Damage Assessment in Japan and Potential Use of New Technologies in Damage Assessment

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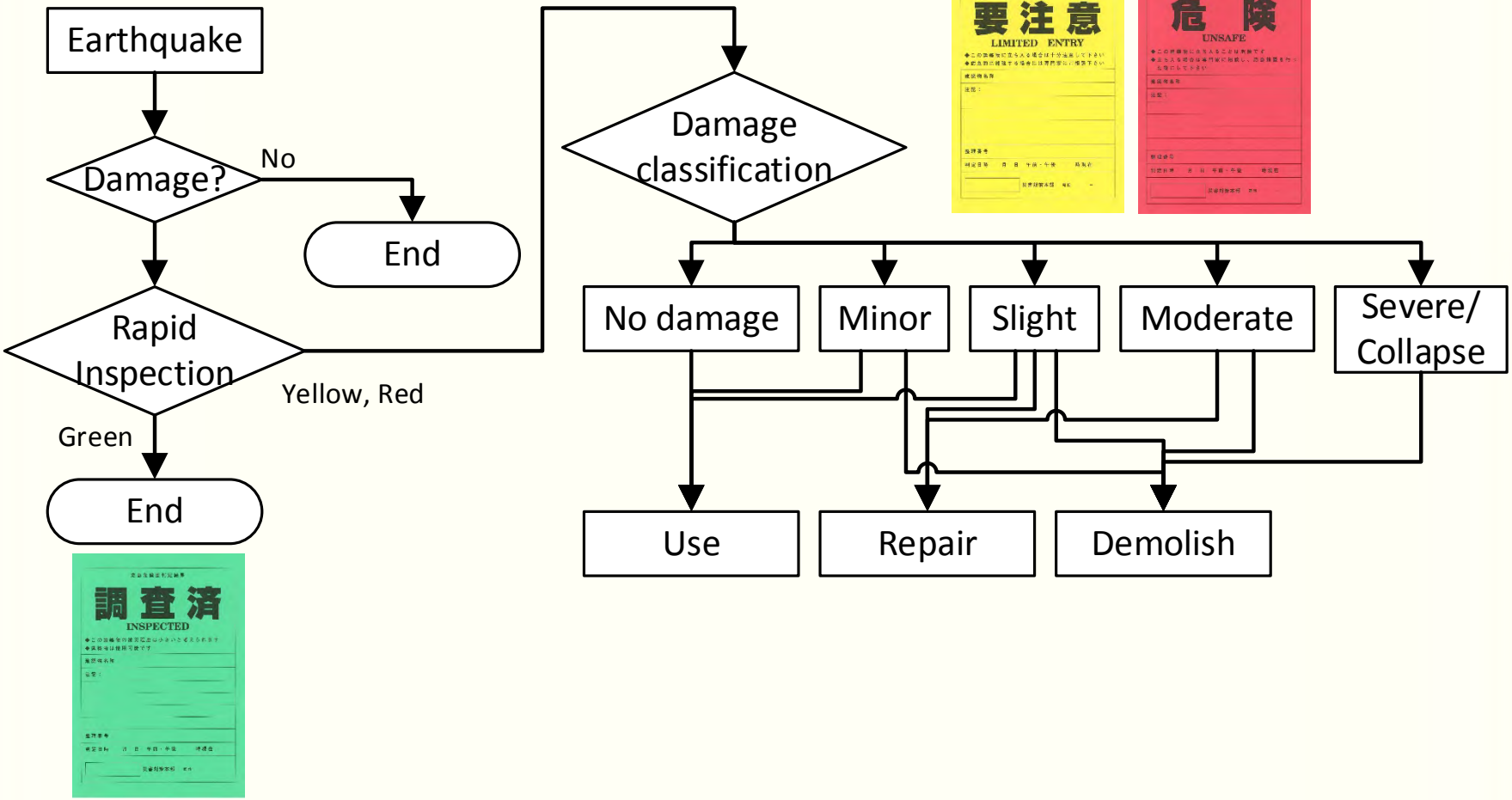
Biography outline

- 1969 Born in Kyusyu, west of Japan
- 1997 Doctoral Degree from
  The University of Tokyo (UoT)
- 1997 Research Associate of IIS, UoT
- 2000 Building Research Institute
- 2006 Associate Professor of
  Yokohama National University
- 2014 Associate Professor of
  Earthquake Research Institute, UoT
- 2018 Professor of ERI, UoT

Japanese Rapid Inspection System



Rapid inspection

Rapid Inspection

- After an earthquake…

Residual seismic capacity should be evaluated

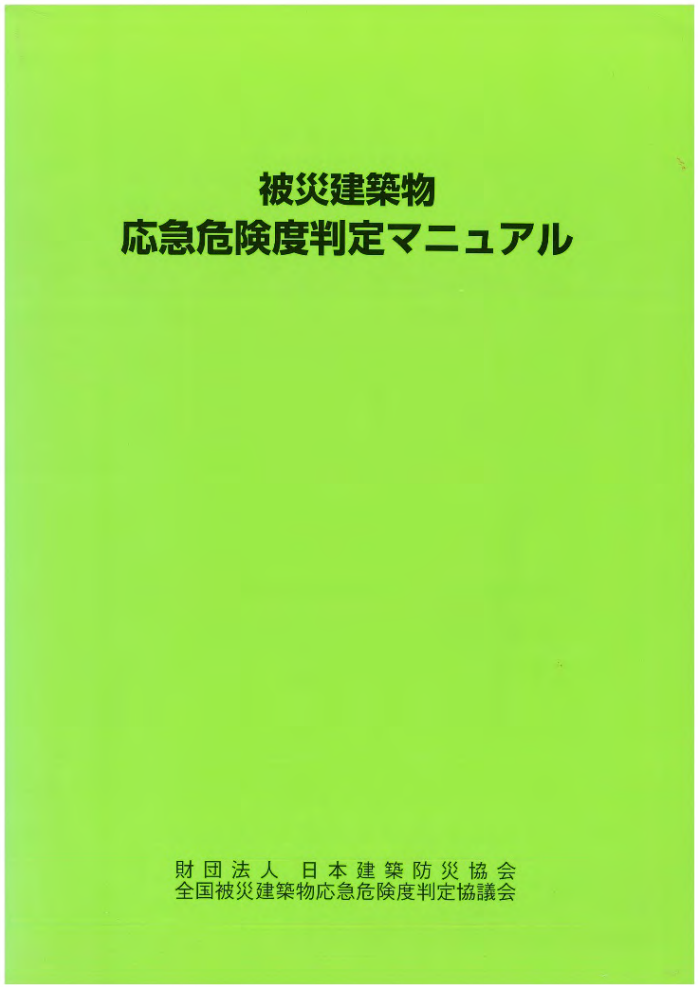
Without adequate residual seismic capacity

To reduce enormous harm due to an aftershock

With adequate residual seismic capacity

To reduce the number of refugees

Rapid inspection manual



- Inspectors must be qualified (Rapid Inspector's license).
  - Licensed as an architectural license
    - 1st grade, 2nd grade, wooden
  - Residents in the registered municipality.
  - Had a lecture for rapid inspector.

Japan Building Disaster Prevention Association (JBDPA)

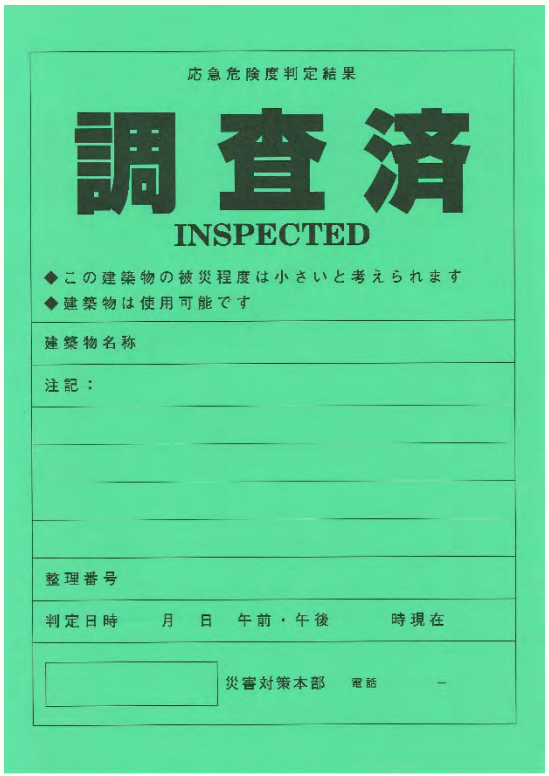
Damage to be investigated

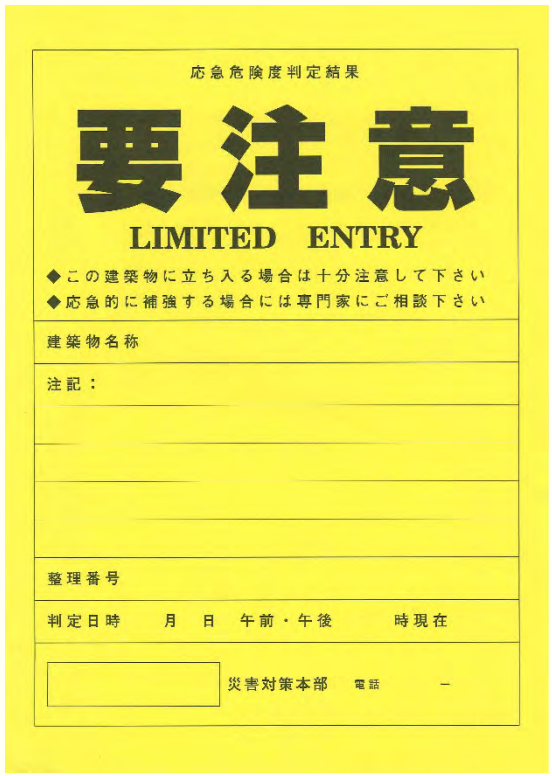
- Structural damage

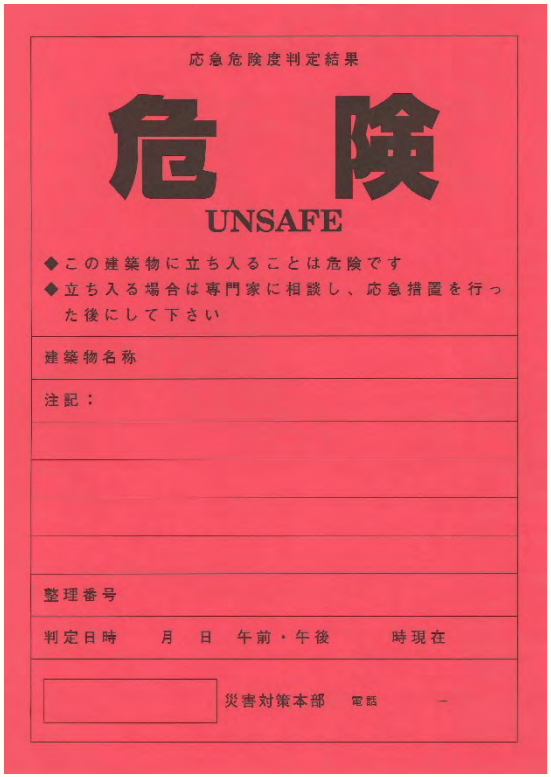
Damage to be investigated

- Non-structural damage：sign board, elevated reservoir, external finishing

Tags to indicate the result

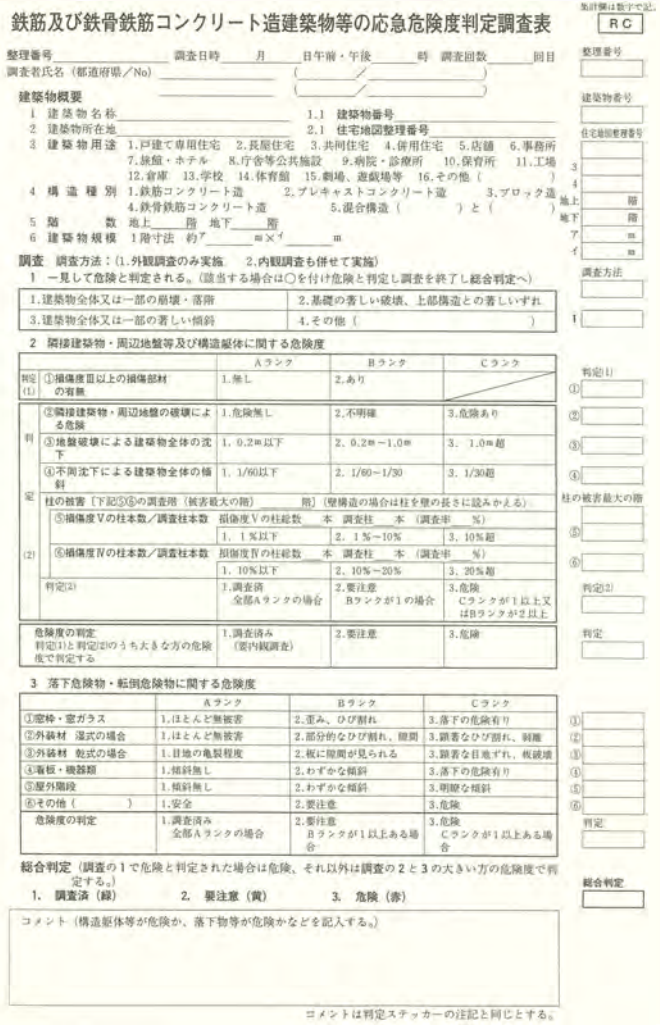






Rapid inspection method

- Use inspection sheet
- One page for one building
  - Different sheet for Wooden, steel, and RC
- For example, the sheet for RC structure will be introduced.



鉄筋及び鉄骨鉄筋コンクリート造建築物等の応急危険度判定調査表

RC

整理番号　調査日時　月　日午前・午後　時　調査回数　回目
調査者氏名（都道府県／No）

建築物概要
1 建築物名称　1.1 建築物番号
2 建築物所在地　2.1 住宅地図整理番号
3 建築物用途　1.戸建て専用住宅　2.長屋住宅　3.共同住宅　4.併用住宅　5.店舗　6.事務所　7.旅館・ホテル　8.庁舎等公共施設　9.病院・診療所　10.保育所　11.工場　12.倉庫　13.学校　14.体育館　15.劇場、遊戯場等　16.その他（　）
4 構造種別　1.鉄筋コンクリート造　2.プレキャストコンクリート造　3.ブロック造　4.鉄骨鉄筋コンクリート造　5.混合構造（　）と（　）
5 階数　地上　階　地下　階
6 建築物規模　1階寸法　約ア　m×イ　m

調査　調査方法：(1.外観調査のみ実施　2.内観調査も併せて実施)
1 一見して危険と判定される。(該当する場合は○を付け危険と判定し調査を終了し総合判定へ)

1.建築物全体又は一部の崩壊・落階	2.基礎の著しい破壊、上部構造との著しいずれ
3.建築物全体又は一部の著しい傾斜	4.その他（　）

2 隣接建築物・周辺地盤等及び構造躯体に関する危険度

		Aランク	Bランク	Cランク
判定(1)	①損傷度Ⅲ以上の損傷部材の有無	1.無し	2.あり	
判定(1)	②隣接建築物・周辺地盤の破壊による危険	1.危険無し	2.不明確	3.危険あり
判定(1)	③地盤破壊による建築物全体の沈下	1. 0.2m以下	2. 0.2m～1.0m	3. 1.0m超
判定(1)	④不同沈下による建築物全体の傾斜	1. 1/60以下	2. 1/60～1/30	3. 1/30超
判定(2)	柱の被害（下記⑤⑥の調査階（被害最大の階）　階）（壁構造の場合は柱を壁の長さに読みかえる）			
判定(2)	⑤損傷度Ⅴの柱本数／調査柱本数	損傷度Ⅴの柱総数　本 調査柱　本（調査率　%）		
判定(2)		1. 1%以下	2. 1%～10%	3. 10%超
判定(2)	⑥損傷度Ⅳの柱本数／調査柱本数	損傷度Ⅳの柱総数　本 調査柱　本（調査率　%）		
判定(2)		1. 10%以下	2. 10%～20%	3. 20%超
判定(2)	判定(2)	1.調査済 全部Aランクの場合	2.要注意 Bランクが1の場合	3.危険 Cランクが1以上又はBランクが2以上
	危険度の判定 判定(1)と判定(2)のうち大きな方の危険度で判定する	1.調査済み（室内観調査）	2.要注意	3.危険

3 落下危険物・転倒危険物に関する危険度

	Aランク	Bランク	Cランク
①窓枠・窓ガラス	1.ほとんど無被害	2.歪み、ひび割れ	3.落下の危険有り
②外装材 湿式の場合	1.ほとんど無被害	2.部分的なひび割れ、剥離	3.顕著なひび割れ、剥離
③外装材 乾式の場合	1.目地の亀裂程度	2.板に隙間が見られる	3.顕著な目地ずれ、板破壊
④看板・機器類	1.傾斜無し	2.わずかな傾斜	3.落下の危険有り
⑤屋外階段	1.傾斜無し	2.わずかな傾斜	3.明瞭な傾斜
⑥その他（　）	1.安全	2.要注意	3.危険
危険度の判定	1.調査済み 全部Aランクの場合	2.要注意 Bランクが1以上ある場合	3.危険 Cランクが1以上ある場合

総合判定（調査の1で危険と判定された場合は危険、それ以外は調査の2と3の大きい方の危険度で判定する。）
1. 調査済（緑）　2. 要注意（黄）　3. 危険（赤）

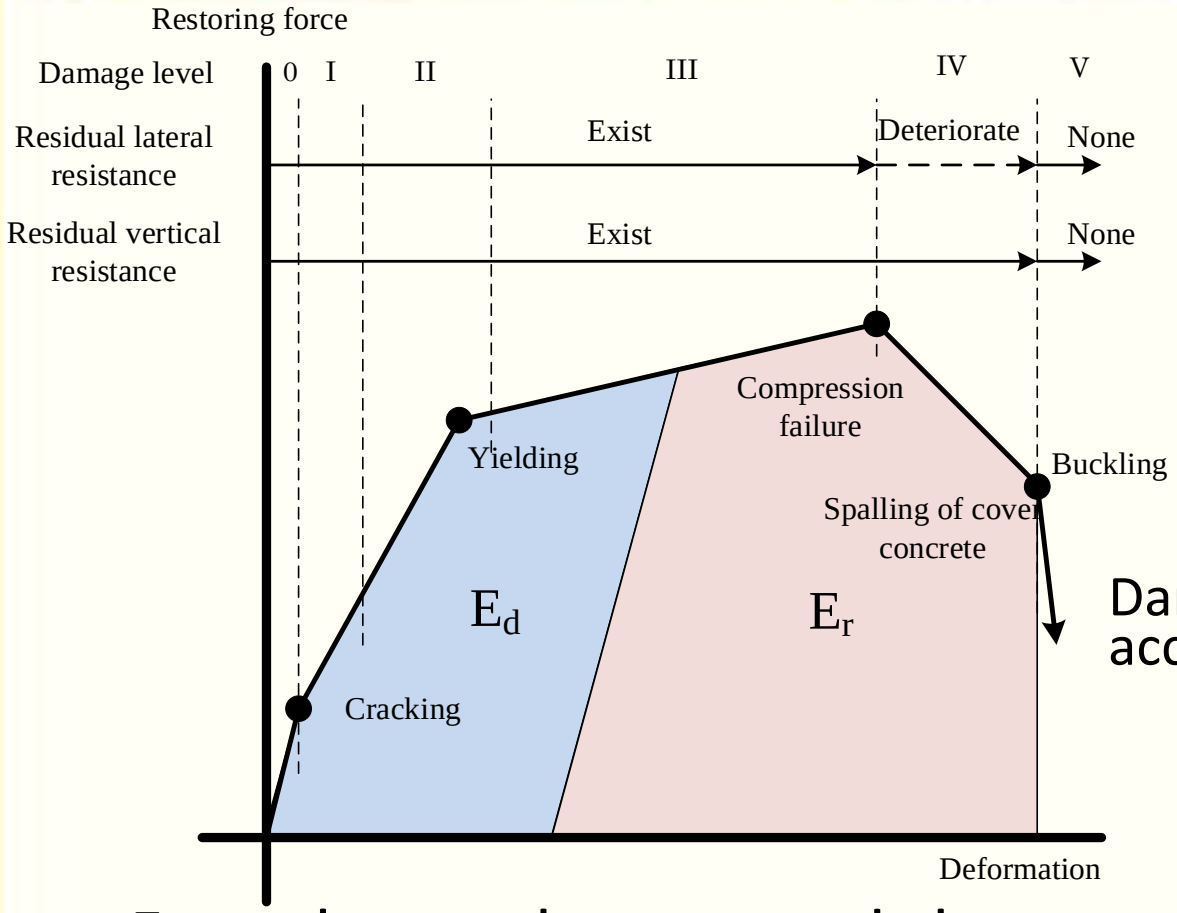
コメント（構造躯体等が危険か、落下物等が危険かなどを記入する。）

コメントは判定ステッカーの注記と同じとする。

Risk of structure and foundation

		Rank A	Rank B	Rank C
(1)	Damage level III or more exists	No	Yes	
(2)	**Neighboring building** or foundation looks dangerous.	No	Unknown	Yes
	Inclination due to uneven settlement	<1/60	1/60 to 1/30	1/30<
	Damage of column (The most severely damaged floor _____th floor)			
	Num. of columns with **damage level V** _____ inspected _____ ratio _____ %			
		<1%	1%-10%	10%<
	Num. of columns with **damage level IV** _____ inspected _____ ratio _____ %			
		<10%	10%-20%	20%<
	Judgement	INSPECTED All are rank A	CAUTION Only one rank B	UNSAFE Others
Overall judgement(Take worse case between (1) and (2)		INSPECTED	CAUTION	UNSAFE

Damage class



$$\eta = \frac{E_r}{E_d + E_r}$$

Damage class is determined according to η.

- For columns, beams, and shear walls

Damage class and η

Damage class	Flexural member	Shear member
I	0.95	0.95
II	0.75	0.60
III	0.50	0.30
IV	0.10	0
V	0	0

- η of the actually damaged building is unknown.

Damage class according to the residual cracks

Damage Class	Condition	
	Flexural member	Shear member
I	Just fine cracks (**width < 0.2mm**) exist, but no reinforcement is supposed to yield.	
II	Member may yield, and visible cracks exist at its ends (**width 0.2mm～1.0mm**).	Clearly visible shear craks exist (**width 0.2～1.0mm**).
III	Non-linear deformation increases and relatively wide flexural cracks (**width 1.0mm～2.0mm**) are visible, but cover concrete does not fall much and core concrete is sound.	Multiple shear cracks, of which width is relatively wide, are observed (**width 1.0mm～2.0mm**), but cover concrete does not fall much, core concrete is sound, and restoring force seems remain.

Damage class according to the residual cracks

Member damage	Damage condition	
	Flexural member	Shear member
IV	There are many **wide cracks**, cover concrete falls down a lot and core concrete gets damaged, and reinforcement is visible. Lateral force carrying capacity may reduced, but columns and walls still carry the gravity load.	There are many wide shear cracks, **cover concrete falls down** a lot and core concrete gets damaged, but buckling/fracture of rebar or hoops are not observed. Lateral force carrying capacity may be maintained.
V	Rebars buckled, and even core concrete falls down. It seems almost no lateral load carrying capacity is left. It is apparent that **columns/walls shorten**. Inclination or settlement may be observed. Rebar may fracture.	

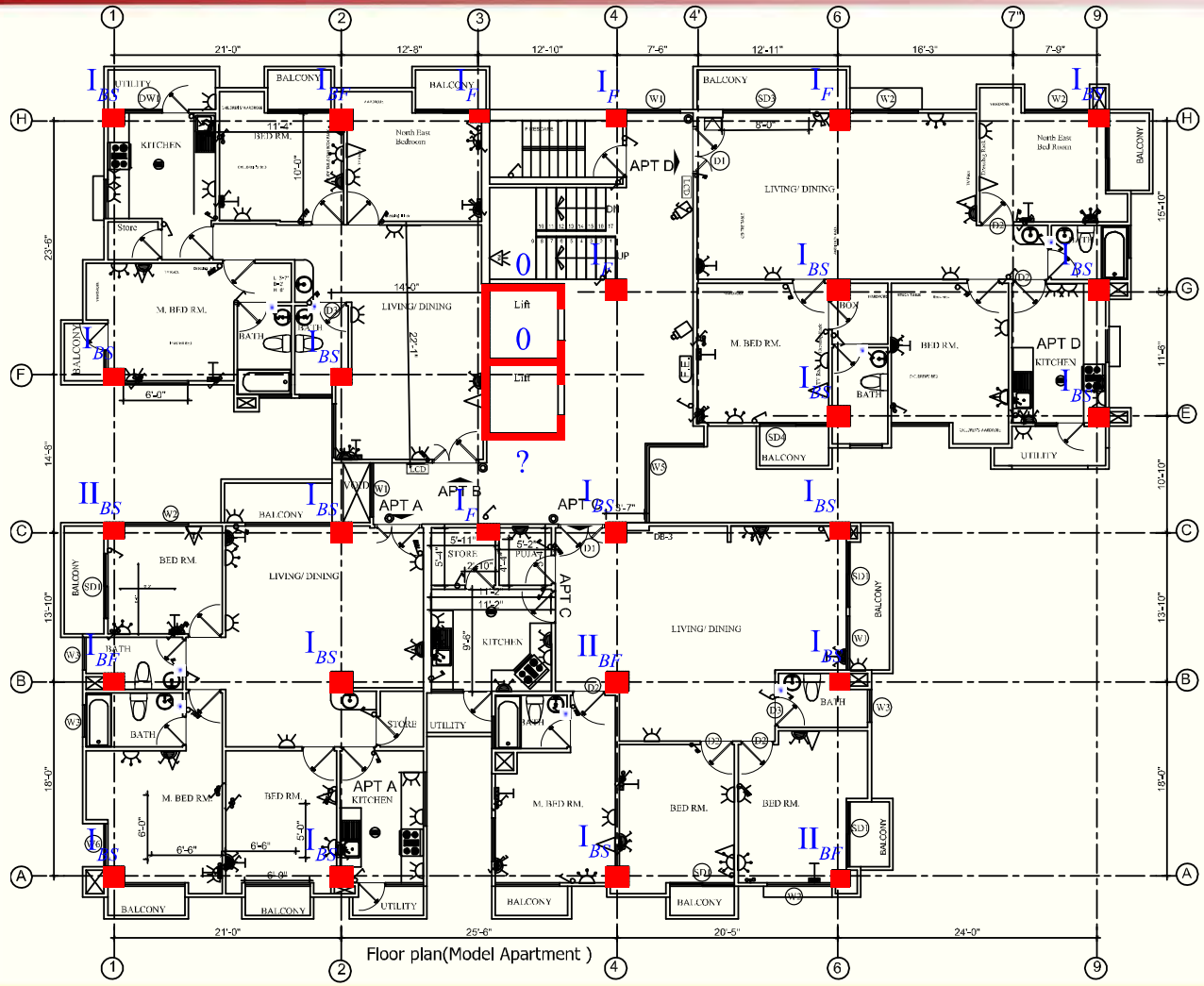
- It can run a fine line between damage classes II and III.

Damage level III

Damage level IV

Damage class V

Example



Risk of falling/turning object

	Rank A	Rank B	Rank C
Window, frame	Almost no damage	Deformed/cracked	High risk to fall
Wet finishing	Almost no damage	Partial damage	Significant damage
Dry finishing	Fine crack in joints	Gap observed	Significant shift
Sign board/machinery	No inclination	Slight inclination	High risk to fall
Outdoor staircase	No inclination	Slight inclination	Significant inclination
Others( )	Safe	Caution	Unsafe
Overall judgement	INSPECTED All rank A	CAUTION One or more rank B	Unsafe One or more rank C

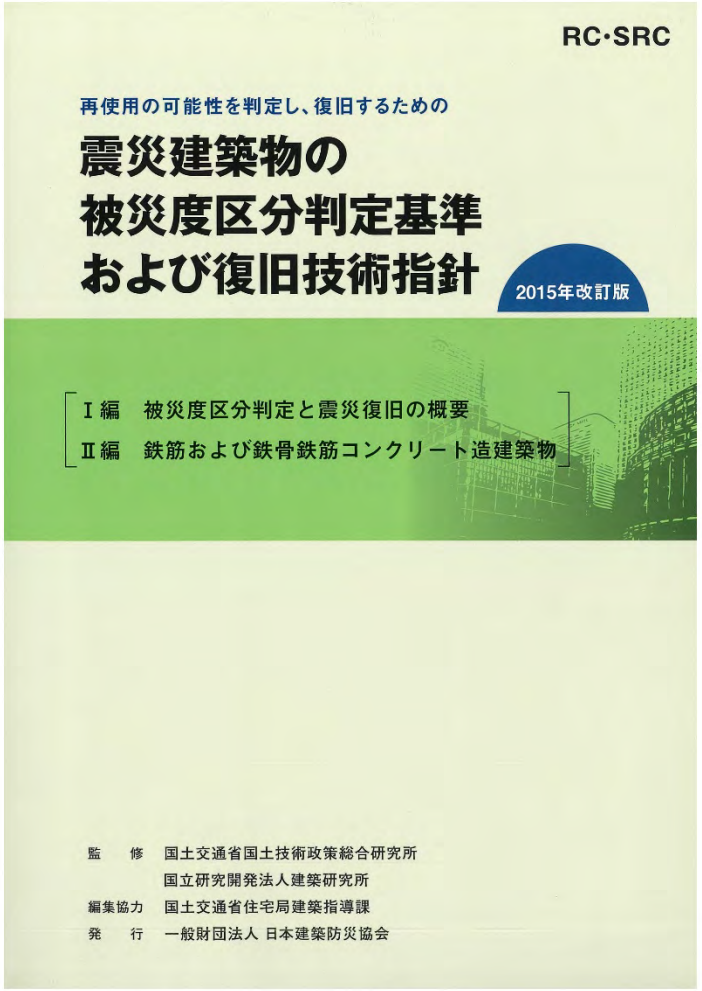
- The final inspection result is the worse rank between structural and non-structural inspection.

Damage classification

What is damage classification?

- Judge if the building, which is tagged as “CAUTION” or “UNSAFE”, should be restored or not.
- Damage classes are ; “No damage”, “Minor damage”, “Slightly damaged”, “Moderately damaged”, “Severely damaged”, and “Collapsed”
- Inspect the damage due to ; soil/foundation, upper structure, non-linear structure, and tsunami

Damage classification



Soil/foundation is also inspected

Damage is classified according to the residual seismic capacity index, R.

Minor	95(%)≦R
Slight	80≦R＜95
Moderate	60≦R＜80
Severe	R＜60
Collapse	total/partial collapse

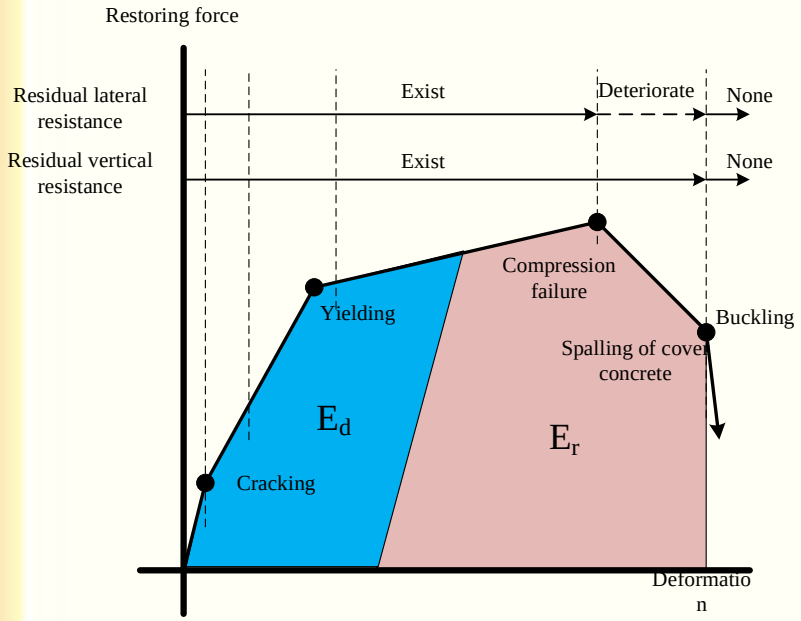
$$R = \frac{{}_{d}I_s}{I_s}$$

I_s Seismic capacity index W/O damage

${}_{d}I_s$ Seismic capacity index W/ damage

A simplified method is also available.

Strength index is reduced according to the damage class of the member



Damage class	Flexural member	Shear member
0	1.00	1.00
I	0.95	0.95
II	0.75	0.60
III	0.50	0.30
IV	0.10	0.00
V	0.00	0.00

Restoration judgement

Damage / SI	Slight	Minor	Severe
Less than 5-	×	×	×
5+	△	×	×
6-	○	△	×
6+	○	○	△

Damage / SI	Minor 95<R<100	Slight 80<R<95	Moderate 60<R<80	Severe R<60
Less than 5-	×	×	×	×
5+	◎	△	△	△
6-	◎	○(△)	△	△
6+	◎	◎(○)	○	△

( ) Building built before 1971

- If the damage level is high even if the seismic intensity is low, the building itself may have some defect.
- Restoration is decided according to the damage class and the seismic intensity.

Present situation of the quick Inspection

- Investigated by visual observation by engineers…

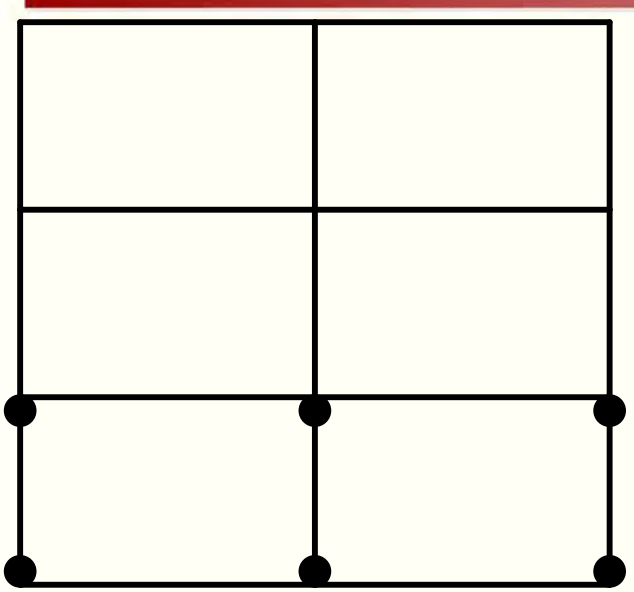
It needs many days to investigate

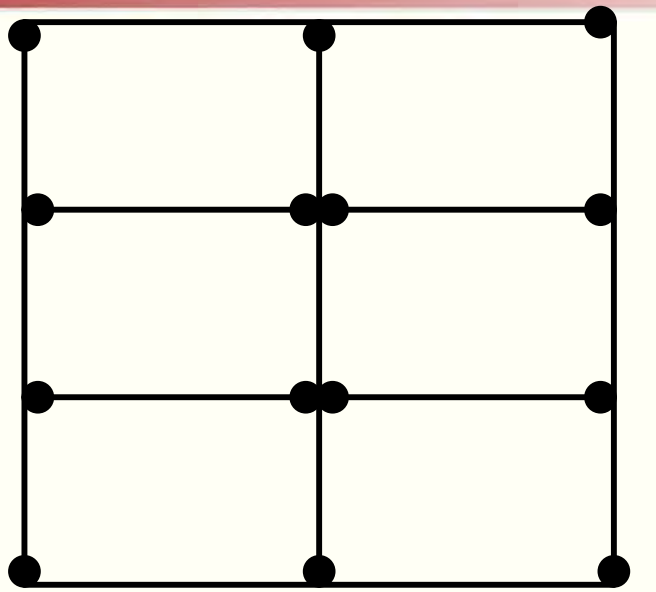
19 days for 46,000 buildings with 5,068 engineers

Many “Limited Entry” judgment

The judgment can vary
according to engineers’ experiences

Disadvantage of the current rapid inspection





Weak column

Inspect the columns

Weak beam

Inspect the all beams

Weak beam system is recommended for the seismic design

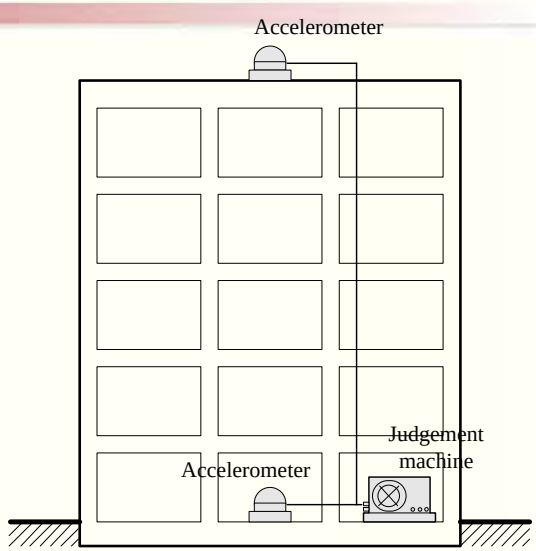
→Difficult to inspect the damage due to ceiling and finishing

Kumamoto Earthquake

- April 14 Mw = 6.2
- April 16 Mw = 7.0
- Casualties 49

New damage classification system

Performance and demand curves are measured



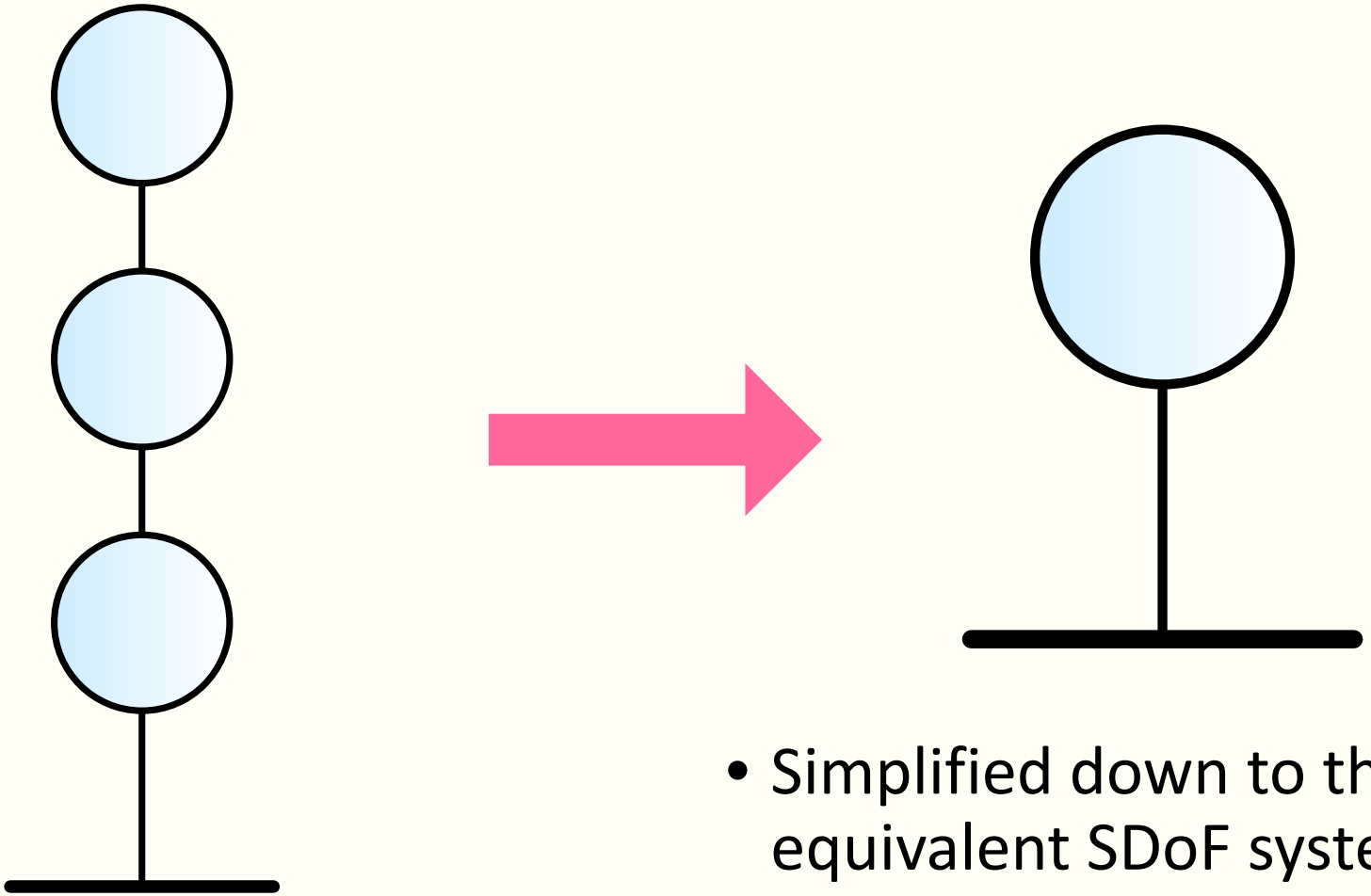
Place few inexpensive accelerometers

Derive displacement from measured acceleration

Evaluate by comparing these curves

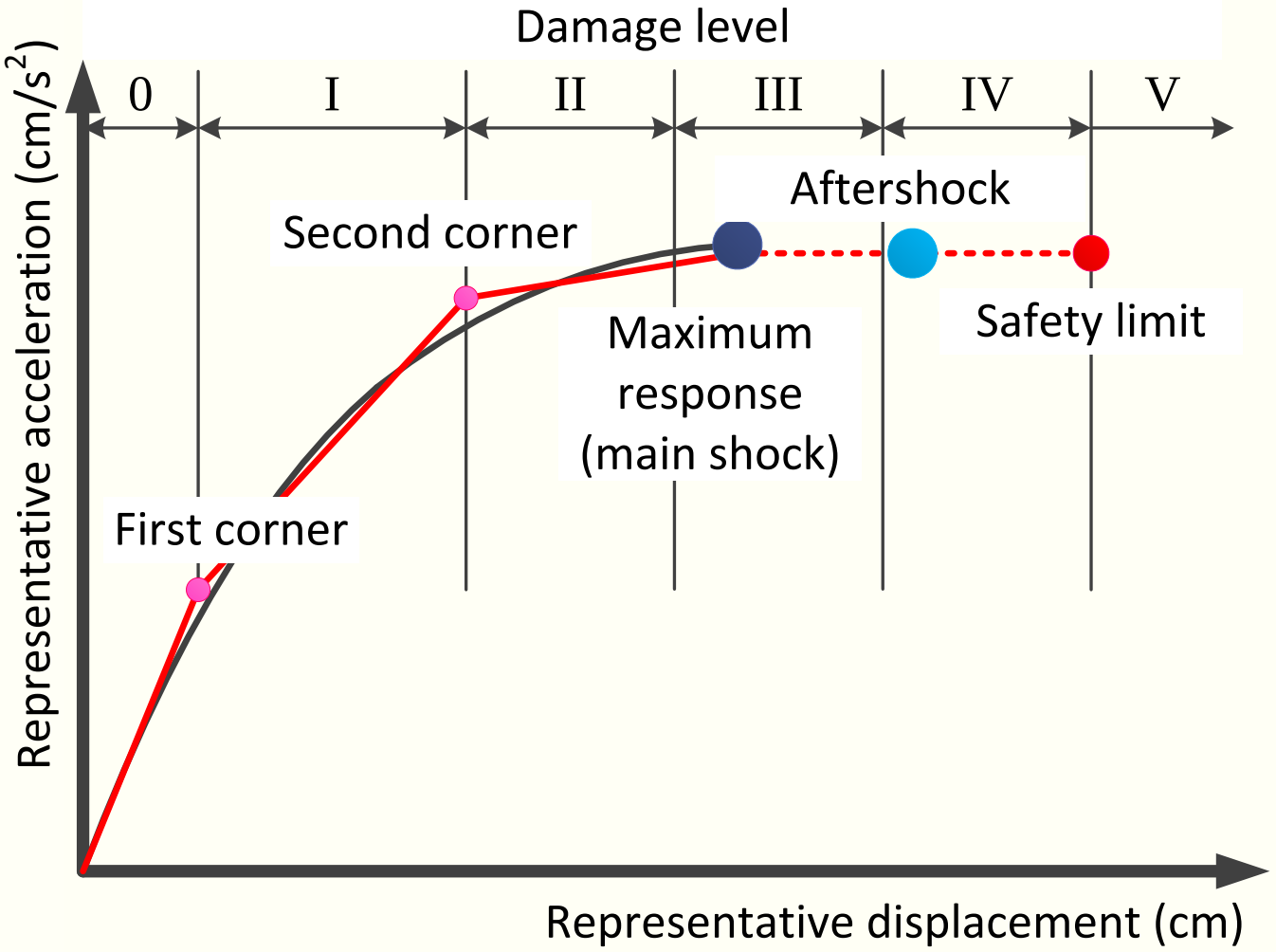
ITK sensor

Damage evaluation



- Simplified down to the equivalent SDoF system

Damage classification w/ SHM

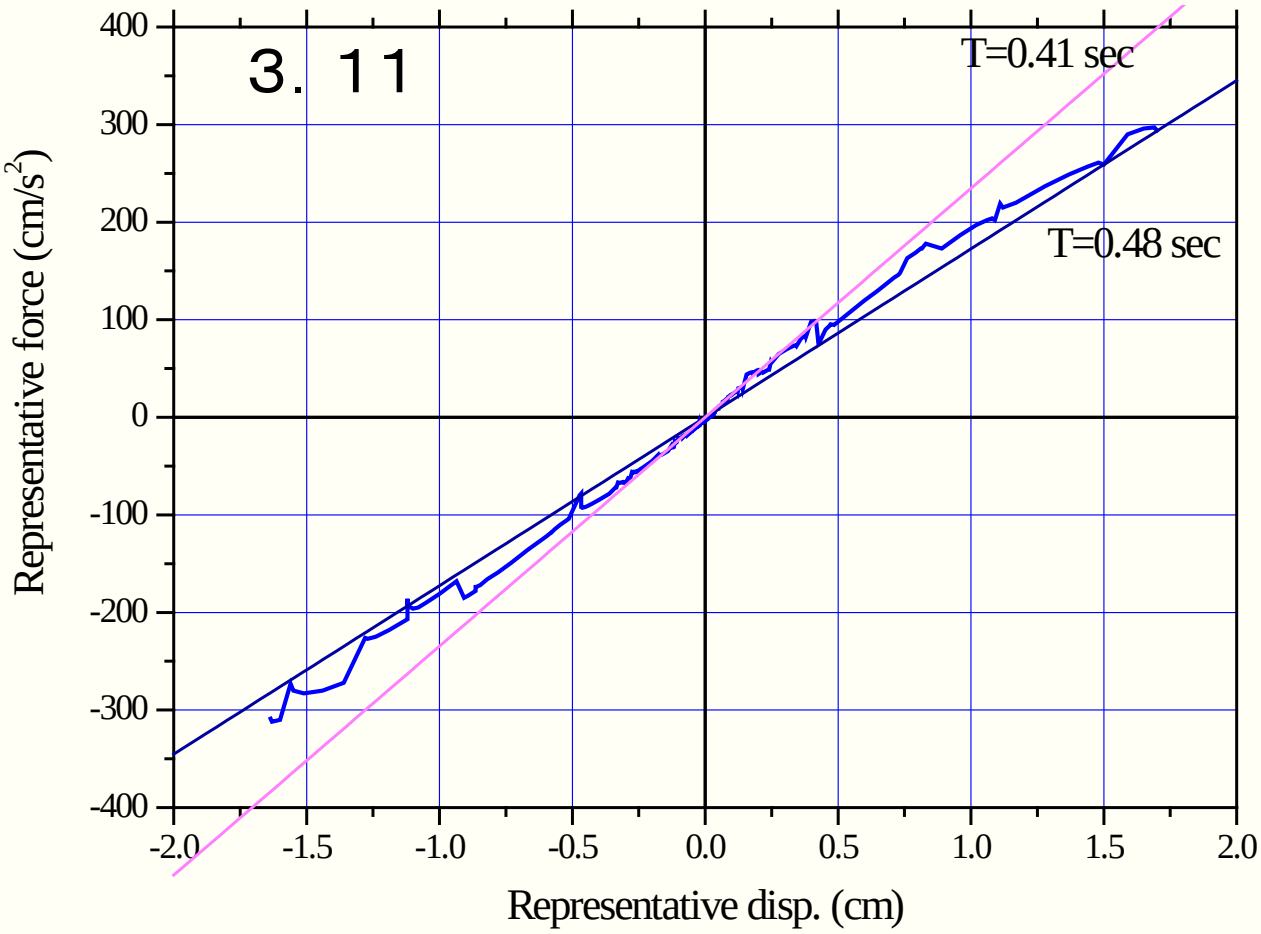


Building Example
Yokohama National Univ.

- Department of architecture

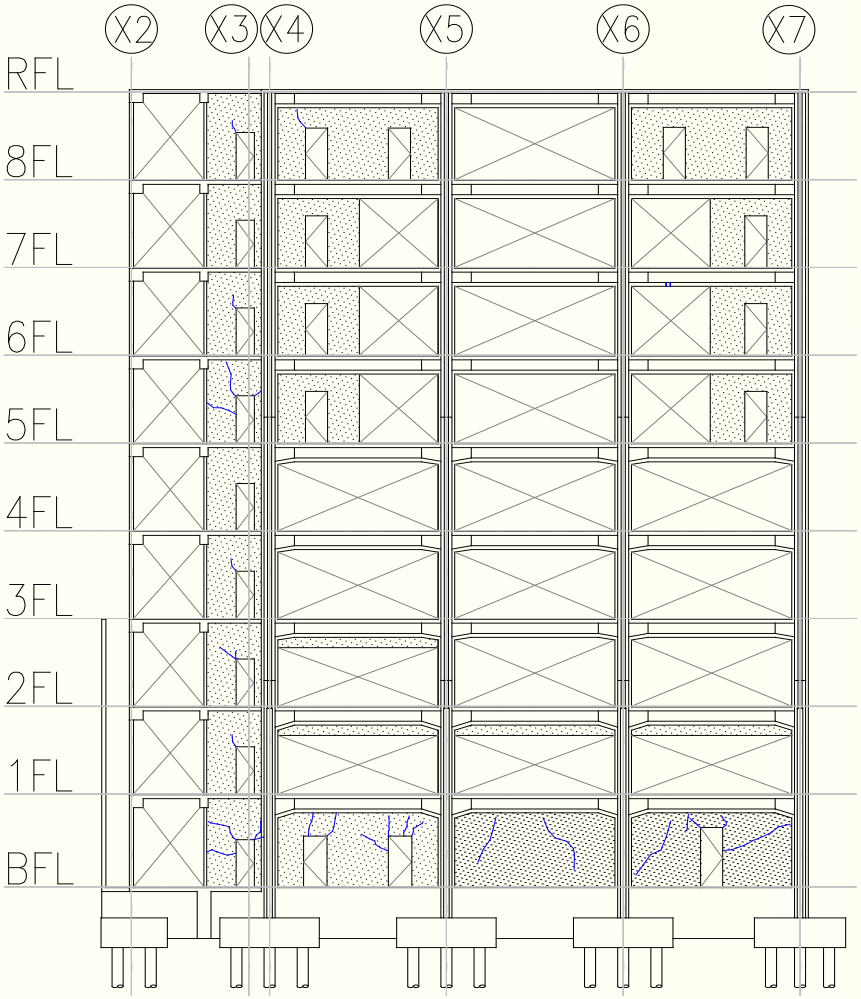
- SRC structure
- H= 30.8 m
- 8-story + 1 BF
- Retrofitted before
  Tohoku EQ

Performance and demand curves



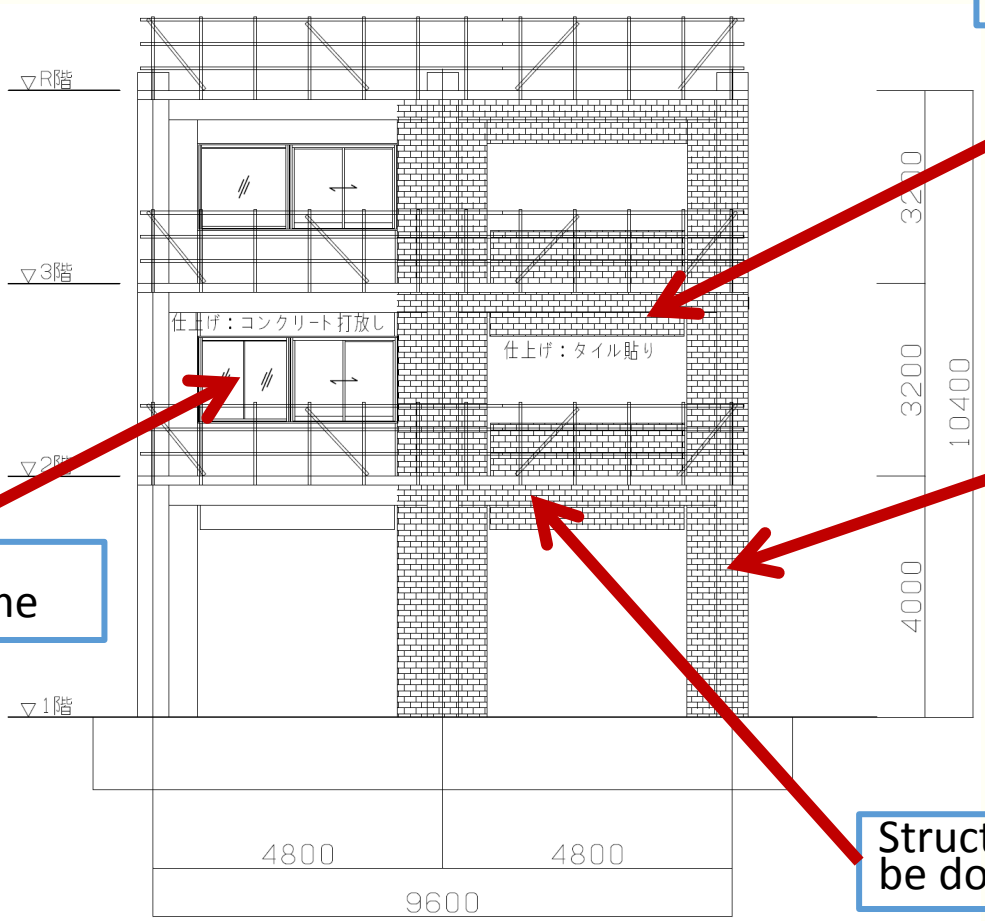
Damage evaluation

- Flexural cracks were observed at the bottom of walls
- Detected damage level coincide the observed level
- The system worked well
- The result was informed to all staffs.



E-Defense test in 2019

December 3 to 6th!



Damage of ceiling system will be detected by video camera

Damage of non-structural members will be detected by accelerometers

Damage of window frame

Structural Health Monitoring will be done with accelerometers

Thank you for your kind attention…