Rwanda Standards Board

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Structural design —

Part 2: Actions on structures — wind actions

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In order to match with technological development and to keep continuous progress in industries, standards are subject to periodic review. Users shall ascertain that they are in possession of the latest edition

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Foreword

Rwanda Standards are prepared by Technical Committees and approved by Rwanda Standards Board (RSB) Board of Directors in accordance with the procedures of RSB, in compliance with Annex 3 of the WTO/TBT agreement on the preparation, adoption and application of standards.

The main task of technical committees is to prepare national standards. Final Draft Rwanda Standards adopted by Technical committees are ratified by members of RSB Board of Directors for publication and gazettment as Rwanda Standards.

DRS 114-1 was prepared by Technical Committee RSB/TC 9, *Civil engineering and building materials*

In the preparation of this standard, reference was made to the following standards:

1) ISO 4354: 1997, *Wind actions on structures*

2) BS EN 1991-1-4: 2005, *Actions on structures — Part 1-4, General actions — Wind actions*

The assistance derived from the above source is hereby acknowledged with thanks.

This second edition cancels and replaces the first edition (RS 114-1: 2011), of which has been technically revised.

DRS 114 consists of the following parts, under the general title *Structural design —:*

— *Part 1: Actions on structures — Densities, self-weight, imposed loads for buildings*

— *Part 2: Actions on structures — Wind actions*

— *Part 3: Thermal actions on Building*

Committee membership

The following organizations were represented on the Technical Committee on *Civil engineering and building materials* (RSB/TC 9) in the preparation of this standard.

University of Rwanda – College of Science and Technology (UR-CST)

Institut d' Enseignement Supérieur (INES- Ruhengeri)

City of Kigali

Green Effect Engineering

Integrated Polytechnic Regional Centre –Kigali (IPRC)

NPD Ltd

REAL Contractors Ltd

Rwanda Housing Authority (RHA)

Rwanda Transport Development Agency (RTDA)

Standard For Sustainability (SFS)

Gasabo 3D

Masss Design Group - Rwanda

NPD Ltd

Enterprises-Generale-des-Constrictions- EGC

TECOS Ltd

Institution of Engineers Rwanda

CIMERWA Ltd

Rwanda Standards Board (RSB) – Secretariat

Introduction

Buildings and their components are to be designed to withstand wind loads. Calculating wind loads is important in design of the wind forces including structural members, components, and cladding, against shear, sliding, overturning, and uplift actions.

Certain aspects necessary to determine wind actions on a structure are mainly dependent on the location and on the availability and quality of meteorological data and the type of terrain. Wind forces may fluctuate with time, but for most of the structures, dynamic effect is small. Therefore, the wind load is treated as lateral static loads. However for tall and slender structures such as the high rise buildings, a dynamic structural wind analysis is required.

Structural design — Part 2: Actions on structures — Wind actions

1 Scope

This Draft Rwanda Standard describes the actions of wind on structures and specifies methods for calculating characteristic values of wind loads for use in designing buildings and civil engineering works for each of the loaded areas under consideration. This includes the whole structure or parts of the structure or elements attached to the structure.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

RS 112, *Basis of structural design*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

fundamental basic wind velocity

hourly mean wind velocity with an annual risk of being exceeded of 0, 02, irrespective of wind direction, at a height of 10 m above flat open terrain and accounting for altitude effects (if required)

3.2

basic wind velocity

fundamental basic wind velocity modified to account for the direction of the wind being considered and the season (if required)

3.3

mean wind velocity

basic wind velocity modified to account for the effect of terrain roughness and topography

3.4

pressure coefficient

external pressure coefficients give the effect of the wind on the external surfaces of buildings; internal pressure coefficients give the effect of the wind on the internal surfaces of buildings.

The external pressure coefficients are divided into overall coefficients and local coefficients. Local coefficients give the pressure coefficients for loaded areas of 1 m2 or less e.g. for the design of small elements and fixings; overall coefficients give the pressure coefficients for loaded areas larger than 10 m2.

Net pressure coefficients give the resulting effect of the wind on a structure, structural element or component per unit area.

3.5

external pressure

pressure acting on an external surface of a building caused by the direct action of the wind

3.6

internal pressure

pressure acting on an internal surface of a building caused by the action of the external pressures through porosity and openings in the external surfaces of the building

3.7

net pressure

pressure difference between opposite faces of a surface

3.8

building height

height of a building or part of a building above its base

3.9

reference height

reference height for a part of a structure is the datum height above ground for the pressure coefficients and is defined with the pressure coefficients for that part

3.10

force coefficient

force coefficients give the overall effect of the wind on a structure, structural element or component as a whole, including friction, if not specifically excluded

4 Symbols (and abbreviated terms)

For the purposes of this Rwanda standard, the following symbols apply.

NOTE: In this Part the symbol dot in expressions indicates the multiplication sign.

A	area
A_{fr}	area swept by the wind
A_{ref}	reference area
F_{fr}	resultant friction force
F_w	resultant wind force
H	height of a topographic feature
I_v	turbulence intensity
K	mode shape factor; shape parameter
L_u	actual length of an upwind slope
b	width of the structure (the length of the surface perpendicular to the wind direction if not otherwise specified)
c_d	dynamic factor
c_{dir}	directional factor
$c_e(z)$	exposure factor
c_f	force coefficient
c_{fr}	friction coefficient
c_p	pressure coefficient
c_{prob}	probability factor
c_r	roughness factor
c_o	topography factor
c_s	size factor
c_{season}	seasonal factor
d	depth of the structure (the length of the surface parallel to the wind direction if not otherwise specified)

e	eccentricity of a force or edge distance
h	height of the structure
k	equivalent roughness
k_p	peak factor
k_r	terrain factor
l	length of a horizontal structure
m	mass per unit length
m_1	equivalent mass per unit length
p	annual probability of exceedance
q_b	reference mean (basic) velocity pressure
q_p	peak velocity pressure
t	averaging time of the reference wind speed, plate thickness
v_m	mean wind velocity
$v_{b,0}$	fundamental value of the basic wind velocity
v_b	basic wind velocity
w	wind pressure
x	horizontal distance of the site from the top of a crest
z_0	roughness length
z_e, z_i	reference height for external wind action, internal pressure
z_g	distance from the ground to the considered component
z_{max}	maximum height
z_{min}	minimum height
z_s	reference height for determining the structural factor

Φ	upwind slope
ρ	air density
σ_v	standard deviation of the turbulence
x-direction	horizontal direction, perpendicular to the span
y-direction	horizontal direction along the span
z	height above ground
z-direction	vertical direction

Indices

crit	critical
e	external ; exposure
fr	friction
i	internal
m	mean
p	peak
ref	reference
v	wind velocity
x	along- wind direction
y	cross-wind direction
z	vertical direction

5 Design situations

5.1 The relevant design situations shall be selected taking into account the circumstances under which the structure is required to fulfill its function.

5.2 Design situations shall be classified as follows:

a) persistent design situations, which refer to the conditions of normal use;

b) transient design situations, which refer to temporary conditions applicable to the structure, e.g. during execution or repair;

c) accidental design situations, which refer to exceptional conditions applicable to the structure or to its exposure, e.g. to fire, explosion, impact or the consequences of localized failure; and

d) seismic design situations, which refer to conditions applicable to the structure when subjected to seismic events.

5.3 The selected design situations shall be sufficiently severe and varied so as to encompass all conditions that can reasonably be foreseen to occur during the execution and use of the structure.

5.4 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.

5.5 Fatigue due to the effects of wind actions should be considered for susceptible structures.

6 Clause Modelling of wind actions

6.1 Nature

Wind actions fluctuate with time and act directly as pressures on the external surfaces of enclosed structures and, because of porosity of the external surface, also act indirectly on the internal surfaces. They may also act directly on the internal surface of open structures. Pressures act on areas of the surface resulting in forces normal to the surface of the structure or of individual cladding components.

Additionally, when large areas of structures are swept by the wind, friction forces acting tangentially to the surface may be significant.

6.2 Representations of wind actions

The wind action is represented by a simplified set of pressures or forces whose effects are equivalent to the extreme effects of the turbulent wind.

6.3 Classification of wind actions

Unless otherwise specified, wind actions shall be classified as variable static actions.

6.4 Characteristic values

The wind actions calculated using this standard are characteristic values. They are determined from the basic values of wind velocity or the velocity pressure.

The basic values are characteristic values having annual probabilities of exceedence of 0.02, which is equivalent to a mean return period of 50 years.

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.

6.5 Models

The effect of the wind on the structure (i.e. the response of the structure), depends on the size, shape and dynamic properties of the structure. This Part covers dynamic response due to a long-wind turbulence in resonance with the along-wind vibrations of a fundamental flexural mode shape with constant sign.

The response of structures shall be calculated according to Clause 8 from the peak velocity pressure, $\boldsymbol{q}_{\mathbf{p}}$, at the reference height in the undisturbed wind field, the force and pressure coefficients and the structural factor $\boldsymbol{c}_{\mathbf{scd}}$ (see Clause 9). $\boldsymbol{q}_{\mathbf{p}}$ depends on the wind climate, the terrain roughness and topography, and the reference height. q_{p} is equal to the mean velocity pressure plus a contribution from short-term pressure fluctuations.

Aero-elastic response shall be considered for flexible structures such as cables, masts, chimneys and bridges.

7 Wind velocity and velocity pressure

7.1 Basis for calculation

The wind velocity and the velocity pressure are composed of a mean and a fluctuating component. The mean wind velocity $\boldsymbol{v}_{\mathbf{m}}$ shall be determined from the basic wind velocity $\boldsymbol{v}_{\mathbf{b}}$ depends on the wind climate as described in 7.2, and the height variation of the wind determined from the terrain roughness and topography as described in 7.3. The peak velocity pressure is determined in 7.5.

The fluctuating component of the wind is represented by the turbulence intensity defined in 7.4.

7.2 Basic Values

7.2.1 The fundamental value of the basic wind velocity, $\boldsymbol{v}_{\mathbf{b,0}}$, is the characteristic ten (10) minute mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in open terrain with low vegetation such as grass and isolated obstacles.

NOTE This terrain corresponds to terrain category II in Table1.

7.2.2 The basic wind velocity shall be calculated from Expression (7.1).

$$\boldsymbol{v}_{\mathbf{b}} = \boldsymbol{c}_{\mathbf{dir}} - \boldsymbol{c}_{\mathbf{season}} - \boldsymbol{v}_{\mathbf{b,0}} \qquad (7.1)$$

where:

v_b the basic wind velocity, defined as a function of wind direction and time of year at 10 m above ground of terrain category II.

$v_{b,0}$ the fundamental value of the basic wind velocity, see (1)**P**

c_{dir} the directional factor, see Note 1.

c_{season} the season factor, see Note 2.

NOTE 1 The recommended value of the directional factor, c_{dir}, for various wind is 1,0.

NOTE 2 The recommended value of the season factor, c_{season}, is 1,0.

NOTE 3 The hourly mean wind velocity having the probability **p** for an annual exceedence is determined by multiplying the basic wind velocity v_b in 4.2.2 by the probability factor, c_{prob} given by Expression (7.2).

$$c_{prob} = \left(\frac{1 - K \cdot \ln(-\ln(1-p))}{1 - K \cdot \ln(-\ln(0{,}98))} \right)^n \qquad (7.2)$$

K is the shape parameter depending on the coefficient of variation of the extreme-value distribution.

n is the exponent.

NOTE The recommended value for **K** is 0,2 and 0,5 for *n*.

7.2.2 For temporary structures and for all structures in the execution phase, the seasonal factor c_{season} may be used. For transportable structures, which may be used at any time in the year, c_{season} should be taken equal to 1.0.

7.3 Mean wind

7.3.1 Variation with height

The mean wind velocity $v_m(z)$ at a height z above the terrain depends on the terrain roughness and topography and on the basic wind velocity, v_b, and shall be determined using Expression (7.3)

$$v_{m(z)} = c_r(z) – c_o(z) – v_b \qquad (7.3)$$

where:

$c_r(z)$ is the roughness factor, given in 7.3.2

$c_o(z)$ is the topography factor, taken as 1,0 unless otherwise specified (See 7.3.4)

NOTE 1 If the topography is accounted for in the basic wind velocity, the recommended value is 1,0.

7.3.2 Terrain categories

Terrain category I

Lakes or area with negligible vegetation and without obstacles

Terrain category II

Area with low vegetation such as grass and isolated obstacles (trees, buildings)

Terrain category III

Area with regular cover of vegetation or buildings or with isolated obstacles (such as villages, suburban terrain, permanent forest)

Terrain category IV

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

7.3.2 Terrain roughness

7.3.2.1 Wind at ground level is subject to boundary layer effect due to interferences from hills, trees, structures, etc. as well as the friction with the ground. This terrain roughness increases turbulence and decreases resulting wind pressures. Wind data collected at airports where the terrain roughness is minimized apply in the design of buildings.

7.3.2.2 The roughness factor, $c_r(z)$, accounts for the variability of the mean wind velocity at the site of the structure due to the height above ground level ,the ground roughness of the terrain upwind of the structure in the wind direction considered.

NOTE The recommended procedure for the determination of the roughness factor at height z is given by Expression (7.4) and is based on a logarithmic velocity profile.

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \qquad \text{for} \qquad z_{min} \leq z \leq z_{max}$$

$$C_r(Z) = C_r(Z_{min}) \qquad \text{for } Z \leq Z_{min} \qquad (7.4)$$

Where

z_0 is the roughness length

k_r terrain factor depending on the roughness length z_0 calculated using

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07} \qquad (7.5)$$

Where

$z_{0,II}$ = 0,05 m (terrain category II, Table 1)

z_{min} Is the minimum height defined in Table 1

z_{max} is to be taken as 200 m

z_0, z_{min} depend on the terrain category. Recommended values are given in Table 1 depending on four representative terrain categories.

Expression (7.4) is valid when the upstream distance with uniform terrain roughness is long enough to stabilise the profile sufficiently, see (2).

Table 1 — Terrain categories and terrain parameters

Terrain category	z_0 **m**	z_{min} **m**
I	0.01	1
II	0.05	2
III	0.3	5
IV	1	10

3.2.3 The terrain roughness to be used for a given wind direction depends on the ground roughness and the distance with uniform terrain roughness in an angular sector around the wind direction. Small areas (less than 10% of the area under consideration) with deviating roughness may be ignored. See Figure 1

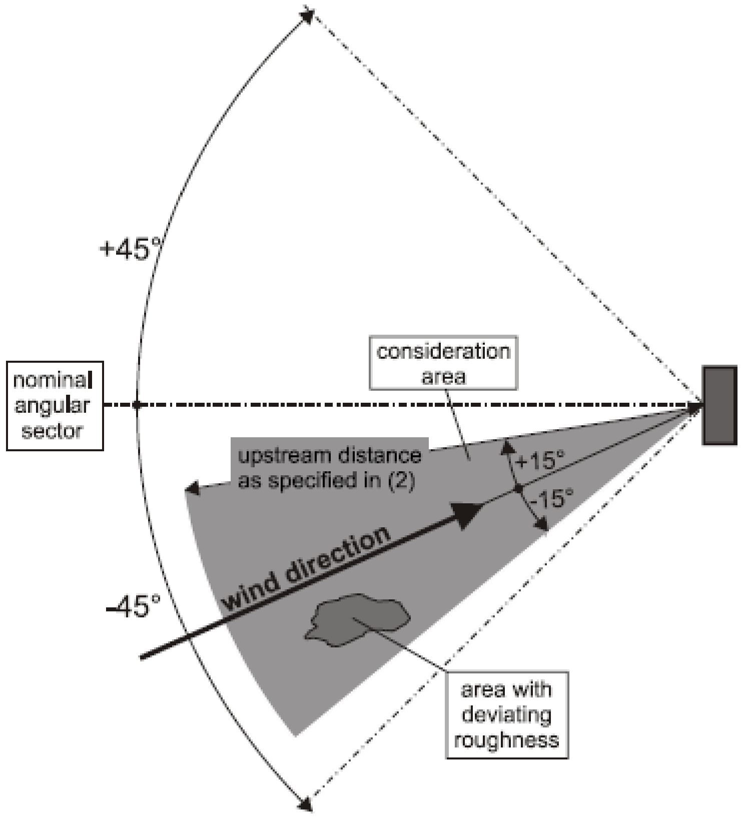

Figure 1: Assessment of terrain roughness

2.2.4 When a pressure or force coefficient is defined for a nominal angular sector, the lowest roughness length within any 30° angular wind sector should be used.

2.2.5 When there is choice between two or more terrain categories in the definition of a given area, then the area with the lowest roughness length shall be used.

7.3.3 Terrain topography

Where topography (e.g. hills, cliffs etc.) increases wind velocities by more than 5% the effects shall be taken into account using the topography factor c_O.

7.3.4 Numerical calculation of topography coefficients

7.3.4.1 At isolated hills and ridges or cliffs and escarpments different wind velocities occur dependent on the upstream slope Φ=H/Lu in the wind direction, where the height H and the length *L*u are defined in Figure 2.

7.3.4.2 The effects of topography may be neglected when the average slope of the upwind terrain is less than 3°. The upwind terrain may be considered up to a distance of 10 times the height of the isolated topographic feature.

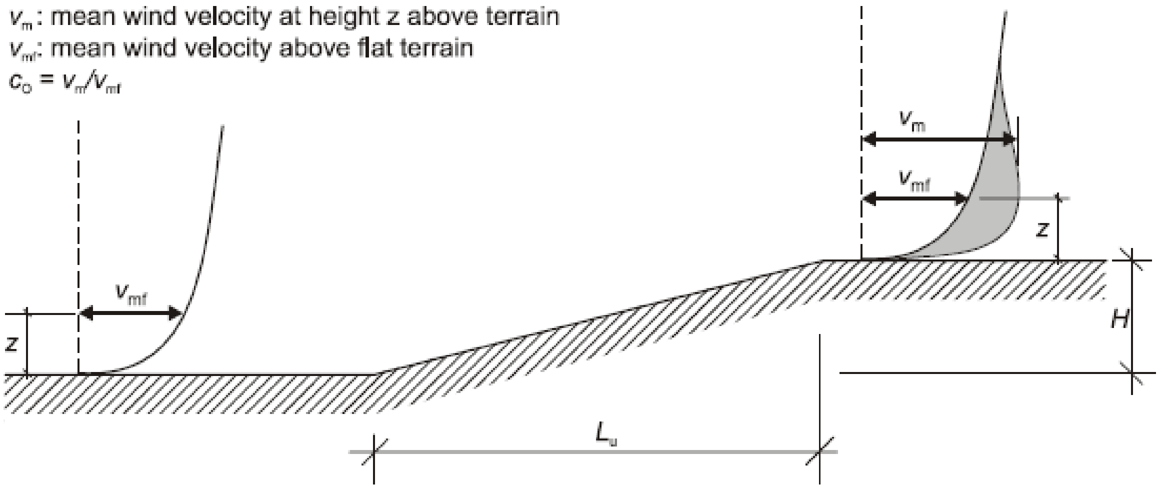

Figure 2 - Illustration of increase of wind velocities over topography

7.3.4.3 The topography factor, $c_O(z)=\boldsymbol{v_m}/v_{mf}$ accounts for the increase of mean wind speed over isolated hills and escarpments (not undulating and mountainous regions). It is related to the wind velocity at the base of the hill or escarpment.

7.4 Wind turbulence

7.4.1 The turbulence intensity $I_v(z)$ at height z is defined as the standard deviation of the turbulence divided by the mean wind velocity.

NOTE 1 The turbulent component of wind velocity has a mean value of 0 and a standard deviation σ_v. The standard deviation of the turbulence σ_v may be determined using Expression (7.6).

$$\boldsymbol{\sigma_{v}} = \boldsymbol{k_r} \;.\; \boldsymbol{v_b} \;.\; \boldsymbol{k_I} \qquad (7.6)$$

For the terrain factor k_r , see Expression (7.5), for the basic wind velocity $\boldsymbol{v_b}$, see Expression (7.1) and for turbulence factor k_I , see Note 2.

NOTE 2 The recommended rules for the determination of $I_v(z)$ are given in Expression (7.7)

$$\begin{aligned} I_v(z) &= \frac{\sigma_v}{v_m(z)} = \frac{k_I}{c_o(z)\cdot\ln(z/z_0)} && \text{for} \quad z_{min} \le z \le z_{max} \\ I_v(z) &= I_v(z_{min}) && \text{for} \quad z < z_{min} \end{aligned} \qquad \textbf{(7.7)}$$

where:

$\boldsymbol{k_I}$ is the turbulence factor. The recommended value for k_I is 1,0.

$\boldsymbol{c_o}$ is the topography factor as described in 7.3.3

$\boldsymbol{z_0}$ is the roughness length, given in Table 1

7.5 Peak velocity pressure

7.5.1 The peak velocity pressure $\boldsymbol{q_p(z)}$ at height z, which includes mean and short-term velocity fluctuations, shall be determined.

NOTE 1 The recommended rule for the determination of $q_p(z)$ is given in Expression (7.8).

$$q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \tfrac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b \qquad (7.8)$$

where:

ρ is the air density, which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storms

$ce(z)$ is the exposure factor given in Expression (7.9)

$$c_e(z) = \frac{q_p(z)}{q_b} \qquad (7.9)$$

q_b is the basic velocity pressure given in Expression (7.10)

$$q_b = \tfrac{1}{2} \cdot \rho \cdot v_b^2 \qquad (7.10)$$

NOTE 2 The recommended value for ρ is 1,25 kg/m^3.

NOTE 3 For flat terrain where $c_O(z)$ = 1,0 (see7.3.3), the exposure factor $c_e(z)$ is illustrated in Figure 2 as a function of height above terrain and a function of terrain category as defined in Table 1.

The exposure factor accounts for the variability of the velocity pressure at the site of the structure due to:

a) the height above ground level,

b) the roughness of the terrain, and

c) the shape and slope of the ground contours in undulating terrain.

The value of the exposure factor may vary with wind direction.

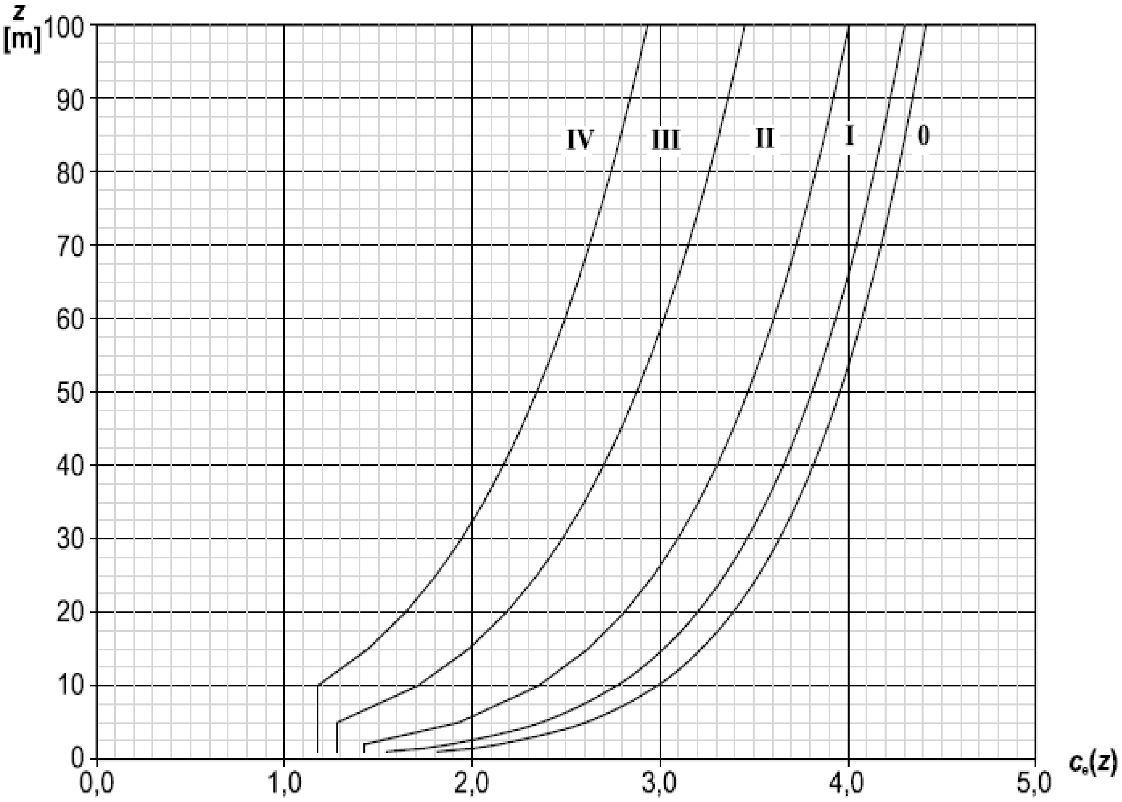

Figure 3 — Illustration of the exposure factor Ce (z) for Co 1.0, Kr = 1.0

The exposure factor accounts for the variability of the velocity pressure at the site of the structure due to:

a) the height above ground level,

b) the roughness of the terrain, and

c) the shape and slope of the ground contours in undulating terrain.

The value of the exposure factor may vary with wind direction.

8 Wind actions

8.1 General

8.1.1 Wind actions on structures and structural elements shall be determined taking account of both external and internal wind pressures. Wind actions which shall be considered in the design of a structure may produce the following:

a) excessive forces or instability in the structure or its structural members or elements;

a) b) excessive deflection or distortion of the structure or its elements;

b) repeated dynamic forces causing fatigue or structural elements;

c) aero-elastic instability, in which motion of the structure in wind produces aerodynamic forces augmenting the motion;

d) excessive dynamic movements causing concern or discomfort to occupants or onlookers.

8.2 Wind zones in Rwanda

Wind zones are based on peak wind velocity and assumptions, such as the assumed height of a future building, wind direction, and a very general topographic and sheltering information.

This standard divides Rwanda into two wind zones (see Table 2).

Annex A shows the map of wind zones and areas affected by the regional wind velocity.

8.3 Wind zones classification

8.3.1 Wind zones are classified as low, moderate, high and very high according to the basic wind velocity (V_b) of the region.

Low: Below 30 m/s

Moderate: 30m/s $\leq V_b \leq$ 43 m/s

High: 44m/s $\leq V_b \leq$ 50 m/s

Very high: $V_b >$ 50 m/s

Table 2 — Wind zones in Rwanda

Zone	Basic Wind velocity	Areas affected
I	29 m/s	Central and eastern regions (see districts affected in annex A)
II	40 m/s	Northern, western and southern regions (see districts affected in annex A)

8.3.2 The wind velocity is sensed by a spinning anemometer which magnetically induces a voltage that is proportional to the wind velocity. This voltage is measured and plotted against time to give a history of wind velocities in a chart called an anemogram. This output is the instantaneous wind velocity at any given time. The voltage is subject to a conversion factor specific to the anemometer for reporting purposes.

8.4 Calculation procedures for the determination of wind actions

The procedures for the determination of wind actions are shown in table 4

8.5 Wind pressure on surfaces

8.5.1 The wind pressure acting on the external surfaces, w_e, shall be obtained from Expression (8.1).

$$w_e = q_p(z_e) \cdot c_{pe} \qquad (8.1)$$

where:

$q_p(z_e)$ is the peak velocity pressure

z_e is the reference height for the external pressure

c_{pe} is the pressure coefficient for the external pressure

NOTE $q_p(z)$ is defined in 7.5

8.5.2 The wind pressure acting on the internal surfaces of a structure, w_i , shall be obtained from Expression (8.2)

$$w_i = q_p(z_i) \cdot c_{pi} \qquad (8.2)$$

where:

$q_p(z_i)$ is the peak velocity pressure

z_i is the reference height for the internal pressure

c_{pi} is the pressure coefficient for the internal pressure

NOTE $q_p(z)$ is defined in 7.5

8.5.3 The net pressure on a wall, roof or element is the difference between the pressures on the opposite surfaces taking due account of their signs. Pressure, directed towards the surface is taken as positive, and suction, directed away from the surface as negative. Examples are given in Figure 5.

8.6 Wind forces

8.6.1 The most common concept of wind is that it produces a force in the direction it moves that is proportional to its wind velocity. This action is referred to as downwind force.

Force = Pressure x Projected Area

8.6.2 The projected area is the area exposed to the wind flow normal to the wind direction. Wind from all directions must be considered to determine the maximum area and maximum force.

8.6.3 For the purpose of calculating the total wind load on a structure, the wind pressure is applied to the orthogonal projection of the structure onto a plane perpendicular to wind direction.

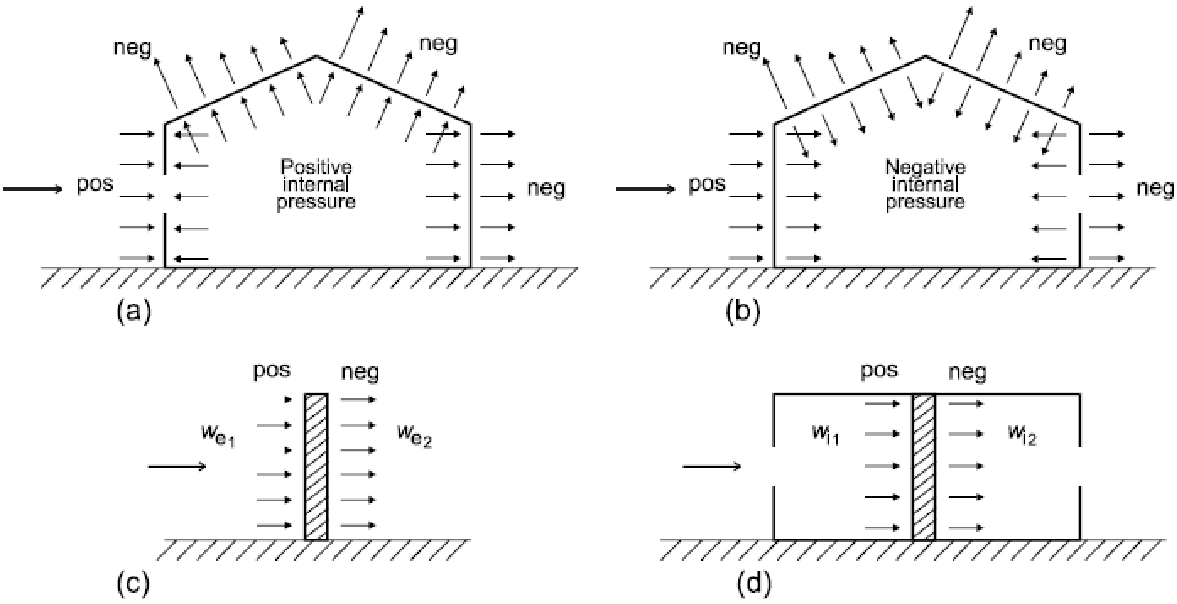

Figure 5 - Pressure on surfaces

8.6.4 The wind force per unit area is assumed to act statically in a direction normal to the surface of the structure or element, except where otherwise specified, e.g. with tangential frictional forces. Both internal and external forces should be considered.

8.6.5 For some structures it may be appropriate to represent the wind forces by their resultants. These resultants shall include along-wind (drag), crosswind (lift), torsional and overturning actions.

8.6.6 The wind forces for the whole structure or a structural component should be determined: by calculating forces using force coefficients or by calculating forces from surface pressures.

8.6.6 The wind force F_w acting on a structure or a structural component may be determined directly by using Expression (8.3)

$$F_w = c_s c_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref} \qquad (8.3)$$

Or by vectorial summation over the individual structural elements by using Expression (8.4)

$$F_w = c_s c_d \cdot \sum_{elements} c_f \cdot q_p(z_e) \cdot A_{ref} \qquad (8.4)$$

where:

$c_s c_d$ is the structural factor as defined in Section 9

c_f is the force coefficient for the structure or structural element, taken equal to 1for all structures.

$q_p(z_e)$ is the peak velocity pressure (defined in 7.5) at reference height z_e taken equal to the total height of a building

A_{ref} is the reference area of the structure or structural element.

8.6.7 The wind force, F_w acting on a structure or a structural element may be determined by vectorial summation of the forces $F_{w,e}$, $F_{w,i}$ and F_{fr} calculated from the external and internal pressures using Expressions (8.5) and (8.6) and the frictional forces resulting from the friction of the wind parallel to the external surfaces, calculated using Expression (8.7).

External forces:

$$F_{w,e} = c_s c_d \cdot \sum_{surfaces} w_e \cdot A_{ref} \tag{8.5}$$

Internal forces

$$F_{w,i} = \sum_{surfaces} w_i \cdot A_{ref} \tag{8.6}$$

Friction forces

$$F_{fr} = c_{fr} \cdot q_p(z_e) \cdot A_{fr} \tag{8.7}$$

where:

$c_s c_d$ is the structural factor as defined in Section 9

w_e is the external pressure on the individual surface at height z_e, given in Expression (8.1)

w_i is the internal pressure on the individual surface at height z_i, given in Expression (8.2)

A_{ref} is the reference area of the individual surface

C_{fr} is the friction coefficient

A_{fr} is the area of external surface parallel to the wind

NOTE 1 For elements (e.g. walls, roofs), the wind force becomes equal to the difference between the external and internal resulting forces.

NOTE 2 Friction forces F_{fr} act in the direction of the wind components parallel to external surfaces.

8.6.8 The effects of wind friction on the surface can be disregarded when the total area of all surfaces parallel with (or at a small angle to) the wind is equal to or less than 4 times the total area of all external surfaces perpendicular to the wind (windward and leeward).

8.6.8 In the summation of the wind forces acting on building structures, the lack of correlation of wind pressures between the windward and leeward sides may be taken into account.

9 Structural factor

9.1 General

The structural factor $c_s c_d$ shall take into account the effect on wind actions from the non simultaneous occurrence of peak wind pressures on the surface (c_s) together with the effect of the vibrations of the structure due to turbulence (c_d).

NOTE The structural factor $c_s c_d$ may be separated into a size factor c_s and a dynamic factor c_d, based on 9.3.

9.2 Determination of structural factor

$c_s c_d$ may be determined as follows:

a) For buildings with a height less than 15 m; the value of $c_s c_d$ may be taken as 1.

b) For facade and roof elements having a natural frequency greater than 5 Hz, the value of $c_s c_d$ may be taken as 1.

c) For 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, the value of $c_s c_d$ may be taken as 1.

d) For chimneys with circular cross-sections whose height is less than 60 m and 6,5 times the diameter, the value of $c_s c_d$ may be taken as 1.

e) Alternatively, for cases a), b), c) and d) above, values of $c_s c_d$ may be derived from 9.3.1.

9.3 Importance factors

The importance factors account for a higher wind load on structures that would be important during an emergency compared to other buildings and temporary structures. These values range from 0.87 to a maximum of 1.25 (see Table 3).

Table 3 — Importance factors for higher wind load on structures

Nature of occupancy	Category	Importance factor
Buildings and other structures that represent a low hazard to human life in the event of failure. Includes agricultural facilities, certain temporary facilities and minor storage facilities	I	0.87
All buildings and other structures except those listed in Categories I, III and IV.	II	1.00
Buildings and other structures that represent a substantial hazard to human life in the event of failure. Includes churches, schools, jails and other highly	III	1.15

occupied structures.		
Buildings and other structures designated as essential facilities. Includes hospitals, emergency facilities, power stations, etc.	IV	1.25

Table 4 — Calculation procedures for the determination of wind actions

Parameter	**Subject reference**
peak velocity pressure q_p	
basic wind velocity v_b	7.2 (2)P
terrain category	Table 1
characteristic peak velocity pressure q_p	7.5 (1)
turbulence intensity I_v	7.4
mean wind velocity v_m	7.3.1
topography coefficient $c_o(z)$	7.3.3
roughness coefficient $c_r(z)$	7.3.2
Wind pressures, e.g. for cladding, fixings and structural parts	
external wind pressure: $w_e = q_p\ c_{pe}$	8.4(1)
internal wind pressure: $w_i = q_p\ c_{pi}$	8.4(2)
Wind forces on structures, e.g. for overall wind effects	
structural factor: $c_s c_d$	9
wind force F_w calculated from force coefficients	8.5 (2)
wind force F_w calculated from pressure coefficients	8.5 (3)

10 Simplified method to calculate wind forces on structures in Rwanda

The design pressure for a given structure can be determined considering its geographical location, exposure (height and surrounding setting), and use. The exterior pressure coefficients are established based on the component size and location on the building. The internal pressure coefficients are determined based on the potential for wind being blown into or sucked out of the building.

Table 5 specifies the minimum wind pressures to be considered for structural design according to regional wind velocity.

The force obtained shall be multiplied by an important factor based on the expected use of the structure (see Table 3).

Table 5 — Minimum design wind pressure

Height (m)	W (kN/m²)	
	Zone A	Zone B
H≤10	0.4	0.70
10 < H≤15	0.55	1.00
15 < H≤30	0.80	1.35
30 < H≤50	1.05	1.60
50 < H≤75	1.35	2.00
75 < H≤100	1.65	2.50

Annex A
(normative)

Wind Zones and areas affected by the regional wind velocity

A wind zone refers to the wind forces that act on a building on a particular building site. The wind zone is mainly characterized by following features:

- The wind region the site is in
- Exposure of the site - whether the site is sheltered or exposed
- Topography (steepness or slope of the land) - whether the land is gentle, moderate or extreme

Once the wind zone has been established, the designer uses this information to determine the bracing requirements of the proposed building. Figure A1(To be developed) shows the map of the two wind zones in Rwanda.

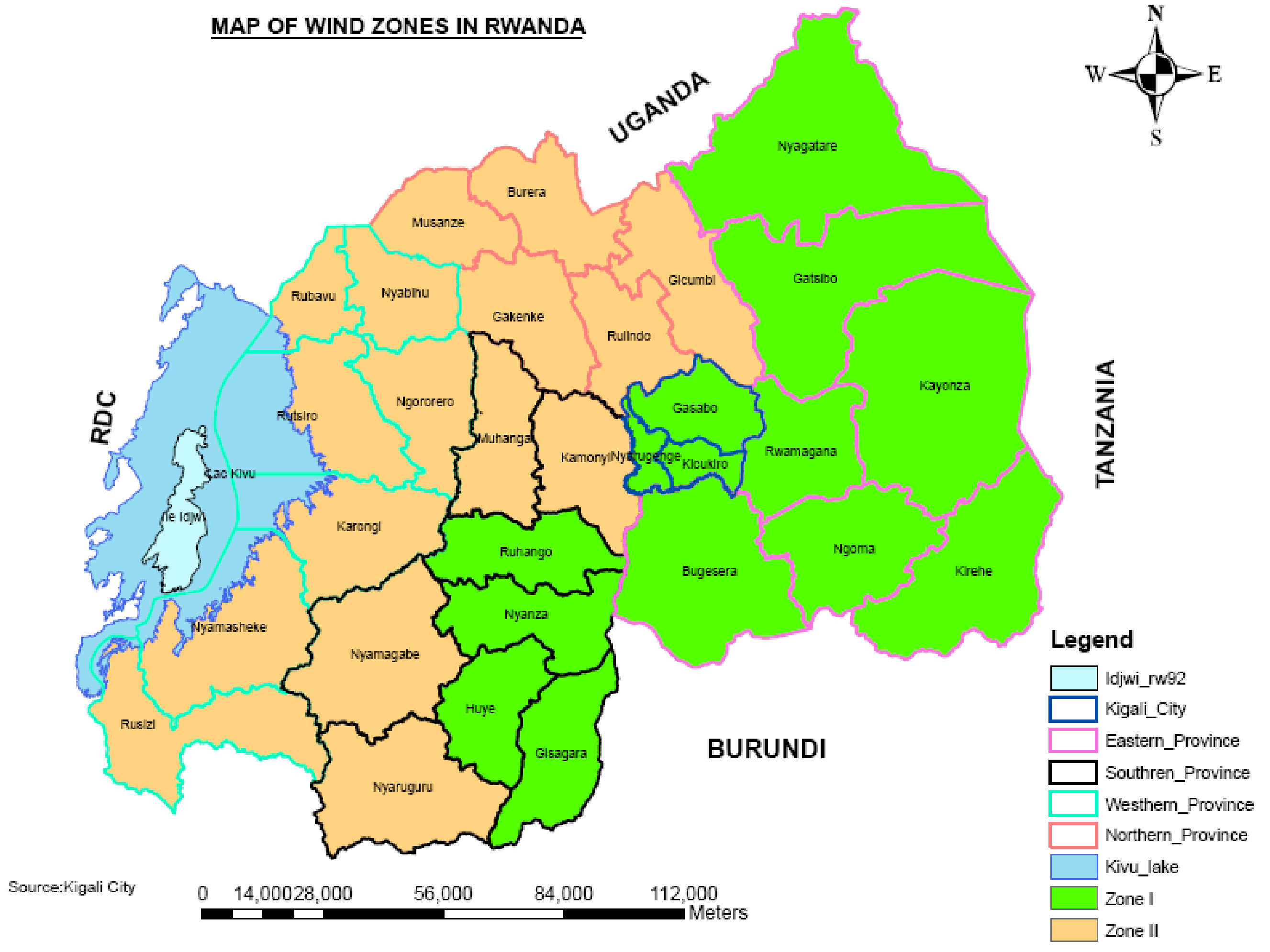

Figure A.1 — Map of wind zones in Rwanda

Table A.1 - Districts affected by the regional wind velocity

Zone I	Zone II
Rulindo district	Rubavu district
Gasabo District	Nyabihu district
Nyarugenge district	Rutsiro district
Kicukiro district	Karongi district
Kamonyi district	Ngororero district
Muhanga District	Nyamasheke district
Ruhango district	Rusizi district
Nyanza district	Musanze district
Huye district	Burera district
Gisagara district	Gicumbi district
Bugesera district	Gakenke district
Rwamagana district	Nyamagabe district
Ngoma district	Nyaruguru district
Kirehe district	
Kayonza district	
Gatsibo district	
Nyagatare district	

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