# DEVELOPMENT OF RESILIENT REINFORCED CONCRETE BUILDING STRUCTURE

Seitaro Tajiri, Hiroshi Fukuyama, Tomohisa Mukai
Building Research Institute

Toshikazu Kabeyasawa
The National Institute for Land and Infrastructure Management

# Introduction

Targets of current earthquake resistant standards

(1) A building should be resilient in the case of a moderate earthquake, and its restoration should not be particularly required.

(2) A building should not collapse and human life should be secured in the case of a great earthquake.

# *Great Hanshin-Awaji Earthquake in 1995*

Many buildings avoided collapse and saved people’s lives as required by the law

- Dwelling functions were lost.
- Restoration costs were so expensive that these buildings were demolished and rebuilt.

## *Mid Niigata Prefecture Earthquake in 2004*

- A lot of semiconductor factory production facilities were damaged.

-> The other companies which the factories had provided products suffer the impact.

- In hospitals, there arose a situation where medical operation could not continue due to the damage to facilities and equipment.

## *Niigataken Chuetsu-oki Earthquake in 2007*

- A precision instrument factory for car engines was damaged.

-> Domestic motorcar manufacturers were forced to stop all their production lines.

# *The 2011 Great East Japan Earthquake*

- Government buildings, which should have become on-site countermeasure centers, were damaged.
- Gymnasiums expected to be used as evacuation sites were damaged.
- Apartment houses were so badly damaged that the dwelling functions were lost.

*Requiements from the society*

Buildings should be resilient and usable enough in the case of a great earthquake.

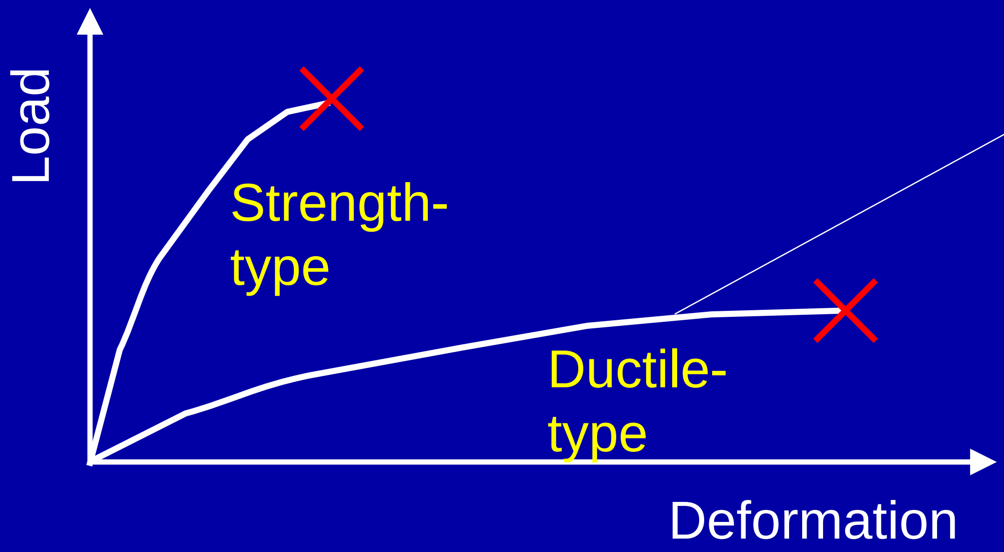
Major gap

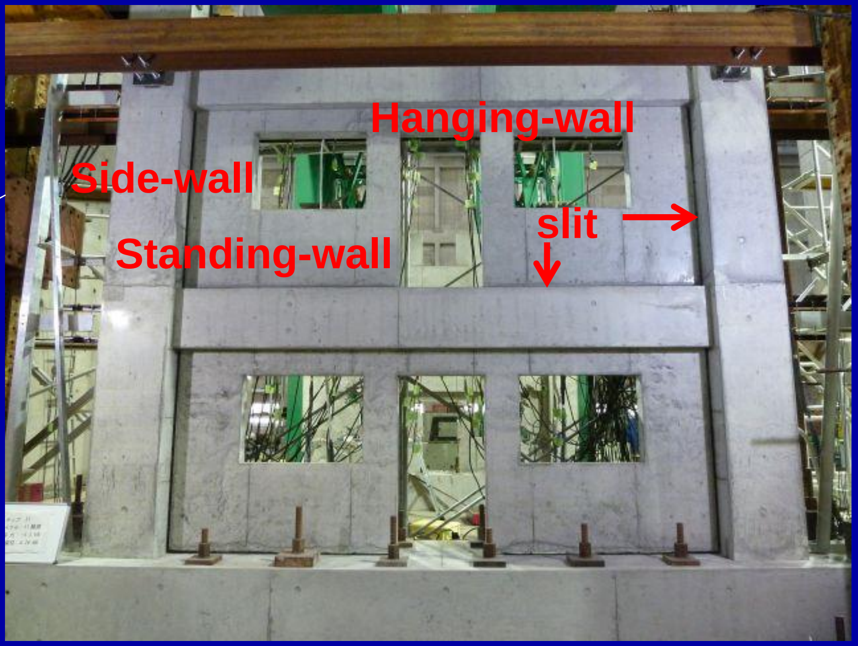
*Requirements by the law*

Not collapsing and protecting human lives

⇒ “How to ensure the resiliency of a building after an earthquake” and “How to promptly restore functions deteriorated by an earthquake” have been strongly required.

# Conventional RC Structure




Most RC buildings, which have nonstructural walls separated from the adjacent beams and columns with structural slits, are designed as ductile type.

-> The deformation or the damage will be large.

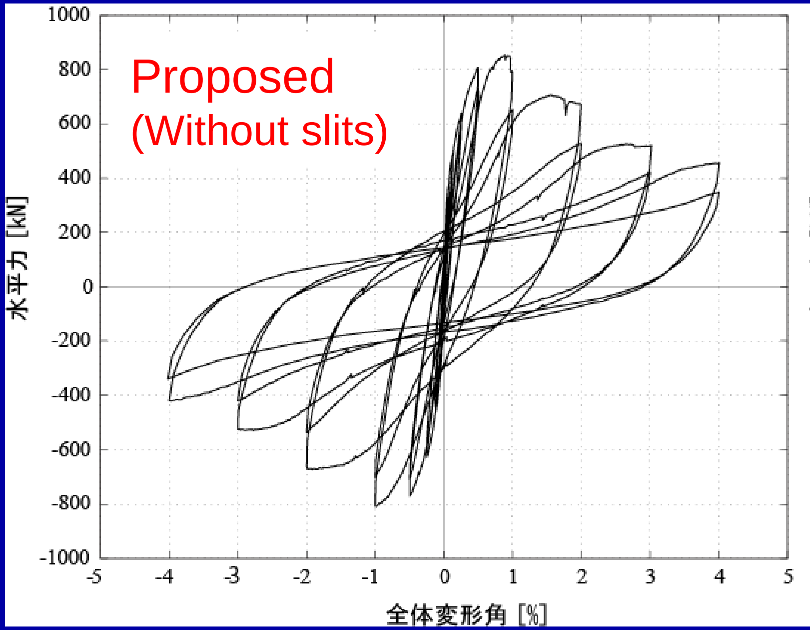
# Proposed Resilient Structure

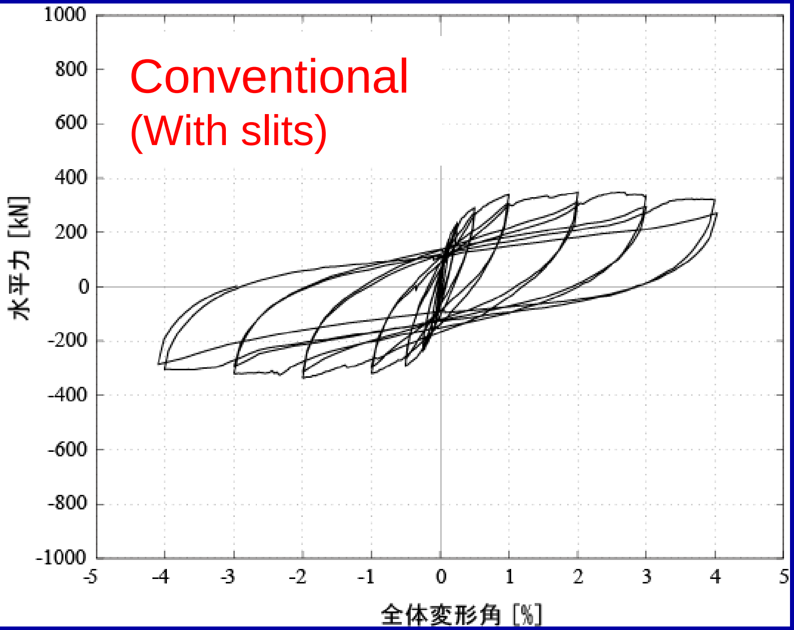
The proposed structure aims to reduce its damage or deformation with increasing strength and rigidity.

- Reinforced concrete structure
- Nonstructural walls are integrated with the adjacent beams and columns without setting slits.
- These walls also have adequate thickness and reinforcement like a structural wall in order to increase strength and ductility.
- Construction will be easier than the conventional.

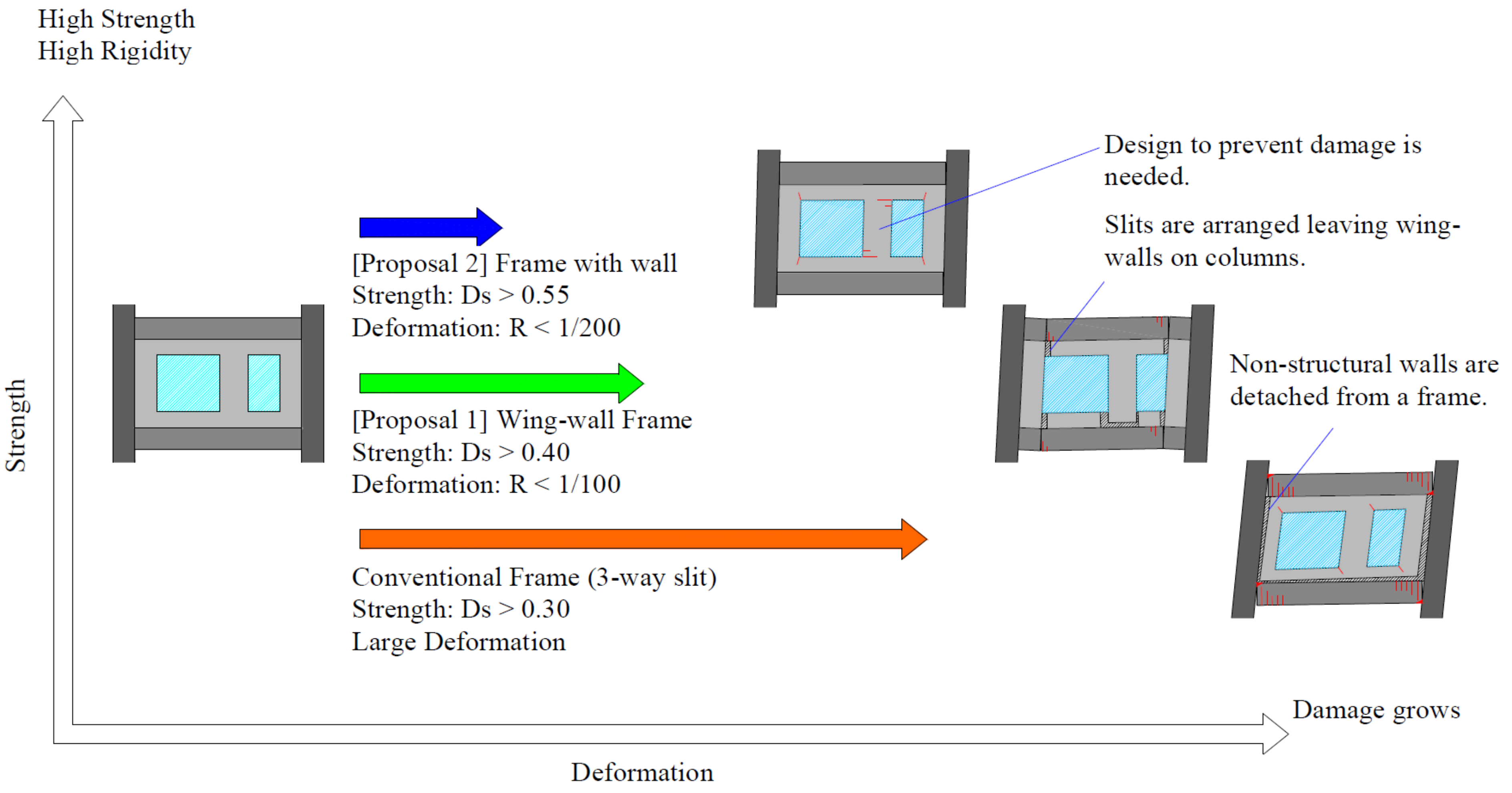
# Comparison with Conventional and Proposed

The strength of the specimen without slits showed more than twice as high as those with slits.



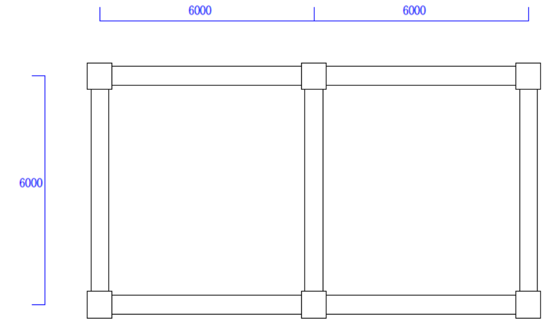



# Types of Proposed Structures

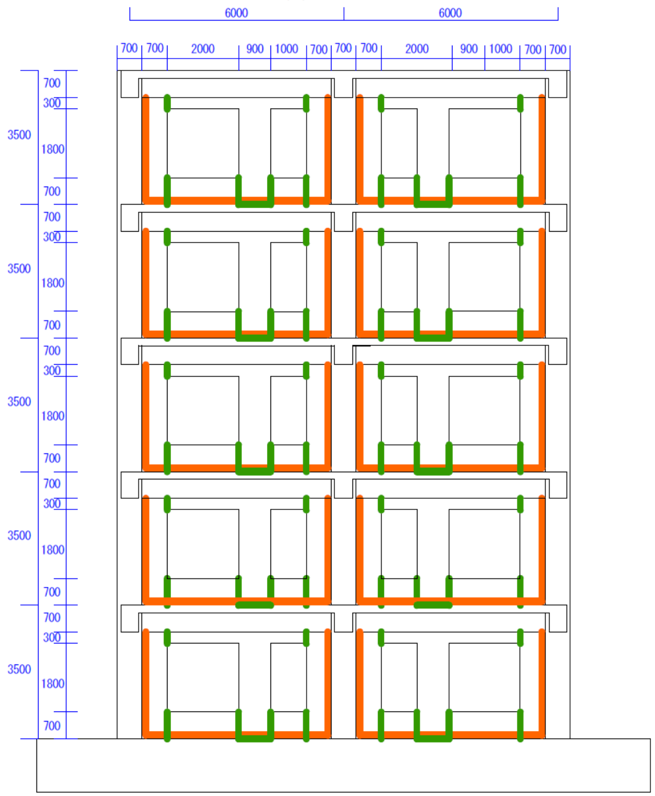


# Feasibility Study of Proposed Structure

| | |
|---|---|
| Shape | 2x1 Span, 5 Stories |
| Span | 6.0 m |
| Story Height | 3.5 m |
| Concrete | 30 N/mm$^2$ |
| Column Section | 700x700 mm |
| Column Main Reinforcement | 16-D25 (SD345) |
| Beam Section | 500x700 mm |
| Beam Main Reinforcement | 6-D25 (SD345) (5F and RF), 8-D25 (SD345) (2-4F) |
| Wall Thickness | 200 mm |
| Wall Vertical and Horizontal Reinforcement | D10@200 double (SD295) |
| End Reinforcing Bar | 4-D13 (SD295) |
| Slab Thickness | 200 mm |
| Slab Bar Arrangement | D10@150 double (S295) |
| Wing-Wall Length | 700 mm |
| Opening 1 | 2000×1800 mm |
| Opening 2 | 1000×1800 mm |

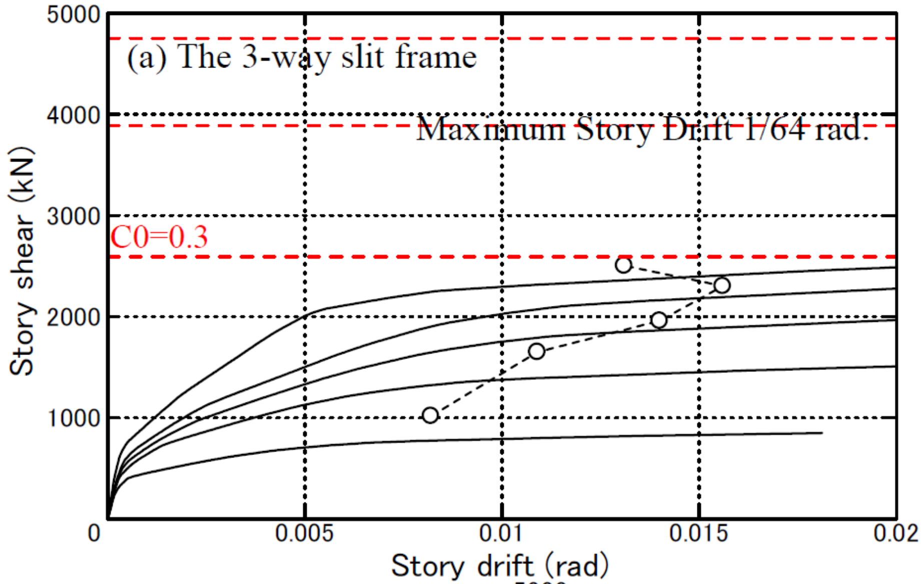


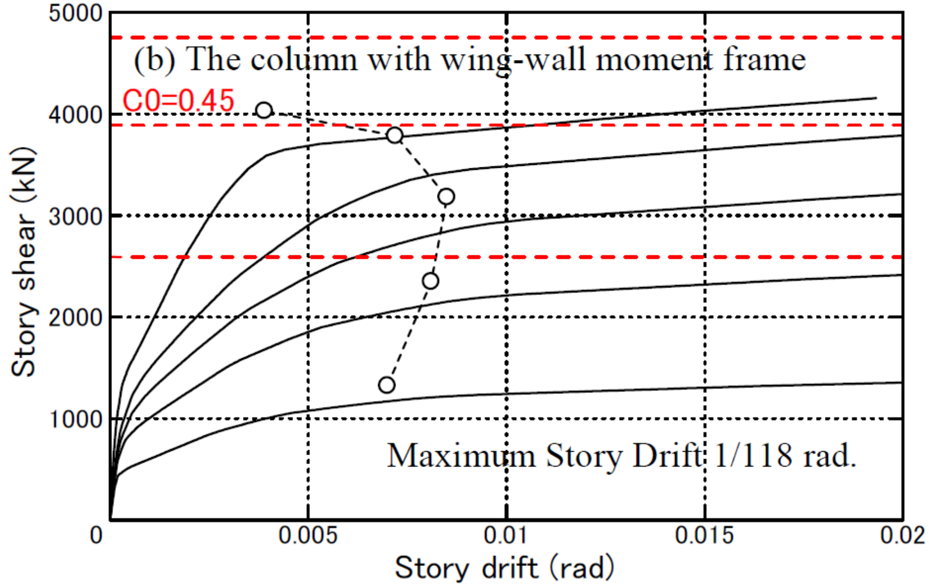
(a) Plan

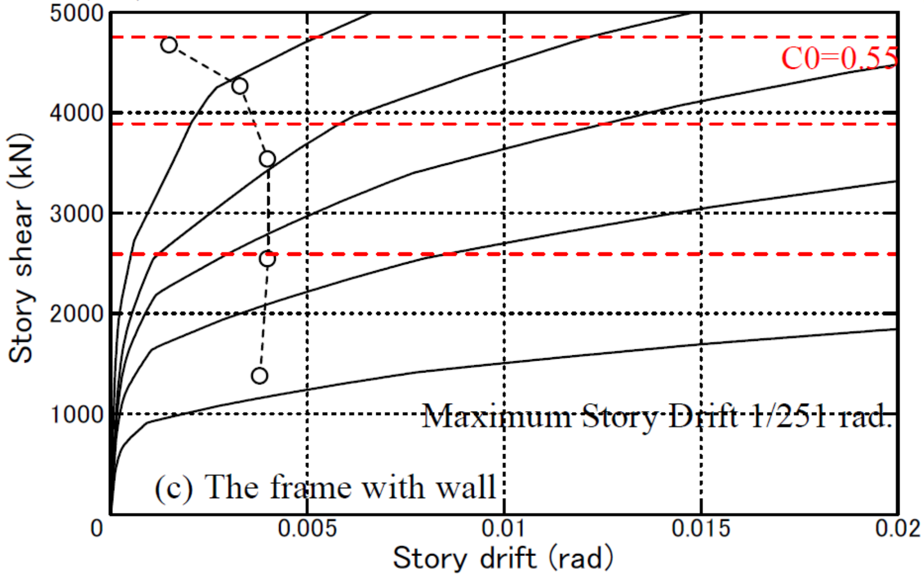


(b) Elevation

# Pushover Curves and Responses



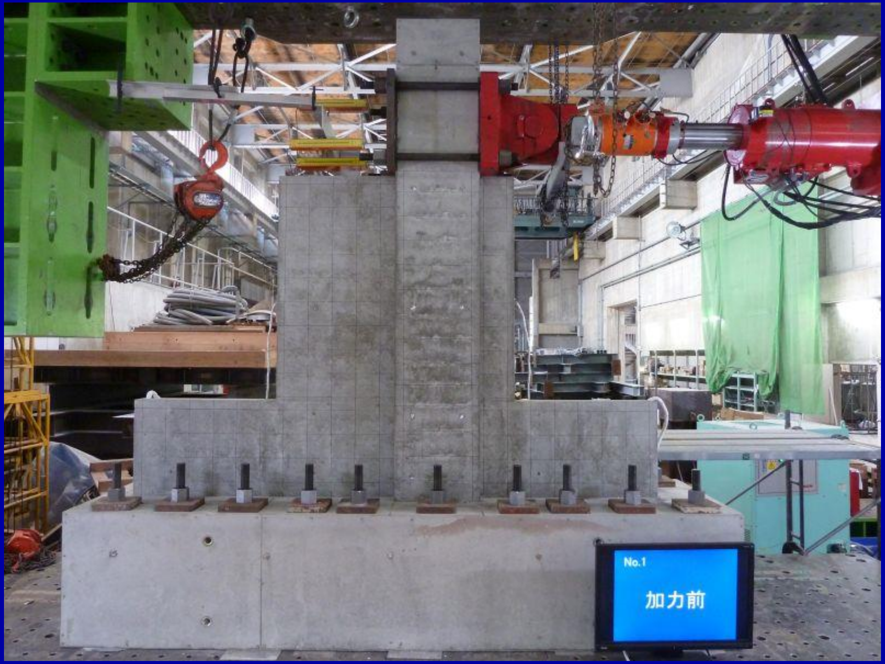



# Beam and Column with Nonstructural Walls

- It is necessary to develop member models which define beams and columns with nonstructural walls for structural designs.

-> Experimental study to clarify structural properties of beams and columns with nonstructural walls.

A column with side-walls




A beam with side, hanging and standing walls

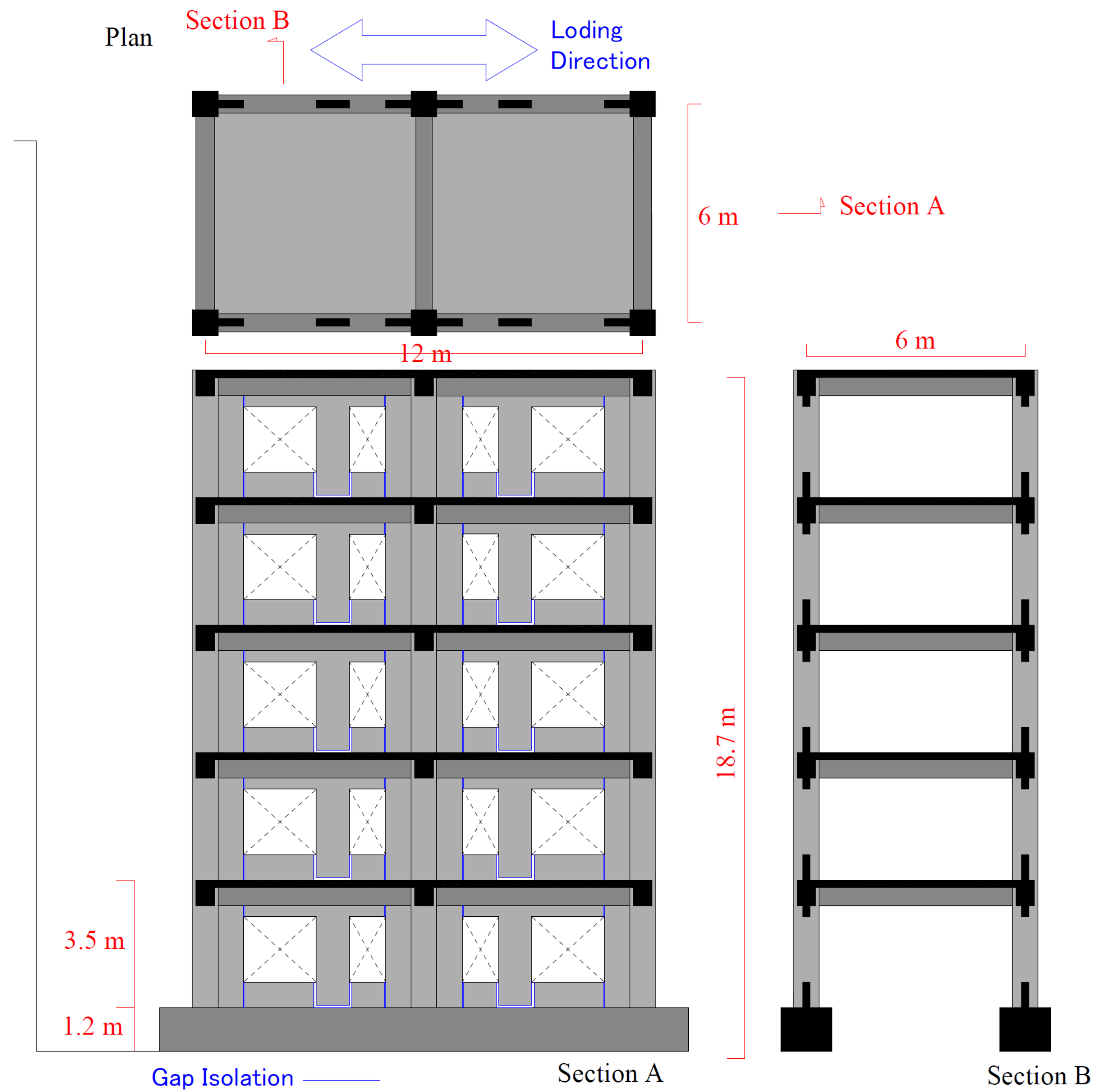
# Frame with Nonstructural Walls

- It is necessary to decide rigid zones at the end of a beam and at the end of a column.
- In the case that a mullion-wall is attached, it is necessary to consider its influence.

-> Experimental study to evaluate the structural properties of frames with nonstructural walls.

# Full-scale Test

Five-story full-scale test will be conducted soon.


Plan
Section B
Loding
Direction
6 m
Section A
12 m
6 m
18.7 m
3.5 m
1.2 m
Gap Isolation
Section A
Section B

# Concluding Remarks

- The damage which cause the loss of building's functions was shown in recent earthquakes.
- "How to ensure the resiliency of a building" and "How to promptly restore" have been strongly required.
- The RC structure which has thick nonstructural walls integrated with columns and beams is proposed for a resilient building. Its damage or deformation is expected to be lower than those of the conventional.
- The progress of research to achieve the practical use of the proposed structures was introduced.