A Study on Basic Wind Speeds of South Korea

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ABSTRACT: Basic wind speed data is very important on designing wind loads for buildings and structures. The basic wind speed on building and bridge design codes in South Korea has been used separately in each other. Moreover, the data were made over than 15 years ago. Then, the data are needed to synchronize and upgrade the basic wind speed value of all Korea Meteorological stations on the building and bridge design codes. To realize it, it is necessity to standardize the basic wind speed of all stations, and then the data can be gotten from past surface roughness and long-term wind speed data. So this study used the Gust Factor (GF) method to standardize yearly maximum wind speed. Also the Monte Carlo simulation tool (Gumbel weight value method) is used to supplement the absence of wind speed data, which are only having short-term data. In this study, we understand that using GF method to estimate the past surface roughness and the simulation tool to simulate up to 100 years of yearly maximum wind speed were acceptable. And the basic wind speed map was made newly using those methods.

KEYWORDS: Basic wind speed, gust factor, gumbel weight value.

1 INTRODUCTION

The early 1960s since the economic development plan conducted concurrently with the acceleration of urbanization, therewith some changes occurred in the terrain. Basic wind speed data is very important on designing wind loads for buildings and structures. The basic wind speed on building and bridge design codes in South Korea has been used separately in each other. Moreover, the data were made over than 15 years ago. Then, the data are needed to synchronize and upgrade the basic wind speed value of all Korea Meteorological stations on the building and bridge design codes. To realize it, it is necessity to standardize the basic wind speed of all stations then the data can be gotten from past surface roughness and long-term wind speed data. Wind velocities measured at meteorological stations are influenced with the change of surface roughness around meteorological stations. Therefore wind velocity must be standardized yearly for the design in environmental and construction area. For the wind standardization, it is necessary to know the ground roughness around the point of measurement, however most of the meteorological stations do not have enough data. this study used the Gust Factor (GF) method to standardize yearly maximum wind speed. Also the Monte Carlo simulation tool (Gumbel weight value method) is used to supplement the absence of wind speed data, which are only having short-term data.

Generally, Gust Factor (GF) has high relation with ground roughness and this study is aimed to determine the daily gust factor of the meteorological stations on yearly basis and to compare the latest ground roughness with the pictorial and geographical map analysis. Also to established availability and standardized wind speed comparing with the GF and surface roughness of each meteorological stations. Long-term data on hourly wind speed from 63 meteorological stations of Korea Meteorological Department have been collected. Ideally, 100 years return period for wind speed is necessary but only about half is available from the various Korea meteorological stations. The oldest wind speed data comes from Seoul meteorological station, which has 45 years of data followed by Busan with 41 years of data. Most meteorological stations have wind speed data only going back 30 years. The daily gust wind data have been processed for annual maximum wind speed for each site. Using the Gumbel probability approach to simulate up to 100 years of yearly maximum wind speed was acceptable to estimate in stations with only 30 years of data and finally it used to make basic wind speed map.

2 METHODOLOGY

2.1 *Meteorological height and wind speed standardization*

Wind loads have become particularly significant because of the increasing number of high-rise buildings. However, it is useful to analyze what parameters could have an influence in calculating the wind load; here the analysis is limited to the gust factor, which is one important parameter affecting the design of structures. The gust factor G is defined as $G = f_g / f$ For all the stations, the average gust factor was calculated using all wind speeds above 10 m/s.

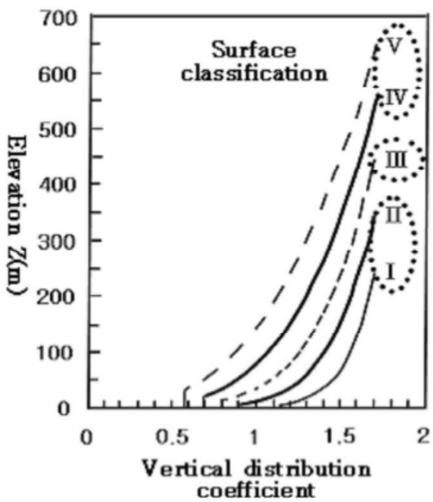


Fig. 1 Vertical distribution factor

Fig.1 shows the vertical distribution factor was the essence of the surface roughness was divided into three grades. Weather for the height of the statue of the vertical distribution of wind speed standard that is widely used among the equations representing the index of following the law was used in this study.

$$V(Z) = V_{z0}\left(\frac{Z}{Z_0}\right)^{\alpha}$$

Where V (Z) is the height Z (m) in the wind speed (m/s), V_{Z0} the standard height of $Z0$ (m) in the average wind speed (m/s), α condition that is determined by the roughness of the surface is constant.

Table 1 shows the wind speed measurement of each surface height on all meteorological stations. Wind speed measurements based on 10m heights above ground are fixed, but some meteorological stations are higher and it’s compared to other weather stations.

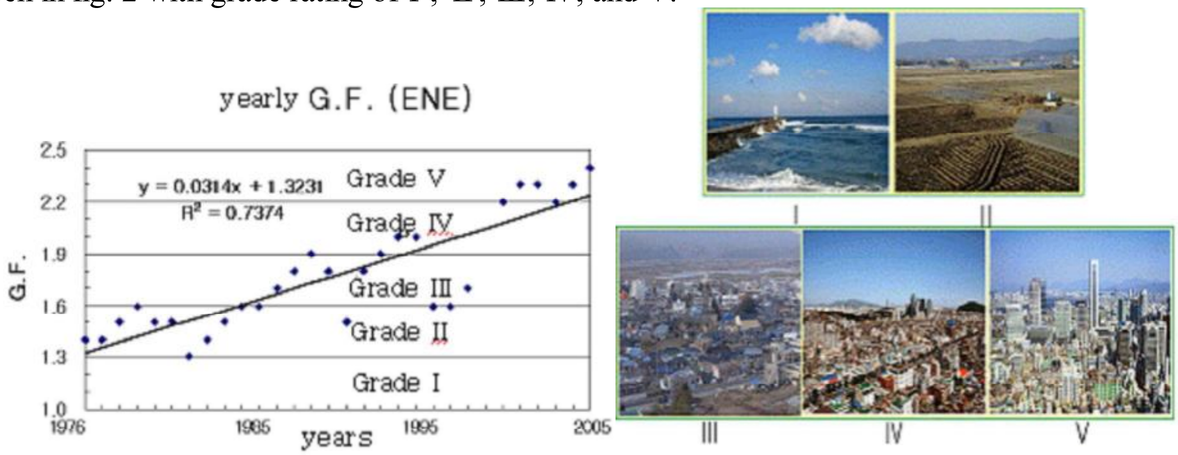
Table 1 Wind speed measurement of meteorological stations

Surface height (m)	Meteorological stations
10	Seoul, Incheon, Suwon, Wonju, Gangneung, Cheongju, Chuncheon, Jecheon, Donghae, Inje, Icheon, Yangpyeong, Ganghwa, Cheonan, Geumsan, Boryeong, Buyeo, Boeun, Ulsan, Gwangju, Daegu, Andong, Wando, Uljin, Seogwipo, Gunsan, Mokpo, Yeosu, Jeonju, Jinju, Uleungdo, Tongyeong, Jangheung, Haenam, Namwon, Buan, Imsil, Jangsu, Jeongeub, geoje, Namhae, Sancheong, Geochang, Miryang, Yeongcheon, Hamcheon, Goheung, Bonghwa, Yeongju, Gumi, Mungyeong, Yeongdeok, Euiseong, Jeju-do.
11.9	Sokcho
13	Taebaek, Heungcheon.
15	Pohang
17.8	Busan
21	Seosan
22.8	Daejeon

In this study, the expression of GF was defined as daily gust wind speed divided by maximum wind speed. The daily wind speed is frequently related to the maximum gust speed through use of a wind gust factor, G that is defined as the ratio of the peak gust speed to the mean wind speed in a particular time period.

$$GF = \frac{Daily\ gust\ wind\ speed}{Daily\ \max.\ wind\ velocity}$$

The basic wind speed refer to gust factor at a height of 10 m above ground level in a grade II terrain (open terrain with average obstruction on the surface being small and scattered), with a mean return period of 30 years. The surface roughness standardization methods can be seen in fig. 2 with grade rating of Ⅰ, Ⅱ, Ⅲ, Ⅳ, and V.



(a) GF surface roughness calculation (ENE direction) (b) Surface roughness classifications

Fig. 2 Surface roughness standardization methods

Fig. 3 is an example of surface roughness standardization by visual observation of Ulsan meteorological station, as can be seen in the figure in wind direction of SE there are some tall buildings and trees can be notice as grade Ⅲ terrain, while the SW wind direction there are high-rise apartments and the buildings around it have severe grade Ⅳ terrain.

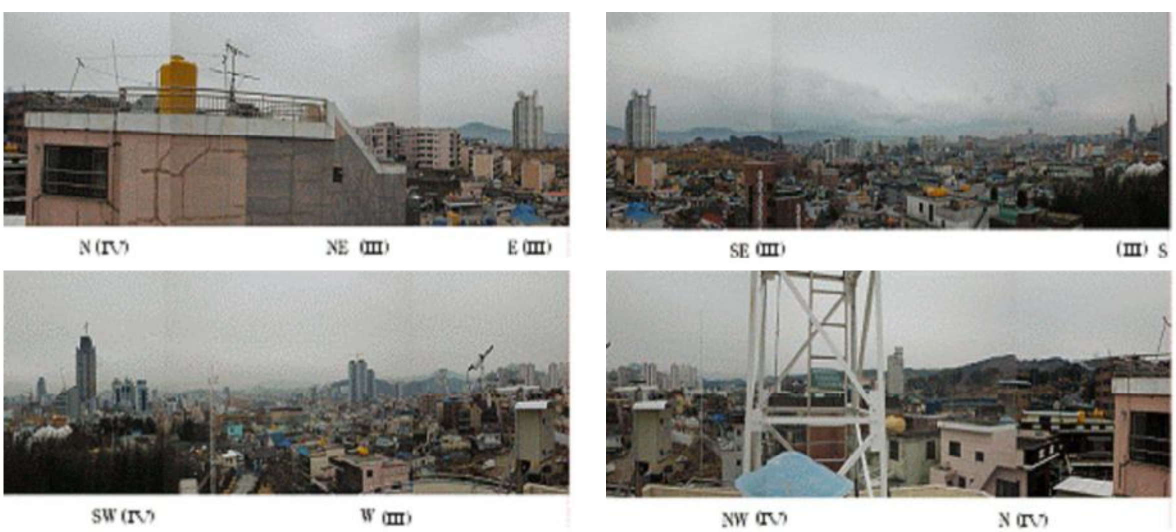


Fig. 3 Surface roughness standardization by visual observation of around Ulsan meteorological station

Table. 2 Show the comparison of surface roughness standardization measured after year 1975 between gust factor method and visual observations on all over Korea meteorological stations. In this table below there are seven big cities as the comparison and between G.F. and visual observation by the same grades represents 50-80%. In addition, all cities in the one grade different represent 100% except in the case of Daejeon (87%) and Daegu (94%) one grade differences.

Table 2 Visual & GF surface roughness comparison (present status)

	Big city													
	Seoul		Incheon		Suwon		Daejeon		Busan		Daegu		Ulsan	
	G.F	Visual	G.F	Visual	G.F	Visual	G.F	Visual	G.F	Visual	G.F	Visual	G.F	Visual
N	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅱ
NNE	Ⅴ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅱ
NE	Ⅳ	Ⅳ	Ⅴ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅳ	Ⅳ	Ⅳ	Ⅲ
ENE	Ⅳ	Ⅴ	Ⅳ	Ⅳ	Ⅱ	Ⅱ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅳ	Ⅳ	Ⅲ
E	Ⅳ	Ⅴ	Ⅳ	Ⅳ	Ⅱ	Ⅱ	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅳ	Ⅳ	Ⅲ
ESE	Ⅳ	Ⅴ	Ⅳ	Ⅳ	Ⅱ	Ⅲ	Ⅱ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ
SE	Ⅳ	Ⅴ	Ⅳ	Ⅲ	Ⅱ	Ⅲ	Ⅱ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅳ	Ⅳ
SSE	Ⅳ	Ⅴ	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅴ	Ⅲ	Ⅳ	Ⅳ
S	Ⅳ	Ⅴ	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅳ
SSW	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅳ	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅳ
SW	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅳ
WSW	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ
W	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ
WNW	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ
NW	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅳ	Ⅲ	Ⅲ	Ⅲ
NNW	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅲ
GF = visual	8 (50%)		10 (62%)		8 (50%)		10 (62%)		10 (62%)		12 (75%)		8 (50%)	
One grade different	16 (100%)		16 (100%)		16 (100%)		14 (87%)		16 (100%)		15 (94%)		16 (100%)	

2.2 *Wind frequency analysis*

Korea meteorological stations daily maximum wind speed data were subjected to probability distribution tests namely Gumbel probability distributions. In the weight value method of Gumbel distribution, the following formulas were used to get the shape parameter (α) and scale parameter (β).

$$\alpha = \frac{l_2}{\ln 2} \quad \text{..........(1)}, \qquad \beta = l_1 - n_e \alpha \quad \text{.............(2)}$$

Where l_1 and l_2 are calculation coefficients.

The probability density function equation for the moment method and weight value method of Gumbel distribution is:

$$f(x) = \frac{1}{\alpha} \exp\left[\frac{(-x-\beta)}{\alpha} - \exp\frac{(-x-\beta)}{\alpha}\right] \quad \text{................(3)}$$

After calculating the shape and scale parameters, the real probability distribution of the data were obtained and plotted. Afterwards, the real probability distribution curves for Korea meteorological stations were compared to the probability density functions of the Gumbel distribution curves. The distribution curve with the closest fit to the real probability distribution curve was chosen to be used in the Monte Carlo simulation.

The daily maximum wind speed return period for Korea meteorological stations were calculated by Hazen method since the data available was less than 100 years using this equation:

$$T = \frac{2m-1}{n-1}$$

Where T is return period, m is rank and n is number of years.

After the choosing the probability distribution, Monte Carlo simulation and comparative analysis was done by following this flowchart as can be seen at fig. 4.

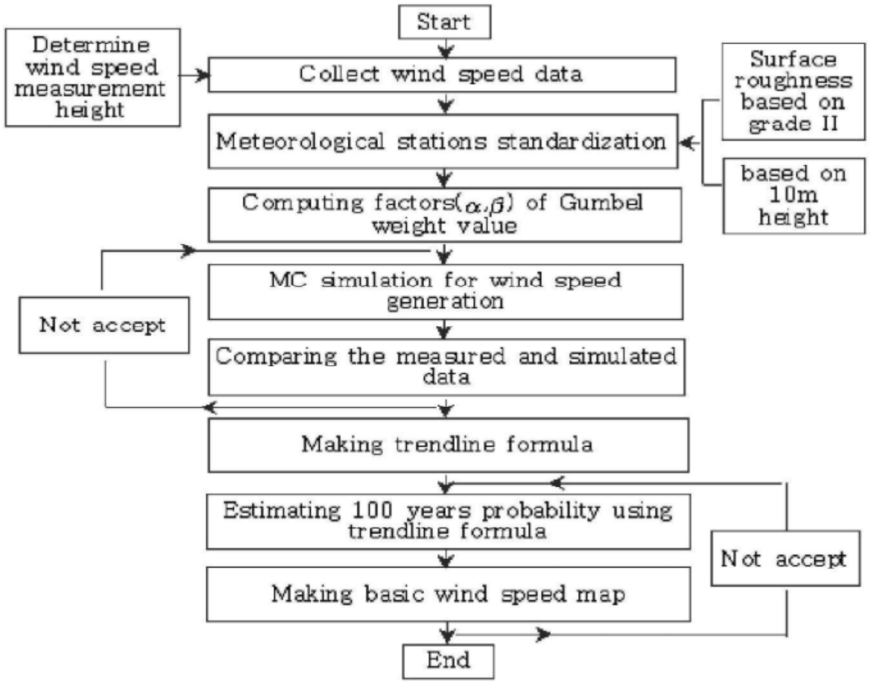


Fig. 4 Flowchart of Basic wind speed generation

Finally, the predicted maximum yearly wind speed values were analyzed for acceptability by plotting and comparing to that of the real data.

3 RESULTS AND DISCUSSION

3.1 *Meteorological measurements of wind speed standardization results*

In this paper, the results of wind speed standardization of Ulsan metrological station from years 1976-2005 are represented in table 3. It shows that yearly maximum wind speed of Ulsan metrological station was standardized into surface roughness grade II (height 10m above ground). It shows that the converted grades from the grade III to grade II was increased about 8.5%, while from the grade IV to grade II was increased about 28.7% and the overall surface roughness converted into grade II was approximately about 11.1% was increased. The comparison between yearly maximum wind speed and converted surface roughness grade II of Ulsan meteorological station (1976-2005) can bee seen in fig. 5. In this study, we understand that GF method was useful to standardized the wind speed from the past surface roughness conditions

Table 3 Yearly max wind speed standardization of Ulsan meteorological station (1976-2005)

Survey				Standardization	Survey				Standardization
Years	Wind direction	Surface roughness	Yearly max wind speed	Converted into grade II	Years	Wind direction	Surface roughness	Yearly max wind speed	Converted into grade II
1976	NNW	Ⅲ	19.7	21.5	1991	NE	Ⅲ	10	10.9
1977	NW	Ⅲ	17.7	19.4	1992	SSE	Ⅲ	8.7	9.5
1978	NNW	Ⅲ	17.3	18.9	1993	ENE	Ⅲ	9.7	10.6
1979	N	Ⅲ	16.7	18.3	1994	ENE	Ⅲ	12.3	13.5
1980	NW	Ⅲ	15	16.4	1995	N	Ⅳ	10	12.8
1981	WSW	Ⅲ	13.3	14.5	1996	W	Ⅲ	8.7	9.5
1982	NW	Ⅲ	16.7	18.3	1997	NW	Ⅳ	11.2	14.3

1983	WSW	Ⅲ	12.7	13.9	1998	WSW	Ⅲ	14.7	16.1
1984	NW	Ⅲ	10.3	11.3	1999	NW	Ⅳ	14.7	18.8
1985	NE	Ⅲ	12.7	13.9	2000	NW	Ⅳ	11.6	14.8
1986	S	Ⅲ	11	12.0	2001	NNW	Ⅳ	11.1	14.2
1987	NNW	Ⅲ	18.3	20.0	2002	ENE	Ⅲ	13.1	14.3
1988	WSW	Ⅲ	15	16.4	2003	ESE	Ⅲ	18.3	20.0
1989	NNW	Ⅲ	14.3	15.6	2004	ENE	Ⅲ	14.8	16.2
1990	WNW	Ⅲ	13	14.2	2005	NE	Ⅳ	11.5	14.7

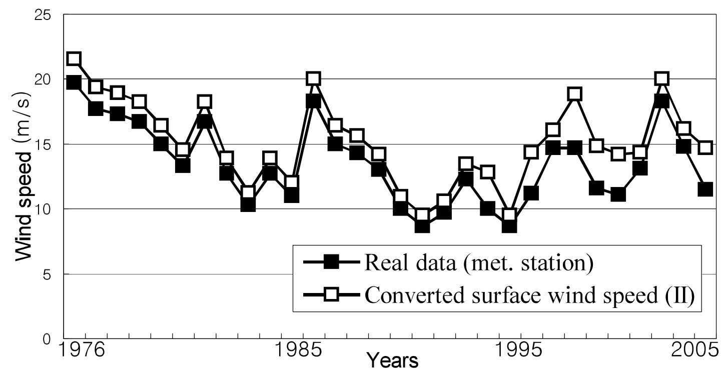
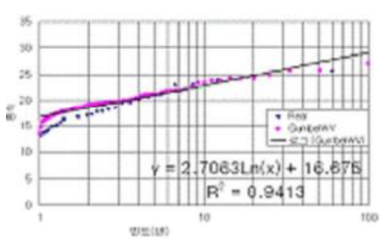


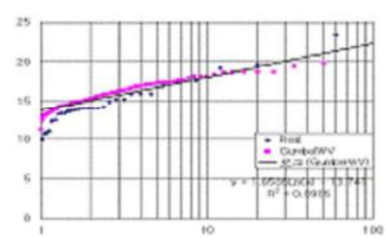
Fig. 5 Comparison of yearly maximum wind speed at Ulsan meteorological station

3.2 *Wind speed frequency analysis and basic wind speed results*

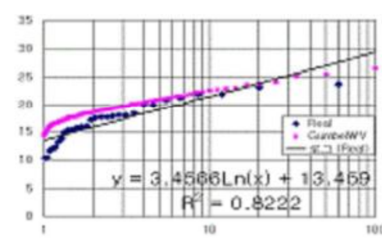
In this paper the 100 years of data was simulated by Monte Carlo simulation for all meteorological stations. Using Gumbel probability distribution, daily maximum wind speed was randomly generated by Monte Carlo simulation. The real and simulated yearly maximum wind speed data were compared and analyzed to determine if the simulated data is acceptable. The non-excess probability percentage of the real and simulated data were compared as shown in fig. 6 and the results show that the curves are very similar which means that the simulated data is acceptable. The Monte Carlo simulation tool using Gumbel probability distribution computed by weight value is used to simulate up to 100 years of yearly maximum wind speed was acceptable to estimated in stations with only 30 years of data and finally it used to make basic wind speed map.



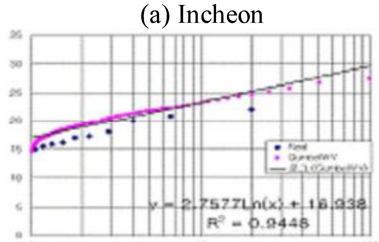
(a) Incheon



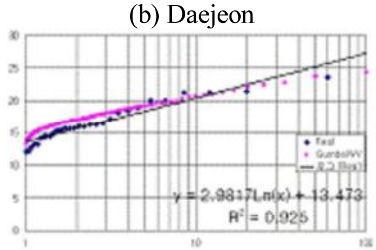
(b) Daejeon



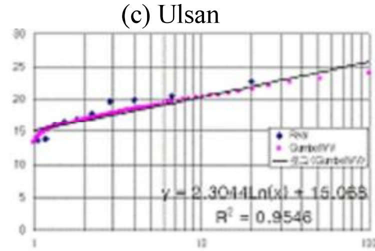
(c) Ulsan



(d) Donghae



(e) Kwangju

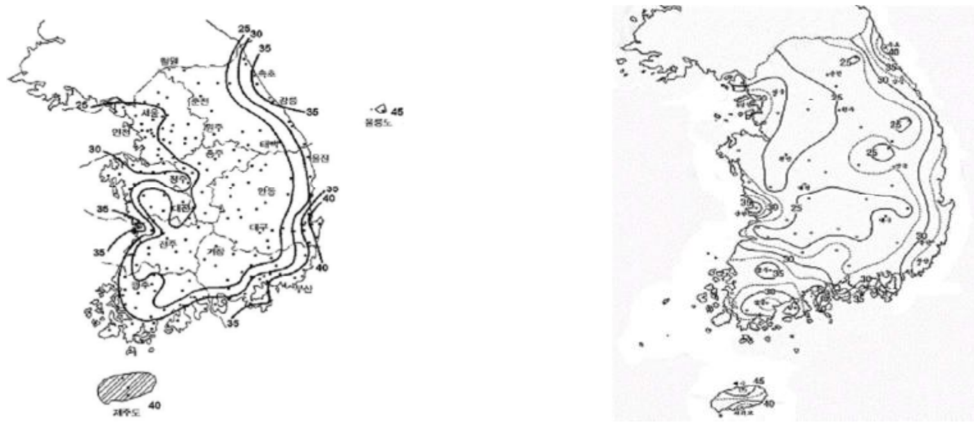


(f) Haenam

Fig. 6 Yearly maximum wind speed real and simulation comparison

3.3 *Basic wind speed map*

Fig. 7 shows the basic wind map by architectural design standards and basic wind speed map using 100 years simulation data. For all the stations, the average gust factor was calculated using all wind speeds above 10 m/s. The gust factor is calculated for 2.5 m/s intervals in wind speed.



a) South Korea Basic wind speed (b) Basic wind speed using 100 years simulation data

Fig. 7 Basic wind speed map

4 *CONCLUSION*

In this study, to make basic wind speed map, we have been done standardization using roughness factor by G.F. method and estimation of 100 years probability wind speed using Monte Carlo simulation tool with Gumbel weight value method on measuring wind speed of meteorological stations in Korea.

So we understood that using GF method to estimate the past surface roughness and the simulation tool to simulate up to 100 years of yearly maximum wind speed were acceptable. And the basic wind speed map was made newly using those methods.

5 ACKNOWLEGMENT

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