The 6th International Conference on Construction Engineering and Project Management (ICCEPM 2015)
Oct. 11 (Sun) ~ 14 (Wed) 2015 • Paradise Hotel Busan • Busan, Korea
www.iccepm2015.org

A Study of Non-Working Days Estimation in the High-rise Construction with Wind Load Data by Radiosonde

Kim Se-Hoon[1] Kim Yea-Sang*[2] Shin Hyuk[3] Kim Hye-Jin[4]

Abstract: This study is based on the data of velocity actually measured at varied the heights in the last 3 years. As mentioned in the World Meteorological Monitoring Plan(World Weather Watch: WWW), using the meteorological data by radiosonde can calculate the probability of velocity greater than 10m/s which is the standard beginning point of non-working condition by wind. The height is divided into sections, with 100m for each section starting from the ocean surface up to 700m high. The data measured at each section could be used for estimating and predicting the probability of non-working days for the construction nearby. For example, the data of Osan region is expected to be applicable for the project located in Seoul which has similar geographical conditions. As comparing the velocity varied with height, non-working days calculated basing on the measured data shows a variation of from -0.3 to +64 days. However, this study use Weibull distribution which considered more reliable, the result is expected to be more useful, as the data was all actually measured in the real conditions.

Keywords: Wind Load / Radiosonde / Non-working Day / High-rise / Construction Period/ Weibull

I. INTRODUCTION

A lot of high-rise buildings are now construction everyday for the purpose of forming landmarks in the cities. Many risk factors should be considered in order to calculate the period of constructions, in which the weather is one of the most important. All the elements of the weather such as rain, snow, wind, temperature, humidity must be checked carefully. While numerous studies on rainfall and temperature are now applied for construction, mainly for the calculation of construction period, those on the wind speed is still insufficient.

The basis for non-working days due to the wind is presented in the Standard safety work instruction. Usually, outside construction work cannot proceed when wind exceed 10m/s. However, the wind speed variation with height is not estimated for every region. One of the reasons is that it's not easy to check the velocity with height. Thus, this paper aims to estimate non-working days more accurately and reasonably than the previous one due to the wind actual data.

II. ESTIMATION WITH PREVIOUS THEORIES

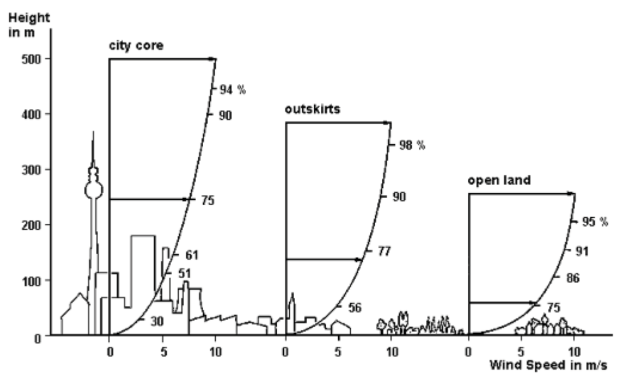

FIGURE 1
GROUND ROUGHNESS & WIND SPEED

Wind is influenced by surface friction, velocity of the surface and vertical distribution of wind speeds follow Power law as the following formula (1) (Claes Dyrbye, Svend Ole Hansen, 1997)

$$V_Z = V_G \left(\frac{Z}{Z_G}\right)^{\frac{1}{a}} \tag{1}$$

$V_Z = Ground\ Wind\ Velocity$

$V_G = Wind\ Velocity\ on\ its\ height$

$Z = Height\ from\ ground\ level$

$Z_G = Standard\ height\ (10m)$

$1/a =\ power\ law\ exponent$

Applying this formula, as shown in TableⅡ, we can obtain wind velocity increasing ratio according to height and ground roughness.

TABLE I
GRADIENT HEIGHT AND POWER LAW EXPONENT WITH ROUGHNESS

Ground Roughness grade	A	B	C	D
Gradient Wind Height	500m	400m	300m	250m
Power law exponent (1/a)	0.33	0.22	0.15	0.10

TABLE Ⅱ
WIND VELOCITY RATIO WITH HEIGHT IN SEOUL(A)

Height	Floor	Vz/VG velocity ratio	Ground wind velocity to make 10m/s (m/s)
700m	219	3.6	2.8
600m	188	3.6	2.8
500m	156	3.6	2.8
400m	125	3.4	3.0
300m	94	3.1	3.3
200m	63	2.7	3.7
100m	31	2.1	4.7
10m	3	1	10

[1] Kim, Se-Hoon, School of Civil & Architectural Engineering, SungKyunKwan University, Suwon 440-746, Korea
[2] Kim, Yea-Sang, School of Civil & Architectural Engineering, SungKyunKwan University, Suwon 440-746, Korea(*Corresponding Author)
[3] Shin Hyuk, Building ENG, Samsung C&T, Seoul 137-956
[4] Kim Hye-jin, Building ENG, Samsung C&T, Seoul 137-956

Thus, measured daily mean wind speed data from ground in Seoul(A) from 1st January, 2011 to 31th December, 2013 is applied to estimate possibility of construction work in accordance with Power law. Data can be convert and create working probability Table Ⅳ.

Using this Table, non-working days(Over 10m/s) can be achieved with formula (2) therefore along the height we can arrange the non-working days , as shown in Figure 2

TABLE Ⅲ
WIND SPEED DISTRIBUTION OF ANNUAL DAY (SEOUL)

Daily mean wind speed (m/s)	0~1	1~2	2~3	3~4	4~5	5~6	6~7	7~8	8~10	Sum
Annual number of days	0	83.6	173	73.4	29	4.8	0.8	0.4	0	365

TABLE Ⅳ
WORKING PROBABILITY TABLE IN SEOUL(A)

Height \ V(m/s)	0~1 m/s	1~2 m/s	2~3 m/s	3~4 m/s	4~5 m/s	5~10 m/s
600~700m	0.0%	0.0%	53.5%	100%	100%	100%
500~600m	0.0%	0.0%	39.8%	100%	100%	100%
400~500m	0.0%	0.0%	21.5%	100%	100%	100%
300~400m	0.0%	0.0%	5.5%	100%	100%	100%
200~300m	0.0%	0.0%	0.0%	71.9%	100%	100%
100~200m	0.0%	0.0%	0.0%	20.0%	100%	100%
10~100m	0.0%	0.0%	0.0%	0.0%	22.4%	100%

$$Annual\ non\ working\ days = \sum Ground\ Wind\ Occurrence \times \text{Working Probability (\%)} \quad (2)$$

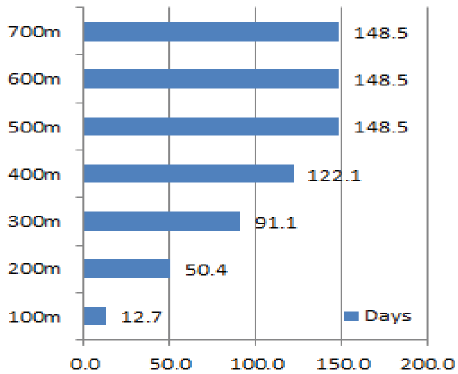

FIGURE 2
NON-WORKING DAYS (SEOUL (A))

The advantage of this method is simple and easy. Thus any region can get and estimate the result with Power law. However, this result changes greatly depending on Power law exponent so, it need to be subdivide the classes. Also, ground roughness which determine Power law exponent changes faster than before. Another disadvantage is difficult to prove data, because it is not based on actual data.

Ⅲ. CALCULATION METHOD UTILIZING RADIOSONDE DATA

A. *Typical methods*

As mentioned in the World Meteorological Monitoring Plan(World Weather Watch: WWW), using the meteorological data by radiosonde can calculate the velocity. The data measured at each section will be used for estimating and predicting the probability of non-working days for the construction nearby. For example, the data of Osan region is expected to be applicable for the project located in Seoul, Gyeonggi Province which has similar geographical conditions. Measured Osan data (2011~2013) was used in this study, with subdivided ground wind velocity, probability over 10m/s was analyzed. This probability can be computed by simply counting the number exceeds standard velocity for each height section, this can create a probability table shown in TableⅥ.

TABLE Ⅴ
MEASURED WIND DATA BY RADIOSONDE (OSAN)

Height	Number of Data	Data weight(%)	Mean (m/s)	Standard deviation
600~700m	306	3.4%	9.33	4.71
500~600m	589	6.5%	8.17	3.36
400~500m	11	0.1%	8.42	3.84
300~400m	402	4.4%	7.75	2.5
200~300m	547	6.0%	4.89	2.97
100~200m	1072	11.8%	2.95	1.67
0~100m	2654	29.2%	1.55	1.21
Sum	9091	100%	5.21	4.3

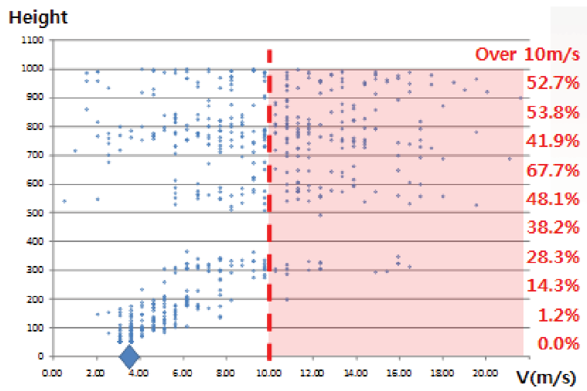

FIGURE 3
ACTUAL DATA DISTRIBUTION BY RADIOSONDE
(GROUND VELOCITY 3~4M/S, OSAN)

TABLE Ⅵ
WORKING PROBABILITY TABLE (OSAN)

Ground Wind Speed	0~1m/s	1~2m/s	2~3m/s	3~4m/s	4~5m/s
600～700m	15.0%	30.0%	38.0%	67.7%	64.7%
500～600m	10.9%	10.9%	21.0%	32.7%	48.1%
400～500m	9.9%	14.9%	23.3%	38.2%	58.2%
300～400m	9.0%	8.8%	13.9%	28.3%	36.4%
200～300m	2.3%	2.3%	4.1%	7.9%	14.3%
100～200m	0.0%	0.0%	0.0%	1.2%	0.0%
0～100m	0.0%	0.0%	0.0%	0.0%	0.0%
Ground Wind Speed	5～6m/s	6～7m/s	7～8m/s	8～9m/s	9~10m/s
600～700m	100%	100%	100%	100%	-
500～600m	80.0%	100%	100%	100%	-
400～500m	83.3%	50.0%	100%	100%	-
300～400m	66.7%	66.7%	66.7%	50.0%	-
200～1300m	12.5%	50.0%	50.0%	50.0%	-
100～200m	0.0%	0.0%	0.0%	0.0%	-
0～100m	0.0%	0.0%	0.0%	0.0%	-

Using this Table Ⅵ, non-working days can be achieved with formula (2) therefore along the height we can arrange the non-working days , as shown in Figure 4

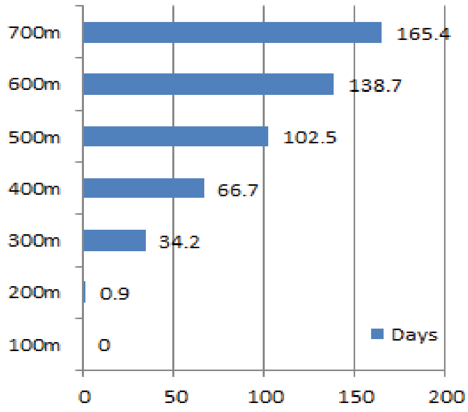

FIGURE 4
NON-WORKING DAYS (OSAN)

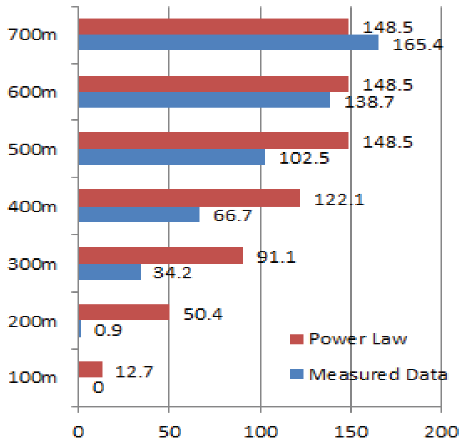

FIGURE 5
COMPARING NON-WORKING DAYS

TABLE Ⅶ
COMPARING NON-WORKING DAYS

Height	Non-working Days		Difference
	`Measured Data	Power Law	
100m	0	12.7	-12.7
200m	0.9	50.4	-49.5
300m	34.2	91.1	-56.9
400m	66.7	122.1	-55.4
500m	102.5	148.5	-46.0
600m	138.7	148.5	-9.8
700m	165.4	148.5	16.9

Therefore, it is possible to compare the values derived from Power law and Actually measured data. Overall, both non-working days tended to increase according to the height, however, measured data appears to be unaffected by the wind up to 200m height. Date also showed a difference -9.8days to -56.9days.

Method by radiosonde can be applicable by utilizing similar region topographically. Thus, it can be considered more reliable, while the combination of factors affecting wind speed cannot be expressed by the Power law formula, radiosonde data, on the other hand, reflects those factors. However, the number of the data for each height section is not regularly distributed, the analysis needs supplement point to make up for such lack of parts. insufficient.

B. Weibull distribution utilizing Radiosonde data

Even though it looked out the non-working days as a measured data, but certainly numbers of data are irregular. Therefore, trying to find a suitable function that can be applied to complement the accuracy of the data.

In this study, Weibull Distribution which is widely used to evaluate the regional distribution of wind to ease and flexibility is used to identify the Wind speed and Non-working days in construction. Weibull is known to be a good match the curve of the wind speed data group. This is because Weibull distribution appears similar to the shape and appearance of the irregular distribution of the distribution characteristics of wind. Therefore, in assuming Weibull distribution as wind speed shape, non-working days to be estimated by the measured data analysis. Weibull distribution function is represented as formula (4) below.

$$\mathrm{f(V)} = \begin{cases} 0 & V < 0 \\ \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} \exp\left(-\left(\frac{V}{c}\right)^{k}\right) & V > 0 \end{cases} \qquad (4)$$

Where, k: Shape parameter, c: Scale parpameter.

A method for determining the coefficient of Weibull, we can choose Moment method, Least Square Method and Maximum Likelihood Estimator to calculate the parameters. Among them, in this study, Least Square Method is adopted, because it is easy to apply and calculate.. As we did in the previous, dividing data for each height (100m) section apply Least Square Method and get the Parameter c, k. Therefore, non-working days by Weibull distribution can derive as shown in Table Ⅷ a nd compare the values.

TABLE Ⅷ
WEIBULL DISTRIBUTION COEFFICIENTS & NON-WORKING DAYS(OSAN)

Height	100m	200m	300m	400m	500m	600m	700m
Number of data	2442	1070	543	409	11	588	318
c: Scale parpameter	1.88	3.31	5.50	9.01	9.83	9.66	10.50
k: Shape parameter	1.75	2.03	1.60	2.80	2.55	2.26	2.22
Base wind Speed(m/s)	10	10	10	10	10	10	10
Probability of base wind speed(%)	0.0%	0.01%	7.43%	26.3%	35.2%	33.9%	40.8%
Non-working days (days)	0	0	27.1	96.1	128.6	123.7	148.8

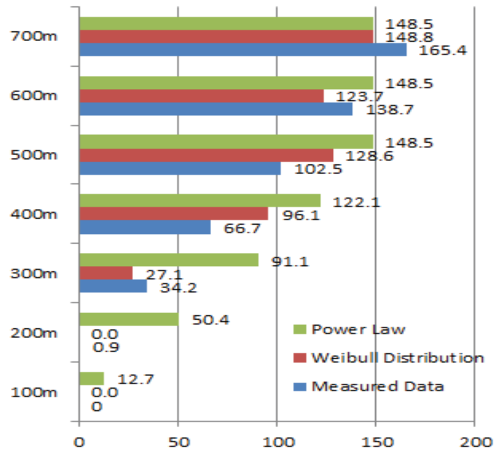

FIGURE 5
COMPARING NON-WORKING DAYS

This value utilizing the measured data and applying Weibull distribution function showed a similar trend. Along the section, it showed a difference from 15days to 29.4days at 300-700m height, up to 300m from the ground was the difference between 0 to 7.1days.

Ⅳ. CONCLUSION

This study is based on the data of velocity actually measured at varied the heights in the last 3 years by radiosonde. Power law that is widely used in traditional was highly sensitive to the Power law exponent, therefore, the need to complement for Power law was covered by this Radiosonde data. Considering that Weibull distribution function is well matched with the wind curve shape, it can be seen as a complement to the result of the lack of data number. It is hoped to become a reliable source to determine the probability of non-working days.

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