KEY CHANGES TO WIND LOAD PROVISIONS OF THE DRAFT TCVN 2737:202x

NGUYEN MANH CUONG[a,*], **VU THANH TRUNG**[a]
[a]Vietnam Institute for Building Sicence and Technology
[*]Corresponding author: *email: nguyencuongibst@gmail.com*
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Abstract: *TCVN 2737:1995 Loads and Actions – Norm for Design [1] is the current Vietnamese design standard to determine the wind loads acting on the buildings & structures. This standard was prepared and officially issued in 1995, and has been effective until today (May 2023). Subsequently, two draft revisions related to wind loads were prepared in 2006 and 2009.The applications of design practices have demonstrated the limitations of TCVN 2737:1995.Therefore, Vietnam Ministry of Construction has asked the Vietnam Institute for Building Science & Technology (IBST) to carefully revise TCVN 2737:1995 and to prepare the new TCVN 2737:202x to meet the present and future requirements for design of buildings and structures as well as to harmonise with the region and the world. Hence, the draft standard TCVN 2737:202x Loads and Actions has been prepared since 2017 and has been uploaded to the IBST website [3] to receive feedbacks and opinions from designers, engineers and experts. This draft is expected to be approved and officially published to replace the current standard TCVN 2737:1995. In the draft of this new standard, there are many contents, including wind load provisions. And this paper presents the key changes to wind load provisions of the new draft TCVN 2737:202x.*

Key words: *Wind loads, TCVN* 2737*, basic wind pressure, reference height, gust effect factor...*

1. Introduction

Since TCVN 2737:1995 has been effective in engineering practices, there were 02 revisions related to wind loads:

- The first time (in 2006): updated the observed wind data to 2000 and added aerodynamic instability according to BS EN 1991-1-4:2005 standard but all formulas related to determination of the wind loads were kept as the originally in TCVN 2737:1995;

- The second time (in 2009) was compiled based on SNIP 2.01.07-85*(2009)[8] and there was a change in topography (according to the topographic form of SNiP 2.01.07-85* (2009), but the basic wind speed was taken according to the B-shaped terrain, which is quite different from that in SNiP 2.01.07-85*(2009) – A type terrain). Furthermore, a key change in this revision is the utilization of 10-minute wind speed instead of the 3-second gust wind to determine wind pressures as adopted in TCVN 2737:1995. In addition, the results of wind load calculated according to this draft standard are also slightly smaller than those calculated according to TCVN 2737:1995. However, this draft standard has not been issueddue to the reasons mentioned.

The development of TCVN 2737:1995 for determining wind loads has some limitations, such as:

- In addition to standard SNiP 2.01.07-85(1989), some contents of Australian standards were used in TCVN 2737:1995. The combination may lead to a mismatch of the standard:

+ Changing the time of averaging wind speed from 10 minutes to 3 seconds (gust winds) while still using the formulas for calculating the static and dynamic component of SNIP 2.01.07-85(1989); Combined with the extension period from 5 years to 20 years will increase the standard value of wind load significantly compared to the original of SNIP 2.01.07-85(1989). In order to reduce this, TCVN 2737:1995 has reduced the values of some coefficients such as: reliability coefficient, dynamic pressure, pulse coefficient... However, those changes do not have basis;

+ The terrain used to determine basic wind speed in TCVN 2737:1995 and SNIP 2.01.07-85(1989) is also different: The terrain type of Russian standard is terrain type A but the terrain type of TCVN 2737:1995 is type B (the same with TCVN

2737:1990).

On the other hand, the current standard lacks regulations on wind tunnel test for high-rise buildings, buildings with complex shapes, aerodynamic instability, hurman comfort, effects of wind with neighboring buildings…

As previously stated, TCVN 2737:202x is expected to replace [1], and is currently on the IBST website to seek opinions and feedbacks before officially approved for publication. Compared with the 1995 version, the 202x version has had some key changes, of which the biggest changes are in the load combinations and the calculation of wind loads acting on the buildings & structures including the aerodynamic (shape) pressure coefficients. This paper presents the key changes related to the calculate wind loads acting on the buildings.

2. Key changes to wind load provisions

The first change to be mentioned is the addition of "limit of application" provision. At Point 10.1.1[2], it is prescribed: “Applicable to buildings with a height of up to 200 m and span not greater than 150 m”. Thus, if [1] does not specify the limit of application, the user can apply it to calculate the wind load without being limited by the scale and grade of the buildings, then when applying [2] for the buildings that are not within the specified range, the calculation will be done by alternative methods. Practical studies and experiments show that calculating wind loads on super high-rise buildings using theoretical formulas is no longer appropriate; Therefore, the introduction of a limit like Point 10.1.1[2] is necessary and is also consistent with other foreign standard systems such as Eurocode, ASCE...

The next change is that [2] has adjusted and supplemented the aerodynamic coefficient factor, c, for some types of buildings in Appendix F, and at the same time issued the provisions: “For cases not mentioned in Appendix F (other shapes of the building, consideration of other directions of wind flow or consideration of the total resistance components of the object in other directions, the need to take into account the influence of neighboring buildings and structures, terrain and the like), then it is necessary to consider the aerodynamic coefficient according to specialized technical documents or wind tunnel test” – Point 10.2.7[2].

Another change is the introduction of "reference height, z_e", which is defined as follows:

a) Towers, piers, tubes, hollow structures and the like: $z_e = z$;

b) Buildings

1) For $h \le b$: $z_e = h$

2) For $b < h \le 2b$

$z > b$: $z_e = h$

$0 < z \le b$: $z_e = b$

3) For $h > 2b$

$z \ge h - b$: $z_e = h$

$b < z < h - b$: $z_e = z$

$0 < z \le b$: $z_e = b$

[2] also change the formula to calculate the value of the coefficient, $k(z_e)$, that takes into account the change of wind pressure according to the reference height, z_e, compared to the gradient height, z_g, and terrain type:

$$k(z_e) = 2{,}01\left(\frac{z_e}{z_g}\right)^{2/\alpha} \quad \text{(Eq (12)[2])}$$

($k(z_e)$ is taken not more than 1,99, 1,97 và 1,98 for the terrain types A, B and C respectively);

(z_e is taken not less than z_{min} specified in Table 8[2]).

Thus, if [1] the coefficient taking into account the change in wind pressure with height “k” is determined according to the corresponding height (z), then to [2] has been replaced by the calculation with the reference height (z_e) – Depends on the size of the windward surface. The source of this adjustment is based on SP 20.13330.2016 as well as EN 1991-1-4 and is consistent with the above aerodynamic coefficient adjustment. Equation (12)[2] is derived from 26.10-1 of ASCE/SEI 7-16. When calculating work according to this formula, the value of k increases compared to the calculated value according to [1] – The difference increases with height; at 200m, it increases about 10% for terrain type B and 11% for terrain types A and C.

The fourth change is the change in the calculation of the dynamic component of the wind loads:

TCVN 2737:1995	TCVN 2737:202x
Separation of static and dynamic components ($W = W_t + W_d$)	The dynamic component is calculated together with the static component by the gust effect coefficient, G_f. Gust effect coefficient is used in almost foreign standard such as: ASCE/SEI 7- 16, BS EN 1991-1-4:2005…
The calculation of the dynamic component is divided into many different situations according to the frequency of the building and the limit value, F_L. In many cases, high-order oscillations must be considered, the calculation is quite complicated.	The calculation needs to consider the frequency value of the first mode (n_1) only. In addition, Appendix E (reference) provides some simple formulas to calculate the Gust factor for the buildings.

The Gust effect coefficient in [2] is derived from the basis of 26.11.5 ASCE/SEI 7-16. The Gust effect coefficient, Gf, is the response coefficient of the structure under the action of wind loads (including the static response component (wind impulse) and dynamic response component, resonance). For "rigid" structures (with first self period $T_1 \leq 1$ s), G_f can be taken as 0,85; For "soft" structures (with first self period $T_1 > 1$ s), G_f is determined by the formula:

$$G_f = 0{,}925\left(\frac{1+1{,}7I(z_s)\sqrt{g_Q^2Q^2+g_R^2R^2}}{1+1{,}7g_vI(z_s)}\right) \quad \text{(Eq (13)[2])}$$

where:

- $I(z_s)$ is the turbulence intensity at the equivalent height of the structure z_s - taken as 0,6h;

$$I(z_s) = c_r\left(\frac{10}{z_s}\right)^{1/6} \quad \text{(Eq (14)[2])}$$

- C_r is the coefficient depending on the terrain type, determined according to Table 10[2].

Thus, TCVN 2737:202x has added wind speed profile and turbulence profile, providing a basis for testing the aerodynamic bellows model.

The fifth change is the change of the input basic wind speed. The inlet wind velocity in [1] is the average wind speed for 3 seconds, repeat period of 20 years; in [2] is still average wind speed for 3 seconds but repeat period is 10 years.

With the above changes, the standard value of the wind load, W_k, at the reference height, z_e, is determined by the formula:

$$W_k = W_{3s,10}*k(z_e)*c*G_f \quad \text{(Eq (10)[2])}$$

Other major differences are that TCVN 2737:202x has given the importance factor of wind load, γ_f (for the main wind load, γ_f is taken as 2,1) and the importance factor of the building, γ_n, according to levels C1, C2, C3 (Appendix H) – Corresponding to risk levels in Regulation No.03 (QCVN 03: 2022).

3. Wind load calculation to buildings

Carry out three examples of wind load calculation according to the draft TCVN 2737:202x and TCVN 2737:1995 for assumed buildings:

- Building No.1: Plan BxL=5x15 (m), 5 storey (height of storey 3,6 m);
- Building No.2: PlanBxL=24x24 (m), 15 storey (height of storey 3,2 m);
- Building No.3: Plan BxL=30x82 (m), 29 storey (height of storey 3,6 m).

(Wind zone IIB, terrain type B)

The results of wind load calculation and comparison are summarized in the following tables (for details see the attached appendix):

Table 1. *Calculation results of wind load on building No.1*

Story	z	$F_{k(2x)}$ (daN)		$F_{k(95)}$ (daN)		γ_n	γ_f	$\gamma_n\gamma_f F_{k(2x)} / F_{k(95)}$	
		B_{ref}	D_{ref}	B_{ref}	D_{ref}			B_{ref}	D_{ref}
1	3,6	1651	6813	2390	7169	1,00	2,10	1,45	2,00
2	7,2	1783	6813	2707	8121	1,00	2,10	1,38	1,76
3	10,8	1942	6813	2912	8736	1,00	2,10	1,40	1,64
4	14,4	2162	6813	3067	9200	1,00	2,10	1,48	1,56
5	18,0	1081	3540	1596	4789	1,00	2,10	1,42	1,55

Story	z	$F_{k(2x)}$ (daN)		$F_{k(95)}$ (daN)		γ_n	γ_f	$\gamma_n\gamma_f F_{k(2x)} / F_{k(95)}$	
		B_{ref}	D_{ref}	B_{ref}	D_{ref}			B_{ref}	D_{ref}
$\gamma_n\gamma_f \sum F_{Ki\,(2x)} / \sum F_{Ki\,(95)} =$								**1,43**	**1,70**
$\gamma_n\gamma_f \sum z_i F_{Ki\,(2x)} / \sum z_i F_{Ki\,(95)} =$								**1,43**	**1,63**

Table 2. *Calculation results of wind load on building No.2*

Story	z	$F_{k(2x)}$ (daN)		$F_{k(95)}$ (daN)		γ_n	γ_f	$\gamma_n\gamma_f F_{k(2x)} / F_{k(95)}$	
		B_{ref}	D_{ref}	B_{ref}	D_{ref}			B_{ref}	D_{ref}
1	3,2	10100	10100	10996	10860	1,00	2,10	1,93	1,95
2	6,4	10100	10100	13337	13065	1,00	2,10	1,59	1,62
3	9,6	10100	10100	15208	14799	1,00	2,10	1,39	1,43
4	12,8	10100	10100	16869	16324	1,00	2,10	1,26	1,30
5	16,0	10100	10100	18408	17289	1,00	2,10	1,15	1,23
6	19,2	10100	10100	19868	18173	1,00	2,10	1,07	1,17
7	22,4	10100	10100	21270	19439	1,00	2,10	1,00	1,09
8	25,6	11686	11686	22122	20662	1,00	2,10	1,11	1,19
9	28,8	11686	11686	22940	21852	1,00	2,10	1,07	1,12
10	32,0	11686	11686	23732	23014	1,00	2,10	1,03	1,07
11	35,2	11686	11686	24602	24154	1,00	2,10	1,00	1,02
12	38,4	11686	11686	25758	25276	1,00	2,10	0,95	0,97
13	41,6	11686	11686	26999	26381	1,00	2,10	0,91	0,93
14	44,8	11686	11686	28227	27473	1,00	2,10	0,87	0,89
15	48,0	5843	5843	14721	14276	1,00	2,10	0,83	0,86
$\gamma_n\gamma_f \sum F_{Ki\,(2x)} / \sum F_{Ki\,(95)} =$								**1,09**	**1,13**
$\gamma_n\gamma_f \sum z_i F_{Ki\,(2x)} / \sum z_i F_{Ki\,(95)} =$								**1,00**	**1,03**

Table 3. *Calculation results of wind load on building No.3*

Story	z	$F_{k(2x)}$ (daN)		$F_{k(95)}$ (daN)		γ_n	γ_f	$\gamma_n\gamma_f F_{k(2x)} / F_{k(95)}$	
		B_{ref}	D_{ref}	B_{ref}	D_{ref}			B_{ref}	D_{ref}
1	3,6	14489	53037	16887	46350	1,15	2,10	2,07	2,76
2	7,2	14489	53037	19927	54142	1,15	2,10	1,76	2,37
3	10,8	14489	53037	22039	59722	1,15	2,10	1,59	2,14
4	14,4	14489	53037	23825	64367	1,15	2,10	1,47	1,99
5	18,0	14489	53037	25785	68730	1,15	2,10	1,36	1,86
6	21,6	14489	53037	27705	74257	1,15	2,10	1,26	1,72
7	25,2	14489	53037	28927	77873	1,15	2,10	1,21	1,64
8	28,8	14489	53037	30242	80995	1,15	2,10	1,16	1,58
9	32,4	14726	53037	31382	84142	1,15	2,10	1,13	1,52
10	36,0	15056	53037	32452	87040	1,15	2,10	1,12	1,47
11	39,6	15361	53037	33463	89539	1,15	2,10	1,11	1,43
12	43,2	15645	53037	34521	92415	1,15	2,10	1,09	1,39
13	46,8	15911	53037	35443	94911	1,15	2,10	1,08	1,35
14	50,4	16161	53037	36331	97316	1,15	2,10	1,07	1,32
15	54,0	16397	53037	37209	99653	1,15	2,10	1,06	1,29
16	57,6	16622	53037	38083	101950	1,15	2,10	1,05	1,26

Story	z	$F_{k(2x)}$ (daN)		$F_{k(95)}$ (daN)		γ_n	γ_f	$\gamma_n\gamma_f F_{k(2x)} / F_{k(95)}$	
		B_{ref}	D_{ref}	B_{ref}	D_{ref}			B_{ref}	D_{ref}
17	61,2	16835	53037	38948	104231	1,15	2,10	1,04	1,23
18	64,8	17039	53037	39824	106520	1,15	2,10	1,03	1,20
19	68,4	17234	53037	40600	108850	1,15	2,10	1,03	1,18
20	72,0	17421	53037	41389	111231	1,15	2,10	1,02	1,15
21	75,6	18839	53037	42194	113676	1,15	2,10	1,08	1,13
22	79,2	18839	53037	43014	116185	1,15	2,10	1,06	1,10
23	82,8	18839	55803	43735	118458	1,15	2,10	1,04	1,14
24	86,4	18839	55803	44468	120783	1,15	2,10	1,02	1,12
25	90,0	18839	55803	45319	123167	1,15	2,10	1,00	1,09
26	93,6	18839	55803	45952	125894	1,15	2,10	0,99	1,07
27	97,2	18839	55803	46693	128047	1,15	2,10	0,97	1,05
28	100,8	18839	55803	47433	129040	1,15	2,10	0,96	1,04
29	104,4	9419	27902	24166	65462	1,15	2,10	0,94	1,03
$\gamma_n\gamma_f\sum F_{Ki\,(2x)} / \sum F_{Ki\,(95)} =$								1,12	1,35
$\gamma_n\gamma_f\sum z_i F_{Ki\,(2x)} / \sum z_i F_{Ki\,(95)} =$								1,04	1,20

Comments:

- Through the introduction and examples above, it shows that the calculate wind loads effect on the high-rise building according to TCVN 2737:202x is easier to use than TCVN 2737:1995;

- The Gust factor calculated according to Appendix E (reference) has a significant difference compared to the calculation by Eq(13)[2] for high-rise buildings;

- In terms of value, through the examples above, it shows the results (Loads acting on each floor, $\gamma_n\gamma_f F_k$; Total moment and bottom shear, $\gamma_n\gamma_f\sum z_i F_{Ki}$ and $\gamma_n\gamma_f\sum F_{Ki}$) according to TCVN 2737:202x giving larger value than calculated according to TCVN 2737:1995;

- Changing the formula for calculating the coefficient k and the reference height, z_e, instead of the height z as in [1] are one of the reasons for the change in the results:

+ At examples 1 and 2: The building with a ratio of the size of the windward area (height / width) is small, the change is quite obvious, especially on the floors below;

+ For long-shaped buildings, the wind load effect in the direction perpendicular to the plane of the long side is greater than other side due to the proportional relationship of the height and width.

4. Conclusions

- This paper presents the key changes to wind load provisions in the draft standard TCVN 2737:202x compared to the wind loads determined based on TCVN 2737:1995, and also introduces some specific examples to compare and evaluate the wind load results;

- The use of wind gust effect factor, G_f, and calculation principle similar to foreign standards (ASCE 7-16) help design engineers to easily prepare spreadsheets or software program or to attach into the commercial structural analysis softwares such as SAP 2000 or ETABS;

- With high-rise buildings, gust effect factor, G_f, calculated according to Appendix E (reference) – [2] has a difference compared to calculated value usingequation (13)[2], so it is recommended to determine G_f by formula (13) of the draft standard [2].

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[7] ASCE/SEI 7-16, Minimum Design Loads and Associated Criteria for Buildings and Other Structures.

[8] SP 20.13330.2016, Loads and Actions.

ANNEX: A.1

RESULTS CALCULATED WIND LOADS ACTION ON BUILDING 1 (BASE ON TCVN 2737:202X)

W_0 (daN)	$V_{3s,50}$ (m/s)	Terrain	b (m)	d (m)	h (m)	n_{1b} (Hz)	n_{1d} (Hz)	$g_{R(b)}$	$g_{R(d)}$	β	$C_{(B)}$	$C_{(D)}$	$I(Z_s)$	L(Zs)	$V(Z_s)_{3600s,50}$
95,0	43,1	B	5,0	15,0	18,0	2,00	2,00	4,352	4,352	0,02	1,31	1,43	0,517	154,8	28,4

Story	Dimensions (m)			Z_e		$K(Z_e)$		G_f (quick)	Q		R_n		R_h		R_b		R_d		R		G_f		W_k (daN/m2)		$F_{k(2x)}$ (daN)	
	B	D	Z	B_{ref}	D_{ref}	B_{ref}	D_{ref}		B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}
1	5,0	15,0	3,6	5,0	15,0	0,87	1,09	0,86	0,92	0,90	0,03	0,03	0,16	0,16	0,43	0,43	0,18	0,18	0,25	0,25	0,91	0,89	91,7	126	1651	6813
2	5,0	15,0	7,2	7,2	15,0	0,93	1,09	0,86	0,92	0,90	0,03	0,03	0,16	0,16	0,43	0,43	0,18	0,18	0,25	0,25	0,91	0,89	99,0	126	1783	6813
3	5,0	15,0	10,8	10,8	15,0	1,02	1,09	0,86	0,92	0,90	0,03	0,03	0,16	0,16	0,43	0,43	0,18	0,18	0,25	0,25	0,91	0,89	107,9	126	1942	6813
4	5,0	15,0	14,4	18,0	15,0	1,13	1,09	0,86	0,92	0,90	0,03	0,03	0,16	0,16	0,43	0,43	0,18	0,18	0,25	0,25	0,91	0,89	120,1	126	2162	6813
5	5,0	15,0	18,0	18,0	18,0	1,13	1,13	0,86	0,92	0,90	0,03	0,03	0,16	0,16	0,43	0,43	0,18	0,18	0,25	0,25	0,91	0,89	120,1	131,1	1081	3540

RESULTS CALCULATED WIND LOADS EFFECT TO BUILDING 1 (BASE ON TCVN 2737:1995)

W_0 (daN)	Terrain	$C_{(B)}$	$C_{(D)}$	γ	ν (B)	ν (D)	f_{1b} (Hz)	f_{2b} (Hz)	f_{1d} (Hz)	f_{2d} (Hz)	ε_{1b}	ε_{2b}	ε_{1d}	ε_{2d}	ξ_{1b}	ξ_{2b}	ξ_{1d}	ξ_{1d}	ψ_{1b}	ψ_{2b}	ψ_{1d}	ψ_{2d}
95,0	B	1,40	1,40	1,20																		

Story	Dimensions (m)			K	ζ	W_{ttc} (daN)		m_K	$yk\ (B_{ref})$		$yk\ (D_{ref})$		$y_k W_{pk}$ (daN)				$y_k^2 m_K$ (daN)				W_{dtc} (daN)				$F_{k(95)}$ (daN)	
	B	D	Z			B_{ref}	D_{ref}	(daN.s2/m)	mode1	mode2	mode1	mode2	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	B_{ref}	D_{ref}
1	5,0	15,0	3,6	0,83	0,53	1991	5974																		2390	7169
2	5,0	15,0	7,2	0,94	0,50	2256	6768																		2707	8121
3	5,0	15,0	10,8	1,01	0,48	2427	7280																		2912	8736
4	5,0	15,0	14,4	1,07	0,47	2556	7667																		3067	9200
5	5,0	15,0	18,0	1,11	0,46	1330	3991																		1596	4789

ANNEX: A.2

RESULTS CALCULATED WIND LOADSACTION ON BUILDING 2 (BASE ON TCVN 2737:202X)

W_0 (daN)	$V_{3s,50}$ (m/s)	Terrain	b (m)	d (m)	h (m)	n_{1b} (Hz)	n_{1d} (Hz)	$g_{R(b)}$	$g_{R(d)}$	β	$C_{(B)}$	$C_{(D)}$	$I(Z_s)$	L(Zs)	$V(Z_s)_{3600s,50}$
95,0	43,1	B	20,0	40,0	36,0	1,00	1,00	4,189	4,189	0,02	1,30	1,34	0,581	177,8	31,6

Story	Dimensions (m)			Z_e		$K(Z_e)$		G_f (quick)	Q		R_n		R_h		R_b		R_d		R		G_f		W_k (daN/m2)		$F_{k(2x)}$ (daN)	
	B	D	Z	B_{ref}	D_{ref}	B_{ref}	D_{ref}		B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}
1	20,0	40,0	3,6	20,0	36,0	1,16	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	123,6	144	8898	20760
2	20,0	40,0	7,2	20,0	36,0	1,16	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	123,6	144,2	8898	20760
3	20,0	40,0	10,8	20,0	36,0	1,16	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	123,6	144,2	8898	20760
4	20,0	40,0	14,4	20,0	36,0	1,16	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	123,6	144,2	8898	20760
5	20,0	40,0	18,0	20,0	36,0	1,16	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	123,6	144,2	8898	20760
6	20,0	40,0	21,6	36,0	36,0	1,31	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	139,9	144,2	10070	20760
7	20,0	40,0	25,2	36,0	36,0	1,31	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	139,9	144,2	10070	20760
8	20,0	40,0	28,8	36,0	36,0	1,31	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	139,9	144,2	10070	20760
9	20,0	40,0	32,4	36,0	36,0	1,31	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	139,9	144,2	10070	20760
10	20,0	40,0	36,0	36,0	36,0	1,31	1,31	0,86	0,88	0,85	0,05	0,05	0,17	0,17	0,28	0,28	0,16	0,16	0,26	0,26	0,88	0,86	139,9	144,2	5035	10380

RESULTS CALCULATED WIND LOADS EFFECT TO BUILDING 2 (BASE ON TCVN 2737:1995)

W_0 (daN)	Terrain	$C_{(B)}$	$C_{(D)}$	γ	ν (B)	ν (D)	f_{1b} (Hz)	f_{2b} (Hz)	f_{1d} (Hz)	f_{2d} (Hz)	ε_{1b}	ε_{2b}	ε_{1d}	ε_{2d}	ξ_{1b}	ξ_{2b}	ξ_{1d}	ξ_{1d}	ψ_{1b}	ψ_{2b}	ψ_{1d}	ψ_{2d}
95,0	B	1,40	1,40	1,20																		

Story	Dimensions (m)			K	ζ	W_{ttc} (daN)		m_K (daN.s2/m)	yk (B_{ref})		yk (D_{ref})		y_kW_{pk} (daN)				$y_k^2m_K$ (daN)				W_{dtc} (daN)				$F_{k(95)}$ (daN)	
	B	D	Z			B_{ref}	D_{ref}		mode1	mode2	mode1	mode2	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	B_{ref}	D_{ref}
1	20,0	40,0	3,6	0,83	0,53	7965	15930																		9558	19117
2	20,0	40,0	7,2	0,94	0,50	9024	18047																		10828	21657
3	20,0	40,0	10,8	1,01	0,48	9707	19414																		11648	23297
4	20,0	40,0	14,4	1,07	0,47	10223	20446																		12267	24535
5	20,0	40,0	18,0	1,11	0,46	10642	21283																		12770	25540
6	20,0	40,0	21,6	1,15	0,45	10997	21994																		13196	26392
7	20,0	40,0	25,2	1,18	0,45	11306	22612																		13567	27135
8	20,0	40,0	28,8	1,21	0,44	11581	23162																		13897	27795
9	20,0	40,0	32,4	1,24	0,44	11829	23659																		14195	28390
10	20,0	40,0	36,0	1,26	0,43	6028	12056																		7234	14467

RESULTS CALCULATED WIND LOADS ACTION ON BUILDING 3 (BASE ON TCVN 2737:202X)

W_0 (daN)	$V_{3s,50}$ (m/s)	Terrain	b (m)	d (m)	h (m)	n_{1b} (Hz)	n_{1d} (Hz)	$g_{R(b)}$	$g_{R(d)}$	β	$C_{(B)}$	$C_{(D)}$	$I(Z_s)$	L(Zs)	$V(Z_s)_{3600s,50}$
95,0	43,1	B	30,0	82,0	104,4	0,25	0,32	3,848	3,905	0,02	1,31	1,42	0,694	220,0	37,2

Story	Dimensions (m)			Z_e		$K(Z_e)$		G_f (quick)	Q		R_n		R_h		R_b		R_d		R		G_f		W_k (daN/m2)		$F_{k(2x)}$ (daN)	
	B	D	Z	B_{ref}	D_{ref}	B_{ref}	D_{ref}		B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}	B_{ref}	D_{ref}
1	30,0	82,0	3,6	30,0	82,0	1,26	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	134,2	179,7	14489	53037
2	30,0	82,0	7,2	30,0	82,0	1,26	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	134,2	179,7	14489	53037
3	30,0	82,0	10,8	30,0	82,0	1,26	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	134,2	179,7	14489	53037
4	30,0	82,0	14,4	30,0	82,0	1,26	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	134,2	179,7	14489	53037
5	30,0	82,0	18,0	30,0	82,0	1,26	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	134,2	179,7	14489	53037
6	30,0	82,0	21,6	30,0	82,0	1,26	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	134,2	179,7	14489	53037
7	30,0	82,0	25,2	30,0	82,0	1,26	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	134,2	179,7	14489	53037
8	30,0	82,0	28,8	30,0	82,0	1,26	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	134,2	179,7	14489	53037
9	30,0	82,0	32,4	32,4	82,0	1,28	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	136,3	179,7	14726	53037
10	30,0	82,0	36,0	36,0	82,0	1,31	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	139,4	179,7	15056	53037
11	30,0	82,0	39,6	39,6	82,0	1,34	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	142,2	179,7	15361	53037
12	30,0	82,0	43,2	43,2	82,0	1,36	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	144,9	179,7	15645	53037
13	30,0	82,0	46,8	46,8	82,0	1,39	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	147,3	179,7	15911	53037
14	30,0	82,0	50,4	50,4	82,0	1,41	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	149,6	179,7	16161	53037
15	30,0	82,0	54,0	54,0	82,0	1,43	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	151,8	179,7	16397	53037
16	30,0	82,0	57,6	57,6	82,0	1,45	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	153,9	179,7	16622	53037
17	30,0	82,0	61,2	61,2	82,0	1,47	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	155,9	179,7	16835	53037
18	30,0	82,0	64,8	64,8	82,0	1,48	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	157,8	179,7	17039	53037
19	30,0	82,0	68,4	68,4	82,0	1,50	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	159,6	179,7	17234	53037
20	30,0	82,0	72,0	72,0	82,0	1,52	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	161,3	179,7	17421	53037
21	30,0	82,0	75,6	104,4	82,0	1,64	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	179,7	18839	53037
22	30,0	82,0	79,2	104,4	82,0	1,64	1,56	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	179,7	18839	53037
23	30,0	82,0	82,8	104,4	104,4	1,64	1,64	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	189,0	18839	55803
24	30,0	82,0	86,4	104,4	104,4	1,64	1,64	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	189,0	18839	55803
25	30,0	82,0	90,0	104,4	104,4	1,64	1,64	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	189,0	18839	55803
26	30,0	82,0	93,6	104,4	104,4	1,64	1,64	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	189,0	18839	55803
27	30,0	82,0	97,2	104,4	104,4	1,64	1,64	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	189,0	18839	55803
28	30,0	82,0	100,8	104,4	104,4	1,64	1,64	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	189,0	18839	55803
29	30,0	82,0	104,4	104,4	104,4	1,64	1,64	0,89	0,83	0,80	0,11	0,09	0,26	0,22	0,59	0,52	0,31	0,26	0,74	0,59	1,05	0,96	174,4	189,0	9419	27902

RESULTS CALCULATED WIND LOADS EFFECT TO BUILDING 3 (BASE ON TCVN 2737:1995)

W_0 (daN)	Terrain	$C_{(B)}$	$C_{(D)}$	γ	ν(B)	ν(D)	f_{1b} (Hz)	f_{2b} (Hz)	f_{1d} (Hz)	f_{2d} (Hz)	ε_{1b}	ε_{2b}	ε_{1d}	ε_{2d}	ξ_{1b}	ξ_{2b}	ξ_{1d}	ξ_{1d}	ψ_{1b}	ψ_{2b}	ψ_{1d}	ψ_{2d}
95,0	B	1,40	1,40	1,37	0,58	0,54	0,34	1,17	0,32	1,09	0,114	0,033	0,122	0,035	1,90	1,42	1,98	1,44	170	48	-447	-140

Story	Dimensions (m)			K	ζ	W_{ttc} (daN)		m_K	yk (B_{ref})		yk (D_{ref})		$y_k W_{pk}$ (daN)				$y_k^2 m_K$ (daN)				W_{dtc} (daN)				$F_{k(95)}$ (daN)	
	B	D	Z			B_{ref}	D_{ref}	(daN.s2/m)	mode1	mode2	mode1	mode2	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	mode 1 B_{ref}	mode 2 B_{ref}	mode 1 D_{ref}	mode 2 D_{ref}	B_{ref}	D_{ref}
1	30,0	82,0	3,6	0,83	0,53	11948	32657	251484	0,00000	0,00002	0,00000	-0,00002	0,01108	0,06277	-0,02819	-0,17852	0,00000	0,00007	0,00000	0,00009	243	290	668	967	16887	46350
2	30,0	82,0	7,2	0,94	0,50	13536	36997	251484	0,00001	0,00004	-0,00001	-0,00004	0,03537	0,16112	-0,07001	-0,39003	0,00002	0,00042	0,00001	0,00038	729	698	1558	1984	19927	54142
3	30,0	82,0	10,8	1,01	0,48	14560	39798	251484	0,00001	0,00006	-0,00001	-0,00006	0,05706	0,24456	-0,11410	-0,59123	0,00005	0,00091	0,00003	0,00082	1134	1022	2448	2900	22039	59722
4	30,0	82,0	14,4	1,07	0,47	15334	41913	251484	0,00002	0,00008	-0,00002	-0,00008	0,07947	0,33463	-0,15967	-0,79835	0,00009	0,00161	0,00006	0,00141	1539	1363	3338	3815	23825	64367
5	30,0	82,0	18,0	1,11	0,46	15963	43631	251484	0,00003	0,00011	-0,00002	-0,00010	0,11523	0,46091	-0,20635	-1,06433	0,00018	0,00293	0,00009	0,00242	2188	1840	4228	4986	25785	68730
6	30,0	82,0	21,6	1,15	0,45	16495	45087	251484	0,00004	0,00013	-0,00003	-0,00012	0,16052	0,56398	-0,33121	-1,34691	0,00034	0,00425	0,00023	0,00374	2998	2215	6676	6206	27705	74257
7	30,0	82,0	25,2	1,18	0,45	16959	46355	251484	0,00004	0,00014	-0,00004	-0,00013	0,18475	0,61585	-0,40300	-1,48886	0,00044	0,00493	0,00033	0,00445	3403	2385	8012	6766	28927	77873
8	30,0	82,0	28,8	1,21	0,44	17372	47483	251484	0,00005	0,00015	-0,00004	-0,00014	0,21815	0,65891	-0,46452	-1,60883	0,00060	0,00551	0,00042	0,00507	3970	2521	9124	7224	30242	80995
9	30,0	82,0	32,4	1,24	0,44	17744	48500	251484	0,00006	0,00015	-0,00005	-0,00015	0,24747	0,68843	-0,53818	-1,70613	0,00076	0,00589	0,00056	0,00558	4456	2607	10459	7580	31382	84142
10	30,0	82,0	36,0	1,26	0,43	18084	49429	251484	0,00006	0,00016	-0,00005	-0,00015	0,27709	0,70407	-0,61266	-1,75707	0,00094	0,00604	0,00071	0,00581	4942	2641	11795	7733	32452	87040
11	30,0	82,0	39,6	1,28	0,43	18397	50284	251484	0,00007	0,00015	-0,00006	-0,00015	0,30696	0,70556	-0,67624	-1,78386	0,00113	0,00596	0,00085	0,00589	5428	2624	12907	7784	33463	89539
12	30,0	82,0	43,2	1,30	0,43	18687	51078	251484	0,00007	0,00015	-0,00007	-0,00015	0,34170	0,68802	-0,76381	-1,77438	0,00138	0,00558	0,00106	0,00573	5996	2538	14465	7682	34521	92415
13	30,0	82,0	46,8	1,32	0,42	18958	51819	251484	0,00008	0,00014	-0,00007	-0,00015	0,37208	0,65578	-0,84034	-1,72803	0,00161	0,00500	0,00127	0,00536	6482	2402	15800	7427	35443	94911
14	30,0	82,0	50,4	1,34	0,42	19213	52515	251484	0,00009	0,00013	-0,00008	-0,00014	0,40266	0,60399	-0,91746	-1,64428	0,00186	0,00418	0,00149	0,00479	6968	2198	17136	7020	36331	97316
15	30,0	82,0	54,0	1,35	0,42	19453	53171	251484	0,00009	0,00012	-0,00008	-0,00013	0,43343	0,54179	-0,99511	-1,52264	0,00213	0,00333	0,00173	0,00406	7454	1959	18471	6461	37209	99653
16	30,0	82,0	57,6	1,37	0,42	19680	53793	251484	0,00010	0,00010	-0,00009	-0,00011	0,46439	0,46913	-1,07326	-1,36268	0,00242	0,00246	0,00199	0,00321	7940	1687	19806	5749	38083	101950
17	30,0	82,0	61,2	1,39	0,41	19896	54383	251484	0,00010	0,00008	-0,00010	-0,00010	0,49552	0,37640	-1,15188	-1,16401	0,00272	0,00157	0,00227	0,00232	8426	1346	21141	4884	38948	104231
18	30,0	82,0	64,8	1,40	0,41	20102	54945	251484	0,00011	0,00006	-0,00010	-0,00008	0,52681	0,27777	-1,23095	-0,92626	0,00304	0,00085	0,00257	0,00145	8912	988	22477	3866	39824	106520
19	30,0	82,0	68,4	1,41	0,41	20299	55483	251484	0,00012	0,00004	-0,00011	-0,00005	0,55344	0,16844	-1,31044	-0,66134	0,00333	0,00031	0,00288	0,00073	9317	596	23812	2747	40600	108850
20	30,0	82,0	72,0	1,43	0,41	20487	55997	251484	0,00012	0,00001	-0,00011	-0,00003	0,58018	0,04835	-1,39032	-0,36911	0,00362	0,00003	0,00321	0,00023	9723	170	25147	1526	41389	111231
21	30,0	82,0	75,6	1,44	0,41	20668	56491	251484	0,00013	-0,00002	-0,00012	-0,00001	0,60701	-0,07284	-1,47059	-0,06179	0,00393	0,00006	0,00356	0,00001	10128	-256	26483	254	42194	113676
22	30,0	82,0	79,2	1,45	0,40	20841	56966	251484	0,00013	-0,00004	-0,00013	0,00002	0,63394	-0,19993	-1,55122	0,27301	0,00425	0,00042	0,00393	0,00012	10533	-698	27818	-1119	43014	116185
23	30,0	82,0	82,8	1,46	0,40	21009	57424	251484	0,00013	-0,00007	-0,00013	0,00005	0,65606	-0,32314	-1,61973	0,62297	0,00452	0,00110	0,00425	0,00063	10857	-1124	28930	-2544	43735	118458
24	30,0	82,0	86,4	1,47	0,40	21170	57865	251484	0,00014	-0,00009	-0,00014	0,00008	0,67824	-0,44725	-1,68848	0,96306	0,00479	0,00208	0,00458	0,00149	11181	-1550	30043	-3917	44468	120783
25	30,0	82,0	90,0	1,48	0,40	21326	58292	251484	0,00014	-0,00012	-0,00014	0,00011	0,70540	-0,57221	-1,75747	1,31810	0,00514	0,00338	0,00493	0,00277	11586	-1976	31156	-5342	45319	123167
26	30,0	82,0	93,6	1,50	0,40	21478	58705	251484	0,00015	-0,00014	-0,00015	0,00013	0,72275	-0,68809	-1,83927	1,67550	0,00536	0,00486	0,00536	0,00445	11829	-2368	32491	-6766	45952	125894
27	30,0	82,0	97,2	1,51	0,40	21624	59105	251484	0,00015	-0,00016	-0,00015	0,00016	0,74507	-0,79971	-1,89609	2,02249	0,00566	0,00652	0,00566	0,00644	12153	-2743	33381	-8140	46693	128047
28	30,0	82,0	100,8	1,52	0,39	21766	59494	251484	0,00015	-0,00018	-0,00015	0,00019	0,76745	-0,90699	-1,90230	2,35886	0,00596	0,00833	0,00566	0,00870	12477	-3101	33381	-9462	47433	129040
29	30,0	82,0	104,4	1,52	0,39	10952	29935	125742	0,00016	-0,00021	-0,00015	0,00022	0,39744	-0,52742	-0,96688	1,42488	0,00318	0,00560	0,00291	0,00631	6441	-1797	16913	-5698	24166	65462