

“Ductility is Damage”
**People Don't want to live in
Damaged Buildings**

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**Professors recommend
Ductile Frames
to students.**

Ductility is Damage 1/2

- The D_s values are 0.25 to 0.55 in Japanese seismic design procedure, and the R factors are 2 to 8 in the USA.
- Almost all structural engineers rely on the plastic deformability of beams, columns and walls of building structures during seismic design of structures.

Ductility is Damage 2/2

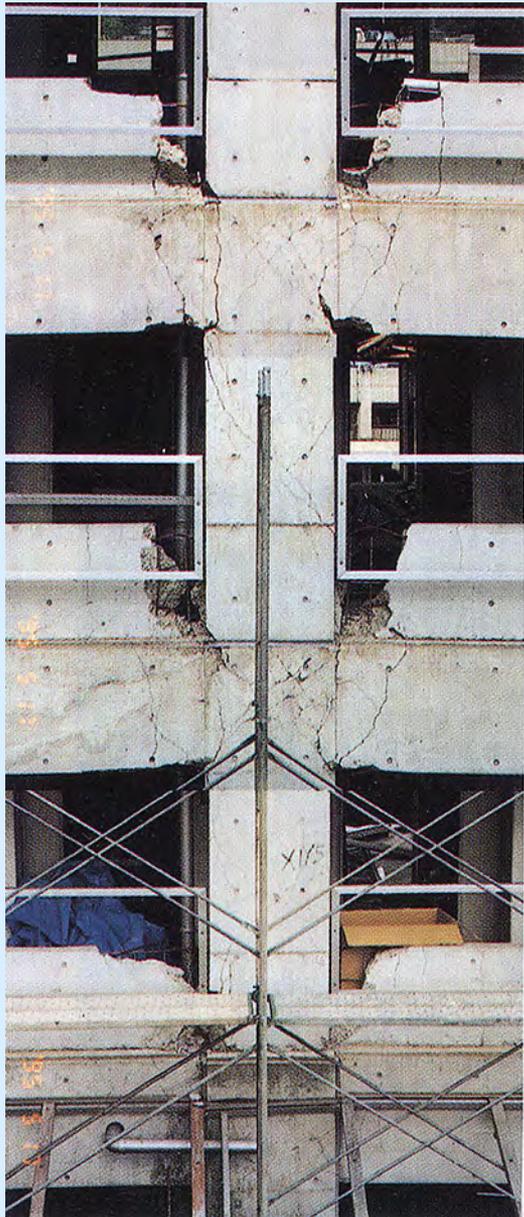
- The ductility as plastic deformation of frames is the damage of structures.
- This is easy to understand for young boys and girls to old ladies and gentlemen.
- Normal people don't want to live in the damaged buildings. Then, these damaged buildings become to be demolished after the big earthquake.

“Designed to protect life in extreme event, but damage is expected”
Prof. Stephen Mahin said.



Kobe Earthquake 1995





4階梁

3階梁

2階梁



7階梁

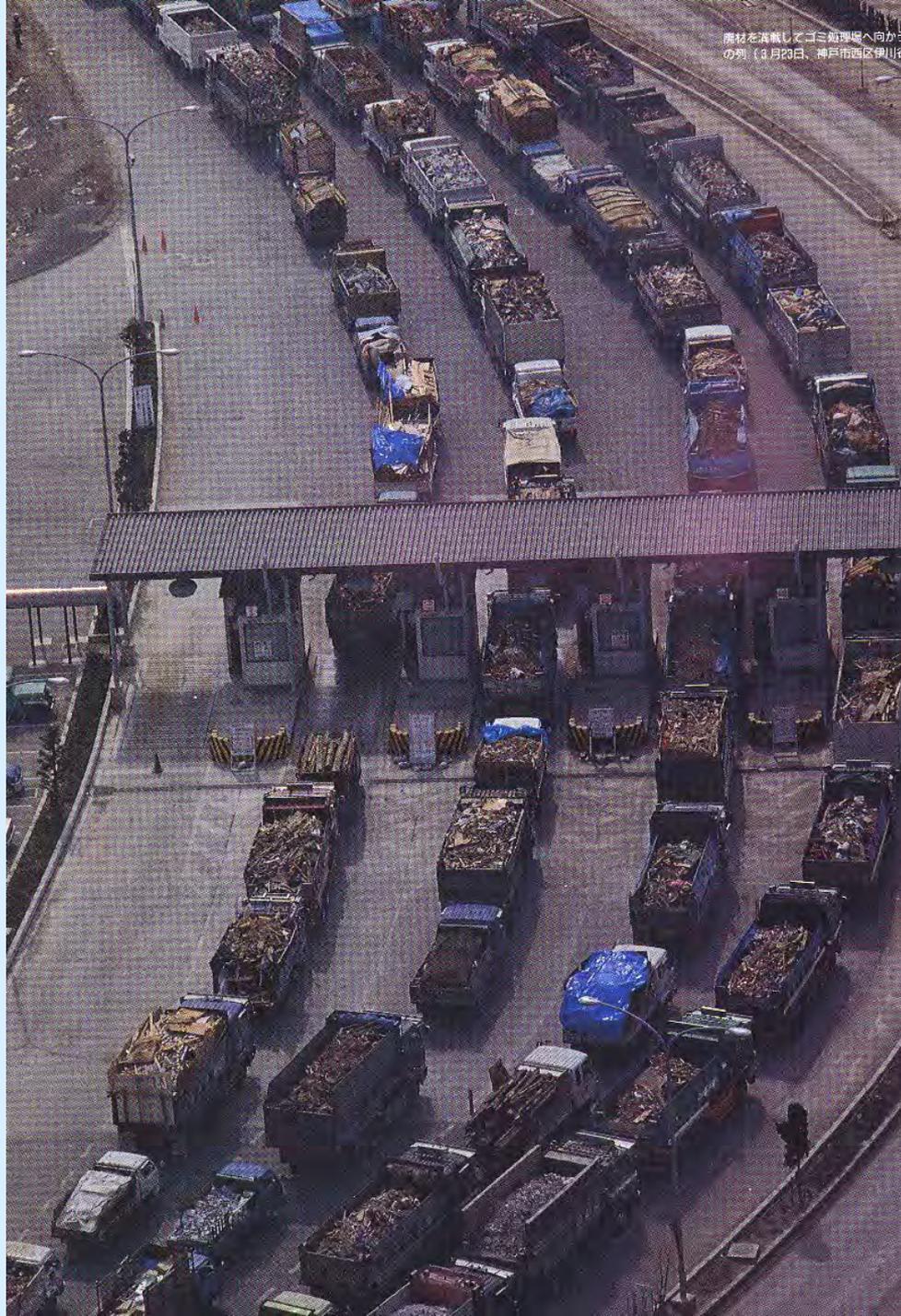
6階梁

5階梁

Perfectly Demolished after 1995 Earthquake



廃材を満載してゴミ処理場へ向かう
の列（8月23日、神戸市西区伊川谷



All trucks were bringing huge gavages produced from collapsed buildings and demolished buildings.

Residual displacements of 14 story Steel Concrete Apartment Building in Sendai-City



Residual displacements of 14 story Steel Concrete Apartment Building in Sendai-City



12 story Steel Concrete Apartment Building of Sendai-City



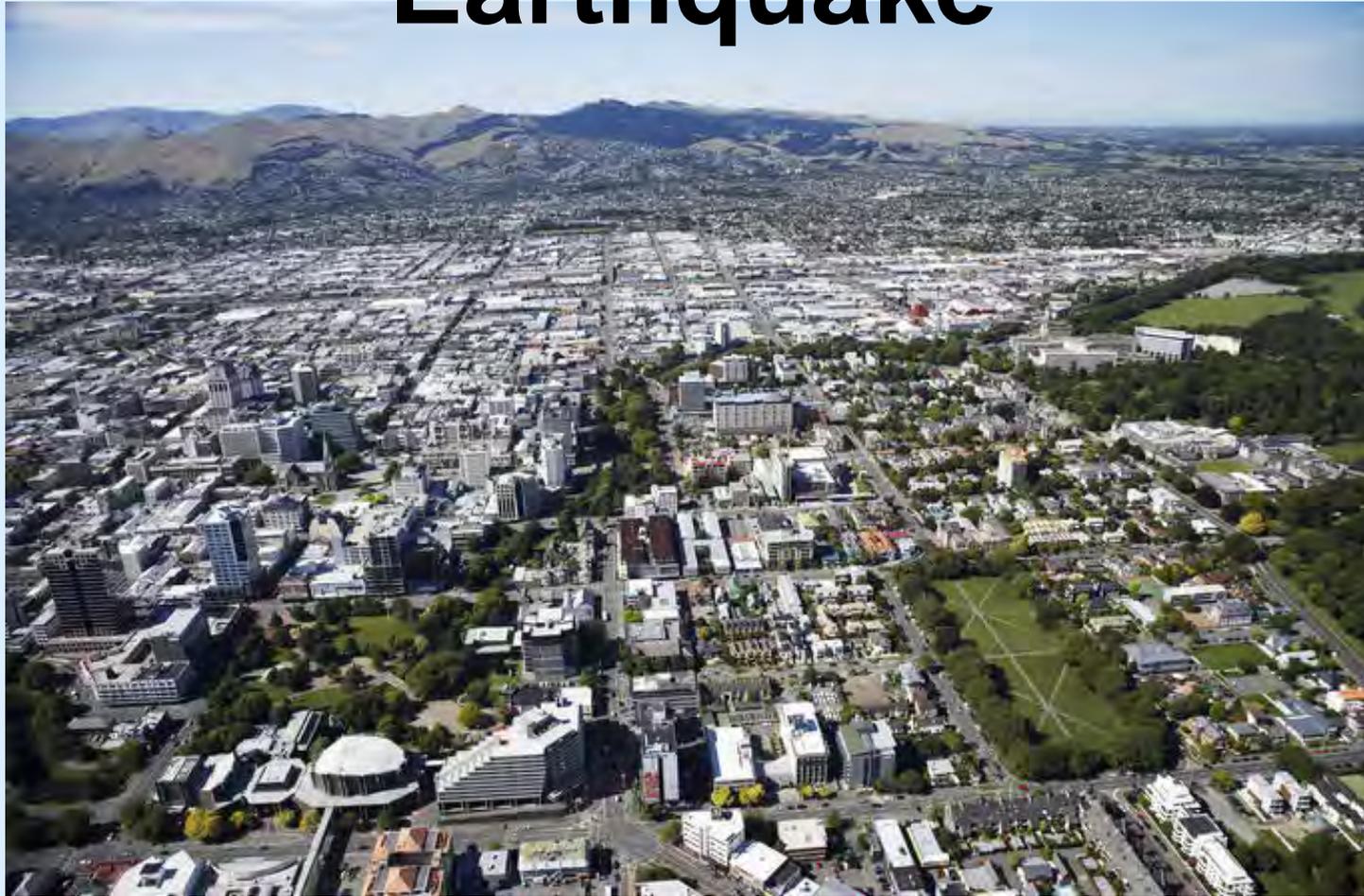
Akira Wada

Courtesy of Prof. Yasushi Sanada, Osaka University

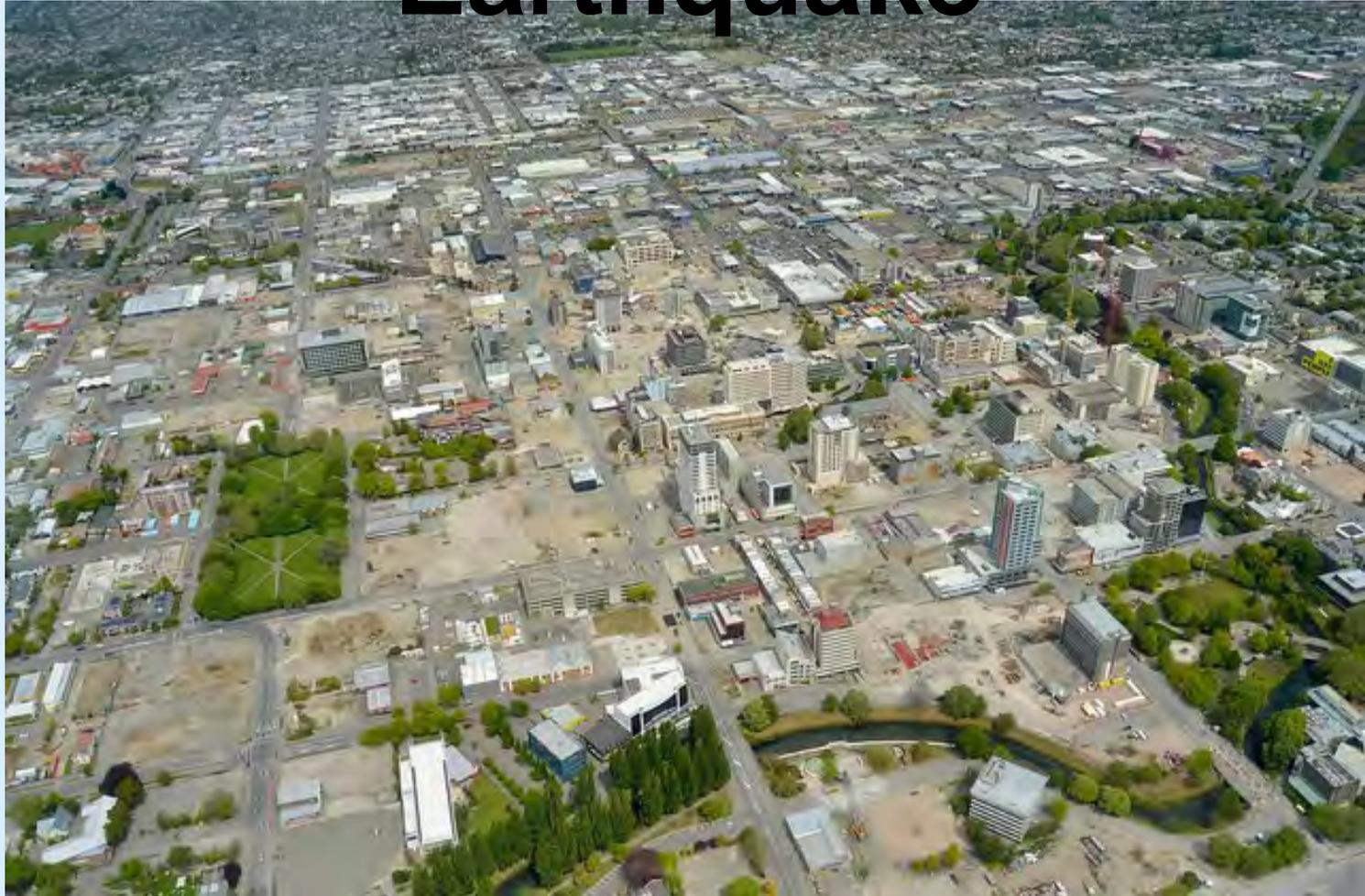
ATC & JSCA

12

Christchurch before 2011 Earthquake



Christchurch after 2011 Earthquake



Current Seismic Design

- H. Only Human life to be safe
- B. Building cannot use after repair
- C. No Continuous Use after earthquake

We can not make our city sustainable and resilience against big earthquake.

We need to change our seismic design concept.

New Seismic Design

- H. Human life have to be safe
- B. Building can use after some repaired
- C. Continuous Use just after earthquake

Against Small and Medium Earthquake ----

We can satisfy H, B and C easily.

Against Big Earthquake -----

We have to satisfy H and B, some case C.

New Seismic Structures

- Seismic Isolated Structures
- Passive Controlled Structures
- Stepping Columns Structures
- Elastic Joints of Pre-casted RC
- Other Good Structures

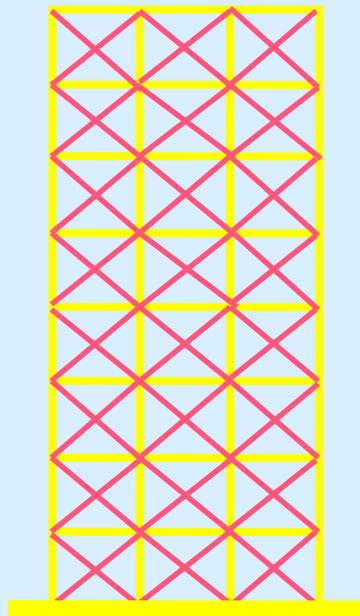
Seismic Isolated Steel Tall Building constructed in TITech.



**Seismic
isolated
apartment
buildings
taller than
30 story
buildings**

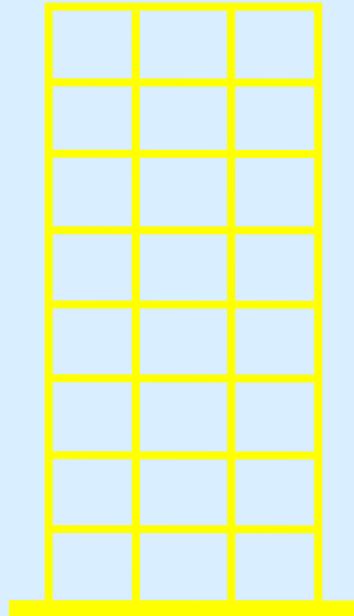


Damage Controlled Structures



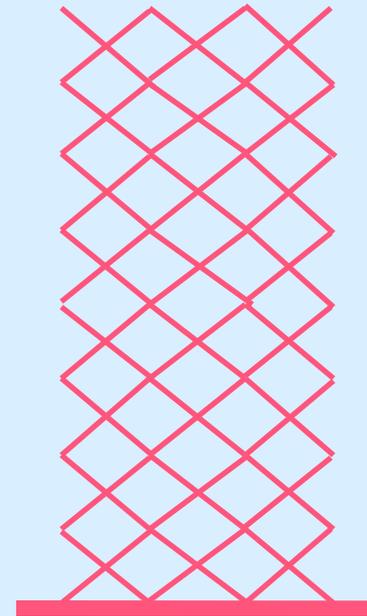
Building Structures

=



Primary Structure
(To Support Vertical Load)

+



Seismic Members
(To absorb earthquake energy)

We have to learn good ideas from Nature

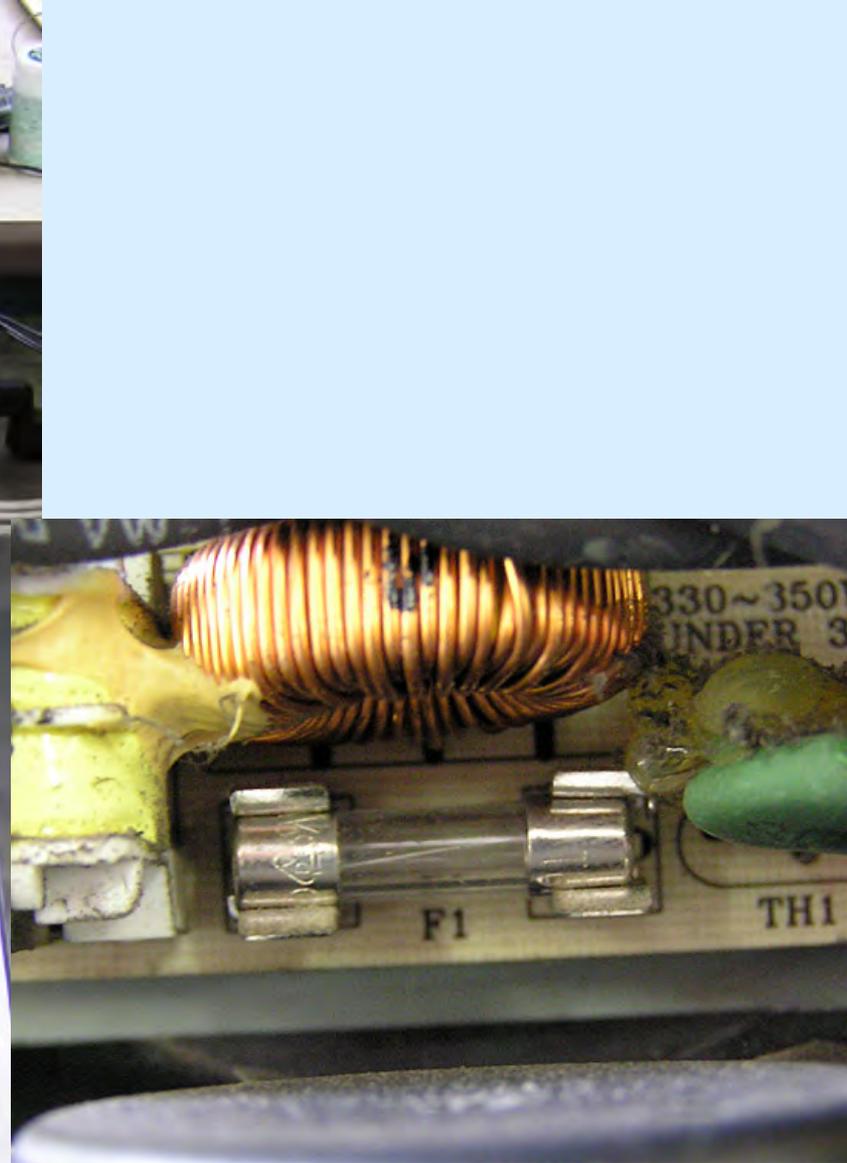
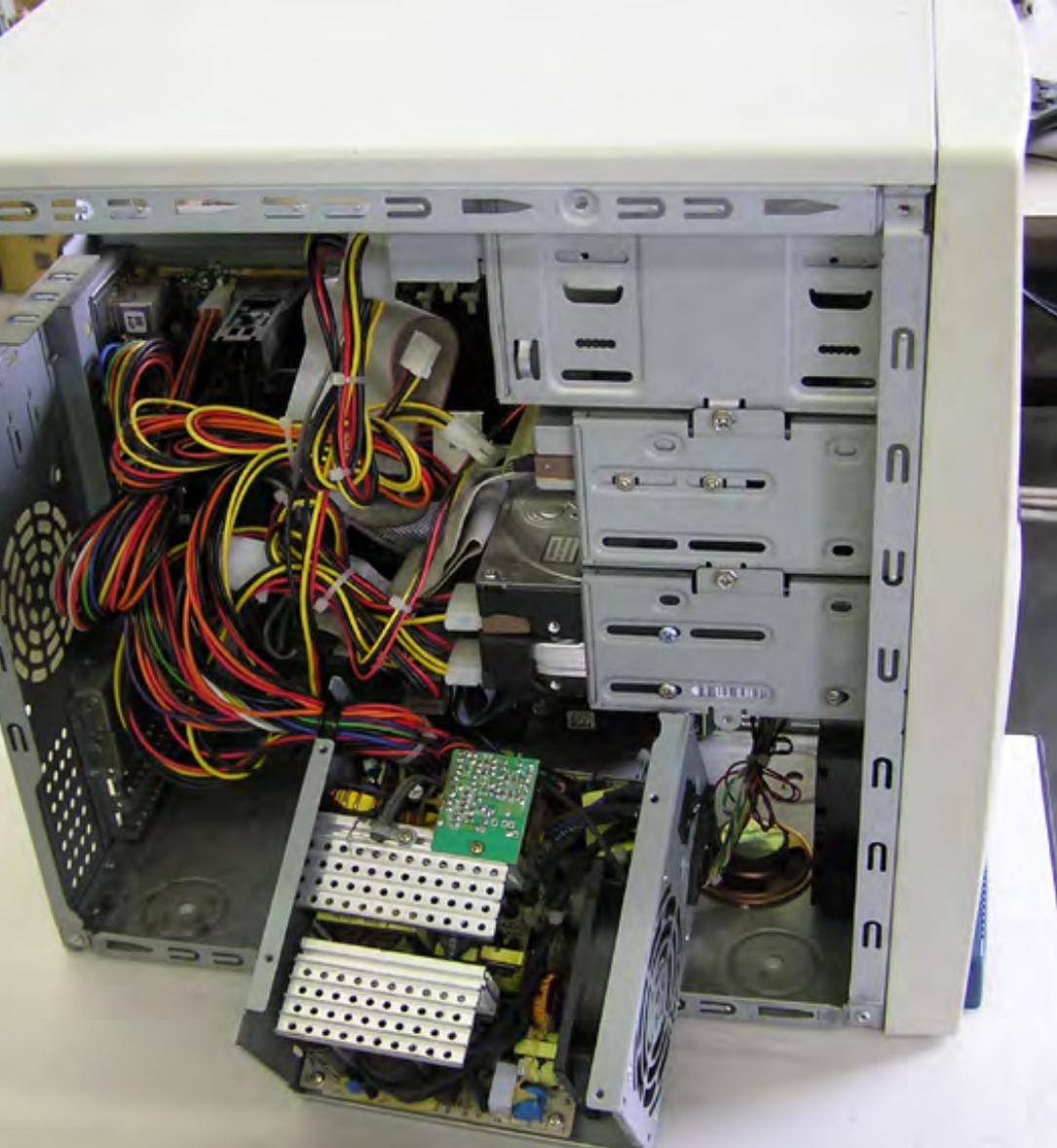


Some kind of Sacrifice for Human Body

Collar bone



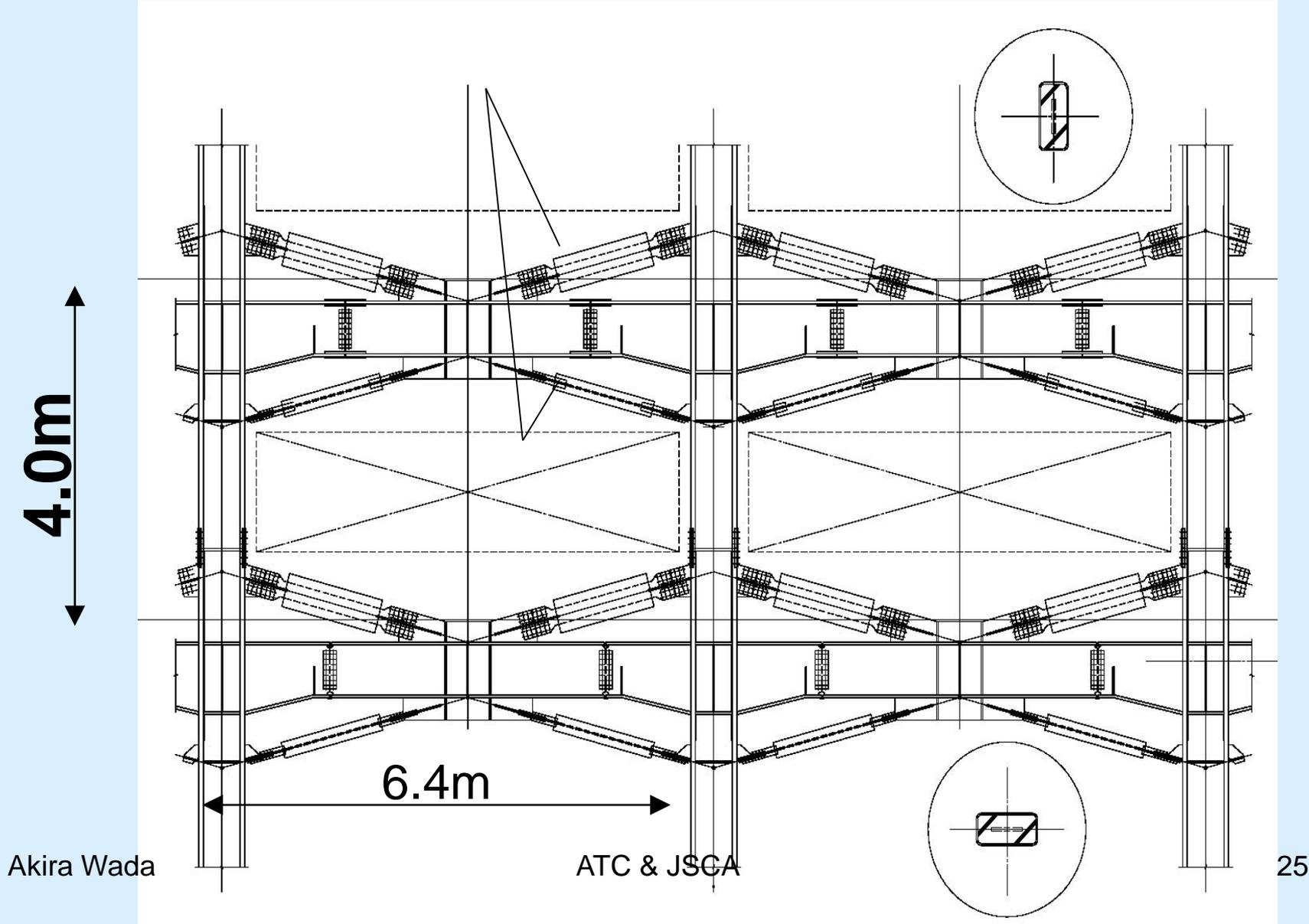
A Bumper protecting people and Bus



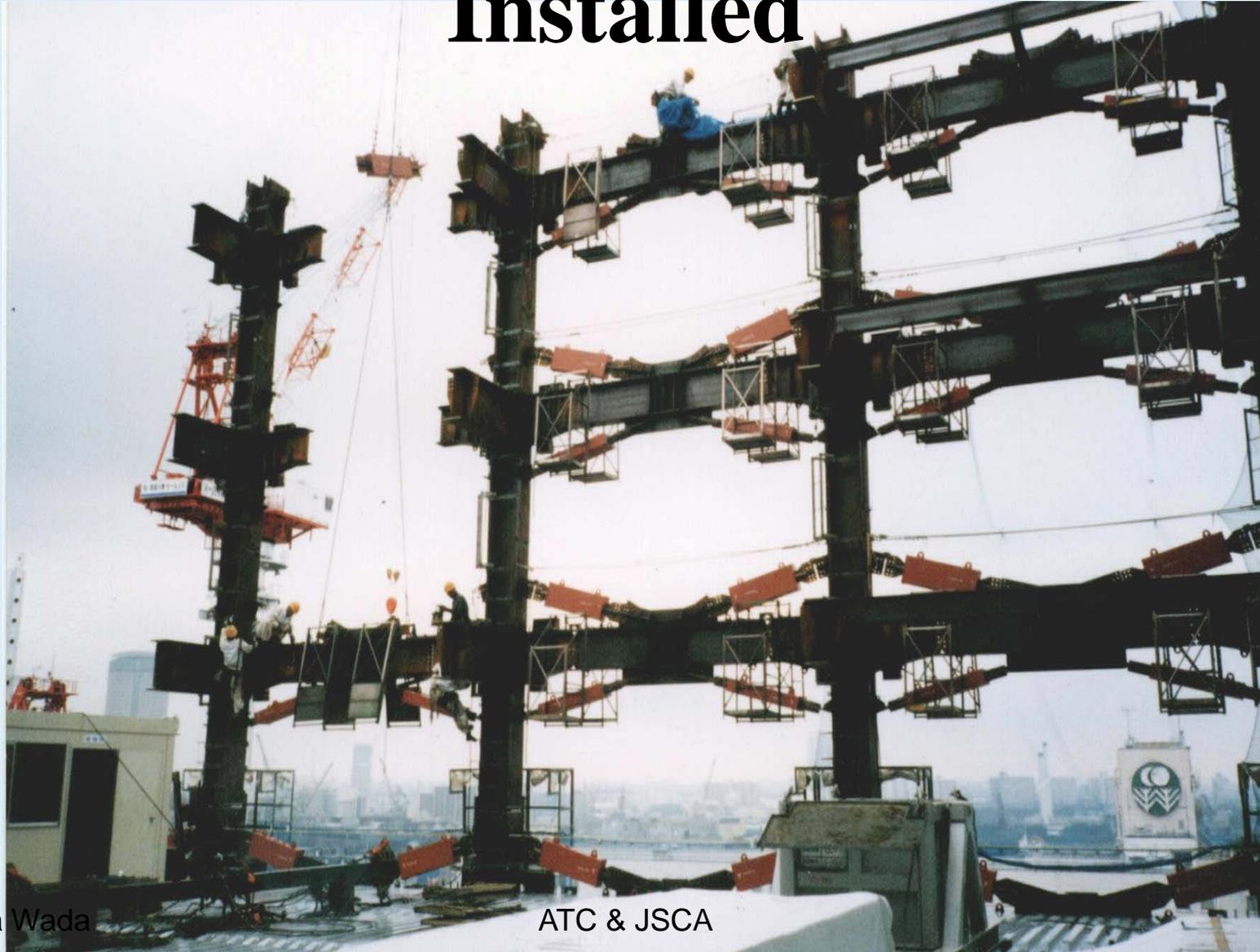
A Fuse protecting important PC



Detail of Unbonded Braces



Many Unbonded Braces are Installed



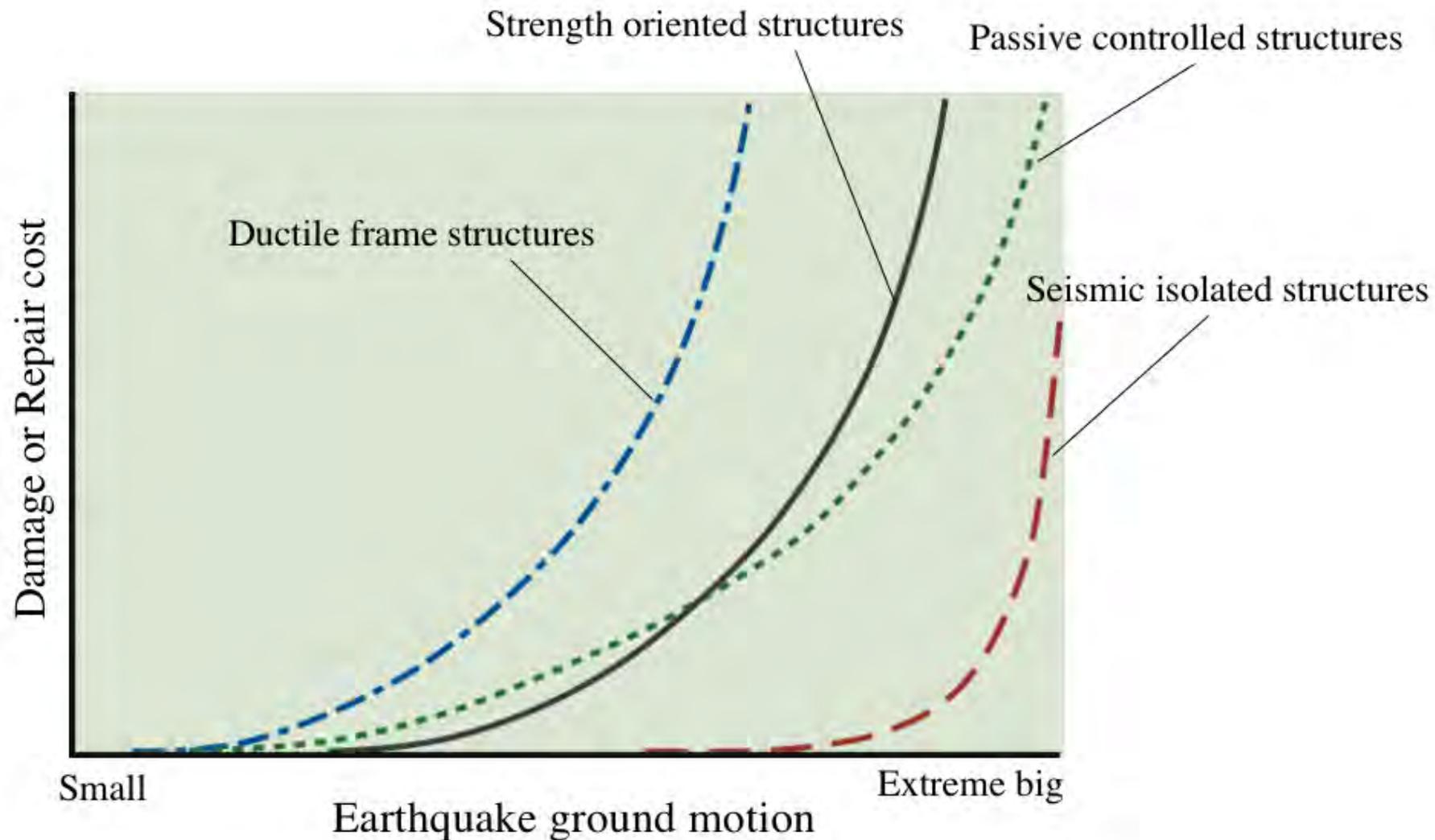
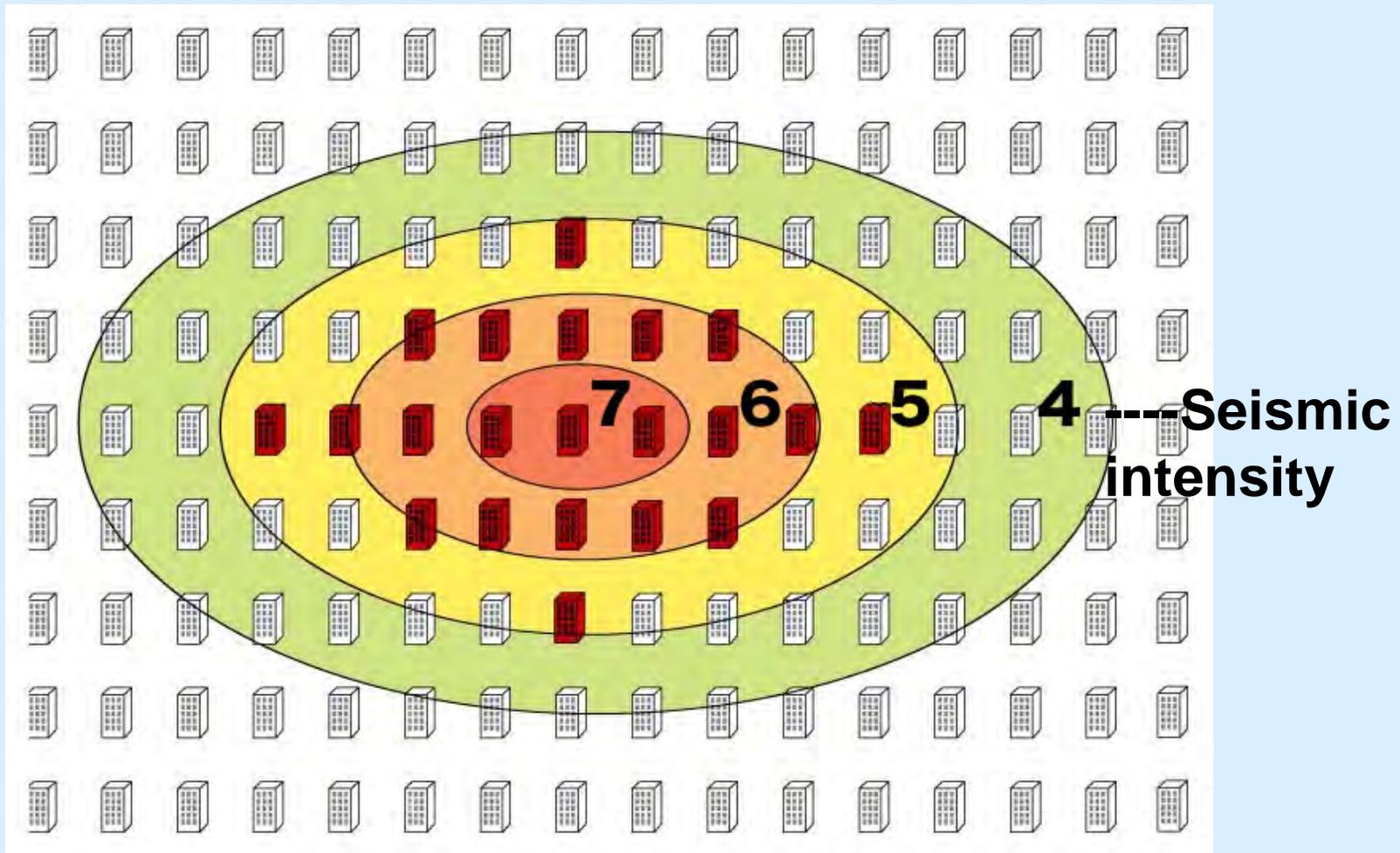


Fig. 1 Earthquake ground motion vs. Damage or Repair cost

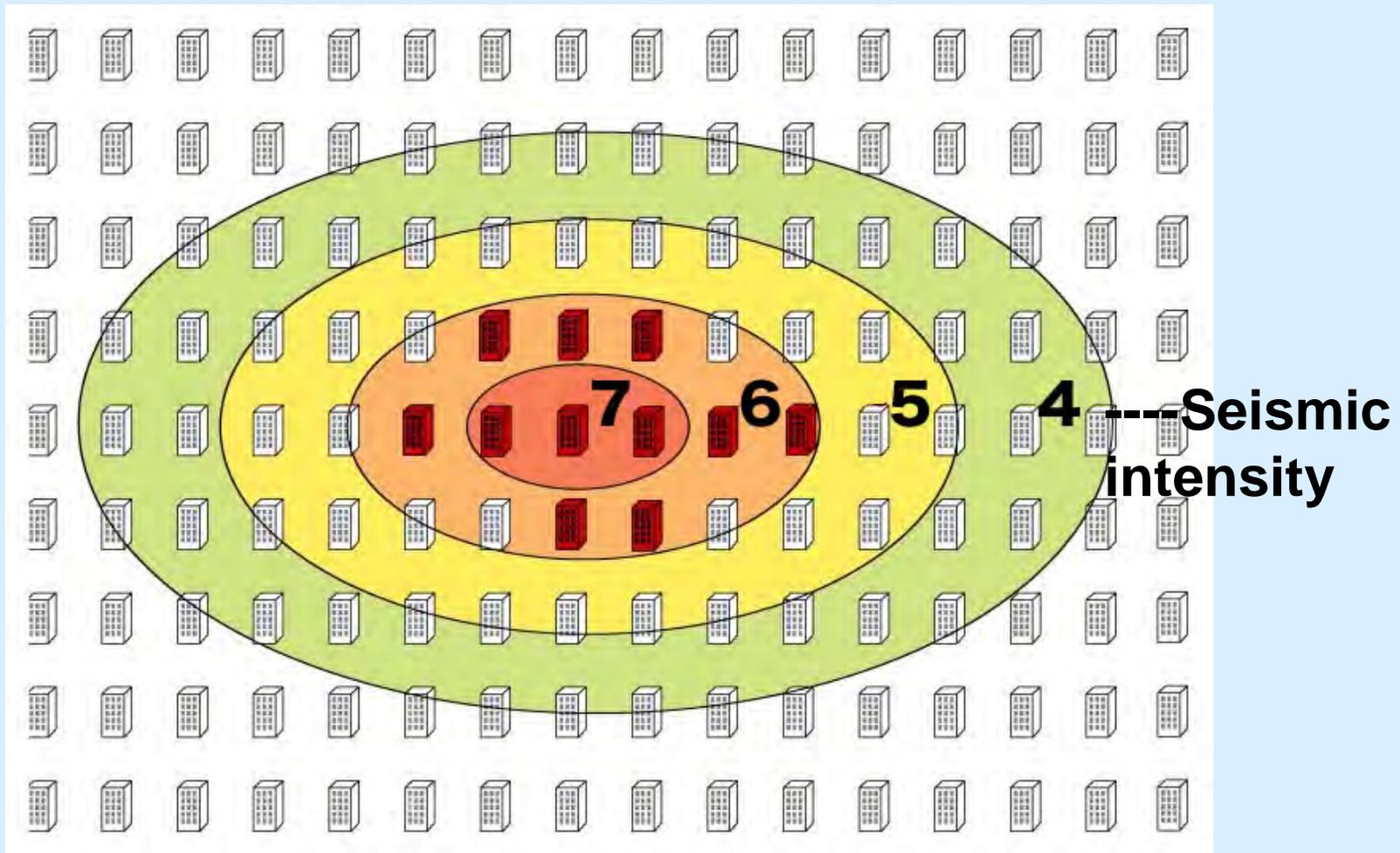


Now in Tokyo

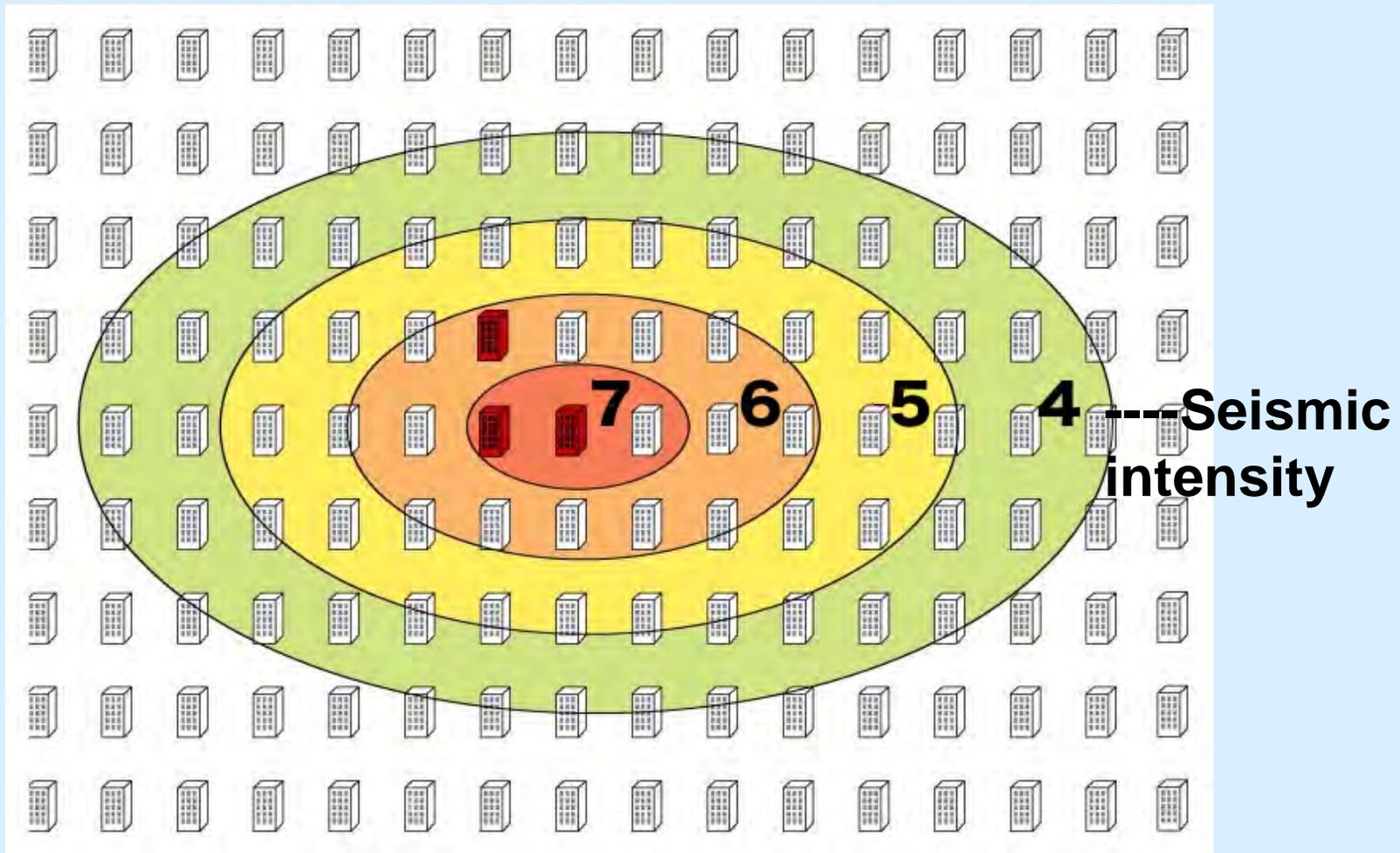




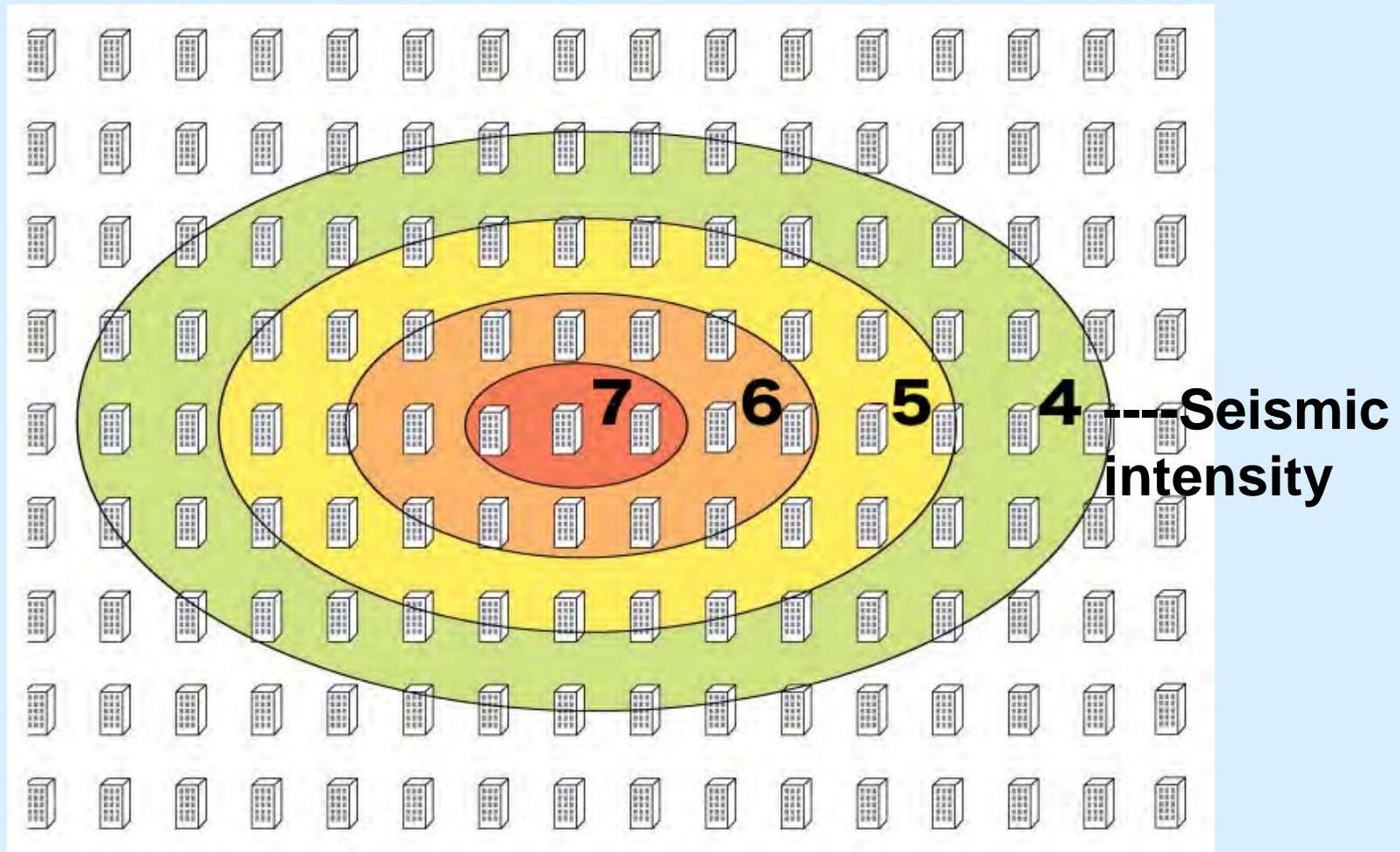
Damages of buildings in the city after big earthquake, in the case that all buildings were designed as ductile frame structure.



Damages of buildings in the city after big earthquake, in the case that all buildings were designed as strength oriented structure.

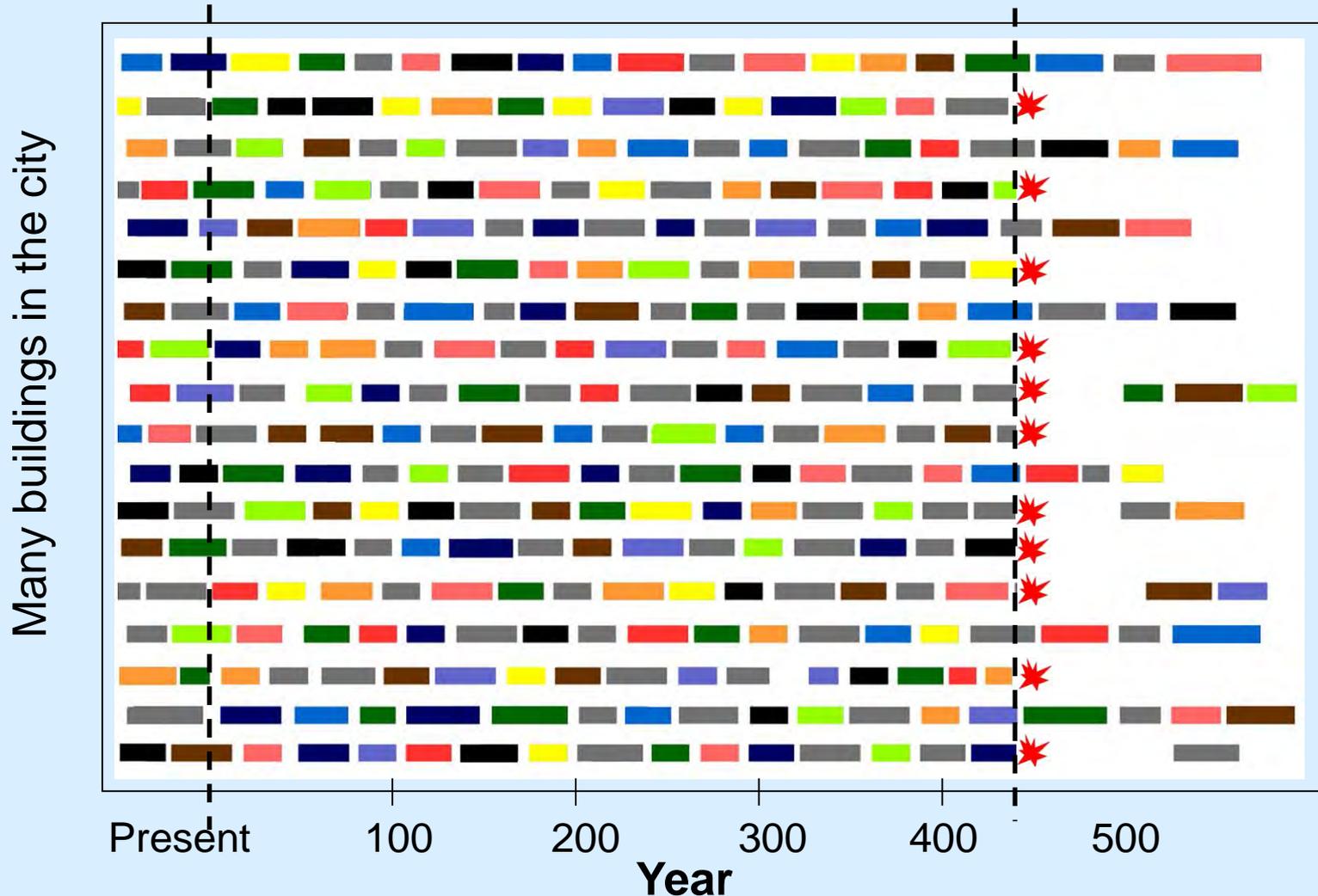


Damages of buildings in the city after big earthquake, in the case that all buildings were designed as passive controlled structures.



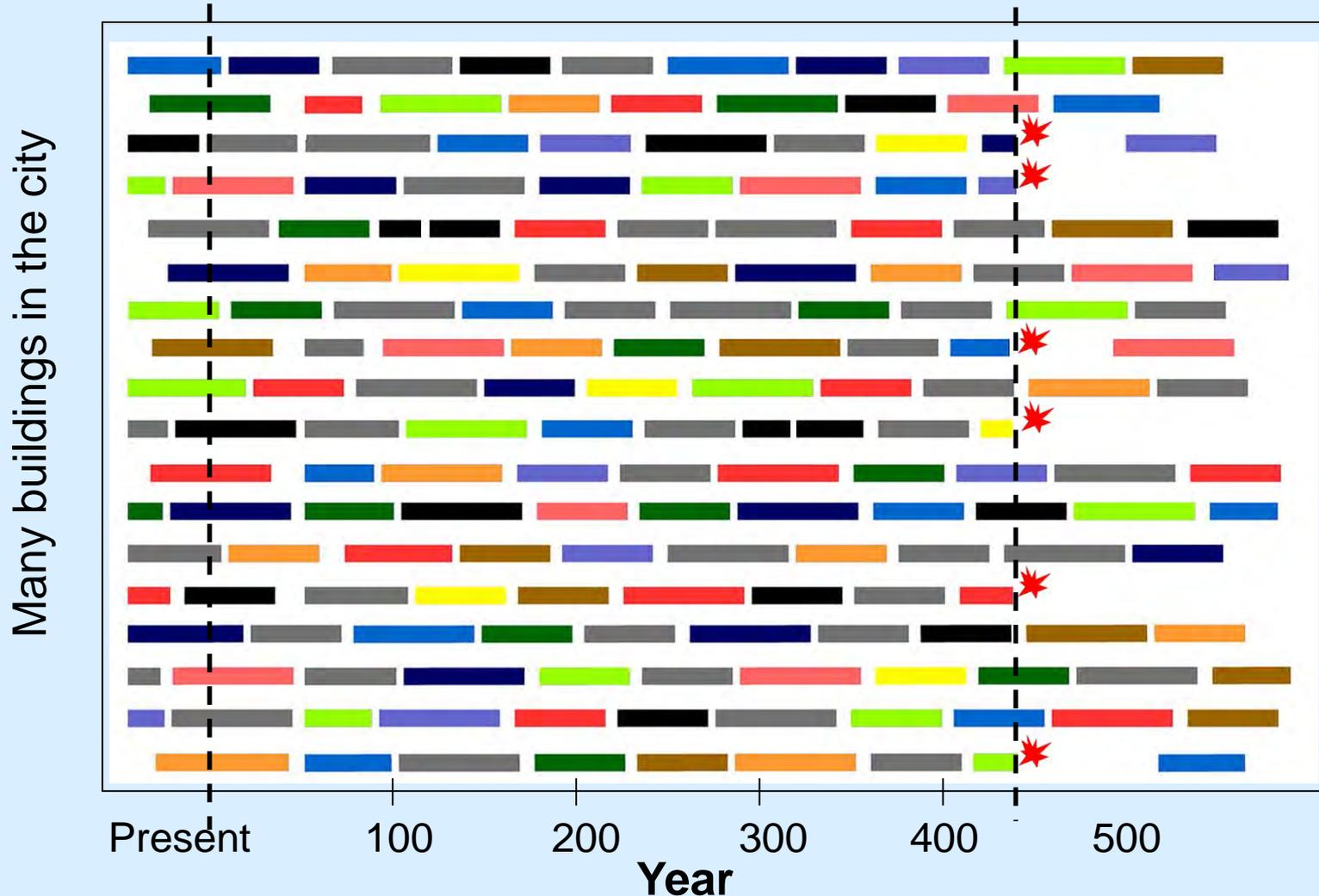
Almost no damage of building in the city after big earthquake, in the case that all buildings were designed as seismic isolated structures.

Big earthquake occurs



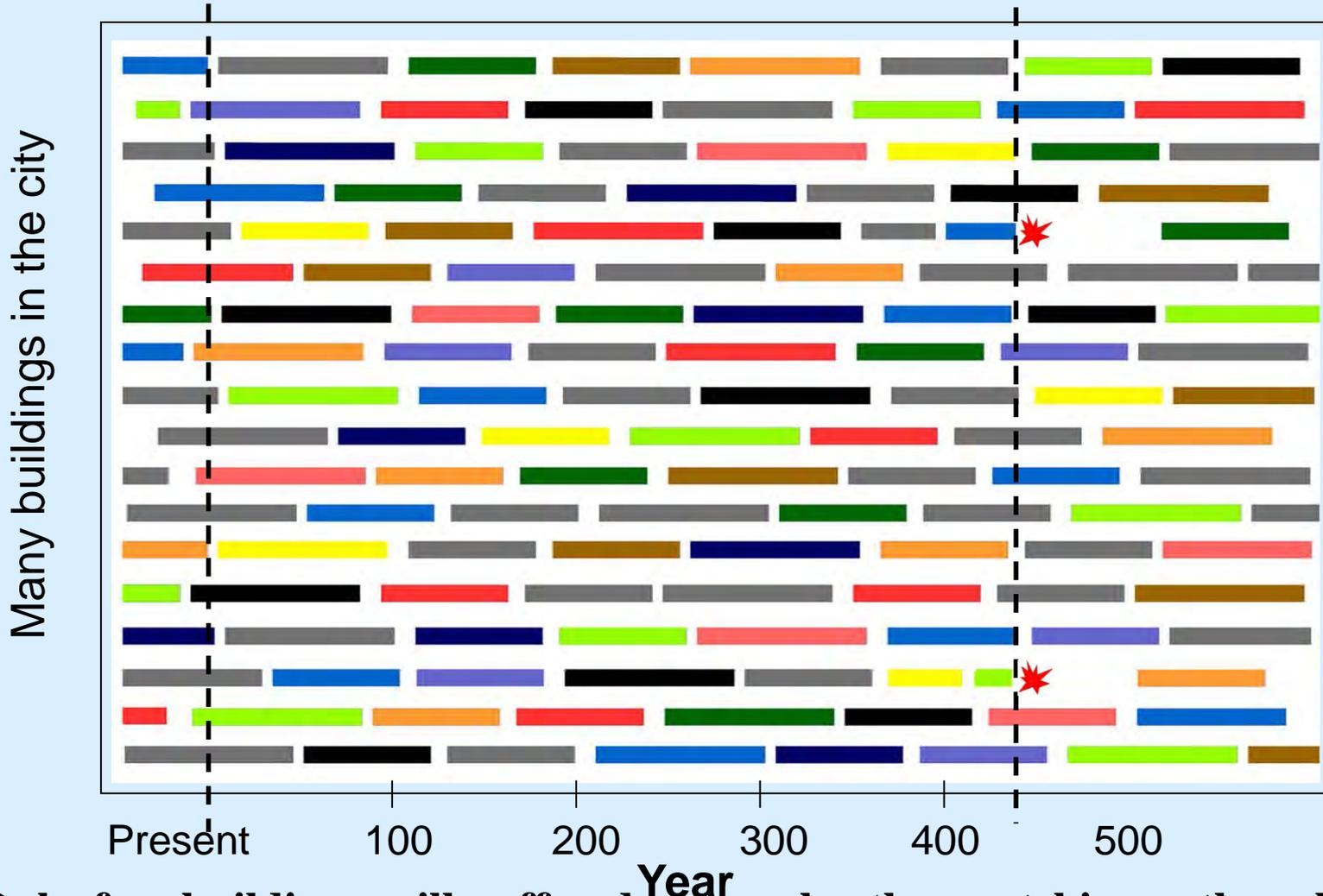
Almost all buildings will be perfectly collapsed by the next big earthquake when these buildings have poor seismic performance.

Big earthquake occurs



Many buildings will be demolished after the next big earthquake when these buildings are designed by ductile moment structural system.

Big earthquake occurs



Only few buildings will suffer damages by the next big earthquake when all buildings are using seismic isolated or passive controlled structures or new technologies.

Conclusion 1/3

- Who does pay money for demolishing many damaged buildings and clean up the damaged city?
- Does money come from insurance, city, prefecture, government or owner?
- When owner did not need to pay it, they will built ductile building, because it seems like cheap.
- A city is consisted of many buildings.

Conclusion 2/3

- After major earthquake, structural engineers put **red tags** to damaged buildings, even if these buildings are not so severe damage, they tend to **put red tag**.
- People don't want to return to **the red tag building**.
- When many buildings were demolished in a city, we can not stay in the city and we can't say that we make a resilient city.

Conclusion 3/3

- We have to consider not only resilience of a building, but also resilience of a city consist of many buildings.
- Then we can not recommended to make buildings rely to large ductility.
- When we make a rule that owner have to pay, people will built his building more strong.

An individual building is component of a big city

- The probability of occurrence of a large earthquake ground motion could be **neglected** in the design process of a building under the economic consideration and the engineering judgments.
- However, this would be **a big gamble** of the city.

Seismic design for a big city

- The seismic issues of a city cannot be solved, if the seismic resistance of its individual building is determined only from the relationship between the life of a single building and the earthquake occurrence in its life span.
- We have to make resilience city and country against big earthquake.

Prof. Robert Park

at Canterbury University

Prof. R. Park introduced ductile moment reinforced concrete frames in earthquake prone countries, but he have said at that time:

Ductility is not final goal.

Thank you very much for your attention.

**We, structural engineers, have a mission
to make the world a better place to live.**

Akira Wada