Implementation of Eurocodes – a regulatory perspective...

Er K Thanabal,
Director,
Building and Construction Authority
6 Aug 2014
Déjà Vu

What if you could change the past?
scope

- Eurocode implementation in S’pore...
- Links between Eurocodes...
- Product Standards, Accreditation/Certification...
- Lateral Actions...
- Brief overview of EC8 application in S’pore...
- Ongoing Initiatives...
- Concluding remarks...
Eurocode implementation in S’pore...
Building Standards in Singapore made known to industry in 2006

In the UK, BS EN versions of Eurocodes for the design of civil and structural engineering works are progressively being developed and are expected to be ready next year. After a transitional period of 3 years when British Standards and BS EN versions of Eurocodes co-exist, the British Standards will be withdrawn by year 2010. In fact, the BS EN version of Eurocode 2 ‘Design of Concrete Structures’ has been completed and BSI has announced recently that it will no longer support BS 8110 ‘Structural Use of Concrete’ Parts 1, 2 and 3 after March 2008. More details about implementation of Eurocodes in the UK is available at Eurocodes’ Web Site which is at: http://www.eurocodes.co.uk.

Many of our technical regulations and standards on civil and structural engineering works are linked to the British Standards. The Building and Construction Standards Committee of SPRING Singapore had consulted the industry and informed BCA of its recommendation that Singapore should align our civil and structural design practices with the Eurocodes. BCA has agreed to adopt the BS EN version of the Eurocodes and plans to specify them in the Approved Documents of the Building Control Regulations after the corresponding British Standards are withdrawn.

BCA and SPRING have jointly formed Technical Committees comprising representatives from professional organizations, practitioners, academia, statutory bodies to study the BS EN versions of Eurocodes and review the corresponding UK National Annexes to see if appropriate modifications need to be made for our use.

We are also making arrangements to prepare our industry and stakeholders for the forthcoming changeover to Eurocodes. BCA and SPRING will progressively arrange talks, seminars or workshops in Singapore. One of such seminars is on BS EN 1992 (Eurocode 2 ‘Geotechnical Design’) which will be held on 2 and 3 Nov 2006. Details of the seminar are in the attached brochure. We will inform the industry of other seminars and workshops when they are finalized.

If you need further clarification, you can contact me or my Senior Manager, Dr. Yang Kin Seng at Tel: 63257571 or e-mail: yang_kin_seng@bca.gov.sg.

Thank you.

Yours faithfully,

[Signature]

ONE SEE HO
COMMISSIONER OF BUILDING CONTROL
DIRECTOR, BUILDING ENGINEERING DIVISION
BUILDING AND CONSTRUCTION AUTHORITY
the Eurocodes ... is it here yet?
Eurocode is here...

Building and Construction Authority

25 Mar 2013

Dear Stakeholder,

IMPLEMENTATION OF STRUCTURAL EUCRODES IN SINGAPORE

Objectives

The current informs the industry that:

(a) Structural Eurocodes will be accredited from 1 April 2013, and co-exist for two years with the current Singapore/British Standards and

(b) Structural Eurocodes will be the only prescribed structural design standards from 1 Apr 2015.

Structural Eurocodes to be implemented on 1 Apr 2013

1. On 28 Sep 2012, we issued a Circular indicating the tentative timeline on the implementation of structural Eurocodes in Singapore. This proposed timeline was subsequently deferred to allow time for the completion of all the Singapore National Annex to the Eurocodes. With the recent completion of the last Singapore National Annex, we are ready to implement Eurocodes for structural design.

2. Singapore's version of the Eurocodes is denoted as 'SS EN' and the corresponding National Annexes denoted as 'NA to SS EN'. As of 1 Apr 2013, the SS EN shall be adhered to for all new projects and new licences shall be held in Singapore and shown in Singapore.

3. Structural Eurocodes will be implemented on 1 Apr 2013. There will be a two-year co-existence period when the current Singapore/British Standards (SB) and the SS EN are accepted for structural plans submission. However, among the use of SS EN with the current SB/BS for the same building will not be accepted, i.e., the same standards shall be used throughout the building design.

4. SS EN as the only prescribed structural design standards after 1 Apr 2015

5. At the end of the two-year co-existence period on 1 Apr 2015, the SS EN will be introduced to the Approved Document. Therefore, the SS EN will be the only prescribed design standards from 1 Apr 2015. The list of SS EN and the corresponding Singapore/British Standards to be withdrawn from the Approved Document is in Annex C. A comparative list of Singapore/British Standards and the equivalent SS EN that replaces them is in Annex D.

Industry training and briefings

6. To prepare the industry for migration to the structural Eurocodes, the BCA Academy and other organisations such as SPREDA, professional associations, and our local universities have been organising training courses and workshops since 2009. These organisations will continue to offer more training courses and workshops to help the local industry practitioners to attain such training courses and seminars to familiarise themselves with the new structural Eurocodes.

7. BCA will also commence briefing seminars to the industry on the regulatory requirements in relation to the adoption of the Eurocodes. The active industry practitioners, especially professional engineers, to attend our briefing seminars to better understand the regulatory requirement if they plan to start adopting SS EN in their structural design.

8. I would appreciate if you could bring the contents of this circular to the attention of your members. Please contact BCA at 5849 6515 or email: ang.lee@bcasg.a.gov.sg if you need further clarification.

Thank you.

Yours faithfully,

K.T. TAMARAJ
Chief Executive, Engineering Directorate Group
Commissioner of Building Control

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1. Details of the training courses and workshops organized by BCA Academy can be obtained at the following site:

   http://www.buildingcontrol.gov.sg/education/training_courses.html

2. Participating professional organisations are the Association of Consulting Engineers Singapore, the Institution of Engineers and the Singapore Institution of Architects.
Eurocode is here...

- Design based on the structural Eurocodes accepted from 1 Apr 2013 onwards...

Building and Construction Authority

We shape a safe, high quality, sustainable and friendly built environment.

Our Ref: BCA BC 15.0.3

25 Mar 2013

See Distribution

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2 On 26 Sep 2011, we issued a circular indicating the tentative timeline on the implementation of structural Eurocodes in Singapore. This proposed timeline was subsequently deferred to allow time for the completion of all the Singapore’s National Annexes to the Eurocodes. With the recent completion of the last Singapore’s National Annex, we are ready to implement Eurocodes for structural design.

3 Singapore’s version of the Eurocodes is denoted as “SS EN”, and the corresponding National Annexes denoted as “NA to SS EN”. All SS EN design standards shall be used with the corresponding NA to SS EN. The number of Parts in SS EN and NA to SS EN applicable in Singapore are shown in Annex A.

4 Structural Eurocodes will be implemented on 1 Apr 2013. There will be a two-year co-existence period when the current Singapore Standards/British Standards (SS/BS) and the SS ENS are accepted for structural plans submissions. However, mixing the use of SS EN with the current SS/BS for the same building will not be accepted, i.e., the same standard shall be used throughout the building design.
Eurocode is here...

- **Structural Eurocodes** will be mandatory wef 1 Apr 2015

projects with ST01 submission from 1 Apr 2015 onwards will have to be Eurocodes...

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Eurocode is here to stay…

2 yrs co-existence period

1 Apr 2013
SS/BS

1 Apr 2015
SS/BS EC EC
### Structural Design

The design of the building structures shall comply with the following Standards –

<table>
<thead>
<tr>
<th>Type of structures</th>
<th>When adopting Singapore or British design standards</th>
<th>When adopting Eurocodes</th>
</tr>
</thead>
</table>
Co-existence period...

the same standard shall be used through the building design.

no mixing of standards
### Overview of the Eurocodes...NAs applicable...

<table>
<thead>
<tr>
<th>code Ref</th>
<th>title</th>
<th>no. of parts</th>
<th>no. of NA to SS EN</th>
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<tbody>
<tr>
<td>SS EN 1990</td>
<td>Basis of structural design</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SS EN 1991</td>
<td>Actions of structure</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>SS EN 1992</td>
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<td>4</td>
<td>4</td>
</tr>
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<td>14</td>
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<tr>
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<td>1</td>
</tr>
<tr>
<td>SS EN 1999</td>
<td>Design of <strong>aluminium structures</strong></td>
<td>*</td>
<td>*</td>
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<td></td>
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**SS EN 1998 – only part 1 applicable...**
## Overview of the Eurocodes... NAs applicable...

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**masonry, aluminium - BS EN versions**
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* timber – SPRING WG formed…*
links between Eurocodes...
### 3 key pillars of Eurocodes...

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<th>Execution Standards</th>
<th>Product Standards</th>
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<td>• Construction, workmanship and quality control</td>
<td>• Specifications for construction products, materials and testing</td>
</tr>
</tbody>
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**Eurocodes**
- design
- execution
- product
3 key pillars of Eurocodes...

Structural Eurocodes
- Structural design

Execution Standards
- Construction, workmanship and quality control

Product Standards
- Specifications for construction products, materials and testing

Eurocode: Basis of Design
Eurocode 1: Actions on Structures
Eurocode 2: Design of Concrete Structures
Eurocode 3: Design of Steel Structures
Eurocode 4: Design of Composite Steel and Concrete Structures
Eurocode 5: Design of Timber Structures
Eurocode 6: Design of Masonry Structures
Eurocode 7: Geotechnical Design
Eurocode 8: Design Provisions for Earthquake Resistance of Structures
Eurocode 9: Design of Aluminium Structures
3 key pillars of Eurocodes...

- **Structural Eurocodes**
  - Structural design

- **Execution Standards**
  - Construction, workmanship and quality control

- **Product Standards**
  - Specifications for construction products, materials and testing

---

**EN 1090 - Execution of steel structures and aluminium structures**

**EN 13670 - Execution of concrete structures**

**EN 1536 - Execution of special geotechnical work: Bored piles**

**EN 1537 - Execution of special geotechnical work: Ground anchors**
3 key pillars of Eurocodes...

- **Structural Eurocodes**
  - Structural design

- **Execution Standards**
  - Construction, workmanship and quality control

- **Product Standards**
  - Specifications for construction products, materials and testing

EN 206 Concrete
EN 13369 Pre-cast Concrete Products
EN 10025 Hot-rolled Structural Steel Products
EN 10080 Steel for Reinforcement
Eurocode design standards...

- **EN 1990**
  - Structural safety, serviceability and durability
- **EN 1991**
  - Actions on structures
- **Concrete**
  - EN 1992
  - EN 1995
- **Structural Steel**
  - EN 1993
  - EN 1996
- **Composite**
  - EN 1994
  - EN 1999
- **EN 1997**
  - Geotechnical
- **EN 1998**
  - Seismic
  - Geotechnical and Seismic design
Eurocode journey...
no resting on laurels...
the Eurocodes … is it here yet?

Development of NAs

Product Standards/Accreditation

Circular issued on EC implementation

2006

2007

2013

2015 (D Day)
Since 2006, numerous SPRING WGs have reviewed the Eurocodes & UK National Annexes. Appropriate modifications made to UK National Annexes to suit Singapore’s conditions.

with the development of our NAs...
Since 2006, numerous SPRING WGs have reviewed the Eurocodes & UK National Annexes. Appropriate modifications made to UK National Annexes to suit Singapore’s conditions. with the development of our NAs...
Product Standards...
structural steel
adoption of product standards work started way back in 2007…

based on EC – Product Conformity/CE mark

FPC system…
BC1, what on earth is that ???
BC1: 2012 version...
BC1: 2012 version...

BS 5950 and EC3

Handbook with explanatory notes
BC1: 2012 version...

- update with new devpts in material standards since 2007
- include new categories of materials (bars & rods, sheet piles)
BC1: 2012 version... include quality assurance reqts for “re-used” struts and sheetpiles used in bracing of excavations.
strut /sheetpile suppliers to ensure proper in-house inspection and testing plans in place to ensure traceability and re-usability of steel sections

material traceability

3rd party independent audits by Inspection Bodies

material re-usability
with these quality assurance system in place, these scenes should never ever been seen here...
inferior material used
inferior material used
deformed and corroded
deformed struts and walers
deformed horizontal strut
strut and sheetpile suppliers with quality assurance system in place...
large sheltered fabrication work shops

quality control visibly in place
spacious yards with proper demarcations
State-of-the-art equipment

in-house QA scheme already in place
room for improvement...
not a silver bullet...
BC1: 2012 version…
design guide covers BS 5950 as well as EC3 and a handbook that provides detailed explanatory notes for BC1

FREE DOWNLOAD
Product Standards...

structural concrete
Saving Gaia - Green concrete

mining of natural aggregates...

environmental degradation...
Eurocode provides a code based approach to encourage wider usage of green concrete...
Dear Sir/Madam,

SS EN 12620 AGGREGATES FOR CONCRETE – A NEW APPROACH TO SPECIFYING AGGREGATES

SS EN 12620 encourages the industry to adopt sustainable practices through a needle-guided approach that covers many other key aspects of the specification, such as sustainability, environmental impact, and the use of recycled materials. The standard is designed to help the industry achieve its objectives through the use of specified, high-quality natural or manufactured aggregates.

1. SS EN 12620 covers the use of aggregates from natural and manufactured sources, including recycled aggregates. A mixture of these aggregates is a step forward in the construction of the current standard, which is a specification for aggregates from natural sources only.

2. SS EN 12620 will be incorporated into the Approved Documents with effect from 12 June 2008. However, in order to allow the industry time to phase in the new standard, SS EN 1300 will continue with SS EN 1300 during the transition period from 12 June 2008.

3. The new EN 12620 standard is available from Beta Singapore, while the new standard also includes a Guidebook on the use of recycled material. This guidebook is available from the Building Engineering Society at the following link: www.bes.org.uk/standard-aggregates-p-1p3-aggregates-

4. A revised Guidebook on the use of recycled material can be obtained from the Building Engineering Society. The guidebook includes a comprehensive list of recycled materials and offers guidance on their use in concrete. Additionally, it includes information on the recycling and disposal of concrete aggregates for use as course aggregate in concrete.

5. The new standard is available from Beta Singapore, while the new standard also includes a Guidebook on the use of recycled materials. This guidebook is available from the Building Engineering Society at the following link: www.bes.org.uk/standard-aggregates-p-1p3-aggregates-

Thank you.

Yours faithfully,

[Signature]

[Name]

DEPUTY DIRECTOR, BUILDING ENGINEERING DIVISION
COMMISSIONER OF BUILDING REGULATORY
Saving Gaia - Green concrete

current code SS 31 permits aggregates from natural sources only...

SS EN 12620 is a step forward...
SS EN 12620 permits aggregates from natural, recycled and manufactured sources...
Saving Gaia - Green concrete recycling, substitutions ...

- cement replacements (GGBS, fly-ash, silica fume)
- recycled concrete aggregates from demolition waste
- sand replacements (washed copper slag, quarry dust)
green cements…

SS EN 206-1 has wider choice of blended green cements…

by-products from other industries (GGBS, fly-ash…) ➔ material that otherwise end up in landfills…

CEM I (OPC)
**Saving Gaia - Green cements**

**blended green cements to SS EN 206-1**

<table>
<thead>
<tr>
<th>CEM</th>
<th>Addition</th>
<th>Portland cement replacement, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>~</td>
<td>0 – 5</td>
</tr>
<tr>
<td>IIA</td>
<td>Silica fume</td>
<td>6 – 10</td>
</tr>
<tr>
<td></td>
<td>Fly ash</td>
<td>6 – 20</td>
</tr>
<tr>
<td>IIB-V</td>
<td>Fly ash</td>
<td>21 – 35</td>
</tr>
<tr>
<td>IVB-V</td>
<td></td>
<td>36 – 55</td>
</tr>
<tr>
<td>IIB-S</td>
<td></td>
<td>21 – 35</td>
</tr>
<tr>
<td>IIIA</td>
<td>GGBS</td>
<td>36 – 65</td>
</tr>
<tr>
<td>IIIIB</td>
<td></td>
<td>66 – 80</td>
</tr>
</tbody>
</table>
Saving Gaia - Green concrete

Concrete cubes of 100mm x 100mm can be used instead of 150mm x 150mm.
SS EN 206-1 – “Concrete – Specification, performance, production and conformity”

Standard relating to the production of structural concrete

Third-party certification of Ready-Mixed Concrete (RMC) producers to ensure good quality concrete
SS EN 206-1 – “Concrete – Specification, performance, production and conformity”

SAC Certification Scheme for RMC to SS EN 206-1 developed and implemented
SS EN 206-1 – “Concrete – Specification, performance, production and conformity”

For major building projects, structural concrete to be obtained from RMCs certified under the SAC Certification Scheme
Concrete design strength

- design based on characteristic cylinder strength, $f_{ck}$ (MPa)
Concrete design strength

concrete class notation
characteristic cylinder strength / characteristic cube strength

e.g., C40/50

cube strength

cylinder strength
EN1992-1-1: Clause 3.1.1 (2)P

3.1.2 Strength

(2)P The strength classes in this code are based on the characteristic cylinder strength $f_{ck}$ determined at 28 days with a maximum value of $C_{\text{max}}$.

Note: The value of $C_{\text{max}}$ for use in a Country may be found in its National Annex. The recommended value is $C_90/105$. BS : 60

**C90/105**

maximum cube strength
Site Investigation (SI) practice
Accreditation of Site Investigation (SI) firms enhance quality and standards of SI practice here…
EC7 compliance…

basic competency framework for Licensed Specialist Builders (SI)

Oct 2012
Lateral Actions...
Wind actions...
Limitations in Wind Codes
limitations...EN 1991-1-4:2009

subject to dynamic response criteria...

excludes:
• cable supported bridges
• torsional and higher modes of vibration...
wind tunnel testing (WTT) recommended !!
REQUIREMENTS FOR WIND TUNNEL TEST FOR TALL, SLENDER AND COMPLEX BUILDINGS AND STRUCTURES

Building codes such as the British Standard 6659-2 (Code of Practice for Wind Loads) and Eurocode 1 EN 1991-1-4 (Seismic actions on structures - Wind actions) provide guidance on the wind forces to be considered in the design of buildings and structures. However, these codes have limitations in their applications as they only cover buildings and structures of certain geometry and dynamic characteristics but not those with highly complex shapes.

2. There are recently more tall and slender buildings and structures being built with complex and highly irregular shapes. When these buildings and structures contain very tall or with highly complex shapes, they fall within the provisions of the BS 6659-2 and EN 1991-4, wind tunnel tests are recommended to be carried out to determine the design wind forces.

3. Qualified persons (QPs) or structural engineers are provided at these code limitations and the need for wind tunnel tests when the provisions in the codes are not applicable. Wind conducting wind tunnel tests. QPs are to ensure that an appropriate and competent wind tunnel testing regime is selected so as to obtain a better understanding of the behavior of such complex buildings and structures under wind forces. Please refer to the attached data sheet on the criteria when selecting wind tunnel tests to be carried out.

* The shape and dynamic characteristics refer to the building's height, slenderness and its propensity to experience turbulent airflow and higher modes of vibration due to wind forces.
CRITERIA FOR WIND TUNNEL TESTS

CRITERIA FOR WIND TUNNEL TESTS

1. Wind tunnel tests are recommended for the design of buildings and structures when one or more of the following criteria are met:

   I. Highrise or slender structures
      - Height > 200m
      - Frequency < 0.2 Hz

   II. Lowrise buildings/structures with complex shape and form
      - Lowrise buildings/structures whose shape in plan or vertical cross section differs significantly from the shapes and forms in BS 6399 Part 2 (Code of Practice for Wind Loads) or those in Chapter 7 of SS EN 1991-1-4 (Eurocode 1: Actions on Structures, Part 1-4: General actions – Wind actions), whichever is applicable. QPs should seek specialist advice, where necessary, in such circumstances taking into account the size and extent of such structures to determine if wind tunnel testing is warranted.

Limitations on loads derived by the wind tunnel test methods

2. When wind tunnel tests are conducted on a specific building, the lateral wind actions determined for use in structural designs should not be less than 80% of those determined from codebased empirical approaches.

3. Compliance with the above does not in any way imply exemptions from other requirements that may be specified in the codes BS 6399-2 and SS EN 1991-1-4.
CRITERIA FOR WIND TUNNEL TESTS

CRITERIA FOR WIND TUNNEL TESTS

1. Wind tunnel tests are recommended for the design of buildings and structures when one or more of the following criteria are met:

   I. Highrise or slender buildings/structures susceptible to dynamic wind excitation
      Dynamic effects are difficult to anticipate as they are dependent on many factors, but could be significant when any of the following apply:
      • height of building or structure of more than 200m
      • building or structure with fundamental natural frequencies less than 0.2Hz

Lowrise with complex shape and form

complex or irregular roof structures which are not exhaustively covered by prescriptive wind codes

Limitations on loads derived by the wind tunnel test methods

2. When wind tunnel tests are conducted on a specific building, the lateral wind actions determined for use in structural designs should not be less than 80% of those determined from code-based empirical approaches.

3. Compliance with the above does not in any way imply exemptions from other requirements that may be specified in the codes BS 6399-2 and SS EN 1991-1-4.
Buildings taller than 200m

240m

240m

245m
Slender buildings

Building/structure with fundamental frequencies < 0.2Hz

1st mode

\[ f < 0.2\text{Hz} \text{ or } T > 5\text{s} \]

\[ T_1 = 5.04\text{s} \]

\[ T_1 = 8.78\text{s} \]
Complex/irregular roof shapes
CRITERIA FOR WIND TUNNEL TESTS

1. Wind tunnel tests are recommended for the design of buildings and structures when one or more of the following criteria are met:

I. Highrise or slender buildings/structures susceptible to dynamic wind excitation
   Dynamic effects are difficult to anticipate as they are dependent on many factors, but could be significant when any of the following apply:

   - Section differs significantly from the shapes and forms in BS 6399 Part

Limitation of loads derived from wind tunnel tests

lateral Wind Action from WTT for use in structural design ≤ 80% of those determined code-based empirical approaches

3. Compliance with the above does not in any way imply exemptions from other requirements that may be specified in the codes BS 6399-2 and SS EN 1991-1-4.
Geometric Imperfection Effects & Notional Load
Imperfections...

the real world is far from perfect !!!
Geometric imperfections (GI)

- generally ranges from 0.25%~0.5% of (DL + LL)
- considered in addition to Wind Loads

Lateral Actions...

GI effects considered for all load combinations in Eurocode and for all building types (rc, structural steel...)

Bracing System

\[ H_i = \theta_i (N_b - N_a) \]

Floor Diaphragm

\[ H_i = \theta_i (N_b + N_a)/2 \]

Roof

\[ H_i = \theta_i N_a \]
# Lateral Actions...

## Load combinations @ ULS (Concrete)

<table>
<thead>
<tr>
<th>BS 8110/CP65</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2DL + 1.2IL + 1.2WL (or NHL(^a))</td>
<td>1.35DL + 1.05IL + 1.5WL + GIE</td>
</tr>
<tr>
<td>1.4DL + 1.4WL (or NHL(^a))</td>
<td>1.35DL + 1.5IL + 0.75WL + GIE</td>
</tr>
<tr>
<td>1.0DL + 1.4WL (or NHL(^a))</td>
<td>1.0DL + 1.5WL + GIE</td>
</tr>
</tbody>
</table>

\(^a\) NHL = 1.5\%(unfactored DL)

GIE = geometric imperfection effects
### Lateral Actions...

**Load combinations @ ULS (Steel)**

<table>
<thead>
<tr>
<th>Structural Steel</th>
<th>BS5950</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$1.4DL + 1.6IL + NHL^b$</td>
<td>$1.35DL + 1.5IL + GIE$</td>
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<tr>
<td></td>
<td>$1.2DL + 1.2IL + 1.2WL$ (or NHL^c)</td>
<td>$1.35DL + 1.05IL + 1.5WL + GIE$</td>
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<tr>
<td></td>
<td></td>
<td>$1.35DL + 1.5IL + 0.75WL + GIE$</td>
</tr>
<tr>
<td></td>
<td>$1.4DL + 1.4WL$ (or NHL^c)</td>
<td></td>
</tr>
</tbody>
</table>

---

^b NHL = 0.5\%(\text{factored DL factored IL})

^c NHL = 1.0\%(\text{factored DL})

GIE = geometric imperfection effects
Wind load – NA to SS EN 1991-1-4

National Foreword

This National Annex was prepared by the Technical Committee of Building Structure and Substructure under the purview of the Building and Construction Standards Committee.


Acknowledgement is made to BSI for the use of information from their publication.

This Singapore NA contains information on those parameters which are left open in EN 1991-1-4 for national choice, known as nationally determined parameters. The Singapore NA is to be read in conjunction with the SS EN 1991-1-4 : 2009 – Eurocode 1: Actions on structures – Part 1-4; General actions – Wind actions. However, the terrain categories in EN 1991-1-4 are not applicable in Singapore.

For continuation of an established design philosophy, all buildings should be capable of resisting, as a minimum, a design ultimate horizontal load applied at each floor or roof level simultaneously equal to 1.5% of the characteristic dead weight of the structure between mid-height of the storey below and either mid-height of the storey above or the roof surface. The design ultimate wind load should not be taken as less than this value when considering load combinations.
all buildings... designed to resist 1.5% characteristic dead weight

design ultimate wind load not lesser than…
The effects of imperfection applied in all the load combinations is applicable for all buildings types (i.e. of concrete, structural steel or composite construction).

In load combinations where wind load is considered, the governing of the two, i.e. the larger of the $1.5\%$(unfactored DL) and ultimate wind load will be adopted in these combinations...

<table>
<thead>
<tr>
<th>Concrete</th>
<th>EC</th>
<th>1.35DL + 1.05IL + 1.5WL + GIE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>1.35DL + 1.5IL + 0.75WL + GIE</td>
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<tr>
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<td></td>
<td>1.35DL + 1.5WL + GIE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0DL + 1.5WL + GIE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structural Steel</th>
<th>EC</th>
<th>1.35DL + 1.5IL + GIE</th>
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<tbody>
<tr>
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<td>1.35DL + 1.5IL + 0.75WL + GIE</td>
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ultimate wind load ≤ 1.5\%(unfactored DL)
brief overview of Eurocode 8 application in Singapore
<table>
<thead>
<tr>
<th>EN Number</th>
<th>The Structural Eurocodes (58 parts)</th>
<th>Nº of Parts</th>
</tr>
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<tbody>
<tr>
<td>EN 1990</td>
<td>Eurocode: Basis of structural design</td>
<td>1</td>
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<tr>
<td>EN 1991</td>
<td><strong>Eurocode 1: Actions on structures</strong></td>
<td><strong>10</strong></td>
</tr>
<tr>
<td>EN 1992</td>
<td>Eurocode 2: Design of concrete structures</td>
<td>4</td>
</tr>
<tr>
<td>EN 1993</td>
<td>Eurocode 3: Design of steel structures</td>
<td>20</td>
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<tr>
<td>EN 1994</td>
<td>Eurocode 4: Design of composite steel and concrete structures</td>
<td>3</td>
</tr>
<tr>
<td>EN 1995</td>
<td>Eurocode 5: Design of timber structures</td>
<td>3</td>
</tr>
<tr>
<td>EN 1996</td>
<td>Eurocode 6: Design of masonry structures</td>
<td>5</td>
</tr>
<tr>
<td>EN 1997</td>
<td>Eurocode 7: Geotechnical design</td>
<td>3</td>
</tr>
<tr>
<td>EN 1998</td>
<td><strong>Eurocode 8: Design of structures for earthquake resistance</strong></td>
<td><strong>6</strong></td>
</tr>
<tr>
<td>EN 1999</td>
<td>Eurocode 9: Design of aluminium structures</td>
<td>3</td>
</tr>
<tr>
<td><strong>Eurocode 8 – Design of structures for earthquake resistance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Part 1</strong>: General rules, seismic actions and rules for buildings</td>
<td>EN 1998-1</td>
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<tr>
<td><strong>Part 2</strong>: Bridges</td>
<td>EN 1998-2</td>
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<tr>
<td><strong>Part 3</strong>: Strengthening and repair of buildings</td>
<td>EN 1998-3</td>
<td></td>
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<tr>
<td><strong>Part 4</strong>: Silos, tanks and pipelines</td>
<td>EN 1998-4</td>
<td></td>
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<tr>
<td><strong>Part 5</strong>: Foundations, retaining structures and geotechnical aspects</td>
<td>EN 1998-5</td>
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<tr>
<td><strong>Part 6</strong>: Towers, masts and chimneys</td>
<td>EN 1998-6</td>
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<tr>
<td>Eurocode 8 – Design of structures for earthquake resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**only Part 1 of EN 1998 applicable in Singapore**

*(DCL design and detailing)*
Seismic Design Requirements for S’pore

- applicable to **new** high-rise bldgs (>20m) on prescribed ground type classes (classified methodology by EC8 which is site-specific)

- also applicable to high-rise bldgs (>20m) undergoing **very major A&A** on prescribed ground type classes.
• not applicable for bridges, underground structures and tunnels

• consideration for liquefaction – not needed
Seismic Design Requirements

Building height, $H > 20$ metres?

- Y: Seismic Action need not be considered in design
- N: Ground Type within building footprint determined according to Clause 2.

Ground Type within building footprint determined according to Clause 2.

- Ordinary building on Ground Type Class “D” or “S”?
- Special building on Ground Type Class “C”, “D” or “S”?

- Y: Seismic Action need not be considered in design
- N: Seismic Action determined according to Clause 3 and Clause 4 using where appropriate, either
  - Lateral Force Analysis Method according to Clause 4.4 or
  - Modal Response Spectrum Analysis Method according to Clause 4.5.

Seismic Action determined according to Clause 3 and Clause 4 using where appropriate, either
- Lateral Force Analysis Method according to Clause 4.4 or
- Modal Response Spectrum Analysis Method according to Clause 4.5.

Building analysed according to combination of actions in Clause 5 and foundation design carried out according to Clause 6

- Drift limitation check according to Clause 7 and
- Minimum structural separation check according to Cause 8

Flowchart from BC3: 2013
Seismic Design Requirements

Building height, \( H \) determined according to **Clause 2**.

- Building height, \( H > 20 \text{ metres} \)?
  - **Y**: Seismic Action need not be considered in design
  - **N**: Ground Type within building footprint determined according to **Clause 2**.

Ground Type within building footprint determined according to **Clause 2**.

- Ordinary building on Ground Type Class “D” or “S_1”? or
- Special building on Ground Type Class “C”, “D” or “S_1”?
  - **Y**: Seismic Action need not be considered in design
  - **N**: Seismic Action determined according to **Clause 3** and **Clause 4** using where appropriate, either
    - Lateral Force Analysis Method according to **Clause 4.4** or
    - Modal Response Spectrum Analysis Method according to **Clause 4.5**.

Seismic Action determined according to **Clause 3** and **Clause 4** using where appropriate, either
- Lateral Force Analysis Method according to **Clause 4.4** or
- Modal Response Spectrum Analysis Method according to **Clause 4.5**.

Building analysed according to combination of actions in **Clause 5** and foundation design carried out according to **Clause 6**.

- Drift limitation check according to **Clause 7** and
- Minimum structural separation check according to **Cause 8**

**Flowchart from BC3: 2013**
Seismic Design Requirements

Building height, $H > 20$ metres?

- Y: Seismic Action need not be considered in design
- N: Ground Type within building footprint determined according to Clause 2.

Ground Type within building footprint determined according to Clause 2.

- Ordinary building on Ground Type Class “D” or “$S_1$”? or
- Special building on Ground Type Class “C”, “D” or “$S_1$”?

- Y: Seismic Action need not be considered in design
- N: Building analysed according to combination of actions in Clause 5 and foundation design carried out according to Clause 6

“Ordinary bldgs” on Ground Types “D” and “$S_1$” or “Special bldgs” on Ground Types “C”, “D” and “$S_1$”

- Drift limitation check according to Clause 7 and
- Minimum structural separation check according to Cause 8

Flowchart from BC3: 2013
Seismic Design Requirements

Building height, $H > 20$ metres?

- **Y**
  - Seismic Action need not be considered in design

- **N**
  - Ground Type within building footprint determined according to Clause 2.
    - Ordinary building on Ground Type Class “D” or “$S_1$”? or
    - Special building on Ground Type Class “C”, “D” or “$S_1$”? 
      - **Y**
        - Seismic Action need not be considered in design
      - **N**
        - Building analysed according to combination of actions in Clause 5 and foundation design carried out according to Clause 6

“Ordinary **bldgs**” on Ground Types “D” and “$S_1$” or
“Special **bldgs**” on Ground Types “C”, “D” and “$S_1$”

*hospitals, fire stations, civil defence installations, Govt Ministry offices and institutional blds*
EC8 considerations applicable only when submissions done in Eurocodes...
BC3 and worked example can be downloaded from BCA’s web-page…
BC3:

worked example:
ongoing initiatives...
steel rebars
Characteristic yield strength - rebars

**SS CP 65**
Reinforcement $\gamma_m = 1.15$

$f_y = 460 \, \text{N/mm}^2$

**EN 1992-1-1**
Reinforcement $\gamma_s = 1.15$

$f_{yk} = 500 \, \text{N/mm}^2$

---

**Table 3.1**
(Note 1)

---

**EC2 Table 2.1N**

**BS4449 Table 4**
Reinforcement $g = 1.15$

Characteristic yield strength - rebars

$\sigma_{yk} = 500 \text{ N/mm}^2$

EN 1992-1-1

Reinforcement $= 1.15$

EC2 Table 2.1N

BS4449 Table 4

EN 10080
Specifying reinforcement

BS 4449
Specifying Reinforcement

EN 1992
Design of concrete structures
cast steel components
failed connector
key structural qualities: strength, ductility, toughness, weldability and machineability
SCOSS note highlights key aspects to be considered in design, procurement, supervision/testing and quality of end product to avoid “unintended consequences”
• casting may be subjected to internal flaws and appropriate non-destructive examination regime should be specified.

• specimens need to be taken for chemical and strength analysis.
similar concerns on cast steel components...
more of such cast steel applications in future...
Provision in EC3 - cast steel product standards

- **BS EN 10293** (Steel Castings for General Engineering Uses)
- **BS EN 10340** (Steel Castings for Structural Uses)
- **BS EN 1559** - Founding Technical conditions of delivery Part 2: Additional requirements for steel castings
Provision in EC3
- cast steel inspection specifications

- **BS EN 1369** (Founding - magnetic particle testing)
- **BS EN 12680** (Founding - ultrasonic examination)
- **BS EN 12681** (Founding - radiographic examination)
(i) Structural steel

| Specification for weldable structural steels. Hot finished structural hollow sections in weather resistant steels – BS 7668; (ii) Hot rolled products of structural steels – BS EN 10025; (iii) Hot finished structural hollow sections of non-alloy and fine grain steels – BS EN 10210; (iv) Cold formed welded structural hollow sections of non-alloy and fine grain steels – BS EN 10219; (v) Stainless steels - BS EN 10088; and (vi) Design Guide on Use of Alternative Structural Steel Materials to BS 5950 and Eurocode 3 – BC 1. |

(vii) Steel Casting for General Engineering Uses – BS EN 10239
(viii) Steel Casting for Structural Uses – BS EN 10340
(ix) Founding – Technical condition of delivery – BS EN 1559:1 and 2
(x) Founding – Ultrasonic examination – BS EN 12680:1 to 2
(xi) Founding – Radiographic examination – BS EN 12681:2003
(xii) Founding – Magnetic particle testing – BS EN 1369:2012

New reqts to be added

Extg reqts
(vii) Steel Casting for General Engineering Uses – BS EN 10239
(viii) Steel Casting for Structural Uses – BS EN 10340
(ix) Founding – Technical condition of delivery – BS EN 1559:1 and 2
(x) Founding – Utrasonic examination – BS EN 12680:1 to 2
(xi) Founding – Radiographic examination – BS EN 12681:2003
(xii) Founding – Magnetic particle testing – BS EN 1369:2012

Approved Document…akan datang…

Structural Steel…

(i) Structural steel

(i) Specification for weldable structural steels. Hot finished structural hollow sections in weather resistant steels. EN 7668;
(ii) Hot rolled products of structural steels. EN 10025;
(iii) Hot finished structural steel with fine grain structures (micro-alloyed steels). EN 10028-3;
(iv) Hot rolled plates of non-alloy and细 grain structural steels. EN 10028-4 and EN 10028-5;
(v) Cold formed sections of non-alloy and fine grain structural steels. EN 10219;
(vi) Cold finished tubes of non-alloy and fine grain structural steels. EN 10217-7.

new reqts to be added

with necessary Factory Production Controls…

complying with these Standards... and
Execution Standard
– Steel Structures
EN 1090, Execution Standard for Steel Structures has provisions for factory prodtn controls for steel fabricators and erectors with key reqts of
• welding quality management system and
• a responsible welding coordinator…
EN 1090, Execution Standard for Steel Structures

a SPRING Standards Workgroup is now looking at how we could adopt such reqts to improve the quality of our steelworks...
Eurocode steel and composite handy design spreadsheets...SSSS
concluding remarks...
D-Day’s almost here…

still not too late…let’s hasten our preparation…

Apr 1, 2015
Happy Birthday, Singapore!
We shape a safe, high quality, sustainable and friendly built environment.

Thank you