# Seismic Actions of Nonstructural Components

14th U.S.-Japan Workshop on Improvement of Structural Design and Construction Practices

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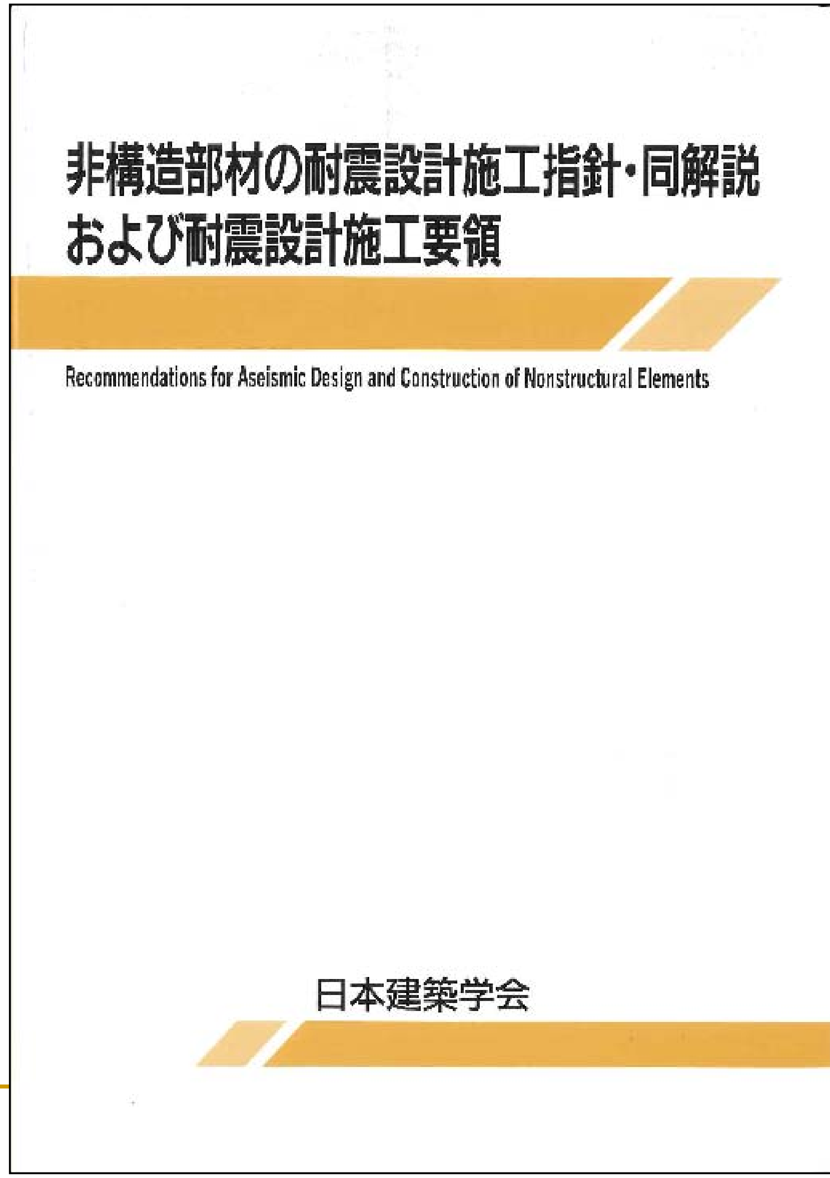
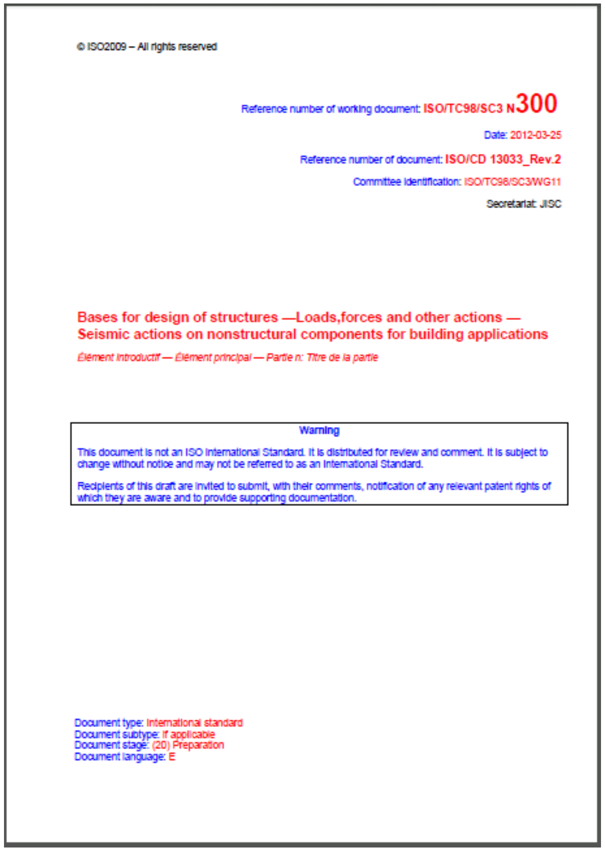
“Guideline, Commentary and Detail of Seismic Design and Construction of Non-structural Components by AIJ



## “Guideline, Commentary and Detail of Seismic Design and Construction of Non-structural Components by AIJ

- January 1978 Izu-Oshima Kinkai Earthquake
- February 1978 Miyagi-Ken-Oki Earthquake
- June 1978 Miyagi-Ken-Oki Earthquake
- October 1985: AIJ Guideline was established
- January 1995 Hyogo-ken Nanbu Earthquake
- January 2003: AIJ Guideline was revised
- March 2011 Tohoku Earthquake

# ISO/CD 13033
# Bases for design of structures —Loads, forces and other actions — Seismic actions on nonstructural components for building applications





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**Bases for design of structures —Loads,forces and other actions — Seismic actions on nonstructural components for building applications**

*Élément introductif — Élément principal — Partie n: Titre de la partie*

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Document subtype: if applicable
Document stage: (20) Preparation
Document language: E

# ISO/TC98/SC3/WG 11 Official Meetings To Date

| | |
|---|---|
| • 25 – 26 June 2009 | Honolulu, Hawaii |
| • 23 – 24 November 2009 | Oslo, Norway |
| • 17 – 18 April 2010 | Honolulu, Hawaii |
| • 1 – 2 September 2010 | San Francisco, California |
| • 30 Nov & 1 Dec 2010 | Delft, Netherlands |
| • 7 & 8 April 2011 | Tsukuba, Japan(cancelled) |
| • 28 & 29 October 2011 | Tokyo, Japan |
| • 23 & 24 November 2011 | Stellenbosch, South Africa |
| • 15 – 16 March 2012 | San Francisco, California |
| • 11 November 2012 | Warsaw, Poland |

We also had an informal meeting

| | |
|---|---|
| - 26 July 2010 | Toronto, Canada |

# ISO/TC98/SC3/WG11 Member Experts, Member Observers and Other Invited Experts ISO/CD 13033

Member Experts

- Simon Foo – Canada
- David Lau - Canada
- Hiroshi Ito – Japan
- Yoshi Waikyama, Japan
- Yuji Ishiyama – Japan (Iso Standard 3010 Liaison)
- Roger Shelton – New Zealand    Secretariat
- Prof. Januz Kawecki – Poland Phil Caldwell – USA (with Square D)
- Robert Doswell – USA (not active)
- John Silva – USA (with Hilti)
- Bob Bachman – USA – ASCE/ANSI    Convener
- Ricardo Medina – USA
- Prof. Johann Retief – South Africa
- Shunsuke Sawada – (ISO TC98/SC3 Secretariat)

Other Invited Experts (attend WG 11 meetings)

- K.C. Tsai – Chinese Taipai (with understanding of China concerns)
- George Yao – Chinese Taipai (with understanding of China concerns)
- Juin-Fu Chai – Chinese Taipai (with understanding of China concerns)
- Carlos Aguirre – Chile

Observers

- Dr. Gerard Canisus – UK – observer
- Jun Kanda (Convener ISO TC98/SC3)

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Annex A (informative) Identification of NSCS requiring seismic evaluation

Annex B (informative) Principles for choosing importance factors for NSCS

Annex C (informative) Principles for choosing the floor response amplification factor (height factor)

Annex D (informative) Principles for choosing the component amplification factor (resonance factor)

Annex E (informative) Principles for determining response modification factors

Annex F (informative) Principles for determining seismic relative displacements for drift-sensitive components

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Annex G (informative) Floor response spectra

Annex H (informative) Methods for verifying NSCS by design analysis

Annex I (informative) NSCS verification by shake table testing

Annex J (informative) NSCS verification through use of experience data

Annex K (informative) Principles of seismic anchorage of NSCS

Annex L (informative) Quality assurance in design and construction

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### 1.3 Components requiring evaluation

a) the NSCS poses a falling hazard;

b) the failure of the NSCS can impede the evacuation of the building;

c) the NSCS contains hazardous materials;

d) the NSCS is necessary to the continuing function of essential facilities after the event; and

e) damage to the NSCS represents a significant financial loss.

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5 Seismic design objectives and performance criteria

-to prevent human casualties associated with falling hazards and blockage of egress paths;

-to ensure post-earthquake continuity of life-safety functions within the building (e.g., sprinkler piping);

-to ensure continued post-earthquake operation of essential facilities (e.g., hospitals, fire stations);

-to maintain containment of hazardous materials;

-to minimize damage to property

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5 Seismic design objectives and performance criteria

For ultimate limit state: ULS

i. NSCS will not collapse, detach from the building structure, overturn or experience other forms of structural failure, breakage or excessive displacement (sliding or swinging) that could cause a life safety hazard.

ii. NSCS will perform as required to maintain continuity of life safety functions (e.g., fire-fighting systems, elevators, and other similar vital life safety systems).

iii. NSCS will remain leak tight as required to prevent unacceptable release of hazardous materials (e.g., vessels, tanks and piping and gas circulation systems that contain hazardous materials)

iv. NSCS will operate as necessary immediately following the earthquake event to ensure continued post-earthquake function of essential facilities

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5 Seismic design objectives and performance criteria

For serviceability limit state: SLS

NSCS subjected to the moderate earthquake ground motions specified at the building site (serviceability limit state: SLS), will perform within accepted limits including limitation of financial loss.

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6 Sources of seismic demand on NSCS

6.1 General

a) inertial acceleration demands;

b) relative displacement demands between points of attachment;

c) impact force demands resulting from interactions with other components or structural members.

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6 Sources of seismic demand on NSCS

6.3 Relative displacement demand

a) relative displacements of attachment points that are located at different floor levels of a building;

b) relative displacements of attachment points that are located on independent, seismically separated buildings;

c) relative displacements of attachment points that are located on two NSCS attached to the same or different floors, including components on vibration isolators;

d) relative displacements of attachment points located on NSCS and the building;

e) relative displacements of attachment points that are located on seismically isolated building and its foundation or between seismically isolated floors.

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Annex D Principles for choosing the component amplification factor (resonance factor)

**Table D.1 - Examples of component amplification factors ($k_{R,p}$) for 5%-damped NSCS**

| Typology see Figure D.1 | Flat (plate) element | | | Linear element | | |
|---|---|---|---|---|---|---|
| Method of attachment to building structure | All face fixed (either front side or back side) | Fixed along upper and lower edges, right and left edges, or all edges | Fixed along one edge only | Fixed along length of component | Both ends fixed | One end fixed |
| Stiff NSCS* | 1,0 | 1,0 | 1,5 | 1,0 | 1,0 | 1,5 |
| Others | 1,0 | 1,5 | 2,5 or more | 1,0 | 1,5 | 2,5 or more |

* *Stiff NSCS* refers to components whose natural frequency is greater than 10 Hz

2.0 in AIJ

2.0 in AIJ

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Annex D Principles for choosing the component amplification factor (resonance factor)

| type | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Connection type between structural and nonstructural | 1 point<br>1 line | multiple points | two lines | four lines | plane |
| Actual connection | NSCS | structure<br>NSCS | slab<br>NSCS<br>slab | NSCS<br>surrounding structure | structure<br>NSCS |
| Example of nonstructural elements | suspended ceiling<br>suspended lighting fixture | curtain wall | partition wall | window<br>door | wall tile<br>cement mortar finishing |
| Dominant external force | inertial force<br>(two direction) | storey drift<br>inertial force | storey drift<br>inertial force | deformation of surrounding wall | strain and/or deformation of structural wall |


**Figure D.1 - Typology of the connection between structural members and NSCS**

# 昭和51年度(1976)　修士論文梗概集
# 伊藤　弘，2次部材の耐震性に関する研究
東京大学大学院工学系研究科建築学専門課程

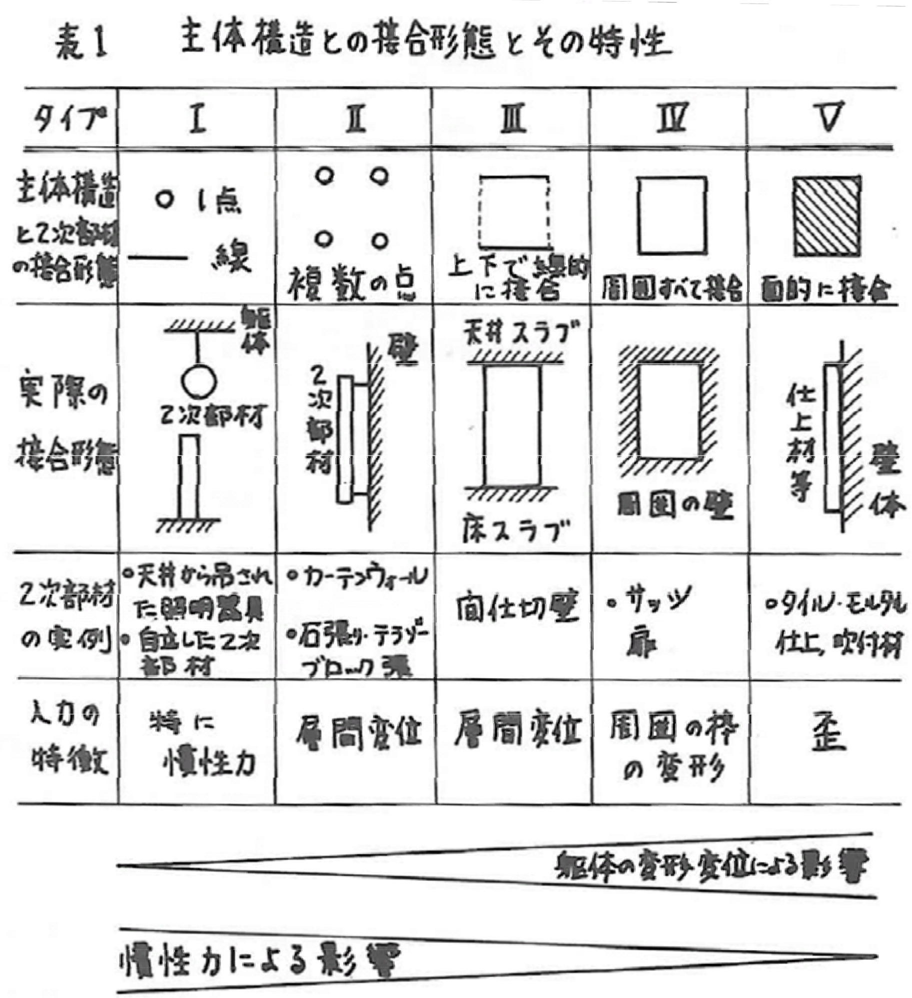



表1　主体構造との接合形態とその特性

| タイプ | I | II | III | IV | V |
|---|---|---|---|---|---|
| 主体構造と2次部材の接合形態 | ○ 1点<br>— 線 | 複数の点 | 上下で線的に接合 | 周囲すべて接合 | 面的に接合 |
| 実際の接合形態 | 躯体<br>2次部材 | 2次部材<br>壁 | 天井スラブ<br>床スラブ | 周囲の壁 | 仕上材等<br>壁体 |
| 2次部材の実例 | ○天井から吊された照明器具<br>○自立した2次部材 | ○カーテンウォール<br>○石張り・テラゾーブロック張 | 間仕切壁 | ○サッシ<br>扉 | ○タイル・モルタル仕上，吹付材 |
| 入力の特徴 | 特に慣性力 | 層間変位 | 層間変位 | 周囲の枠の変形 | 歪 |

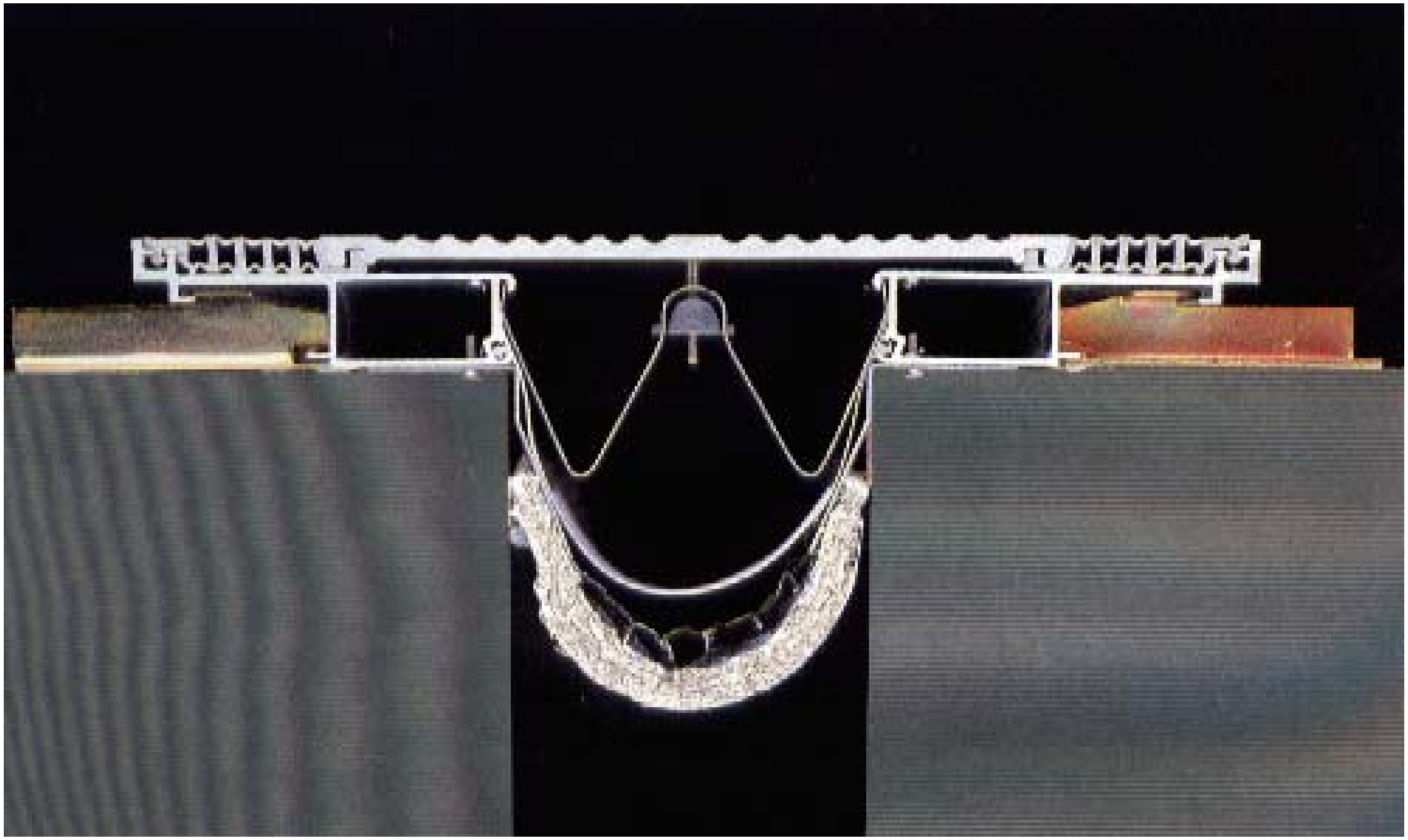
躯体の変形変位による影響

慣性力による影響

## F.3 Displacement between buildings

Displacement between buildings may be conservatively estimated as the absolute sum of the horizontal displacements of two adjacent buildings at the points of attachment.

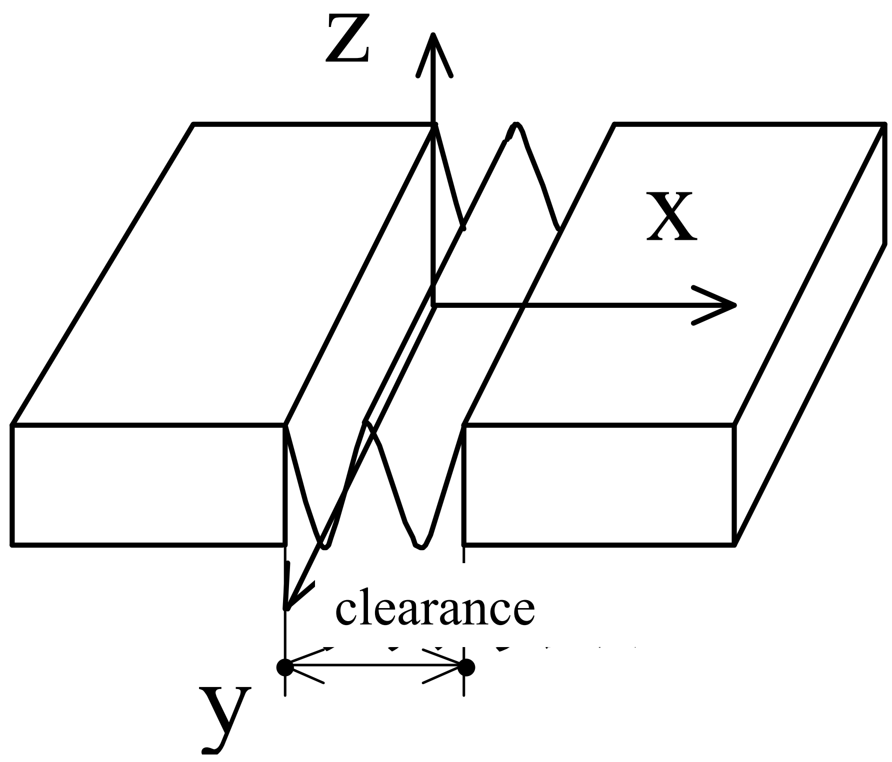
Alternatively, it may be taken as the square root of the sum of the squares (SRSS) of the calculated displacements.



Example of  expansion joint

Example of expansion joint

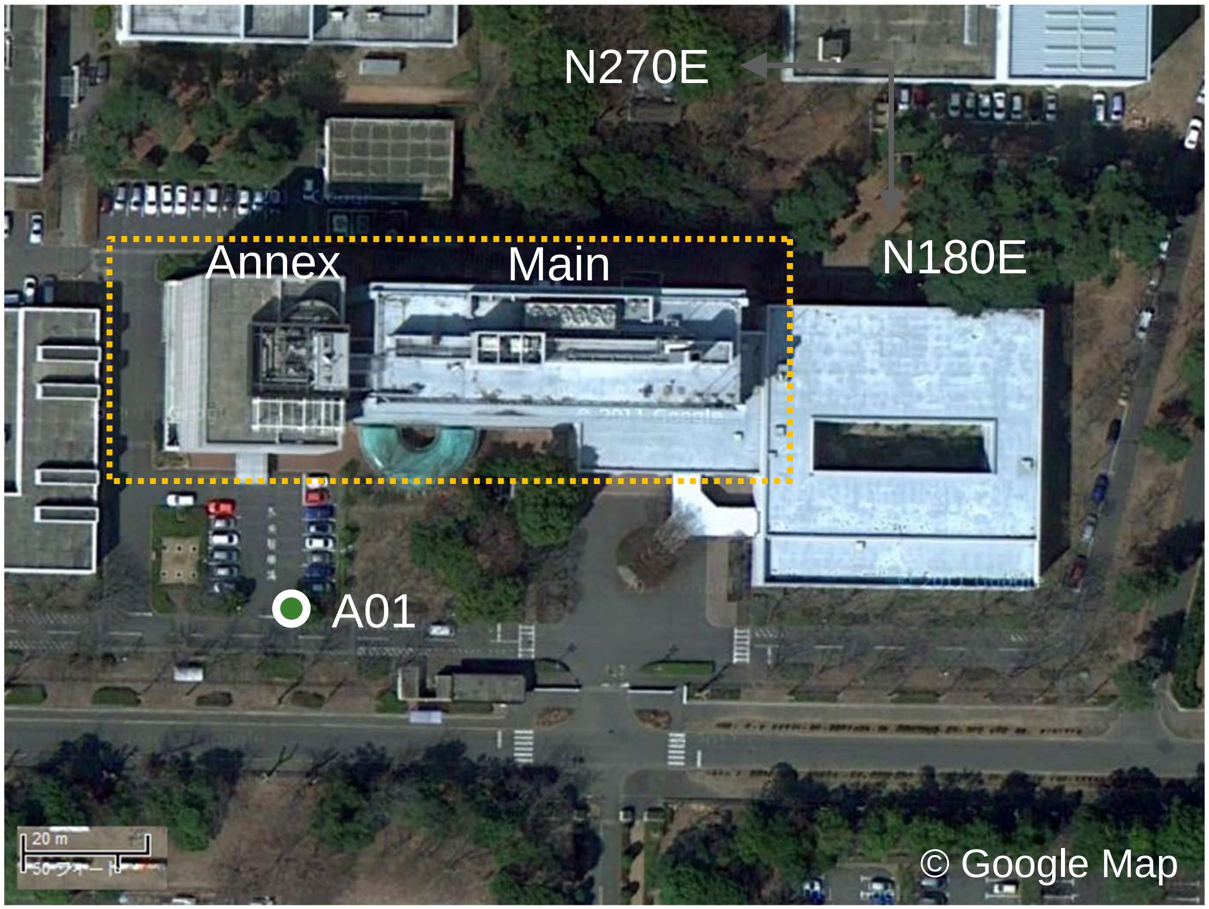
# 3 Dimensional Move of expansion joint



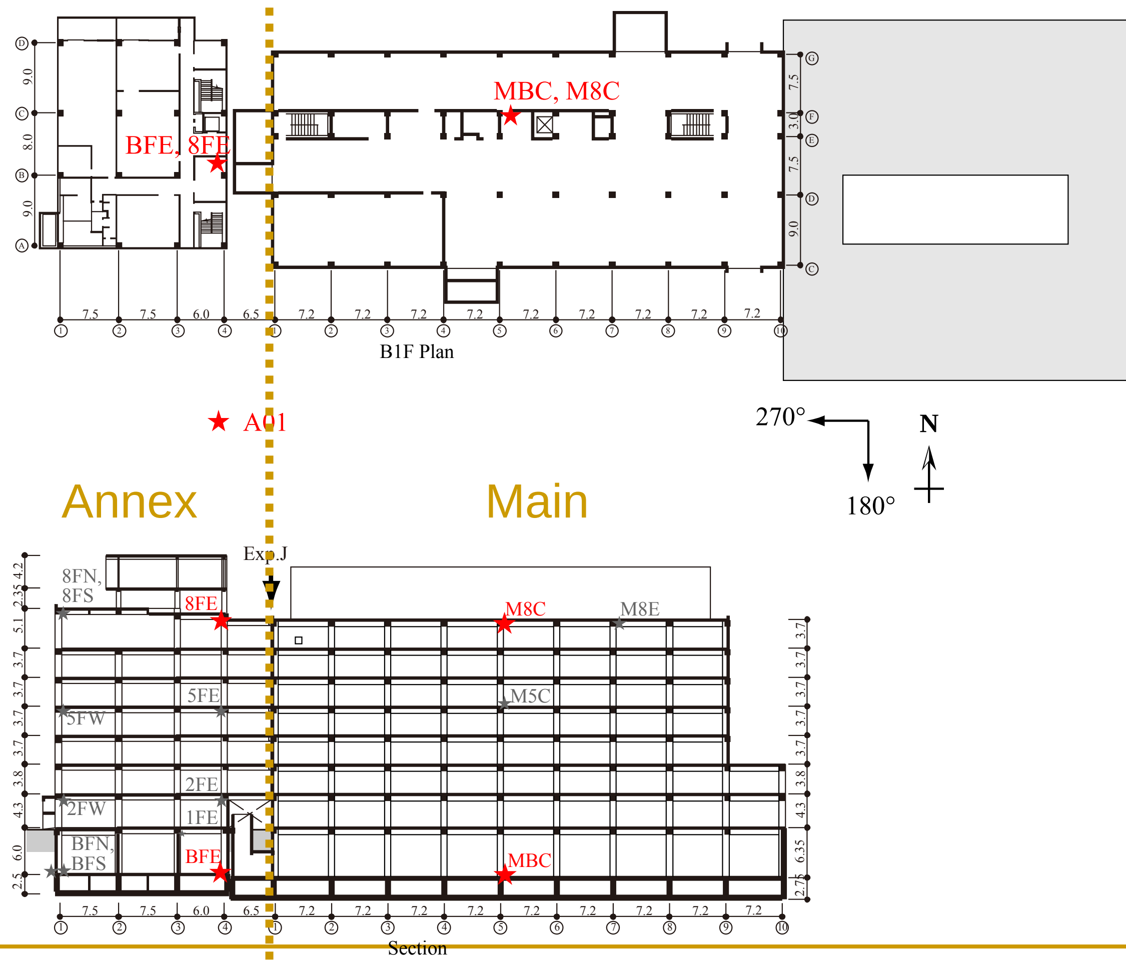
# ANX: BRI buildings

- 8- and 7-story SRC buildings (with B1F)
- 22 sensors in two buildings and ground

# Building layout at ANX

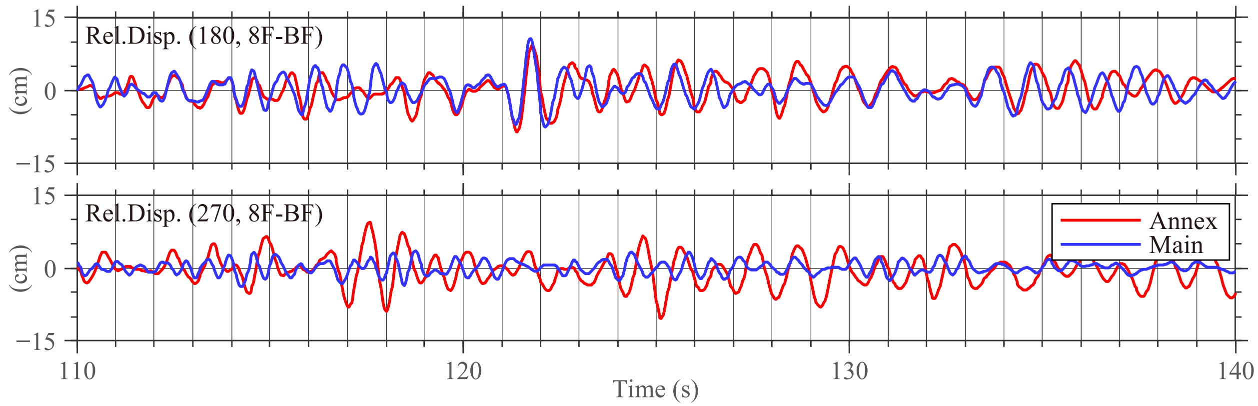


# Sensor configuration in BRI buildings at ANX

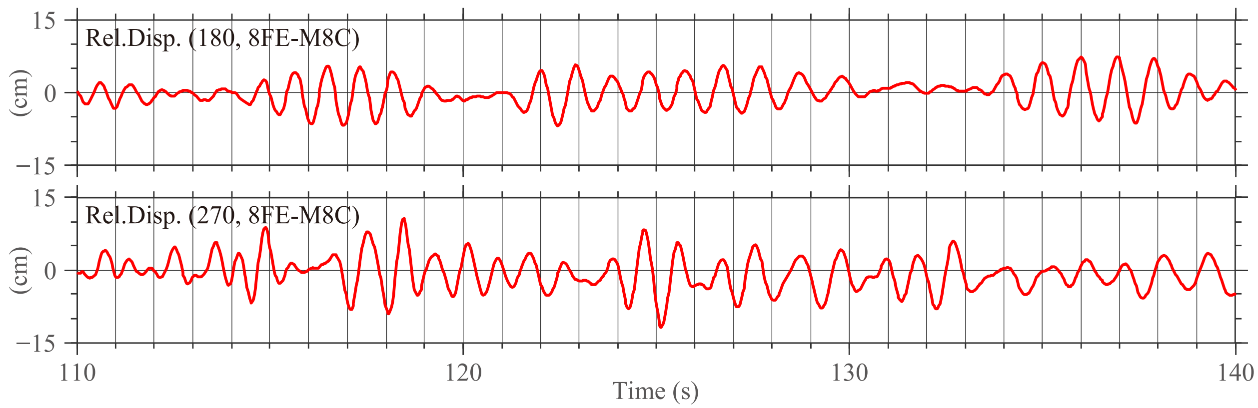


# Damage to expansion joint

# Displacement of expansion joint




Building displacement (8F-BF)




Displacement of expansion joint (8F)

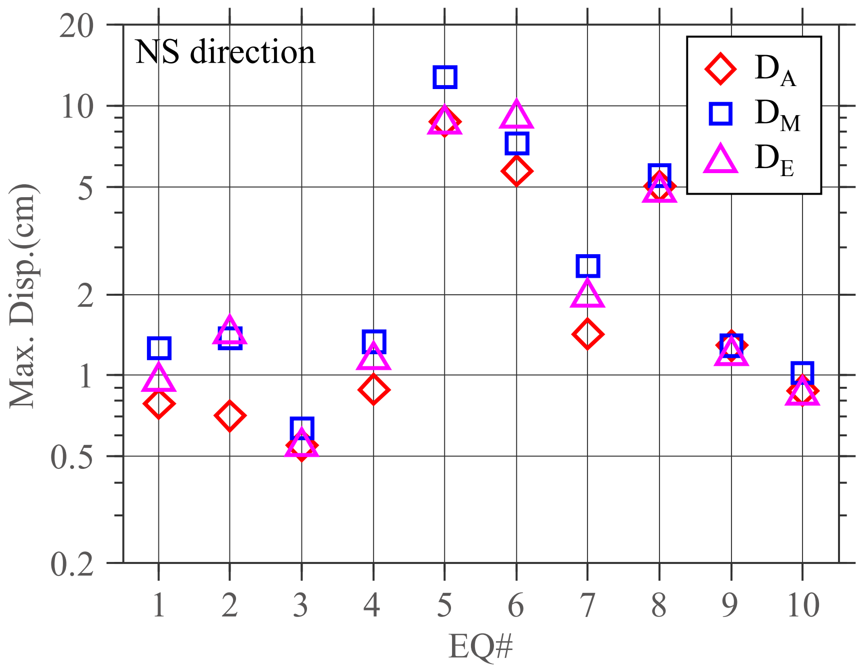
# Displacement of expansion joint

- $D_{\mathrm{A}}$: Max. disp. of annex bldg. (8F-B1F)
- $D_{\mathrm{M}}$: Max. disp. of main bldg. (8F-B1F)
- $D_{\mathrm{E}}$: Max. disp. of expansion joint
- Estimation (1): $D_{\mathrm{E1}} = |D_{\mathrm{A}}| + |D_{\mathrm{M}}|$
- Estimation (2): $D_{\mathrm{E2}} = \sqrt{{D_{\mathrm{A}}}^2 + {D_{\mathrm{M}}}^2}$

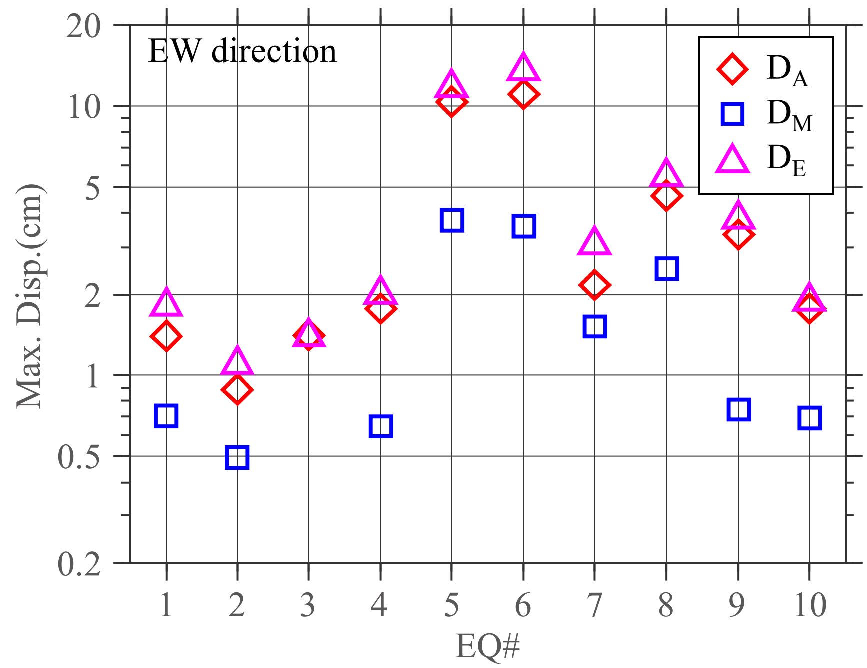
# Earthquakes discussed

| # | Date | Epicenter | *h* (km) | *M* | *Δ* (km) | PGA ($cm/s^2$) | $I_{JMA}$ |
|---|---|---|---|---|---|---|---|
| 1 | 2004/10/06 23:40 | S Ibaraki Pref. | 66 | 5.7 | 17 | 55 | 3.8 |
| 2 | 2005/10/19 20:44 | Off Ibaraki Pref. | 48 | 6.3 | 91 | 40 | 3.5 |
| 3 | 2007/07/16 10:13 | Off Jochuetsu, Niigata Pref. | 17 | 6.8 | 205 | 19 | 3.6 |
| 4 | 2008/05/08 01:45 | Off Ibaraki Pref. | 51 | 7 | 138 | 50 | 3.6 |
| 5 | 2011/03/11 14:46 | Off Sanriku | 24 | 9 | 330 | 279 | 5.3 |
| 6 | 2011/03/11 15:15 | Off Ibaraki Pref. | 43 | 7.7 | 107 | 151 | 4.7 |
| 7 | 2011/03/19 18:56 | N Ibaraki Pref. | 5 | 6.1 | 85 | 81 | 3.9 |
| 8 | 2011/04/11 17:16 | Hama-dori, Fukushima Pref. | 6 | 7 | 105 | 118 | 4.6 |
| 9 | 2011/04/12 14:07 | Naka-dori, Fukushima Pref. | 15 | 6.4 | 114 | 39 | 3.5 |
| 10 | 2011/04/16 11:19 | S Tochigi Pref. | 79 | 5.9 | 26 | 45 | 3.6 |

# Maximum Displacements

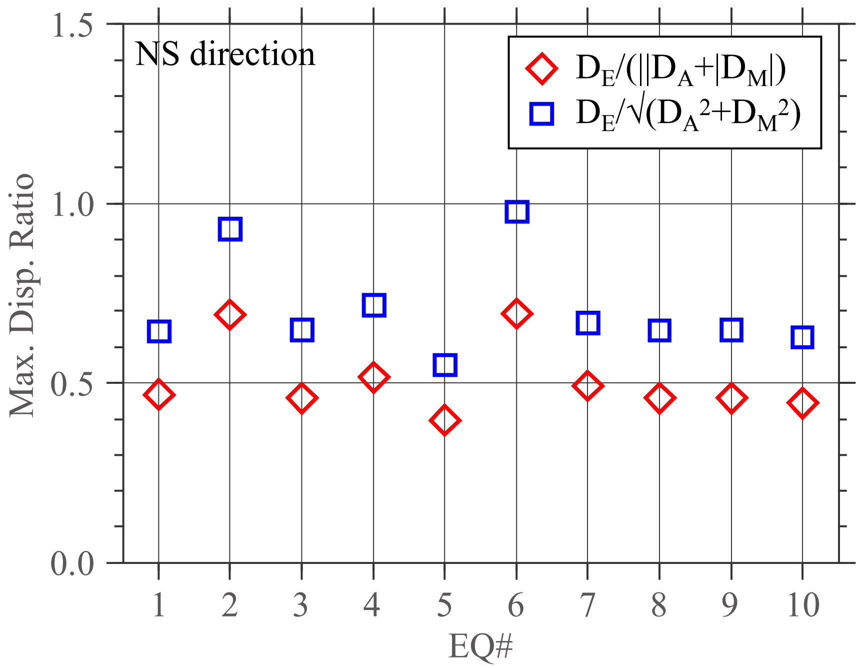



NS direction

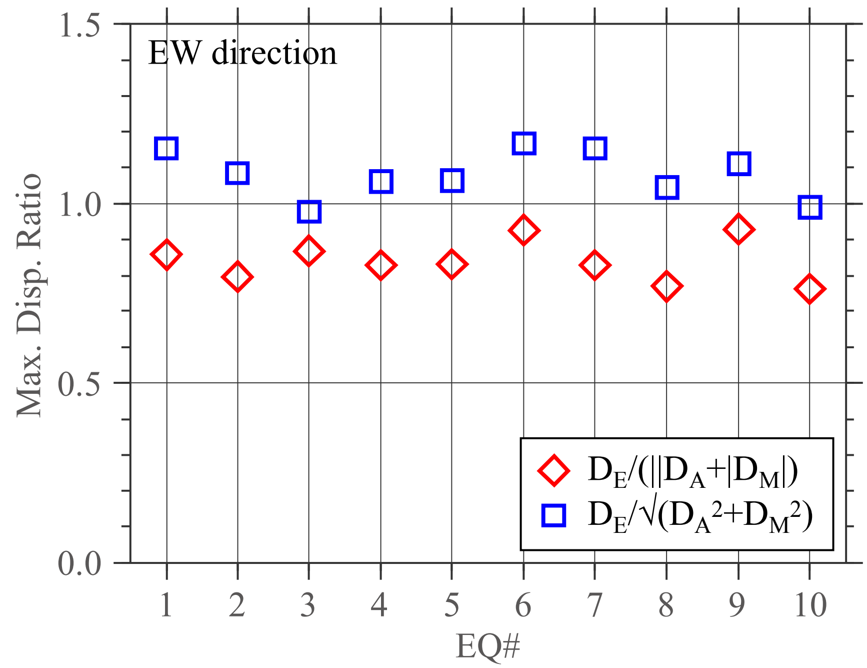



EW direction

# Comparison with (1) and (2)




NS direction




EW direction