National Reports on Wind-Resistant Design of South Korea

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ABSTRACT: This paper reviews domestic activities in the wind engineering field in Korea on the last five years which aims to improve and develop of wind-resistant design criteria on structures to mitigate the abnormal weather.

KEYWORDS: Wind-resistant design, basic wind speed map, wind-induced vibration, abnormal weather, wind load criteria, guidelines.

1 RESEARCH DETAILS

In the research group progresses regarding wind-resistance were covering several sectors including the basic wind speed map was modified, the design criteria for wind load and wind-induced vibration were improved and developed, and the criteria and instructions on the design of bridges and other structures, which can mitigate the abnormal weather in the current situation where changes in climate features due to abnormal climate and variations in wind velocity due to sudden urbanization cannot be properly dealt with, because the criteria for wind-resistant design have not been amended since 1992. The details of research regarding wind resistance are as follows:

- ⓐ Construction, civil engineering structures for design basic wind speed Map improvement.
- ⓑ Prevention of damage by blast wind environment.
- ⓒ Improvement the domestic wind load criteria (buildings, bridges and other structures).
- ⓓ Buildings wind attack angle / torsional Wind Load Evaluation Method.
- ⓔ Classification of buildings according to the development of wind load estimation division process.
- ⓕ Structure a combination of the horizontal wind development.
- ⓖ Wind vibration awareness of the residents building structures assesment.
- ⓗ Building design standards developed a unique frequency wind vibration.
- ⓘ Amplitude and the residents of a building consent by the attitude of wind vibration design criteria development.
- ⓙ Weather and road bridges over parts of the facility wind resistance design criteria / maintenance and development of guidelines
- ⓚ Bridges and buildings developed by Numerical Analysis of design criteria based on the data construction.

2 RESEARCH AND DEVELOPMENT RESULTS

2.1 *Annual endorsement information and results*

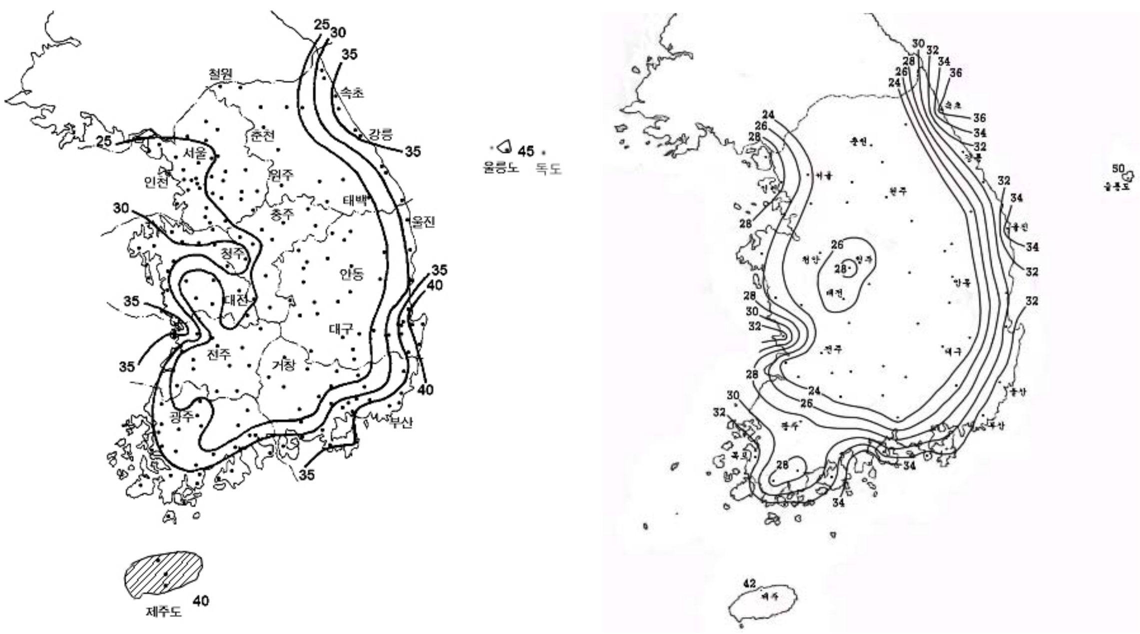
In the first year, related materials and data such as domestic and overseas reports and papers were collected. Based on the collected materials, theoretical research and analysis were performed. Technological information related to this research was collected from advanced foreign countries, and the applicability of the information to Korea was analyzed. Based on the result, plans for the development of methodologies appropriate for Korea were made. In addition, the directions of empirical experiments and over all research and plans were established, and are search road map by year was established before this research started.

In the second year, based on the research results in the first year, databases on each detail task were created, a theoretical research basis was established, and basic experiments were performed as the initial stage of empirical research.

In the third and fourth years, theoretical research and related experiments were performed in order to make the research details in the second year concrete as the advanced empirical research stage. Furthermore, a database on research results was created and a system program was made. These visible research results were presented.

In the fifth year, the research results so far were completed. Standards and instructions were proposed to apply them to actual work. In order for these results to be applied in actual work, experts at related institutions and academic societies need to verify the results. Results of research regarding wind resistance are as follows.

ⓐ. Improvement of the Basic Wind Speed Map and Countermeasures for Wind Environment Damage Reduction due to a Sudden Gust of Wind
- Modification Proposal for the Basic Wind Speed Map
  - ▪ Presentation of Basic Wind Velocity at the Frequency of 100 Years all over the Nation by Standardizing Wind Velocity at Each Observatory
- Proposal for Criteria of Environmental Wind Condition and Establishment of Criteria for the Installation of Wind Shield
  - ▪ Proposal for Criteria of Environmental Wind Condition Modified to be Appropriate for the Reality of Korea



a) Basic wind speed map (1995) b) Current project

Fig. 1 Basic wind speed map

ⓑ. Improvement and Development of Design Criteria for Wind Load at Buildings

- Proposal of Evaluation Criteria for Wind Load
    - Proposal for Evaluation Criteria for the Load of Across-Wind and Torsional Wind at Buildings
    - Proposal for Evaluation Criteria for Wind Load Depending on the Size of Buildings (Low-rise Buildings, Medium-rise Buildings, and Skyscrapers)
    - Presentation of Buildings, the Objects of Dynamic Analysis and Wind Tunnel Experiments

● Wind load on high-rise building

In KBC2009, wind loads on building are estimated by using following equation.

$$W_f = \{G_f \cdot (q_z \cdot C_{pe1} - q_h \cdot C_{pe2})\} \cdot A \text{ (N)} \quad (1)$$

$$q_z = \frac{1}{2}\rho V_z^{\,2} \quad (\text{N/m}^2) \quad (2)$$

$$V_z = V_0 \cdot K_{zr} \cdot K_{zt} \cdot I_w \quad (3)$$

Where G_f is the gust effect factor ; q_z, q_h are the velocity pressure at the height z above ground and the mean roof height h ; C_{pe1}, C_{pe2} are the mean wind pressure coefficient on windward and leeward wall; A is effective area ; ρ is air density ; V_z, V_0 is the design wind velocity and the basic wind velocity ; K_{zr} is wind speed profile factor; K_{zt} topography factor and I_w importance factor.

Empirical equations of estimating wind load given by Y.C. Ha et al.(2008) as following:

$$W_f = \{G_f \cdot q_h (C'_{pe1} - C'_{pe2})\} \cdot A \quad (4)$$

Where C'_{pe1}, C'_{pe2} are wind pressure coefficient on windward and leeward: they are given by following:

$$C'_{pe1} = 0.8\kappa_z + 0.028\left(\frac{D}{B}\right) \quad (5)$$

$$\kappa_z = \left(\frac{z}{H}\right)^{2\alpha} \quad [\,20m < z\,] \quad (6.a)$$

$$\kappa_z = \left(\frac{20}{H}\right)^{2\alpha} \quad [\,20m \geq z\,] \quad (6.b)$$

$$C'_{pe2} = -0.5 \quad [\,D/B \leq 1\,] \quad (7.a)$$

$$C'_{pe2} = -0.5 + 0.25\ln(D/B)^{0.8} \quad [\,D/B > 1\,] \quad (7.b)$$

Where κ_z is wind pressure distribution coefficient according to the height of building.

● Wind load on middle and low-rise building

The Static Procedure defined here was developed in response to this demand. The following conditions apply to this procedure. (a) It applies to buildings that do not have height more than 15m, do not have a special shape or structural system and are small, as like a house, store, warehouse and factory. (b) The construction site is suburban, corresponding to Category B. For Category C, a factor for increasing wind loads is taken into account. This procedure can be applied to buildings in Category A sites, but it overestimates wind loads so that it is safe. Buildings are rarely built on Category D sites, there are outside of the Static Procedure. (c) The design return period is 50 years. Because, small buildings with mean roof height smaller than 15m are involved in Importance Category 2 and Importance Factor corresponds to 0.95.

By substituting above assumptions into equation (4), design wind speed on the Surface Roughness Category B and C are derived as:

$$\mathrm{V}_{\mathrm{z,B}} = V_0\left(0.45Z^{0.22}\right)\times 1.0 \times 0.95 = 0.428V_0Z^{0.22} \tag{8}$$

$$\mathrm{V}_{\mathrm{z,C}} = V_0\left(0.71Z^{0.16}\right)\times 1.0 \times 0.95 = 0.675V_0Z^{0.16} \tag{9}$$

Design velocity pressure on the Surface Roughness Category B and C are derived as:

$$q_{z,B} = \frac{1}{2}\rho V_{0,B}^2 = 0.112V_0^2Z^{0.44} \tag{10}$$

$$q_{z,C} = \frac{1}{2}\rho V_{0,C}^2 = 0.112V_0^2Z^{0.30} \tag{11}$$

By substituting equation (10) into equation (1), and then selecting Gust Effect Factor for Surface Roughness Category B to 2.2 and putting force coefficient as $C_f = C_{pe1} - C_{pe2}$, wind loads W_{sf} for wind force resisting main-frames on small buildings becomes simply as;

$$W_{sf} = 0.25V_0^2Z^{0.44}C_fA \tag{12}$$

Where: $V_0 =$ wind speed (m/s) and $z =$reference height (m)

Finally, wind loads on the low-rise buildings, obtained by wind tunnel studies, were compared to the estimates by the Static Procedure of equation (12). If Surface Roughness Category has B and side ratio of low-rise buildings has 2.0, then wind loads obtained by the KBC2009 are larger about 1.4time than the estimates by Static Procedure of equation (12). The KBC2009 may be called to conservative method for low-rise buildings.

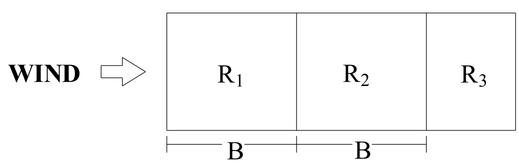
Table 1 External pressure coefficients of small buildings

Object	Division	C_{pe}	
		KBC	Proposed
windward	B/H > 1	0.8	0.6
leeward	D/B =0 ~ 1	-0.5	-0.5
	D/B = 2	-0.3	-0.3
	D/B ≥ 4	-0.2	-0.3
roof	B/D > 2	-0.7	-0.9
	R_1		-0.8
	R_2		-0.3
	R_3		-0.2

R_1: distance from the edge of windward roof to the distance B of leeward direction

R_2: distance from B to 2B

R_3: distance from 2B to the edge of leeward



ⓒ. Improvement and Development of Design Criteria for Wind-Induced Vibration at Buildings

- Proposal for Evaluation Criteria for Wind-Induced Vibration
    - ▪ Presentation of Evaluation Criteria for the Vibration Serviceability of Residential and Office Buildings

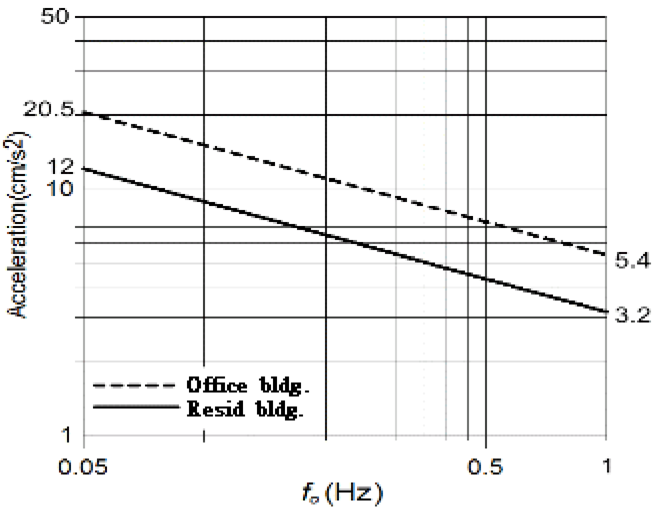


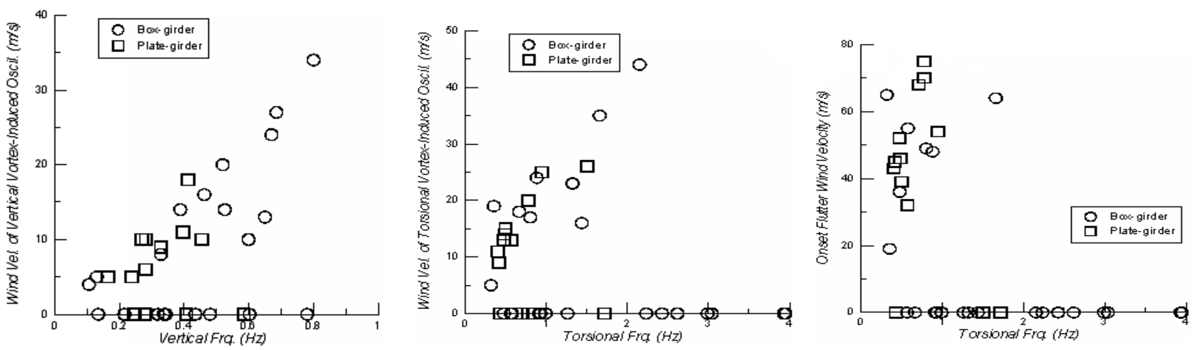
Fig. 2 Guideline for residential and offices structures of wind vibration utilization estimation curve

ⓓ. Improvement and Development of Wind Resistant Design Criteria for Highway Bridges and Other Structures

- Criteria for the Static and Dynamic Design of Bridge Structures of 200m or Less
    - ・ Proposal for the Improvement of Static Wind Load in the Event of Amending the Design Criteria for Road Bridges
    - ・ Criteria for Dynamic Design: Proposal for Natural Frequency in Each Vibration Mode
    - ・ Guidelines on Wind Resistance: Selection and Presentation of Efficient Wind Resistance Plans for Each Bridge Type
- Proposal for Instructions on Design Wind Load on Glare Reducing Devices
- Proposal for Guidelines on Experiments for 2-D Wind Tunnel of 200m or Less

Wind tunnel test performance guideline:

- First vertical mode of natural frequency: 1.0Hz or less
- First twisting mode of natural frequency: 0.6Hz or less



a) Vertical flow vibration b) Twist flow vibration c) Release vibration

Fig. 3 Bridge dynamic desig

Plate / Box Girder cross-section of static wind aerodynamic coefficient recommendation

Plate girder:	Drag coefficient $Cp(down)$	2.1-0.1(B/D) [B/D<5], 1.6 [B/D>5]
	Lift coefficient $Cp(up)$	0.8
Box girder:	Drag coefficient $Cp(down)$	1.6 (current maintenance)
	Lift coefficient $Cp(up)$	1.6-0.075(B/D) [B/D<8], 0.8 [B/D>8]

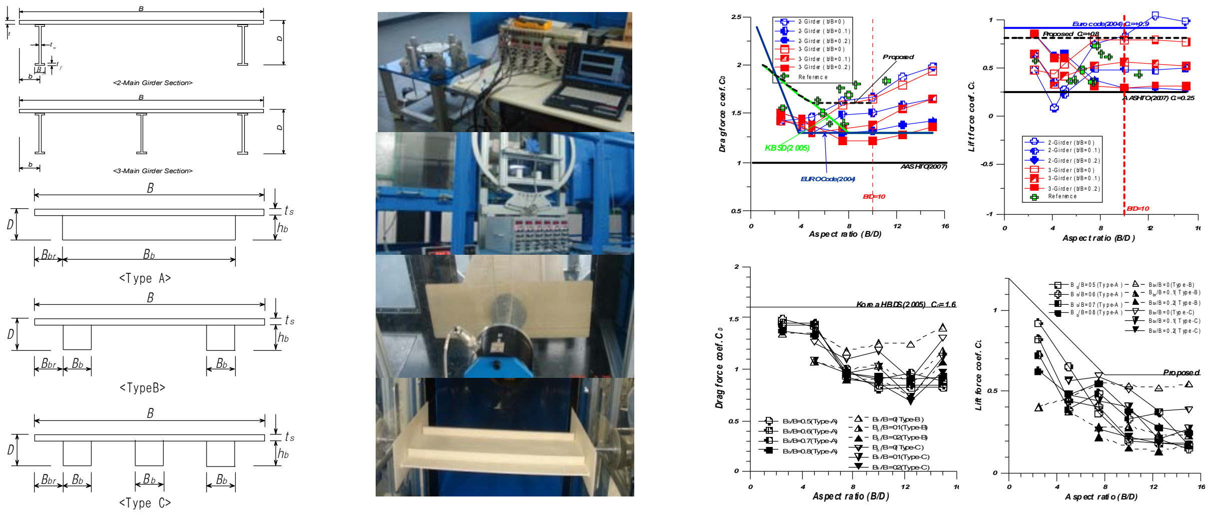


Fig. 4 Plate / Box Girder cross-section of static wind coefficient recommendation

3 ACKNOWLEDGEMENT

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