Lecture 2

Wind Forces and Damage to Buildings and Structures

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The 21st Century Center of Excellence Program

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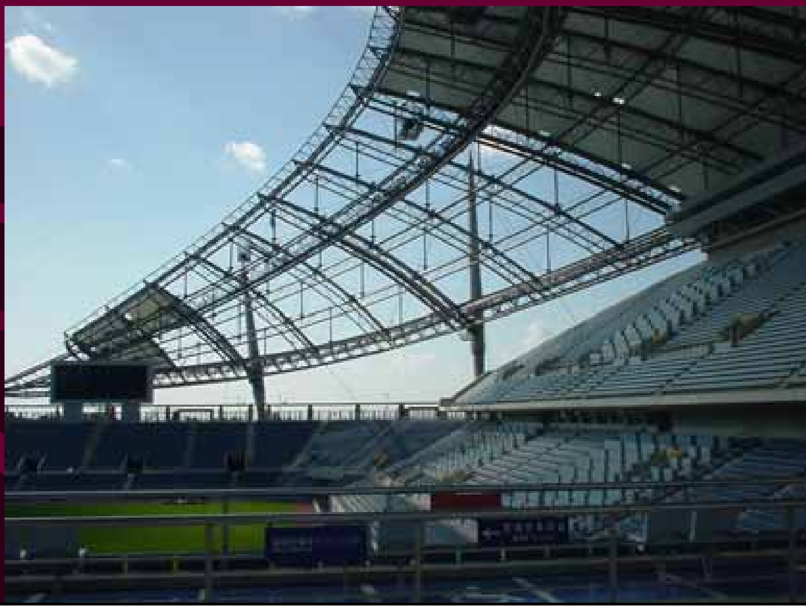
Damage due to Typhoons

Typhoon Damage to Soccer Stadium in Cheju Island, Korea August 30, 2002



Damage to Power Transmission Towers

Typhoon No.21, October 1, 2002

Damage in Miyakojima due to Typhoon No.14 (Maemi), September 11, 2003

Damage in Miyakojima due to Typhoon No.14 (Maemi), September 11, 2003

Damage to a roof of a gymnasium

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Damage due to Typhoon No. 14 (Maemi) in Miyakojima Island, September 11, 2003

Damage due to Typhoon No. 14 (Maemi) in Busan, Korea, September 12, 2003

Damage due to Typhoon No. 14 (Maemi) in Busan, Korea, September 12, 2003

Wind-born debris

TYPHOON 0314, 2003

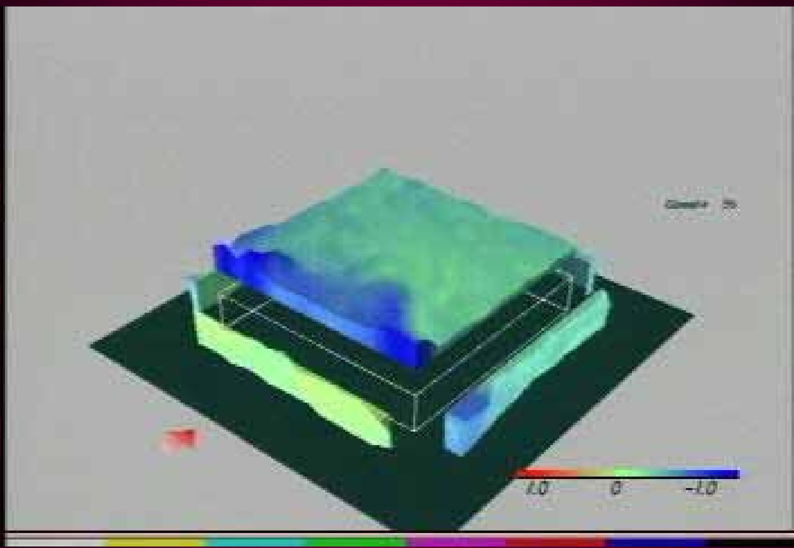
Wind-born debris

TYPHOON 0314, 2003

Typhoon Maemi (No.14, 2003)

- Miyakojima Island Meteorological Station (Okinawa Pref., Japan)
  - Maximum Mean Wind Speed : 34.8m/s
  - Maximum Peak Gust : 74.1m/s (10th highest in Japan)
  - Lowest Pressure : 912 hPa (8th lowest in Japan)
- Miyakojima Self-Defense Force
  - Maximum Peak Gust : 87m/s

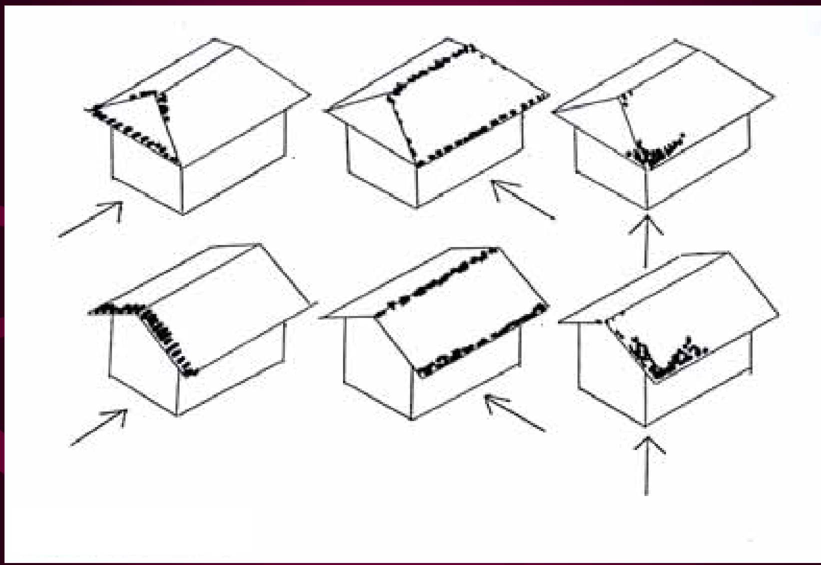
Fluctuating roof pressures



Damage to trees

TYPHOON 7513, 1975

Most Likely Locations of Damage



Damage to roof tiles

TYPHOON 7513, 1975

Damage to a folded steel roof

TYPHOON 7513, 1975

Damage to a folded steel roof

TYPHOON 7905, 1979

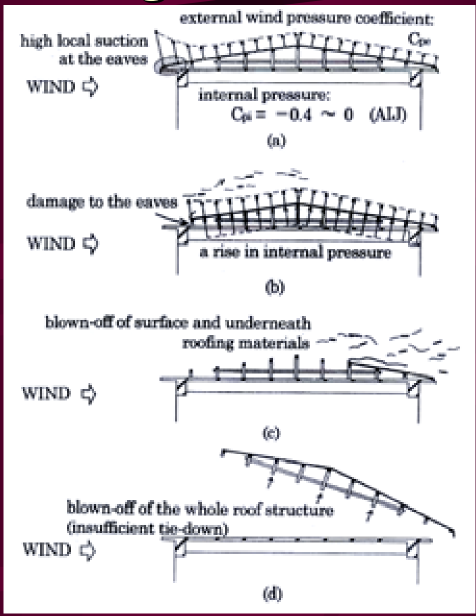
Wind-born debris

TYPHOON 7513, 1975

Blown-off of roofs

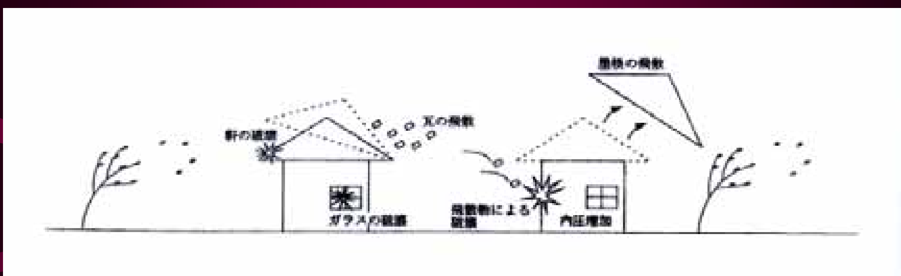
TYPHOON 7513, 1975

Damage Correlation



by Yasushi Uematsu, 1992

Chain of Damage



Wind-born debris

TYPHOON 9119, 1991

Wind-born debris

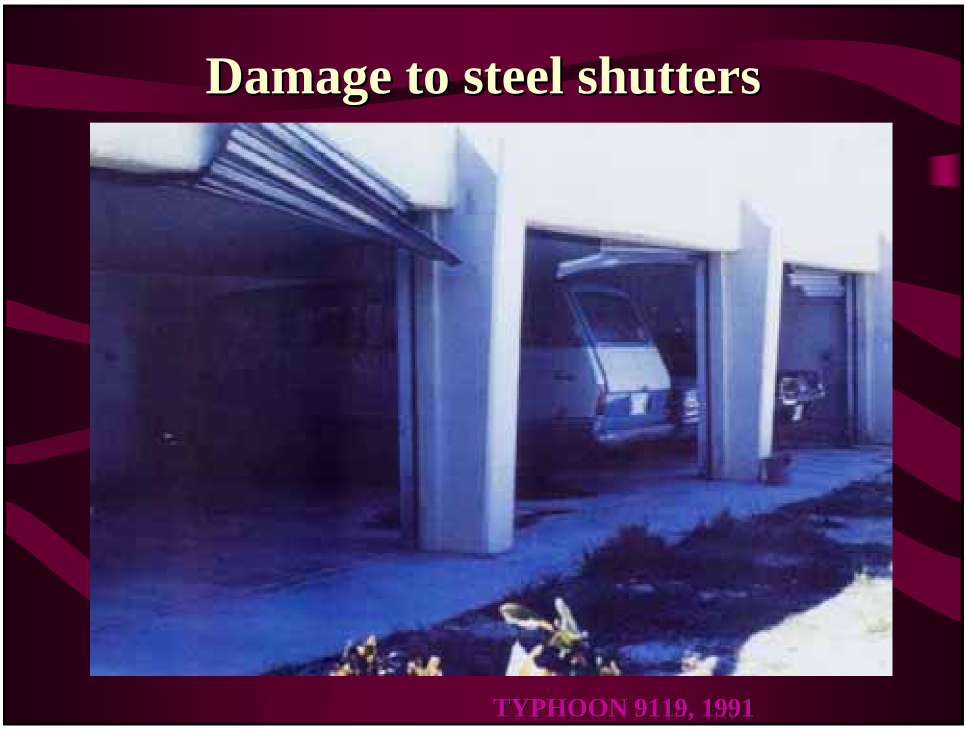
Steel roof sheet flew from upstream (Typhoon 7513)

Damage to a wooden house

TYPHOON 7513, 1975

Damage to cladding

TYPHOON 7513, 1975

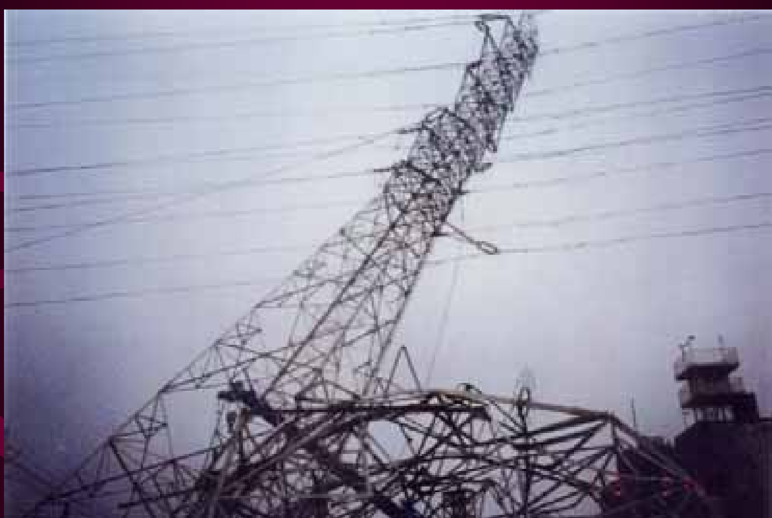

Damage to steel shutters
TYPHOON 9119, 1991


Damage to truss towers
TYPHOON 7905, 1975

Damage to a power transmission tower

TYPHOON 1991 (Courtesy of J. Maeda)

Damage to a power transmission tower



TYPHOON 9119, 1991 (by courtesy of J. Maeda)

Inclination of steel reinforcing bars

TYPHOON 7905, 1979

Damage to a wooden telegraph pole

TYPHOON 7513, 1975

Damage to a RC telegraph pole

TYPHOON 7513, 1975

Falling down of gravestones

TYPHOON 7513, 1975

Falling down of gravestones

TYPHOON 7513, 1975

TYPHOON 7513, 1975

Falling Down of Gravestones

B (cm)	*D* (cm)	*H* (cm)	ρ (kg/m^3)	V_{cr} (m/s)	Falling Down
24.5	24.5	90.0	3370	54.7	Yes
24.5	24.5	64.0	2420	55.0	Yes
26.0	26.0	70.0	2420	56.0	Yes
16.0	22.3	48.0	2420	57.8	No
16.0	21.5	53.0	2420	53.1	Yes
24.2	24.2	57.0	2420	57.5	No
38.5	38.5	104.0	2690	71.5	No
25.5	18.0	62.5	2420	40.9	Yes
26.0	25.0	69.5	2420	53.9	Yes
30.0	28.5	74.5	2420	59.3	No

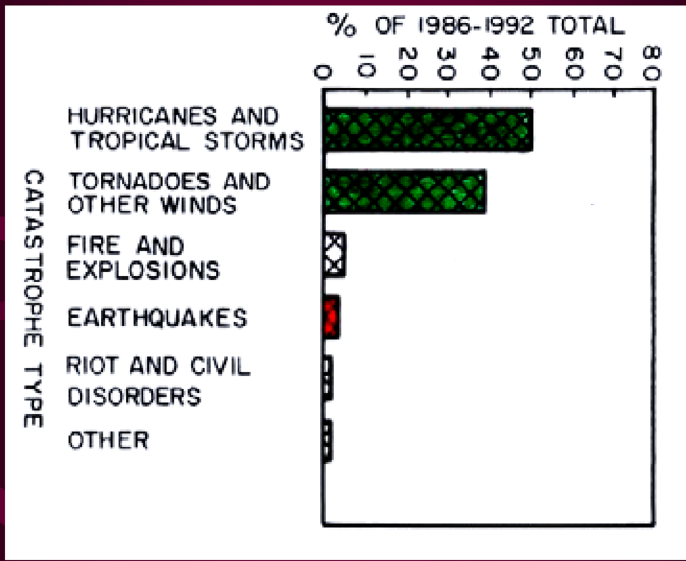
Damage to a steel building of under-construction

by courtesy of Junji Maeda

World Natural Disasters and Insurance Paid (as of 1999)

	USD
1992 Hurricane Andrew	14 Billion
1994 Northridge Earthquake	9 Billion
1991 Typhoon 9119	5 Billion
1990 Storm Dahlia	4 Billion
1989 Hurricane Hugo	3.5 Billion

Rate of Causes of Property Insurance Money



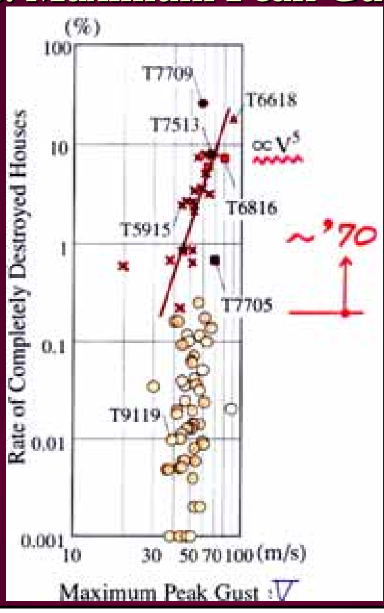
Jack Cermak, 1996

Strong Typhoons in Japan

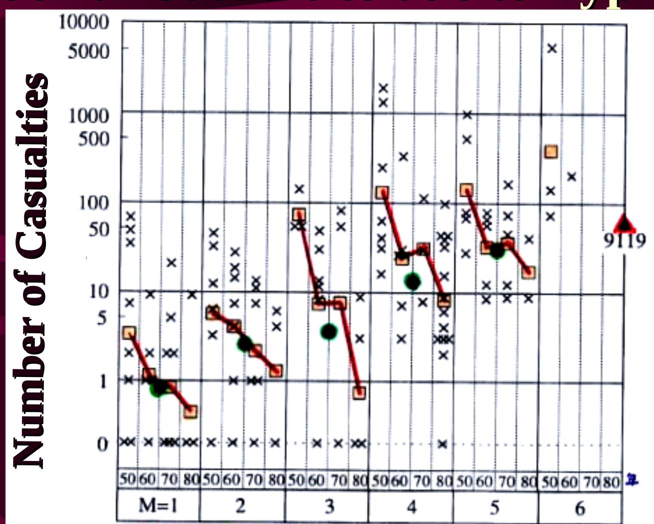
Typhoon		Fatalities	Damaged Buildings*
Muroto	1934	3,036	92,740
Suonada	1942	1,158	102,374
Makurazaki	1945	3,756	89,839
Catherine	1947	1,930	9,298
Toyamaru	1954	1,761	207,542
Kanogawa	1958	1,269	16,743
Isewan	1959	5,098	833,965
T9119	1991	63	14,538

* Damaged Buildings include severely damaged buildings only, defined as those of which more than 50% of the main frames collapsed

Rate of Completely Destroyed Houses vs. Maximum Peak Gust



Number of Casualties due to Typhoons



Number of casualties due to 114 typhoons in 40 years, 1951-1990 (Fukumasa, 1992)

Damage due to Tornados and Downbursts

Tornado Damage in South Africa

Courtesy of Adam Goliger

Devastation of Cape Town; 1999

Courtesy of Adam Goliger

Tornado in Kumagaya August 8, 2003

10-06

Recent reduction of wind damage

Causes

- Improvement of structural performance
- Improvement in accuracy of weather forecasting and hurricane information (Meteorological Satellites, Computers)
- Development of communication tools (TV, Internet) → Reduction of casualties
- Development of disaster prevention systems
- Improvement of infrastructure
- Development of wind resistant design

Reasons why windstorms were most feared in the past

Windstorms

- Diameter : up to 1,000km
- Frequently occurs
  (Energy is discharged every year.)
- Lack of Prediction／Communication Methods

→ Attacks without caution → Casualties

Earthquakes

- Local
- Not Frequent
  (Energy is discharged every hundreds years.)

Wind Damage

- 85% of economic loss by natural disasters in the world is due to wind damage.
- An underestimate of economic loss due to wind
  - Improvement in accuracy of weather forecasting and hurricane information (Meteorological Satellites)
  - Development of communication tools (TV, Internet) → Reduction of casualties
  - Development of disaster prevention systems
  - Improvement of infrastructure

→ Reduction of casualties

Wind Forces

- Pressure acting on surfaces

→ Heavy weight and stiff buildings have an advantage.

→ Light weight and flexible high-rise buildings are vulnerable to wind

Wind Forces

- Buildings should be designed to be heavy weight and stiff.

→Three Piglets

・Eldest piglet：
Straw House ✕ *Worst !*

・Middle piglet：
Wooden House ○

・Youngest piglet：
Brick House ◎ *Good !*

Wind-induced Phenomena

U =10〜15m/s （10min mean, 15m/s：1-year recurrence in Tokyo)
・Damage to umbrellas
・Vibration perception in flexible high-rise buildings

U = 20m/s
・Seasick and uneasiness in high-rise buildings
・Damage to garage shutters ・Falling down of pedestrians

U = 25m/s
・Damage to roof tiles
・Damage to window panes due to wind-born debris

U = 30m/s
・Collapse of RC block fences ・Damage to steel sheet roofing
・Collapse to wooden houses ・Falling down of gravestones

U = 35m/s （50-year recurrence in Tokyo)
・Damage to window panes due to wind pressure

U = 40m/s (200-year recurrence in Tokyo)
・Damage to cladding of high-rise buildings

U = 45m/s (600-year recurrence in Tokyo))
・Main frame stresses in high-rise buildings exceed elastic limit

(Peak Gust is 1.5〜2 times *U*)

Wind Forces

Points of Wind Resistant Design

- Local Negative Pressures
- Roofs
- Openings such as Windows
- Wind Debris → Shutters

Importance of Wind Resistant Design

Wind Load Predominant Structures & Parts

- Window Panes, Claddings
- Membrane Structures
- High-rise Buildings (*H* >200m in Japan)
- Long-span Bridges
- Tall Chimneys, Steel Towers etc.

Wind Load Important Structures

- Wooden Houses
- Factory Buildings, Warehouses
- Gymnasium, Baseball Domes
- Long-span Exhibition Halls

Falsehood and Truth in Safety

What is Safety ?

- "Safety" is a "risky" term.

•"Safety" has a totalitarian and emotional sound.

" It is sufficiently safe to take a specified necessary sectional area. However, as the section has three times the necessary area, it is safe three times. "

→ Three times infinity ?
→ Absoluteness is shown faintly.

Intention of misleading: SAFETY ZONE ???

Safety in the Law

- Building Standard Law in Japan
  Safety : no collapse, no loss of life
- Legally Necessary Procedures
  Legal Preparation of Design Documents
- Safety in Social Procedure
  ≠ True Safety
  → Intentional Misapprehension

Less Improvement of Structural Performance

- Merit of a higher grade of structural performance

→ rarely experienced in the life time of an individual building (events of decades or hundreds of years of recurrence)

→ A group of buildings consisting of a city is sustained for a long period beyond an individual building's life time.
National security, Urban building group

cf. Two times the design seismic force requires an increase of only several % in the total construction cost.

Improvement of Equipment Performance

- Merit of a higher grade performance of service equipment

(Air-conditioners, Lights, Elevators, etc.)

→ can be experienced immediately after setting up

→ Significant increase in equipment costs in these decades

An Accident at Amaru-valley Railroad Bridge (December 28, 1986)

- An out-of-service seven-car train fell from a bridge due to strong wind.
- Six persons were killed.
- Regulations specify the lowest limit wind speed as 25m/s for passing Amarube bridge.
- The alarm device was sounded at that time.
- The criminal liability of the person in charge at the site was confirmed.

However • • •

- This limit wind speed had not been followed, and there had been no accident.

An Accident at Amarube-valley Railroad Bridge (December 28, 1986)

- If he had stopped the train, ignoring the precedent, the result would have been:
  - Confusion of train time schedule
  - Complaints from passengers
  - Economic loss / Compensation for delay
  - →Storm of criticisms from the public and his superior or colleagues
  - →He could even have been fired.
- Dilemma

The fact that "A tragic accident will occur, if he does not stop the train" can never be proved.

⇨ It should not be finished only by the responsibility of the person in charge.

Lesson from the Amarube-valley Accident

- Too Conservative Service Regulations
  - Regulation maker's excuse
  - Persons in charge at the site can not maintain it for too frequent events.
- Realistic and Reasonable Provisions
  - The specified limit wind speed and its frequency
  - Physical reason for the limit wind speed and the probability of accident
  - Social / Economic loss due to stopping the train
- Discussion based on Scientific Data

Human Activities

- doing one's best
  - Limited Cost
  - Limited Manpower
  - Limited Time
  - Limited Knowledge

- There is nothing absolutely safe.
- Everything is accompanied by a risk.

Life and Safety

- Mixed discussions of Safety and Life
  - should be made carefully.
- Life (+Society)
  - Eccentric emotionally-charged arguments dominate the discussions.
  - "Life" is used as a trump or all-powerful.
  - "Life" is always far superior to all scientific arguments

→ Tears, Apologies, Kneel Down, etc.

What is Life ?

Fatalities due to Accidents and Disasters (1969, USA)

Car Accidents	55,790	Air-plane	1,780
Down Fall	17,830	Falling Obstacles	1,270
Fire	7,450	Electric Shock	1,150
Drowning	6,180	Train	880
Toxic	4,520	Lightning	160
Gunfire	2,310	Tornado	90
Machine	2,050	Hurricane	90
Ship	1,740	etc.	8,700
		Total	112,000

What is Life ?

- Car Accidents：

10,000 people are killed every year in Japan.

＝ 20 jumbo jet airplane crashes

＝ A jumbo jet crashing every two weeks.

→ Survivors can enjoy daily convenience at the sacrifice of 10,000 lives every year.

Lies and Truth in Safety

Nuclear Power Plants

- Opponents / Media
  - treat it as the most dangerous devil
  - never forgive any trivial accidents
- Promotors
  - emphasize spurious safety
  - keep all trivial accidents from sight

Industrial Accidents

Fatality : Injured : Uninjured

= 1 : 30 : 300

→ A serious accident results from a chain of trivial accidents

→ Only way to reduce a serious accident is to eliminate all trivial accidents

Disaster Prevention

- Qualitative and quantitative estimation of social merits
- Scenario of possible accidents
- Risk of accidents / disasters
- Countermeasure for disaster prevention
- Ripple effects of accidents / disasters
- Acceptable or not for the society
- Comparisons with alternative methods

- Discussions based on reliable scientific data
- Creation of social environment for frank open discussions → Society gazing at Risk

Disaster Prevention Staring Fixedly at Risk

- If we can never crash or collapse,
  - jumbo jet passenger planes
  - cars
  - high-rise buildings, etc.

  can not be available.
- Nothing can be made absolutely safe.

→We have to discuss disaster prevention facing Risk.

Disaster Prevention
Staring Fixedly at Risk

- We cannot do business if we say “Risk”.
- Safety Index ＝ (1－ Risk Index)

∴Either will do.

→ Sweeping problems under the rug

- Immature Society for disaster prevention or risk management

→ Engineers should not abandon the chance for genuine discussion on disaster prevention by using spurious safety.

Repeating Damage

KNOWING

BUT NOT ACTING !