仁濟大學校

Housing classification and Calculation of the Maximum Surface Wind speed to estimate wind damage potential by Typhoon

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1. Introduction

Natural Disasters increases due to the Climate Change

from IPCC (2007)

- expect that the tropical storm such as typhoon and hurricane will strengthen the power with the rise of the sea surface temperature.
- At the end of 21st century, we prospect that the earth's average temperature will rise until maximum 6.4 ℃ and sea level will rise 59 cm .

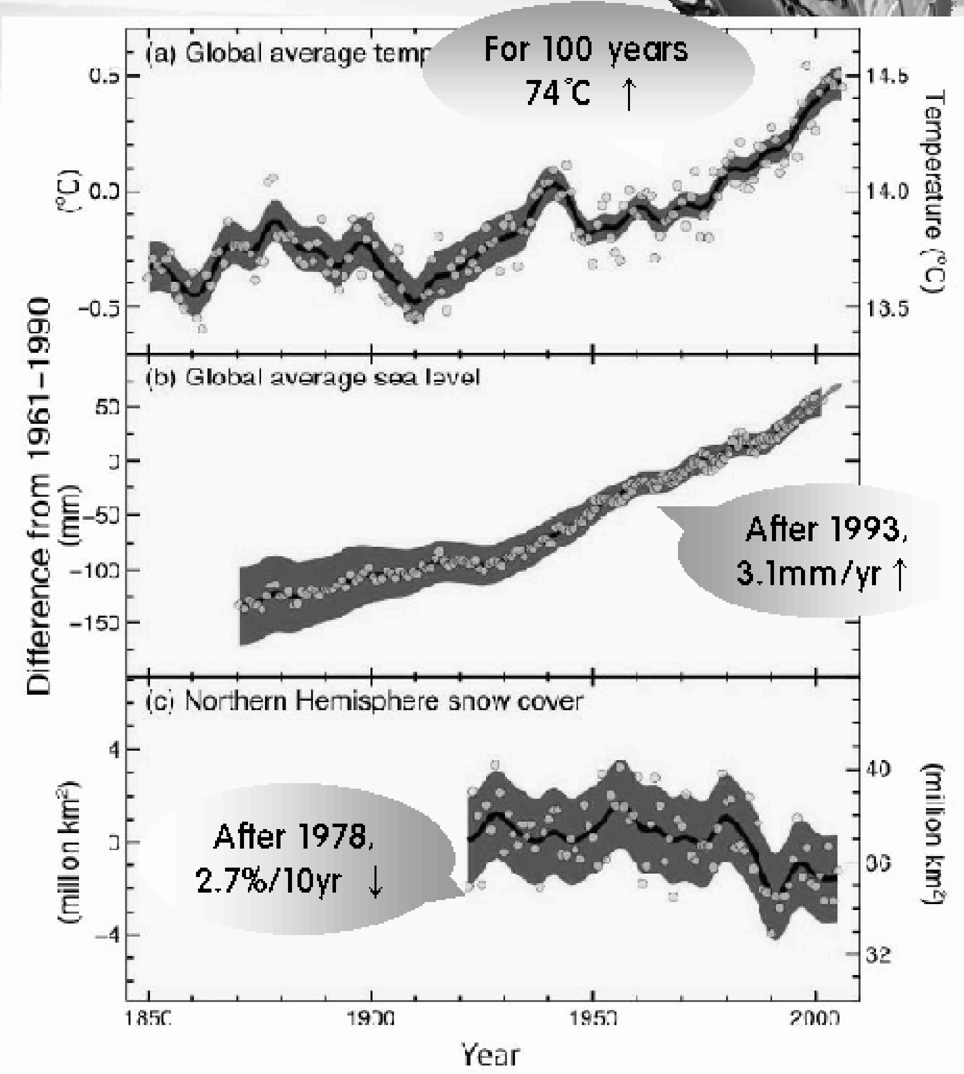


Fig. 1. Changes in temperature, sea level and northern hemisphere snow cover.

Hazard Prediction Model in USA

- HAZUS, HAZUS-MH, PHRLM etc.
- calculate the surface wind velocity considering topography and various lands of facilities → forecast the location of damage and a scale by classify of standardizes structure, which is standing on the basis of the unified GIS data.

Insurance Co & Hazard Prediction Model

- International insurance company such as Munich Re etc.
  : use a model forecasting loss of property damage.
- AIR Worldwide Corporation, Risk Management Solutions, ABS Group Company made the model of forecasting more than 9 kinds of disaster..

In Korea

- Typhoon track of type 2 and 7, which is affecting the Korean peninsula , increases (Park et al, 2006)
- Establish Korea National Emergency Management Agency(2004)
  : storm and flood damage mitigation with each county .
  → attach weight to recovery

Typhoon damages

- rainfall : flooding, landslide, inundation, outflow of earth and sand etc.
- A strong wind(damage on structure) : structure failure, external wall failure, roof and signboard failure, secondary damage of lives due to fly materials, discomfort due to vibration of apartment, damage of ship etc.

Wind damage potential

- Topography of Korea composed of coast and mountain area. : very careful consideration of wind load is needed.
  ▶ characteristics of wind, wind load assessment are needed.
- Wind damage potential by typhoon ▷ preparation of law and plan of natural disaster mitigation

2. Purpose of this Study

In order to estimate wind damage potential by Typhoon

☞ 1) we estimate the potential surface maximum wind speed

☞ 2) we have to classify the housing type to estimate wind load on structure

3. Method

Estimate wind damage potential by Typhoon

The Maximum Surface Wind speed » **Wind load to housing**

The Maximum Surface Wind speed:

- Franklin(2003)
- Axe(2005)
- Vickery and Skerlj (2005)

→ 3-second Gust

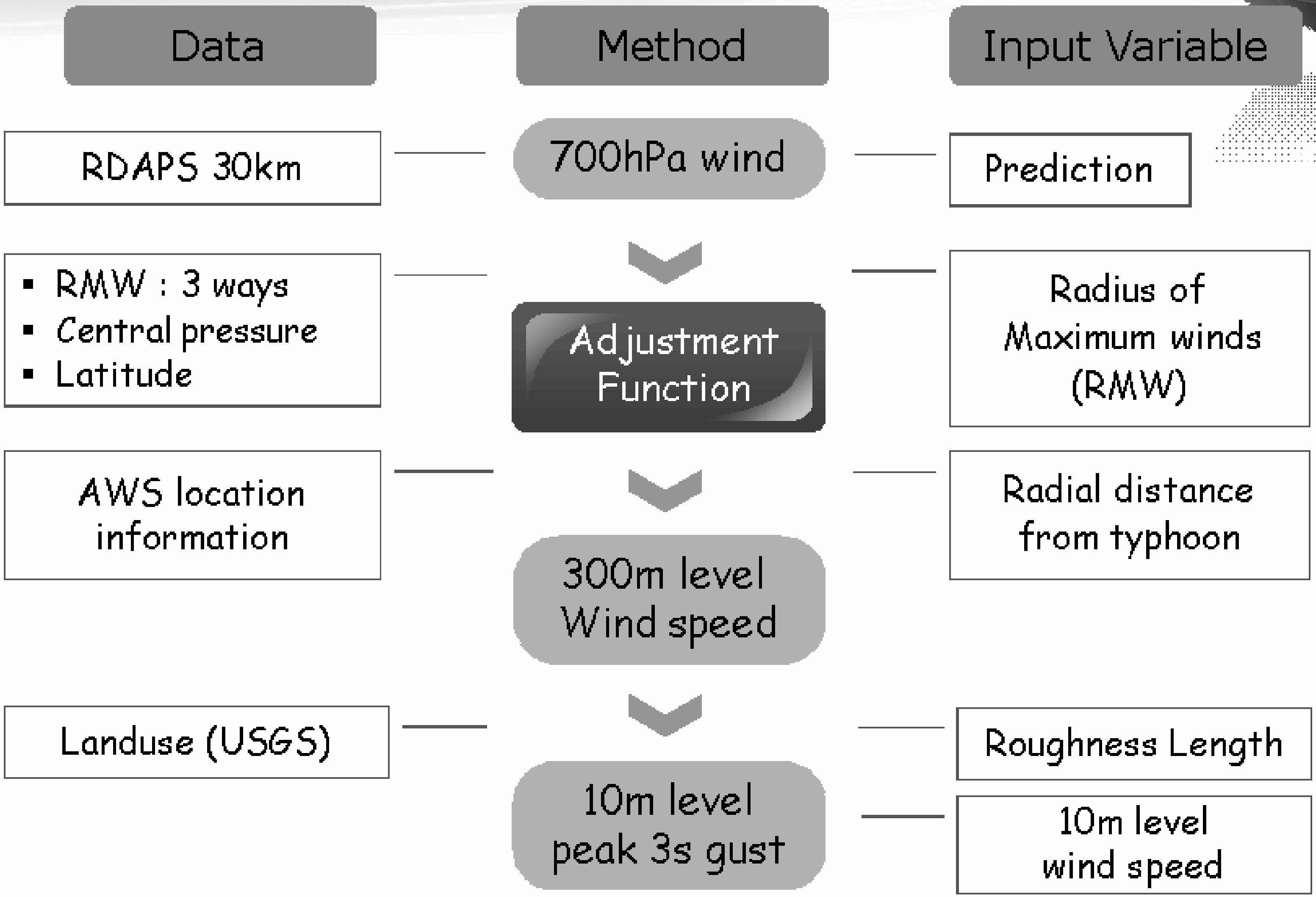
Wind load to housing:

→ Housing Classification

- the stories
- Roof type
- Height
- Side ratio

:

4.1. Process of peak 3s gust calculation and input variables



4.2. Case

Case

Typhoon Rusa : 1500 LST August 31 ~ 0300 LST September 1, 2002

Area

- Area range is 7.4km~30km from radius of maximum wind(RMW) of typhoon
- AWS data

Method

- Wind Field Module of PHRLM
  - Franklin(2003) : study on the wind speed profile of typhoon center by the drop sonde
  - Vickery and Skerlj(2005) : Gust Factor Model

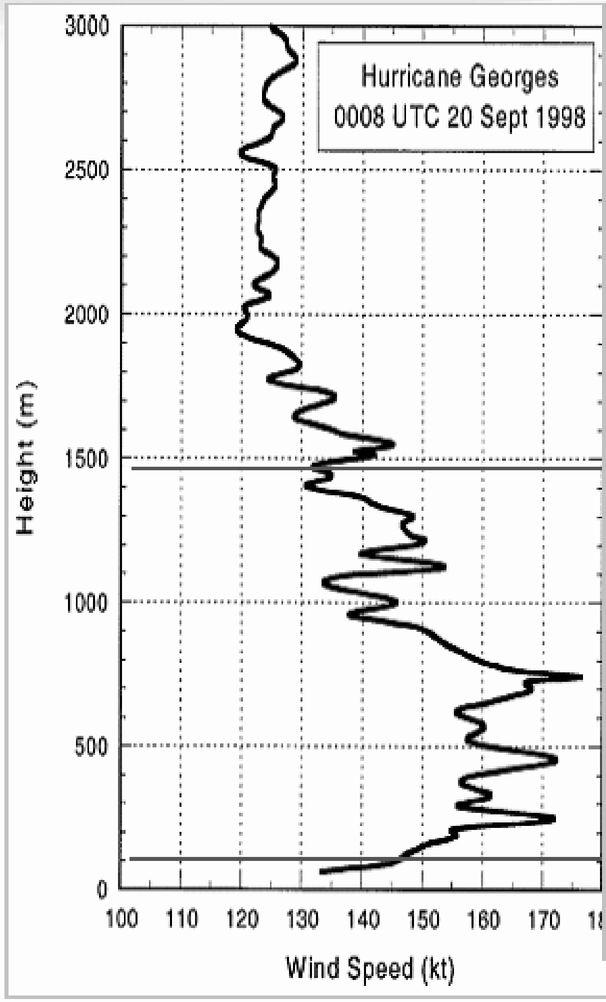


Fig. 2. Dropwindsonde wind speed profile from the eyewall of Hurricane Georges.

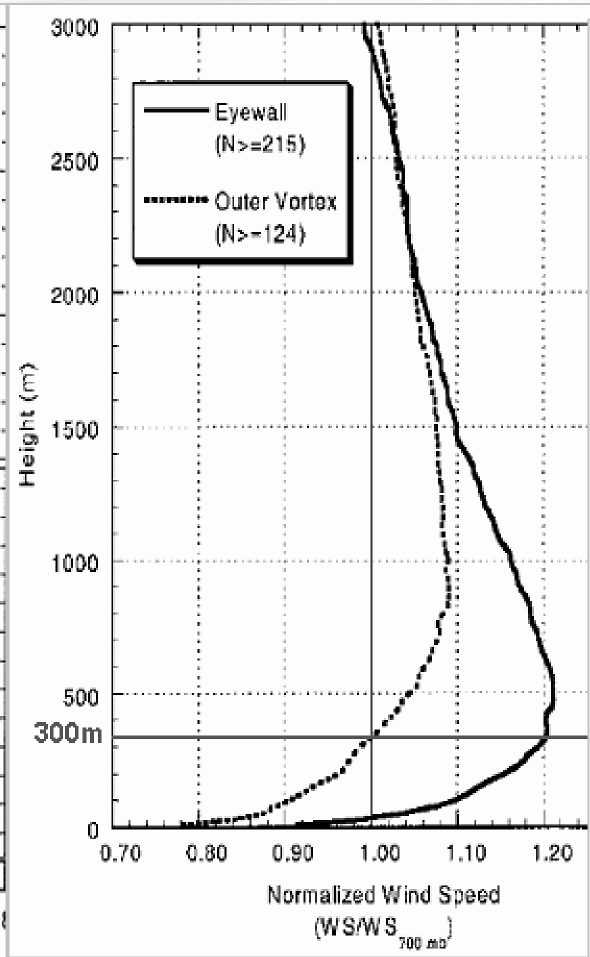


Fig. 3. Mean hurricane wind speed profiles for the eyewall and outer-vortex regions.

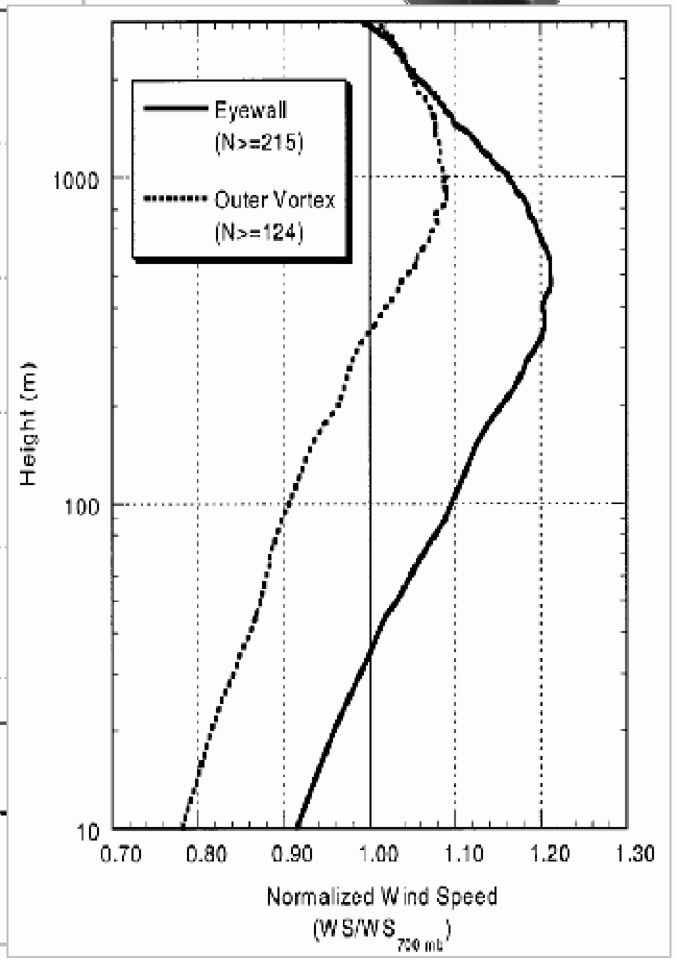


Fig. 4. As in Fig. 3 except that the height axis is plotted on a logarithmic scale.

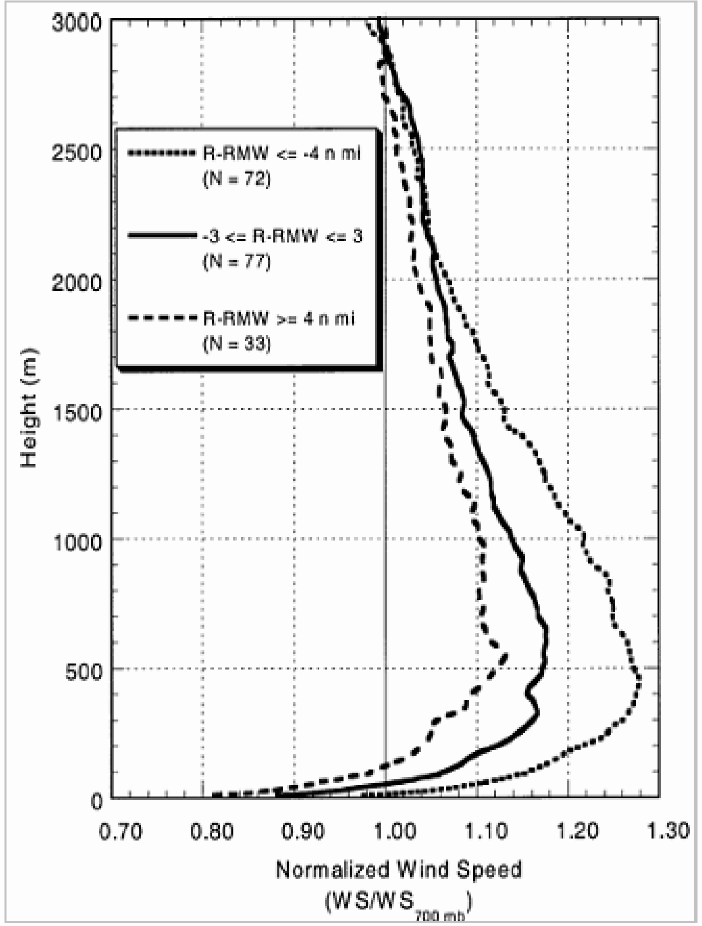


Fig. 5. Mean wind speed profiles for eyewall sondes released.

Flight level	Eyewall	Outer vortex (convection)	Outer vortex (not in convection)
700 hPa	0.90	0.85	0.80
850 hPa	0.80	0.80	0.75
925 hPa	0.75	0.75	0.75
1000 ft (305 m)	0.80	0.80	0.80

- The surface maximum wind speed is similar with 80-90 % of 700 hPa wind speed(Franklin, 2003).
- But as the height gets lower, the difference of
- wind speed between the center of hurricane and
- RMW gets more bigger(Fig. 5).

- So We need adjustment function which is to adjust wind speed according to the distance between hurricane center and RMW.

4.3. Adjustment Function & RMW

700hPa wind → Adjustment Function(Adj) → 300m level wind speed

Adj (조정계수) : according to the distance from typhoon center

Franklin (2003), Axe (2003).

- In the eye ~ 1.25
- In the eyewall ~ 1.15
- Just Outside the eyewall ~ 1.05
- Outer Vortex ~ 1.00

$$Adj(r) = 1.05 - \frac{.05}{30km}(r - (R_{max} + 7.4km))$$

In this study, we use upper equation.

- Radial distance (r) : 15m/s 부는 영역
- Radius of Maximum winds, RMW : R_{max}

		RMW			
Eye	30 ~ 7.4km	7.4km ~	~ 7.4km	7.4 ~ 30km	30km ~ 300km
Adj	1.25	1.15		1.05	1.00

Fig. 6. 300m level increase factors to continuous distance from the RMW.

3 function to calculate the Radius of Maximum Wind

$$\ln R_{\max} = 2.0633 - 0.0001900\Delta p^2 + 0.0007336 Lat^2 + \epsilon \quad \cdots \quad (1)$$

$$\ln R_{\max} = 2.636 - 0.00005086\Delta p^2 + 0.0394899\psi \quad \cdots \quad (2)$$

$$\ln R_{\max} = 2.556 - 0.000050255\Delta p^2 + 0.042243032\psi \quad \cdots \quad (3)$$

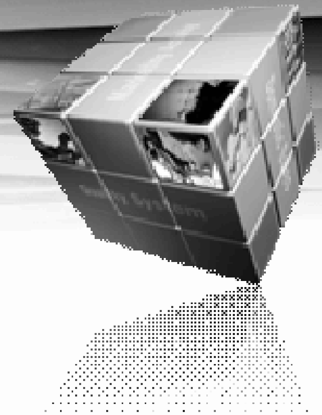
- ✓ Δp : pressure difference (1013 hPa – pressure of typhoon center)
- ✓ Lat and Ψ : Latitude of typhoon center
- ✓ ϵ : 0.3

Table 1. The process of estimates for RMW.

RMW(km), WS : wind speed (m/s)

Time			AWS		700hPa	RMW		
M	D	H	site	WS	WS	(1)	(2)	(3)
8	31	15	723	-	29.42	46.70	38.55	47.44
			793	2.9	29.42	46.70	38.55	47.44
		18	748	8.3	28.51	49.45	40.35	50.34
			765	1.7	28.51	49.45	40.35	50.34
		21	912	8.2	20.17	52.90	40.86	53.91
			703	5.5	21.84	52.90	40.86	53.91
9	1	03	821	0.3	24.14	56.68	40.50	57.89
			818	1.1	21.73	56.68	40.50	57.89

4.4. 300m Level Wind Speed



- Adj = 1.05 ~ 1.15
- 700hPa wind speed × Adj = 300m level wind speed

Table 2. The process of estimates for 300m level wind speed.

WS : wind speed (m/s)

Time			AWS		700hPa	RMW			Adj			300m level WS		
M	D	H	site	WS	WS	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
8	31	15	723	-	29.42	46.70	38.55	47.44	1.10	1.09	1.10	32.46	32.06	32.50
			793	2.9	29.42	46.70	38.55	47.44	1.11	1.10	1.11	32.71	32.31	32.75
		18	748	8.3	28.51	49.45	40.35	50.34	1.11	1.10	1.11	31.70	31.27	31.74
			765	1.7	28.51	49.45	40.35	50.34	1.11	1.10	1.11	31.67	31.24	31.71
		21	912	8.2	20.17	52.90	40.86	53.91	1.11	1.09	1.11	22.36	21.95	22.39
			703	5.5	21.84	52.90	40.86	53.91	1.11	1.09	1.12	24.34	23.90	24.38
9	1	03	821	0.3	24.14	56.68	40.50	57.89	1.11	1.09	1.11	26.84	26.19	26.89
			818	1.1	21.73	56.68	40.50	57.89	1.11	1.08	1.11	24.12	23.53	24.16

4.5. Peak 3-second Gust(10m)

Peak 3-second gust

$$V3 = Va \times G_{10nim,3}$$

$$where,\ G_{10min,3} = Gust\ factor$$

Actual terrain wind speed at 10m

$$Va = (U^*a/0.4)\,(Ln\,(10/Zoa))$$

$$where,\ U^*a = Actual\ terrain\ firction\ velocity\ (m/s)$$

Friction velocity at 10m

- Open terrain ▶ $U^*o = Vo \times 0.4/[Ln\,(10.0/0.03)]$
- Actual terrain ▶ $U^*a = U^*o/[\,(Zoo/Zoa)]^{0.0706}$

$$where,\ Zoa = Roughness\ length\,(m)\ \ based\ \ on\ \ upstream\ \ terrain$$

Surface wind speed for open terrain produced by the wind model

$$Vo = U_{300}\frac{Ln\,(10/Zoo)}{Ln\,(300/Zoo)}$$

$$where,\ Zoo = Roughness\ length\,(m)\ \ \mathrm{for}\ \ the\ open\ terrain\ = 0.03$$

Table 3. The process of estimation for actual terrain friction velocity at 10m level. *WS : wind speed(m/s)

Time			AWS		700hPa	300m	Vo	U*o	Zoa	U*a	Va
M	D	H	site	WS	WS	WS	WS	WS	(m)	WS	WS
8	31	15	723	-	29.42	32.06	20.22	1.39	0.0001	0.93	26.79
			793	2.9	29.42	32.31	20.38	1.40	0.0001	0.94	27.01
		18	748	8.3	28.51	31.27	19.72	1.358	0.2	1.55	15.19
			765	1.7	28.51	31.24	19.70	1.357	0.2	1.55	15.17
		21	912	8.2	20.17	21.95	13.84	0.953	0.2	1.09	10.66
			703	5.5	21.84	23.90	15.07	1.038	0.15	1.16	12.21
9	1	03	821	0.3	24.14	26.19	16.52	1.137	0.15	1.27	13.38
			818	1.1	21.73	23.53	14.84	1.022	0.15	1.14	12.02

- 10m wind speed considering real topography are similar with 0.6~0.9 of 700hPa wind speed. This result coincide with Franklin's study(2003).

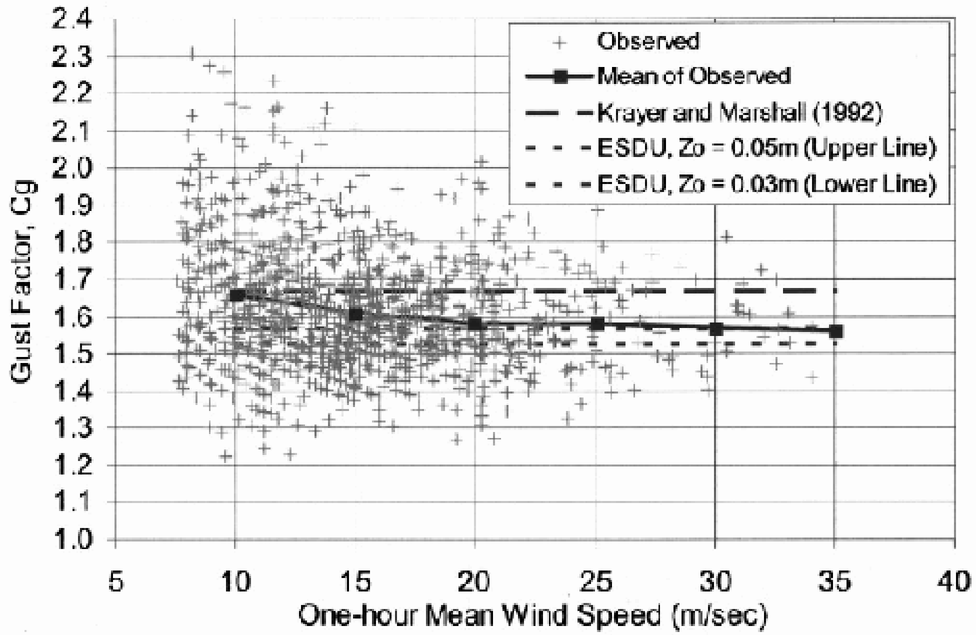
- The surface wind is similar with 0.5~0.6 of 300m wind speed. Because surface wind is sensitive with roughness length. So we needs high resolution roughness length data.

4.6. Gust Factor Model

Vickery and Skerlj (2005) – *PHRLM(2003)*

In order to use the Hurricane wind field model,

We compared Durst(1960), krayer and Marshall (1992),and ESDU(1983) ,the proceeding studies about gust factor and ESDU(1983)'s gust factor model was displaying the gust factor well in the center of the hurricane .



Gust factor

$$G_{10min,3} = 1 + T_{il} P_f(3)$$

$$V3 = Va \times G_{10nim,3}$$
$$where,\ G_{10min,3} = Gust\,factor$$

T_{il} : Longitudinal turbulent intensity
= $\sigma_u(z) / U_h$

Standard deviation of the wind speed

$$\sigma_u(z) = \frac{7.5\eta u^* \left(0.09\,Ln\left(\frac{10}{Zoa}\right) + 0.538\right)^{\eta 16}}{\left(1 + 0.156\,Ln\left(\frac{u^*}{f \cdot Zoa}\right)\right)}$$

$$\sigma_u(z) = standard\ deviation\ of\ the\ wind\ speed$$

f : Coriolis parameter
= 2 (7.292 $\times 10^{-5}$ sin (Lat))
u^* : Friction velocity (m/s)
Zoa : Roughness length based on upstream terrain
η : Height scaling parameter based on a height of 10m = 1 - 6 f (10 / u^*)

Max 3s winds

$$P_f(3) = \left(\sqrt{2Ln(600C_r)} + \frac{0.557}{\sqrt{2Ln(600C_r)}}\right)\frac{\sigma_u(z,3)}{\sigma_u(z)}$$

$$P_f(3) = (2.67 + 0.2086)\frac{\sigma_u(z,3)}{\sigma_u(z)}$$

$$P_f(3) = peak\ factors\ \mathrm{for}\ the\ \max\ 3\,second\ winds$$

C_r : the wind fluctuation cycling rates
$\sigma_u(z,3)$: Standard deviation of the wind speed (1cycle/3 seconds)

4.7. Result

Table 4. The process of estimation for peak 3-second gust at 10m level.

* WS : wind speed(m/s)

Time			AWS		700hPa	300m	Va	u^*	$\sigma_{u(z)}$	$\sigma_{u(z,3)}$	$P_f(3)$	$G_{10min,\ 3}$	V3
M	D	H	site	WS	WS	WS	WS	WS	WS	WS			WS
8	31	15	723	-	29.42	32.06	26.79	0.93	2.74	2.37	2.51	1.26	33.67
			793	2.9	29.42	32.31	27.01	0.94	2.76	3.43	2.50	1.26	33.92
		18	748	8.3	28.51	31.27	15.19	1.55	3.72	3.43	2.51	1.62	24.55
			765	1.7	28.51	31.24	15.17	1.55	3.73	3.24	2.50	1.62	24.53
		21	912	8.2	20.17	21.95	10.66	1.09	2.67	2.32	2.50	1.63	17.36
			703	5.5	21.84	23.90	12.21	1.16	2.87	2.50	2.50	1.60	19.42
9	1	03	821	0.3	24.14	26.19	13.38	1.27	3.14	2.72	2.50	1.69	21.25
			818	1.1	21.73	23.53	12.02	1.14	2.83	2.46	2.50	1.59	19.13

- Peak 3s gust at 10m level are 1.5 times more strong than 10m wind speed of real land(Va) and are less than 300m wind speed

5.1. Common Housing Types

Detached Dwelling

- The wind load is different with the story number,

→ in this study we selected one story of detached dwelling

- The average area of detached dwelling : 62.81㎡ ~ 95.56㎡ (19평 ~ 29평)
- The most common residence area is under 85㎡ (25.7평)

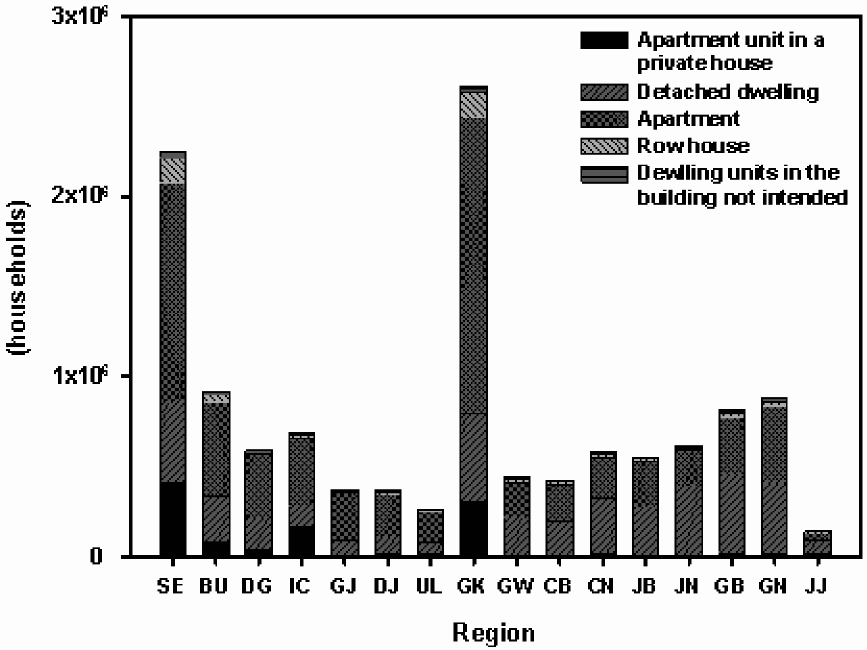


Fig. 1. Type of housing by region(2005).

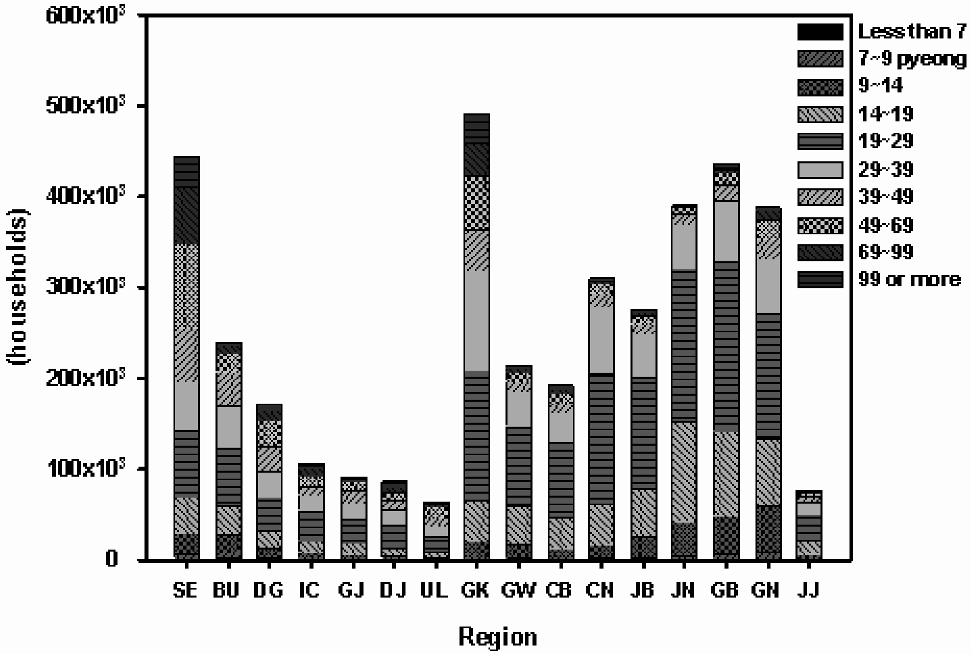


Fig. 2. Total area of detached dwelling by region(2005).

5.2. Roof Structure Types

- The roof types in Korea are variety and complex different with America.
- Jung(2006) classified the roof types of detached dwelling in Korea into 14 types ▶ main type : a gable roof, hipped roof

- Development of Web-based code for assessment of wind load on structures.
- Nam(2003) classified the roof types of detached dwelling in Korea into 6 types in order to calculate wind load on structure

  ▶ flat roof, curved roof, leaned roof, gable roof, multi gable roof, saw roof

- impossible to estimate the wind load considering all of the factors so we considered just the 4 of the following : height of structure, side ratio, roof type, story number

Table 1. Assumed structural type definitions (PHRLM, 2005)

	No of Stories	Exterior Wall	Roof Materials	Roof Type
Type 1	1story	concrete blocks	Shingle/Tile	Gable
Type 2	1story	concrete blocks	Shingle/Tile	Hip
Type 3	1story	Wood	Shingle/Tile	Gable
Type 4	1story	Wood	Shingle/Tile	Hip
Type 5	2 story	1 story: concrete block; 2 story: wood	Shingle/Tile	Gable
Type 6	2 story	1 story: concrete block; 2 story: wood	Shingle/Tile	Hip
Type 7	2 story	Wood	Shingle/Tile	Gable
Type 8	2 story	Wood	Shingle/Tile	Hip
Type 9	1story	concrete blocks	Metal	Gable
Type 10	1story	concrete blocks	Metal	Hip
Type 11	1story	Wood	Metal	Gable
Type 12	1story	Wood	Metal	Hip
Type 13	2 story	1story: concrete block; 2 story: wood	Metal	Gable
Type 14	2 story	1story: concrete block; 2 story: wood	Metal	Hip
Type 15	2 story	Wood	Metal	Gable
Type 16	2 story	Wood	Metal	Hip

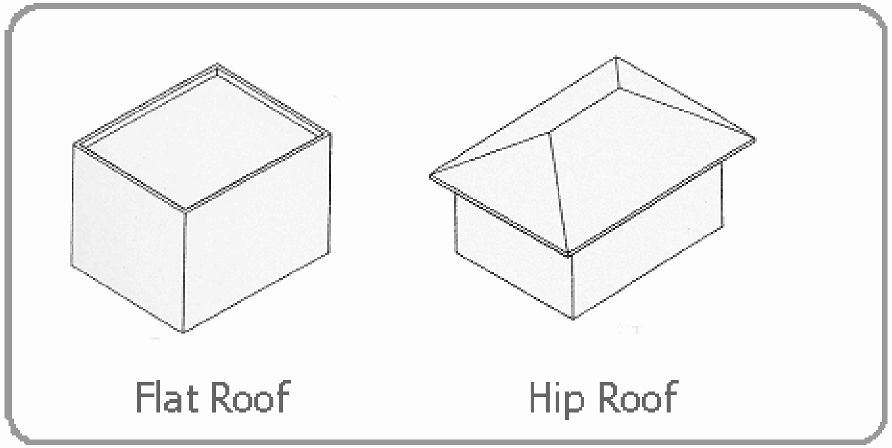
- As you see in this table, in America they just selected Gable Roof and Hipped Roof among many types (PHRLM, 2005)
- so we are going to decide the representative roof type out of many roof types shown in the previous study(Jung, 2006; Nam, 2003)

Most Common Roof Types

Table 2. The roof type distribution by year (Shin, 2002).

Types \ Year	60s	The first half 70s	Late in the 70s	The first half 80	Late in the 80s	The first half 90	Late in the 90s	Average
Flat	23.1	39.0	46.3	41.6	50.0	66.7	58.1	52.8
Eyeblow	0.0	0.0	0.0	5.2	34.2	21.6	29.0	18.9
Gable	15.4	17.2	33.3	15.8	7.9	3.9	3.2	8.9
Hipped	53.8	43.8	20.3	37.3	5.3	2.0	3.2	15.6
Others	7.7	0.0	0.0	0.0	2.6	5.9	6.5	3.9

- This table shows the roof types distribution by years researched by Shin and as you can see the flat, eyeblow, and hipped are the most common types but eyeblow and the flat are almost the same so we can just devide into two types, flat and hipped.



5.3. roof Height

- In Korea the roof and ceiling height are very variety and complex but in western structure's ceiling height is 2.4~3.2m and roof height is 2.6~3.0m(Oh, 1998)

- Previous study(Lee, 2006; Choi, 2000) shows that the living room's ceiling height is more than 2.1m and the room's ceiling height is 2.3~2.4m

- detached dwelling's ceiling height is usually 2.6m and detached dwelling's ceiling height which is recently built by Korea national housing corporation is 2.7m. (Lee SY, 2008; Han, 2007)

- ceiling height : 2.3m
- roof height : 2.6m

5.4. Side Ratio

side ratio

- The side ratio can be different by the designs, so we need to decide the side ratio corresponding to the common area of 62.81㎡~95.56㎡
- It is hard to get the plan type of detached dwelling, so we got it from apartment which has the same area of the detached dwelling
- And from this plan type of apartment we are going to decide the side ratio.

- We choose 4 construction company that of the most executing construction work.
- Daewoo E$C, Daelim, GS E$C, and Samsung C$T
- We got the 110 plan types of apartments witch area is 62.81㎡~95.56㎡

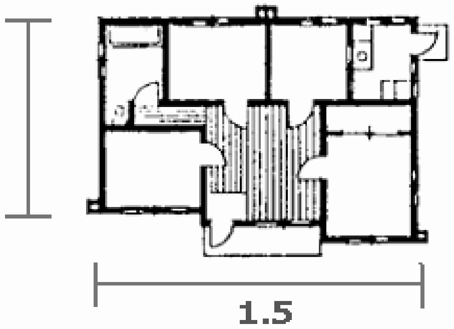
Table 3. the side ratio according to the area of apartment

Total area (pyeong)	Number of case	Average area (m^2)	Side ratio
29	1	77.03	1.5
30	2	76.84	1.4
31	1	75.52	1.3
32	17	84.85	1.5
33	47	86.61	1.5
34	25	84.92	1.6
35	17	84.95	1.6
Total/Mean	110	81.53	1.5

The average of side ratio according to the detached dwelllings area between 62.81㎡ and 95.56㎡ is 1.5 as you see in this table.

(예) 85㎡인 주택

- width : 11,300mm[1]
- length : 7,530mm



Summary

To get the wind load potential by the typhoon we estimated the peak 3s gust on structure and as we surveyed the representative type and characteristics of detached dwelling in Korea, the results are as follow as;

1. 700hPa wind → 300m level wind speed → 10m level peak 3s gust

2. Estimate the peak 3s gust of typhoon which had an influence in Korea
   ▶ The wind load is different for all types of residential building.

3. 1 story detached dwelling average area range is between 62.81㎡ and 95.56㎡ ▶ we selected 85㎡ (25.7pyeong) which is the most common area

4. Most common roof types : Flat roof and Hip roof
5. average ceiling height: 2.6m
6. Side ratio : 1.5