SEISMIC DESIGN PROVISIONS FOR ANCHORS: CONCEPT AND IMPLEMENTATION IN THE U.S

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Agenda

US code overview

Seismic design methodology

Seismic Design Category & Seismic Use Group definitions

Conclusions
U.S. code overview

ACI 318

ACI 318 – D
strength design provisions for cast-in-place & post-installed

ASCE/SEI 7-05

IBC 2003/2006
cast-in-place & post-installed
(ref. IBC 2003 Section 1913.1)
(ref. IBC 2006 Section 1912.1)

ACI 355.2
pre-qualification tests for post-installed (mechanical)

AC193
pre-qualification tests
(mechanical anchors)

AC308
strength design provisions & pre-qualification tests
(adhesive anchors)

ESR

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Agenda

US code overview

Seismic design methodology

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Conclusions
Options for the seismic design of anchorages

I. anchorage designed for a plastic hinge

II. anchorage designed for capacity of structural system

III. anchor resistance governed by ductile anchor yield

IV. anchorage designed for a multiple of the calculated seismic force
Options for the seismic design of anchorages

I. anchorage designed for a plastic hinge

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IV. anchorage designed for a multiple of the calculated seismic force
Options for the seismic design of anchorages

yielding attachment

overload protection strategies for anchor connections
Options for the seismic design of anchorages

I. anchorage designed for a plastic hinge

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Options for the seismic design of anchorages

Edge distance too small to satisfy ductility criteria based on steel strength.
Options for the seismic design of anchorages

I. anchorage designed for a plastic hinge

II. anchorage designed for capacity of structural system

III. anchor resistance governed by ductile anchor yield

IV. anchorage designed for a multiple of the calculated seismic force
Coalinga earthquake of May 1983

Surge tank ABs: 38 mm A307 bolts stretched uniformly 25 to 40 mm

H. J. Degenkolb
Options for the seismic design of anchorages

I. anchorage designed for a plastic hinge

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III. anchor resistance governed by ductile anchor yield

IV. anchorage designed for a multiple of the calculated seismic force
Overturned medical gasses tank, Olive View Hospital
Northridge 1994
Re-anchoring failed tank with 4 large dia. anchors per leg

new anchors
Agenda

US code overview

Seismic design methodology

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Conclusions
<table>
<thead>
<tr>
<th>Seismic Design Category (SDC)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Structures in regions where anticipated ground motions are minor, even for very long return periods.</td>
</tr>
<tr>
<td>B</td>
<td>Seismic Use Group I and II structures in regions of seismicity where only moderately destructive ground shaking is anticipated.</td>
</tr>
<tr>
<td>C</td>
<td>Seismic Use Group III structures in regions where moderately destructive ground shaking may occur as well as Seismic Use Group I and II structures in regions with somewhat more severe ground shaking potential.</td>
</tr>
<tr>
<td>D</td>
<td>Seismic Use Group I, II and III structures in regions expected to experience destructive ground shaking but not located very near major active fault lines</td>
</tr>
<tr>
<td>E</td>
<td>Seismic Use Group I and II structures in regions located very close to major active fault lines</td>
</tr>
<tr>
<td>F</td>
<td>Seismic Use Group III structures in regions located very close to major active fault lines</td>
</tr>
</tbody>
</table>

## Seismic use groups

<table>
<thead>
<tr>
<th>Seismic use group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Structures not assigned to Group II and III, representing as lesser life hazard only insofar as there is probability of fewer occupants in the structure and the structure are lower and/or smaller.</td>
</tr>
<tr>
<td>II</td>
<td>Structures having a large number of occupants or where the occupants’ ability to exit is restricted.</td>
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<tr>
<td>III</td>
<td>Essential facilities, e.g. Hospitals, Emergency Repose Facilities, required for post-earthquake recovery.</td>
</tr>
</tbody>
</table>

Agenda

US code overview

Seismic design methodology

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Conclusions
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• The present methods for seismic qualification of anchor systems in the U.S. are generally simple, however they are developing and evolving.

• Wherever possible, the design of connections involving discrete anchors should strive to protect the anchor against premature and sudden failure.

• Codes in the U.S. have up until recently focused on the loading side of the anchoring connection.

• The design of anchors for earthquake forces requires attention to detailing and consideration of stiffness (load path) and displacement demand as well as strength.

• There is no substitution for sound engineering judgment when designing and detailing for seismic applications