Special Project for Reducing Vulnerability for Urban Mega Earthquake Disasters
(ii) Maintenance and Recovery of Functionality in Urban Infrastructures

Behavior of Structural Walls of 1/3-Scale 6-Story Reinforced Concrete Building in Shaking Table Tests

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  (ii) Maintenance and Recovery of Functionality in Urban Infrastructures

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Background

- buildings as a target
  - low- to middle-rise apartment buildings with open-first-story, which are designed according to the current structural design code
    - high demand for parking space and stores at the first floor
    - buildings designed by allowable stress design and ultimate strength design
    - buildings with structural walls and non-structural walls

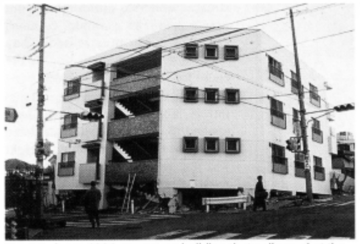

Fig. 10. A pre-1981 apartment building that collapsed at the soft first story.

Fig. 11. A pre-1981 apartment building that collapsed at the soft first story.

PERFORMANCE OF REINFORCED CONCRETE BUILDINGS

Damage to buildings by the earthquake was much more severe in buildings built before the 1971 code revision took effect. The investigation conducted by the AIJ Kinki Branch revealed that in the Chuo Ward of Kobe City, the center of Kobe, 18 reinforced or steel-encased reinforced concrete buildings constructed before 1971 collapsed or suffered severe damage (see Fig. 9). On the other hand, only two of those buildings built between 1971 and 1981 were found collapsed or severely damaged. No concrete buildings built after the 1981 revision collapsed.

Collapse of Soft First Story

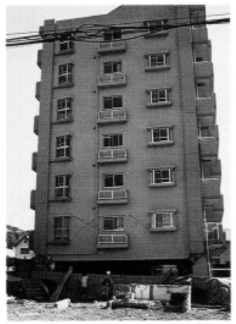

Fig. 12. A post-1981 apartment building that collapsed at the soft first story.

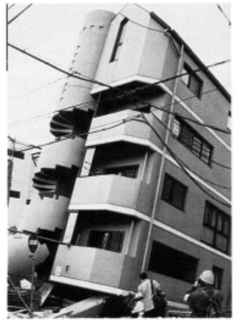

Fig. 13. A post-1981 apartment building that collapsed at the soft first story.

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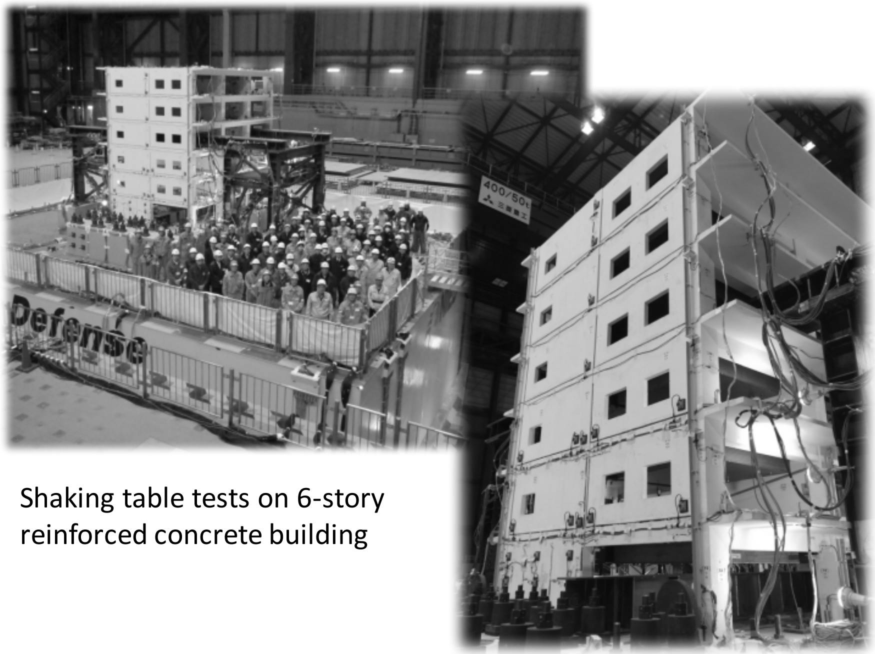
Objectives

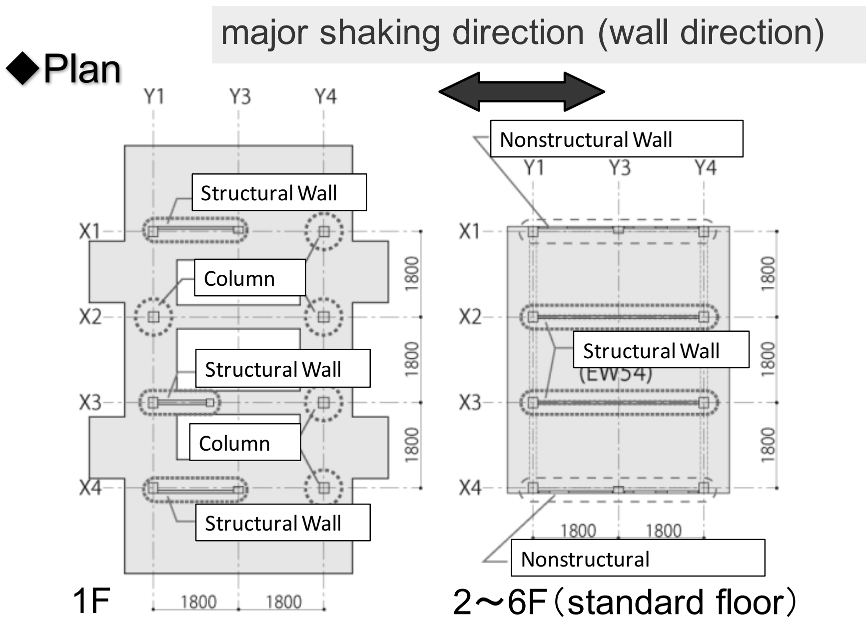
- how do RC buildings collapse?
- how do we define the collapse, and safety or collpase margin?
- how can we predict the collapse?
- how can we estimate the capacity at collapse?
- how large margin of safety to failure over the design capacity to be given by the current design procedure is expected?
- how can we estimate stiffness and capacity of frames with non-structural walls?
- how can we estimate the capacity of structural walls under bi-directional loading?

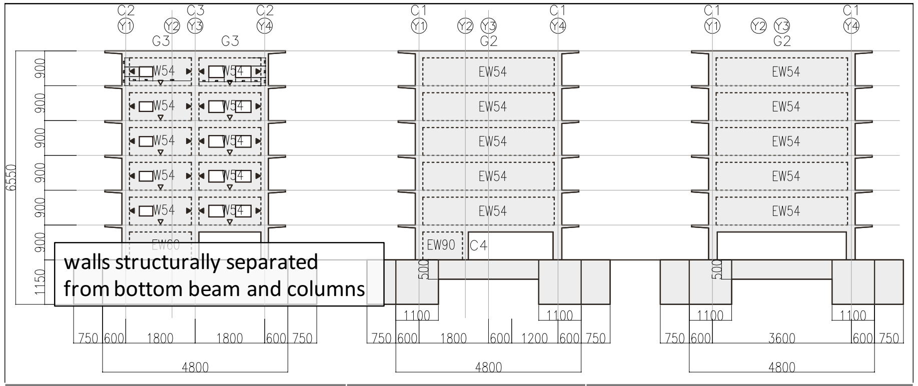
Contents

- Shaking table test on a 1/3-scale 6-story reinforced concrete building
- Numerical analysis to capture the torsional behavior of the building and sliding observed at the bottom of the structural walls

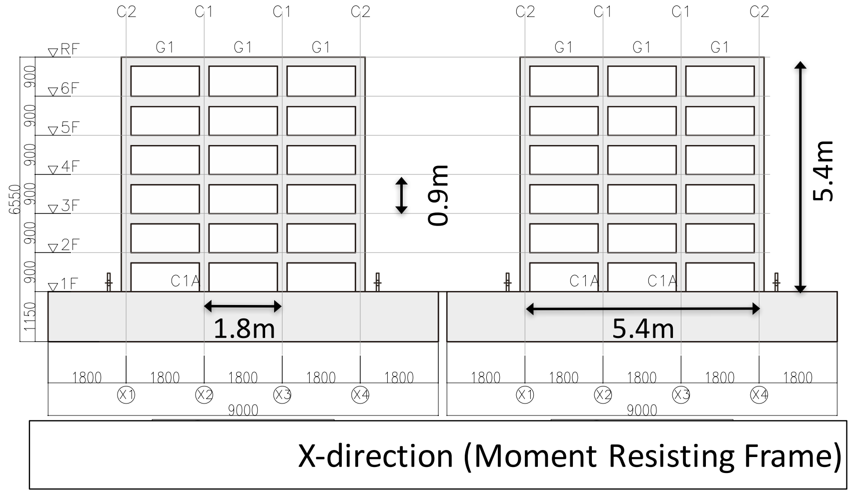


Shaking table tests on 6-story reinforced concrete building





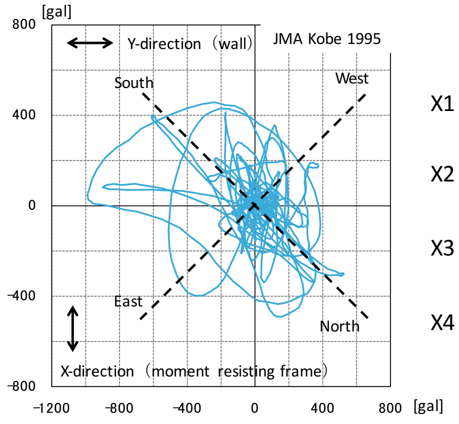
	Prototype	1/3-scale test unit
Y (wall) direction	6m x 2	1.8m x 2
X (MRF) direction	6.2m x 3	1.8m x 3
Floor area [m^2]	293	26.4
Total weight [kN]	26470	1988
Weight of test unit [kN]	—	514
Total additional weight [kN]	—	1474
Additional mass [kN/story]		246

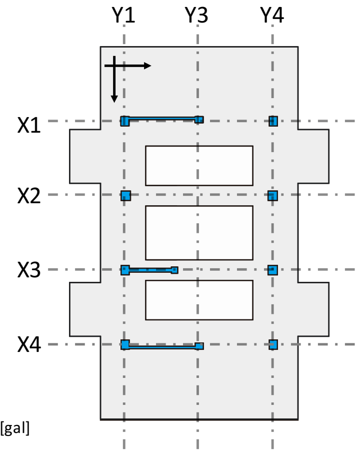


◆Input Wave

Contracted by a factor of 1/√3.3 in time by acceleration law

JMA Kobe 1995 + JR Takatori 1995 (for the last run)



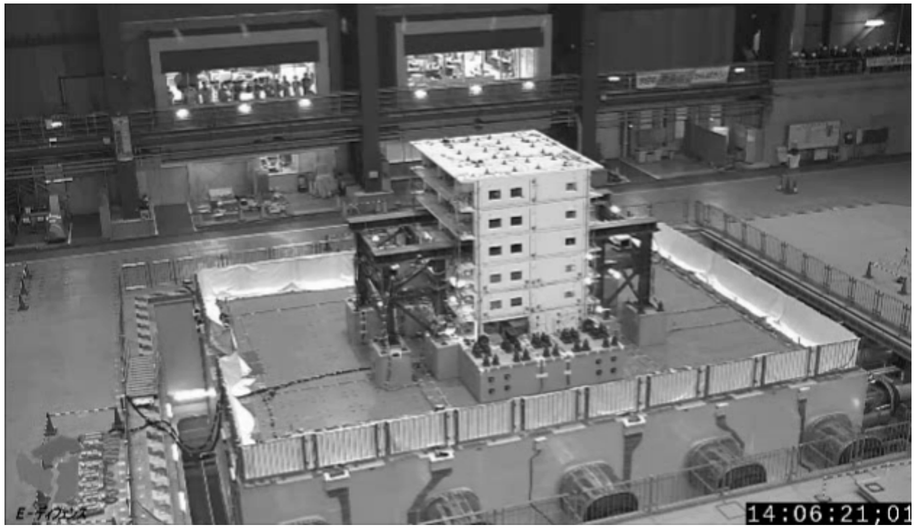


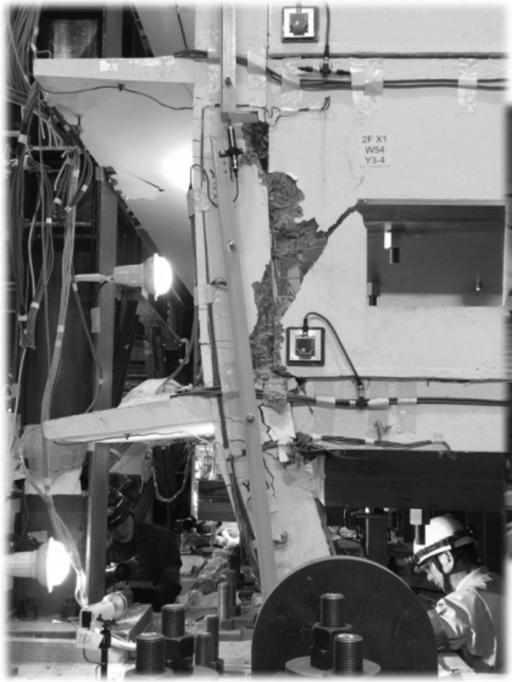
Input waves and responses wall direction

Day	Ratio to the original PGA	Q_B [kN]	C_B	R_{1max} [rad.]
Day1	10%	140.4	0.08	1/12857
	40%	769.1	0.42	1/2500
	55%	1212	0.66	1/882
	70%	1342	0.73	1/629
Day2	55%	1029	0.56	1/756
	70%	1342	0.73	1/536
	100%	1975	1.08	1/149
Day3	55%	1373	0.75	1/201
	120%	2160	1.18	1/37
	140%	1747	0.95	1/13
	140%	1161	0.63	1/11
	Takatori 120%	1506	0.82	1/6

Q_B : base shear response [kN], C_B : base shear coefficient,
R_{1max} : max. story drift angle [rad]

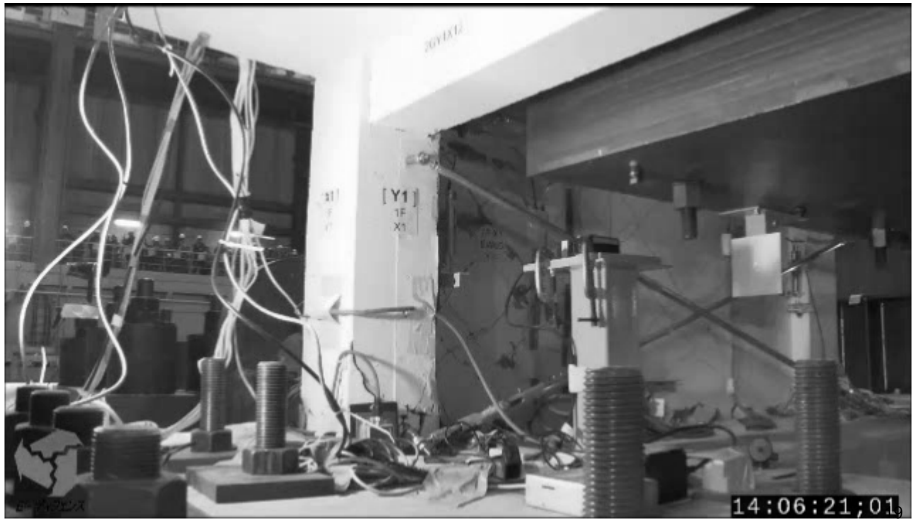
#3-5(JMA Kobe 140%-1) 1/2





After failure:
tip of balcony collided with steel frame

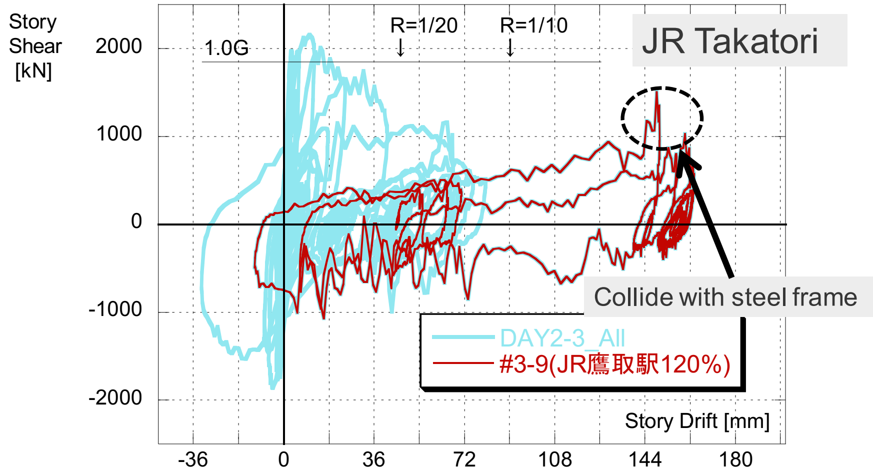
#3-5(JMA Kobe 140%-1)　1/2
wall in X-4 frame on the 1st floor



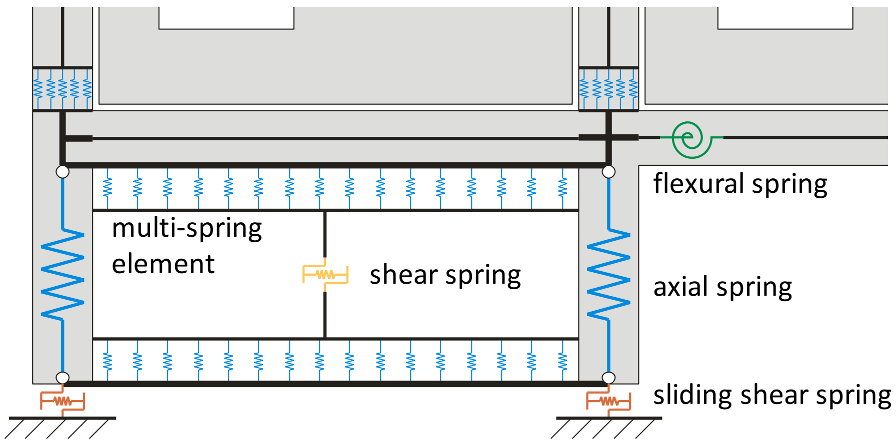
#3-5(JMA Kobe 140%-1)　1/2
wall in X-2 frame on the 2nd floor

Test results: 1st story –wall direction-

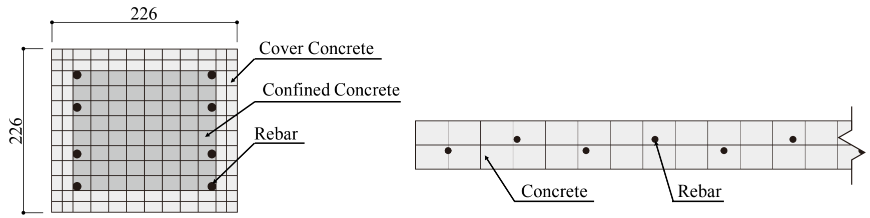
DAY2[JMA Kobe100%] ～ DAY3[JMA Kobe120%
～140%～140%～JR Takatori120%]



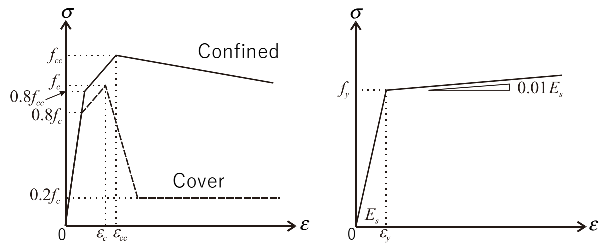
Numerical analysis using multi-spring idealization for wall with sliding shear spring at the bottom



analytical modeling of columns and walls

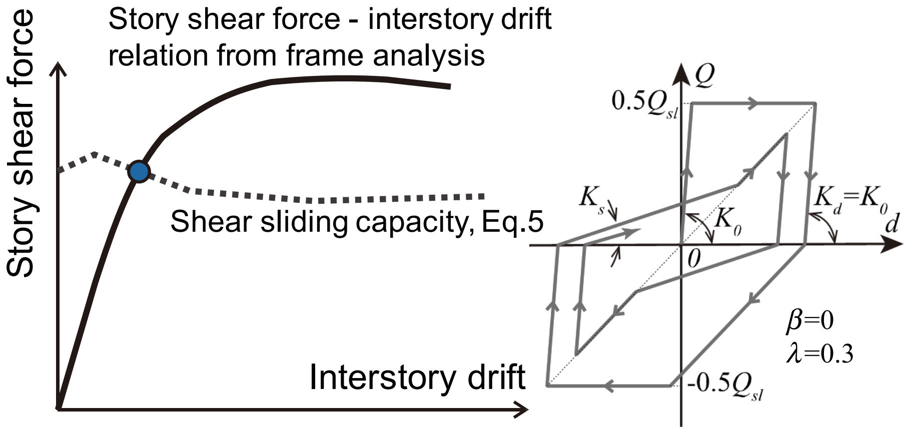


Column and wall section elements for MS model

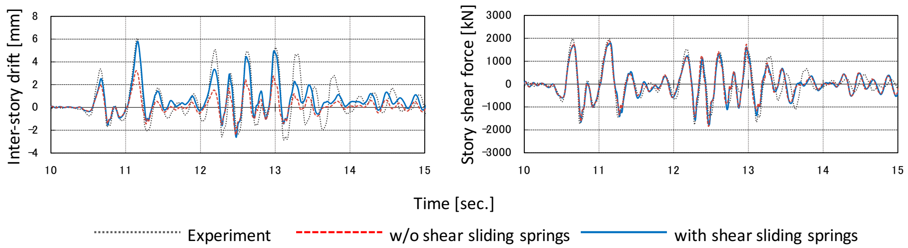


Stress-strain relationships for concrete and reinforcing bar

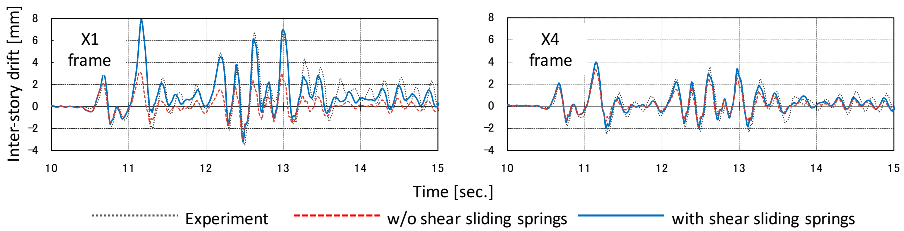
Shear force - displacement relationship for sliding shear spring



Eq.5: $Q_{sl} = \mu \sum C_c + \sum 1.65 a_s \sqrt{\sigma_B f_y \left(1-\alpha^2\right)}$



Time histories of interstory drift and story shear response in the 1st floor



Interstory drift time histories of X-1 and X-4 frames

Conclusions

- The shaking table test on a 1/3-scale 6-story reinforced concrete condominium was briefly outlined.
- The focus of this paper was primarily on the torsional behavior of the building and sliding observed at the bottom of the structural walls.
- Structural behavior of walls at large displacements were well captured by introducing the idealized sliding shear springs at the bottom of the walls in the analytical model.