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Digest

Determining wind actions using Eurocode 1

Part 1: Guidance on the use of BS EN 1991-1-4

Paul Blackmore

Eurocode 1 for wind actions, BS EN 1991-1-4[1], replaces BS 6399-2[2], which was withdrawn in 2010. The scope of BS EN 1991-1-4 is much wider than BS 6399-2: where BS 6399-2 was limited to building structures and mildly dynamic response, BS EN 1991-1-4 includes buildings and civil engineering works and a more comprehensive approach to dynamic response, including vortex shedding and other aerodynamic instabilities. There are a number of significant differences between these standards, particularly with respect to dynamic response, which will be unfamiliar to UK engineers. It was therefore felt that some additional background information and worked examples would be beneficial.

This three-part Digest will help the user to understand the new approach to wind loading used in the Eurocode. It is aimed at engineers, architects and other professionals who need to understand how to calculate the effect of wind on buildings and design options to minimise it. Wind loads on bridges are not covered in this Digest.

Part 1 of this Digest gives guidance on the use of BS EN 1991-1-4, its UK National Annex[3] and the non-conflicting complementary information published in PD 6688-1-4[4]. Parts 2 and 3 give worked examples of the Eurocode methodology, including dynamic response. This update to Part 1 replaces the guidance published in 1999.

Using BS EN 1991-1-4

In the UK, BS EN 1991-1-4 must always be used in conjunction with the UK National Annex. There are over 60 nationally determined parameters (NDPs) in the standard. Member states may provide alternative procedures or values for each of these NDPs. The National Annex gives guidance on these NDPs and their application in the UK. The Eurocode system also allows non-conflicting complementary information (NCCI) to be used; in the UK this is found in PD 6688-1-4. This published document includes background information, commentary on interpretation of some clauses and additional pressure coefficient data for building forms outside of the scope of the standard. It also includes Annex A (*Vortex shedding and aerodynamic instabilities*), which replaces Annex E in BS EN 1991-1-4. PD 6688-1-4 does not have the status of a British Standard.

In this Digest we will refer to BS EN 1991-1-4 as the 'EN', the UK National Annex to BS EN 1991-1-4 as the 'NA' and PD 6688-1-4 as the 'PD'.

Structural factor c_sc_d

The structural factor c_sc_d accounts for the dynamic response of the structure and the correlation of the wind gusts over the surface of the structure. The factor c_sc_d may be taken as 1.0 in the following cases:

- all buildings with a height < 15 m
- framed buildings < 100 m high with structural walls and with height/crosswind breadth < 4
- circular chimneys < 60 m high and with height/diameter < 6.5.

Digest

Determining wind actions using Eurocode 1

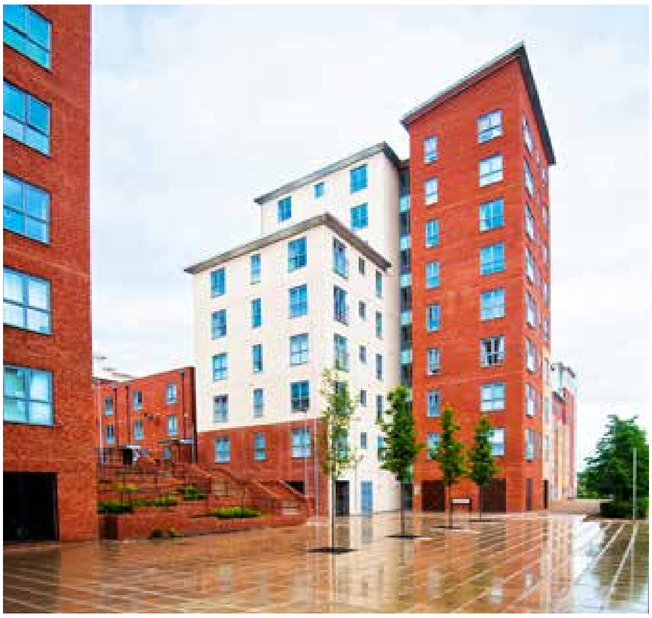
Part 2: Worked examples – wind loads on a two-storey house and 128 m tower

Paul Blackmore

This is the second part of a three-part Digest giving guidance on the use of Eurocode 1 (BS EN 1991-1-4). This Digest is aimed at engineers, architects and other professionals who need to understand how to calculate the effect of wind on buildings and design options to minimise it. Wind loads on bridges are not covered in this Digest.

Part 2 of this Digest demonstrates the calculation procedure for determining wind loads and includes example calculations for a two-storey house and a 120 m residential tower on an 8 m podium. Part 1 gives advice and guidance on the use of BS EN 1991-1-4 and Part 3 gives an example calculation of dynamic response using the full dynamic method given in BS EN 1991-1-4 Annex B for inwind response in the fundamental mode. This update to Part 2 replaces the guidance published in 1999.

In this Digest we will refer to BS EN 1991-1-4[1] as the 'EN', the UK National Annex to BS EN 1991-1-4[2] as the 'NA' and PD 6688-1-4[3] as the 'PD'.



Example 1: Two-storey house

This example demonstrates the approach to be used for determining the peak velocity pressure and the cladding and overall loads on a typical two-storey house. For this example it has been assumed that the site lies on the outskirts of Sheffield. This site has been chosen because it is typical of inland towns and illustrates the typical conservatism arising from the simplified options for determining peak velocity pressure. For sites close to the west coast there will be less conservatism and for sites near the east coast there will be more conservatism.

Assumptions for this example are:

- the site altitude A is 120 m
- the site is less than halfway up a hill so orography is not significant (NA Figure NA.2)
- the map wind speed $v_{b,map}$ (NA Figure NA.1) for the site is 22 m/s
- the principal dimensions of the house and its orientation and location in relation to nearby buildings are shown in Figures 1 and 2
- the season factor c_{season} = 1.0 and the probability factor c_{prob} = 1.0 (values applicable for a permanent building)
- the distance to the edge of the town and the distance to the shore vary as shown in Table 1.

In this example three options for determining the peak velocity pressure are considered:

- Option 1: taking 12 wind directions (least conservative)
- Option 2: taking four orthogonal wind directions (best compromise)
- Option 3: taking the single worst case irrespective of direction (most conservative).

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Digest

Determining wind actions using Eurocode 1

Part 3: Worked example – calculation of forces on a tower using the full dynamic method

Paul Blackmore and Gordon Breeze

This is the third part of a three-part Digest giving guidance on the use of Eurocode 1 (BS EN 1991-1-4). This Digest is aimed at engineers, architects and other professionals who need to understand how to calculate the effect of wind on buildings and design options to minimise it. Wind loads on bridges are not covered in this Digest.

Part 3 of this Digest demonstrates the calculation procedure for determining wind loads using the full dynamic method from Annex B of BS EN 1991-1-4. It includes an example calculation for determining the dynamic response of a 128 m tall building (referred to as 'Example 3' to differentiate from the examples referred to in Part 2).

Part 1 gives advice and guidance on the use of BS EN 1991-1-4 and Part 2 demonstrates the calculation procedure for determining wind loads and includes example calculations for a two-storey house and a 120 m tall tower on an 8 m podium. This update to Part 3 replaces the guidance published in 1999.

In this Digest we will refer to BS EN 1991-1-4[1] as the 'EN', the UK National Annex to BS EN 1991-1-4[2] as the 'NA' and PD 6688-1-4[3] as the 'PD'.

Introduction

The wind-induced dynamic response of a building can be broken down into alongwind response, crosswind response and torsional response. These responses can be analysed independently and the overall response determined by combining together each of the components. The alongwind dynamic response is dependent on the scale, magnitude and frequency of the turbulence in the approaching wind. The overall alongwind response includes the static (or quasi-static) response due to the approaching mean wind speed. The crosswind dynamic response is more complex and can include a number of excitation mechanisms such as vortex shedding and aeroelastic instabilities such as galloping and flutter (Box 2), as well as crosswind buffeting. The incident wind can also generate crosswind (or lift) forces depending on the approaching wind angle and the cross-sectional shape of the building. Torsional dynamic response can be amplified by the centre of twist of the building being offset from its centre of mass, ie a rectangular building with the lifts and stairwells concentrated at one end of the building. It can also be caused by non-symmetrical wind forces, or where an upwind building shelters one-half of the building. Non-symmetrical wind forces can also be produced if there is a nearby adjacent building at one end that creates a localised region of accelerated or sheltered flow.

The EN provides calculation procedures for the alongwind dynamic response of the first fundamental mode of bending and for vortex shedding response. It does not consider torsional dynamic response, crosswind buffeting response or response from higher modes of vibration (Box 3). For particular designs