EN 1991-1-4:2005

Wind actions

EN 1991-1-4:2005 Contents

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Annex

A. Terrain effects

B. Procedure 1 for determining the structural factor

C. Procedure 2 for determining the structural factor

D. Structural factors for different types of structures

E. Vortex shedding and aeroelastic instabilities

F. Dynamic characteristics of structures

Section 1 General – 1.1 Scope

(2) This Part is applicable to:

- Buildings and civil engineering works with heights up to 200 m

- Bridges having no span greater than 200 m, provided that they satisfy the criteria for dynamic response

(3) This part is intended to predict characteristic wind actions on land-based structures, their components and appendages

Section 1 General – 1.1 Scope

Draft corrigendum to EN 1991-1-4:2005
22 January 2008

(11) Guyed masts and lattice towers are treated in EN 1993-3-1 and lighting columns in EN 40

(12) This part does not give guidance on the following aspects:

- **torsional vibrations, e.g. tall buildings with a central core**
- **bridge deck vibrations from transverse wind turbulence**
- **wind actions on cable supported bridges**
- **vibrations where more than the fundamental mode needs to be considered**

Section 2 Design situations

(1)P The relevant wind actions shall be determined for each design situation identified in accordance with EN 1990, 3.2.

(2) Traffic, snow and ice

(3) Execution

(4) Where in design windows and doors are assumed to be shut under storm conditions, the effect of these being open should be treated as an accidental design situation

Section 3 Modelling of wind actions

3.1 Nature

3.2 Representations of wind actions

3.3 Classification of wind actions

(1) Unless otherwise specified, wind actions should be classified as variable fixed actions

3.4 Characteristic values

(1)

Note: All coefficients or models, to derive wind actions from basic values, are chosen so that the probability of the calculated wind actions does not exceed the probability of these basic values

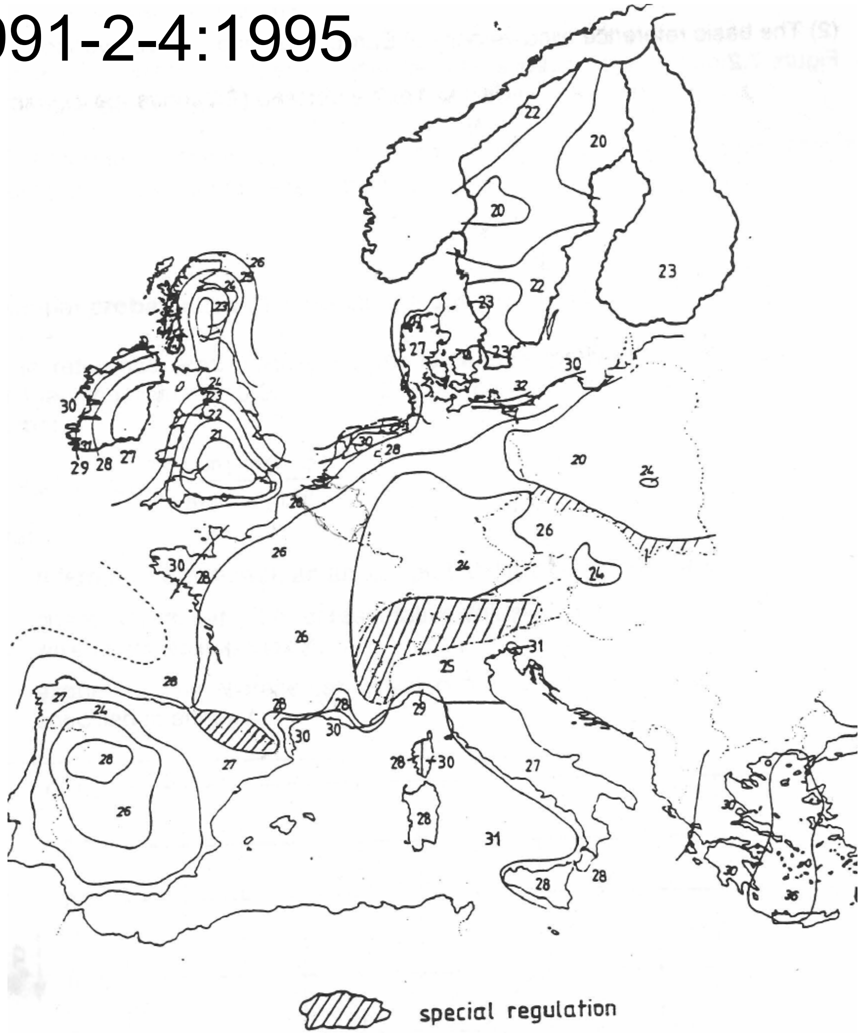
3.5 Models

Section 4 Wind vel. and vel. pres. - 4.2 Basic values

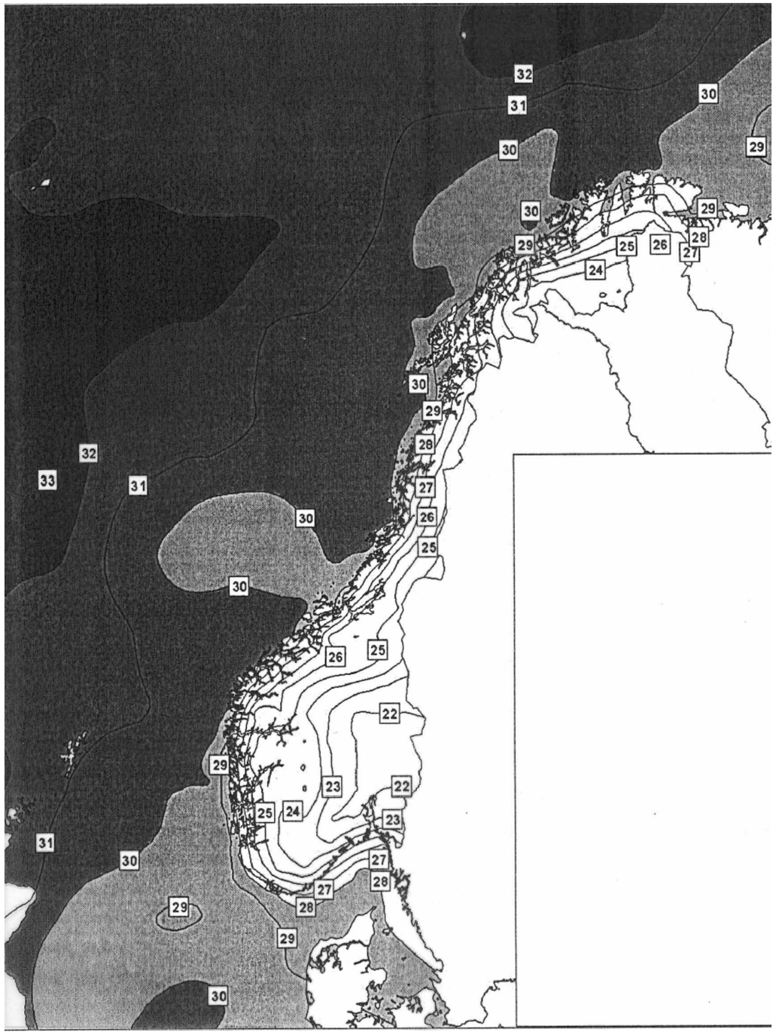
$$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$$

Section 4 Wind vel. and vel. pres. - 4.2 Basic values

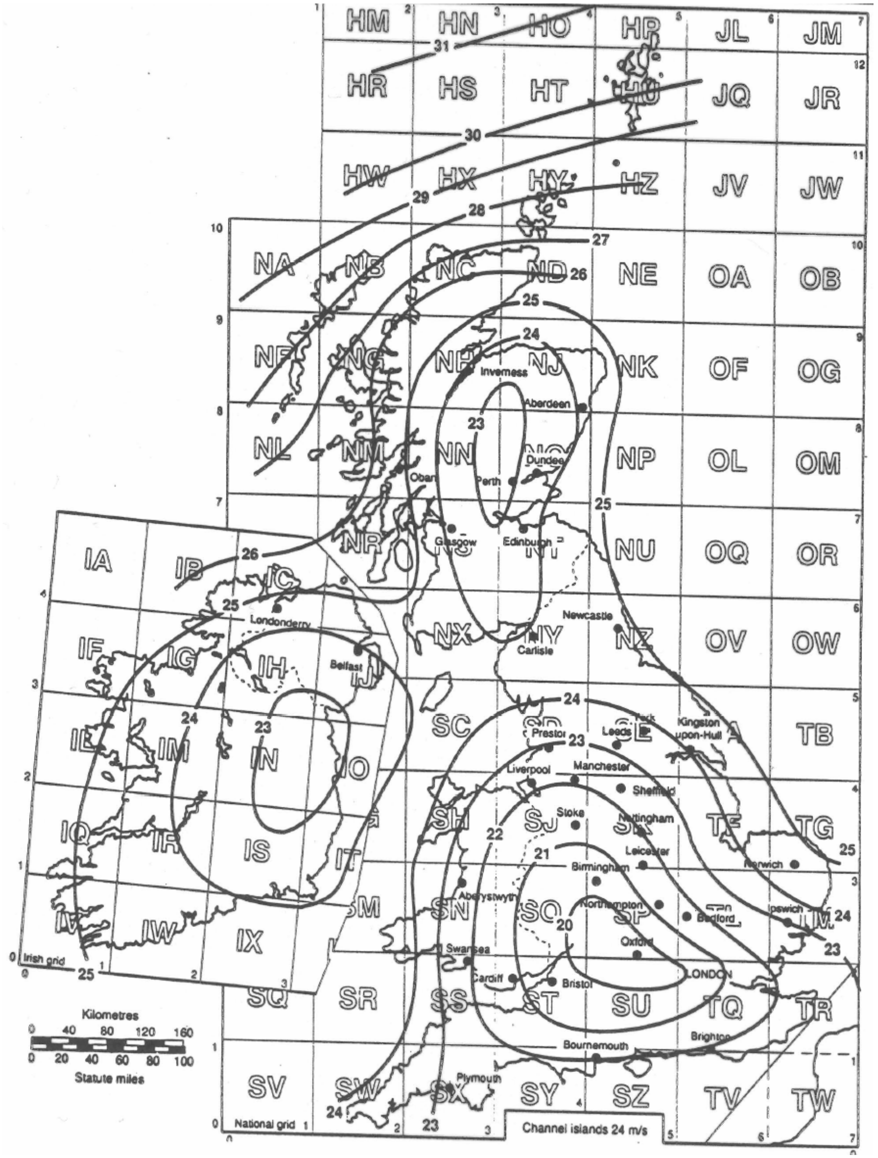
ENV 1991-2-4:1995



Norway: Basic wind velocity. NS 3491-4:2002



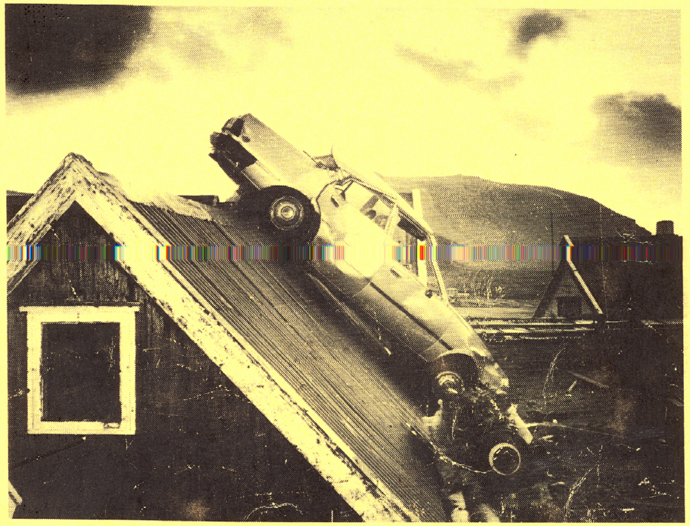
UK: Basic wind velocity. BS 6399-2:1997



Faroe Islands – extreme winds

EKSTREMVINDE PÅ FÆRØERNE

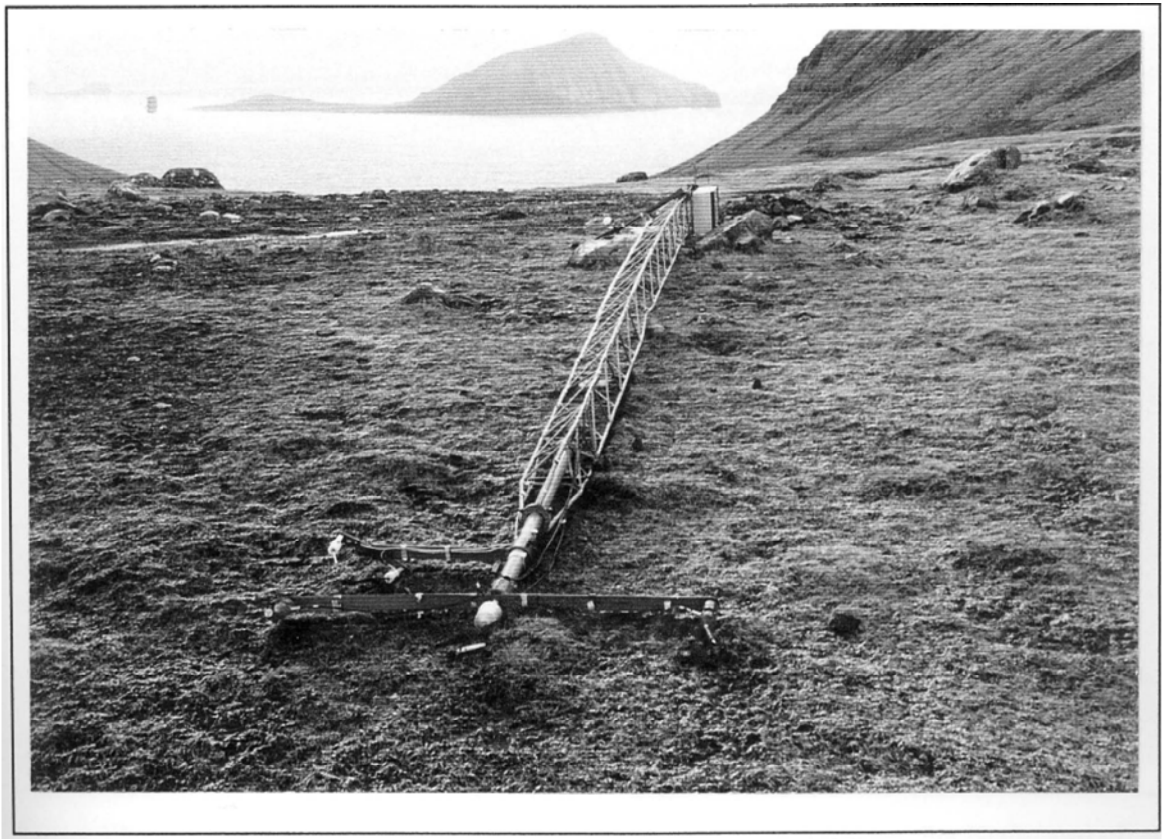
En analyse af ekstreme vindhastigheder



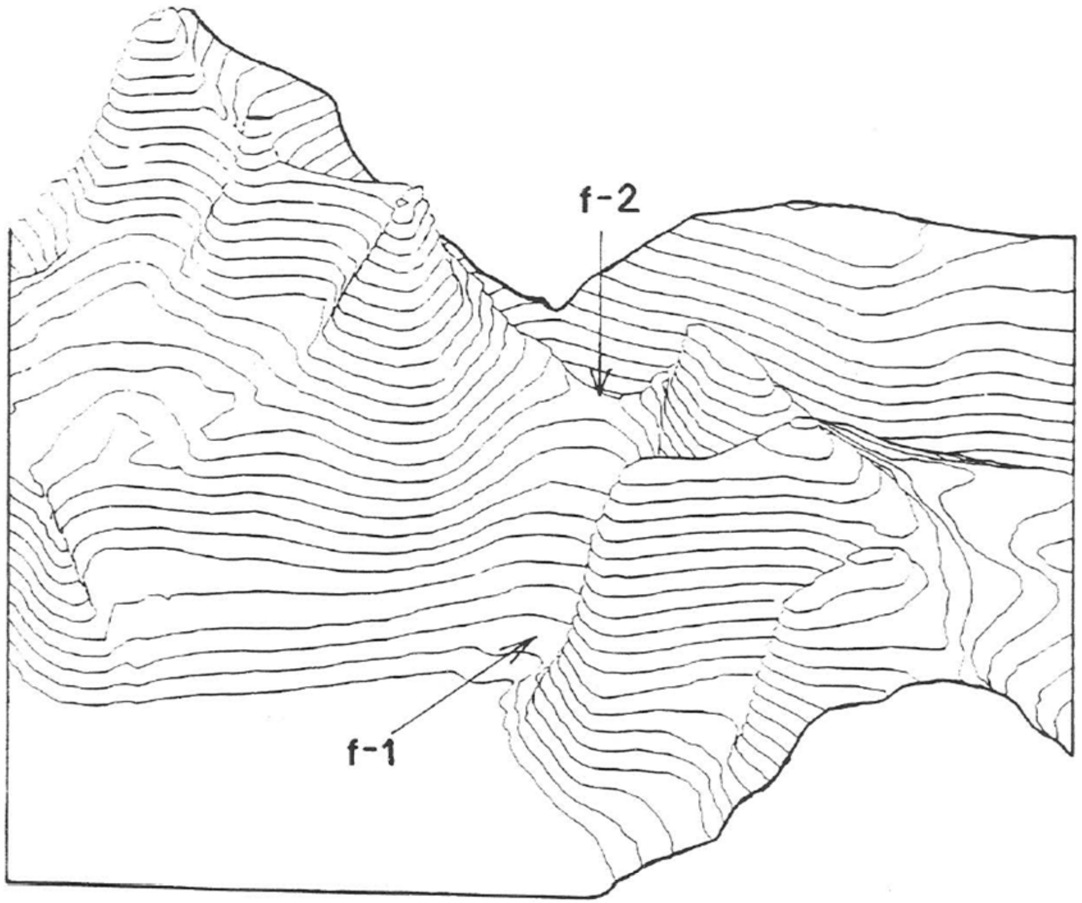
Hovedrapport

Jan Poulsen og Einar Brimnes

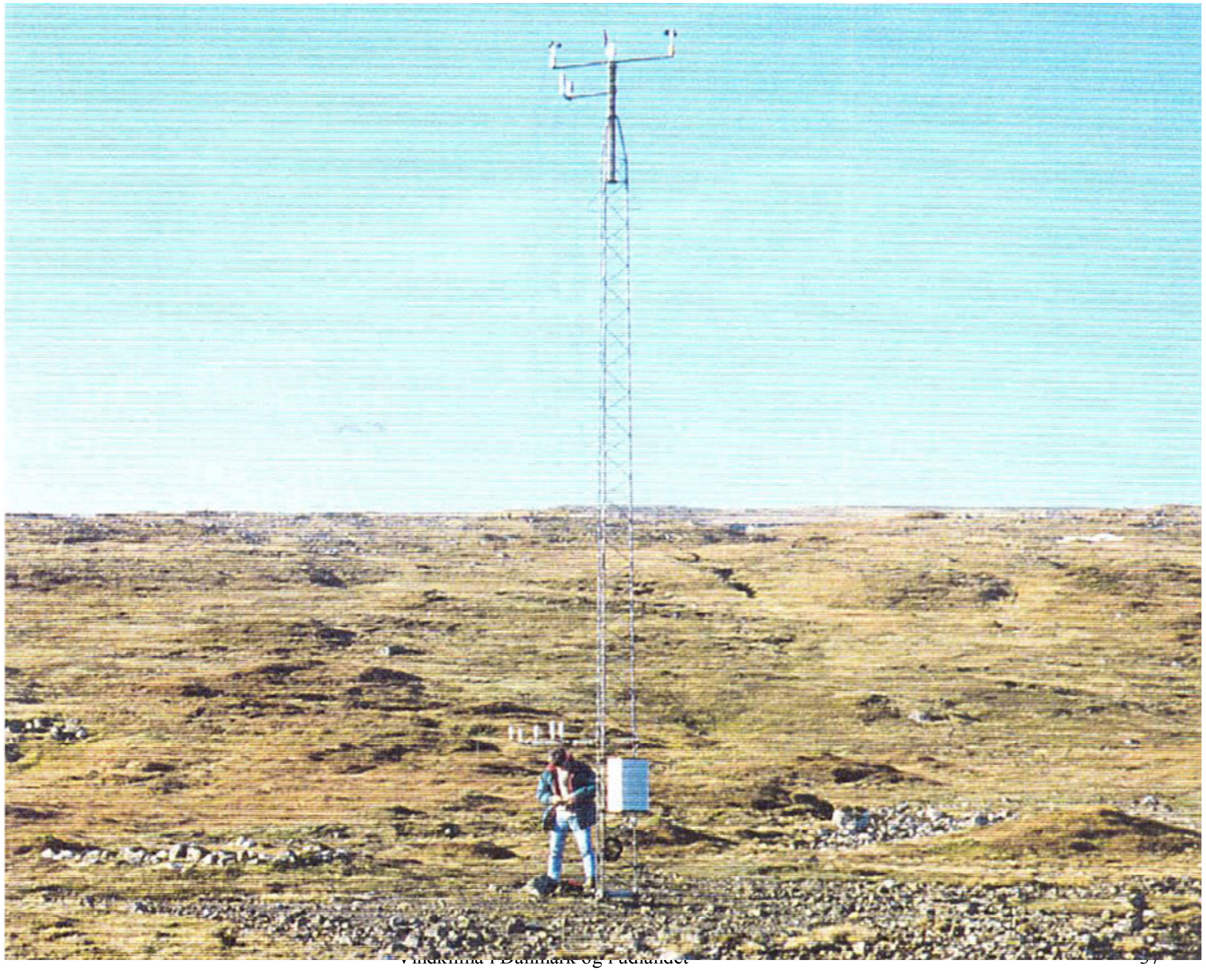
Faroe Islands – extreme winds



Faroe Islands – measuring stations



Faroe Islands - Glyvursnes

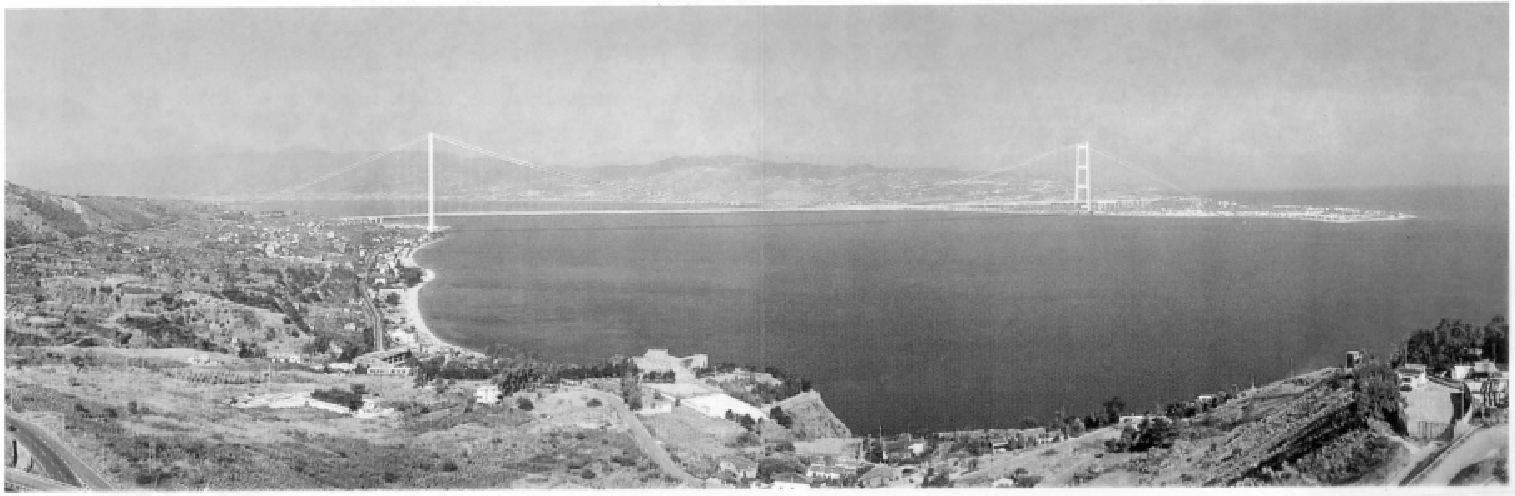


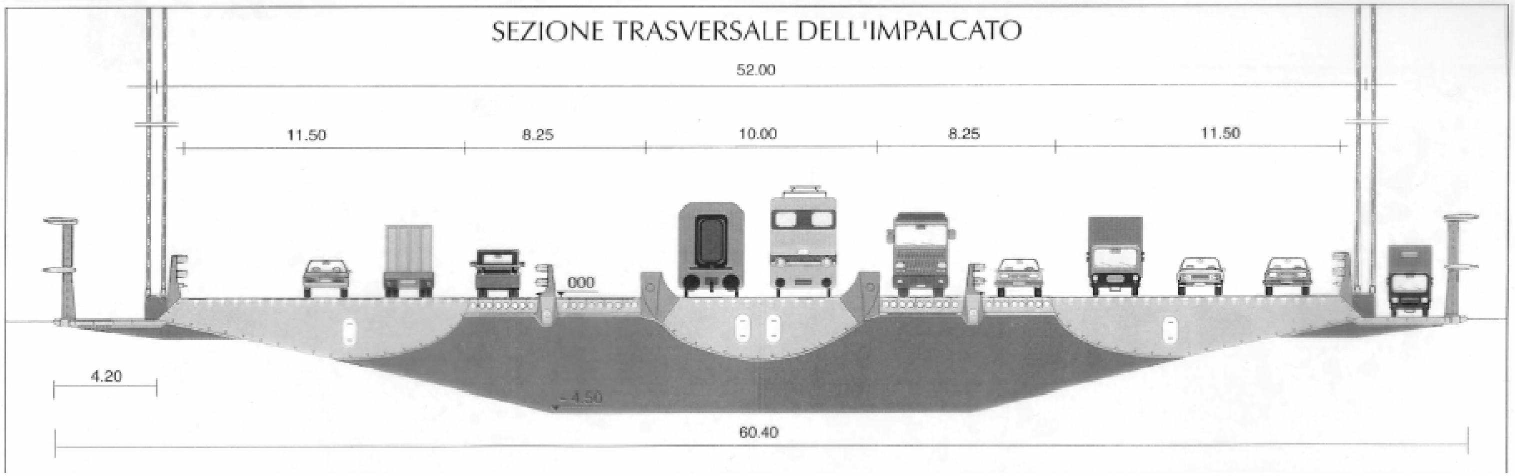
Faroe Islands – basic wind velocities

Station	$V_g(10)$ m/s	$V_g(50)$ m/s	$V_g(100)$ m/s	Ekstrapolation formel
f-1 Norðradalur	-	-	-	-
f-2 Norðradalsskarð	52	58	61	41,8 + 4,24 ln T
f-3 Sund	20	23	24	16,1 + 1,75 ln T
f-4 Oyrareingir	31	35	37	24,2 + 2,86 ln T
f-5 Skála	27	31	32	21,7 + 2,31 ln T
f-6 Leirvík	25	29	30	20,8 + 2,02 ln T
f-7 Klaksvík	25	28	29	20,5 + 1,84 ln T
f-8 Glyvursnes	31	35	36	25,1 + 2,41 ln T

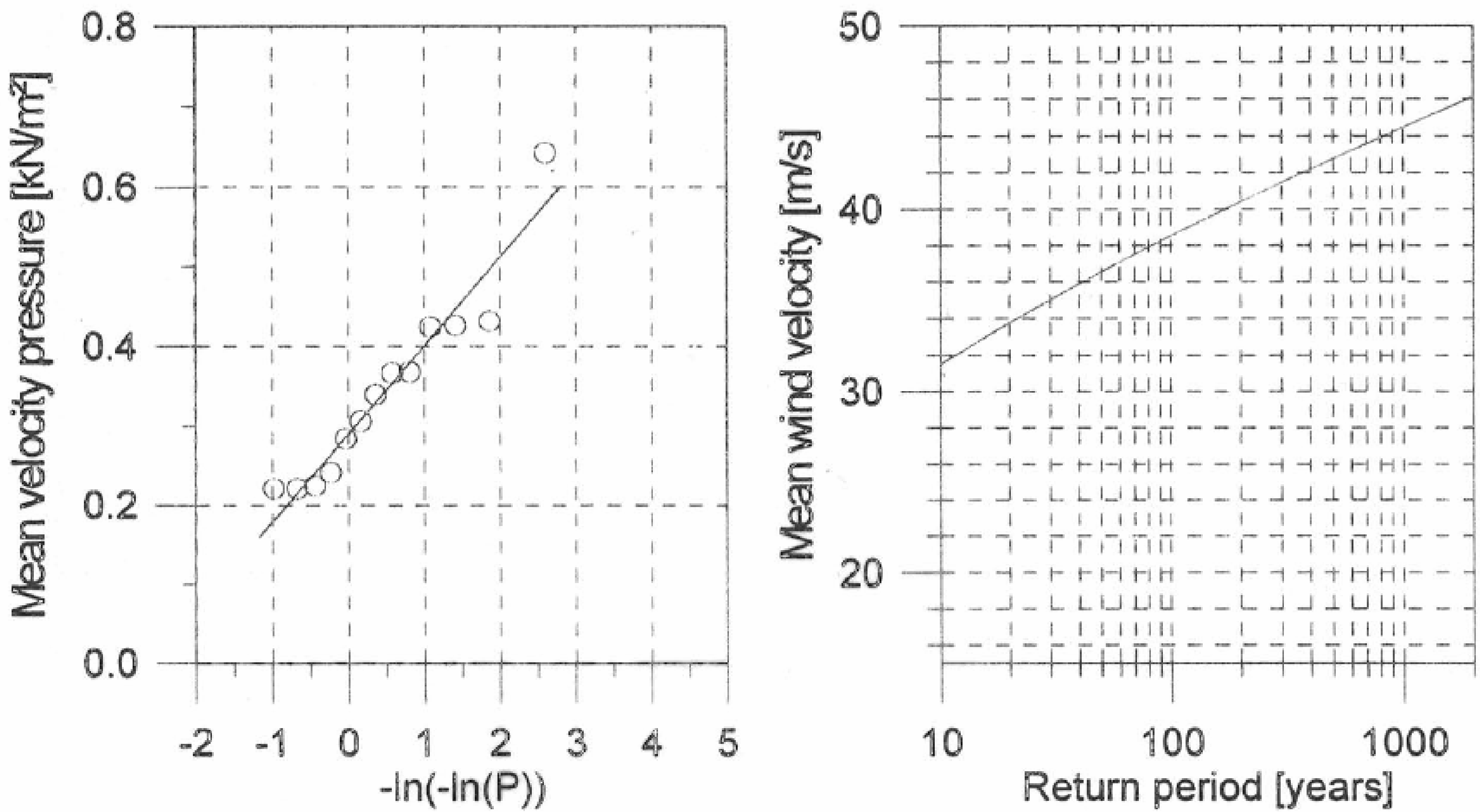
Italy - Messina

Il Progetto di Massima Definitivo



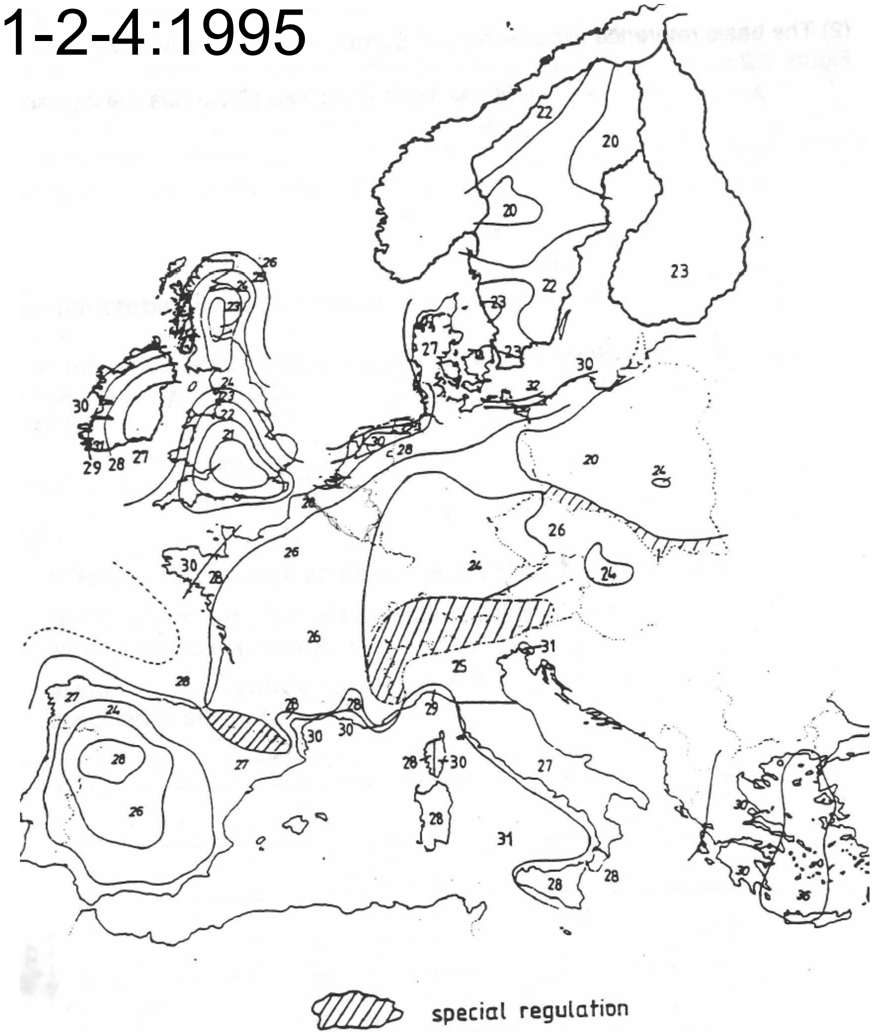


Southerly winds at Messina – bridge deck height

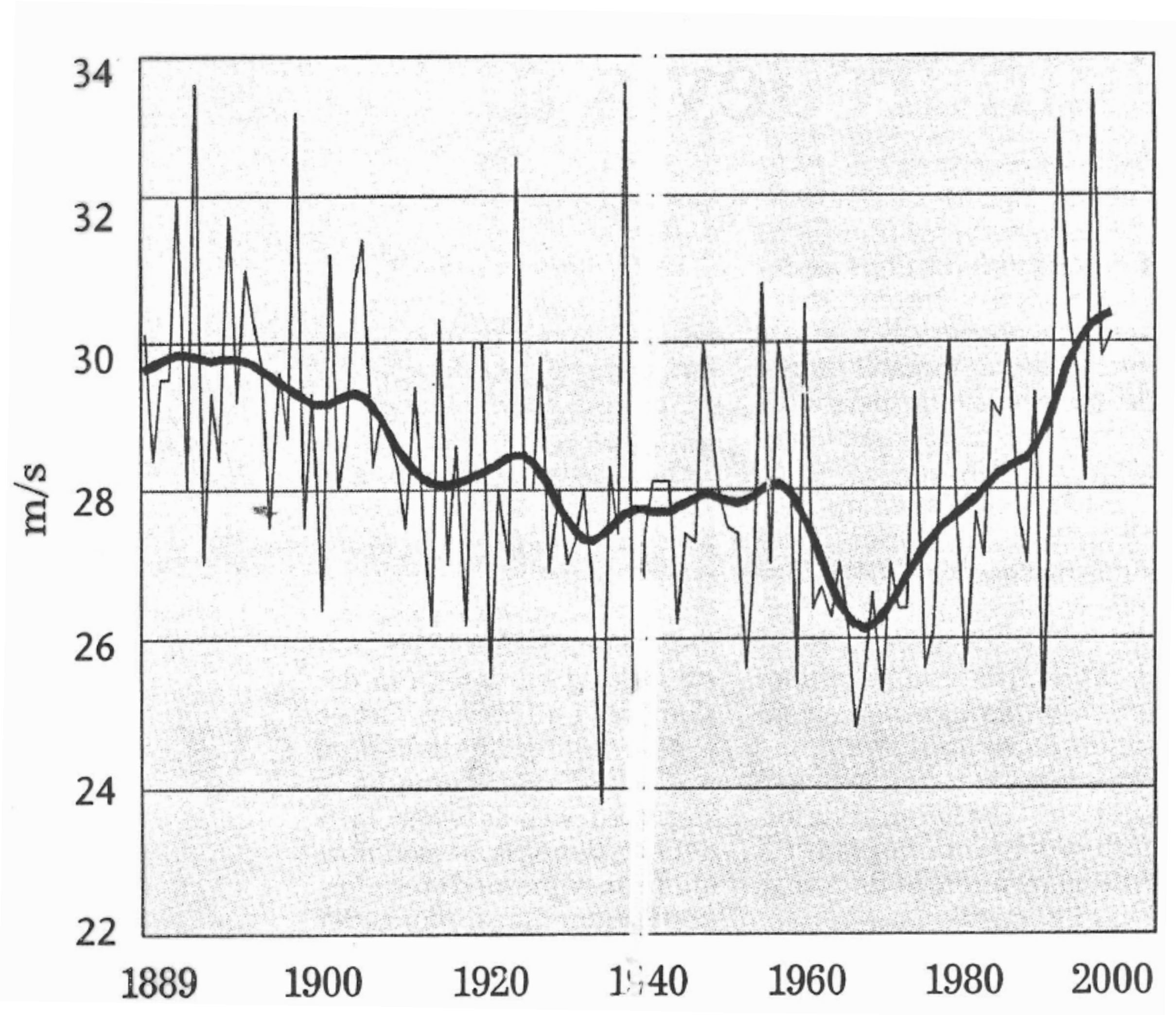


Basis for updated European wind map?

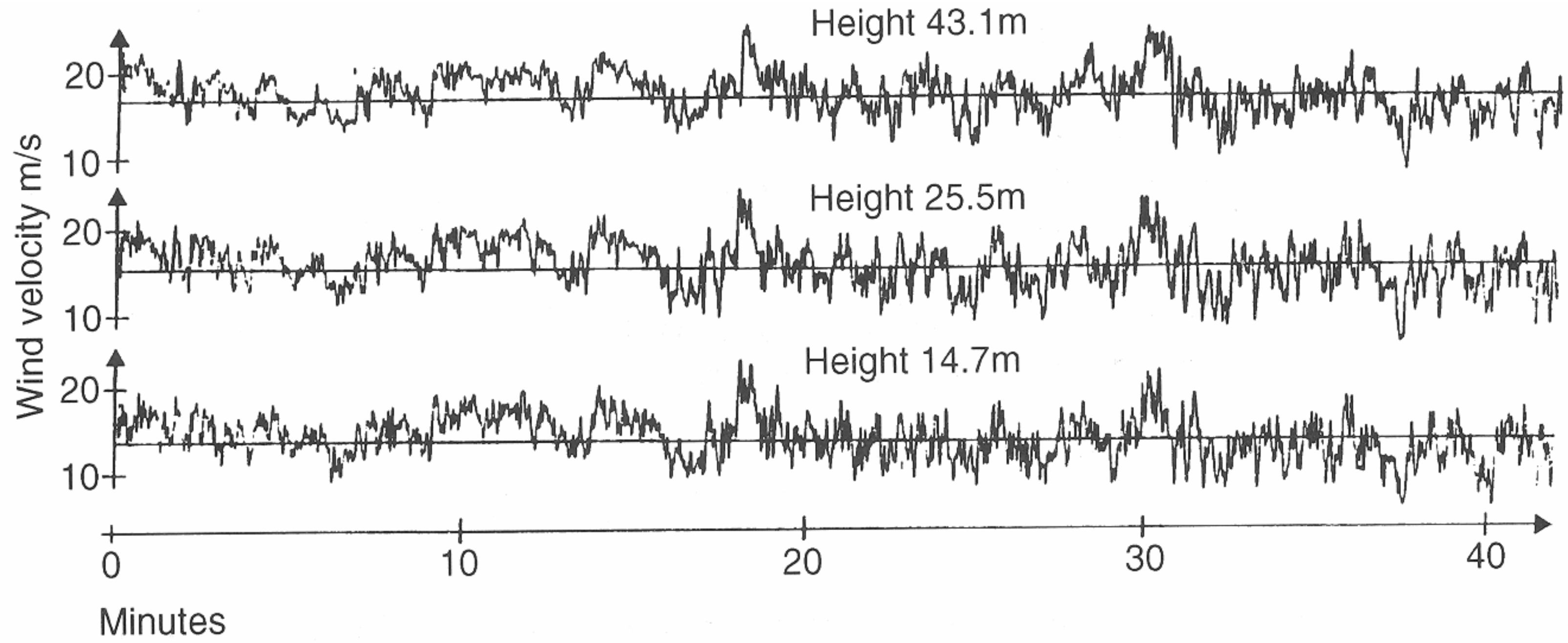
ENV 1991-2-4:1995



Climatological changes?



Influence of terrain - measured wind velocities



Section 4.3 Mean wind

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

Section 4.3.2 Terrain roughness

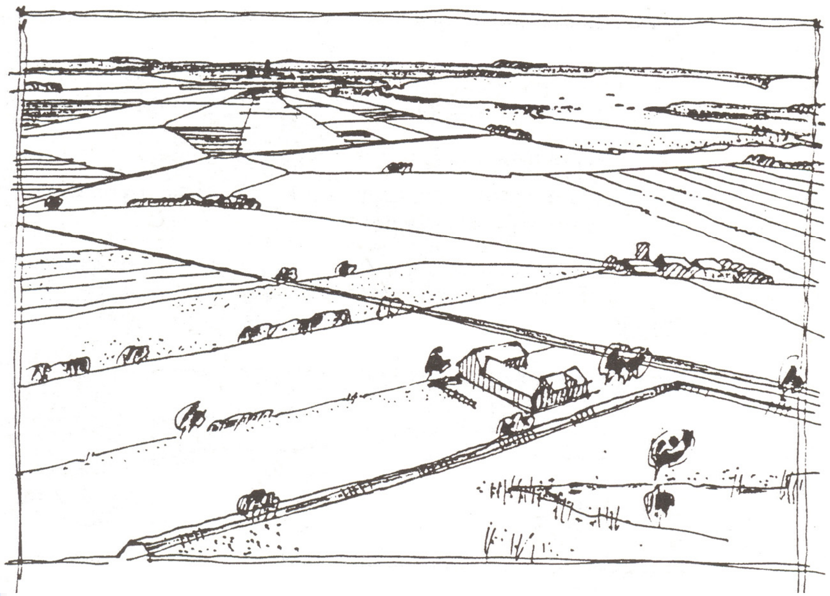
$$c_r(z) = k_r \cdot \ln(z / z_0)$$

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}} \right)^{0{,}07} \qquad z_{0,II} = 0{,}05\,m$$

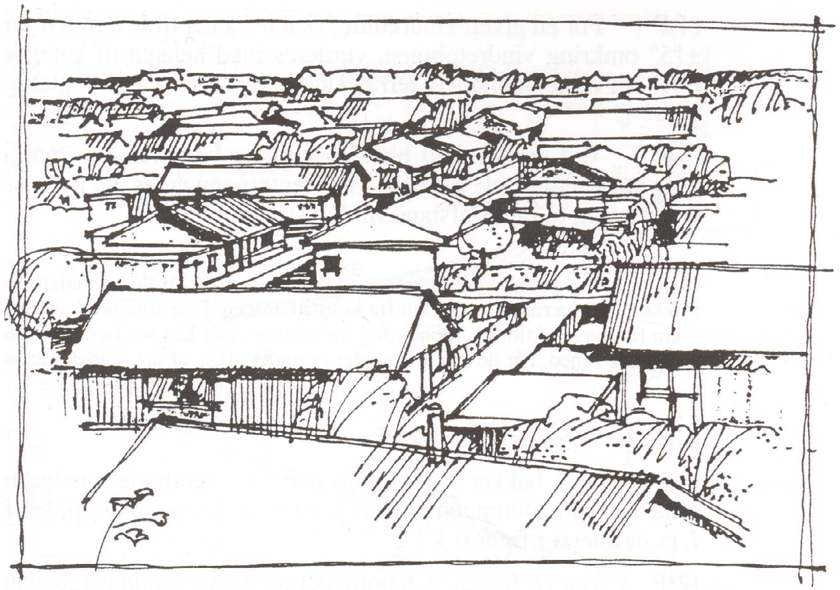
Terrain categories and terrain parameters

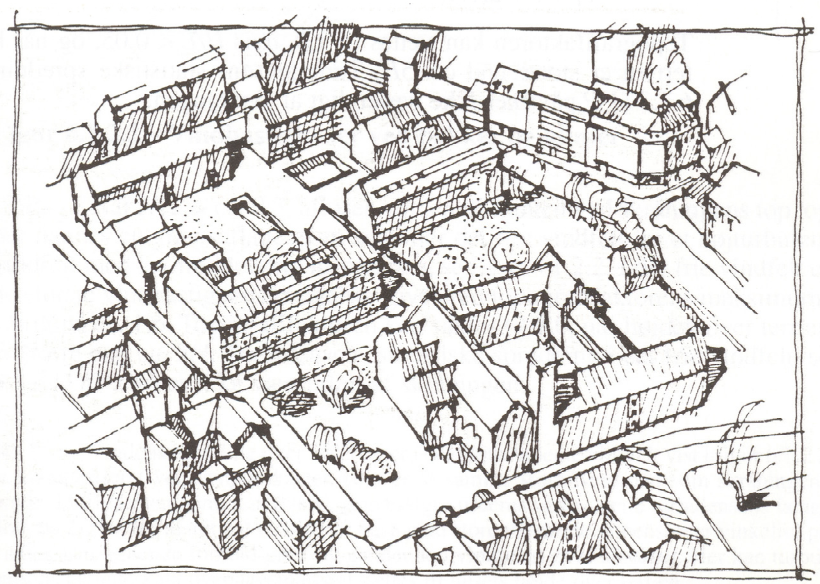
Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
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)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
NOTE: The terrain categories are illustrated in A.1.			

Annex A: Terrain category I and II

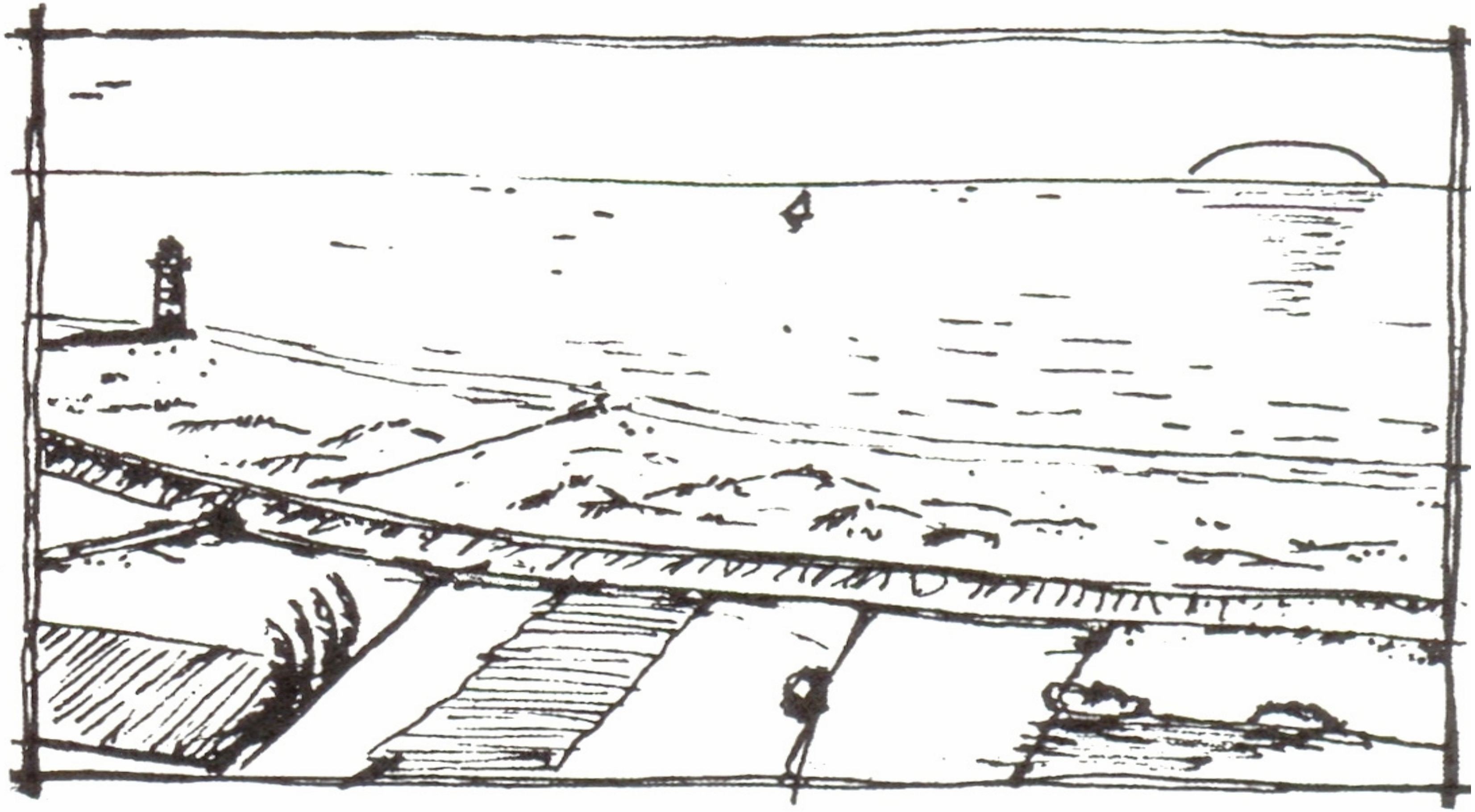


Annex A: Terrain category III and IV



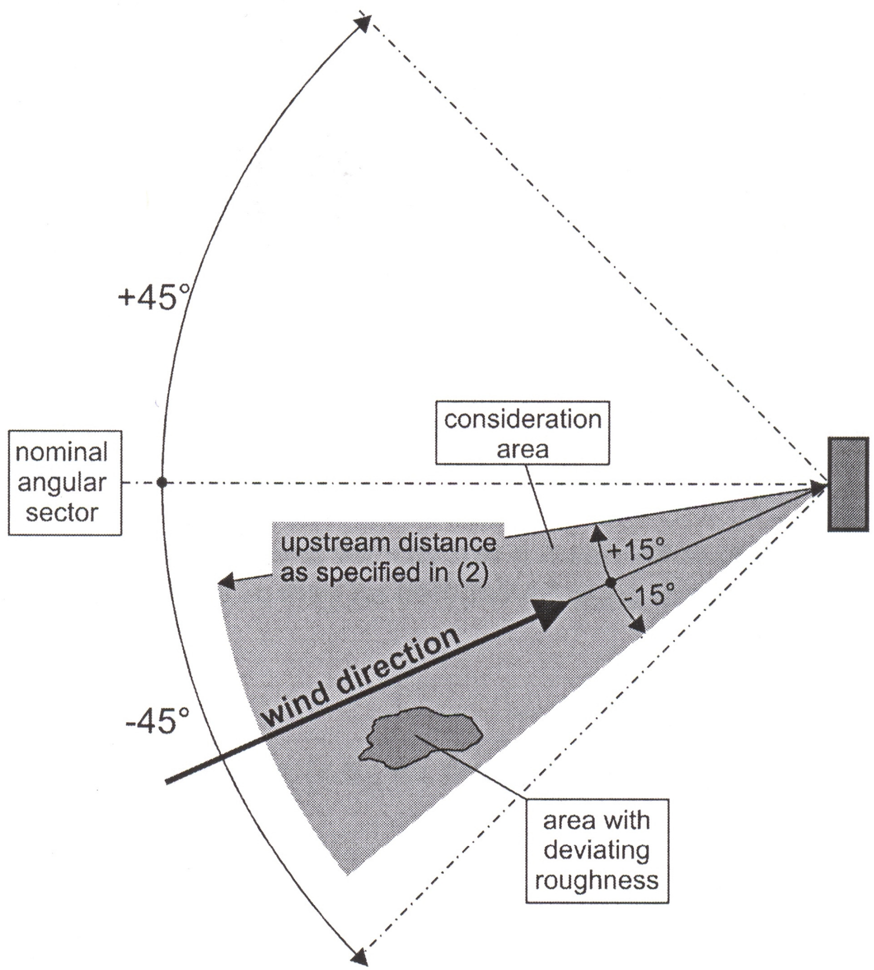


Annex A: Terrain category 0 – coastal area

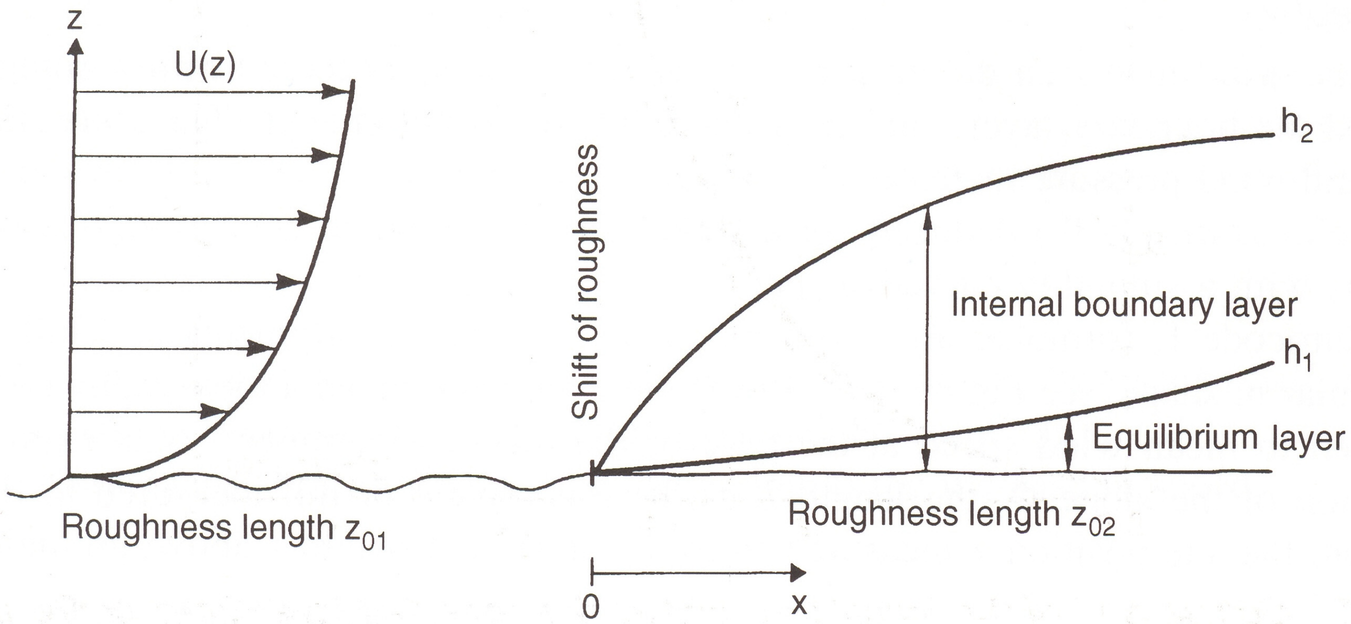


Coastal area exposed to the open sea

Figure 4.1 - Assessment of terrain roughness



A.2 Transition between roughness categories



A.2 Transition between roughness categories

Procedure 1

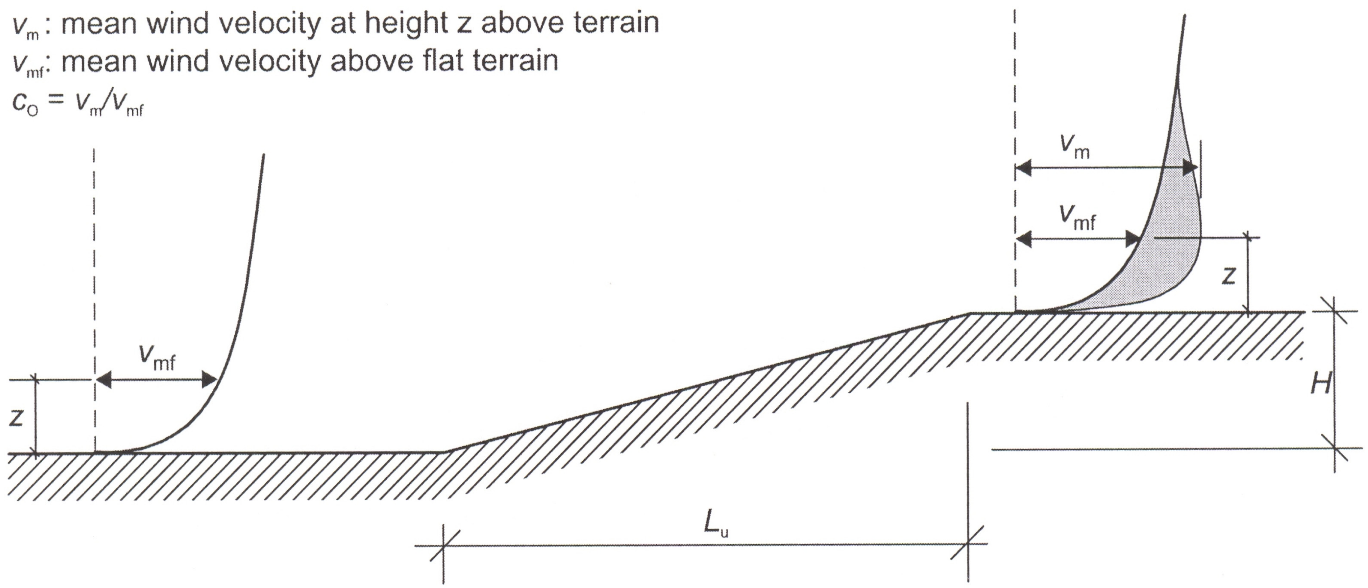
If the structure is situated near a change of terrain roughness at a distance:

- less than 2 km from the smoother category 0
- less than 1 km from the smoother categories I to III

the smoother terrain category in the upwind direction should be used.

Small areas (less than 10% of the area under consideration) with deviating roughness may be ignored.

A.3 Terrain orography. Figure A.1



Section 4.4 Wind turbulence. Turbulence intensity

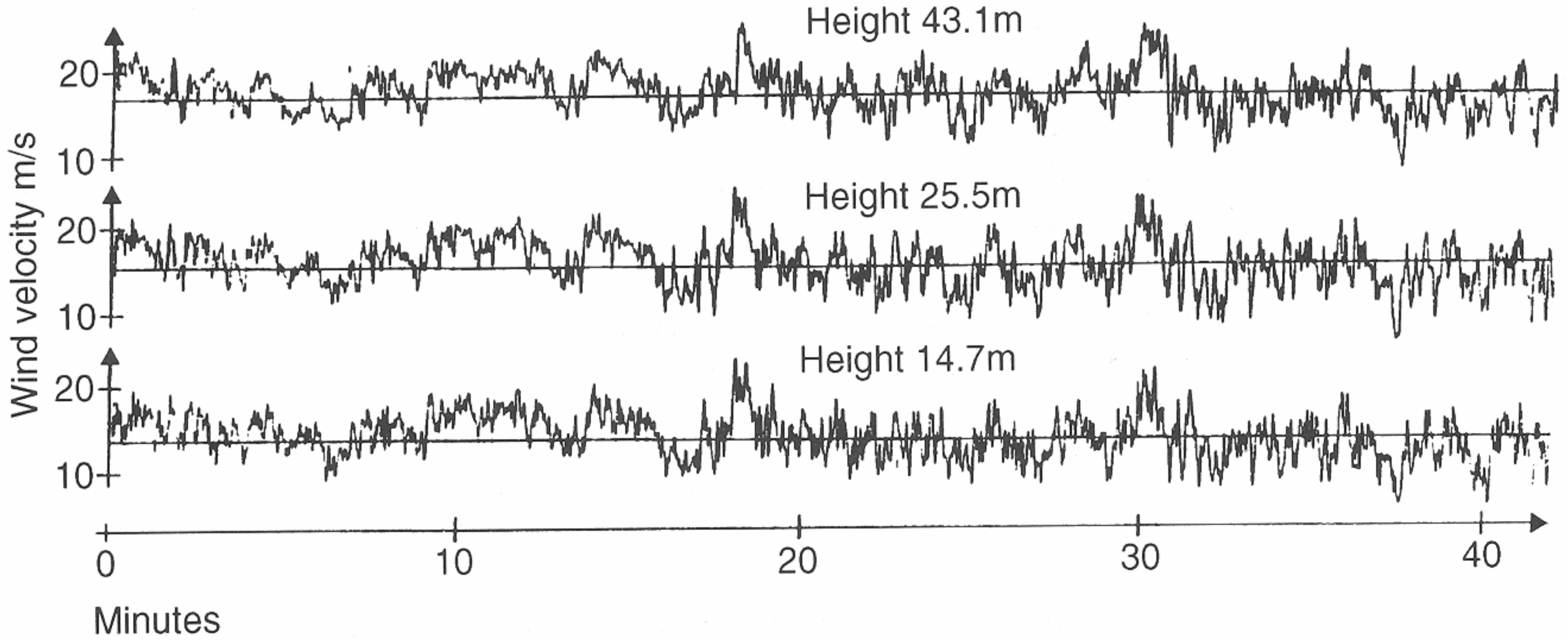
$$I_v(z) = \frac{1}{c_o} \frac{k_I}{\ln(z / z_0)}$$

Section 4.5 Peak velocity pressure, peak velocity

$$q_p(z) = (1 + 7 \cdot I_v(z)) \cdot \frac{1}{2} \cdot \rho \cdot v_m^2(z)$$

$$v_p(z) = \sqrt{1 + 7 \cdot I_v(z)} \cdot v_m(z)$$

Measured wind velocities



Section 5 Wind actions – 5.1 General

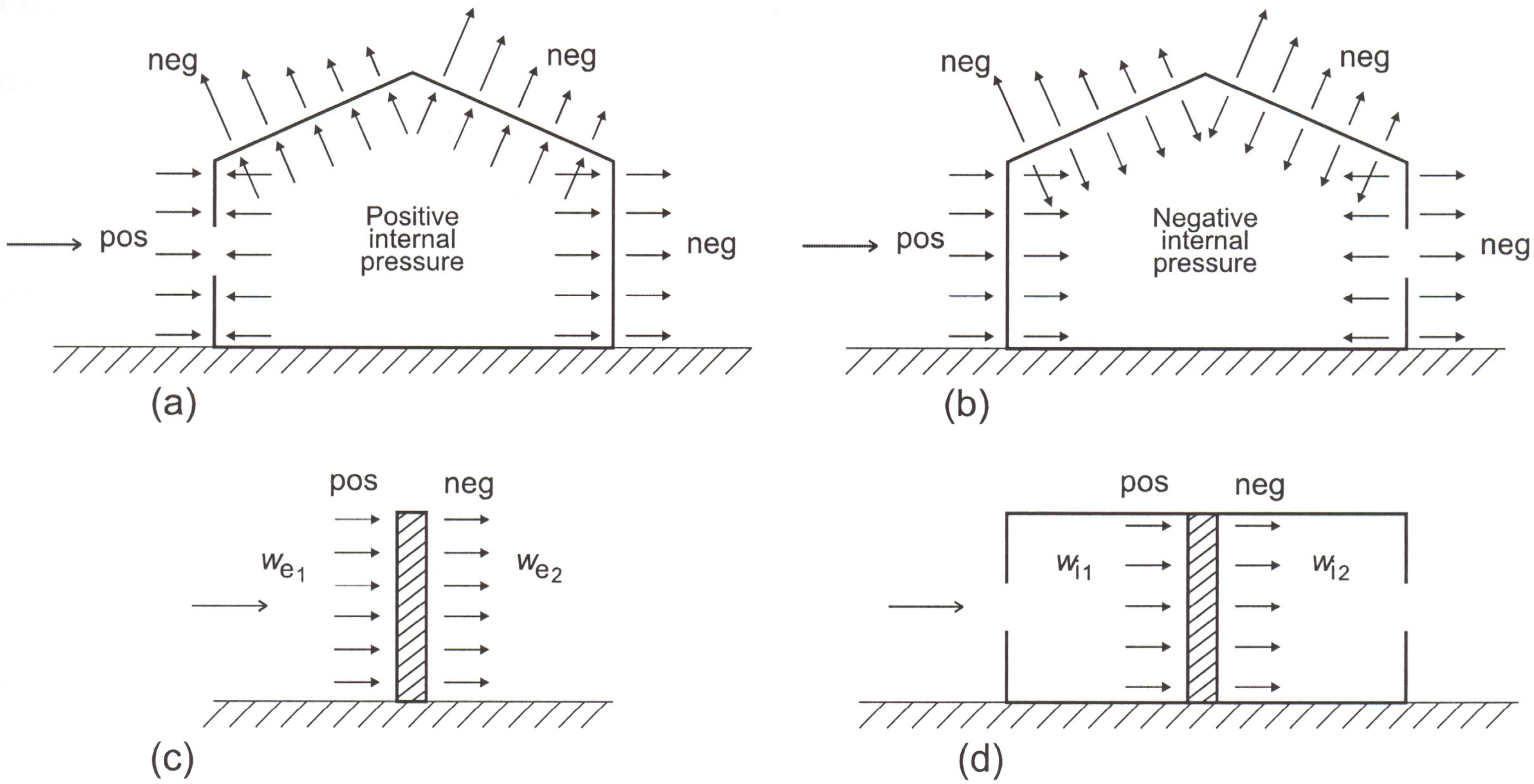
Parameter	Subject Reference
peak velocity pressure q_p	
basic wind velocity v_b	4.2 (2)P
reference height z_e	Section 7
terrain category	Table 4.1
characteristic peak velocity pressure q_p	4.5 (1)
turbulence intensity I_v	4.4
mean wind velocity v_m	4.3.1
orography coefficient $c_o(z)$	4.3.3
roughness coefficient $c_r(z)$	4.3.2
Wind pressures, e.g. for cladding, fixings and structural parts	
external pressure coefficient c_{pe}	Section 7
internal pressure coefficient c_{pi}	Section 7
net pressure coefficient $c_{p,net}$	Section 7
external wind pressure: $w_e=q_p\, c_{pe}$	5.2 (1)
internal wind pressure: $w_i=q_p\, c_{pi}$	5.2 (2)
Wind forces on structures, e.g. for overall wind effects	
structural factor: $c_s c_d$	6
wind force F_W calculated from force coefficients	5.3 (2)
wind force F_W calculated from pressure coefficients	5.3 (3)

Section 5.2 Wind pressure on surfaces

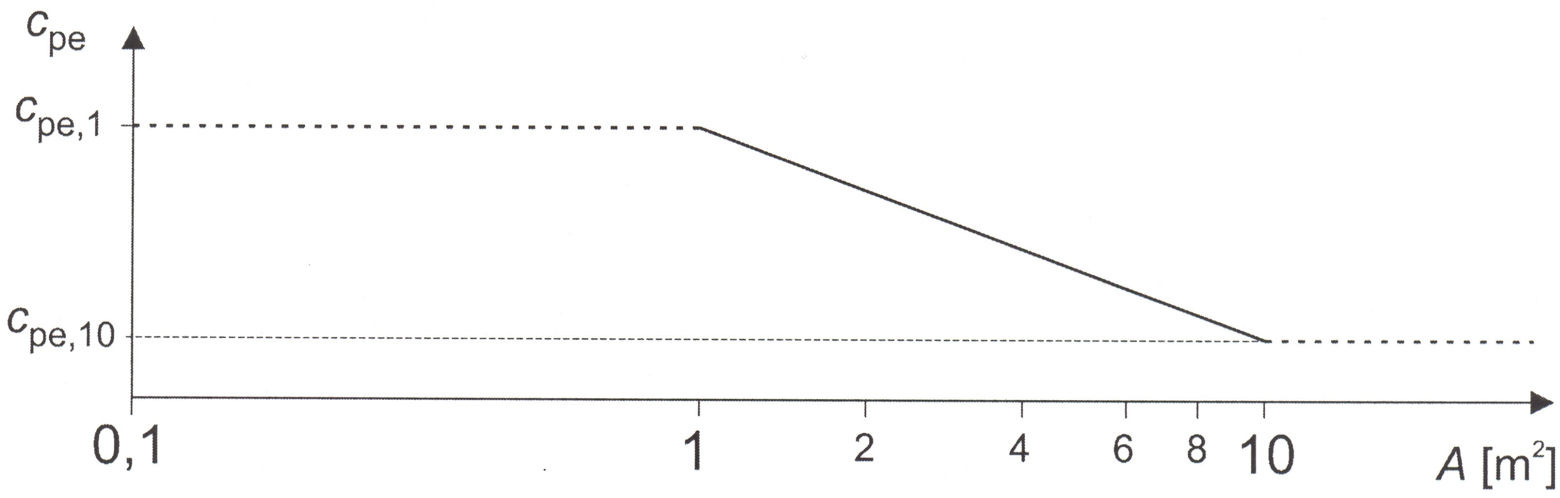
$$w_e = q_p(z_e) \cdot c_{pe}$$

$$w_i = q_p(z_i) \cdot c_{pi}$$

Figure 5.1 – Pressure on surfaces

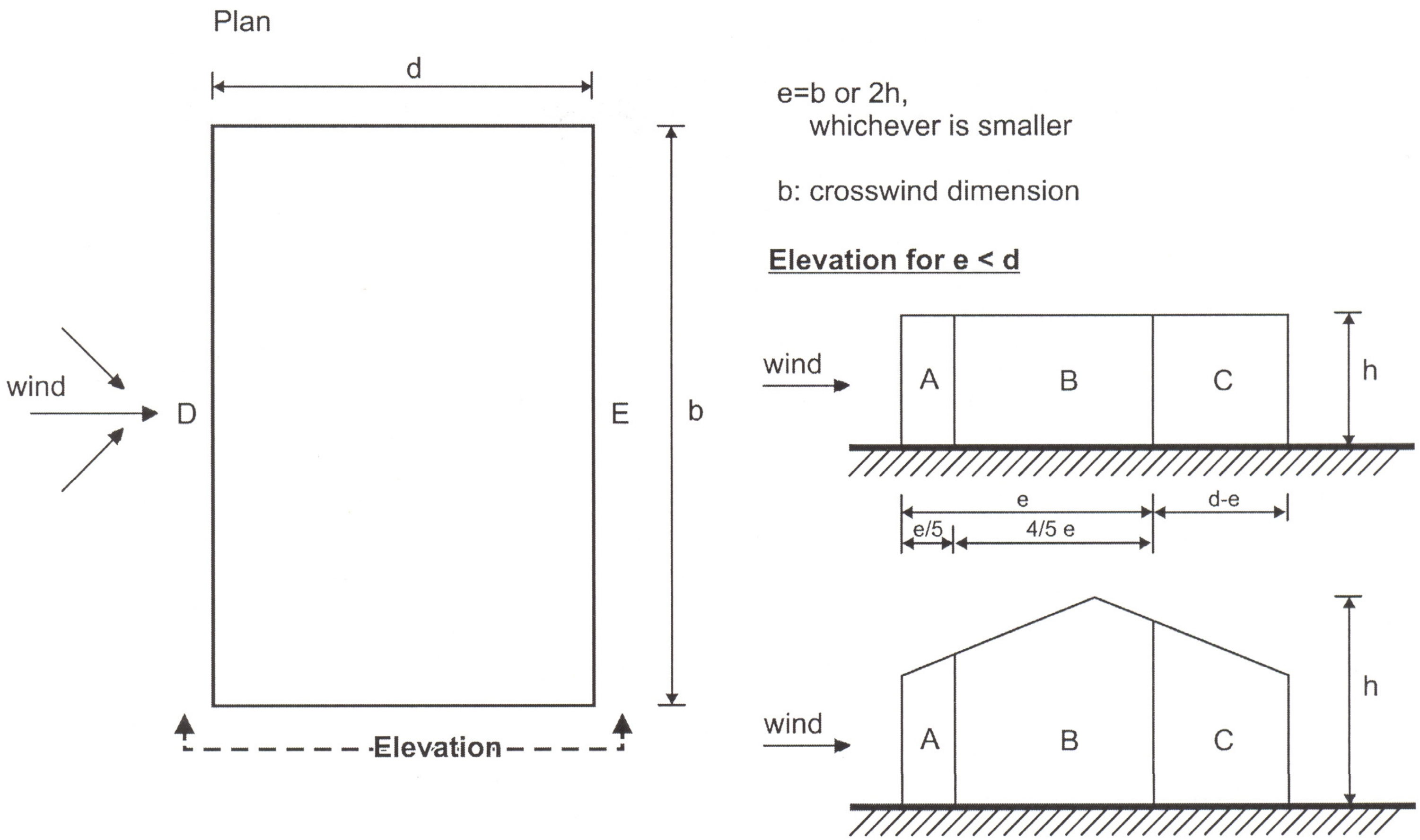


Section 7.2 Pressure coeff. for buildings. Figure 7.2



The figure is based on the following:
for 1 m^2 < A < 10 m^2 $c_{pe} = c_{pe,1} - (c_{pe,1} - c_{pe,10}) \log_{10} A$

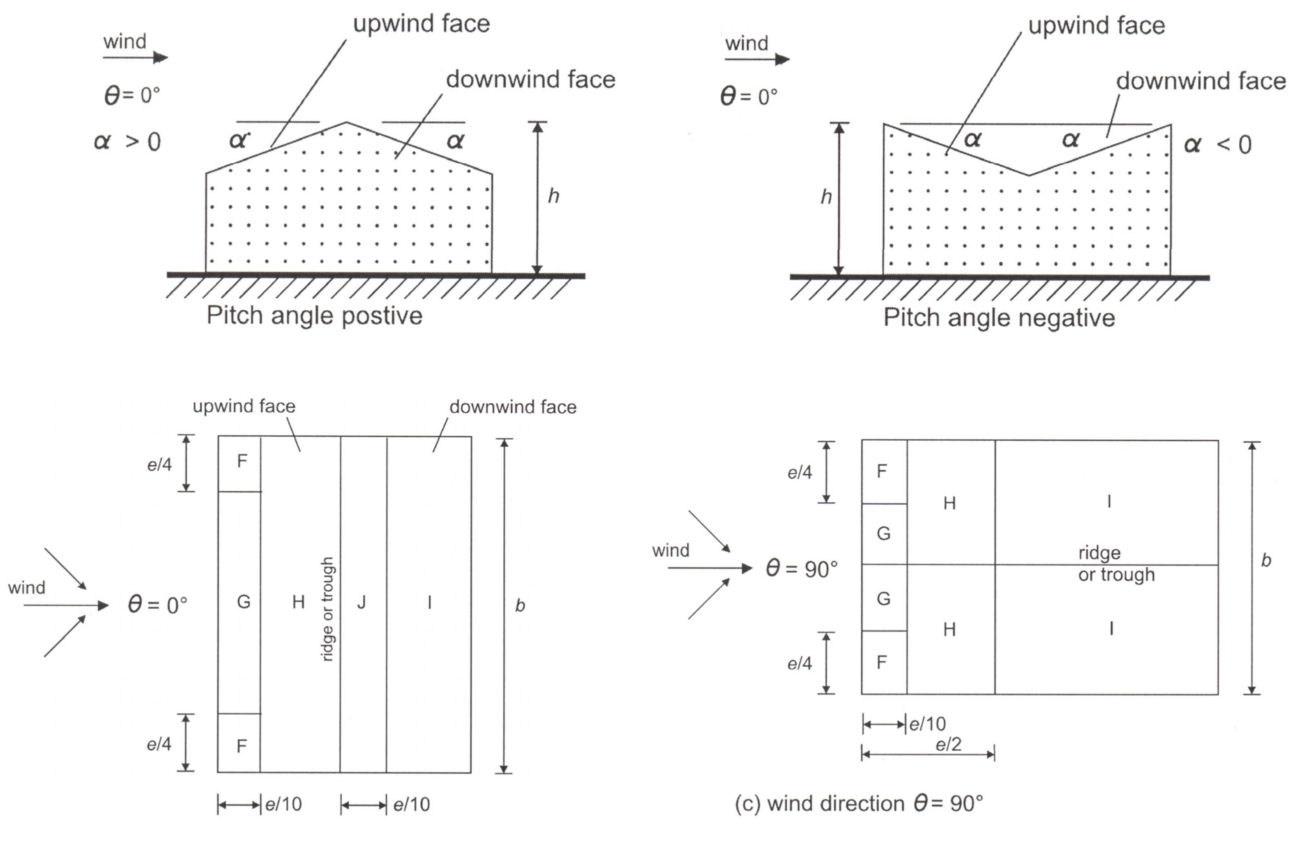
Section 7.2.2 Vertical walls. Figure 7.5



Section 7.2.2 Vertical walls. Table 7.1

Zone	A		B		C		D		E	
h/*d*	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

Section 7.2.5 Duopitch roofs. Figure 7.8



(b) wind direction θ = 0°

Section 7.2.5 Duopitch roofs. Table 7.4a

Pitch Angle α	Zone for wind direction $\theta = 0°$									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-0,6		-0,6		-0,8		-0,7		-1,0	-1,5
-30°	-1,1	-2,0	-0,8	-1,5	-0,8		-0,6		-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

Section 5.3 Wind forces

$$F_w = c_s c_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref}$$

6.2 Determination of structural factor

The structural factor may be taken as 1 for

a) buildings with a height less than 15 m

b) facade and roof elements having a natural frequency greater than 5 Hz

c) framed buildings which have structural walls and which are less than 100 m high and whose height is less than 4 times the in-wind depth

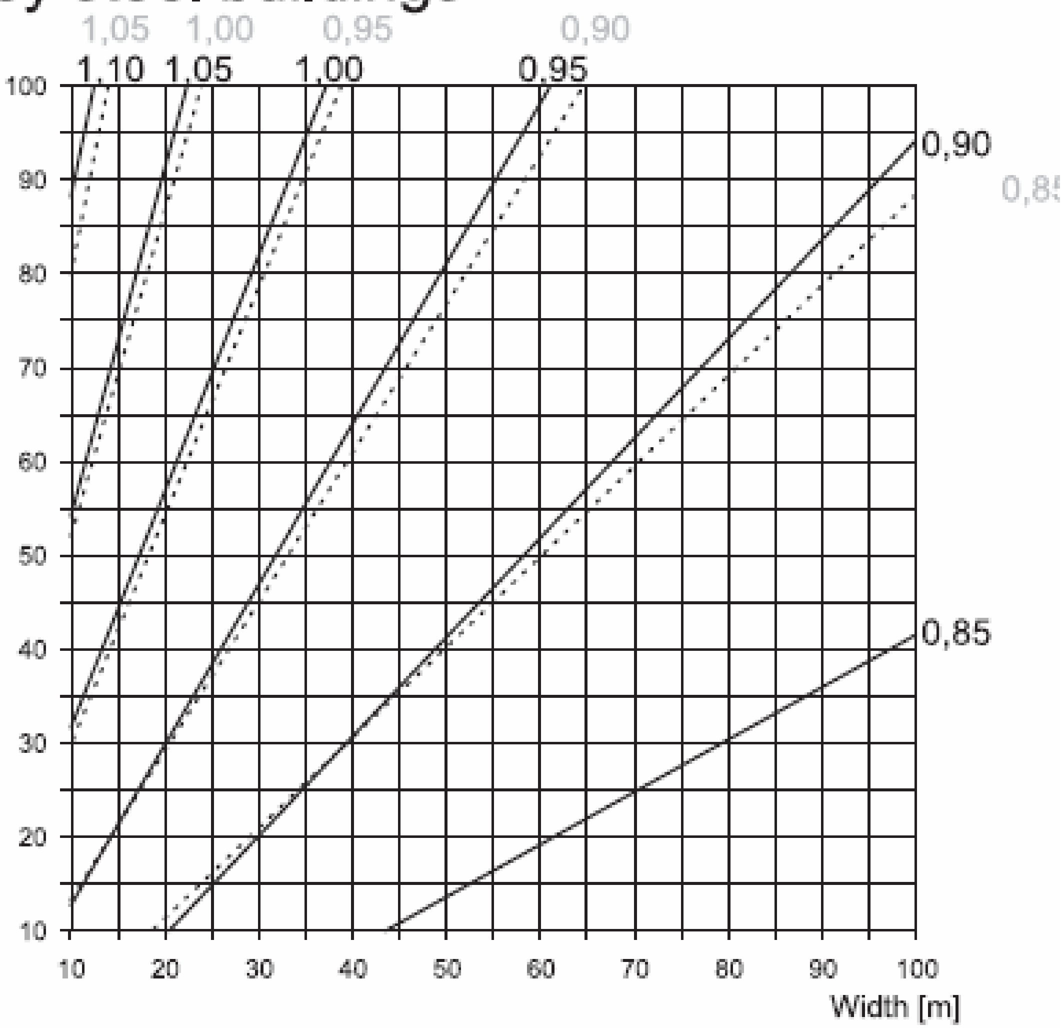
d) chimneys with circular cross-sections whose height is less than 60 m and 6,5 times the diameter

Annex D Structural factor

$c_s c_d$ for multistorey steel buildings

based on:

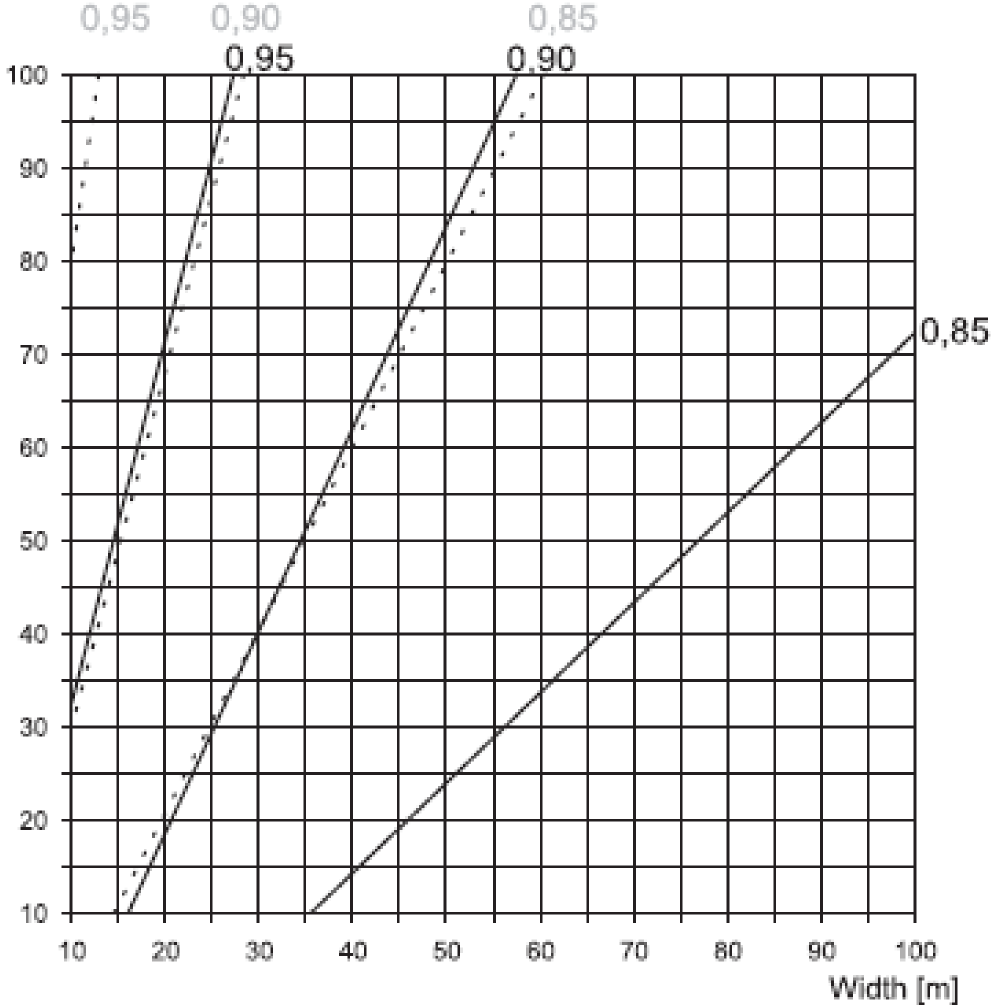
δ_s=0,05
roughness category II (solid lines)
roughness category III (dotted lines)
v_b=28 m/sec
δ_a=0



Annex D Structural factor

$c_s c_d$ for multistorey concrete buildings

based on:
δ_s=0,1
roughness category II (solid lines)
roughness category III (dotted lines)
v_b=28 m/sec
δ_a=0

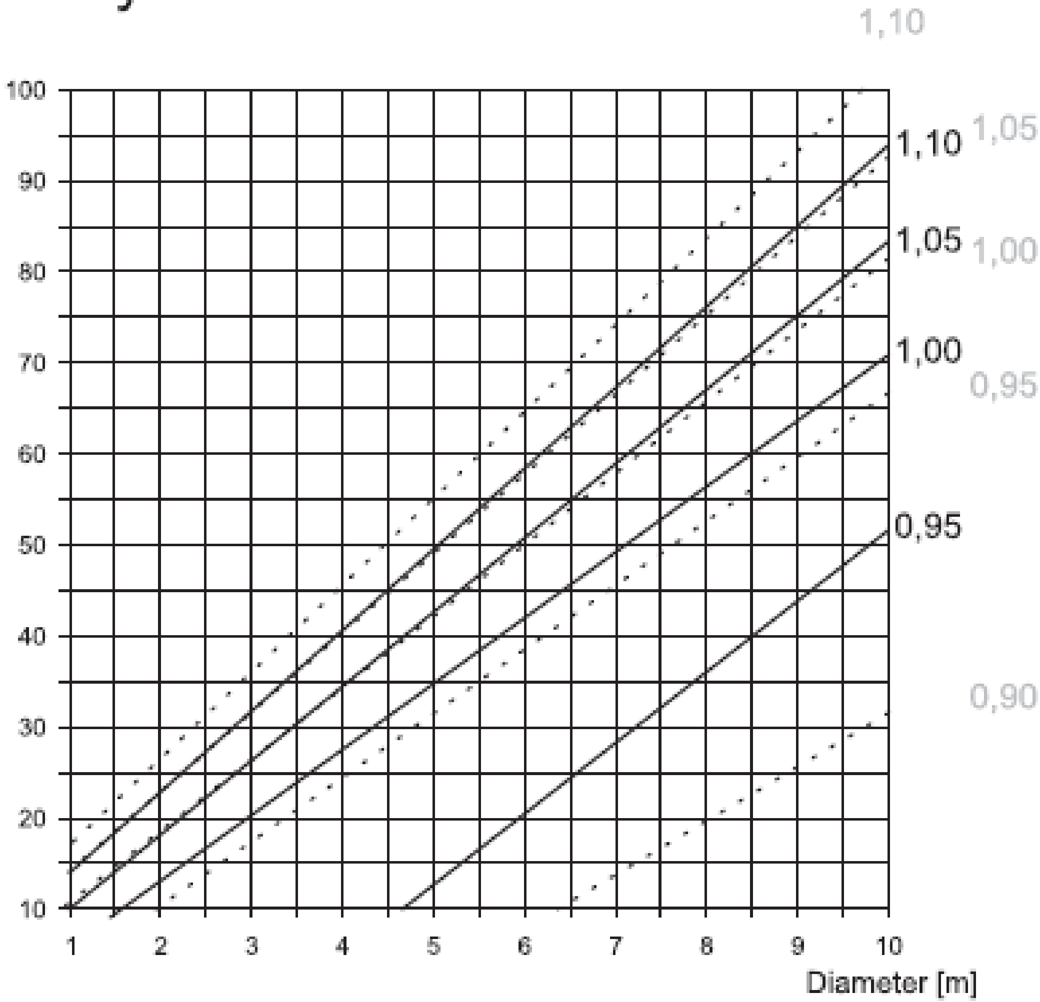


Annex D Structural factor

$c_s c_d$ for steel chimneys without liners

based on:

δ_s=0,012
W_s/W_t=1
roughness category I (solid lines)
roughness category II (dotted lines)
v_b=28 m/sec
δ_a=0

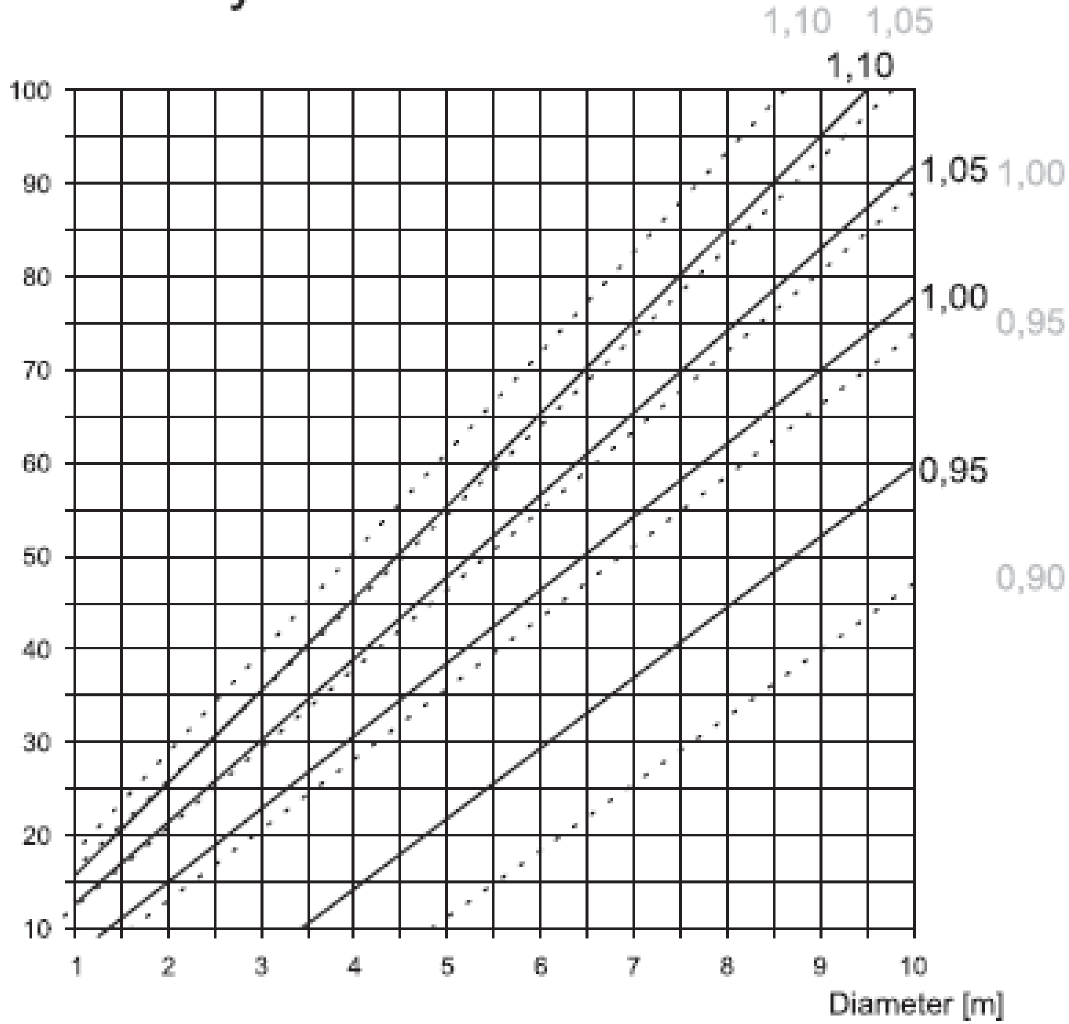


Annex D Structural factor

$c_s c_d$ for concrete chimneys without liners

based on:

δ_s=0,03
roughness category I (solid lines)
roughness category II (dotted lines)
v_b=28 m/sec
δ_a=0

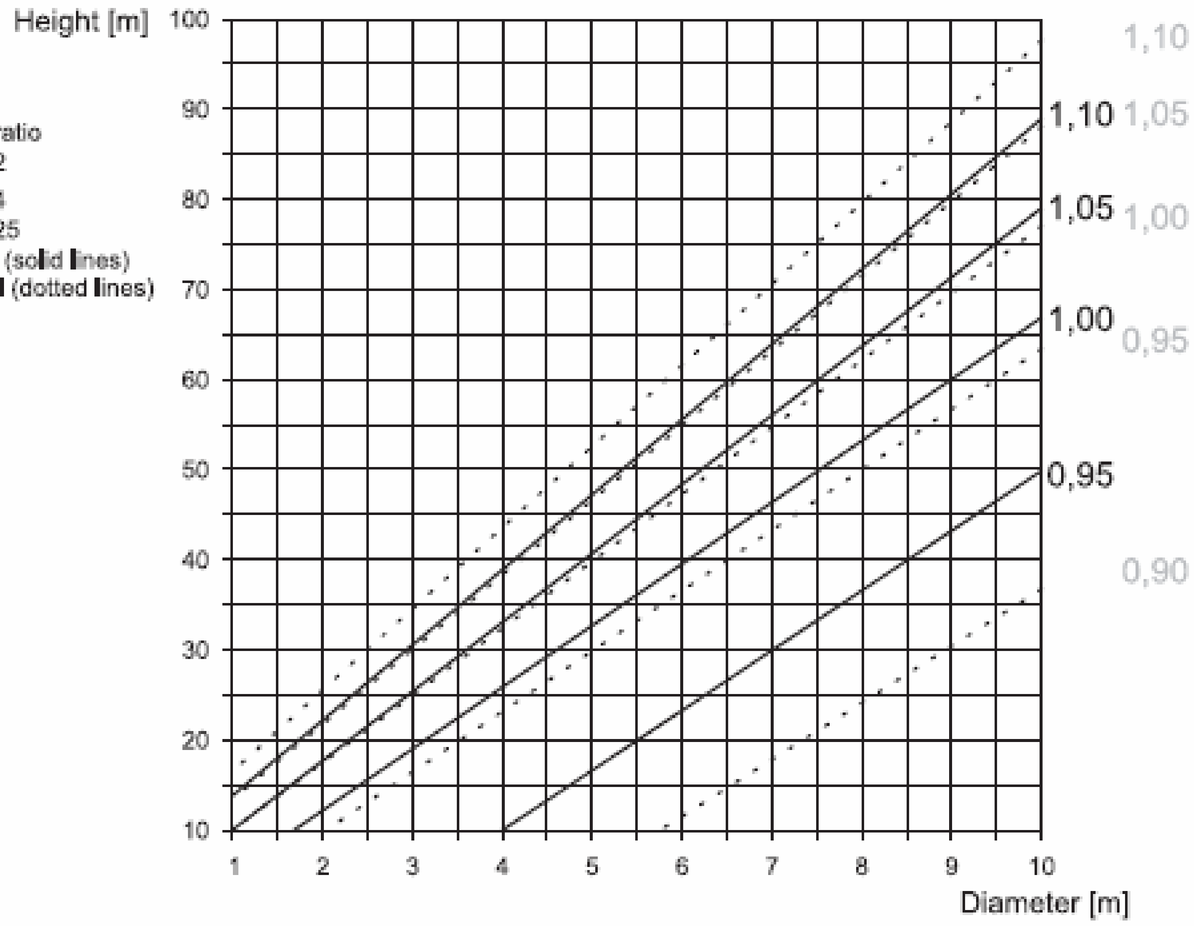


Annex D Structural factor

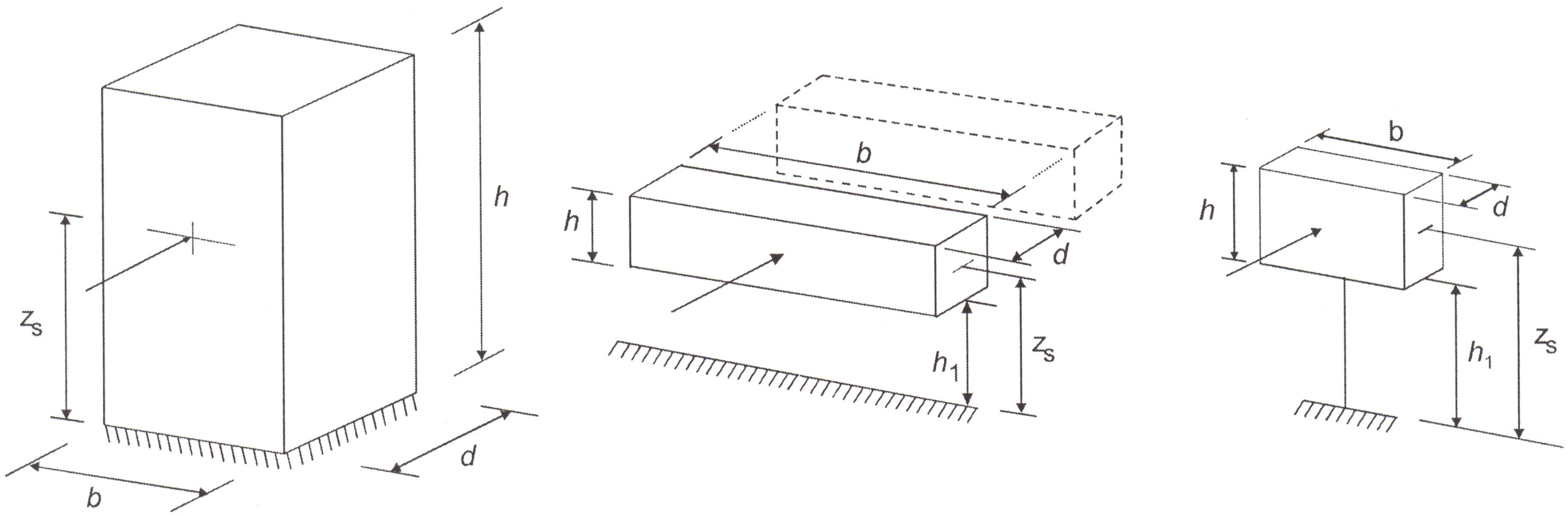
$c_s c_d$ for steel chimneys with liners

based on:

δ_s=depending on h/b-ratio
$h/b<18$ δ_s=0,02
$20 \leq h/b \leq 24$ δ_s=0,04
$h/b>26$ δ_s=0,025
roughness category II (solid lines)
roughness category III (dotted lines)
v_b=28 m/sec
δ_a=0



Section 6 Structural factor. Figure 6.1



NOTE Limitations are also given in 1.1 (2)

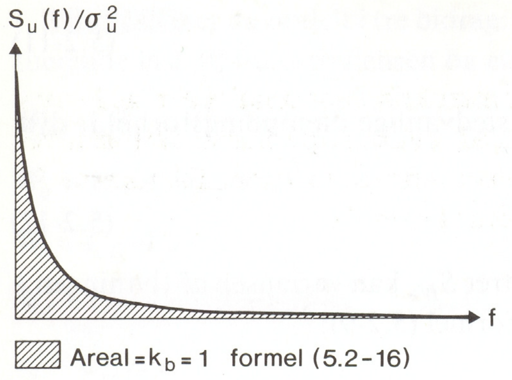
Section 6.3 Detailed procedure

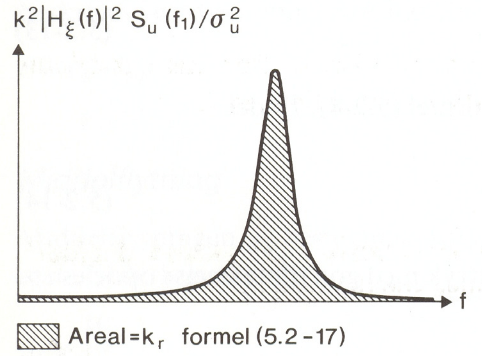
$$c_s c_d = \frac{1 + 2 \cdot k_p \cdot I_v(z_s) \cdot \sqrt{B^2 + R^2}}{1 + 7 \cdot I_v(z_s)}$$

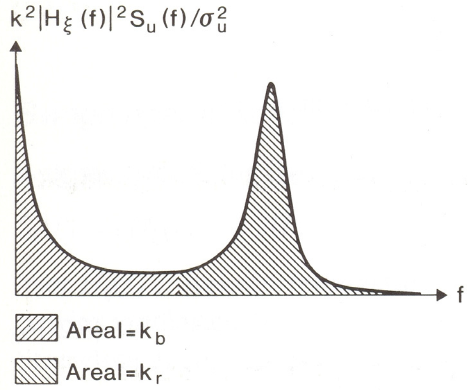
$$c_s = \frac{1 + 7 \cdot I_v(z_s) \cdot \sqrt{B^2}}{1 + 7 \cdot I_v(z_s)}$$

$$c_d = \frac{1 + 2 \cdot k_p \cdot I_v(z_s) \cdot \sqrt{B^2 + R^2}}{1 + 7 \cdot I_v(z_s) \cdot \sqrt{B^2}}$$

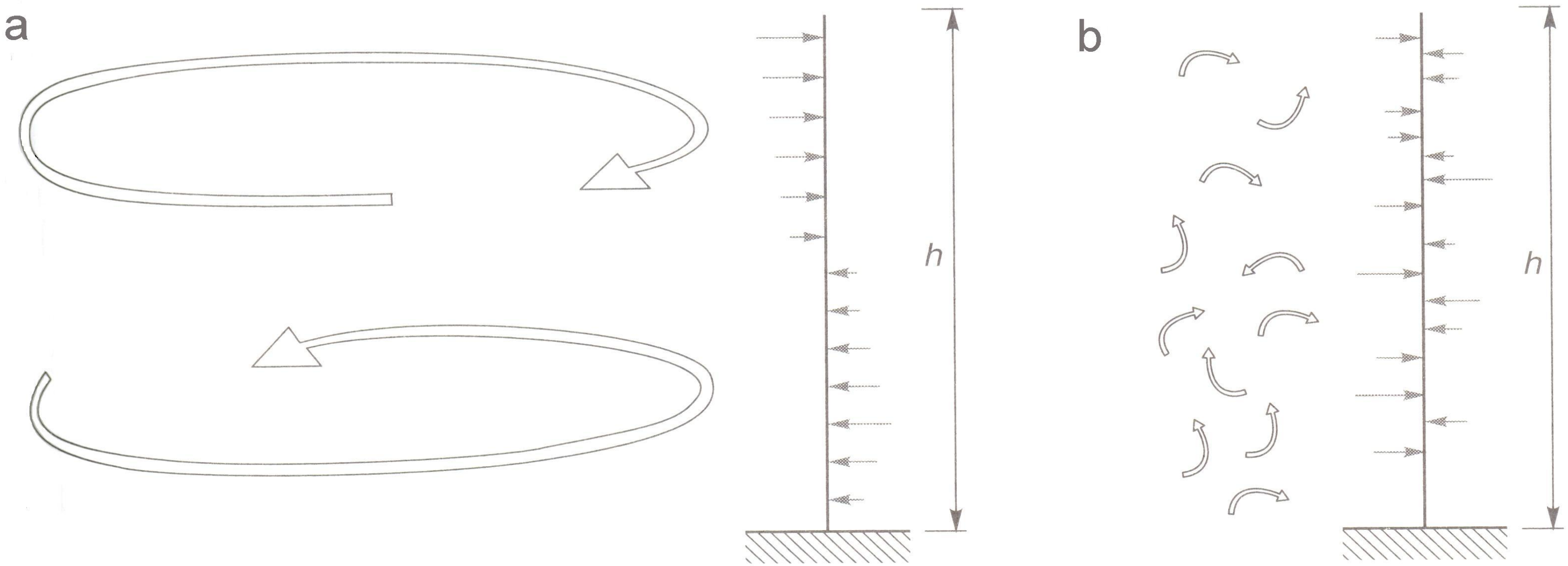
Backgrund turbulence and resonance turbulence



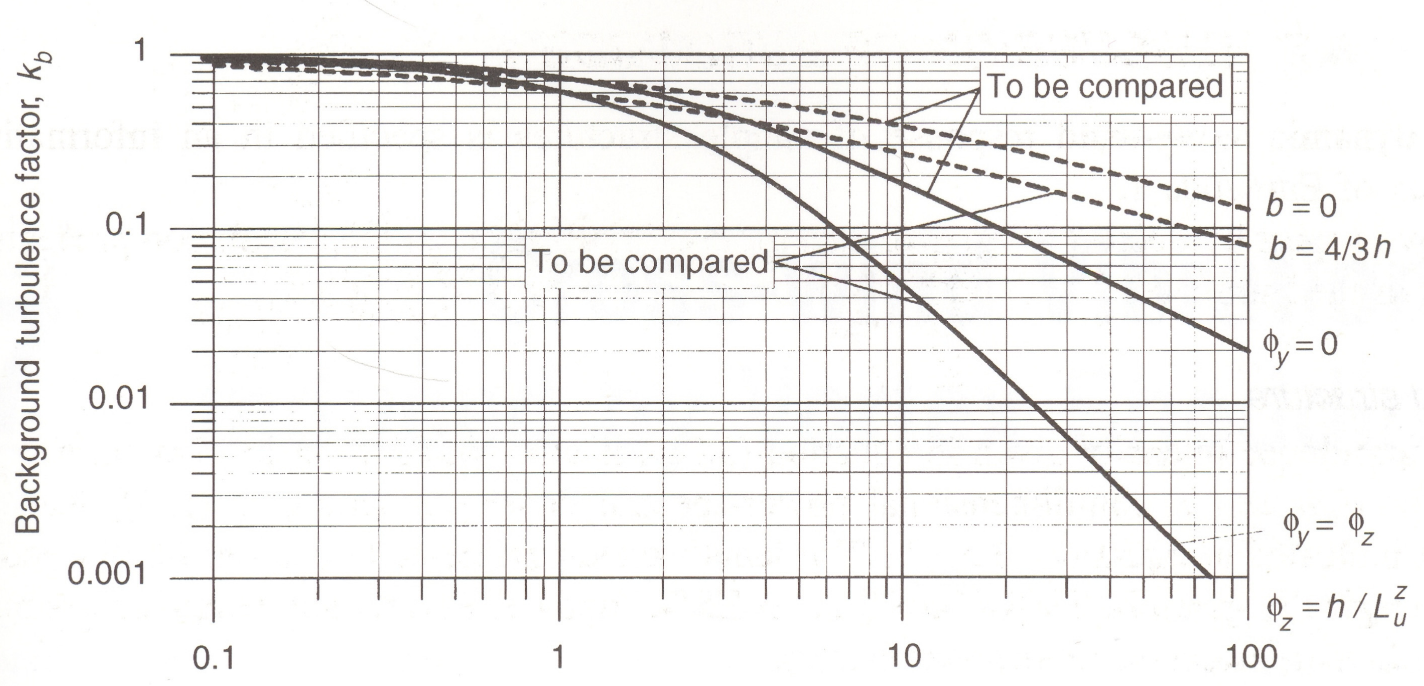




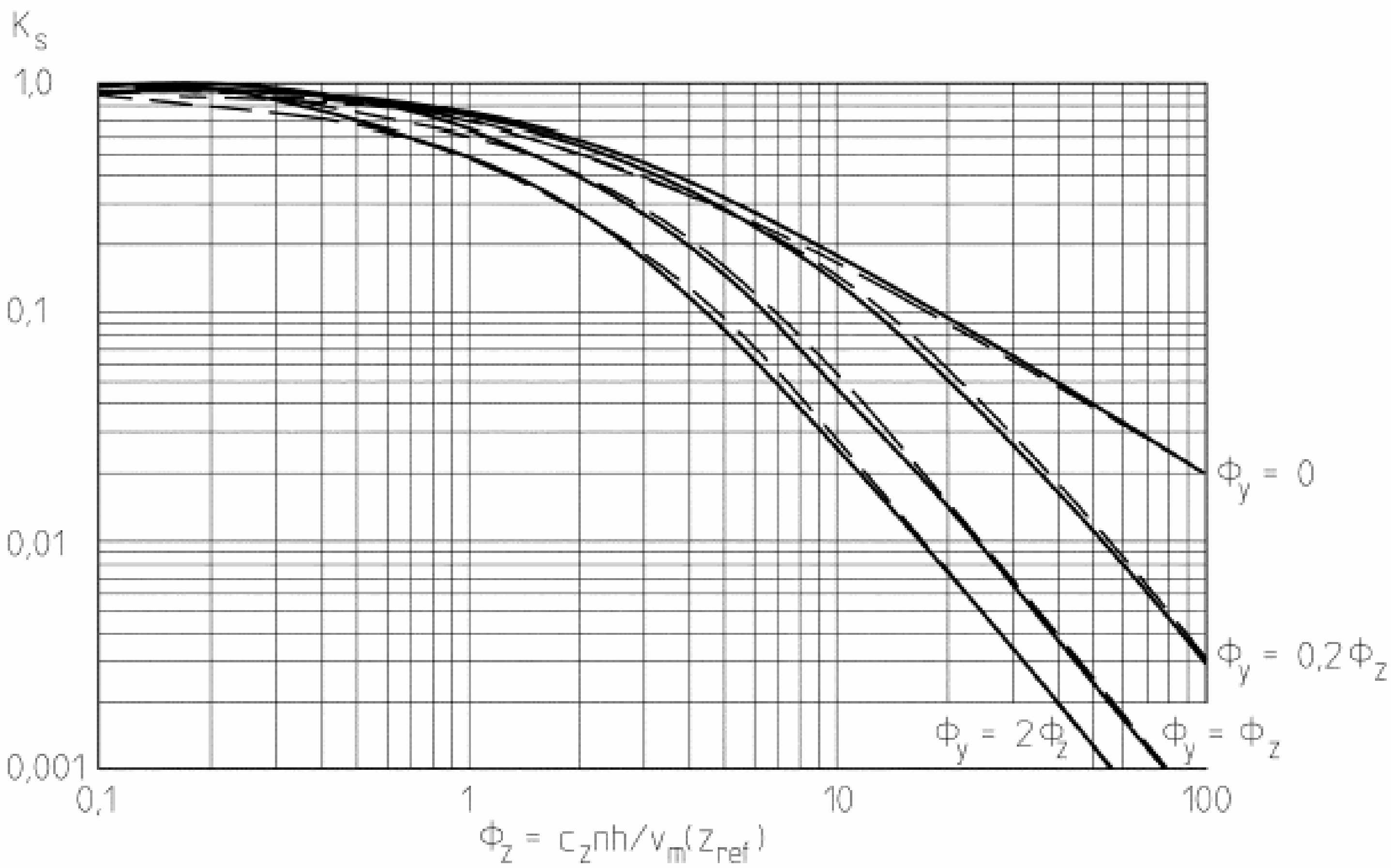
Wind vortices versus structural size



Procedure 1 (dotted line) versus theory (solid line)



Procedure 2 (dotted line) versus theory (solid line)



Structural factor. Procedure 1 or 2?

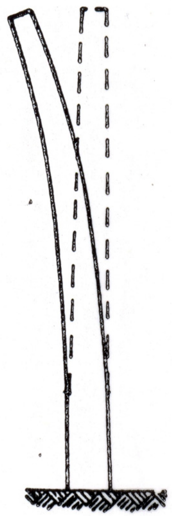
Procedure 2 has a more accurate representation of the theoretical background compared to procedure 1

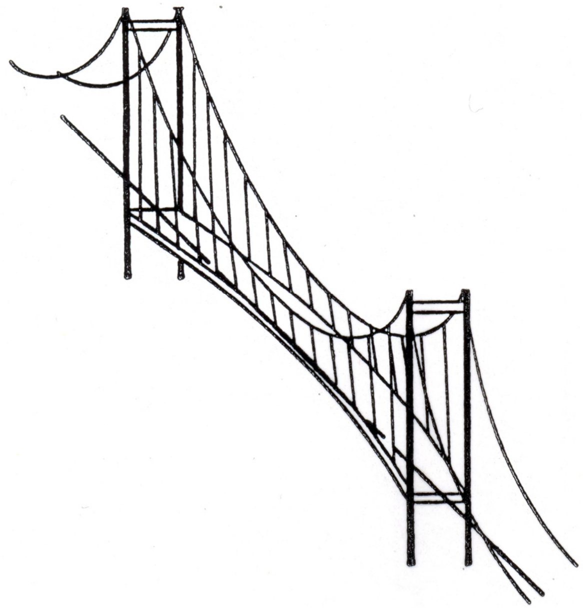
Annex E Vortex shedding

Chimneys

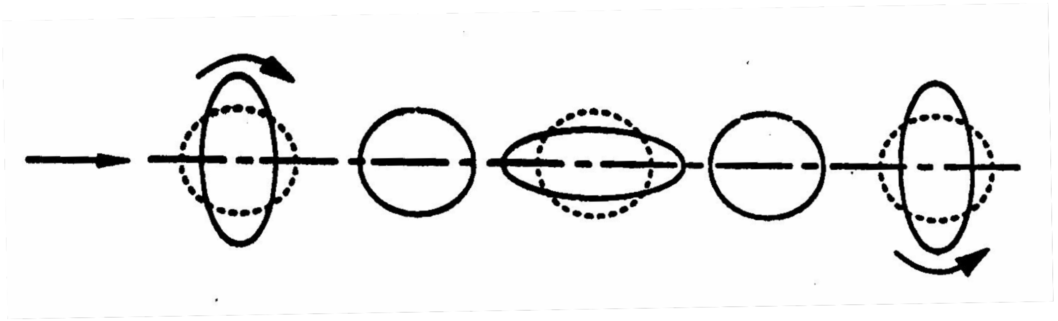
Bridges

Annex E Vortex shedding. Bending vibrations





Annex E Vortex sheding. Ovalling vibrations

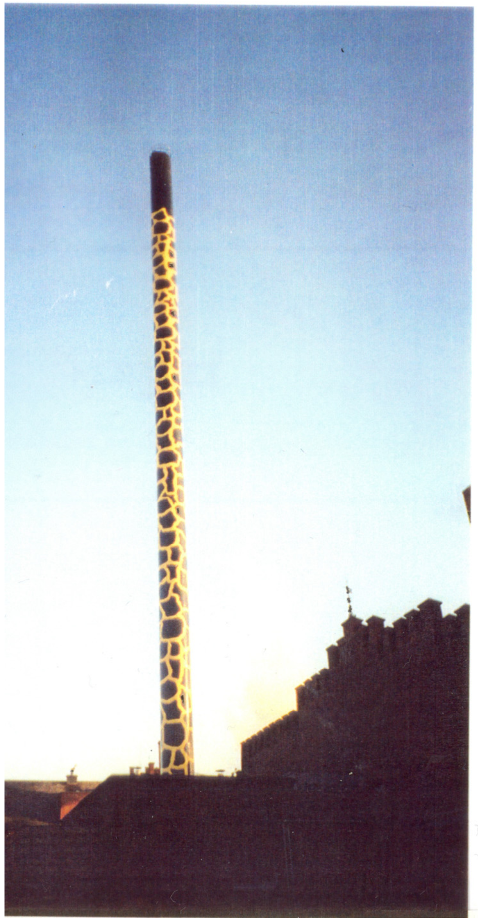


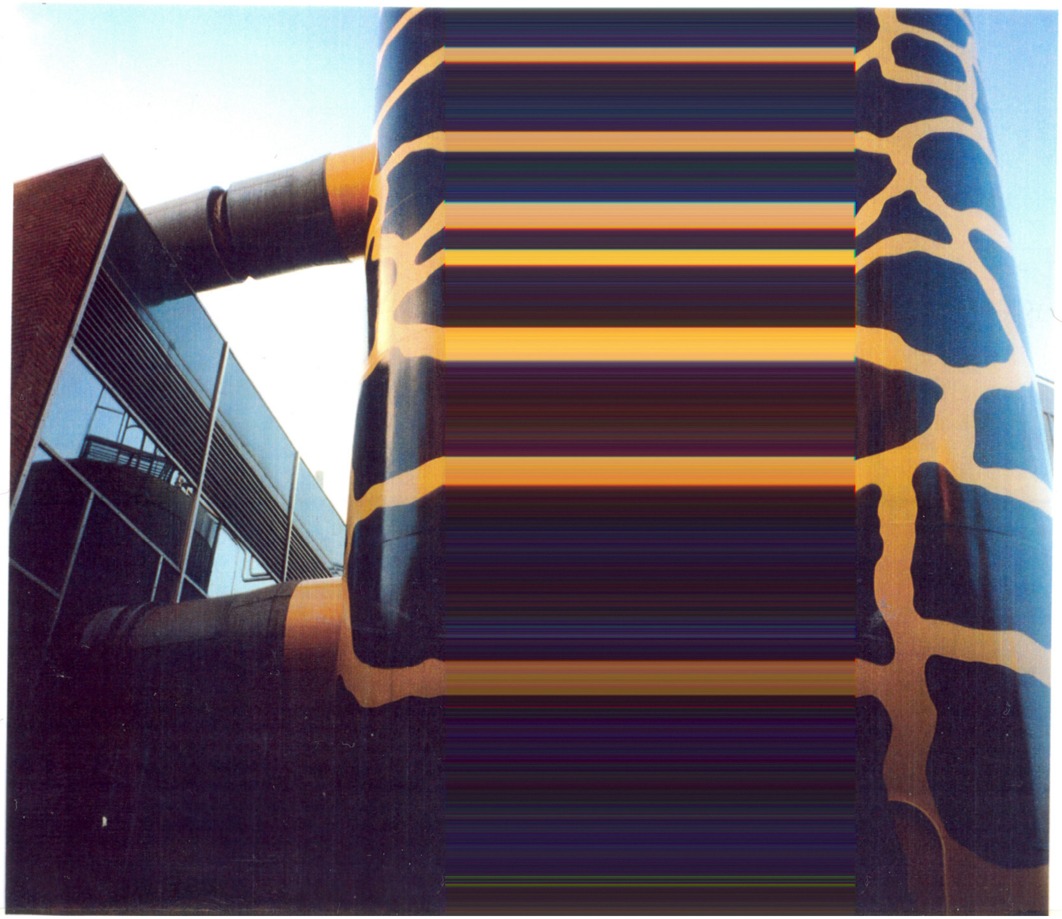
Annex E Vortex shedding. Critical wind velocity

$$v_{crit,i} = \frac{b \cdot n_{i,y}}{St}$$

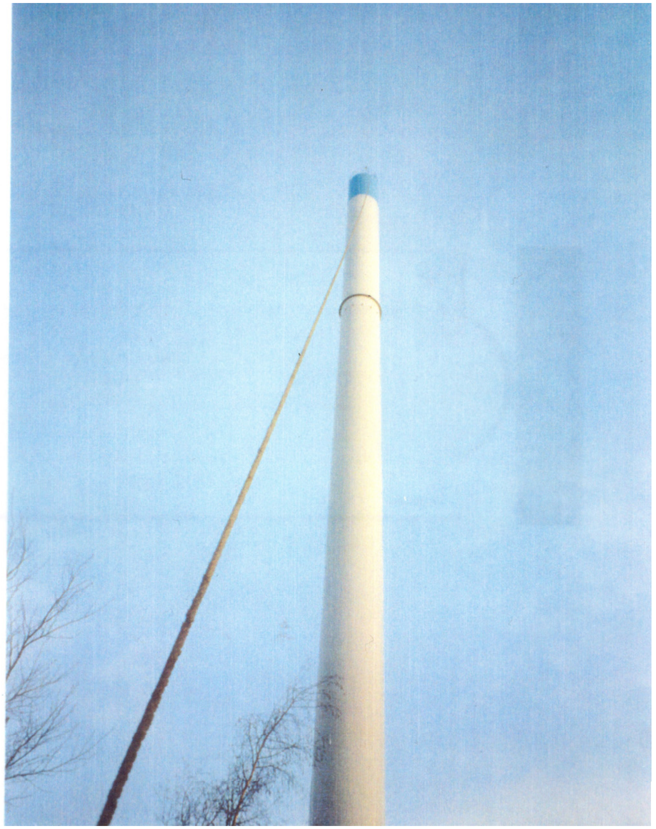
$$v_{crit,i} = \frac{b \cdot n_{i,o}}{2 \cdot St}$$

Vortex shedding. Chimneys





Vortex shdding. Chimneys



Approach 1 versus approach 2

Approach 1: Vortex-resonance model

Approach 2: Spectral model

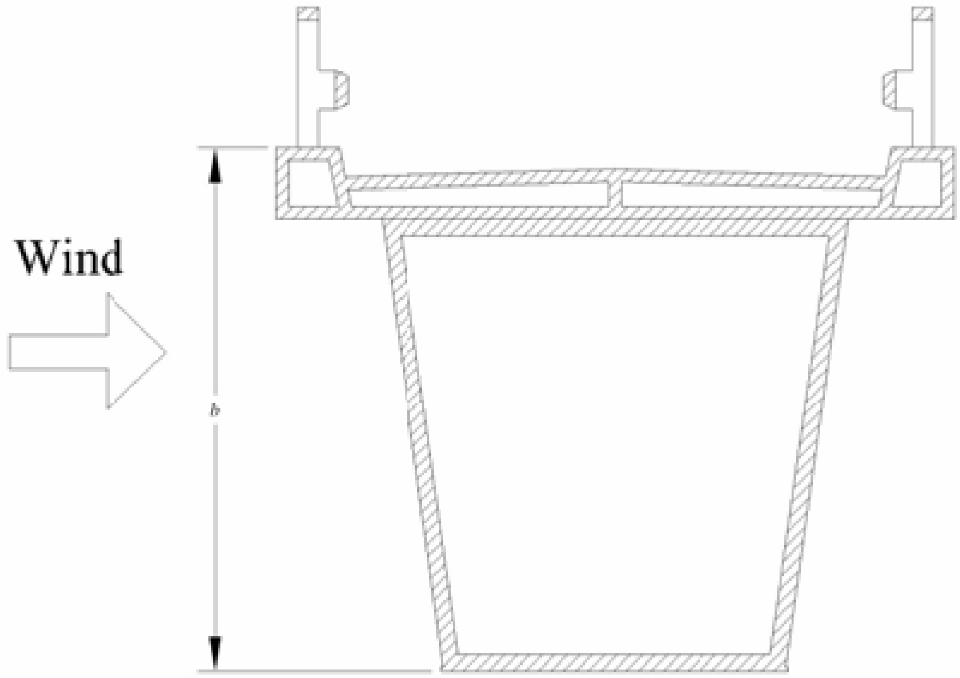
Turbulence is an active parameter only in approach 2

E1.5.1 General
(3)

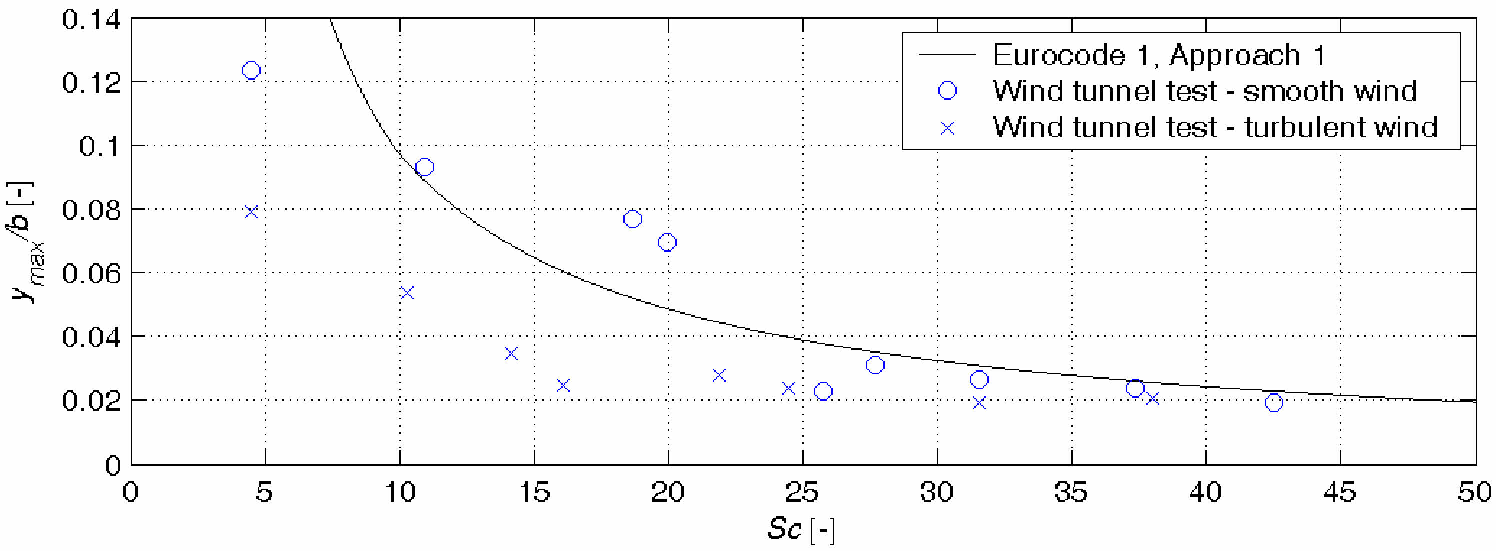
Approach 2 allows for the consideration of different turbulence intensities, which may differ due to meteorological conditions.

For regions where it is likely that it may become very cold and stratified flow condition may occur (e.g. in coastal areas in Northern Europe), approach 2 may be used.

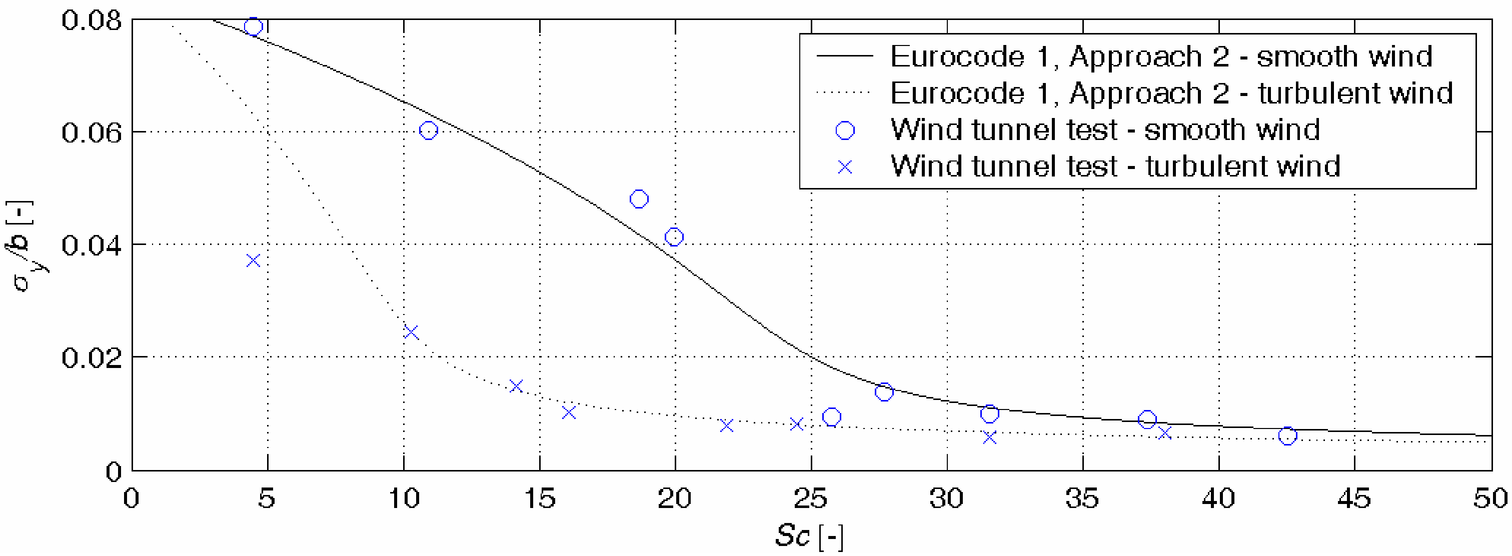
Vortex shedding. Bridge cross section



Vortex shedding. Bridge cross section. Approach 1



Vortex shedding. Bridge cross section. Approach 2



Vortex shedding. Approach 1 or 2?

Approach 2 has a more accurate representation of the physical phenomenon compared to approach 1