1. Limit states, design situations, values for loads (actions), load factors and load combinations for ordinal structures

<table>
<tr><th></th><th>Eurocode EN 1990</th><th>ASCE Standard 7-10</th><th>CSA</th><th>Australian code</th></tr>
<tr><td>Limit state</td><td>■ Ultimate limit state (ULS)
■ Serviceability limit state (SLS)</td><td rowspan="2">■ Strength limit state
■ Serviceability limit state</td><td rowspan="2">■ Ultimate limit state (ULS)
■ Fatigue limit state (FLS)
■ Serviceability limit state (SLS)</td><td rowspan="2"></td></tr>
<tr><td>Design situation</td><td>■ Persistent situation
■ Transient situation
■ Accidental situation
■ Seismic design situations</td></tr>
<tr><td>Classification of actions (loads)</td><td>■ Permanent action, G
■ Variable action, Q
■ Accidental action, A</td><td>■ Permanent load
■ Variable load</td><td>■ Permanent load, G
■ Variable load, Q
■ Rare loads, E</td><td>■ Permanent action
■ Imposed action
■ Wind, snow and ice & earthquake action</td></tr>
<tr><td>Values of actions (loads)</td><td>■ <u>For permanent action</u>
- Characteristic value, G_k
■ <u>For variable action</u>
- Characteristic value, Q_k
- Combination value, $\psi_0 Q_k$
- Frequent value, $\psi_1 Q_k$
- Quasi-permanent value, $\psi_2 Q_k$
■ <u>For accidental action</u>
- Characteristic value, A_k</td><td>■ Nominal load, Q_n</td><td>■ Specified loads
- <u>For permanent load</u>
the mean value
- <u>For variable action</u>
$R \geq$50 years (or $P_{AE} \leq 0.02$)
- <u>For rare load</u>
$R \approx$2500 years (or $P_{AE} \approx 0.0004$)
R : return period
P_{AE} : annual exceedance probability</td><td>■ Design events for safety
<table><tr><th rowspan="2">Importance Level</th><th colspan="3">Annual probability of exceedance</th></tr><tr><th>Wind</th><th>Snow</th><th>Earth-quake</th></tr><tr><td></td><td>Non-cyclonic / Cyclonic</td><td></td><td></td></tr><tr><td>1</td><td>1:100 / 1:200</td><td>1:100</td><td>1:250</td></tr><tr><td>2</td><td>1:500 / 1:500</td><td>1:150</td><td>1:500</td></tr><tr><td>3</td><td>1:1000 / 1:1000</td><td>1:200</td><td>1:1000</td></tr><tr><td>4</td><td>1:2000 / 1:2000</td><td>1:250</td><td>1:1500</td></tr></table></td></tr>
<tr><td>Partial factors for actions (load factors)</td><td>■ Partial factors for actions, γ_f</td><td>■ Load factor, γ</td><td>■ Load factor, α</td><td>■ None</td></tr>
<tr><td>Design value of action (factored load)</td><td>■ Design value ($F_d = \gamma_f F_r$)</td><td>■ Factored load, γQ_n</td><td>■ Factored load</td><td>■ Design value of action</td></tr>
<tr><td>Combination of actions (load combinations)</td><td>■ For example
Varied by limit state and design situation
(for example)
$\sum_{j\geq 1} \gamma_{G,j} G_{k,j} + \gamma_P P + \gamma_{Q,1} Q_{k,1} + \sum_{i>1} \gamma_{Q,i} \psi_{0,i} G_{k,i}$</td><td>■ Load Combination
$\sum_i \gamma_i (Q_n)_i$</td><td>■ Basic Combination
$\sum \alpha_{G_i} G_i + \alpha_{Q_j} Q_j + \sum_{k\neq j} \alpha_{C_{jk}} Q_k$
■ Rare Load Combination
$\sum G_i + E + \sum_{k\neq j} \alpha_{C_{Ek}} Q_k$
α_{Q_j} : Principal load factor
$\alpha_{C_{jk}}$: Companion load factor</td><td></td></tr>
</table>

2. Target reliability for ordinal structures

<table>
<tr><th></th><th>Eurocode EN 1990</th><th>ASCE Standard 7-10</th><th>CSA</th><th>Australian code</th></tr>
<tr><td>Target Reliability</td><td>■ Minimum values for reliability index β (ULS)
<table><tr><th rowspan="2">Reliability Class</th><th colspan="2">reference periods</th></tr><tr><th>1 year</th><th>50 years</th></tr><tr><td>RC3</td><td>5.2</td><td>4.3</td></tr><tr><td>RC2</td><td>4.7</td><td>3.8</td></tr><tr><td>RC1</td><td>4.2</td><td>3.3</td></tr></table>■ Target reliability index β for Class RC2 structural members
<table><tr><th rowspan="2">Limit state</th><th colspan="2">reference periods</th></tr><tr><th>1 year</th><th>50 years</th></tr><tr><td>USL</td><td>4.7</td><td>3.8</td></tr><tr><td>Fatigue</td><td></td><td>1.5-3.8</td></tr><tr><td>SLS (irreversible)</td><td>2.9</td><td>1.5</td></tr></table></td><td>■ Acceptable reliability (maximum annual probability of failure) associated reliability indexes for load conditions that do not include earthquake
<table><tr><th rowspan="2">Basis</th><th colspan="4">Risk Category</th></tr><tr><th>I</th><th>II</th><th>III</th><th>IV</th></tr><tr><td>b1</td><td>2.5</td><td>3.0</td><td>3.25</td><td>3.5</td></tr><tr><td>b2</td><td>3.0</td><td>3.5</td><td>3.75</td><td>4.0</td></tr><tr><td>b3</td><td>3.5</td><td>4.0</td><td>4.25</td><td>4.5</td></tr></table>- b1: failure that is not sudden and does not lead to widespread progression of damage
- b2: failure that is either sudden or leads to widespread progression of damage
- b3: failure that is sudden and results in widespread progression of damage

■ anticipated reliability (maximum probability of failure) for earthquake
<table><tr><th></th><th colspan="3">Risk Category</th></tr><tr><th></th><th>I & II</th><th>III</th><th>IV</th></tr><tr><td>f1</td><td>10%</td><td>6%</td><td>3%</td></tr><tr><td>f2</td><td>25%</td><td>15%</td><td>10%</td></tr></table>- f1: total or partial structural collapse
- f2: failure that could result in endangerment of individual lives</td><td>■ CAN/CSA-S6-06 : β = 3.50
- for bridges with a 75-year design life

■ Bartlett et al. (2003) : β ≥ 3.0
- normal building components with a 50-year design life for ductile failures

■ CSA(1981)
- steel and concrete buildings for ULS based on 30-year life
<table><tr><th rowspan="2">Safety Class</th><th colspan="2">Type of Failure</th></tr><tr><th>Gradual</th><th>Sudden</th></tr><tr><td>Not serious</td><td>2.5</td><td>3.0</td></tr><tr><td>Serious (normal buildings)</td><td>3.5</td><td>4.0</td></tr><tr><td>Very serious</td><td>4.0</td><td>4.5</td></tr></table>■ CSA S408-81 : β=3.5
for brittle failures with a ??-year design life

■ Bartlett (2007) : β=4.0
for brittle failure of concrete element with a ??-year design life

■ CISC 2010 : β=4.5
for fracture of steel on net section with a ??-year design life</td><td>■ Annual structural reliability indices (β) for structural components and connections
<table><tr><th>Importance Level</th><th>Permanent & imposed actions</th><th>Wind, earthquake & snow actions</th></tr><tr><td>1</td><td rowspan="4">3.8</td><td>3.2</td></tr><tr><td>2</td><td>3.4</td></tr><tr><td>3</td><td>3.6</td></tr><tr><td>4</td><td>3.8</td></tr></table></td></tr>
<tr><td>Factor for importance of structure (reliability modification)</td><td>■ K_{FI} factor for actions,
<table><tr><th></th><th colspan="3">Reliability Class</th></tr><tr><th></th><th>RC1</th><th>RC2</th><th>RC3</th></tr><tr><td>K_{FI}</td><td>0.9</td><td>1.0</td><td>1.1</td></tr></table></td><td>■ load modifier, η_i
a factor relating to ductility, redundancy, and operational importance</td><td>■ Importance factor, I</td><td></td></tr>
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