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Damage Cost for Private Property by Extreme Wind over the past 10 Years in Korea

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Abstract: Recently, the natural disaster has increased worldwide. In Korea, the damage to life and property caused by a typhoon, heavy rain, heavy snow and extreme wind also increases every year. Among natural disasters, the frequency and strength of wind has increased because sea surface temperature has risen due to the increase of the average temperature of the Earth. In case of the extreme wind disaster, it is impossible to control or reduce the occurrence and the recovery cost always exceeds the damage cost. Therefore, quantitative estimation of the damage cost for extreme wind needs to be established beforehand to install proactive countermeasures. In this study, the damage for private properties was analyzed based on the data for the past 10 year in Korea. The damage cost curve was also suggested for the metropolitan cities and provinces. The result shows the possibility for the regional application of the damage cost curve because the damage cost of regional area is estimated based on the cost of cities and provinces.

Key words: Damage cost curve, private property, extreme wind, instantaneous wind velocity, Korea

INTRODUCTION

In recent years, the occurrence of natural disasters is increasing because of the unexpected changes in the global climate and casualties and damage to property occur every year even in Korea owing to natural disasters such as typhoons, heavy rain, heavy snow and extreme wind. The result of inquiring into the Annual Disaster Reports of the Ministry of Public Safety and Security (the former National Emergency Management) from 2005 till 2014 shows that considerable property damage has occurred because of natural disaster and the cost of recovery always exceeds the damage (Fig. 1).

In one of the existing global studies on extreme wind, Emanuel (2005) reported that the intensity and duration of a hurricane, one of the causes of extreme wind are increasing following an increase in the average global temperature, the ocean surface temperature in particular, after reviewing the destructibility of tropical cyclones for the last 30 year. He also said that the property loss due to hurricanes could increase in the future owing to an increase in the intensity of extreme wind and the population of the coastal area. Lee and Rosowky (2005) evaluated the extreme wind vulnerability of wooden buildings accounting for most detached houses in the USA and those vulnerable to extreme wind considering the roof form, geographical location, specification of the nail and roof edge form. They proposed the exposure

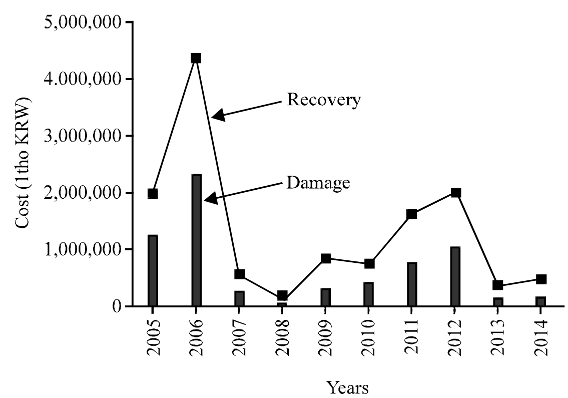

Fig. 1: Natural disaster damage and recovery cost by year (ministry of public safety and security, 2005~2014)

factor used for the calculation of air pressure of wind, topographic factor, directional coefficient and the other factors.

In a domestic study on the damage caused by extreme wind and Kim and Kim (2004) reported the causes of extreme wind damage to be overturn, deformation, vibration, fatigue and scattering resulting from extreme wind. This was done through a case investigation on the houses and roofs, utility poles and iron structures and tower-shaped structures damaged by typhoon Rusa in

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2002. In addition, the damage to structures was also reported to be diverse, ranging from local to overall damage. Kang *et al.* (2003) reported that measures need to be taken by the unit of vulnerable zone for extreme wind as the extreme wind damage to the buildings located in the inner part of an apartment complex is greater than that to the buildings located in the outer part closer to the beach. Here, the influence of extreme wind was analyzed on the damage cases of the buildings in Pusan where extreme wind damage has occurred due to typhoon Maemi in 2003. In addition, they also reported that measures against vibration are also required not only for steel frame structures but also for reinforced concrete structures because vibration of the buildings caused by extreme wind causes an unpleasant feeling for residents. In those previous researches regarding extreme wind damage in Korea have been on the causes for the occurrence of extreme wind disasters, the influence area and reduction measures. Recently, researches on extreme wind vulnerability have been carried out to evaluate the damage by extreme wind expected in the future as well. Lee *et al.* (2009) have proposed a fragility curve using an empirical method for houses and an analytical method for greenhouses and pens through evaluation on the extreme wind risk of private facilities. However, additional studies are required because the examples of extreme wind damage on facilities are not sufficient.

In this study, the facilities vulnerable to extreme wind disasters were identified through an investigation on the extreme wind disaster damage that occurred in Korea. An extreme wind damage curve was estimated based on the facility considering the instantaneous wind speed measured by an Automatic Weather Station (AWS) of the Korea Meteorological Administration. The result of this study can be utilized in future as the basic data for the estimation of the damage to structures caused by extreme wind; it can be applied to policy decision making such as establishment of a preventive measure against extreme wind disaster as effective data.

MATERIALS AND METHODS

Natural disasters including extreme wind increase social and national cost considerably by not only causing direct damage to human lives and buildings but also bringing about indirect damage to transportation, communication and infrastructure. In addition, it is impossible to control or reduce the causes of natural disasters such as extreme wind and the recovery cost after the occurrence of a disaster is greater than the damage cost as shown in Fig. 1. Therefore, actions for ensuring safety and protecting property of the nation and people

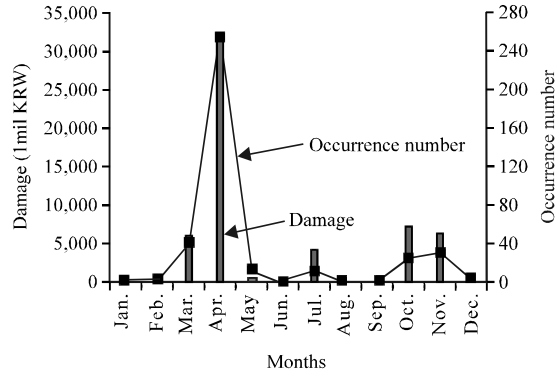

Fig. 2: Extreme wind damage and number of occurrences by month

are required to be taken to reduce the social and economic losses caused by natural disasters through proactive response to natural disasters.

In the wind and flood damage insurance which is a national policy insurance, extreme wind is defined as the wind blowing at a speed >14 m sec^{-1} or at an instantaneous speed >20 m sec^{-1} on land that at a speed >17 m sec^{-1} or at an instantaneous speed faster than 25 m sec^{-1} in a mountain area which are the criteria for issuing a warning for extreme wind (Wind and Flood Damage Insurance of the Natural Disaster Information Center). Lee *et al.* (1997) classified the extreme wind into typhoons, seasonal wind, cyclones and frontal wind based on dynamic weather conditions and air-mass-climatological climate classification. In here, seasonal wind represents the West-high/East-low type atmospheric pressure pattern in Korea during the Winter which typically appears with dense contour lines and large pressure gradients between October and March and cyclone and frontal wind represent the wind between March and October excluding typhoons and seasonal wind. On investigating the Annual Disaster Reports from 2005 till 2014 we could see that based on the number of occurrences, extreme wind damage occurred most frequently in April showing a value of 257 times as shown in Fig. 2. In addition, based on damage cost, April was shown to be the greatest, followed by October and then November (Fig. 2).

In the USA which is advanced in managing natural disasters, the FEMA (Federal Emergency Management Agency) predicts the damage caused by floods, earthquakes and hurricanes by using the HAZUS-MH. Particularly, in the hurricane model, the damage to a facility is expressed in the vulnerability curve which shows the probability for 50% of the facility to be destroyed at a certain wind speed and the fragility curve which shows the probability of exceeding for a specific wind speed. In the hurricane model, the fragility curve is presented considering the wall structure of the facility, the presence or absence of a garage, roof form and whether there is a cover and a loss curve for the building and the interior furnishings is presented for evaluating the total damage to the facility (FEMA, 2012).

In Korea, studies on the vulnerability and loss of facilities caused by extreme wind were carried out only recently and on limited facilities. Moreover, for the damage caused by extreme wind disasters that are managed by the National Disaster Information Centre, only the total damage by facility in the damaged district is presented. Accordingly, to prepare vulnerability curves to be used for evaluating the damage caused by extreme wind in future, additional data for individual prices of facilities is required; to evaluate the damage to facilities reflecting the characteristics of the extreme winds that have an impact on Korea, additional studies are required.

To estimate the damage caused by extreme wind disasters predicted in future, the extreme wind disasters and damage that occurred in Korea in the past were investigated. As the extreme wind damage by city and facility are presented in the Annual Disaster Reports from 2005, the Annual Disaster Reports were used for the estimation of the extreme wind damage curve. Additionally, the instantaneous wind speed at the time when extreme wind damage occurred which was not included in the Annual Disaster Reports was estimated using the data of the Korea Meteorological Administration.

RESULTS AND DISCUSSION

On reviewing the extreme wind damage by facility item, the damage to private facilities, public facilities, buildings, ships and farmlands was found to be 85.9%, 10.7, 2.1, 1.2 and 0.1%, respectively as shown in Fig. 3 (Anonymous, 2014). Accordingly, in this study, the extreme wind damage curve was estimated for private facilities to which the greatest damage occurs. On preparing the extreme wind damage curves using the damage to private facilities in 17 cities and provinces in Korea caused by extreme wind and the instantaneous wind speeds, two damage curves of Chungcheongbuk-do and Jeollabuk-do were drawn as shown in Fig. 4 and 5. The extreme wind damage curves prepared by carrying out a statistical analysis for the districts among the 17 cities and provinces in which the likeliness of damage occurrence resulting from extreme wind was thought to be high owing to extreme wind with instantaneous speed of 20 m sec^{-1} or faster occurred 30 time or more for the last 10 year (Table 1) were as shown in Fig. 6.

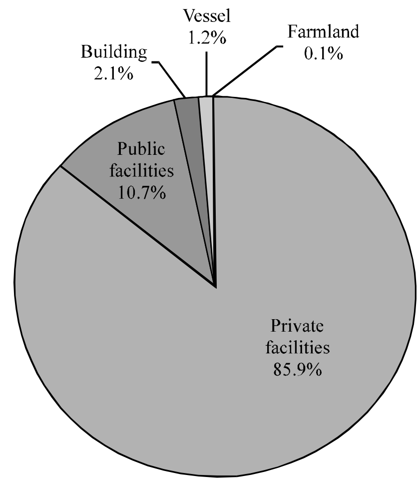

Fig. 3: Extreme wind damage by facility item (annual disaster report from 2005-2014)

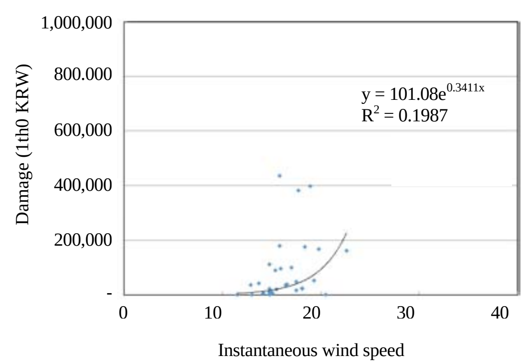

Fig. 4: Extreme wind damage curve of private facilities (Chungcheongbuk-do)

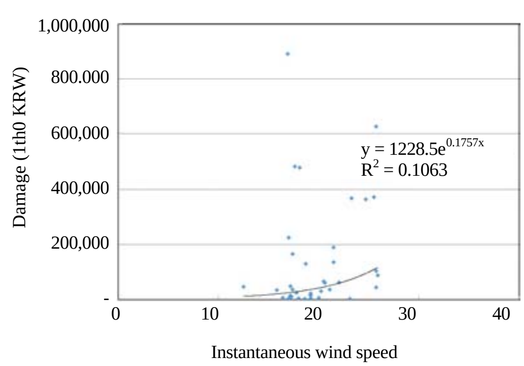

Fig. 5: Extreme wind damage curve of private facilities (Jeollabuk-do)

When the relation between the instantaneous wind speed and extreme wind damage is expressed in an exponential function that of Chungcheongbuk-do is that

Table 1: Cities and provinces where extreme wind occurred 30 times or more for 10 year

Classification	Chungcheongbuk-do	Chungcheongnam-do	Jeollabuk-do	Jeollanam-do	Gyeongsangbuk-do	Gyeongsangnam-do
Number of occurrence	33	41	40	38	50	35
Number of times of occurrence (20 m sec^{-1} or faster)	2	14	16	25	20	13
Occurrence rate (%)	6.1	34.1	40.0	65.8	40.0	37.1

Table 2: Extreme wind damage to private facilities and number of times of occurrence for last 10 year

Classification	Embankment/fence	Pen/silkworm house	Aquaculture	Fishing gear	Greenhouse
Extreme wind damage (1,000 KRW)	44,200	2,660,979	9,941,579	10,324,850	27,023,473
Number of times of occurrence	14	68	34	33	289
Number of times of occurrence (20 m sec^{-1} or faster)	10	32	20	14	104
Occurrence rate (%)	71.4	47.1	58.8	42.4	36.0

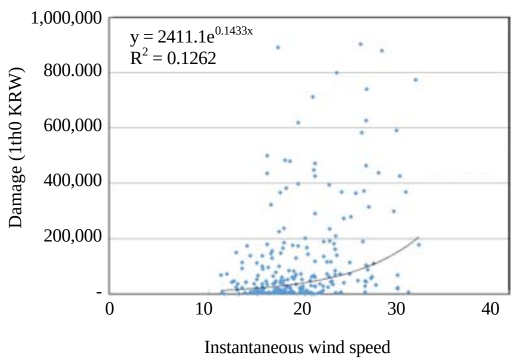

Fig. 6: Extreme wind damage curve of private facilities (6 cities and provinces)

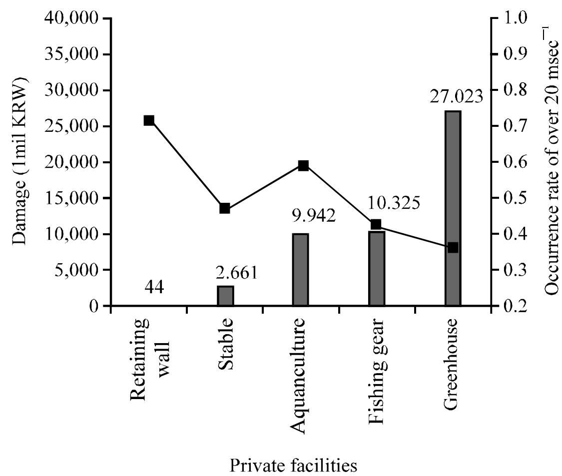

Fig. 7: Extreme wind damage to private facilities and occurrence rate

of Jeollabuk-do is and that of the six cities and provinces is shown to be which indicates that the more the instantaneous wind speed increases the more the extreme wind damage cost increases.

On adding the extreme wind damage to private facilities for the last 10 year, greenhouse accounted for the greatest damage, showing a value of approximately 27 bln. KRW followed by fishing gear (about 10.3 bln. KRW), aquaculture (about 9.9 bln. KRW), pen/silkworm house (about 2.66 bln. KRW) and embankment/fence (about 40 mln. KRW) (Table 2 and Fig. 7). On reviewing the relation between the extreme wind damage to private facilities and the extreme wind occurrence rate, though the extreme wind damage to embankment/fence was small, the correlation between the instantaneous wind speed and extreme wind damage was shown to be high as extreme wind damage mostly occurred when the instantaneous wind speed was 20 m sec^{-1} or more. In the case of the greenhouse, to which the extreme wind damage was shown to be the highest, the correlation between the instantaneous wind speed and extreme wind damage was shown to be relatively low as the occurrence rate of instantaneous wind speed >20 m sec^{-1} was shown to be 36.0%. This means that large damage occurs to greenhouses even when the wind speed is lower than the criterion for extreme wind and more attention is required to be paid when manufacturing and constructing greenhouses. However, as the difference in the extreme wind damage appeared to be considerable at similar instantaneous wind speeds and the reliability of the extreme wind damage curves of Seoul where no extreme wind damage occurred and of Daegu, Sejong and Jeju Island where only a small number of extreme wind damage occurred was found to below, additional data is required to increase the reliability.

CONCLUSION

In this study, extreme wind damage curves by wind speed were estimated by reviewing the instantaneous wind speed data of Korea Meteorological Administration and the extreme wind damage data of the Annual Disaster Reports in Korea. On reviewing the Annual Disaster Reports, the extreme wind damage to private facilities was found to be the greatest, among which the damage of greenhouse was the greatest and the most sensitive. In the extreme wind damage curves of the whole country and that of each city and province, the extreme wind damage is shown to increase as the instantaneous wind speed increases. However, in some areas, the estimation of the extreme wind damage curve was impossible as data was insufficient. In addition as the extreme wind damage for estimating the extreme wind damage curve in this study is the sum of the damage to each facility, not the damage to individual facilities, it is can be applicable to the estimation of the extreme wind damage in wide areas. This section investigated the seismic safety of the weir structure from numerical analyses using two different methods:

- Design response spectrum
- Time history of linear and nonlinear earthquake

In particular, one-directional design response spectrum and a horizontal directional earthquake was applied and the time increment for the linear and nonlinear analysis using Newmark method was determined to be 0.001 sec. In the case of the design spectrum analysis, Square Root of the Sum of the Squares (SRSS) method in ABAQUS was carried out for the modal combination of modes. The maximum horizontal displacement of the weir structure with the linear tie-connection FE model under the design response spectrum was 6.87 cm at the end sill area in downstream direction as shown in Fig. 5. Figure 6 showed the maximum and minimum principal stress distributions in accordance with the linear elastic FE model of the weir body and mass concrete under design response spectrum corresponding to KBC 2009. The stresses occurred at joint connection between the weir sill and the stilling basin. Also, the principal tensile and compressive stress of the weir body including the stilling basin and end sill was 2.364 and 0.1719 Mpa, respectively. It revealed that the seismic performance of the weir structure was significantly influenced by the tensile stress in comparison with the compressive stress.

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