staircases



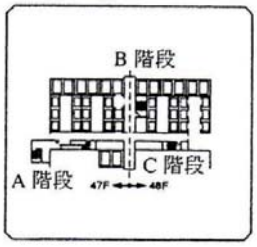
Concourse: 1st floor



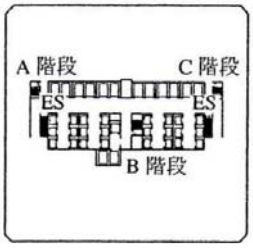
Plaza level: 2nd floor



Sky lobby on 44th floor



Transfer level

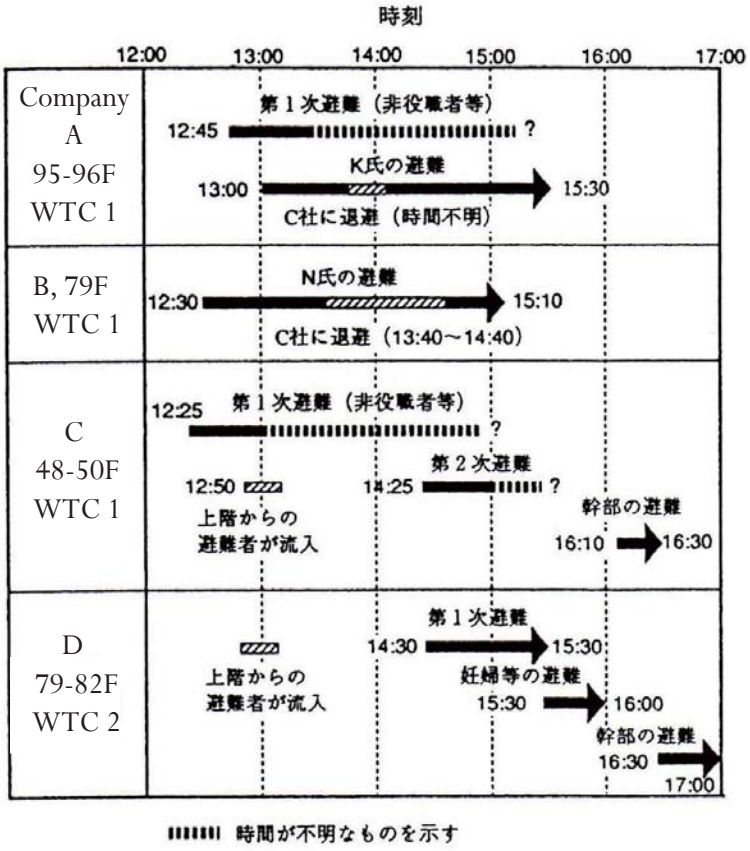


Sky lobby on 78th floor

Typical floor plan (95th floor)

WTC bombing

- Some Japanese occupants escape
  - People started to escape at the early stage took a long time (over 2 hours) to reach ground. Furthermore, they were affected by smoke during evacuation.
  - People stayed there and started to escape at the late timing after extinguishing fire took approx. 30 mins by downstairs walking.
  - People evacuated from building without announcement from control center.



Evacuation from some companies

First Interstate Tower fire

- Floor plan of center-core type
  - Some floors had corridor between office room and stairs
  - Corridors made firefighting possible on the upper stairs

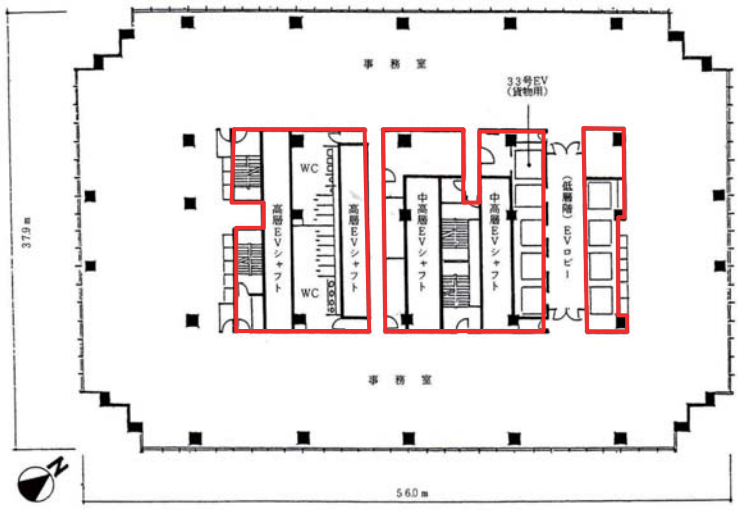


図１　低層部基準階平面図
（現地入手資料より作成、寸法は図面読取りによる）

First Interstate Tower fire

- Loss of spandrel
  - Deformation and melting of Aluminum mullion

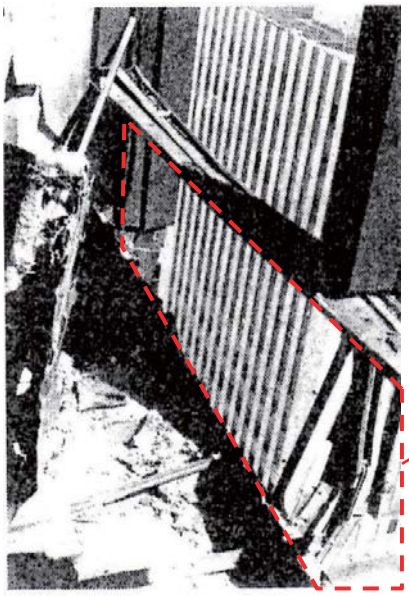


写真7　スパンドレル部分の損傷状況

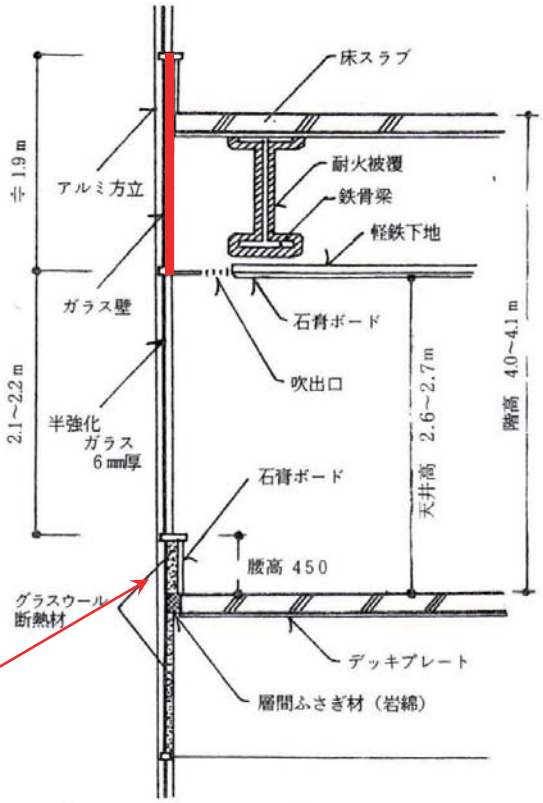


図3　外壁カーテンウォールの仕様

（注）現場調査およびヒヤリング結果に基づき作成。寸法は推定による。

First Interstate Tower fire

- Outline of evacuation
  - People was fortunate to be able to reach to ground or roof top using stairs and EVs responding to smoke movement in building.

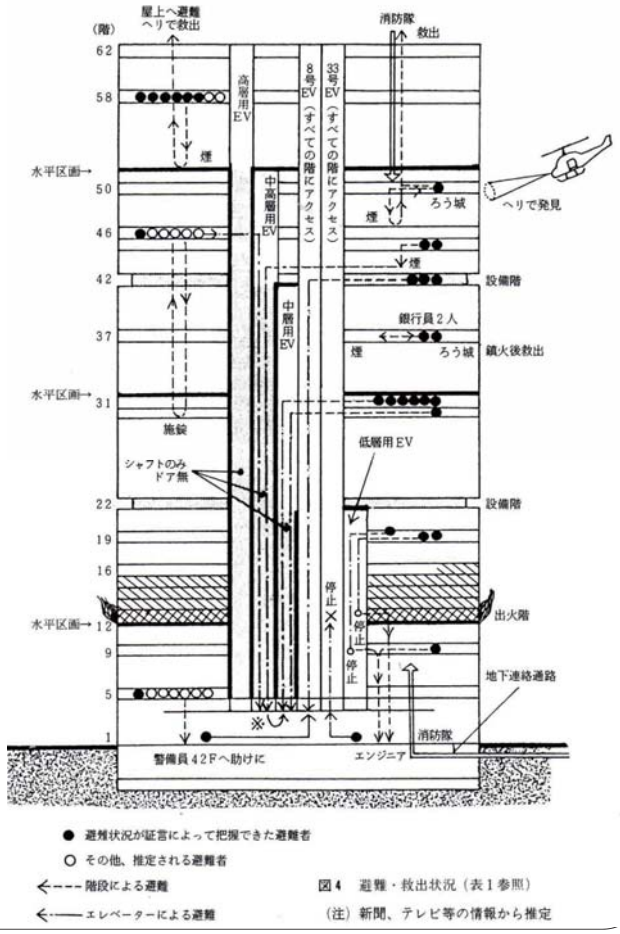


図4　避難・救出状況（表1参照）

（注）新聞、テレビ等の情報から推定

Summary

- Safe evacuation requirements of the BSL in Japan have been amended as necessary to appropriately reflect lessons learned from the experiences of major fire incidents
- As for designing super high-rise buildings,
  - Prevent from spreading fire through a vertical shaft and via outside of external wall
  - Prevent smoke from propagate into especially stairs and other vertical shafts
  - Reduce the stack effect in vertical shafts (EV, stair and so on)
- If a fire occurs and develops (by failure of early-stage fire suppression) in super high-rise building,
  - Make occupants evacuate effectively and smoothly using emergency broadcasting system without congestion and long-time waiting in staircases

Thank you so much for your attention.