Seismic Actions of Nonstructural Components

14th U.S.-Japan Workshop on Improvement of Structural Design and Construction Practices
December 3-5, 2012

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Director, Housing Renovation and Dispute Settlement Research Institute, Japan
“Guideline, Commentary and Detail of Seismic Design and Construction of Non-structural Components by AIJ
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- 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/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)
ISO/TC98/SC3/WG11 Member Experts, Member Observers and Other Invited Experts ISO/CD 13033
ISO/CD 13033
Bases for design of structures — Loads, forces and other actions — Seismic actions on nonstructural components for building applications

Foreword
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1 Scope
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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
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
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
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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.
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) elements</th>
<th>Linear elements</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>
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</table>

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

2.0 in AlJ

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

<table>
<thead>
<tr>
<th>Type</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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</thead>
<tbody>
<tr>
<td>Connection type between structural and nonstructural</td>
<td>1 point</td>
<td>multiple points</td>
<td>two lines</td>
<td>four lines</td>
<td>plane</td>
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<tr>
<td>Actual connection</td>
<td>NSCS</td>
<td>NSCS</td>
<td>slab</td>
<td>NSCS</td>
<td>NSCS</td>
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<tr>
<td>Example of nonstructural elements</td>
<td>suspended ceiling</td>
<td>curtain wall</td>
<td>partition wall</td>
<td>window</td>
<td>wall tile</td>
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<tr>
<td>Dominant external force</td>
<td>inertial force (two directions)</td>
<td>storey drift inertial force</td>
<td>storey drift inertial force</td>
<td>deformation of surrounding wall</td>
<td>strain and/or deformation of structural wall</td>
</tr>
</tbody>
</table>

Figure D.1 - Typology of the connection between structural members and NSCS
昭和51年度(1976) 修士論文総集
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

<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>2点</td>
<td>3点</td>
<td>上下</td>
<td>周囲</td>
</tr>
<tr>
<td>接合形態</td>
<td>部材</td>
<td>2次部材</td>
<td>サラスラブ</td>
<td>床スラブ</td>
<td>固め</td>
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</table>

表1 主体構造との接合形態とその特性

- 表示: 表示
- テキスト: テキスト

2次部材の実例
- 天井から吊られた照明器具
- 自然光の利用

入力の特徴
- 慣性力
- 層間変位
- 層間変位
- 周開の変形
- 型

\[ \text{慣性力による影響} \]

\[ \text{層間変位による影響} \]
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

Diagram showing 3D movement in the x, y, z directions with clearance indicated.
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

4.3 3.8 3.7 3.7 3.7 3.7 5.1 2.3 4.2 6.0 2.5

Exp.J

Section

B1F Plan

Annex Main

270°

180°

N
Damage to expansion joint
Displacement of expansion joint

Building displacement (8F-BF)

Displacement of expansion 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 expansion joint
- Estimation (1): $D_{E1} = |D_A| + |D_M|$
- Estimation (2): $D_{E2} = \sqrt{D_A^2 + D_M^2}$
Earthquakes discussed

<table>
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<th>$M$</th>
<th>$\Delta$ (km)</th>
<th>PGA (cm/s²)</th>
<th>$I_{JMA}$</th>
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Maximum Displacements

NS direction

EW direction

EQ#
Comparison with (1) and (2)

NS direction

EW direction

\[ \frac{D_E}{\left| |D_A + |D_M| \right|} \]
\[ \frac{D_E}{\sqrt{D_A^2 + D_M^2}} \]