Wind Loads Standard and Present Developments of Wind Environment Problems in Korea

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ABSTRACT: This paper describes two subjects Fist part describes mainly Wind Loads of Standard Design Loads for Buildings of the Architectural Institute of Korea (AIK), which was approved by the Ministry of Construction and Transportation (MCT) on May 2000, so that it has been in use as the Korean National Building Code for the structural design of buildings and structures. Second part is to introduce for present development for wind environment problems, such as pedestrian discomfort around tall buildings, hindrance of air pollution diffusion in inland cities and ventilation problems due to urban development, in Korea. The main purpose of this paper is to introduce the brief backgrounds of revision and the contents of Wind Loads and environment in Korea to Asia-Pacific wind societies.

KEYWORDS: wind load, wind environment, basic wind speed, velocity pressure, gust effect factor, wind forces/pressure coefficient, air diffusion, ventilation, wind tunnel test.

Part 1 Wind Load Standard

INTRODUCTION

The current Korean Building Law (KBL), which is established by the MCT, has been revised in 1987 and applied to the whole buildings and structures in Korea. Most of the design loads for buildings and structures, such as dead, live, snow, wind and earthquake load, were included in KBL. It has been found that some requirements in the KBL, in special design loads, are no longer appreciated with the social environments, such as development of the construction and economy. So it is necessary to improve and enrich the KBL. In 1996, the MCT requested the AIK to revise loads part of the KBL. They wanted to separate loads part from the KBL and have an independent Loads Standard, which is more suitable for the rapidly developing of construction and economy of our country. The AIK set up seven working groups to revise design loads. Seven working groups carried out in an effort during three years (from October 1996 to December 1999) to contain more detailed, realistic, reasonable load data in a new revision and to provide more realistic, economic design environment to the structural engineers. The Standard Design Loads for Buildings of the AIK (AIK Standard) has been completed in 1999 with the help of academics and practicing professionals, and approved by the MCT on May 2000. Therefore, since May 2000, the AIK Standard has been used for the structural design of buildings and structures instead of the KBL, and has a role of the Korean National Building Code.

The AIK Standard consist in six load section, Section 2 Dead Loads, Section 3 Live Loads, Section 4 Snow Loads, Section 5 Wind Loads, Section 6 Earthquake Loads, Section 7 Soil, Hydrostatic Pressure and Other Loads. Most contents of loads were amended in this version based on the large amount of investigation. Among of them, Section 5 Wind Loads would be largely changed and Section 7 newly added. A brief background of revision and the contents of Wind Loads will be given out in this paper.

OUTLINE OF REVISED CONTENTS OF WIND LOADS

Korea located in severe wind climate region. The Typhoon attacked Korea on averaging 3 per year in frequency. It has caused severe disasters every year. Typhoon Rusa, in 2002, took a path to enter in the southern and go out eastward of the Korean Peninsula. It was recorded a gust wind speed of 57 m/s, which is the maximum value since meteorological observation has been started in Korea. The Rusa caused heavy disasters with death tolls of 246. Building damages were severe; more than 7,643 houses were damaged in Typhoon Rusa, most of them totally destroyed. Therefore, wind loads in Korea must be importantly considered in the structural design of buildings and structures.

The contents of Section 5 Wind loads of the AIK Standard are largely changed from the previous KBL. The reasons are those which cover the needs corresponding to the development of the construction and economy, reflect the variation of wind data influenced significantly by the changing of local environment, such as the expansion of city or town, near meteorological station. The big differences of Wind Loads of the AIK Standard comparing to the previous KBL are as followings:

(1) The map of basic wind speed corresponding to a return period of 100 years is drawn for all locations in Korea. The basic wind speed corresponds to the 10-minute mean wind speed at an equivalent elevation of 10m above ground for flat, open country. The values are established from data of annual-maximum wind speeds collected at 56 meteorological stations in South Korea where data has been recorded for the past 20 years or more. The observed data were modified to reflect the environmental changing of near stations. And then the data were statistically reduced using extreme value analysis. In previous KBL, the basic wind speed was only illustrated on the large cities in Korea. It is established by a deterministic method based on selecting to the peak values among annual maximum 10-minute mean wind speeds recorded at the meteorological stations for the past 35 years.

(2) The classification of surface roughness is increased from 3 Categories to 4 Categories. The purpose is to reflect the changing of local environment, such as the expansion of city or town.

(3) For estimating wind loads, three different approaches are described, because there are big differences in their sizes and dynamic characteristics. The first is for determining horizontal wind loads for structural frames, the second is for structural roof frames loads, and the third is for components/cladding loads. The previous KBL applied the same method to the structural frames and components/claddings.

(4) Gust effect factors are specified for the rigid buildings and flexible buildings individually, because they have big differences in their dynamic responses.

(5) Importance factor is indicated. It is to be determined by corresponding to the design return period of structures, considered a social sense of values for the use of those. Structure needed 100 years return period to estimate wind load has importance factor of 1.0.

(6) In geological conditions, Korean peninsula is connected by small or large ridge. The construction sites are frequently located in escarpments, hills or ridges. To reflect these topographical features, we give out the topographic factor. It is applied only to wind speed amplification factor for escarpments, hills or ridges.

(7) Wind tunnel tests are recommended when the building or other structure under consideration satisfies one or more of the following conditions: is very slender so that it is doubtful whether across-wind vibration, torsional vibration, vortex induced vibration or aeroelastic instability shall be caused significantly: has the large-span membrane roof or the large-span suspension roof so that it is doubtful whether the aeroelastic instability shall be caused.

WIND LOADS OF AIK

1 GENERAL

1.1 *Scope of application.*

(1)This Section describes wind loads for the design of buildings and other structures that respond elastically in wind actions.
(2) For structural frames, two different design wind loads are described. The first is for the design of buildings, and the second is for the design of roofs.
(3) Design wind loads for component/claddings of buildings are applied on the surface finishing-materials of buildings, the frames supporting claddings and the joint element of those.

1.2 *Estimation Principle*

(1) Wind loads are divided into 3 categories. The first is for determining horizontal wind loads for structural frames of buildings, the second is for structural frames of roofs, and the third is for component/claddings of buildings.
(2) The wind loads for structural frames are generally calculated from the product of the design velocity pressure, the gust effect factor, the wind force or pressure coefficient and the projected area. However, the design wind loads for component/claddings of buildings are calculated from the product of the design velocity pressure, the sum of the gust external and internal coefficient and the projected area.
(3) Wind tunnel tests are recommended when the building or other structure under consideration satisfies one or more of the following conditions: is very slender so that it is doubtful whether across-wind vibration, torsional vibration, vortex induced vibration or aeroelastic instability shall be caused significantly: has the large-span membrane roof or the large-span suspension roof so that it is doubtful whether the aeroelastic instability shall be caused.

2 DESIGN VELOCITY PRESSURE

2.1 *Procedure for estimating design velocity pressure*

(1) Design wind velocity q_z shall be calculated from Equation (1).

$$q_z = \frac{1}{2} \cdot \rho \cdot V_z^2 \qquad (1)$$

where ρ= air density (1.225kg/m^3 can be used), V_z= design wind speed at height z above ground surface (m/s, given in (2)).

(2) Design wind speed V_z is the wind speed at the design height z and shall be calculated from Equation (2).

$$V_z = V_0 \cdot K_{zr} \cdot K_{zt} \cdot I_w \tag{2}$$

where V_0= basic wind speed (m/s) depending on the location in Korea (defined in 2.2), K_{zr}= wind speed vertical profile factor (defined in 2.3), K_{zt} = wind speed-up factor for topography (defined in 2.4), I_w= importance factor for building (defined in 2.5).

2.2 *Basic wind speed*

Basic wind speed V_0 is illustrated in Figure 1 for various locations in Korea. The basic wind speed corresponds to the 10-minute mean wind speed at an elevation of 10m above ground for flat and open terrain with a return period of 100 years. The basic wind speed can be estimated from the wind speed data, if there had been an effective wind data around near construction site.

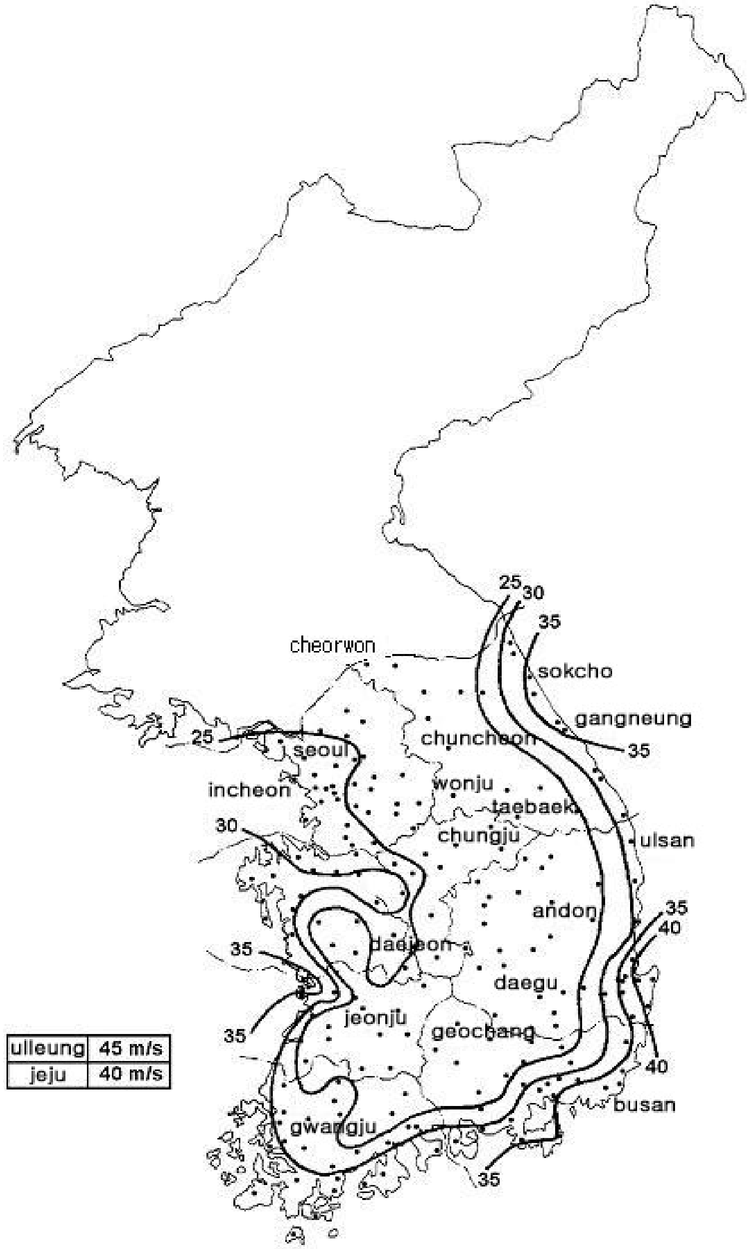


Figure 1 Basic wind speed V_0 in Korea

2.3 *Wind speed vertical profile factor*

(1) Terrain categories are defined in Table 1 by according to the conditions around the construction site.

Table 1 Terrain categories

Terrain categories	Construction site conditions

D	Exposed open terrain with scattered obstructions (height is less than 1.5m), grassland, beach or airport
C	Open terrain with scattered domestic houses or scattered obstruction (height is from 1.5m to 10m)
B	City with closely spaced domestic houses or scattered medium-rise buildings (from 4 story to 9-story)
A	Large city center with closely spaced tall buildings (higher than 10-story)

(2) Wind speed vertical profile factors K_{zr} are defined in Table 2 by according to the terrain categories for construction site.

Table 2 Wind speed vertical profile factor K_{zr}

Reference height above ground level	Terrain categories			
	A	B	C	D
$Z \leq Z_b$	0.58	0.81	1.0	1.13
$Z_b < Z \leq Z_g$	$0.22\ Z^{\alpha}$	$0.45\ Z^{\alpha}$	$0.71\ Z^{\alpha}$	$0.97\ Z^{\alpha}$

Table 3 Values of Z_b, Z_g and α

Terrain categories	A	B	C	D
Z_b (m)	20	15	10	5
Z_g (m)	500	400	300	250
α	0.33	0.22	0.15	0.10

Notations: Z_b = starting height of boundary layer above ground surfaces (m), Z_g = gradient height (m), α = exponent of mean wind speed vertical profiles dependent on terrains.

2.4 *Wind speed-up factor for topography*

(1) For Construction site located in the flat terrain where the local topographic conditions have no effect on wind speed, wind speed-up factor for topography K_{zt} can be estimated 1.0 basically.

(2) For construction site located in the escarpments, hills and ridges where the local topographic conditions have effect on wind speed, wind speed-up factor shall be considered. The vertical and horizontal boundaries, which can be considered the wind speed-up effects for the topography, are defined in Table 4. The wind speed-up factors for the topography are defined in Table 5 by according to the inclination angles.

Table 4 Boundaries reflecting the wind speed-up factor for the topography

Topographic categories	Boundary reflecting wind speed-up factor	Scope of applications	
		Windward	Leeward

Hills, ridges	Vertical height (above ground surface)	The greater of L_u and 1.7H	
	Horizontal height (above crest)	The greater of 1.5 L_u and 2.5H	
Escarpments	Vertical height (above ground surface)	The greater of L_u and 1.7H	
	Horizontal height (above crest)	The greater of 1.5 L_u and 2.5H	The greater of 3 L_u and 5H

Notations: H= the height of the hill, ridge or escarpment (m), L_u = the horizontal distance upwind from the crest to a level half the height below the crest (m).

Table 5 Wind speed-up factor for the topography (K_{zt})

Upwind slope (ϕ)	Wind speed-up factor (K_{zt})	
	Escarpments ($\phi_d \le 0.05$)	Hills, ridges ($\phi_d \le 0.1$)
0.05	1.05	1.11
0.1	1.09	1.21
0.2	1.18	1.41
≥ 0.3	1.27	1.61

Notes: For hills and ridges with downwind slope 0.05 < ϕ_d <0.10, linear interpolation between the K_{zt} values for escarpments, and hills and ridges in Table 5 shall be permitted.

Notations: ϕ = the upwind slope calculated from $\phi = H/2L$, ϕ_d = the average downwind slope measured from the crest of a hill, ridge or escarpment to the ground level at distance of 5H.

2.5 *Importance factor*

Importance factors I_w are defined in Table 6 corresponding to the design return period of buildings and structures, which is considered a social sense of values for the use of those.

Table 6 Importance factor

Importance	Occupancy, function and scale of buildings	Importance factor
Extra	Buildings and other structures having critical national defense functions or dangerous functions, hospitals, communication centers, power generating stations, telecommunication stations, or public official facilities with a total floor area greater than 1,000 square meters Apartments higher than 15-story	1.10
(1)	Stadium, exhibition facilities, marketing facilities or transport facilities with a total floor area greater than 5,000 square meters Residential facilities, office-hotel, residence or apartments with higher than 5-story	1.00
(2)	Structures not included in extra, (1) and (3)	0.95

(3)	Temporary, agricultural or minor storage facilities	0.81

3 GUST EFFECT FACTOR

3.1 *Scope of application*

This section defines the procedure for estimating the gust effect factor on structural frames of buildings and roofs.

3.2 *Gust effect factor*

(1) If buildings are rigid or the resonance due to the along-wind actions could not be caused, the gust effect factor G_f for structural frames of buildings and roofs is defined in Table 7 according to terrain categories of construction site.

Table 7 Gust effect factor for structural frames (G_f)

Terrain categories	Gust effect factor (G_f)
A	2.5
B	2.2
C	1.9
D	1.8

(2) If buildings are slender and flexible, the mean roof height is over 100m or the resonance effects due to the along-wind actions could be doubtful, the gust effect factor for structural frames of buildings is calculated from Equation (3). The rigid buildings and the flexible buildings shall be classified according to Figure 2.

$$G_f = 1 + g_f \cdot \gamma_f \sqrt{B_f} \quad (3)$$

where $\gamma_f = (\frac{3+3\alpha}{\alpha+2}) I_h$, $I_h = 0.1 \ (\frac{h}{Z_g})^{-\alpha-0.05}$

$$B_f = 1 - \left[\frac{1}{\left\{1 + 5.1(L_h/\sqrt{hB})^{1.3}(B/h)^k\right\}^{1/3}} \right], \quad k = \begin{matrix} 0.33 : h \geq B \\ -0.33 : h < B \end{matrix}, \quad L_h = 100 \ (\frac{h}{30})^{0.5}$$

$$g_f = \sqrt{2\ln(600\nu_f) + 1.2}, \quad \nu_f = n_0 \sqrt{\frac{R_f}{B_f + R_f}}$$

$$R_f = \frac{\pi}{4\zeta_f} \cdot S \cdot F$$

$$F = \frac{4(n_0 L_h / V_h)}{\left\{1 + 71(n_0 L_h / V_h)^2\right\}^{5/6}}$$

$$S = \frac{4(n_0 L_h / V_h)}{\{1 + 2.1(n_0 h / V_h)\}\{1 + 2.1(n_0 B / V_h)\}}$$

where G_f = gust effect factor, γ_f = turbulence factor, I_h = turbulence intensity at the reference height, B_f = back ground excitation factor, h = reference height (m), B = projected breadth (m), V_h = wind velocity at the reference height (m/s), L_h = turbulence scale at the reference height, α = exponent of mean wind speed vertical profiles dependent on terrains (defined in 2.3), Z_g = gradient height (m), g_f = peak factor, ν_f = level crossing factor, n_0 = natural frequency for the first mode in along-wind direction, R_f = resonance factor, ζ_f = critical damping ratio for the first mode in along-wind direction, F = wind force spectrum factor, S = size reduction factor.

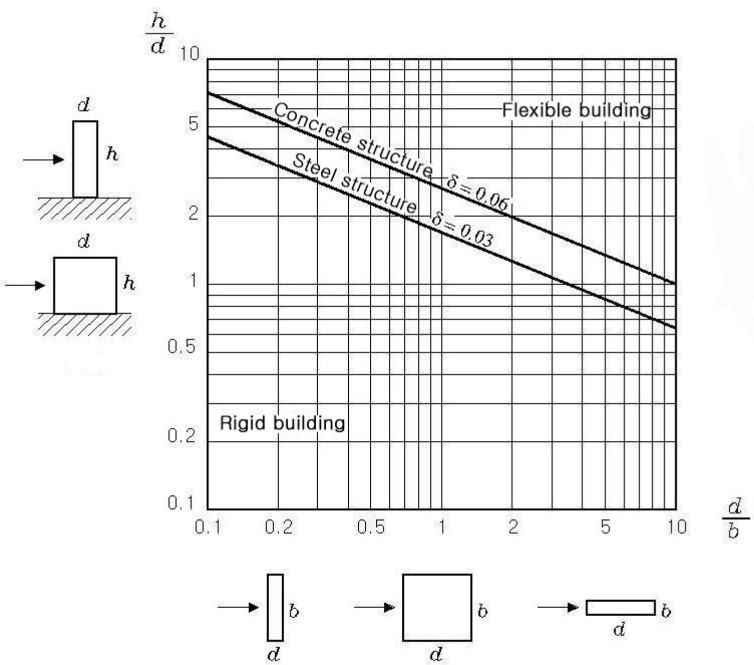


Figure 2 Classifications of the rigid buildings and the flexible buildings.

4 WIND LOADS ON STRUCTURAL FRAMES OF BUILDINGS

This section defines the procedures for estimating horizontal wind loads on structural frames of closed or opened buildings under gust action.

4.1 *Procedure for estimating wind loads*

(1) Horizontal wind loads W_f for structural frames of closed buildings are calculated from Equation (4).

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

(4)

where q_z = design velocity pressure on the windward face at the design height of z (kgf/m^2), q_h = design velocity pressure on the leeward face at the mean roof height of h (kgf/m^2), G_f = gust effect factor (defined in 3.2), C_{pe1} = wind pressure coefficients on the windward face (defined in 8.1(1)), C_{pe2} = wind pressure coefficients on the leeward face (defined in 8.1(1)), A = projected area (m^2).

(2) Horizontal wind loads W_f for structural frames of opened buildings or other structures are calculated from Equation (5).

$$W_f = q_z \cdot G_f \cdot C_f \cdot A$$

(5)

where C_f = wind force coefficients (defined in 8.1(3)).

5 WIND LOADS ON STRUCTURAL ROOF FRAMES

This section defines the procedure for estimating wind loads on the structural roof frames of closed, partially opened buildings or free roofs.

5.1 *Procedure for estimating wind loads*

(1) Wind loads for structural roof frames W_r of closed or partially opened buildings are calculated from Equation (6).

$$W_r = q_h \cdot (G_f \cdot C_{pe} - G_i \cdot C_{pi})A$$

(6)

where q_h = design velocity pressure on the leeward face at mean roof height of h (kgf/m^2), G_f = gust effect factor (defined in 3.2), C_{pe} = external pressure coefficient (defined in 8.1(1)), G_i = gust effect factor for internal pressure (defined in 8.1(2)), C_{pi} = internal pressure coefficient (defined in 8.1(2)), A = projected area (m^2).

(2) Wind loads W_r for structural frames of free roofs are calculated from Equation (7).

$$W_r = q_h \cdot G_f \cdot C_f \cdot A$$

(7)

where C_f = wind force coefficients (defined in 8.1(3)).

6 WIND LOADS ON COMPONENT/CLADDINGS

This section defines the procedure for estimating wind loads of component/claddings of buildings and roofs.

6.1 *Procedure for estimating wind loads*

(1) For walls of buildings subjected positive pressures, wind loads W_c for component/claddings are calculated from Equation (8).

$$W_c = q_z \cdot (GC_{pe} - GC_{pi})A \tag{8}$$

where q_z = design velocity pressure at height of z (kgf/m^2), GC_{pe} = gust external pressure coefficient (defined in 8.2(1)), GC_{pi} = gust internal pressure coefficient (defined in 8.2(2)), A = subjected area (m^2).

(2) For walls of buildings or roofs subjected to negative pressures, wind loads W_c for component/claddings are calculated from Equation (9).

$$W_c = q_h \cdot (GC_{pe} - GC_{pi})A \tag{9}$$

where q_h = design velocity pressure at the mean roof height of h (kgf/m^2).

7 DYNAMIC EFFECTS DUE TO THE WIND ACTIONS

Wind tunnel tests or a rational analyses that incorporates the dynamic properties of the main wind-force resisting system, are recommended, when the buildings or other structures under consideration are doubtful whether across-wind vibration, torsional vibration, vortex induced vibration or aeroelastic instability shall be caused significantly.

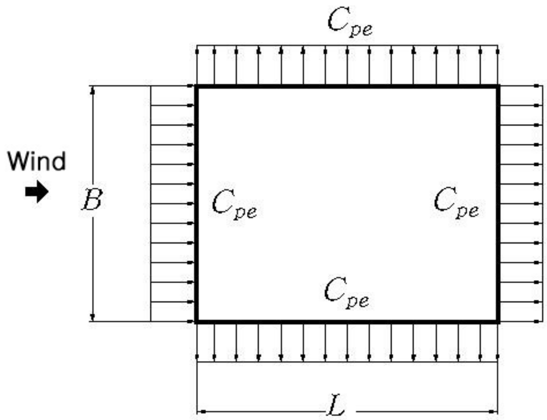
8 WIND FORCE COEFFICIENTS AND WIND PRESSURE COEFFICIENTS

This section defines wind pressure coefficients and force coefficients on the structural frames and component/claddings of buildings and roofs.

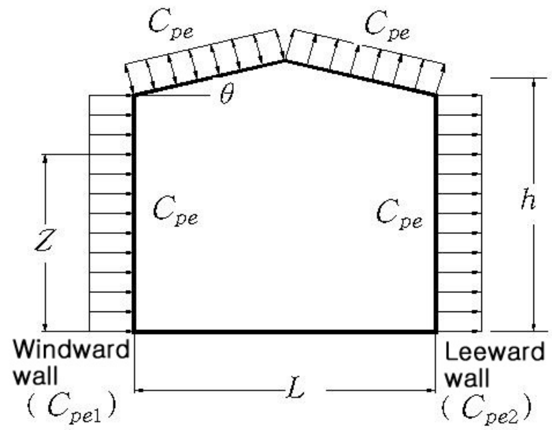
8.1 *Wind pressure coefficients and force coefficients for the structural frames*

(1) External pressure coefficient for closed or partially opened buildings.
The external pressure coefficients for closed or partially opened buildings are given in Table 8. For estimating the wind loads on the windward external wall, the velocity pressure q_z corresponding to the design height of z above ground level shall be taken. However, for estimating the leeward or the side walls, the velocity pressure q_h corresponding to the mean roof height of h shall be taken.

Table 8 External pressure coefficients for closed or partially opened buildings



Plane



Elevation

(a) External pressure coefficients for walls (C_{pe})

	L/B	C_{pe}	Applicant velocity pressure
Windward walls	All values	0.8	q_z
Leeward walls	0~1	-0.5	q_h
	2	-0.3	
	≥ 4	-0.2	
Side walls	All values	-0.7	q_h

(b) External pressure coefficients for roofs (C_{pe})

Wind directions	Windward faces								Leeward faces
	h/L	Slope (θ)							
		0	10~15	20	30	40	50	≥ 60	
Slope roofs	≤ 0.3	-0.7	0.2[1)]	0.2	0.3	0.4	0.5	0.01 θ	-0.7
			-0.9[1)]						
	0.5	-0.7	-0.9	-0.75	-0.2	0.3	0.5	0.01 θ	
	0.1	-0.7	-0.9	-0.75	-0.2	0.3	0.5	0.01 θ	
	≥ 1.5	-0.7	-0.9	-0.9	-0.9	-0.35	0.2	0.01 θ	
Flat roofs	h/B or $h/L \le 2.5$	-0.7							-0.7
	h/B or $h/L > 2.5$	-0.8							-0.8

Note: 1) Either of positive pressure and negative pressure shall be checked.
Notations: B = the projected breadth of the buildings (m), L =the depth of the buildings (m), Z = the design height above ground level (m), h = the reference height (mean roof height), θ = the roof slope ($^\circ$, in degrees).

(2) Internal pressure coefficients and their gust effect factor for the closed buildings

Internal pressure coefficients and internal gust effect factor for the closed buildings are given in Table 9.

Table 9 Internal pressure coefficients (C_{pi}) and their gust effect factor for the closed buildings (G_i)

C_{pi}	G_i
0.0 or –0.4	1.3

(3) Force coefficients

Force coefficients, such as chimneys, tanks, monoslope free roofs, solid signs, lattice frameworks and trussed towers, are given in the AIK Standard. Which of them, the force coefficients for the monoslope free roofs are given Table 10 according to roof slopes.

Table 10 Wind force coefficients for the monoslope roof (C_f)

Roof slope (θ)	C_f for L/B values of:						
	5	3	2	1	1/2	1/3	1/5
10	0.2	0.25	0.3	0.45	0.55	0.7	0.75
15	0.35	0.45	0.5	0.7	0.85	0.9	0.85
20	0.5	0.6	0.75	0.9	1.0	0.95	0.9
25	0.7	0.8	0.95	1.15	1.1	1.05	0.95
30	0.9	1.0	1.2	1.3	1.2	1.1	1.0

Roof slope (θ)	Location of center of pressure (X_c/L) for L/B values of:		
	L/B = 2~5	L/B = 1	L/B =1/5~1/2
10~20	0.35	0.3	0.3
25	0.35	0.35	0.4
30	0.35	0.4	0.45

Notes: 1) Wind forces are normal to the surface. Two cases shall be considered: (a) wind forces directed inward; and (a) wind forces directed outward. 2) Wind shall be assumed to deviate by $B \pm 10^\circ$ from horizontal.

Notations: B = dimension of roof measured normal to wind direction (m), L = dimension of roof measured parallel to wind direction (m), X_c = distance to center of pressure from windward edge of roof (m), θ = roof slope ($^\circ$, in degrees).

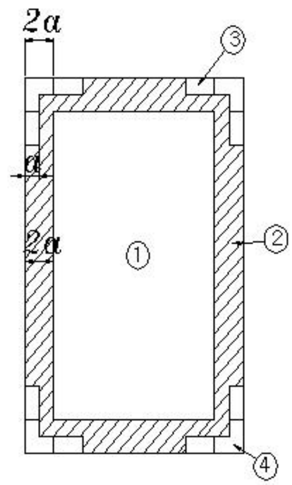
8.2 *Gust external coefficients and gust internal coefficients for the component/claddings*

(1) Gust external coefficients

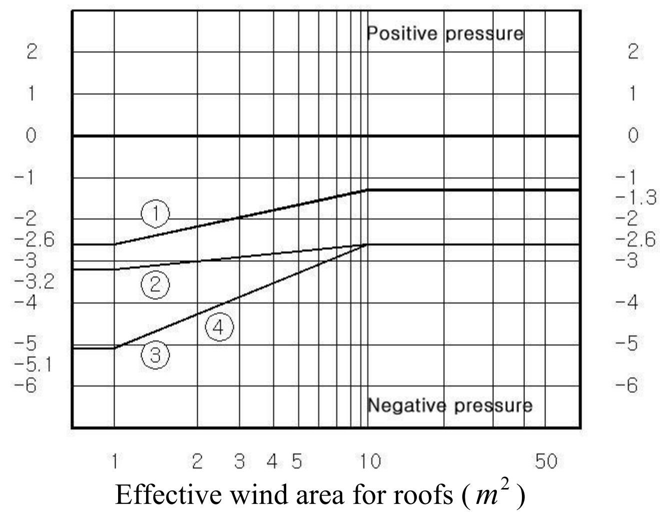
The gust external coefficients for various buildings are given in the AIK Standard. For example, for buildings with rectangular sections whose height are greater than 20m, gust external coefficients are given in Table 11. Gust external coefficients for walls and roofs with the height less than 20m are given in Table 12 and Table 13, respectively. For walls, gust external coefficients shall be considered by either of the maximum positive and negative values.

Table 11 Gust external coefficients for the buildings with heights greater than 20m (GC_{pe})

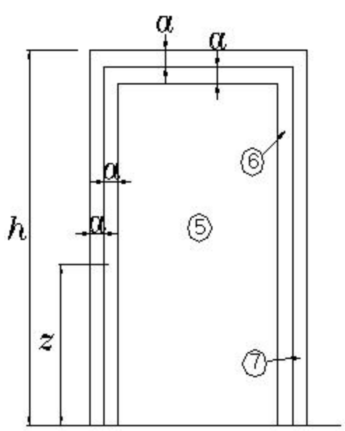
Plane



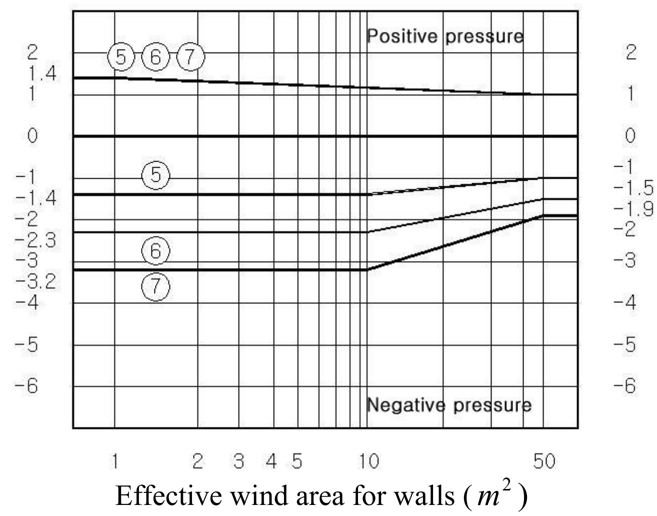
GC_{pe}



Elevation



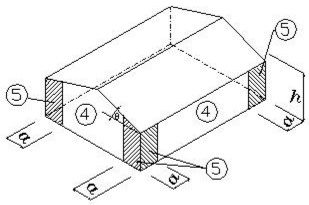
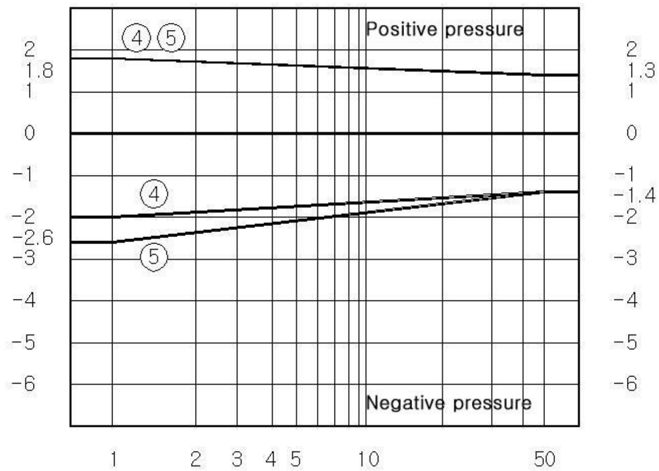
GC_{pe}



Notes: Each component shall be designed for maximum positive and negative pressures.

Notations: a = smaller value of either 5% of least horizontal dimension or 0.5h, but not less than 1m, h = the mean roof height (m), z = the design height above ground level (m).

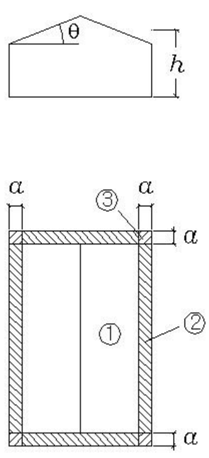
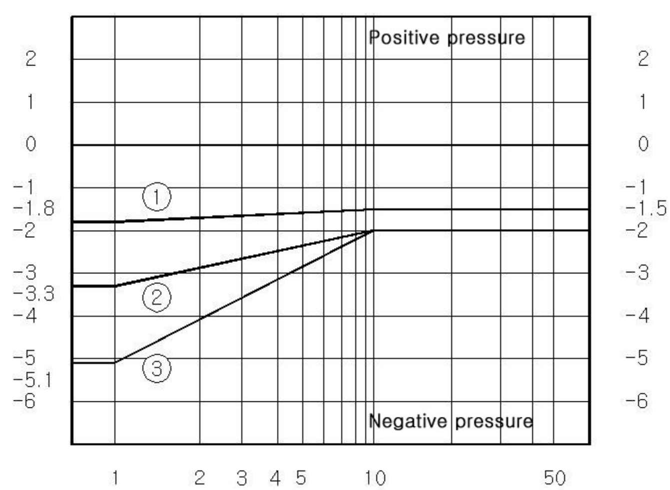
Table 12 Gust external coefficients for the walls with heights less than 20m (GC_{pe})

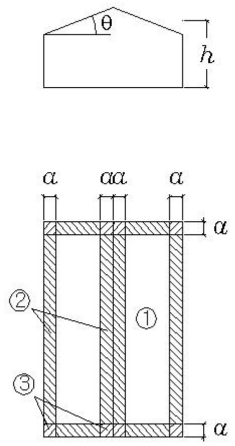
W A L L S	 	GC_{pe}  Effective wind area for walls (m^2)

Notes: Each component shall be designed for maximum positive and negative pressures. 2) Vertical scale denotes GC_{pe} to be used with q_h based on terrain category C. 3) Values of GC_{pe} for walls shall be reduced by 10% when $\theta \leq 10^{\circ}$.

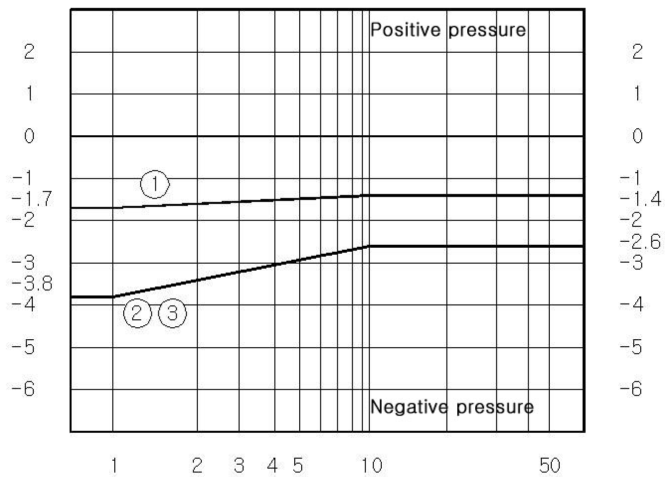
Notations: a = smaller value of either the 10% of least horizontal dimension or 0.4h, but not less than either 4% of least horizontal dimension or 1m, h = the mean roof height (m).

Table 13 Gust external coefficients for the roofs with heights less than 20m (GC_{pe})

R O O F S	a)  $\theta \leq 10^{\circ}$	GC_{pe}  Effective wind area for roofs (m^2)
	b)	GC_{pe}



$10^\circ < \theta \leq 30^\circ$



Effective wind area for roofs (m^2)

(2) Gust internal coefficient

Gust internal coefficient for estimating component/claddings of closed buildings can be used 0.0 or –0.52.

CONCLUSION

It is necessary timely to revise the Loads Standard corresponding to the needs of technical and economical developing. The new revision of the Standard Design Loads for Buildings of the AIK in 2000, in special Wind Loads, are carried out in an effort to contain more detailed, realistic and reasonable load data. We are sure that it will be more suitable for the structural design practice and provide more realistic, economical design environment to the structural engineers.

Part 2 The Present Development of Wind Environment Problems

1. Introduction

The high-rise office buildings constructed in the metropolitan cities of Korea since around the time of the 1988 Seoul Olympics, with residential buildings reaching 50-60 stories, have towered up in major cities like Seoul and Busan. Korea is no exception for environmental problems concerning wind, such as air diffusion problems including extreme winds caused by high-rise buildings as in metropolitan cities of developed countries. Recently, these kinds of problems have further increased due to frequent arrivals of typhoons. A variety of accidents big and small have occurred due to strong winds in recent years, such as the canvas breakage at the World Cup Stadium on Jeju Island caused by the Typhoons Fungsen and Rusa, and the toppling of the gantry crane at Shingamman port in Busan by Typhoon Maemi. The hindrance of air pollution diffusion in inland cities, such as Seoul or Daegu, is due to side effects of urbanization such as rural wind inflow hindrance causing Heat-Island Phenomenon. Ventilation problems are existent in many areas due to urban development, such as lack of adequate wind (or even mechanical ventilation) in residential underground car parks, roofed traditional markets, and buildings adjacent to elevated inner-city roadways and railways. However, there is currently a lack of adequate regulations or statutes to solve these problems. Now, an introduction of recent developments follows:

2. Typhoon Maemi hit Korean hard

Typhoon Maemi hit the Korean Peninsula hard in Sept. of 2003. Maemi caused unprecedented damages from the time it landed in Korea on Sept. 12 2003 until it left the following day on Sept.13. 2003. Korea recorded large casualties of 119 persons killed and 12 missing, with an additional 4,781 bil. KRW (= USD 4bil.) in property loss and damage, such as the gantry crane toppling at a Shinkamman port of Busan (Photo 1). The typhoon was accompanied by strong winds with a maximum wind velocity of 60.0 m/sec (18:00 Sept.12, 2003), which broke the previous record of 58.3 m/sec (August 30, 2000).

The central pressure of Typhoon Maemi (940hPa – 950hPa) was the lowest of all the typhoons that passed through Korea. The seawater temperature of the southern coasts was 28°C, which could supply sufficent energy for powerful winds. The Gust Factor for the typoon in the Jeju area was posted at 1.2 - 1.8 and that of Jolla-do and Gyeongsang-do areas at 1.2 - 1.8, and in the Gangwon-do area at 1.4 - 2.0.

The G. F. of the southern costal area of Korea is showed in fig. 2.2.

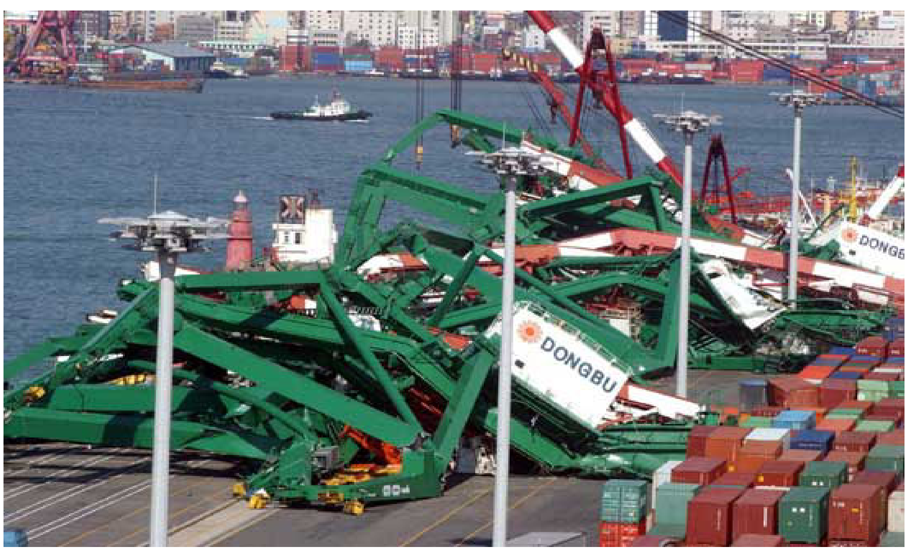


Fig. 2.1 Gantry Cranes Overturned by Typhoon Maemi

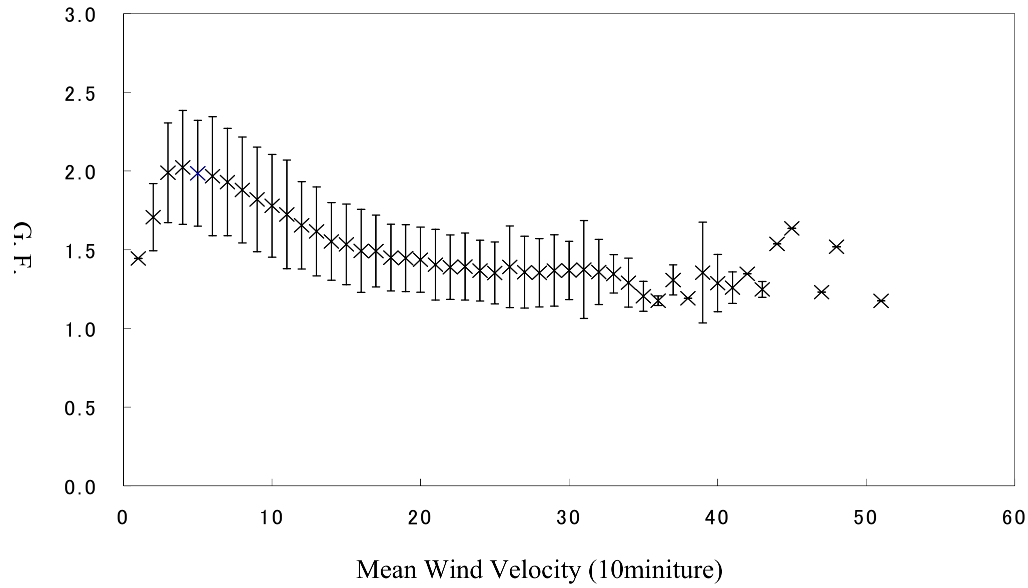


Fig. 2.2 Gust Factor of Southern Costal Area of Korea

3. Extreme Wind in and around High-rise Buildings

Extremely tall high-rise residential buildings and office buildings are rising up in great numbers in metropolitan cities like Seoul. Extreme wind problems in and around tall buildings have been drawing increasing public attention especially for residential buildings, because they are densely constructed with many apartment units in Korea. Consultation regarding the building wind and building vibration due to strong wind are made with the Architecture Consultation Committee of provincial and local governments whenever architecture permits for large scale buildings more than 16 stories tall or an area of 30,000 ㎡ is to be issued. Most high-rise buildings constructed in recent years must take wind tunnel tests before receiving the architecture permits. The assessment standard of building wind is not defined specifically for Korea, but is assessed according to the well-known Davenport or Murakami standard widely used. However, a Seoul metropolitan regulation stipulates the inclusion an expert of wind tunnel test in among the member of the Architecture Consultation Committee.

Fig. 3.1 Photograph of Model of High- rise Building in Seoul

4. Natural Ventilation induced by Wind

4.1 Wind-inducted Ventilation of Apartment underground Car Parks

Most of the parks for apartments constructed in large cities are located underground according to building capacity. However, new constructions require planning for an increase in the amount of resident vehicles and more effective utilization of open space. However, mechanical ventilation systems are usually not installed due to high cost and the fact that even when installed they are seldom operated due to high operation and maintenance expenses. The current ventilation of underground car parks is achieved by natural ventilation, through vehicles entrance and exits, pedestrian stairwells and 'dry areas'. Therefore the air in car parks is of poor quality. Mandatory installation of mechanical ventilation facilities results only in additional cost without actual utilization. Our government is in search of methods of how to get natural ventilation to smoothly solve these problems. The experimental research is presented in Example1 (Fig.1 Table 1).

(Example 1) Wind-inducted Ventilation of Apartment underground Car Park

Fig4.1 Photograph of Model

Table 4.1 Type of Openings

	Explanations
Type I	Vehicle entrances and exits only
Type II	Type I + 6 openings
Type III	Ventilation openings with 6 Dry Areas
Type IV	4 Dry Areas + 4 ventilation openings

- Test Results

Frequency distributions of ventilation cycle of all wind directions are presented. Ventilation cycles coming to 80% frequency are 0.13 rounds /hr for Type I, 0.184 rounds/hg for Type II, 0.252 rounds/hr for Type III and 0.236 rounds/hr for Type IV respectively. Therefore natural ventilation by wind corresponds to 5.4% for Type I, 7.8% for Type II, 10.7% for Type III and 10% for Type IV respectively, which is comparable to 2.36 rounds/hr needed for mechanical ventilation.

4.2 Ventilation Problems of Roofed Traditional Markets

The traditional markets (alley markets without roofs) are shrinking under the influence of mammoth department stores and discount stores. Furthermore they are environmentally in poor condition because building winds are rising as high buildings are towering up near the traditional markets. Local Korean governments are enforcing 'Changeover Projects' to add arcades to improve the environment of traditional markets in recent years. (Fig. 2, Fig. 3) However, traditional markets with arcades have no mechanical ventilation facilities and few sources for natural ventilation. Low ventilation volume causes high temperatures in summer, storage problems for edible foodstuffs that cannot be stored refrigerators due to the environment of traditional markets, and foul smells coming from agricultural and seafood products causing difficulties for market customers and traders. Presently our government has been endeavored its efforts to smooth out these problems by funding research in wind-tunnel tests and data interpretation, but so far could not work out a specific counter-plan.

4.3 Obstruction of Cross Ventilation of Apartments by Elevated Construction Structure

Cross ventilation obstruction of residential buildings by elevated construction structures is not regulated by statutes. However, the residents of an apartment complex neighboring a 4-way major roadway filed a suit related to environmental interferences with the ventilation. Based on the results of wind-tunnel simulation tests executed by experts after the 30m high elevated roads and railways had been constructed, the residents were compensated for the ventilation interference as well as other problems to the construction by Seoul City.

(Example 2) Wind-inducted Ventilation of Apartment by High Elevated Structures

Fig. 4.2 Test Model

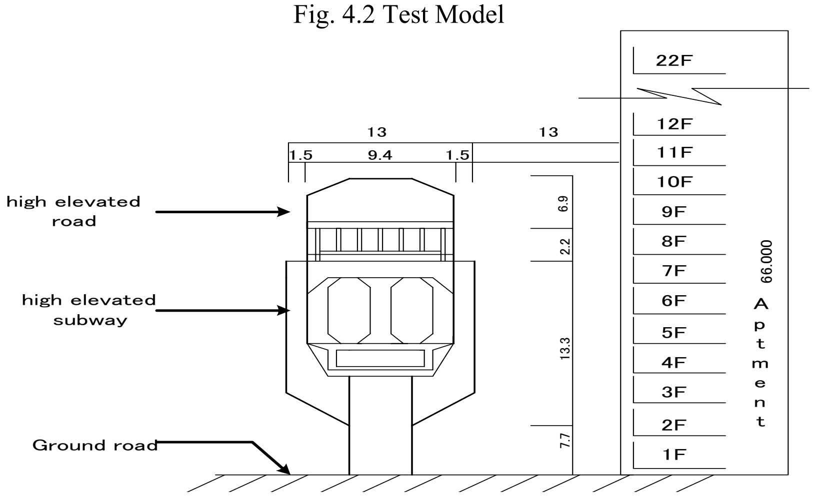


Fig.4.3 Section of High-Elevated Structure by Apartment, unit: m

- Test Results

The wind-inducted ventilation rate of H apartments after the construction of the structures showed reduction of as much as 40-50% in the direction of SW, SSW, S, SSE and NNE. Summer cross ventilation hindrance was expected as much as 35% in the direction of W and NE.

5. Urban Air Pollution and Wind passages

Air pollution in Seoul is at serious levels due to the increase of traffic and high-density urban development in recent years. The concentration of air pollution in the southern area of the Han River and in the vicinity of the Han River was relatively low compared to the northern downtown areas of the Han River but its conditions became quite different now. One research's result pointed out that it is a phenomenon caused by the following: First, the Han River and its vicinities, which are the main wind passages of Seoul, were blocked after high-density apartment complexes along the Han River and Yoido, Kangnam have been constructed in recent years; Second, the inflow passages of rural winds coming from the neighboring mountainous areas were also blocked due to low residential areas on the outskirts had been developed in large scale into high-density extremely high-rise buildings;

Third, heat island phenomenon in summer also adds to the problem. Most of the recent redevelopment plans built large high collective residential buildings without considering diffusion of air-polluting substances or fresh air inflow. In this case the inflow of clean and fresh air formed in the neighboring greens or mountains, into cities is blocked by the construction of high-rise buildings. Accordingly, Seoul City deems that the diffusion of pollution substances is tightly related with wind passages and is scheduled to complete a "Wind Passage Map" by 2007 to be reflected in municipal plans and construction plans. The experimental research is shown in Example 4. (Fig. 6, Fig. 7)

(Example 3) Ventilation by the Shape and Placement of Apartments

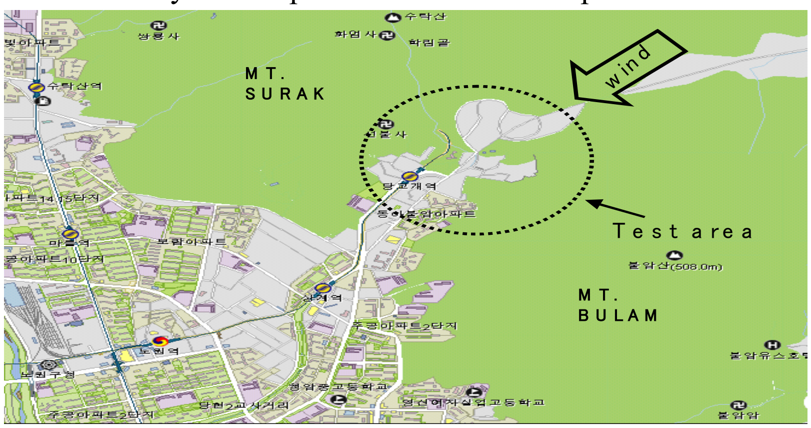
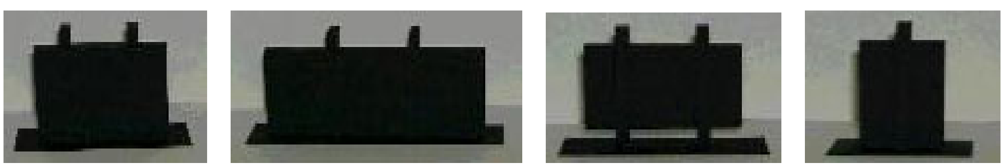


Fig5.1 Scheme of boundary of test area



1) Type1 2) Type2 3) Type3 4) Type4

Fig5.2. Type of Model Apartment

- Test Result of Example

Table5.1. Number of ventilation times (wind velocity: 1m/s at building height)

Cases/Item	Type1	Type2	Type3	Type4
C/Co	822.3	792.2	359	412.3
Ventilation(㎥/hr)	0.0592	0.0614	0.1355	0.118
Ventilation times (time/hr)	199.33	206.73	456.23	397.31
Ventilation times of real scale (time/hr)	0.25	0.26	0.57	0.50

6. Discussion and Conclusion

As discussed above, wind environment problems in Korea arise in a variety of ways such as building winds, wind ventilation of underground apartment car parks, cross ventilation in residential housings, wind passages, air pollution diffusion etc. Typhoons and strong local winds are becoming more frequent in recent years due to increased of global warming. However, enactment of appropriate regulations and statutes to smooth out these problems is lacking due to low-expenditure high-return economically-oriented policies and the short-sighted perception of building constructors, designers and owners on structural stability due to environmental conditions. The relevant measurements regarding extreme wind in around tall buildings etc. for high-rise buildings are reviewed by the previously mentioned professional committee members for the construction of larger high-rise buildings, but it is ignored for smaller ones. On the other hand, government supported research on these problems is not backed by an equivalent amount of government regulatory participation via construction safety laws. Wind environment problems are surfacing as socially important issues due direct personal impact, such as highway wind gusts and roadway wind-thrown ground-snow problems, which is directly related to increased car accidents.

It is recommended that regulations and statutes related to the discussion above by our national, provincial and local governments be prepared for prompt implementation to lessen such wind related damages.

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