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EC 1: Wind Loads

EC 1: Charges dues au vent

EC 1: Windeinwirkungen

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SUMMARY

This paper explains the principle of the two procedures for the calculation of the wind load on structures: simplified and detailed methods. The first one has been developed from the detailed method for those buildings and structures which are not sensitive to dynamic effects. Examples are given for buildings with heights from 10 to 200 m, for a low rise large steel building and a 150 m high concrete tower.

RESUME

L'article présente le principe des deux méthodes de calcul, la méthode simplifiée et la méthode détaillée, utilisées pour calculer des surcharges de vent exercées sur des bâtiments. La première a été déduite de la méthode détaillée pour des bâtiments non sensibles aux actions dynamiques du vent. Il donne des exemples pour des bâtiments dont la hauteur varie entre 10 et 200 m, pour un grand hangar de faible hauteur en acier et pour une tour en béton armé.

ZUSAMMENFASSUNG

Es wird das Prinzip der beiden Berechnungsmethoden, die «vereinfachte» und die «detaillierte» Methode, zur Windlastberechnung an Bauwerken, erläutert. Die erstere ist aus der detaillierten Methode für solche Bauwerke entwickelt worden, die nicht schwingungsempfindlich sind. Es werden Beispiele für Gebäude mit Höhen zwischen 10 und 200 m, für eine niedrige, grosse Stahlhalle und einen Stahlbetonturm gegeben.

1. INTRODUCTION

This paper presents a brief description of the actual draft of the Eurocode 1, part 2.7 "Wind Action" [1]. The process of developing the code is still going on, but the principles are more or less fixed. The existing EC-draft is based on modern knowledges in the field of windengineering which has been introduced into new national standards or drafts of national codes. Furthermore it follows the guideline of ISO-Standard of Wind load, TC 98 [2].

2. OBJECT, FIELD OF APPLICATION AND SCOPE

The code gives rules and methods for calculating the **static** and **dynamic** response of buildings and other structures, i. e. towers, masts, chimneys, bridges, walls etc. Because of the large variation of types of buildings and structures as well as its site location a **detailed method** is proposed which covers most of the practical cases and which is presented in a form for computer application. The detailed method covers all dynamic effects.

It is known, that the majority of the buildings require only a simple rule. For those buildings and structures not very sensitive to wind load, i. e. the wind load is not significant for the design, a **simplified method** is presented, too. These method does not cover dynamic effects and is therefore only applicable for buildings and structures where dynamic effects are negligible.

The simplified method does not take into account the reduction of the wind load with increasing building size (aerodynamic admittance function). Therefore this simple rule gives higher values than the detailed method. Fig. 1 illustrates this effect.

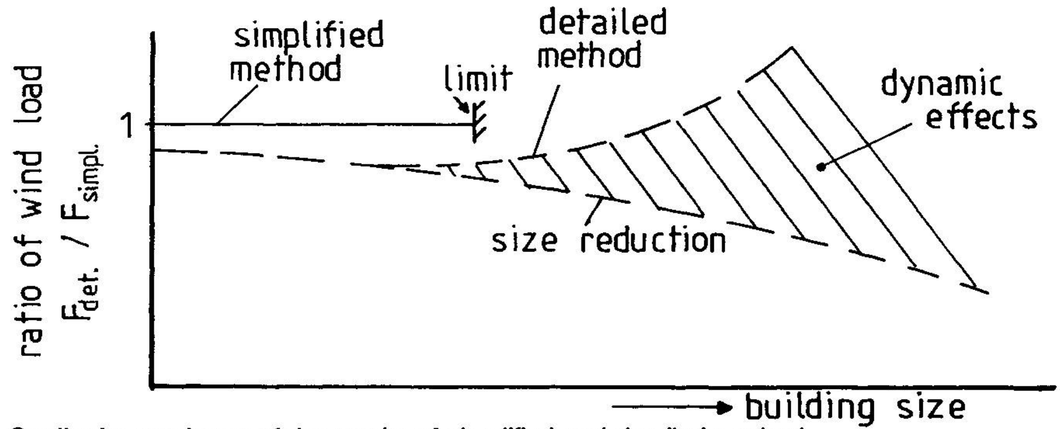


Fig. 1 Qualitative tendency of the results of simplified and detailed method.

In all cases it is allowed to apply the detailed method. These should be done if the economy of the design is significantly influenced by the wind load. Nevertheless the simplified method can be used within its limit of application for a first rough estimation.

3. CRITERIA FOR THE RANGE OF APPLICATION OF SIMPLIFIED METHOD

For buildings the criteria is only related to alongwind response and is given in Fig. 2. The graphs have been calculated using the detailed method and varying the design wind speed, the b/d ratio as well as the roughness category of the site.

The criterion includes an approximation for the fundamental frequency, n_x:

$$n_x \geq \frac{46}{h} \quad [Hz]$$

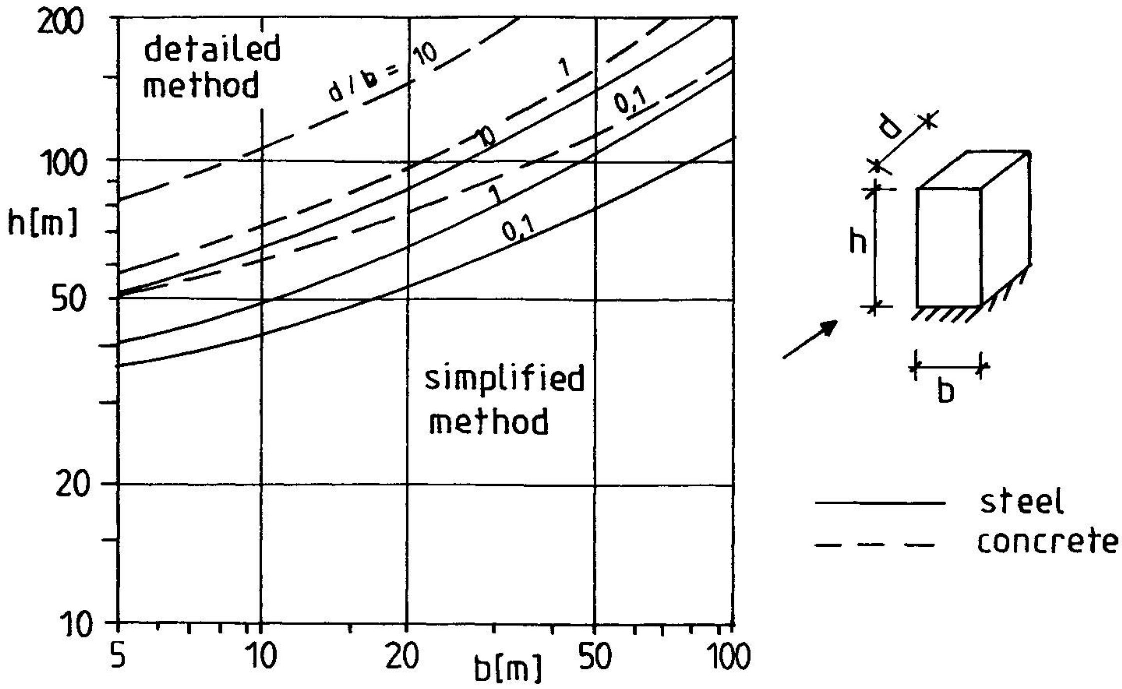


Fig. 2 Geometry criteria for application the simplified method for buildings.

From Fig. 2 it is obvious, that a wide range of buildings can be covered by the simplified method.

For chimneys, towers, bridges and similar slender structures the vortex shedding is the domain criteria. The criteria can be simple expressed by the slenderness h/d (s. Table 1)

	simplified method, if l/d ≤	
chimneys, towers	12	
posts	8	
bridges	slabs	girder
l ≤ 200 m	12	20
	24	40

Table 1 Criteria for application the simplified method for bridges and elongated vertical structures.

4. COMPARISON OF SIMPLIFIED AND DETAILED METHOD

The comparison is made here for the resultant wind force, only. The resultant wind force, F_w, in the detailed method is

$$F_w = c_f \cdot A_{ref}\left(1+2g_x I_v\sqrt{Q_o^2+R_x^2}\right) c_r^2(z_{ref}) \cdot c_t^2(z_{ref}) \cdot c_x^2(x)\frac{\rho}{2}v_{ref}$$

where the quantities g_x, I_v, Q_o, R_x, $c_r(z_{ref})$, $c_t(z_{ref})$, $c_x(x)$ depend on the size of the structure, its natural frequency n_x, its damping δ_x, the aerodynamic parameters of the wind and the characteristic of the site fetch. For the simplified method the following approximation has been made:

g_x = peak factor = 3.5

$\sqrt{Q_o^2+R_x^2}$ = background (Q_o) and frequency function (R_x) = 1

$c_t(z_{ref})$ = topography coefficient = 1

$c_x(x)$ = transition coefficient = 1

We get the expression for F_w in the simplified version:

$$F_w = c_f \cdot A_{ref}\,(1 + 7\,I_v)\,c_r^2(z_{ref}) \cdot \rho/2\ v_{ref}^2$$

or

$$F_w = c_f \cdot c_e(z_{ref}) \cdot \rho/2\ v_{ref}^2\ A_{ref}$$

where

$c_e(z_{ref})$ = $(1 + 7\,I_v)\,c_r^2(z_{ref})$ = exposure coefficient (see Fig. 3), which includes the turbulence of the wind, I_v, and the roughness coefficient, $c_r(z_{ref})$, (wind speed variation versus heigth of the four roughness categories).

c_f = force coefficient which is given in Annex B of EC 1, part 2.7 for the different structures types

A_{ref} = reference area, which is related to c_f and defined in Annex B, together with c_f

z_{ref} = reference height of the structure which is referred to c_f and defined in Annex B together with c_f

ρ = air density = 1,25 kg/m^3

v_{ref} = reference wind speed, which is the mean wind velocity at **10 m above flat open country** (category 2 of the roughness categories) averaged over a **period of 10 min** with an annual **probability of exceedence of 0,02** (50 years return period). It can be found in the detailed wind maps of Annex A of EC 1, part 2.7 for the different countries.

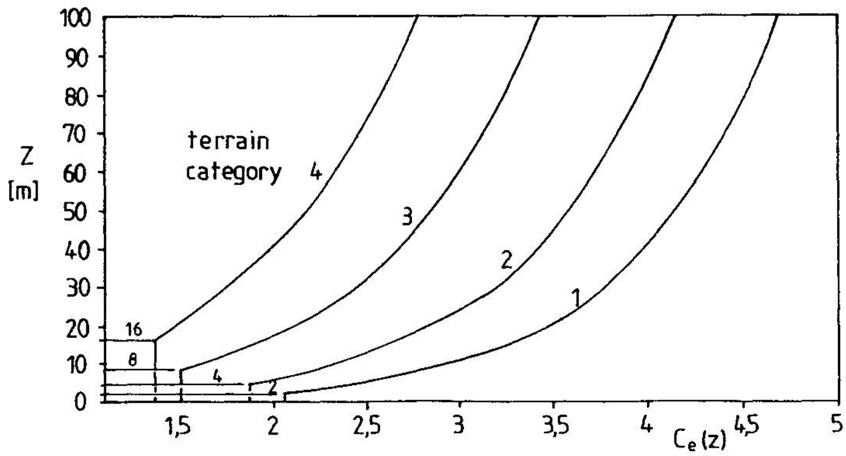
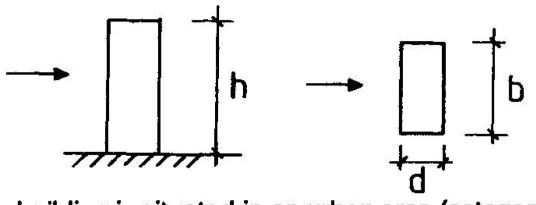


Fig. 3 Exposure coefficient c_e as a function of heigth z above ground.

5. EXAMPLES

5.1 Steel building of different height



h = 10 ÷ 200 m
b = 20 m
d = 10 m

The building is situated in an urban area (category 2) with a reference wind speed of v_{ref} = 27,5 m/s. The force coefficient is set to constant, c_f = 1,3. From the criterion of Fig. 2 the simplified method may be applied up to a heigth of 50 m. In Fig. 4 the calculated wind force per m², F_w/A_{ref} is plotted against the building height h for the simplified and the detailed method. For h < 50 m the result of simplified method is above the result obtained by the detailed method, while for h > 50 m the detailed method has to be applied because of increasing dynamic response.

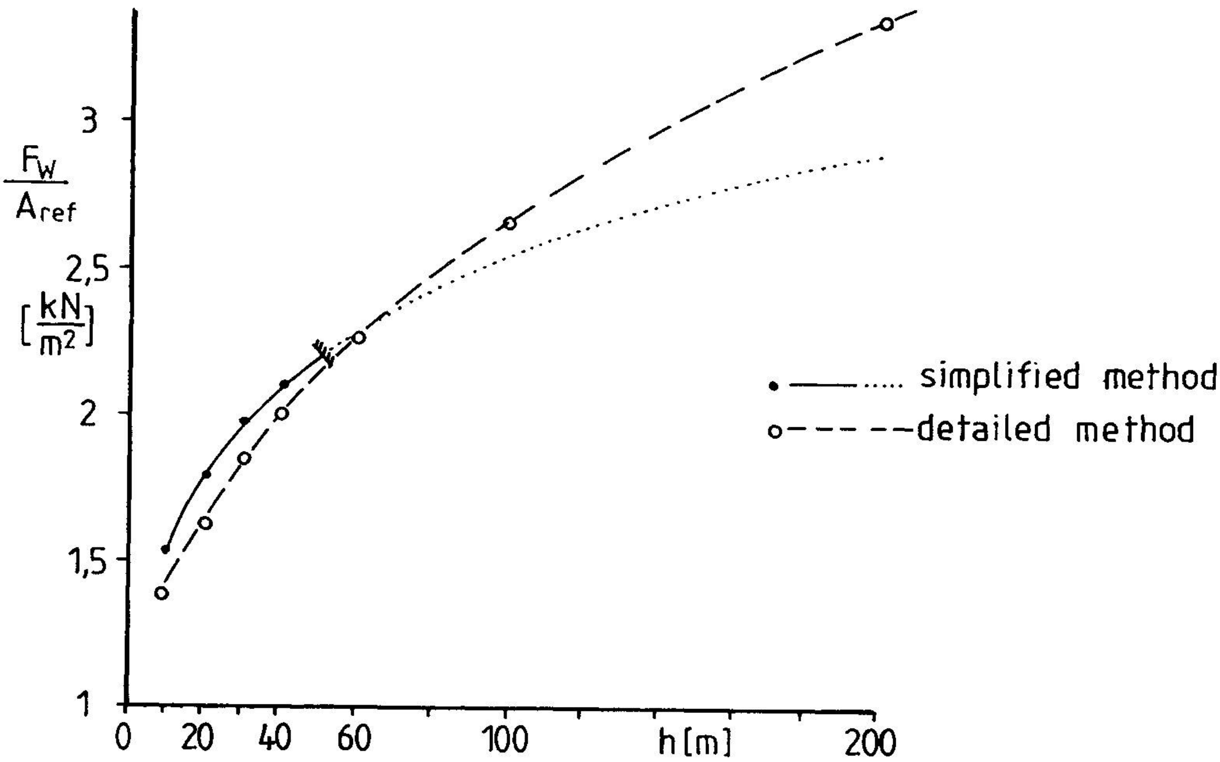
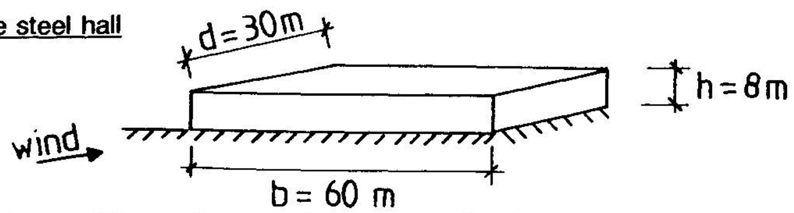


Fig. 4 Calculated wind force per m² for the buildings of example 5.1. Comparison of simplified method with detailed method.

5.2 Large low rise steel hall

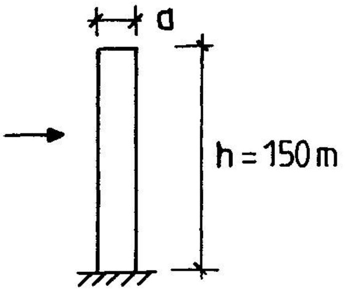


under the same site condition as in example 5.1 we get for the

simplified method: F_w/A_{ref} = 1,40 kN/m²
detailed method: F_w/A_{ref} = 1,19 Kn/m²

i.e. the simplified method presents nearly 18 % higher wind loads. The reason for this fact in the neglected size factor in the simplified method.

5.3 Concrete tower



v_{ref} = 27,5 m/s

roughness category 2

5.3.1 Small slenderness, d = 13 m:

$$\lambda = h/d = 11{,}5 < 12$$

From the criteria for towers and stacks this structures may be calculated with the simplified method. Both calculations, simplified and detailed method come to the same result

$$\frac{F_w}{A_{ref}} = 1{,}47 \ kN/m^2$$

The reason for the good agreement is, that the size factor as well as the dynamic effect may be negligible.

5.3.2 Large slenderness, d = 5 m

$$\lambda = h/d = 30 > 12$$

This structure has to be calculated with the detailed method. The along wind force is

$$\frac{F_w}{A_{ref}} = 2{,}23 \ kN/m^2$$

and is 52 % above the result which would be received with the simplified method.

6. CONCLUSION

The simplified method presents results which are close to those of the detailed method, if the structures are small or rather slender, i. g. the size factor as well as the dynamic effects are negligible. For large but rigid buildings, the size effect reduces the wind load. These effect is included in the detailed method only, and 20% reduction or more can be expected.

If the structures become sensitive to dynamic effects, the detailed method must be used. The simplified method will lead to unsafe results for those cases.

7. REFERENCES

[1] EC 1, part 2.7 Wind load, Static and dynamic action, draft of the Project Team PT 5, Febr. 92

[2] ISO/TC 98/SC 3/WG 2 Wind Action on Structures, Final Draft, July 1990