Eurocodes and the Egyptian construction industry

Introduction to Eurocodes: EC0 Basis of Structural Design and EC1 Actions on structures
by Jean-Armand Calgaro, Chairman of CEN/TC250

Organised with the support of the Egyptian Organization for Standardization and Quality
EN 1990 – Eurocode: Basis of Structural Design

Ratification: 29-11-2001

Availability: 24-04-2002

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EN 1990: BASIS OF STRUCTURAL DESIGN

For the design of buildings and civil engineering works every Eurocode part from,

- EN 1991: Eurocode 1: Actions on Structures, and
- The design Eurocodes EN 1992 to EN 1999

has to be used together with EN 1990

EN 1990 provides the material independent information required for the design of buildings and civil engineering works for the Eurocodes suite.
EN 1990: BASIS OF STRUCTURAL DESIGN

EN 1990 : BASIS OF STRUCTURAL DESIGN: CONTENTS

Foreword
Section 1 : General
Section 2 : Requirements
Section 3 : Principles of limit states
Section 4 : Basic variables
Section 5 : Structural analysis and design assisted by testing
Section 6 : Verification by the partial factor method

Annex A(n);(N): Application for buildings (1); bridges (2)
Annex B (I): Management of structural reliability for construction works
Annex C (I): Basis for partial factor design and reliability analysis
Annex D (I): Design assisted by testing
Future Annexes

A2 (N) : Application for bridges
A3 (N) : Application for towers, masts and chimneys
A4 (N) : Application for silos and tanks
A5 (N) : Application for cranes and machinery

E1 (I ?) : Structural bearings
E2 (I ?) : Expansion joints
E3 (I ?) : Pedestrian parapets
E4 (I ?) : Vehicle parapets
E5 (I ?) : Ropes and cables
EN 1990 is based on the

- **limit state concept**

used in conjunction with the

- **partial factor method**
EN 1990: BASIS OF STRUCTURAL DESIGN

The limit state concept

Irreversible limit states
Maintenance
Serviceability limit state
Required level at the end of the intended working life

Structural value
Safety margin
Ultimate limit-state

Time

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Objectives of EN 1990

EN 1990 describes the *principles* and *requirements* for the

- Safety
- Serviceability
- Durability

of structures
The intended users of EN 1990 include

• Designers and Constructors
• Code drafting Committees
• Public Authorities, (e.g. to set safety criteria)
• Clients
EN 1990: BASIS OF STRUCTURAL DESIGN

SECTION 1 - GENERAL

• 1.1 Scope
• 1.2 Normative References
• 1.3 Assumptions
• 1.4 Distinction between Principles and Application rules
• 1.5 Definitions
• 1.6 Symbols
1.1 Scope

(1) EN 1990 establishes Principles and requirements for the safety, serviceability and durability of structures, describes the basis for their design and verification and gives guidelines for related aspects of structural reliability.

(2) EN 1990 is intended to be used in conjunction with EN 1991 to EN 1999 for the structural design of buildings and civil engineering works, including geotechnical aspects, structural fire design, situations involving earthquakes, execution and temporary structures. NOTE For the design of special construction works (e.g. nuclear installations, dams, etc.), other provisions than those in EN 1990 to EN 1999 might be necessary.

(3) EN 1990 is applicable for the design of structures where other materials or other actions outside the scope of EN 1991 to EN 1999 are involved.

(4) EN 1990 is applicable for the structural appraisal of existing construction, in developing the design of repairs and alterations or in assessing changes of use. NOTE Additional or amended provisions might be necessary where appropriate.
1.3 Assumptions
(1) Design which employs the Principles and Application Rules is deemed to meet the requirements provided the assumptions given in EN 1990 to EN 1999 are satisfied (see (2)).

(2) The general assumptions of EN 1990 are:
- the choice of the structural system and the design of the structure is made by appropriately qualified and experienced personnel;
- execution is carried out by personnel having the appropriate skill and experience;
- adequate supervision and quality control is provided in design offices and during execution of the work, i.e., factories, plants, and on site;
1.3 Assumptions (cont.)
- the construction materials and products are used as specified in EN 1990 or in EN 1991 to EN 1999 or in the relevant execution standards, or reference material or product specifications;
- the structure will be adequately maintained;
- the structure will be used in accordance with the design assumptions.

NOTE There may be cases when the above assumptions need to be supplemented.
EN 1990: BASIS OF STRUCTURAL DESIGN

1.4 Distinction between Principles and Application Rules

• The Principles (letter P) comprise:
  ▪ general statements and definitions for which there is no alternative, as well as
  ▪ requirements and analytical models for which no alternative is permitted unless specifically stated.

• It is permissible to use alternative design rules different from the application rules given in EN 1990, provided that it is shown that the alternative rules accord with the relevant principles and are at least equivalent with regard to resistance, serviceability and durability which would be achieved for the structure using Eurocodes.

NOTE If an alternative design rule is substituted for an application rule, the resulting design cannot be claimed to be wholly in accordance with EN 1990 although the design will remain in accordance with the Principles of EN 1990. When EN 1990 is used in respect of a property listed in an Annex Z of a product standard or an ETAG, the use of an alternative design rule may not be acceptable for CE marking.
THE REQUIREMENTS

• Basic requirements (safety; serviceability; robustness and fire)
• Reliability differentiation
• Design working life
• Durability
• Quality Assurance
EN 1990: BASIS OF STRUCTURAL DESIGN

Basic Requirements (Structural Reliability)

Safety

Durability

Serviceability

Robustness

Sustainable Use of Natural Resources

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in EN 1990 for the reliability of construction works include:

**Structural safety:** A structure shall be designed and executed in such a way that it will, during its intended life with appropriate degrees of reliability, and in an economic way sustain all actions likely to occur during execution and use. **Safety of people, the structure and contents.**

**Serviceability:** A structure shall be designed and executed in such a way that it will, during its intended life with appropriate degrees of reliability and in an economic way remain fit for the use for which it is required. **Functioning, comfort and appearance of the structure.**
The fundamental requirements in EN 1990 for the reliability of construction works include:

**Robustness:** A structure shall be designed and executed in such a way that it will not be damaged by events such as:

- Explosions
- Impact and
- Consequences of human errors

to an extent disproportionate to the original cause

*Note: The events to be taken into account are those agreed for an individual project with the client and the relevant authority*
Limiting potential damage from identified hazards

Basic Requirements of EN 1990: Eurocode: Basis of Structural Design give principles for limiting potential damage by a number of means including:

- avoiding, eliminating or reducing a hazard
- selecting a structural form which has a low sensitivity to the considered hazard
- using the most appropriate materials and products
- various design options similar to current UK practice
EN 1990: BASIS OF STRUCTURAL DESIGN

Vehicle impacts (very severe)
EN 1990: BASIS OF STRUCTURAL DESIGN

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THE REQUIREMENTS

- Basic requirements (safety; serviceability; robustness and fire)
- Reliability differentiation
- Design working life
- Durability
- Quality Assurance
Reliability differentiation

An appropriate degree of reliability for the majority of structures is obtained by design and execution according to Eurocodes 1 to 9, with appropriate quality assurance measures.

EN 1990 provides guidance for obtaining different levels of reliability.
The choice of the levels of reliability for a particular structure should take account of the relevant factors, including:

- the possible cause and/or mode of attaining a limit state;
- the possible consequences of failure in terms of risk to life, injury, potential economical losses;
- public perception to failure;
- the expense and procedures necessary to reduce the risk of failure.
THE REQUIREMENTS

• Basic requirements (safety; serviceability; robustness and fire)
• Reliability differentiation
• Design working life
• Durability
• Quality Assurance
The Basic Requirements for design working life states:

The design working life is the assumed period for which a structure is to be used for its intended purpose with anticipated maintenance but without major repair being necessary.

A design working life of
- 50 years for buildings
- 100 years for bridges

is recommended.
EN 1990: BASIS OF STRUCTURAL DESIGN

THE REQUIREMENTS

• Basic requirements (safety; serviceability; robustness and fire)
• Reliability differentiation
• Design working life
• Durability
• Quality Assurance
Durability

- It is an assumption in design that the durability of a structure or part of it in its environment is such that it remains fit for use during the design working life given appropriate maintenance.

- The structure should be designed in such a way that deterioration should not impair the durability and performance of the structure having due regard to the anticipated level of maintenance.
Durability

Interrelated factors to be considered:

• The intended and future use of the structure
• The required performance criteria
• The expected environmental influences
• The composition, properties and performance of materials
• The choice of structural system
Durability

Interrelated factors to be considered (cont)

- The shape of members and structural detailing
- The quality of workmanship and level of control
- The particular protective measures
- The maintenance during the intended life
Quality Assurance and Quality Control

In order to provide a structure that corresponds to the requirements and to the assumptions made in the design, appropriate quality management measures should be in place. These measures comprise:

- definition of the reliability requirements,
- organisational (e.g. company and individual responsibilities) measures, and
- controls at the stages of design, execution, use and maintenance.

EN ISO 9001:2000 is an acceptable basis for quality management measures, where relevant.
<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 1991-1-1</td>
<td>Densities, self-weight, imposed loads for buildings</td>
</tr>
<tr>
<td>EN 1991-1-2</td>
<td>Actions on structures exposed to fire</td>
</tr>
<tr>
<td>EN 1991-1-3</td>
<td>Snow loads</td>
</tr>
<tr>
<td>EN 1991-1-4</td>
<td>Wind actions</td>
</tr>
<tr>
<td>EN 1991-1-5</td>
<td>Thermal actions</td>
</tr>
<tr>
<td>EN 1991-1-6</td>
<td>Actions during execution</td>
</tr>
<tr>
<td>EN 1991-1-7</td>
<td>Accidental actions</td>
</tr>
<tr>
<td>EN 1991-2</td>
<td>Traffic loads on bridges</td>
</tr>
<tr>
<td>EN 1991-3</td>
<td>Actions induced by cranes and machinery</td>
</tr>
<tr>
<td>EN 1991-4</td>
<td>Actions in silos and tanks</td>
</tr>
</tbody>
</table>
EN 1991-1-1- Imposed loads

• Foreword
• Section 1 General
• Section 2 Classification of Actions
• Section 3 Design Situations
• Section 4 Densities of Construction And Stored Materials
• Section 5 Self-weight of Construction Works
• Section 6 Imposed loads on Buildings
• Annex A Tables For Nominal Density of Construction Materials, And Nominal Density And Angles of Repose For Stored Materials (I)
• Annex B Vehicle Barriers And Parapets For Car Parks (I)
Main Categories of Use

- **Residential, social, commercial and administration areas**
  - 4 categories (A, B, C and D)

- **Areas for storage and industrial activities**
  - 2 categories (E1 and E2)

- **Garages and vehicle traffic (excluding bridges)**
  - 2 categories (F and G)

- **Roofs**
  - 3 categories (H, I and K)
### Table 6.2 – Imposed loads on floors, balconies and stairs in buildings

<table>
<thead>
<tr>
<th>Categories of loaded areas</th>
<th>$q_k$ [kN/m$^2$]</th>
<th>$Q_k$ [kN]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Floors</td>
<td>1.5 to 2.0</td>
<td>2.0 to 3.0</td>
</tr>
<tr>
<td>- Stairs</td>
<td>2.0 to 4.0</td>
<td>2.0 to 4.0</td>
</tr>
<tr>
<td>- Balconies</td>
<td>2.5 to 4.0</td>
<td>2.0 to 3.0</td>
</tr>
<tr>
<td><strong>Category B</strong></td>
<td>2.0 to 3.0</td>
<td>1.5 to 4.5</td>
</tr>
<tr>
<td><strong>Category C</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- C1</td>
<td>2.0 to 3.0</td>
<td>3.0 to 4.0</td>
</tr>
<tr>
<td>- C2</td>
<td>3.0 to 4.0</td>
<td>2.5 to 7.0 (4.0)</td>
</tr>
<tr>
<td>- C3</td>
<td>3.0 to 5.0</td>
<td>4.0 to 7.0</td>
</tr>
<tr>
<td>- C4</td>
<td>4.5 to 5.0</td>
<td>3.5 to 7.0</td>
</tr>
<tr>
<td>- C5</td>
<td>5.0 to 7.5</td>
<td>3.5 to 4.5</td>
</tr>
<tr>
<td><strong>Category D</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- D1</td>
<td>4.0 to 5.0</td>
<td>3.5 to 7.0 (4.0)</td>
</tr>
<tr>
<td>- D2</td>
<td>4.0 to 5.0</td>
<td>3.5 to 7.0</td>
</tr>
</tbody>
</table>

**NOTE:** Where a range is given in this table, the value may be set by the National annex. The recommended values, intended for separate application, are underlined. $q_k$ is intended for the determination of general effects and $Q_k$ for local effects. The National annex may define different conditions of use of this Table.
### EN 1991-1-1- Imposed loads (Reduction factor for floors)

\[ \alpha_A = \frac{5}{7 \psi_0 + \frac{A_0}{A}} \quad A_0 = 10 \text{ m}^2 \]

\[ \text{Exp (6.1) - Clause 6.3.1.2(10)} \]

<table>
<thead>
<tr>
<th>A (m²)</th>
<th>( \alpha_A ) (EN 1991-1-1 with ( \psi_0 = 0.7 ))</th>
<th>( \alpha_A ) (EN 1991-1-1 with ( \psi_0 = 1.0 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0.75</td>
<td>0.96</td>
</tr>
<tr>
<td>80</td>
<td>0.63</td>
<td>0.84</td>
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<tr>
<td>120</td>
<td>0.59</td>
<td>0.80</td>
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<tr>
<td>160</td>
<td>0.56</td>
<td>0.78</td>
</tr>
<tr>
<td>240</td>
<td>0.54</td>
<td>0.76</td>
</tr>
</tbody>
</table>

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### EN 1991-1-1- Imposed loads (reduction factor for imposed loads from several storeys)

\[
\alpha_n = \frac{2 + (n - 2)\psi_0}{n}
\]

\( n > 2 \)

<table>
<thead>
<tr>
<th>( n )</th>
<th>( \alpha_n ) (EN 1991-1-1); ( \psi = 0.7 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0.9</td>
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<tr>
<td>4</td>
<td>0.85</td>
</tr>
<tr>
<td>5</td>
<td>0.82</td>
</tr>
<tr>
<td>6</td>
<td>0.8</td>
</tr>
<tr>
<td>7</td>
<td>0.79</td>
</tr>
<tr>
<td>8</td>
<td>0.78</td>
</tr>
<tr>
<td>9</td>
<td>0.77</td>
</tr>
<tr>
<td>10</td>
<td>0.76</td>
</tr>
</tbody>
</table>
Annex A - Nominal densities of construction and stored materials

- Designated as an *Informative* Annex
- 12 tables:
  - 5 for construction materials (concrete/mortar, masonry, wood, metals and ‘other materials’);
  - 1 for bridge materials (asphalts, ballast, fills, railway sleepers);
  - 1 for stored construction materials (aggregates, bentonite, gypsum and fresh water); and
  - 5 for stored products (agricultural, foodstuffs, liquids, solid fuels and industrial)
EN 1991-1-2- Actions on structures exposed to fire

- Woodshed: 0.6 m² - 400 kW
- Flame: 20 kW
- Layer fire: 1 m² – 2 MW

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EN 1991-1-2 : Actions on structures exposed to fire

Car fire – 10 m² – 8 MW

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EN 1991-1-2 : Actions on structures exposed to fire

Warehouse fire – 8000 m² – > 800 MW

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EUROPEAN HARMONISATION

CONSTRUCTION PRODUCT DIRECTIVE (1988-12-21)

• ESSENTIAL REQUIREMENTS:
  - Mechanical resistance and stability
  - Safety in case of fire
  - Hygiene, health and environment
  - Safety in use
  - Protection against noise
  - Energy, economy and heat retention

EN 1991-1-2 : Actions on structures exposed to fire
ESSENTIAL REQUIREMENTS

SAFETY in CASE of FIRE

Concerning the construction work:

- Load Bearing Capacity ... for a Specific Period of Time
- The Generation and Spread of Fire and Smoke are limited
- The Spread of Fire to Neighbouring Construction is limited
- The Occupants can leave the Works or be rescued
- The Safety of Rescue Teams is taken into Consideration
HARMONISATION OF ASSESSMENT METHODS

To prove compliance with Essential Requirements:
- tests
- calculation and/or design methods
- combination of tests and calculations
EN 1991-1-2 : Actions on structures exposed to fire

- **THERMAL ACTIONS**

- **MECHANICAL ACTIONS**
EN 1991-1-2 : Actions on structures exposed to fire

**THERMAL ACTIONS**

- Nominal Time-Temperature Curves
- Natural Fire Models
  - Simplified fire models
  - Advanced fire models
EN 1991-1-2: Actions on structures exposed to fire

Nominal Time-Temperature Curves

- Standard time-temperature curve
- Hydrocarbon fire
- External fire

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EN 1991-1-2 : Actions on structures exposed to fire
Compartment fire for internal elements 230 MJ/m²
Harmonized European standards for construction in Egypt

EN 1991-1-2: Actions on structures exposed to fire

Compartment Fires for external elements

- column
- facade
- beam
- floor
- partition wall
- corridor
- flame
- opening
- fire in one room
EN 1991-1-2 : Actions on structures exposed to fire

BASIC PRINCIPLE

• Load-bearing function of a structure shall be assumed if:

\[ E_{d,t, fi} \leq R_{d,t, fi} \]

where:

- \( E_{d,t, fi} \) : design effect of actions (Eurocode 1 Part 1-2)
- \( R_{d,t, fi} \) : design resistance of the structure at time \( t \)
Background to Wind Action

- Wind is highly turbulent and random in nature
- The fundamental equations of fluid motion are difficult to solve
- All ‘solutions’ for wind effects are only approximations
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<tr>
<th>Section/Annex</th>
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<td>Design situations</td>
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<td>Modelling of wind actions</td>
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<td>Section 4</td>
<td>Wind velocity and velocity pressure</td>
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<td>Section 5</td>
<td>Wind actions</td>
</tr>
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<td>Section 6</td>
<td>Structural factor $c_s c_d$</td>
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<td>Section 7</td>
<td>Pressure and force coefficients</td>
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<td>Section 8</td>
<td>Wind actions on bridges</td>
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<td>Annex A</td>
<td>Terrain effects</td>
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<td>Annex B</td>
<td>Procedure 1 for structural factor $c_s c_d$</td>
</tr>
<tr>
<td>Annex C</td>
<td>Procedure 2 for structural factor $c_s c_d$</td>
</tr>
<tr>
<td>Annex D</td>
<td>Graphs of $c_s c_d$ for common building forms</td>
</tr>
<tr>
<td>Annex E</td>
<td>Vortex shedding &amp; aeroelastic instabilities</td>
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<tr>
<td>Annex F</td>
<td>Dynamic characteristics of structures</td>
</tr>
</tbody>
</table>
Section 1 - General

SCOPE

Includes

• Building and civil engineering works with heights up to 200m
• Bridges with spans of less than 200m (subject to dynamic response criteria)

Excludes

• Guyed masts and lattice towers (EN 1993-7-1)
• Lighting columns (EN40)
• Cable supported bridges
• Torsional and higher modes of vibration
# Section 4: Wind velocity and velocity pressure

## Terrain Categories

<table>
<thead>
<tr>
<th>Terrain category</th>
<th>$z_0$ (m)</th>
<th>$z_{\text{min}}$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Sea or coastal area exposed to the open sea</td>
<td>0.003</td>
<td>1</td>
</tr>
<tr>
<td>I. Lakes or flat and horizontal area with negligible vegetation and without obstacles</td>
<td>0.01</td>
<td>1</td>
</tr>
<tr>
<td>II. Areas with low vegetation such as grass and isolated obstacles, separated by at least 20 obstacle heights</td>
<td>0.05</td>
<td>2</td>
</tr>
<tr>
<td>III. Areas with regular cover of vegetation or buildings or with isolated obstacles separated by &lt; 20 obstacle heights</td>
<td>0.3</td>
<td>5</td>
</tr>
<tr>
<td>IV. Areas in which at least 15% of the surface is covered with buildings whose average height exceeds 15m</td>
<td>1.0</td>
<td>10</td>
</tr>
</tbody>
</table>
Terrain categories (Annexe A)

**Category 0**
Sea or coastal area exposed to the open sea

**Category I**
Lakes or flat and horizontal area with negligible vegetation and without obstacles

**Category II**
Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

**Category III**
Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)

**Category IV**
Area in which at least 15% of the surface is covered with buildings and their average height exceeds 15 m

EN 1991-1-4: Eurocode 1 - Part 1-4 - Wind actions

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EN 1991-1-4 : Eurocode 1 - Part 1-4 - Wind actions

Section 4: Wind velocity and velocity pressure

**Basic wind velocity**

\[ v_b = c_{\text{dir}} \cdot c_{\text{season}} \cdot v_{b,0} \cdot c_{\text{prob}} \]

where \( v_{b,0} = 10 \text{ minute mean velocity at } 10\text{m above ground of category II} \) \( (z_0 = 0.05) \)

- \( c_{\text{dir}} \) = directional factor
- \( c_{\text{season}} \) = seasonal factor
- \( c_{\text{prob}} \) = probability factor

**Mean wind velocity**

\[ v_m(z) = c_r(z) \cdot c_0(z) \cdot v_b \]

Where

- \( c_r(z) \) = roughness factor = \( k_r \ln(z/z_0) \)
- \( k_r \) = terrain factor depending on \( z_0 \)
- \( c_0(z) \) = orography factor

\[ k_r = 0.19 \left( \frac{z_0}{Z_{0,II}} \right)^{0.07} \]
EN 1991-1-4 : Eurocode 1 - Part 1-4 - Wind actions – An example

Zone | $v_{b,0}$ (m/s)
--- | ---
Zone 1 | 24,0
Zone 2 | 26,0
Zone 3 | 28,0
Zone 4 | 30,0
Zone 5 (Antilles, Réunion) | 34,0
Section 4: Wind velocity and velocity pressure

Peak velocity pressure

\[ q_p(z) = c_e(z) \left( \frac{1}{2} \rho v_m^2(z) \right) \]

\[ c_e(z) = c_r^2(z) \left[ 1 + \frac{7k_lk_r}{c_r(z)} \right] \]

where

\[ c_e = \text{exposure coefficient} \]
\[ \rho = \text{air density (1,25 kN/m}^3) \]
\[ k_l = \text{turbulence coefficient (generally 1,0)} \]
<table>
<thead>
<tr>
<th>Terrain category</th>
<th>( z_0 ) (m)</th>
<th>( z_{\text{min}} ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.003</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>0.01</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>0.05</td>
<td>2</td>
</tr>
<tr>
<td>III</td>
<td>0.3</td>
<td>5</td>
</tr>
<tr>
<td>IV</td>
<td>1.0</td>
<td>10</td>
</tr>
</tbody>
</table>

\( z_{\text{max}} = 200 \) m
EN 1991-1-4 : Eurocode 1 - Part 1-4 - Wind actions

Terrain category

z (m) Height above ground

c_e(z) exposure coefficient (without orography effect)

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**Section 5: Wind actions (bridges)**

Wind pressure

\[ w = q_p(z_e) c_p \]

Wind force (using pressure coefficients)

\[ F_w = c_s c_d \sum w A_{ref} \]

Wind force (directly)

\[ F_w = c_s c_d c_f q_p(z_e) A_{ref} \]

Wind force (using vectorial summation)

\[ F_w = c_s c_d \sum c_f q_p(z_e) A_{ref} \]
Eurocode 1: Actions on structures
EN 1991-1-5  General Actions
Thermal Actions
EN 1991-1-5: CONTENTS

- Section 1 General
- Section 2 Classification of actions
- Section 3 Design situations
- Section 4 Representation of actions
- Section 5 Temperature changes in buildings
- Section 6 Temperature changes in bridges
- Section 7 Temperature changes in industrial chimneys, pipelines, silos, tanks and cooling towers
- Annexes
Changing the return period for transient design situations

- 50 years
- 10 years

Harmonized European standards for construction in Egypt
The temperature distribution within an individual structural element is split into the following four essential constituent components:

(a) A uniform temperature component, $\Delta T_u$;

(b) A linearly varying temperature difference component about the z-z axis, $\Delta T_{My}$;

(c) A linearly varying temperature difference component about the y-y axis, $\Delta T_{Mz}$;

(d) A non-linear temperature difference component, $\Delta T_E$. This results in a system of self-equilibrated stresses which produce no net load effect on the element.
Diagrammatical representation of constituent components of a temperature profile

Center of gravity

\[
\Delta T_u + \Delta T_{My} + \Delta T_{Mz} + \Delta T_E
\]
EN 1991-1-5: Temperature changes in buildings

Thermal actions on buildings due to climatic and operational temperature changes need to be considered in the design of buildings where there is a possibility of the ultimate or serviceability limit states being exceeded due to thermal movement and/or stresses.

Volume changes and/or stresses due to temperature changes may also be influenced by:

- shading of adjacent buildings,
- use of different materials with different thermal expansion coefficients and heat transfer,
- use of different shapes of cross-section with different uniform temperature.
EN 1991-1-5: Temperature changes in buildings

In accordance with the temperature components given, climatic and operational thermal actions on a structural element need to be specified using the following basic quantities:

- A uniform temperature component $\Delta T_u$ given by the difference between the average temperature $T$ of an element and its initial temperature $T_0$.

- A linearly varying temperature component given by the difference $\Delta T_M$ between the temperatures on the outer and inner surfaces of a cross section, or on the surfaces of individual layers.

- A temperature difference $\Delta T_p$ of different parts of a structure given by the difference of average temperatures of these parts.
Harmonized European standards for construction in Egypt
Indicative values of inner environment \( (T_1 \text{ and } T_2) \) 
And \( T_{out} \) (i.e.\( T_{max} + T_1, T_2 \text{ or } T_3 \)) for buildings above ground, for regions between latitudes 45\(^\circ\)N and 55\(^\circ\)N

<table>
<thead>
<tr>
<th>( T )</th>
<th>Season</th>
<th>Characteristic Values of the temperature ( (^\circ C) )</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_1 )</td>
<td>Summer</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>( T_2 )</td>
<td>Winter</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>( T_3 )</td>
<td>Summer</td>
<td>Relative absorption depends on surface colour. (bright light surface)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>Elements facing North-East</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>Elements facing South-West</td>
</tr>
<tr>
<td>( T_4 )</td>
<td>Summer</td>
<td>Relative absorption depends on surface colour. (light coloured surface)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Elements facing North-East</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>Elements facing South-West</td>
</tr>
<tr>
<td>( T_5 )</td>
<td></td>
<td>Relative absorption depends on surface colour. (dark surface)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>Elements facing North-East</td>
</tr>
<tr>
<td></td>
<td></td>
<td>42</td>
<td>Elements facing South-West</td>
</tr>
</tbody>
</table>
Indicative temperatures $T_{\text{out}}$ for underground parts of buildings
For regions between latitudes 45°N and 55°N

<table>
<thead>
<tr>
<th></th>
<th>Season</th>
<th>Temperature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_6$</td>
<td>Summer</td>
<td>8</td>
<td>Temperature for depth below the ground level, less than 1 m.</td>
</tr>
<tr>
<td>$T_7$</td>
<td>Summer</td>
<td>5</td>
<td>Temperature for depth below the ground level, more than 1 m.</td>
</tr>
<tr>
<td>$T_8$</td>
<td>Winter</td>
<td>-5</td>
<td>Temperature for depth below the ground level, less than 1 m.</td>
</tr>
<tr>
<td>$T_9$</td>
<td>Winter</td>
<td>-3</td>
<td>Temperature for depth below the ground level, more than 1 m.</td>
</tr>
</tbody>
</table>
• $\Delta T_N$ produces a variation of length. It influences
  - The design of expansion joints
  - The design of bearings
  It produces action effects in statically undetermined structure
  (portal bridges, arch bridges, etc.) and in continuous rails of
  railway bridges
• $\Delta T_M$ produces a rotation in every cross-section
  - In a statically determined girder
    • Deformation but no action effects
  - In a statically undetermined girder
    • Deformation and action effects
• Horizontal component (recommended value $\pm 5^\circ C$)
• $\Delta T_E$ produces self-balanced stresses in the cross-section
BRIDGE TYPES

- Type 1 Steel deck
  - steel box-girder
  - steel truss or plate girder

- Type 2 Composite deck

- Type 3 Concrete deck
  - concrete slab
  - concrete beam
  - concrete box-girder
Determination of thermal effects

CONCRETE BRIDGE

Type 1

Correlation between minimum/maximum shade air temperature (Tmin/Tmax)

And

minimum/maximum uniform bridge temperature component (Te.min/Te.max)

Harmonized European standards for construction in Egypt
# Table 6.1: Recommended values of linear temperature difference component for different types of bridge decks for road, foot and railway bridges

<table>
<thead>
<tr>
<th>Type of Deck</th>
<th>Top warmer than bottom</th>
<th>Bottom warmer than top</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\Delta T_{M,\text{heat}}$ (°C)</td>
<td>$\Delta T_{M,\text{cool}}$ (°C)</td>
</tr>
<tr>
<td>Type 1: Steel deck</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>Type 2: Composite deck</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>Type 3: Concrete deck:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- concrete box girder</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>- concrete beam</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>- concrete slab</td>
<td>15</td>
<td>8</td>
</tr>
</tbody>
</table>

**NOTE 1:** The values given in the table represent upper bound values of the linearly varying temperature difference component for representative sample of bridge geometries.

**NOTE 2:** The values given in the table are based on a depth of surfacing of 50 mm for road and railway bridges. For other depths of surfacing these values should be multiplied by the factor $k_{\text{sur}}$. Recommended values for the factor $k_{\text{sur}}$ is given in Table 6.2.
# EN 1991-1-5 – Thermal actions

Table 6.2: Recommended values of $k_{sur}$ to account for different surfacing thickness

<table>
<thead>
<tr>
<th>Surface Thickness</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top warmer than bottom</td>
<td>Bottom warmer than top</td>
<td>Top warmer than bottom</td>
</tr>
<tr>
<td>[mm]</td>
<td>$k_{sur}$</td>
<td>$k_{sur}$</td>
<td>$k_{sur}$</td>
</tr>
<tr>
<td>unsurfaced</td>
<td>0,7</td>
<td>0,9</td>
<td>0,9</td>
</tr>
<tr>
<td>waterproofed $^1$</td>
<td>1,6</td>
<td>0,6</td>
<td>1,1</td>
</tr>
<tr>
<td>50</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>100</td>
<td>0,7</td>
<td>1,2</td>
<td>1,0</td>
</tr>
<tr>
<td>150</td>
<td>0,7</td>
<td>1,2</td>
<td>1,0</td>
</tr>
<tr>
<td>ballast (750 mm)</td>
<td>0,6</td>
<td>1,4</td>
<td>0,8</td>
</tr>
</tbody>
</table>

$^1$ These values represent upper bound values for dark colour
EN 1991-1-5 – Thermal actions

Temperature differences for bridge decks: Type 1 – Steel decks bridges (reproduced from EN 1991-1-5)

1a. Steel deck on steel box girders

\[
\Delta T_1 = 24^\circ C \\
\Delta T_2 = 14^\circ C \\
\Delta T_3 = 8^\circ C \\
\Delta T_4 = 4^\circ C
\]

\[
h_1 = 0.1m \\
h_2 = 0.2m \\
h_3 = 0.3m \\
h_4 = 0.1m
\]

1b. Steel deck on steel truss or plate girders

\[
\Delta T_1 = 21^\circ C \\
\Delta T_1 = -5^\circ C
\]

\[
h_1 = 0.5m \\
h_1 = 0.1m
\]
EN 1991-1-5 – Thermal actions

Temperature differences for bridge decks: Type 2 – Composite decks bridges (re-produced from EN 1991-1-5)

<table>
<thead>
<tr>
<th>Normal Procedure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>h_1</td>
</tr>
<tr>
<td>h _1</td>
<td>h _2</td>
</tr>
<tr>
<td>h _2</td>
<td>h _1</td>
</tr>
</tbody>
</table>

\[ h_1 = 0.6h, \quad h_2 = 0.4m \]

<table>
<thead>
<tr>
<th>h (m)</th>
<th>(\Delta T_1) (°C)</th>
<th>(\Delta T_2) (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>0.3</td>
<td>16</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Simplified Procedure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>(\Delta T_1)</td>
</tr>
</tbody>
</table>

\[ \Delta T_1 = 10°C \]

\[ \Delta T_1 = -10°C \]
## EN 1991-1-5 – Thermal actions

**Temperature differences for bridge decks: Type 3 – Concrete decks bridges (re-produced from EN 1991-1-5)**

<table>
<thead>
<tr>
<th>Type of Construction</th>
<th>Temperature Difference (ΔT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a) Heating</td>
</tr>
<tr>
<td>3a. Concrete slab</td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td>100mm surfacing</td>
<td>ΔT₁, ΔT₂</td>
</tr>
<tr>
<td>3b. Concrete beams</td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>100mm surfacing</td>
<td>h₁, 0.3h but ≤0.15m</td>
</tr>
<tr>
<td>3c. Concrete box girder</td>
<td><img src="image5" alt="Diagram" /></td>
</tr>
<tr>
<td>100mm surfacing</td>
<td>surfacing depth in metres)</td>
</tr>
<tr>
<td></td>
<td>by h - h₁ - h₂)</td>
</tr>
</tbody>
</table>

### Table

<table>
<thead>
<tr>
<th>h [m]</th>
<th>ΔT₁ [°C]</th>
<th>ΔT₂ [°C]</th>
<th>ΔT₃ [°C]</th>
<th>ΔT₄ [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤0.2</td>
<td>8.5</td>
<td>3.5</td>
<td>0.5</td>
<td>-2.0</td>
</tr>
<tr>
<td>0.4</td>
<td>12.0</td>
<td>3.0</td>
<td>1.5</td>
<td>-4.5</td>
</tr>
<tr>
<td>0.5</td>
<td>13.0</td>
<td>3.0</td>
<td>2.0</td>
<td>-6.5</td>
</tr>
<tr>
<td>≥0.8</td>
<td>15.0</td>
<td>3.0</td>
<td>2.5</td>
<td>-7.6</td>
</tr>
<tr>
<td>≤1.5</td>
<td>-8.4</td>
<td>-0.5</td>
<td>-1.0</td>
<td>-6.4</td>
</tr>
</tbody>
</table>
Temperature differences between the inner and outer web walls of large concrete box girder bridges:
Recommended value 15°C

Simultaneity of uniform and temperature difference components (recommended values)

\[
\Delta T_{M,heat} (or\Delta T_{M,cool}) + 0,35\Delta T_{N,\exp} (or\Delta T_{N,con})
\]

\[
0,75\Delta T_{M,heat} (or\Delta T_{M,cool}) + \Delta T_{N,\exp} (or\Delta T_{N,con})
\]

Differences in the uniform temperature component between different structural elements:
- 15°C between main structural elements (e.g. tie and arch); and
- 10°C and 20°C for light and dark colour respectively between suspension/stay cables and deck (or tower).
EN 1991-1-5 – Thermal actions
Temperature differences between the outer faces of bridge piers, hollow or solid

Bridge axis

5°C

±15°C

Harmonized European standards for construction in Egypt
Design of Bridges with Eurocodes
EN 1990 + Annex A2
EN 1991-1/-1, 3, 4, 5, 6, 7
EN 1991-2 : Traffic loads

EN 1992-1+2 : concrete bridges
EN 1993-1+2 : steel bridges
EN 1994-1+2 : composite bridges
EN 1995-1+2 : timber bridges
EN 1997-1 : foundations
EN 1998-1+2+5 : bridges in seismic zones
EN 1991-2
Eurocode 1: Actions on structures – Part 2: Traffic Loads on Bridges
EN 1991-2 - Traffic loads on bridges

• FOREWORD
• SECTION 1 GENERAL
• SECTION 2 CLASSIFICATION OF ACTIONS
• SECTION 3 DESIGN SITUATIONS
• SECTION 4 ROAD TRAFFIC ACTIONS AND OTHER ACTIONS SPECIFICALLY FOR ROAD BRIDGES
• SECTION 5 ACTIONS ON FOOTWAYS, CYCLE TRACKS AND FOOTBRIDGES
• SECTION 6 RAIL TRAFFIC ACTIONS AND OTHER ACTIONS SPECIFICALLY FOR RAILWAY BRIDGES
| ANNEX A (I) | Models of special vehicles for road bridges |
| ANNEX B (I) | Fatigue life assessment for road bridges – Assessment method based on recorded traffic |
| ANNEX C (N) | Dynamic factors $1+\phi$ for real trains |
| ANNEX D (N) | Basis for the fatigue assessment of railway structures |
| ANNEX E (I) | Limits of validity of load model HSLM and the selection of the critical universal train from HSLM-A |
| ANNEX F (I) | Criteria to be satisfied if a dynamic analysis is not required |
| ANNEX G (I) | Method for determining the combined response of a structure and track to variable actions |
| Annex H (I) | Load models for rail traffic loads in transient situations |
EN 1991-2 - Traffic loads on bridges
Traffic load models for road bridges
- Vertical forces: LM1, LM2, LM3, LM4
- Horizontal forces: braking and acceleration, centrifugal, transverse

Groups of loads
- gr1a, gr1b, gr2, gr3, gr4, gr5
- characteristic, frequent and quasi-permanent values

Combination with actions other than traffic actions
LOAD MODEL FOR LIMIT STATES OTHER THAN FATIGUE LIMIT STATES

- Field of application: loaded lengths less than 200 m (maximum length taken into account for the calibration of the Eurocode – For very long loaded lengths, see National Annex)

- Load Model Nr. 1
  Concentrated and distributed loads (main model)

- Load Model Nr. 2
  Single axle load

- Load Model Nr. 3
  Set of special vehicles

- Load Model Nr. 4
  Crowd loading: 5 kN/m²
The main load model (LM1)

\[ q_{1k} = 9 \text{ kN/m}^2 \]
\[ q_{2k} = 2.5 \text{ kN/m}^2 \]
\[ q_{3k} = 2.5 \text{ kN/m}^2 \]

\[ q_{rk} = 2.5 \text{ kN/m}^2 \]

EN 1991-2 - Traffic loads on bridges
EN 1991-2 - Traffic loads on bridges

Load model Nr. 2 (LM2)

Recommended value:

$$\beta_Q = \alpha_Q$$

(0.9 for the 2\textsuperscript{nd} class)
Fatigue Load Models for road bridges

- Load Model Nr. 1 (FLM1) : Similar to characteristic Load Model Nr. 1
  \[ 0.7 \times Q_{ik} - 0.3 \times q_{ik} - 0.3 \times q_{rk} \]
- Load Model Nr. 2 (FLM2) : Set of « frequent » lorries
- Load Model Nr. 3 (FLM3) : Single vehicle
- Load Model Nr. 4 (FLM4) : Set of « equivalent » lorries
- Load Model Nr. 5 (FLM5) : Recorded traffic
EN 1991-2 - Traffic loads on bridges

Fatigue Load Model Nr.3 (FLM3)
Harmonized European standards for construction in Egypt

EN 1991-2 - Traffic loads on bridges

Load models for footbridges

• LOAD MODEL Nr.1
  Uniformly distributed load $q_{fk}$

• LOAD MODEL Nr.2
  Concentrated load $Q_{fwk}$
  (10 kN recommended)

• LOAD MODEL Nr.3
  Service vehicle $Q_{serv}$
EN 1991-2 - Traffic loads on bridges

Recommended characteristic value for:
- footways and cycle tracks on road bridges,
- short or medium span length footbridges:

\[ q_{fk} = 5,0 \text{ kN/m}^2 \]

Recommended expression for long span length footbridges:

\[ q_{fk} = 2,0 + \frac{120}{L + 30} \text{ kN/m}^2 \]

\( L \) is the loaded length [m]

\[ q_{fk} \geq 2,5 \text{ kN/m}^2 \quad q_{fk} \leq 5,0 \text{ kN/m}^2 \]
EN 1991-2 - Traffic loads on bridges

Railway bridges - Notation and dimensions specifically for rail tracks – Section 6

s  : Gauge
u  : Cant
Qs  : Nosing force

(1) Running surface
(2) Longitudinal forces acting along the centreline of the track
The characteristic values may be adjusted to the expected traffic on the bridge by a multiplication factor $\alpha$ which shall be one of the following:

$$0.75 - 0.83 - 0.91 - 1.00 - 1.10 - 1.21 - 1.33 - 1.46$$

1.33 is the recommended value for important and international lines. When selected, the same factor $\alpha$ shall be applied to the other rail traffic action components, in particular to centrifugal forces, nosing forces, and acceleration and braking.
Load Models SW/0 and SW/2
(Heavy rail traffic)

EN 1991-2 - Traffic loads on bridges

<table>
<thead>
<tr>
<th>Load models</th>
<th>$q_{vk}$ [kN/m]</th>
<th>$a$ [m]</th>
<th>$c$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW/0</td>
<td>133</td>
<td>15,0</td>
<td>5,3</td>
</tr>
<tr>
<td>SW/2</td>
<td>150</td>
<td>25,0</td>
<td>7,0</td>
</tr>
</tbody>
</table>
Example of a heavy weight waggon (DB, 32 axles, selfweight 246 t, pay load 457 t, mass per axle 22 t, $L_{tot} = 63.3$ m)
EN 1991-2 - Traffic loads on bridges

Models HSLM-A et HSLM-B for international high speed lines

\[ N \times 170\text{kN} \]
EN 1991-2 - Traffic loads on bridges

Dynamic effects

Stresses and strains in a bridge deck due to rail traffic (including the associated acceleration) are amplified or reduced by the following phenomena:

- Loading celerity due to the speed of rail traffic crossing the bridge and the bridge inertia,

- Successive loads crossing the bridge with more or less regular spacings, which can excite the structure and, in some cases, lead to resonance,

- Variations of wheel loads due to imperfection of tracks or of the vehicle (including wheel irregularities).

To cover these effects, EN 1991-2 defines 3 dynamic amplification factors.
Maximum permissible vertical deflection \( \delta \) for railway bridges with 3 or more successive simply supported spans corresponding to a permissible vertical acceleration of \( b_v = 1 \) m/s\(^2\) in a coach for speed \( V \) [km/h]
EN 1991-2 - Traffic loads on bridges

Fatigue – Example of light train (type 1) for fatigue verifications

\[ \sum Q = 6630\text{kN} \quad V = 200\text{km/h} \quad L = 262,10\text{m} \quad q = 25,3\text{kN/m}^2 \]
Traction and braking forces act at the top of the rails in the longitudinal direction of the track. They shall be considered as uniformly distributed over the corresponding influence length $L_{a,b}$ for traction and braking effects for the structural element considered. The direction of the traction and braking forces shall take account of the permitted direction(s) of travel on each track. Their characteristic value is given in the Table below:

<table>
<thead>
<tr>
<th>Traction force</th>
<th>$Q_{lak} = 33 \text{ [kN/m]} \ L_{a,b} \text{ [m]} \leq 1000 \text{ [kN]}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Load Models LM 71, LM SW/0, LM SW/2 et HSLM</td>
<td></td>
</tr>
<tr>
<td>Braking force</td>
<td>$Q_{lbk} = 20 \text{ [kN/m]} \ L_{a,b} \text{ [m]} \leq 6000 \text{ [kN]}$</td>
</tr>
<tr>
<td>For Load Models LM 71, LM SW/0 et HSLM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$Q_{lbk} = 35 \text{ [kN/m]} \ L_{a,b} \text{ [m]}$</td>
</tr>
<tr>
<td>For Load Model LM SW/2</td>
<td></td>
</tr>
</tbody>
</table>
**EN 1991-2 - Traffic loads on bridges**

**Design Situation I – Equivalent loads** $Q_{A1d}$ and $q_{A1d}$

- (1) max. 1.5s or less if against wall
- (2) Track gauge $s$
- (3) For ballasted decks the point forces may be assumed to be distributed on a square of side 450mm at the top of the deck.

**Design Situation II - equivalent load** $q_{A2d}$

- (1) Load acting on edge of structure
- (2) Track gauge $s$
EN 1991-2 - Traffic loads on bridges

Aerodynamic effects as a result of passing trains

Examples of characteristic values of pressure $q_{1k}$ for simple vertical surfaces parallel to the track
Combined response of structure and track to variable actions

The effects resulting from the combined response of the structure and the track to variable actions shall be taken into account for the design of the bridge superstructure, fixed bearings, the substructure and for checking load effects in the rails. Traction and braking forces, thermal actions, effects of vertical loads due to traffic (the associated dynamic effects may be neglected) shall be taken into account for the determination of the response. The use of the following model is recommended.
Thank you for your attention