NONSTRUCTURAL EARTHQUAKE DAMAGE AND DESIGN GUIDE AS COUNTERMEASURES IN JAPAN

17th U.S.-Japan-New Zealand 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.
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 13033:2013
Bases for design of structures — Loads, forces and other actions — Seismic actions on nonstructural components for building applications

Foreword
Introduction
1 Scope
2 Normative references
3 Terms and definitions
4 Symbols (and abbreviated terms)
5 Seismic design objectives and performance criteria
6 Sources of seismic demand on NSCS
7 General conditions for determining seismic demand on NSCS
8 Quantification of elastic seismic demand on NSCS
9 Verification of NSCS
10 Verification of seismic load path between NSCS and building structural system
11 Quality assurance and enforcement
ISO 13033:2013
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
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
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.
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
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
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.
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.
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.
Annex D Principles for choosing the component amplification factor (resonance factor)

<table>
<thead>
<tr>
<th>Typology see Figure D.1</th>
<th>Flat (plate) element</th>
<th>Linear element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method of attachment to building structure</td>
<td>All face fixed (either front side or back side)</td>
<td>Fixed along upper and lower edges, right and left edges, or all edges</td>
</tr>
<tr>
<td>Stiff NSCS*</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Others</td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

* Stiff NSCS refers to components whose natural frequency is greater than 10 Hz.
Annex D Principles for choosing the component amplification factor (resonance factor)

![Figure D.1 - Typology of the connection between structural members and NSCS](image-url)
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

<table>
<thead>
<tr>
<th>タイプ</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>主体構造と2次部材の接合形態</td>
<td>1点</td>
<td>複数の点</td>
<td>上下で隅角に接合</td>
<td>周囲で隅角に接合</td>
<td>面的に接合</td>
</tr>
<tr>
<td>実際の接合形態</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2次部材の実例</td>
<td>天井から吊り下げた照明器具</td>
<td>自立した2次部材</td>
<td>カーテンウォール</td>
<td>石張りの壁</td>
<td>仕上げ壁</td>
</tr>
<tr>
<td>入力の特性</td>
<td>特に慣性力</td>
<td>層間変位</td>
<td>層間変位</td>
<td>周囲の変形</td>
<td>引</td>
</tr>
</tbody>
</table>

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 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

- **x** direction
- **y** direction
- **z** direction

**clearance**
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

Annex Main Building

B1F Plan

Annex

Main

Exp.J

MBC, M8C

A01

Section
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): $D_{E1} = |D_A| + |D_M|$
- Estimation (2): $D_{E2} = \sqrt{D_A^2 + D_M^2}$
## Earthquakes discussed

<table>
<thead>
<tr>
<th>#</th>
<th>Date</th>
<th>Epicenter</th>
<th>( h ) (km)</th>
<th>( M )</th>
<th>( \Delta ) (km)</th>
<th>PGA (cm/s²)</th>
<th>( I_{JMA} )</th>
</tr>
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<tbody>
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<tr>
<td>8</td>
<td>2011/04/11 17:16</td>
<td>Hama-dori, Fukushima Pref.</td>
<td>6</td>
<td>7</td>
<td>105</td>
<td>118</td>
<td>4.6</td>
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<td>2011/04/12 14:07</td>
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<td>26</td>
<td>45</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Maximum Displacements

NS direction

EW direction

EQ#
Comparison with (1) and (2)

NS direction

EW direction

$D_E/\sqrt{DA^2 + DM^2}$

$D_E/||DA + DM||$
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 itohiro@gakushikai.jp