NONSTRUCTURAL EARTHQUAKE DAMAGE AND DESIGN GUIDE AS COUNTERMEASURES IN JAPAN

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Workshop on the Improvement of Structural Engineering and Resilience

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Falling down of Precast Concrete Curtain Wall in June 1978 Miyagi-Ken-Oki Earthquake

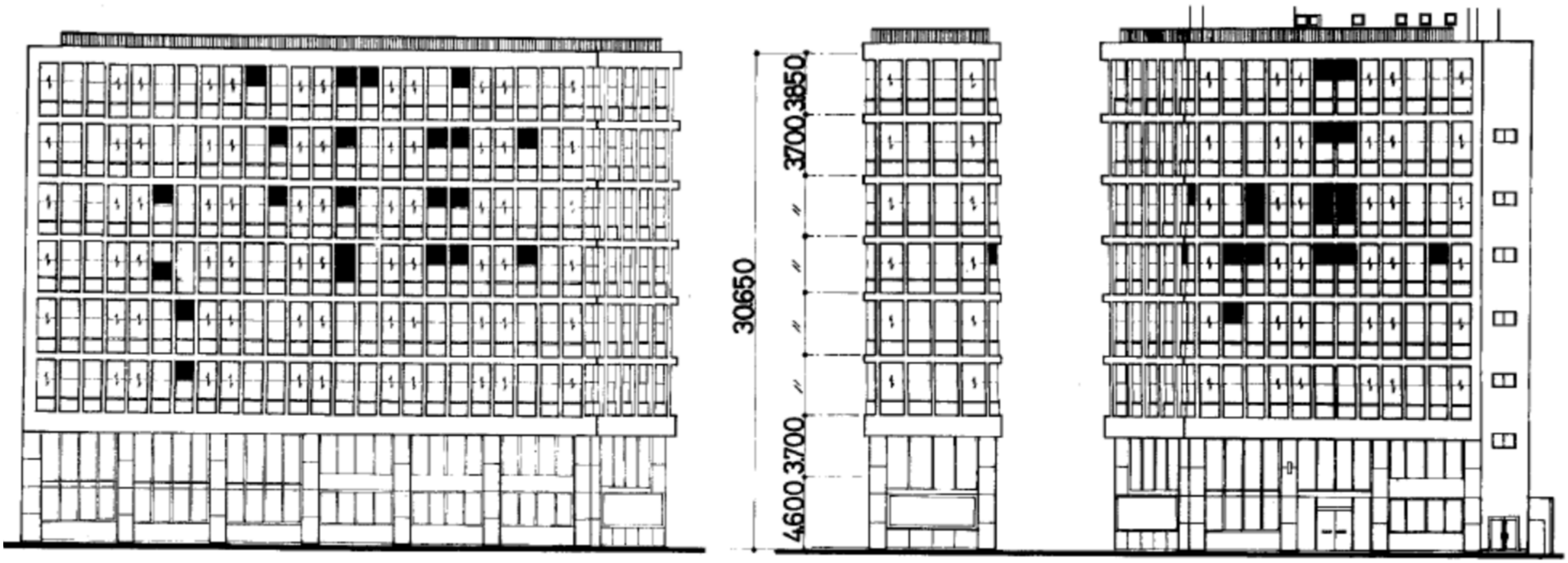
Design guide as Countermeasure

In October 1978, the following new item was added to Notification No.109 of the Ministry of Construction / 1971

(2)curtain walls made from precast concrete panels shall be allowed to move at either their top or bottom supporting structures. Provided that, this shall not apply in cases where it has been confirmed, either through structural calculation or experiment, that conspicuous deformation will not appear in the curtain walls made from precast concrete panels nor in their supporting structures.

1978 June: Earthquake damage
1978 October: The new item was added to Notification No.109 of the Ministry of Construction / 1971.
The countermeasure of the new item had been the common understandings among the engineers.

Glass and window damage in February 1978 Miyagi-Ken-Oki Earthquake



south elevation

east elevation

■ : Cracked and/or falling down windows

Design guide as Countermeasure

In October 1978, the following new item was added to Notification No.109 of the Ministry of Construction / 1971

(4)When a fixed sash window (excluding those with wired glass) containing glass is installed as a curtain wall, sealing material, which hardens, shall not be used. Provided that, this shall not apply in cases where measures are taken to prevent damage and harm caused by the glass falling.

1978 February: Earthquake damage
1978 June: Earthquake damage
1978 October: The new item was added to Notification No.109 of the Ministry of Construction / 1971.
The countermeasure of the new item had been the common understandings among the engineers.

But quite similar window damage happened in 2005 West Off Fukuoka Prefecture Earthquake

Damage of window glass in 2005 West Off Fukuoka Prefecture Earthquake(1)

Damage of window glass in 2005 West Off Fukuoka Prefecture Earthquake(2)

Damage of falling down of suspended ceiling

Falling down of suspended ceiling
in the gymnasium
（2001 Geiyo Earthquake）

Falling down of suspended ceiling
in the airport terminal building
（2003 Off Tokachi Earthquake)

Falling down of suspended ceiling in the indoor swimming pool
(2005 Off Miyagi Prefecture Earthquake）

Design guide as Countermeasure

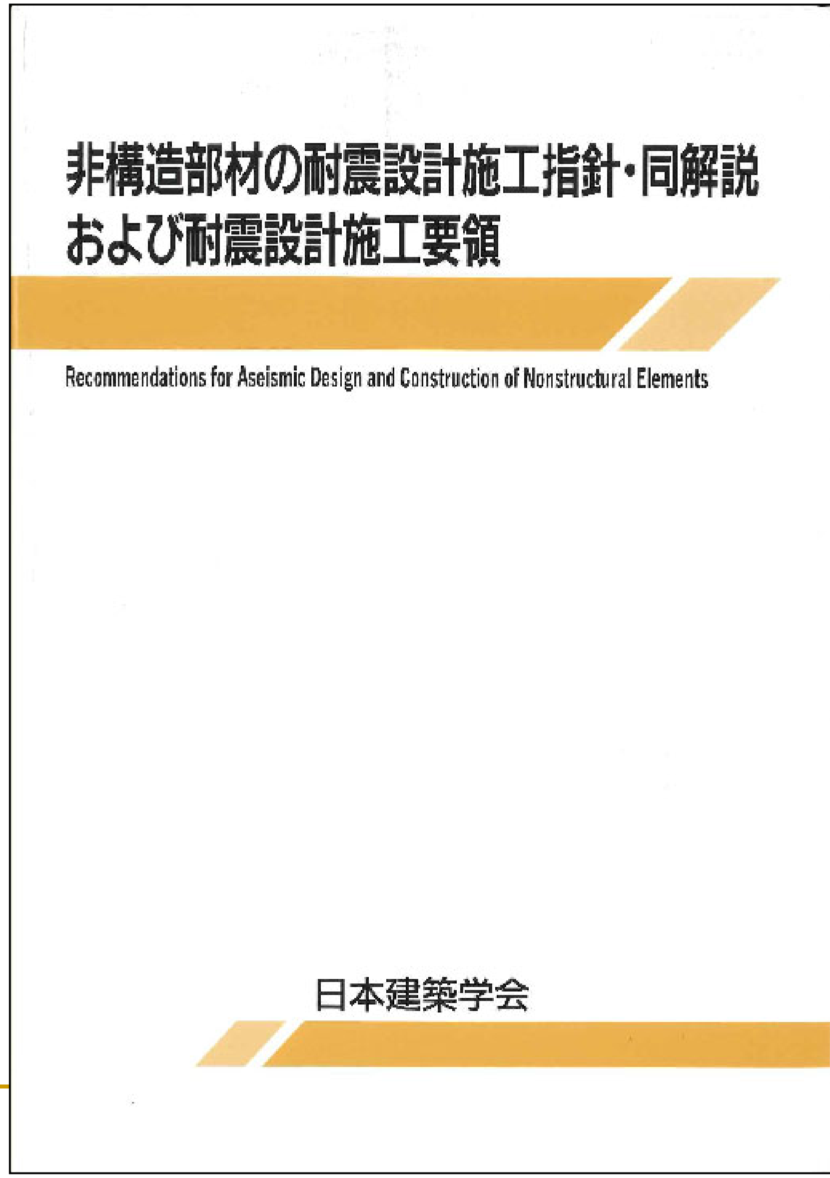
March 2001:Geiyo Earthquake: Earthquake damage of suspended ceiling
June 2001:Ministry of Land, Infrastructure, Transport, and Tourism MLIT provided the technical advice on suspended ceiling.

September 2003: Off Tokachi Earthquake : Earthquake damage of suspended ceiling
October 2003:MLIT provided the technical advice on suspended ceiling again.

August 2005 Off Miyagi Prefecture Earthquake: Earthquake damage of suspended ceiling

March 2011:Great East Japan Earthquake: Earthquake damage of suspended ceiling
July 2013:The revision of the article No.39 of the Building Standard Law Enforcement Order was posted.
August 2013:The new item was added to Notification No.109 of the Ministry of Construction / 1971.

Recommendations for Aseismic Design and Construction of Nonstructural Elements by AIJ



Recommendations for Aseismic Design and Construction of Nonstructural Elements by AIJ

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

Recommendations for Aseismic Design and Construction of Nonstructural Elements by AIJ

Part 1:Comprehensive Design Guideline for nonstructural elements

Scope, Terms and definitions, Seismic design objectives and performance criteria, design displacements and inertial force etc.

→ ISO13033 Seismic actions on nonstructural components for building applications

Part 2:Design guide for each nonstructural elements

The each guide is often described as prescriptive expression.

The provided guides are for;

Curtain Wall

Autoclaved Lightweight Aerated Concrete Panel

Glass and Window

Suspended ceiling

etc.

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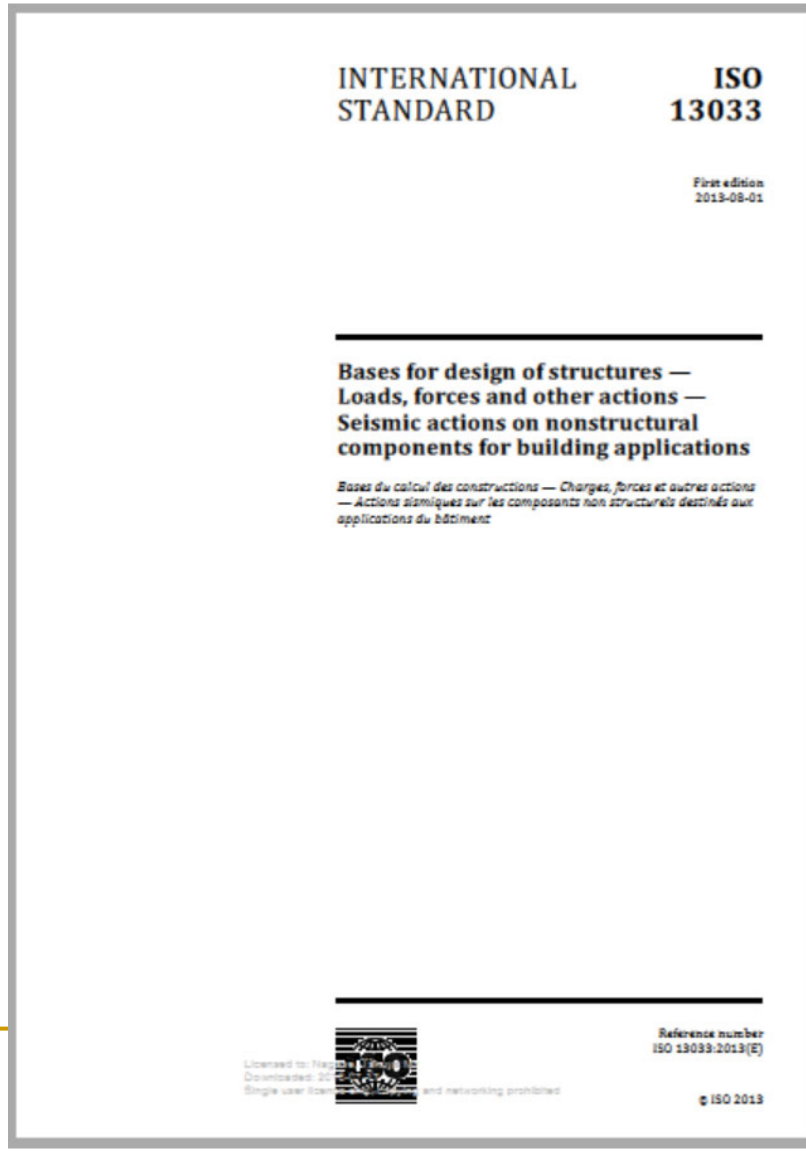
INTERNATIONAL STANDARD

ISO 13033

First edition
2013-08-01

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

Bases du calcul des constructions — Charges, forces et autres actions — Actions sismiques sur les composants non structurels destinés aux applications du bâtiment

Reference number
ISO 13033:2013(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
• 19 & 20 March 2013	Honolulu, Hawaii

We also had an informal meeting

- 26 July 2010	Toronto, Canada

ISO/TC98/SC3/WG11 Member Experts, Member Observers and Other Invited Experts ISO 13033:2013

Member Experts

- Simon Foo – Canada
- David Lau - Canada
- Hiroshi Ito – Japan
- Yoshio Wakiyama, 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 Taipei (with understanding of China concerns)
- George Yao – Chinese Taipei (with understanding of China concerns)
- Juin-Fu Chai – Chinese Taipei (with understanding of China concerns)
- Carlos Aguirre – Chile

Observers

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

ISO/TC98/SC3/WG11 Member Experts, Member Observers and Other Invited Experts ISO 1303313033:2013

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

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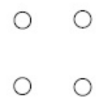
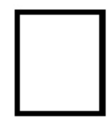
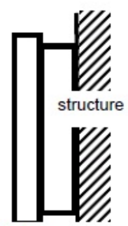
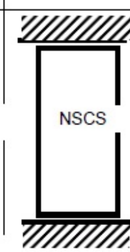
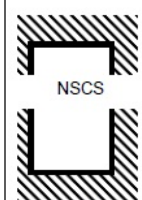
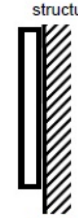
Annex D Principles for choosing the component amplification factor (resonance factor)

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

Effect of inertial force of structure

Effect of strain and/or deformation of structure

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
master’s thesis abstract of Hiroshi Ito in 1977

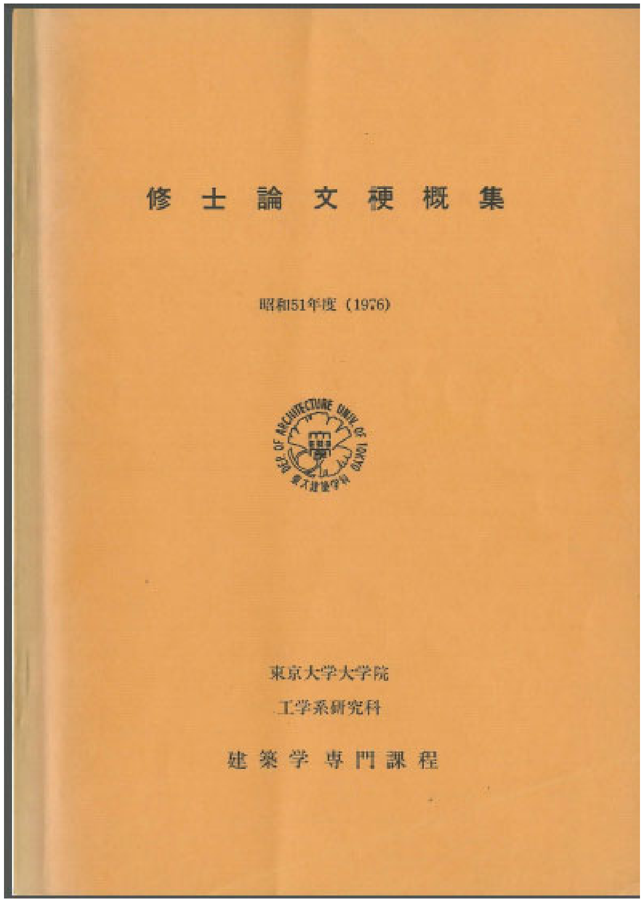
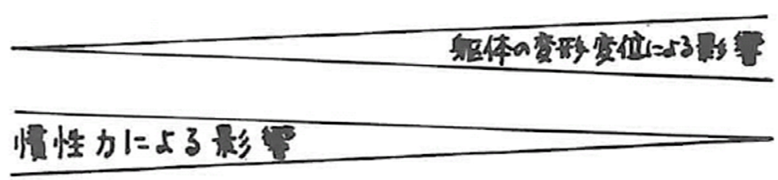


表1　主体構造との接合形態とその特性

タイプ	I	II	III	IV	V
主体構造と2次部材の接合形態	○ 1点 — 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 2次部材	2次部材 壁	天井スラブ 床スラブ	周囲の壁	仕上材等 壁体
2次部材の実例	○天井から吊された照明器具 ○自立した2次部材	○カーテンウォール ○石張り・テラゾーブロック張	間仕切壁	○サッシ 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



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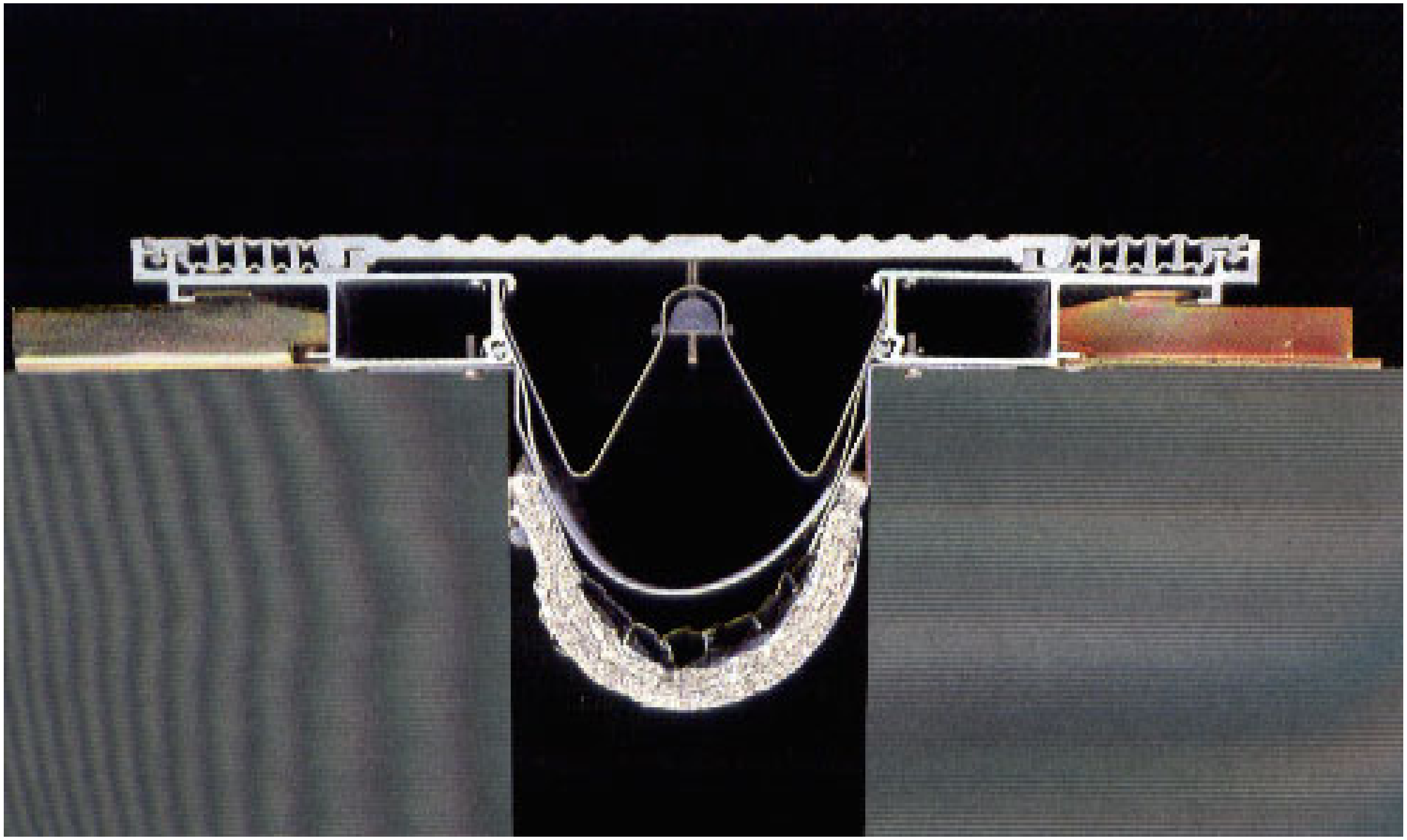
F.3 Displacement between buildings

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.

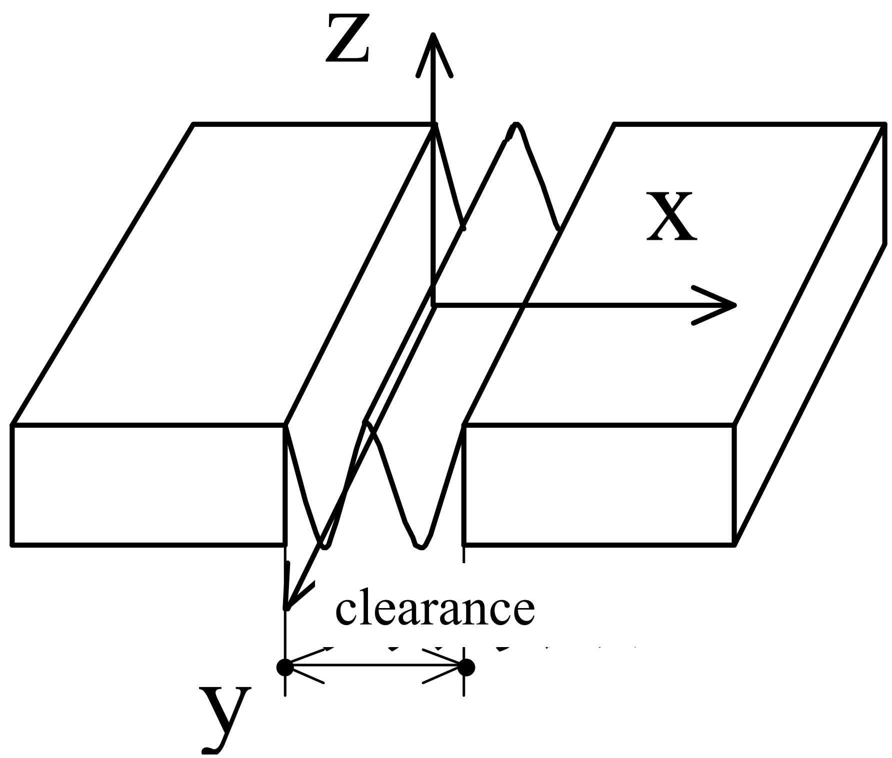


Example of seismic joint

In Japan, this part is usually called as the expansion joint to accommodate the seismic movement between the parts of the building..

In USA, this part is usually called as seismic joint.

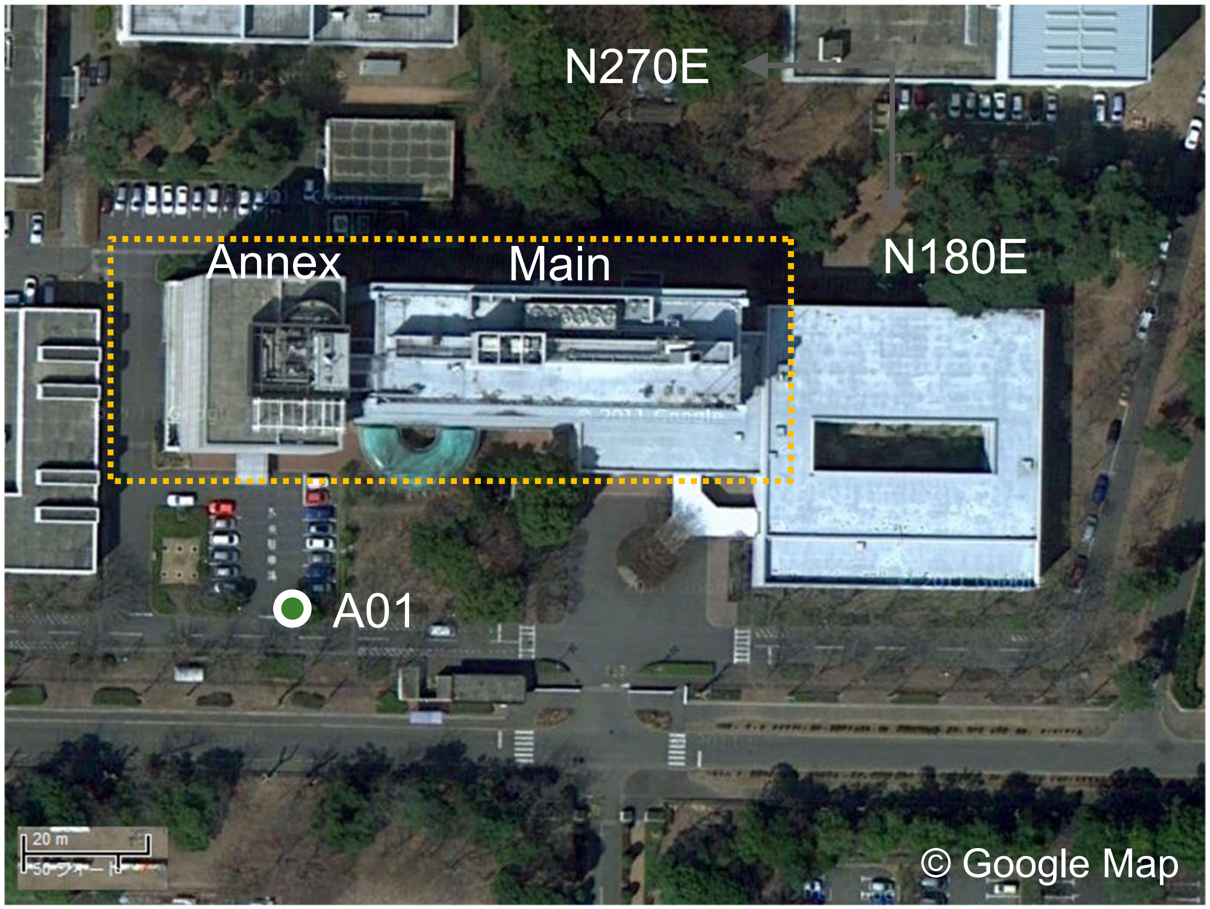
3 Dimensional Move of seismic joint



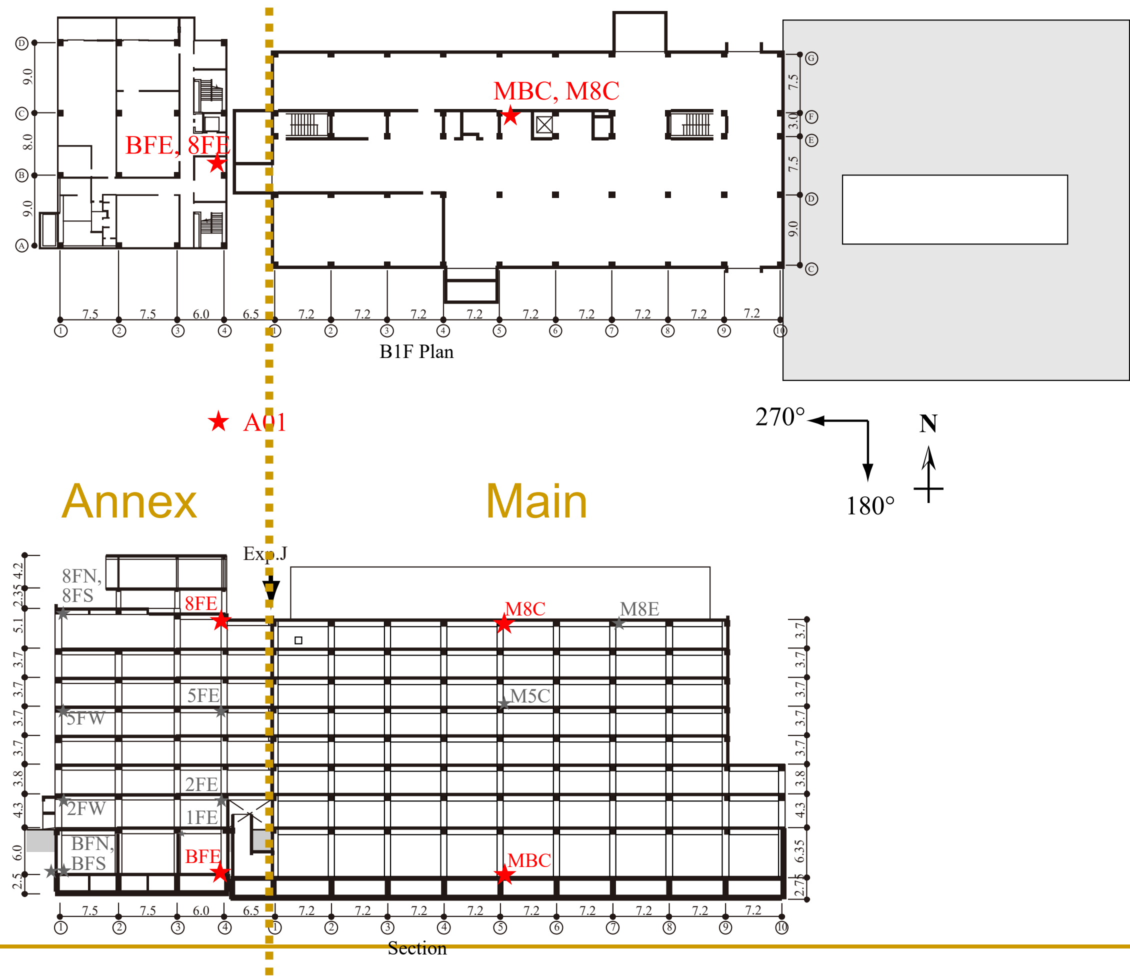
ANX: BRI buildings

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

Building layout at ANX

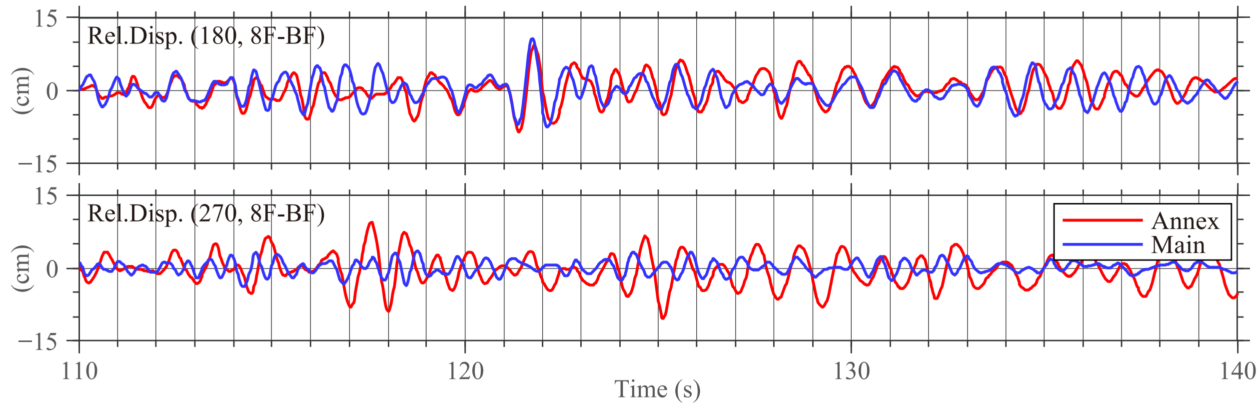


Sensor configuration in BRI buildings at ANX

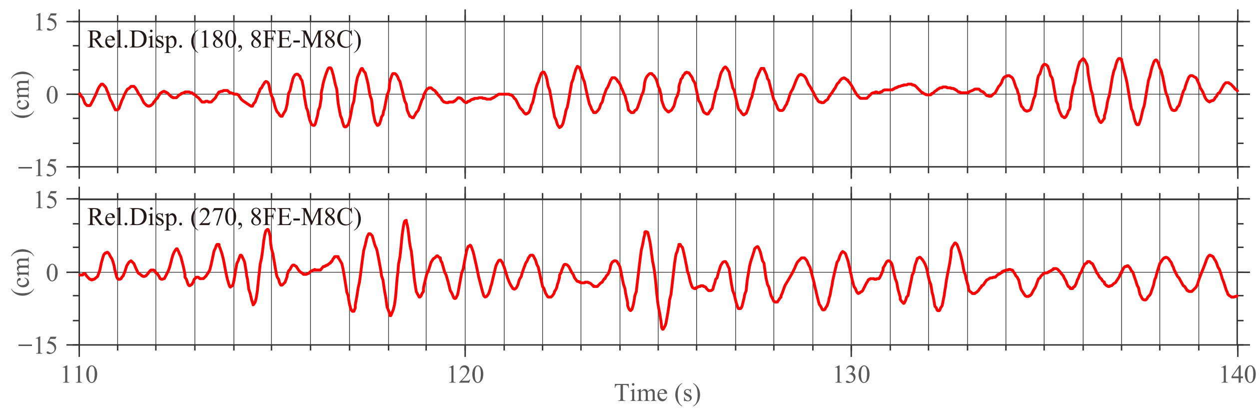


Damage to seismic joint

Displacement of seismic joint



Building displacement (8F-BF)



Displacement of seismic joint (8F)

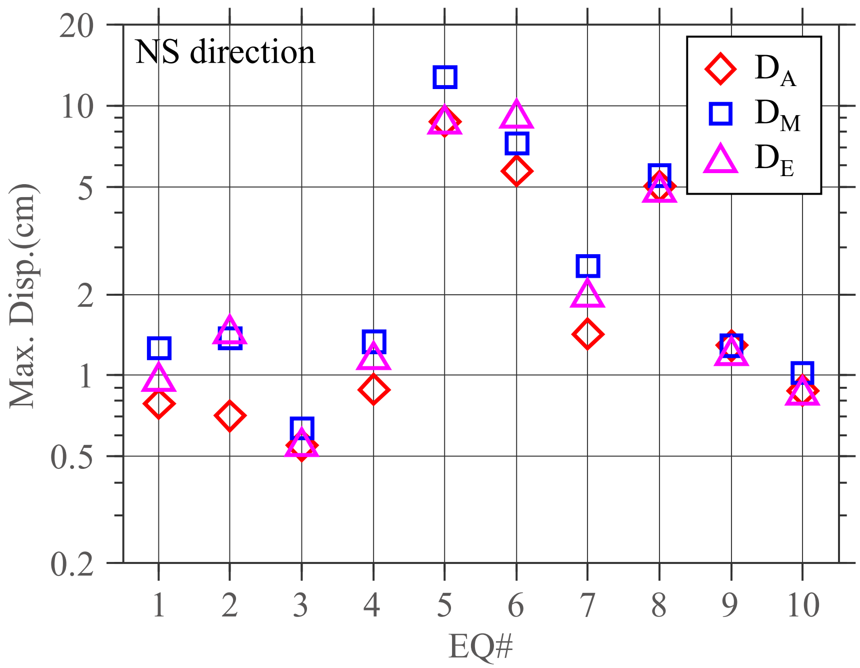
Displacement of expansion joint

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

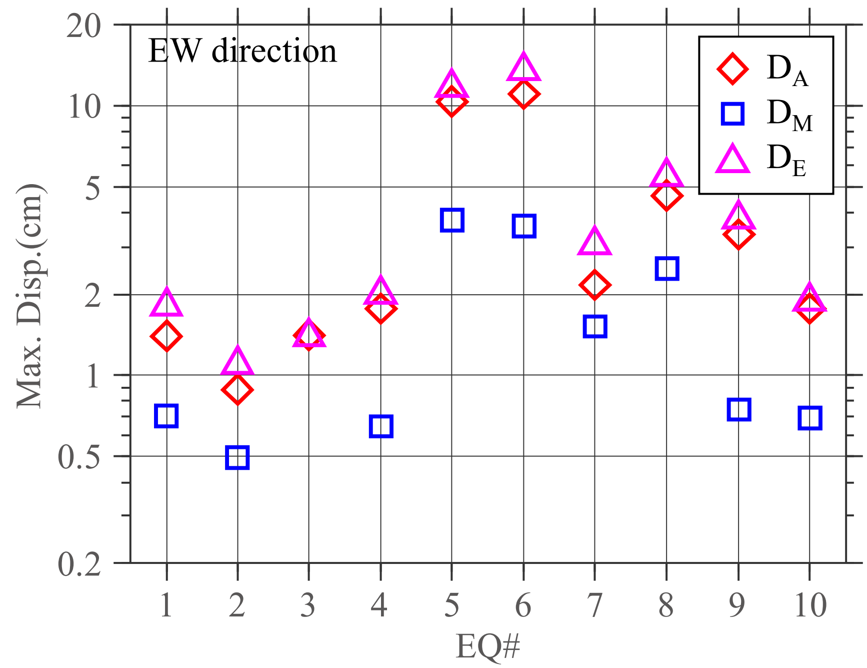
Earthquakes discussed

#	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

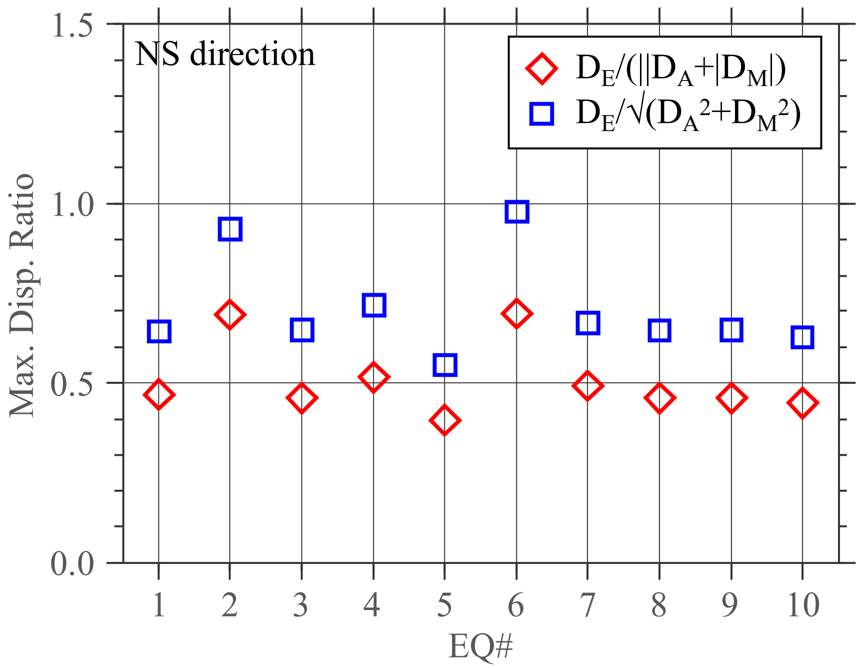


NS direction

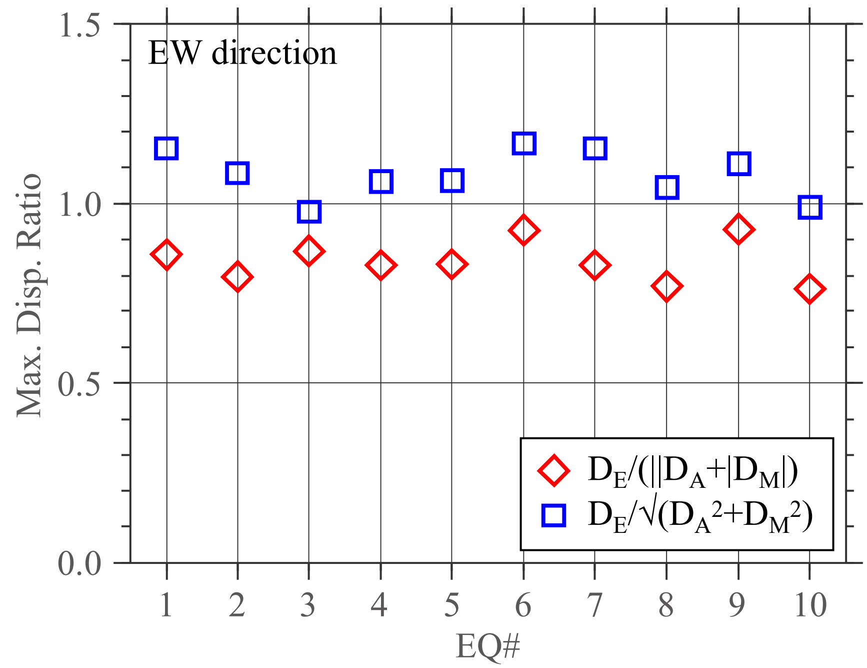


EW direction

Comparison with (1) and (2)



NS direction



EW direction

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5 year passed after the establishment of ISO 13033.

Regular periodical review of ISO13033 has started.

The deadline of the voting for the ISO is December 1st 2018.

Welcome the comments to

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