FROM PROLOGUE TO EPILOGUE IN SOLUTIONS FOR SEISMIC RESILIENCE OF MEGA-CITY

Akira Wada
Professor Emeritus
Tokyo Institute of Technology

Nobi earthquake 1891

Akira Wada

Nobi earthquake 1891

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Kanto earthquake 1923

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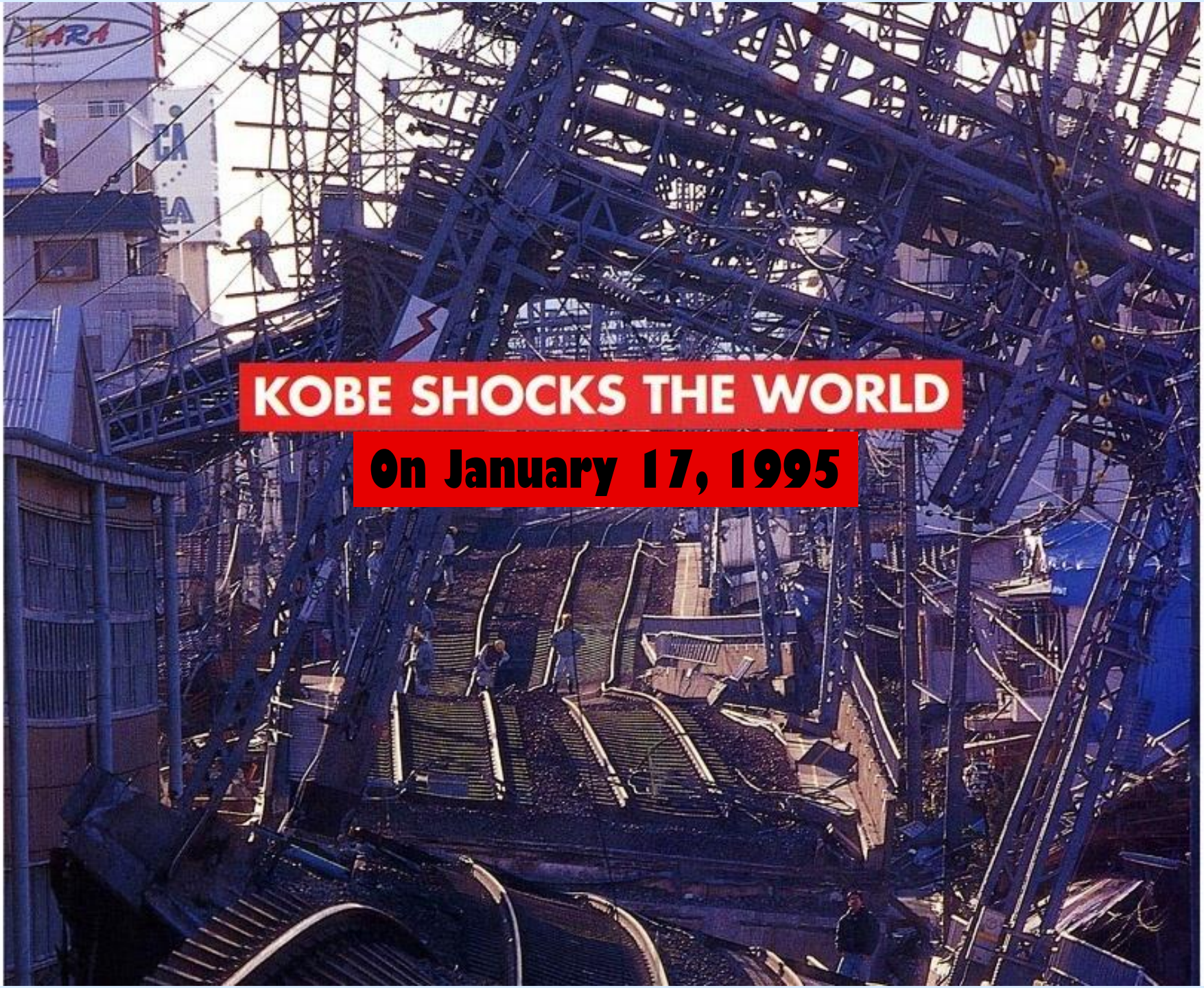
KOBE SHOCKS THE WORLD
On January 17, 1995

Akira Wada

Kobe earthquake at 1995

Akira Wada

Kobe earthquake at 1995

Akira Wada

Kobe earthquake at 1995

Akira Wada

Kobe Earthquake 1995

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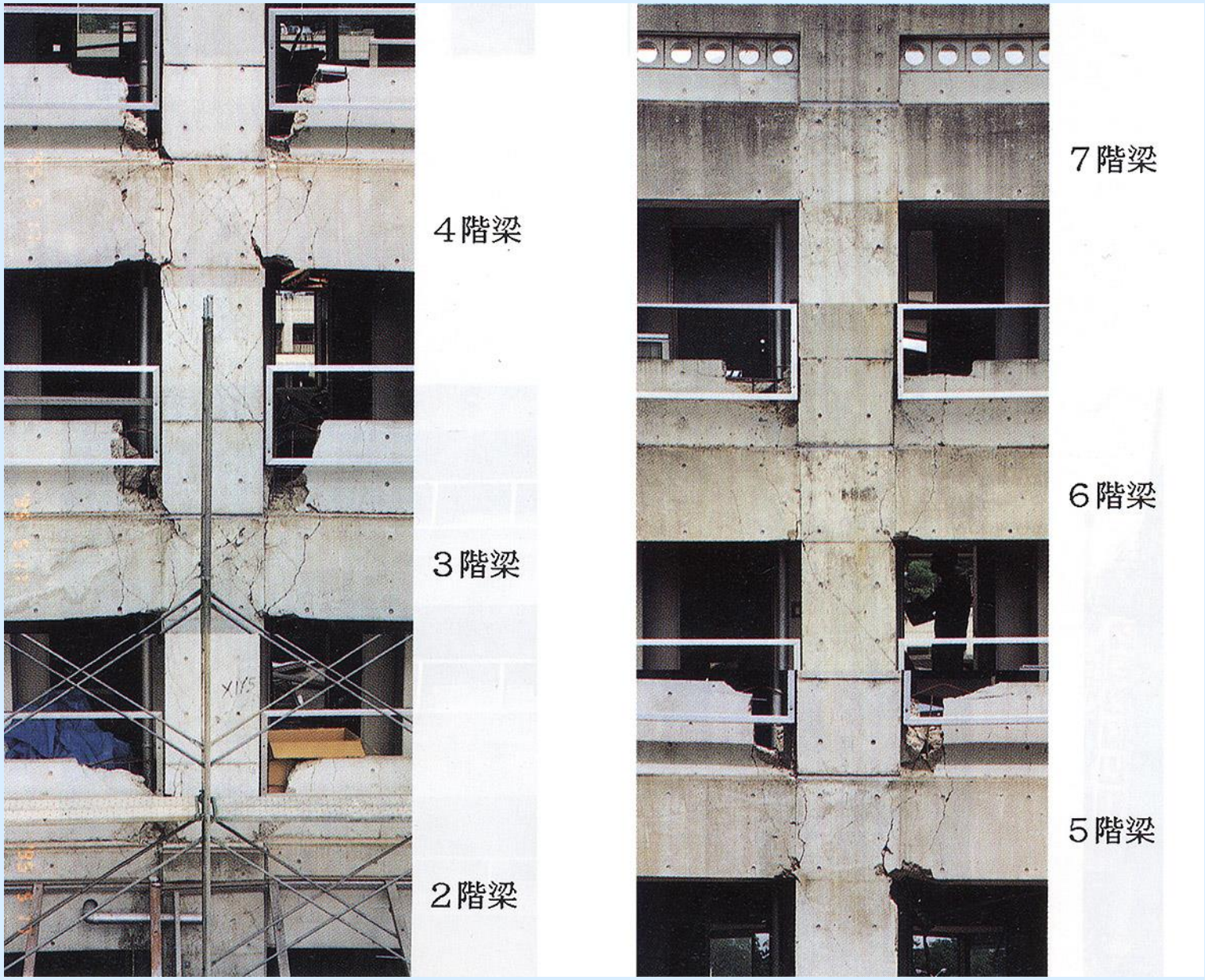
株式会社新井組　１９９５年技術研究報告集より



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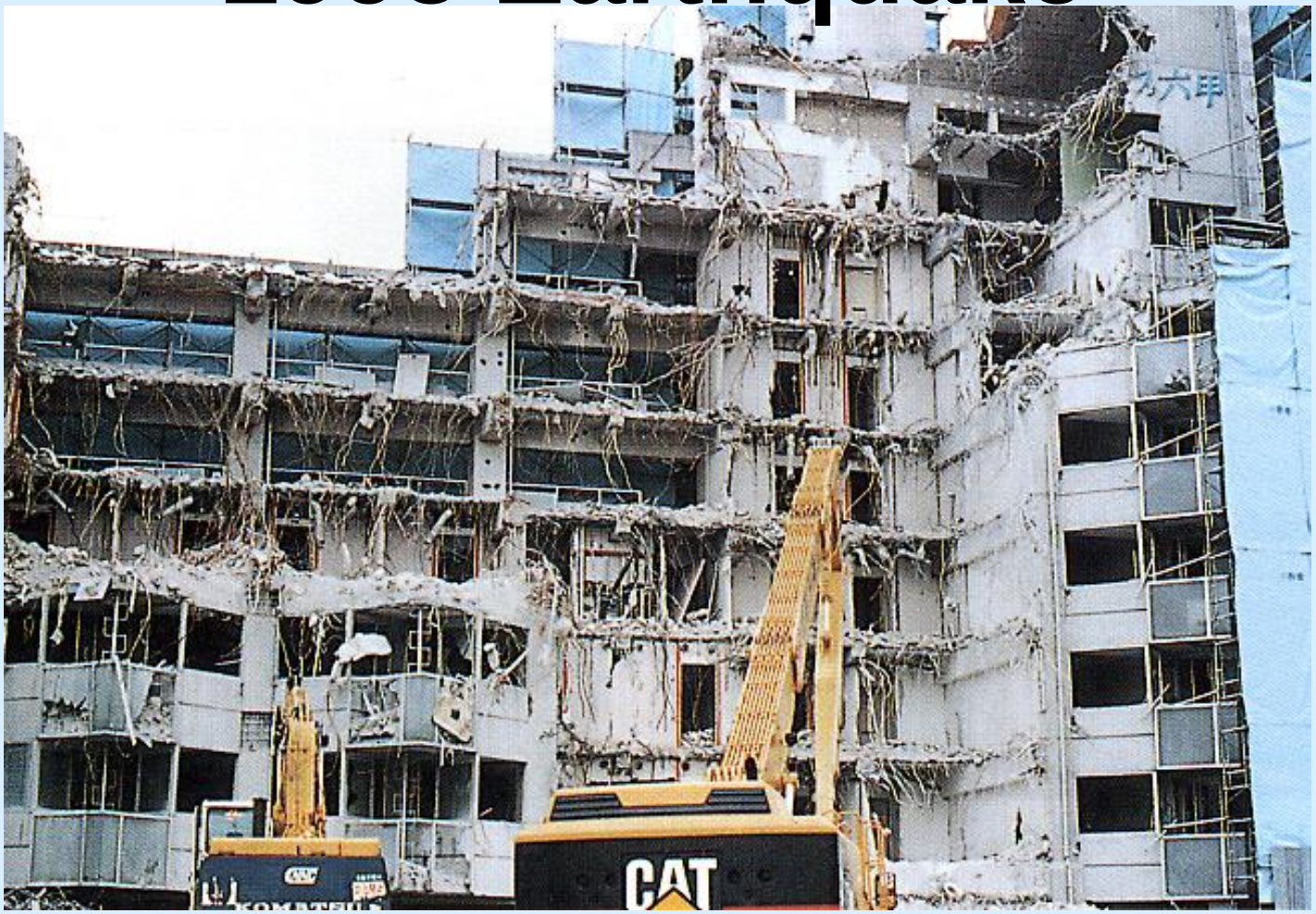
Perfectly Demolished after 1995 Earthquake



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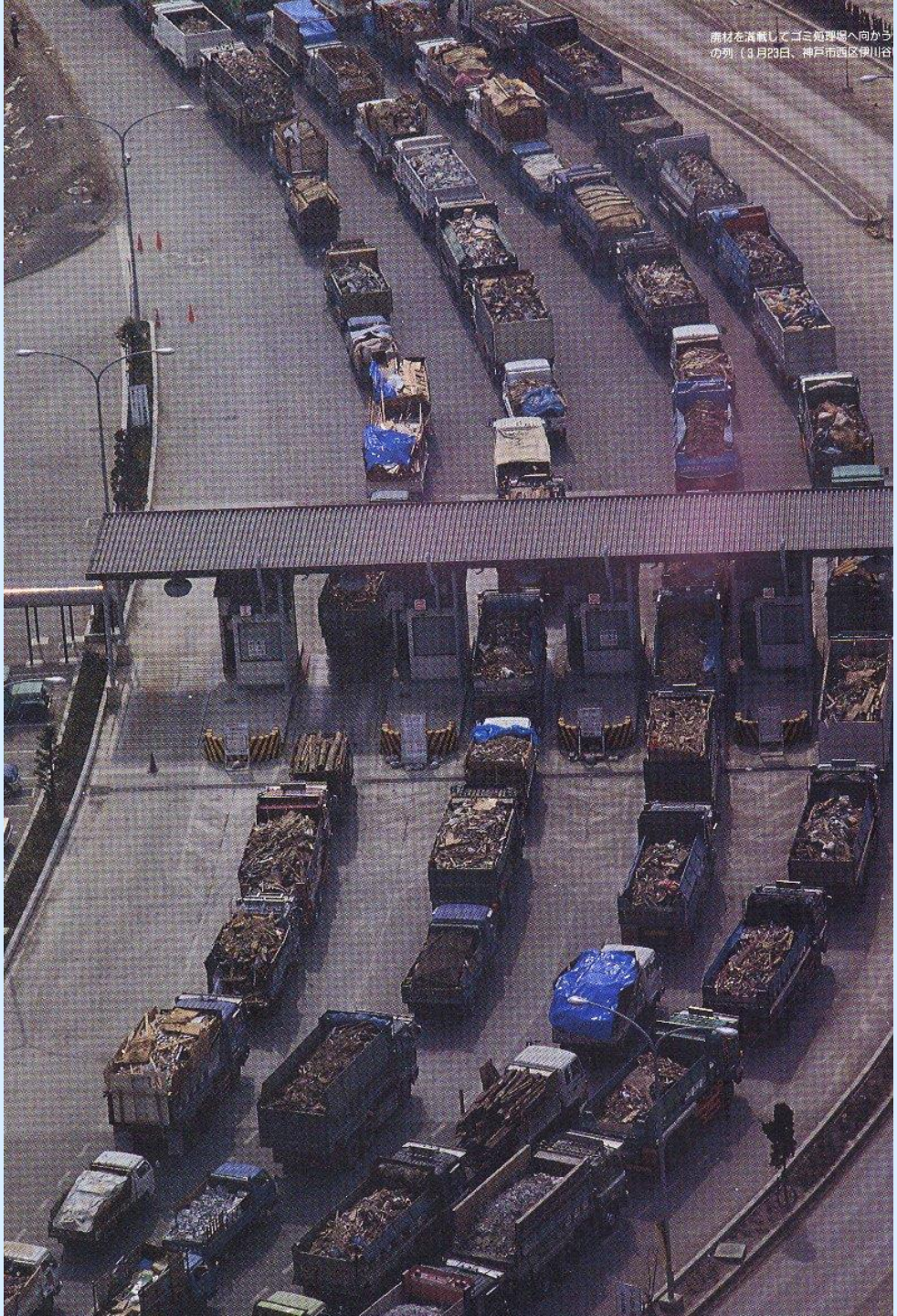

All trucks were bringing huge gavages produced from collapsed buildings and demolished buildings.

East Japan Earthquake at 2011

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

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

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12 story Steel Concrete Apartment Building of Sendai-City

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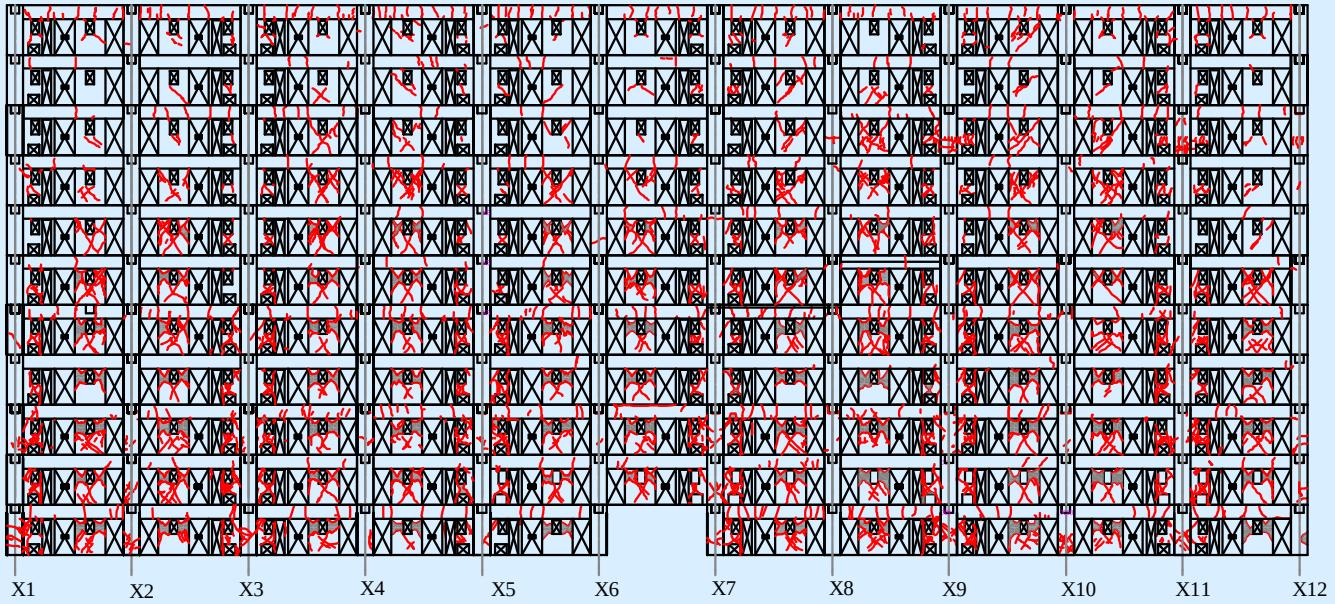
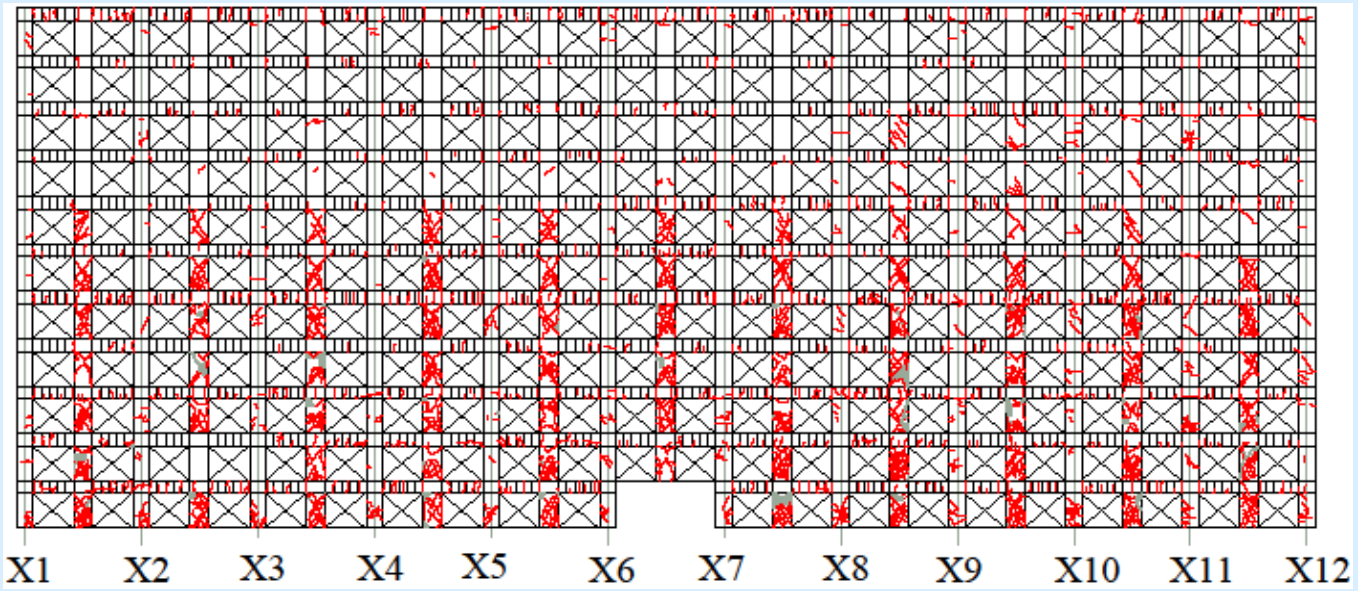
Courtesy of Prof. Yasushi Sanada, Osaka University

West Frame



East Frame



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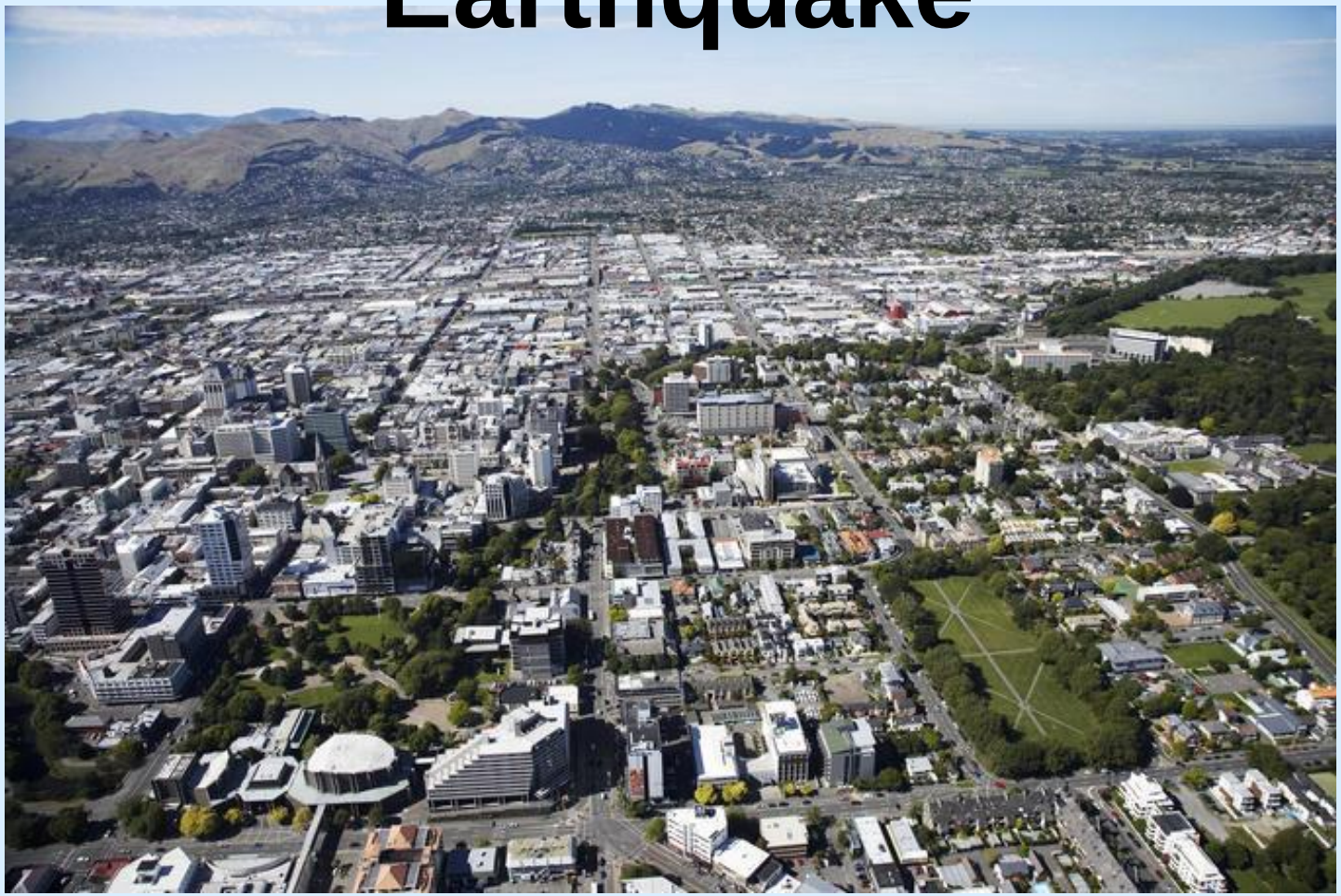
Courtesy of Prof. Yasushi Sanada, Osaka University

Christchurch before 2011 Earthquake



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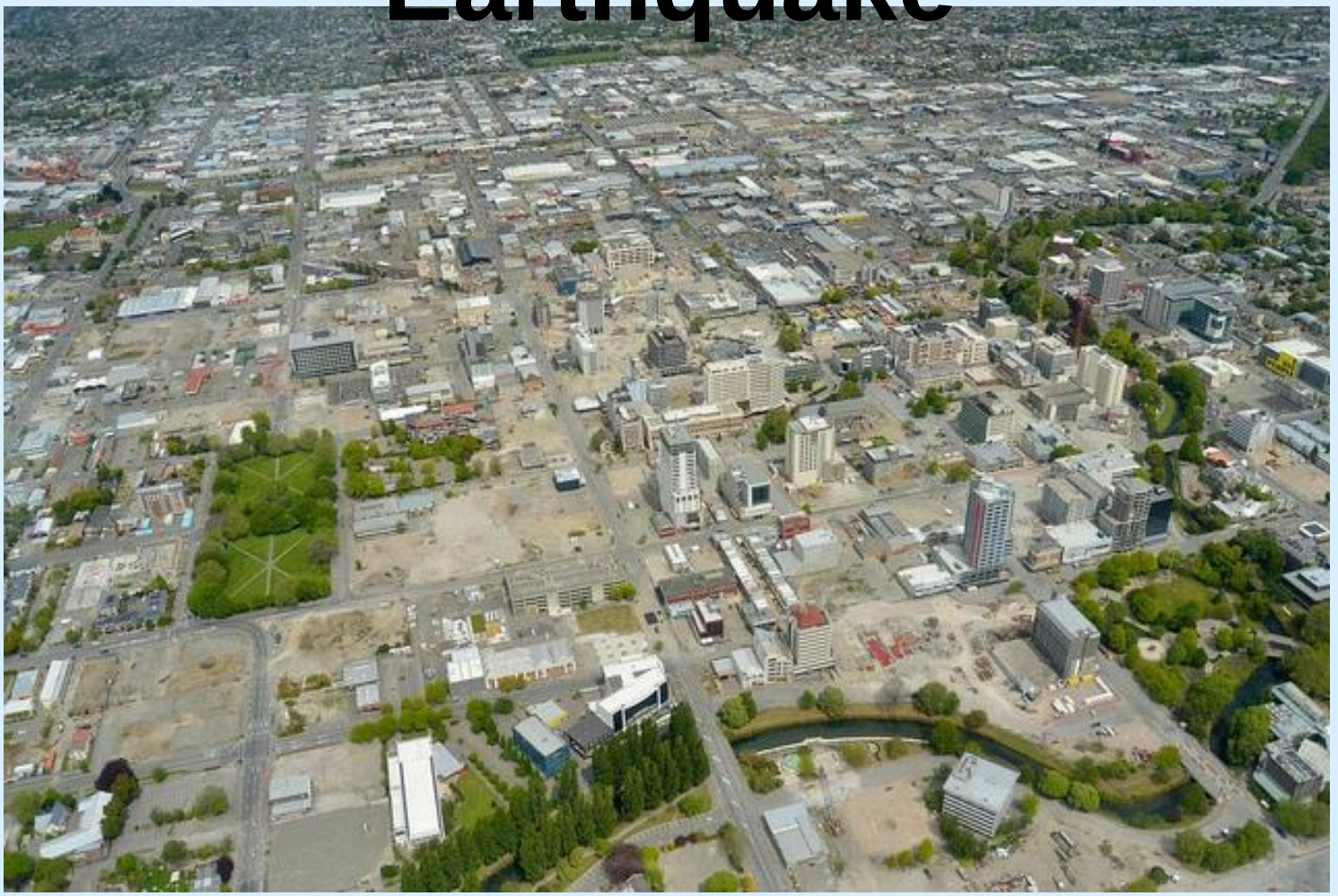
Christchurch after 2011 Earthquake



Our responsibility and mission were not satisfied

Professors recommend
Ductile Frames
to students.

Ductility is Damage 1/2

- The Ds 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.

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
twin steel tall
building
in TITech
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Apartment buildings taller than 30 story buildings

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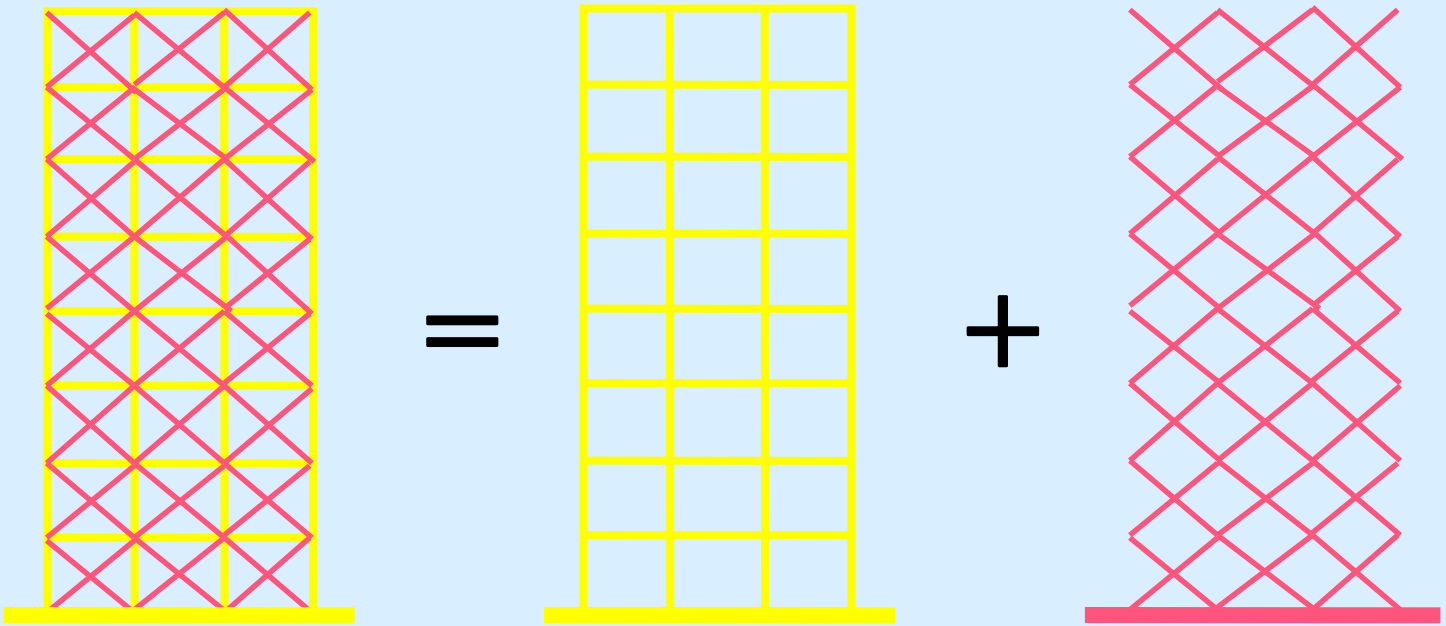
Damage Controlled Structures



Building Structures

Primary Structure

(To Support Vertical Load)

Seismic Members

(To absorb earthquake energy)

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We have to learn good ideas from Nature

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A Bumper protecting people and Bus

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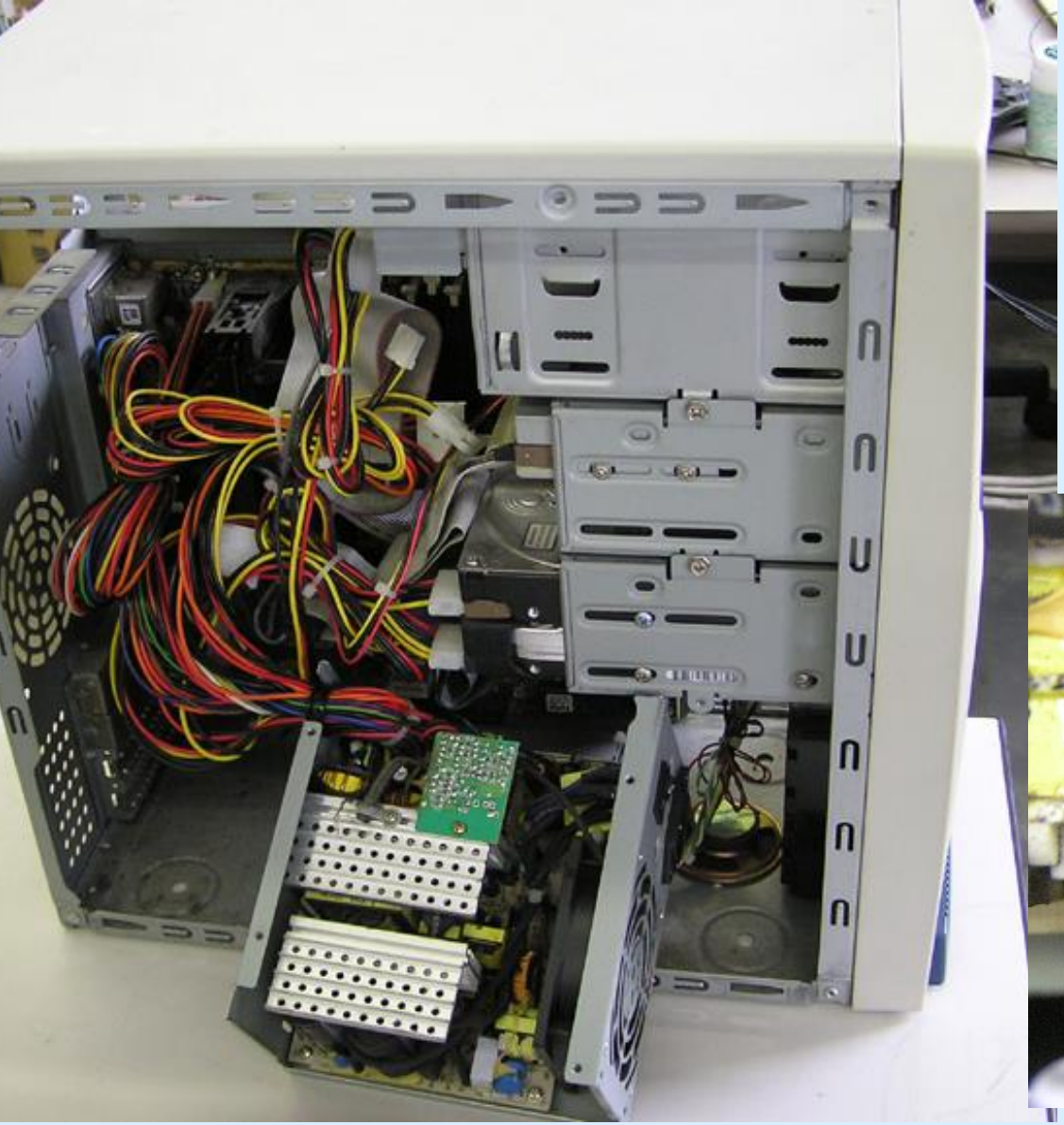

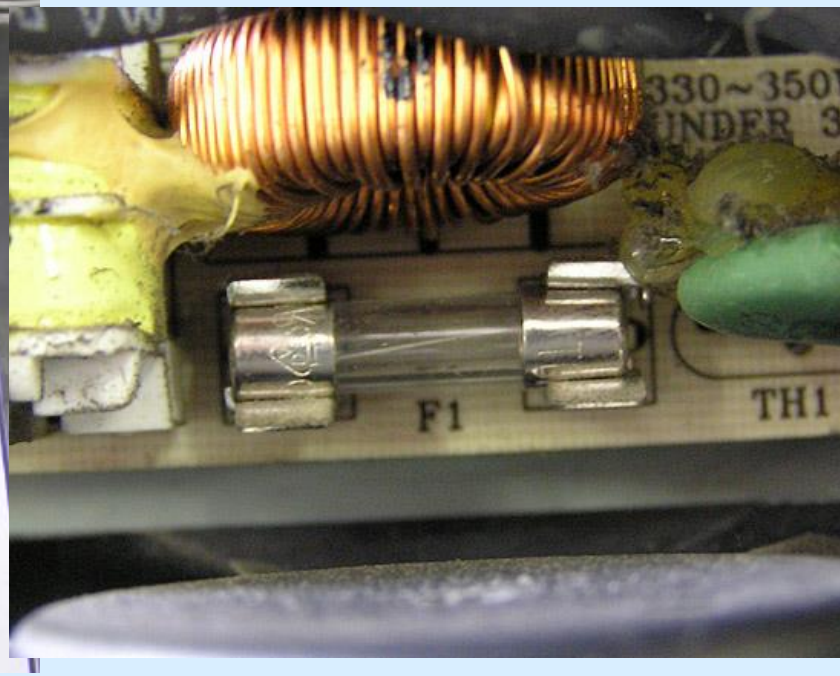

A Fuse protecting important PC

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1987 to 1988

Buckling Restrained Braces

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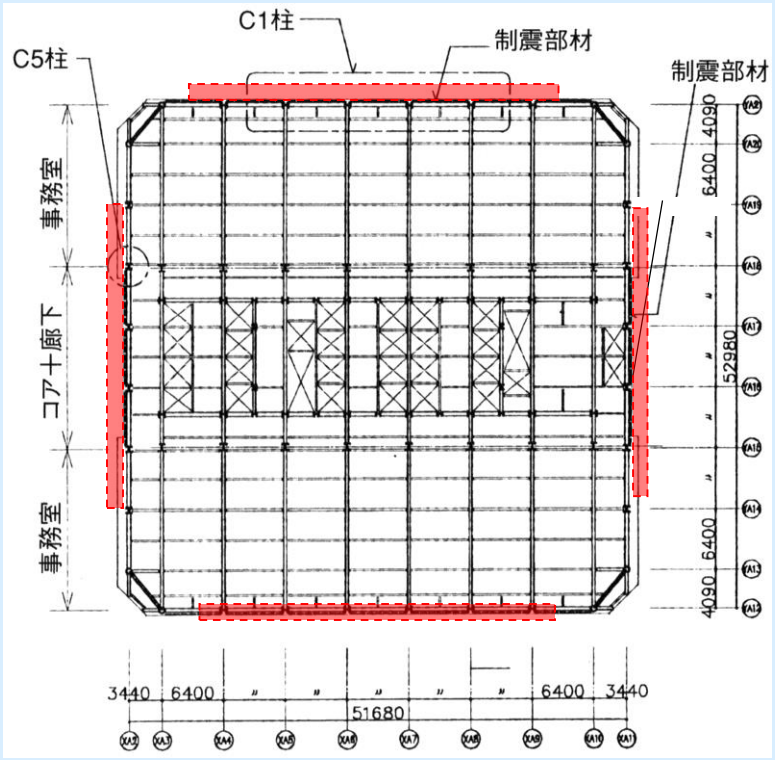
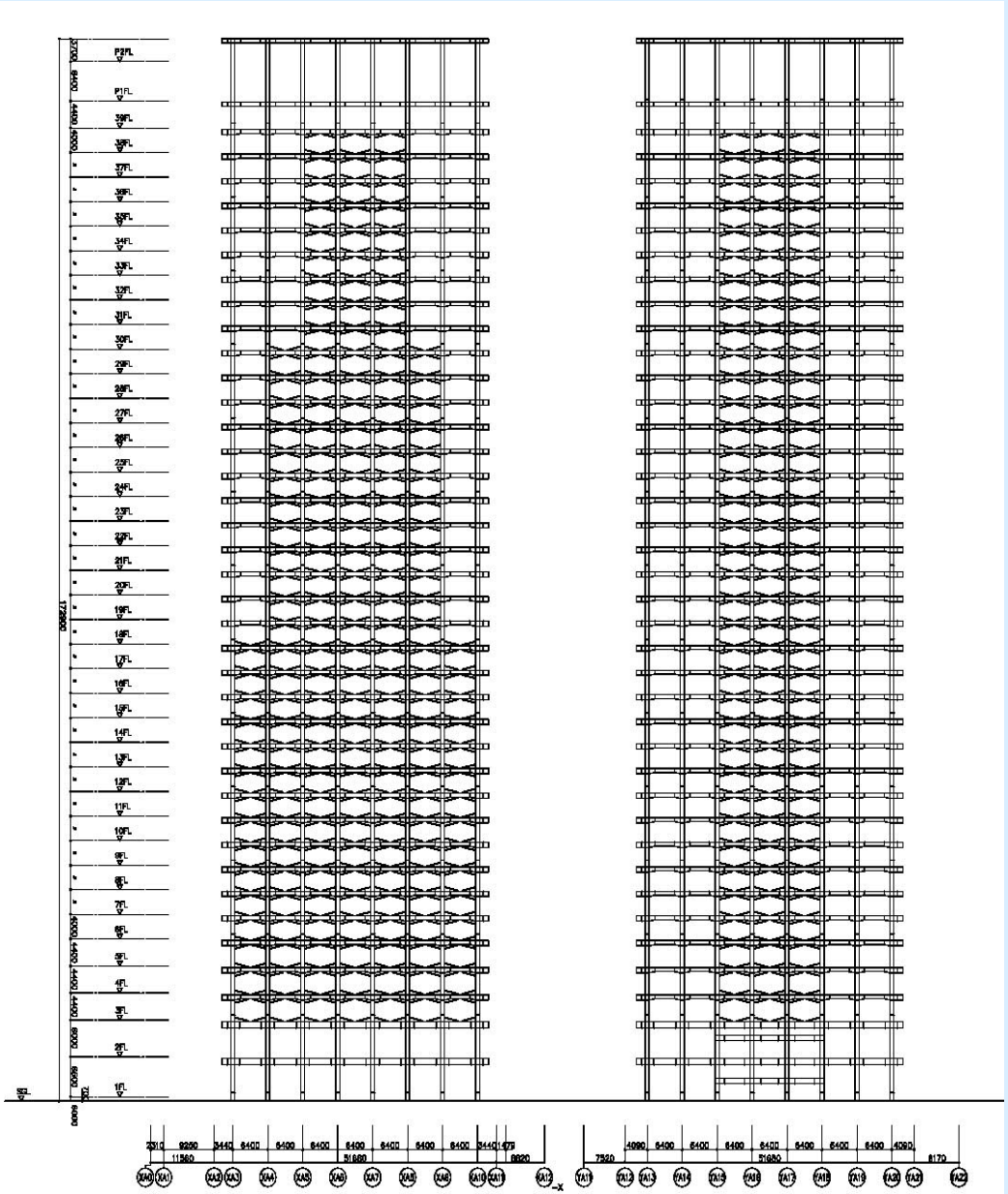
Framing Plan & Elevation





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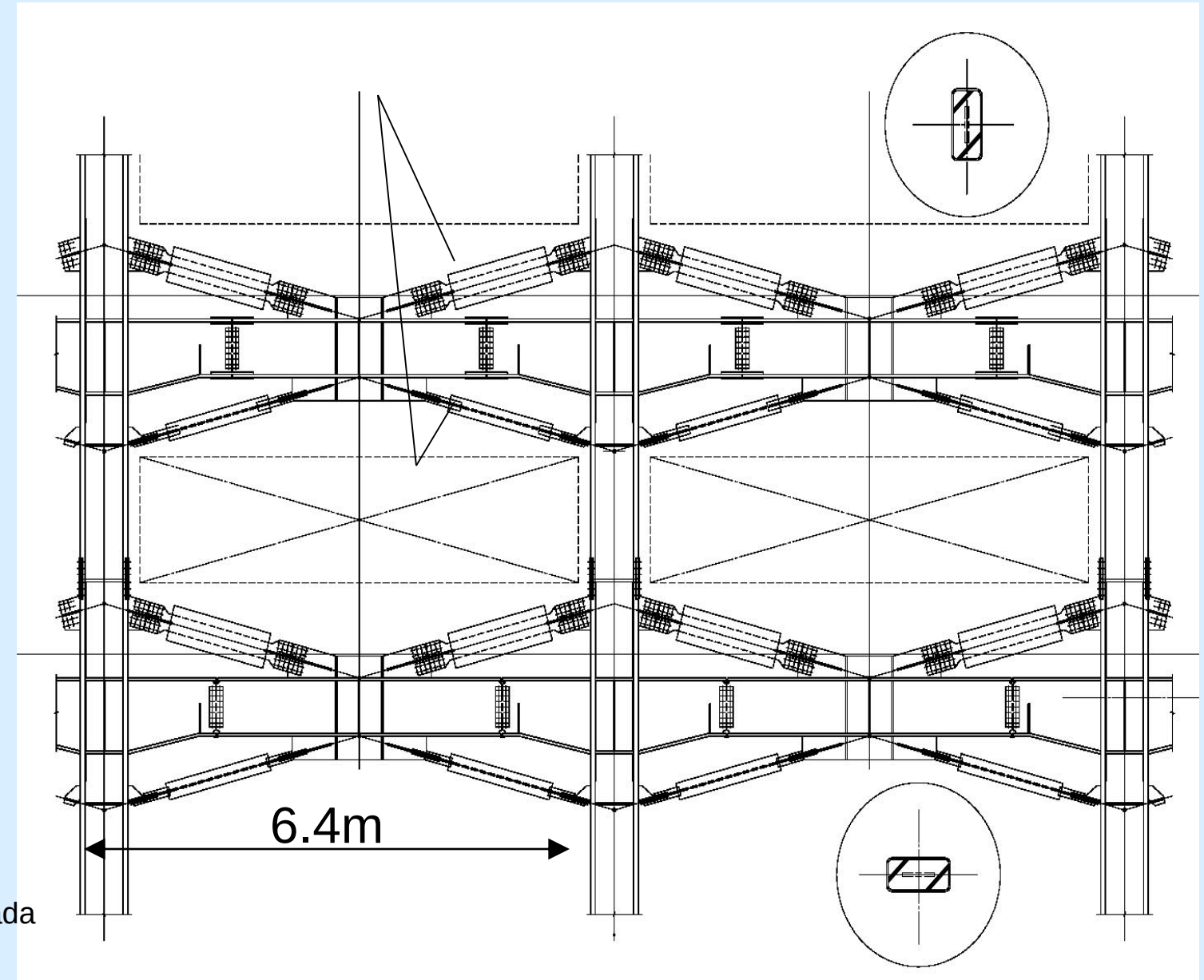
Detail of Unbonded Braces



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Many Unbonded Braces are Installed

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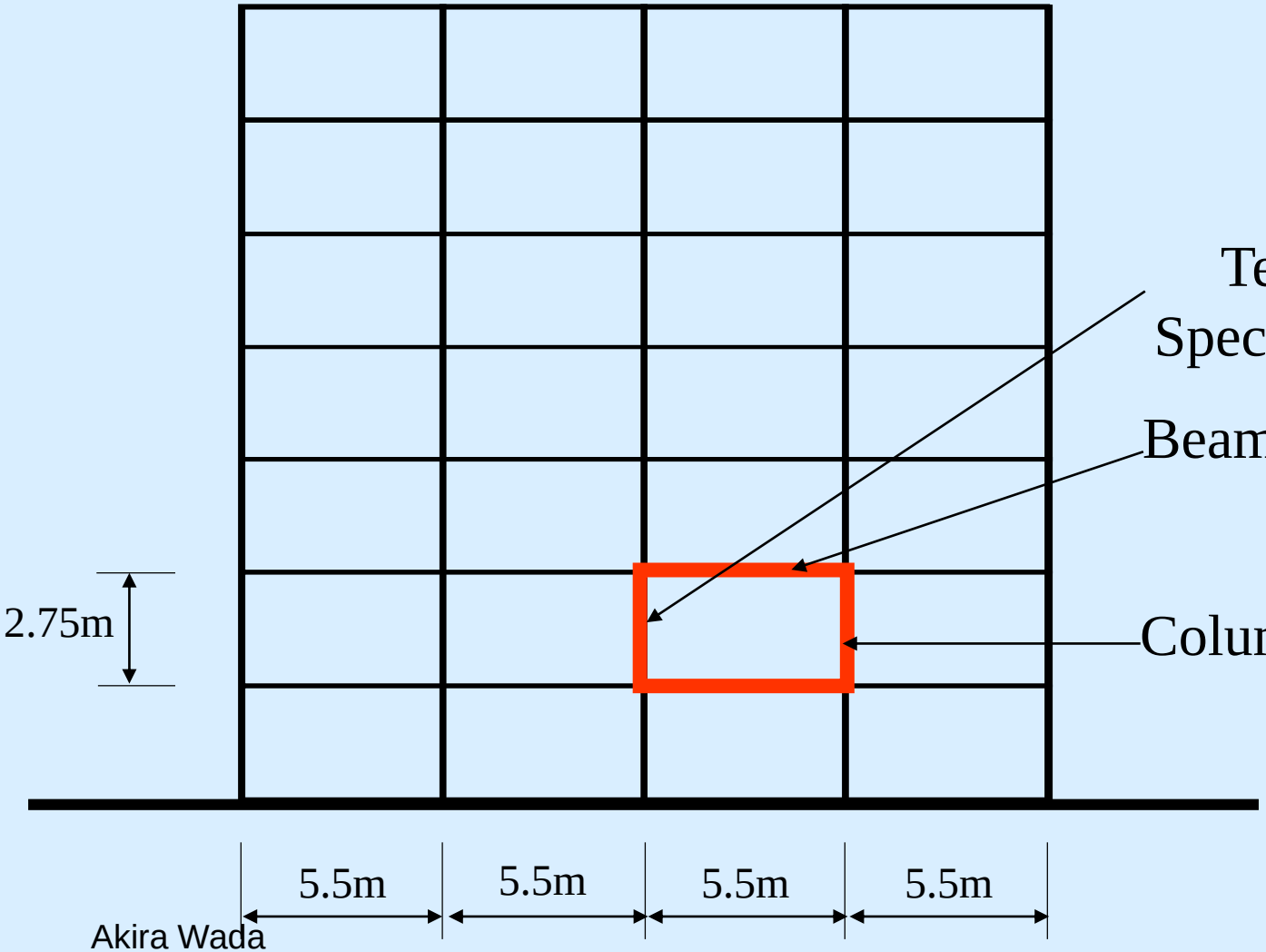
Shaking table tests for RC frame



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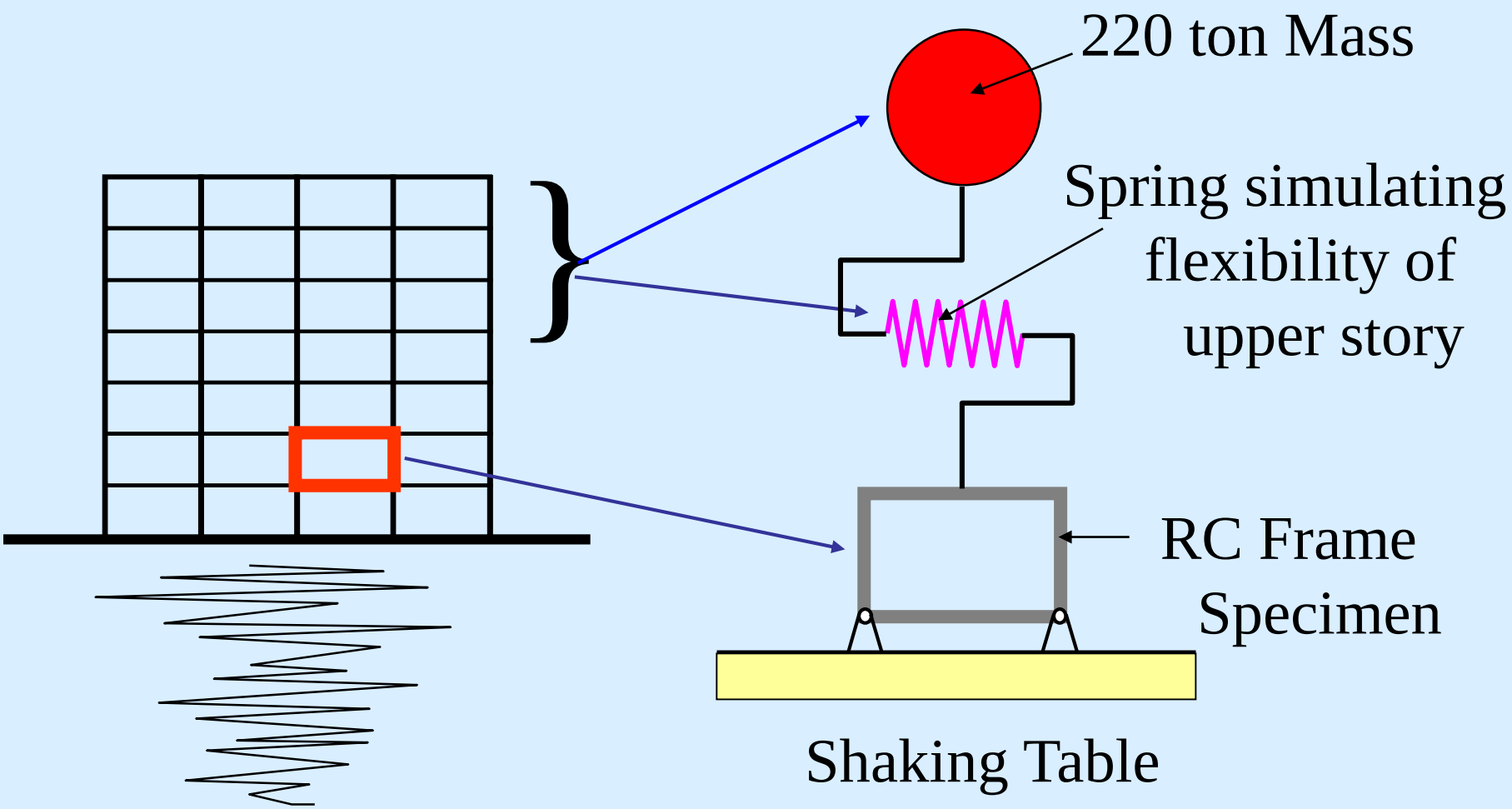
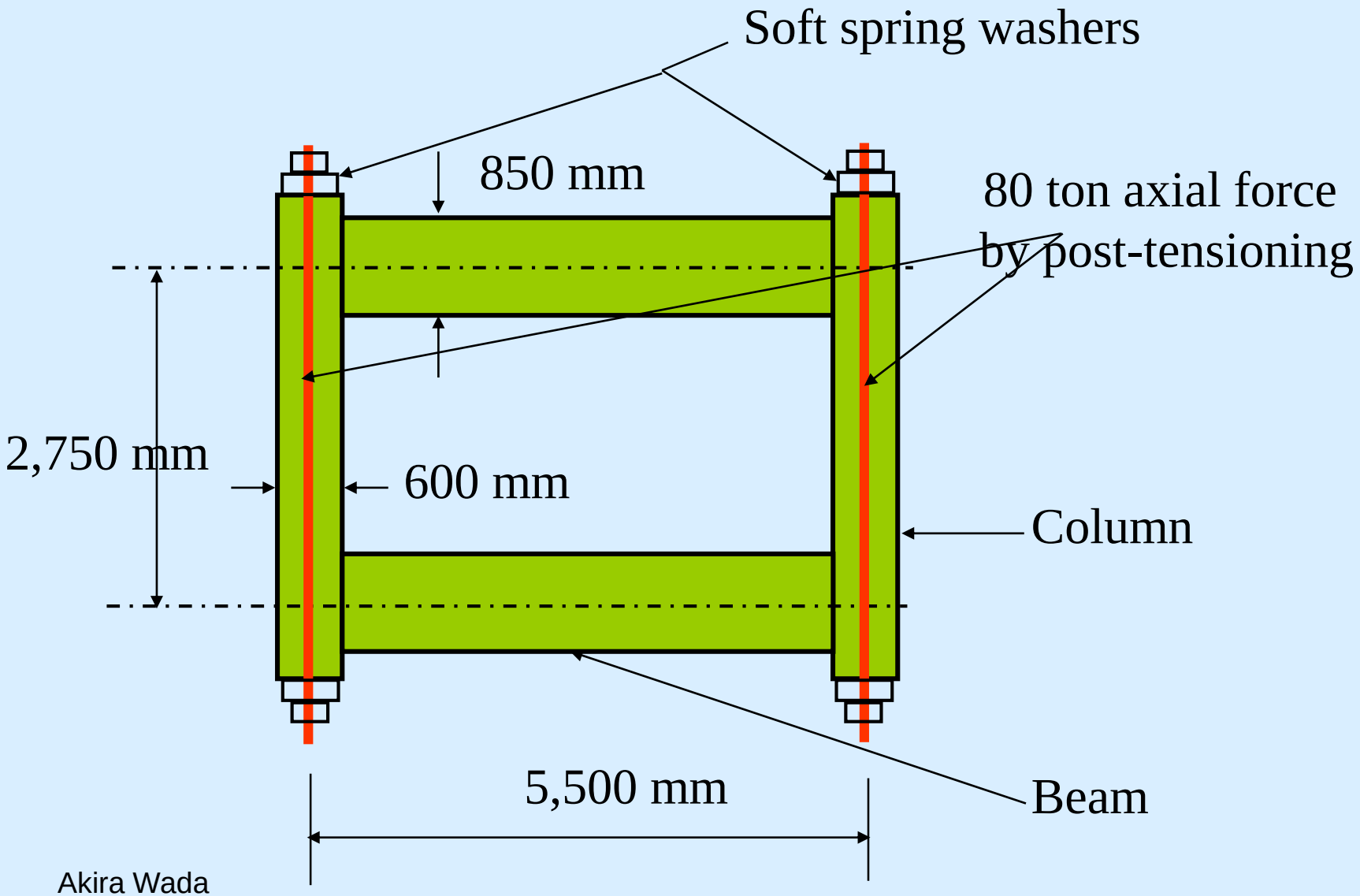
Additional mass and flexibility



Introduction of column axial forces



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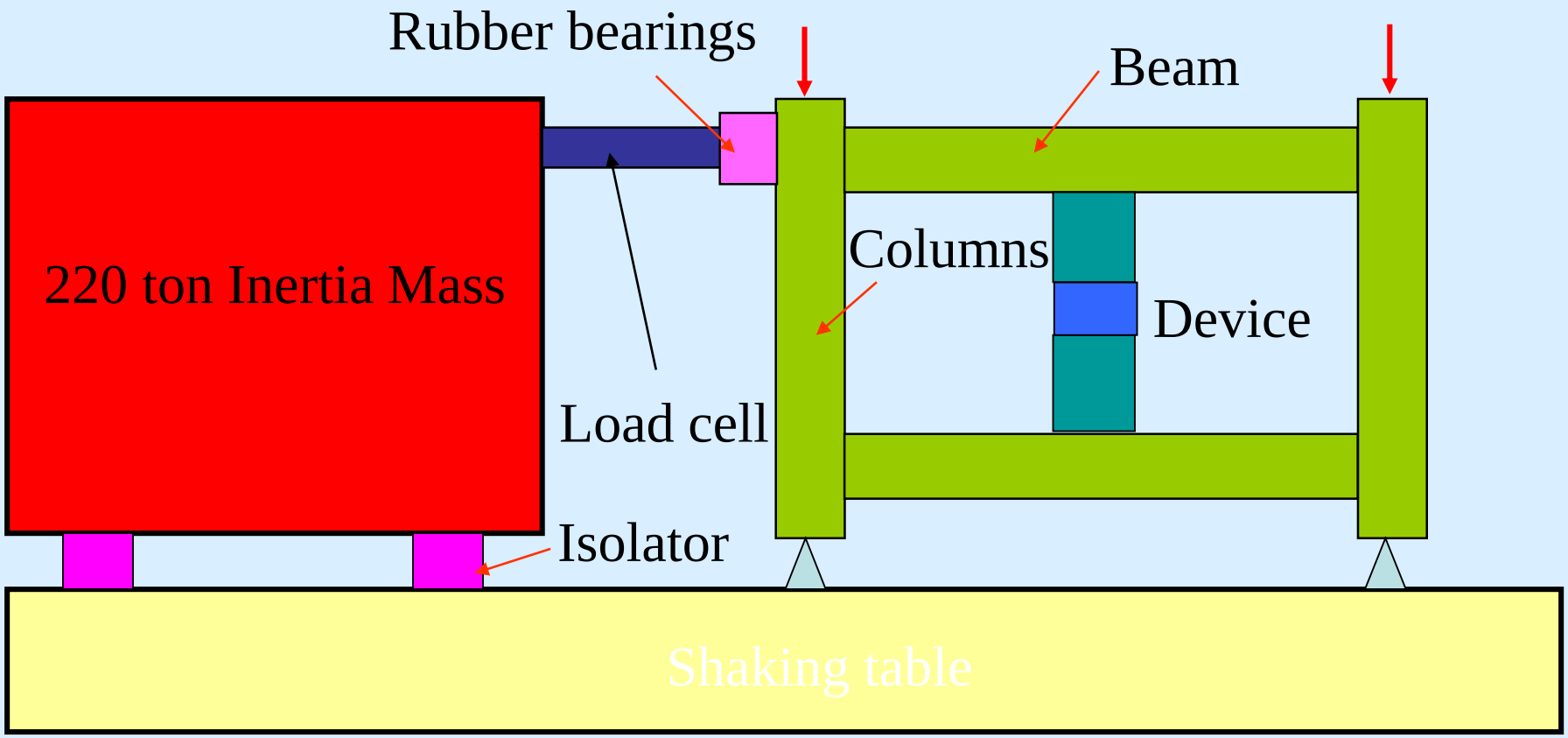
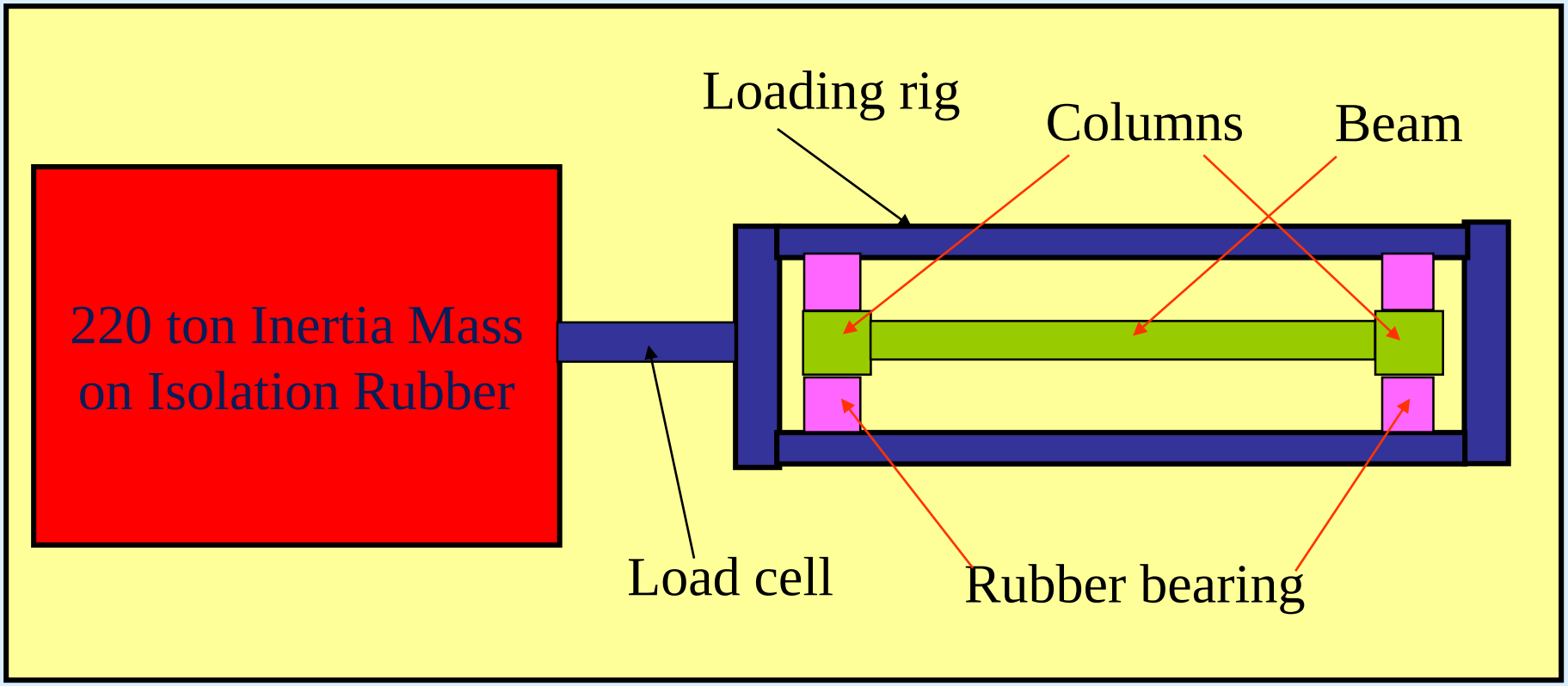
Elevation view during test



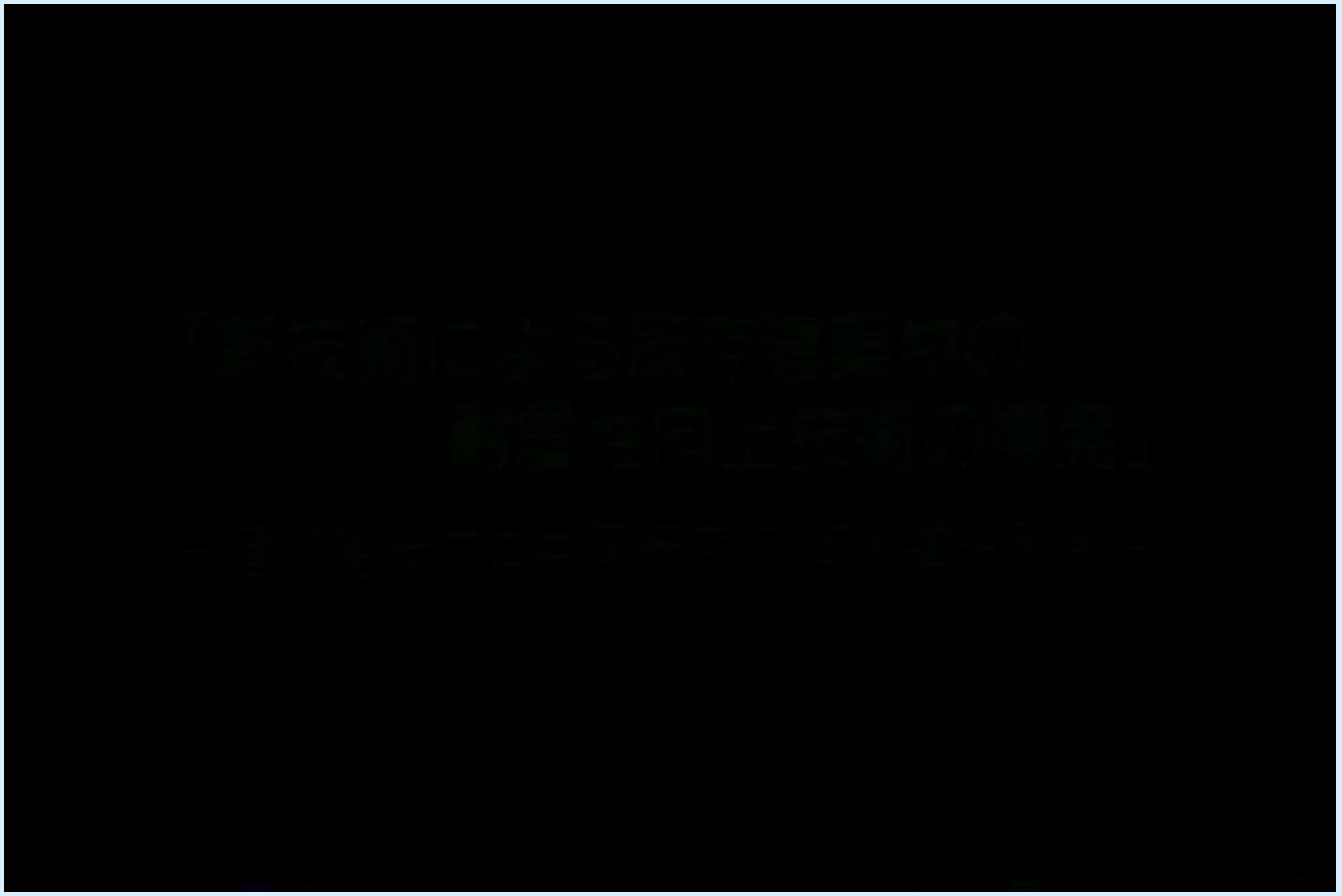
Natural period of the system : $T_1 = 0.6\text{sec}$

Plan view during test



Shaking Table

Natural period of the system : $T_1 = 0.6\text{sec}$



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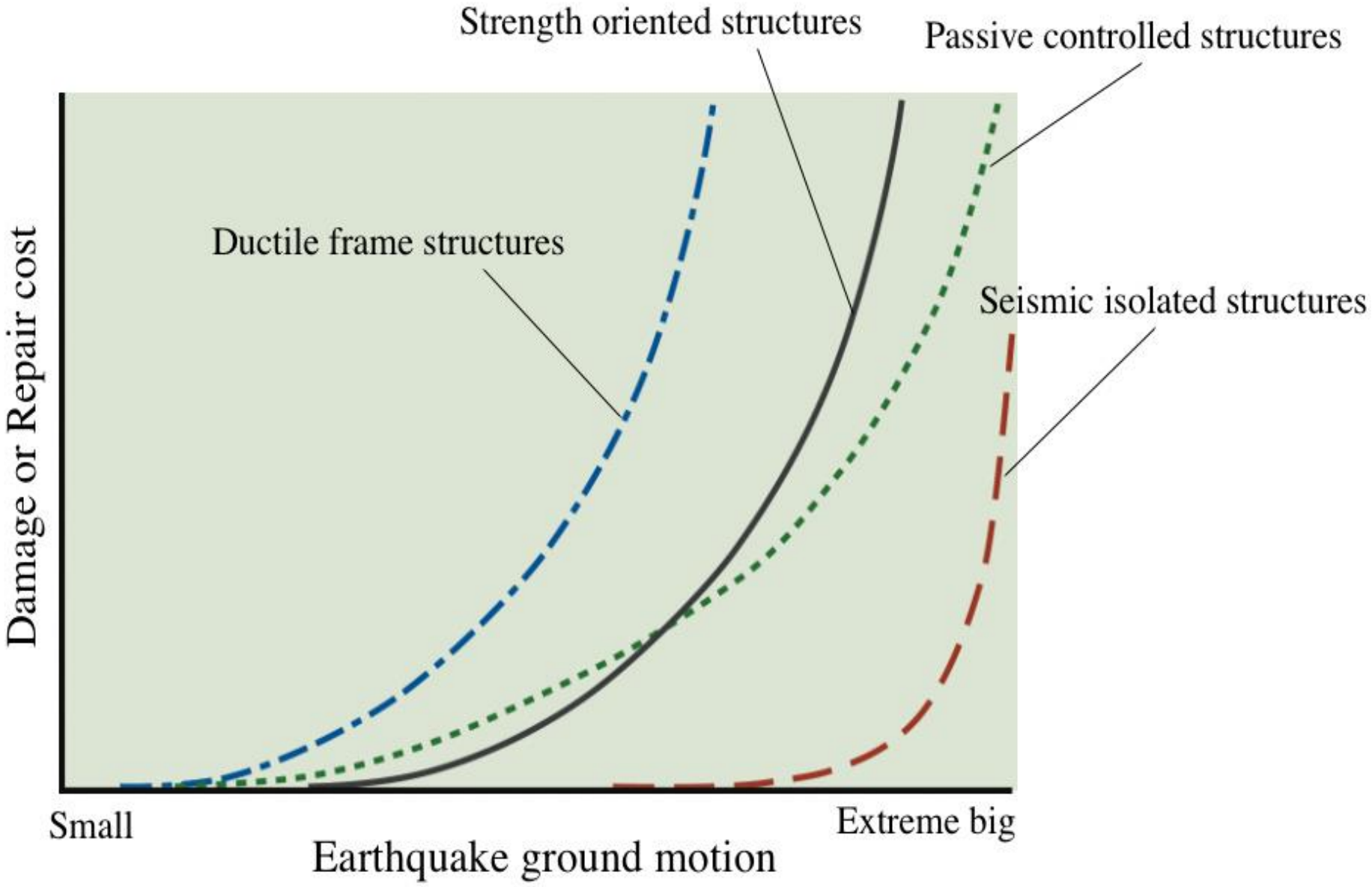
Strength oriented structures
Passive controlled structures
Ductile frame structures
Seismic isolated structures
Damage or Repair cost
Small
Extreme big
Earthquake ground motion

Akira Wada


Tokyo
Akira Wada

Tokyo

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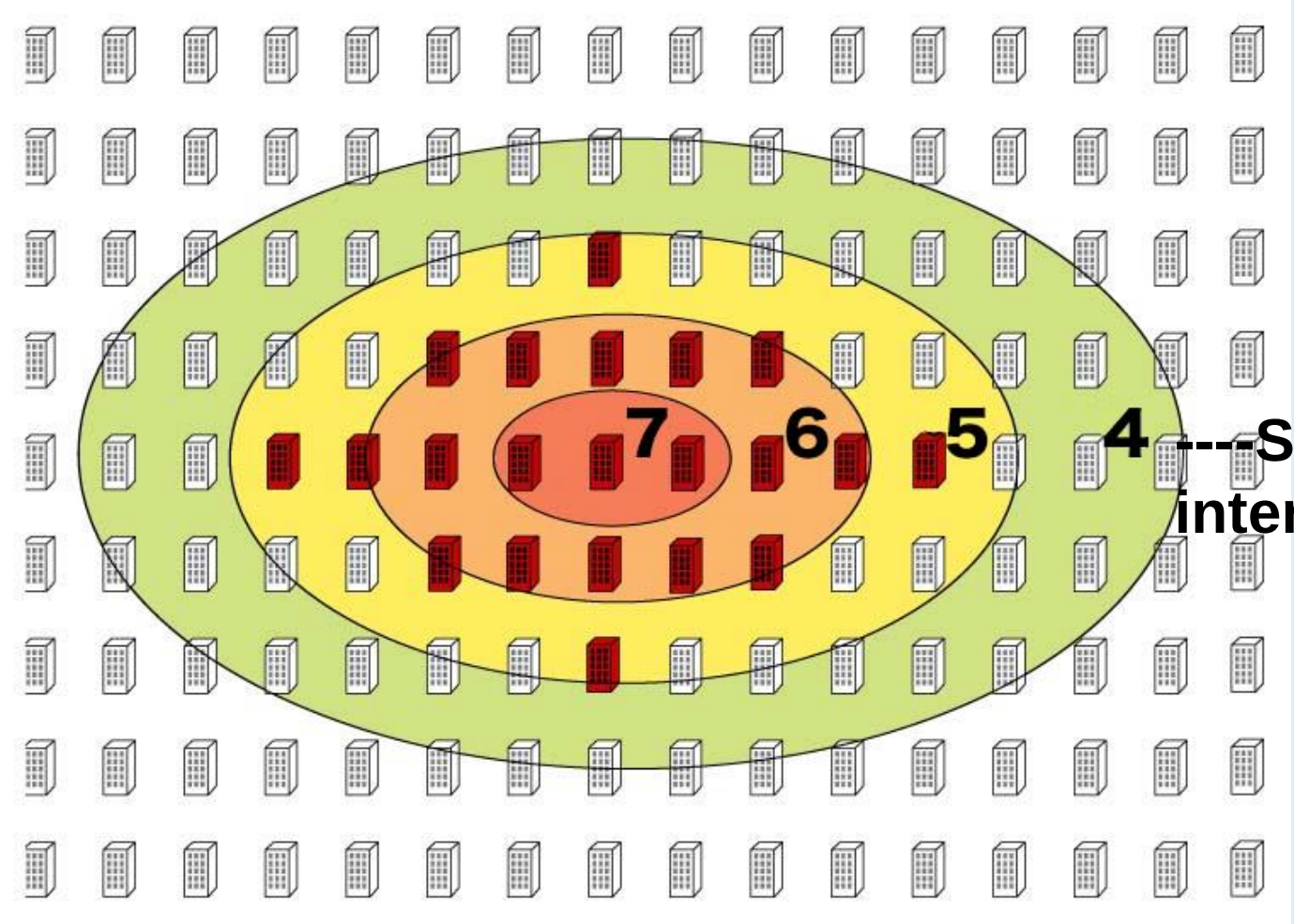

Damages of buildings in the city after big earthquake, in the case that all buildings were designed as ductile frame structure.

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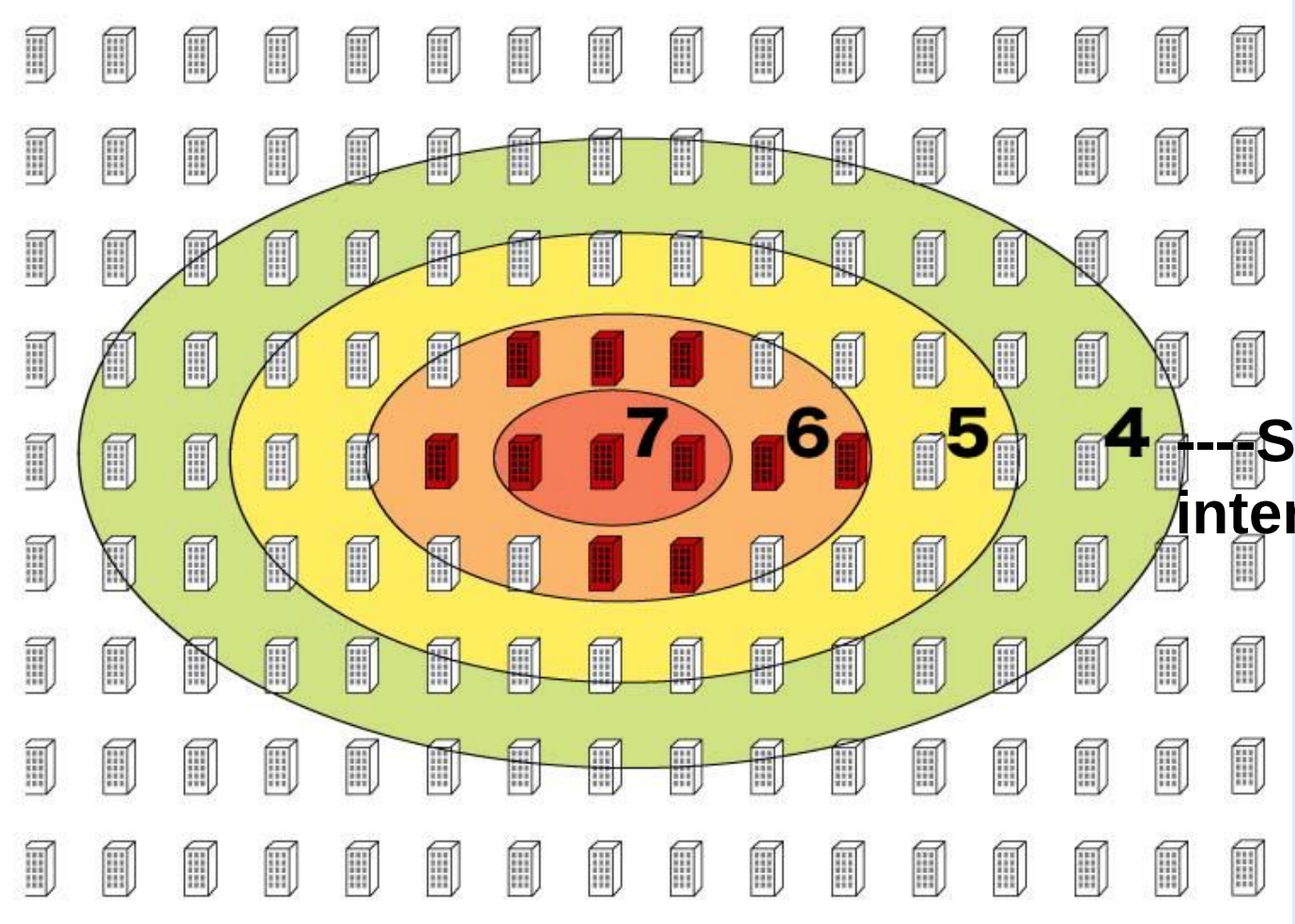

Damages of buildings in the city after big earthquake, in the case that all buildings were designed as strength oriented structure.

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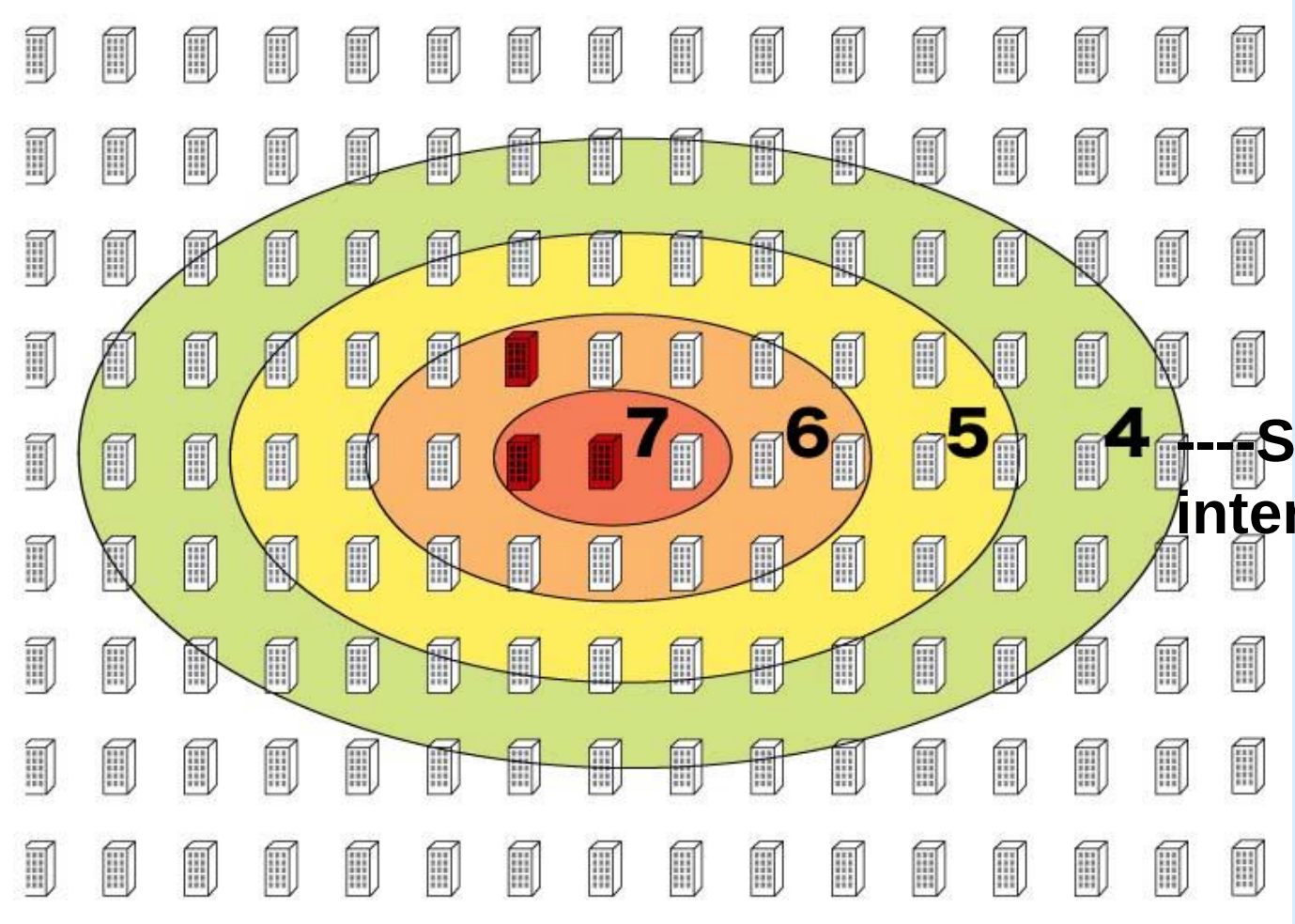

Damages of buildings in the city after big earthquake, in the case that all buildings were designed as passive controlled structures.

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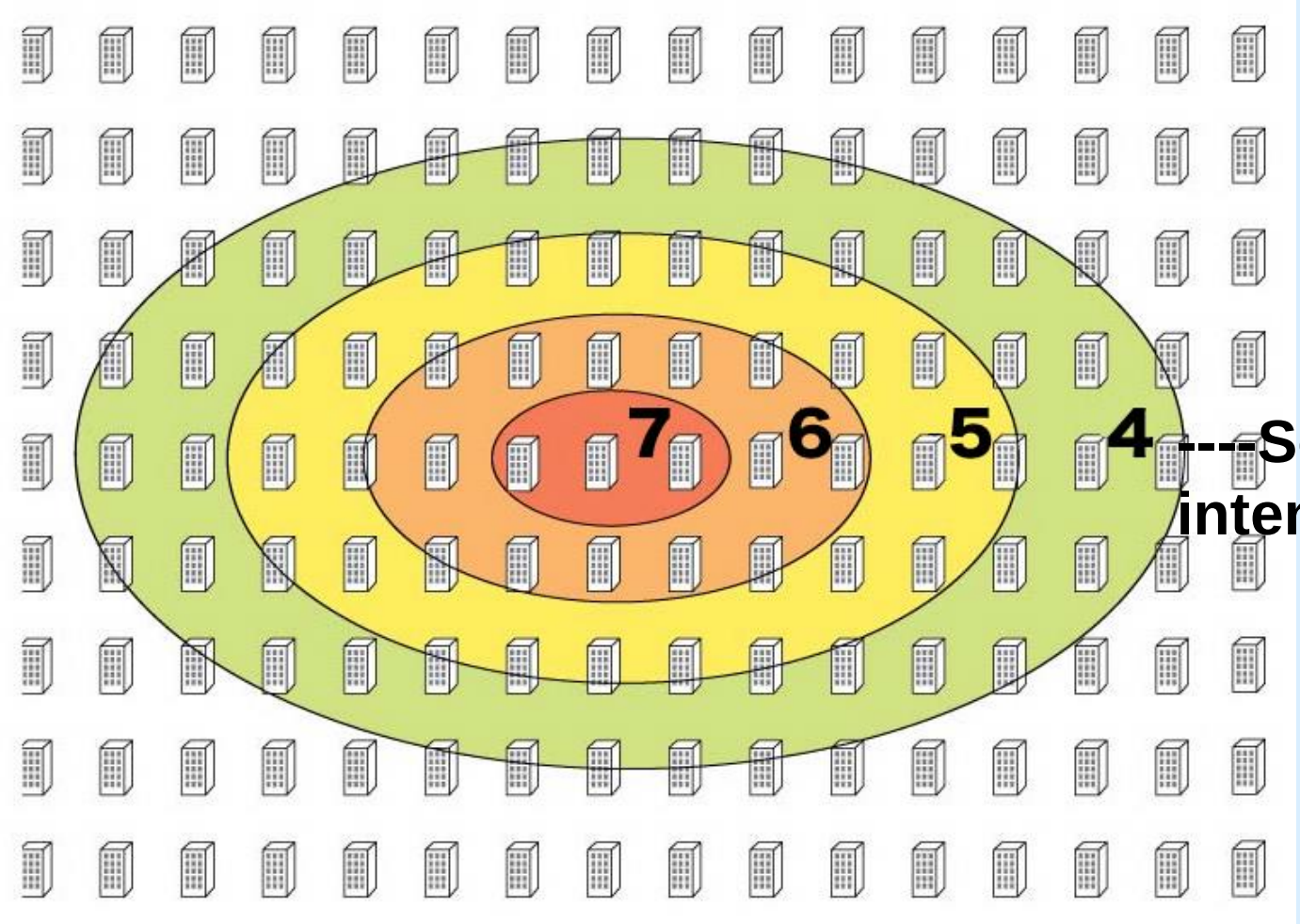

Almost no damage of building in the city after big earthquake, in the case that all buildings were designed as seismic isolated structures.

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

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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.

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:

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.

Epilogue must be Happy End

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

Akira Wada