ABSTRACT: This paper presents topographic effects over 3-D complex hills with transmission towers collapsed during typhoon passage. The meteorological station data were analyzed and wind-tunnel tests were performed to investigate the possible causes of the failure. Topographic factors from the experiment were compared with those from major codes and standards. It was observed that topographic factors from the major codes and standards are hard to apply to the actual complex 3-D hills. Topographic effects are very difficult to be reflected in the codes and standards because actual terrains are so complex. It is understandable that only AIJ recommendations require that topographic effects over 3-D hills be estimated in the wind-tunnel tests.

KEYWORDS: topographic factor; transmission tower; 3-D complex terrain; typhoon; wind-tunnel experiment; codes and standards

1 INTRODUCTION

Wind loads on a structure depend upon the characteristics of approach wind, the geometry of the structure, wind exposure, wind-induced interference effects, wind-structure interaction, and topography. Jackson et al.[1], Bowen[2], Taylor et al.[3], and Selvem[4] reported simple methods to estimate topographic factors for three types of topographical features: (1) 2-D hills, (2) 2-D escarpments, and (3) 3-D axisymmetric hills. These studies were based on a single isolated hill, ridge or cliff which was idealized. Sometimes the methods are hard to apply to the actual situations. Li et al.[5] confirmed that topographic factors of the major codes and standards are rather different, especially in the influent range of the topography in horizontal direction, as well as in the vertical direction. Chock et al.[6,7] made three topographic model of mountains of Hawaii and performed wind-tunnel experiments for evaluation of topographic amplification of wind speed. They concluded that the magnitude of wind speed-up did not have a strong relationship to site elevation in complex terrain; that topographic influences on wind speed are highly directional; and that three-dimensional effects, such as channeling and downslope acceleration phenomena through valleys, can be significant.

When typhoon “Maemi” crashed into South Korea’s southern provinces, several transmission towers located on hills were collapsed. Major codes and standards in the world would provide information to estimate wind loads on transmission towers. However, the topographic factor over hills and escarpments in major codes and standards is very scattered even in the same slope of a hill or an escarpment. In this study, topographic factors of the hill were measured by experiments. A 1:833 scale topographic model of actual site was tested in the 4.5m x 2.5m boundary layer wind tunnel. A normal problem associated with model blockage can be avoided by the large boundary layer wind tunnel. Topographic factors for the actual sites from a series of wind tunnel tests were provided. The topographic factors from the experiment were compared with those from the major codes and standards.

2 DESCRIPTION OF TYPHOOON “MAEMI” AND THE TRANSMISSION TOWERS

The typhoon No. 14 “Maemi” brought record winds of instantaneous maximum wind speed of 60m/sec in Jejudo, Korea. The typhoon affected the most southern part of Korean peninsula.
According to the Tongyoung Meteorological Station, during typhoon passage, the maximum wind speed and instantaneous maximum wind speed were 30.8 m/sec (South) and 43.8 m/sec (South-East), respectively.

The transmission towers in the mountains called Mt. Ilbong and Mt. Ilibong were collapsed during typhoon attack. The mountains are located about 7.5 km NNE of the center of Tongyoung. The top of Mt. Ilbong is about 190 m and the top of Mt. Ilibong is about 226 m above sea level. The two transmission towers are the tower #141 (Fig. 1) and the tower #142. The towers were built in 1976 and were supposed to be repaired and reinforced sooner or later. The tower #141 was located 125 m above sea level in between two hills. When winds enter a narrow canyon, the streamlines of the wind may converge or contract, causing an amplification of wind speeds in the narrow part of the canyon (Fig. 2). The tower #142 was 75 m above sea level in the mid-slope of the Mt. Ilibong.

3 WIND TUNNEL EXPERIMENTS

The accurately contoured 1:833 scaled topographic model of Mt. Ilbong and Mt. Ilibong was built as shown in Figure 3. The radius of the entire topography was 1,583 m, which was presumed to be enough to look in topographic effect and to cover the collapsed area. In the design of structures, strong winds from all directions must be taken into account. However, the wind direction in the wind-tunnel tests was limited to some directions because the ridge line of the terrain was continuously expanded to SSW direction. The wind direction considered in the study is as shown in Figure 4. Wind direction was marked with clockwise rotation starting from the N direction.

Analogue outputs from these instruments were low-pass filtered at 1 kHz and sampled at 200 Hz, for 9 seconds per sample. Statistical quantities including the mean, standard deviation and peak values were averaged over three 9s samples. To model the structure of the wind over the topographic model, similarity of several non-dimensional parameters including the mean wind speed profile, longitudinal turbulence intensity profile, and the power spectral density of the longitudinal turbulence was required.

4 RESULTS OF WIND TUNNEL EXPERIMENTS

The topographic factor by hills is defined as $M = \frac{V'(z)}{V(z)}$, where $V'(z)$ is the modified wind speed at height $z$ above the surface of a hill and $V(z)$ is the speed of the approaching wind at the same height $z$ above ground. All model results have been scaled to the full-scale values.

Figure 5 shows the topographic factors with height at the location of the transmission tower #141 at the considered wind direction. When the wind approached from the N, NNE, and NNW, the mountains slowed down the wind in a certain region (below about 100 m). From this level
above the surface, the winds were accelerated up to the topographic factor of 1.38 depending on
the wind direction. When the wind approached from the southeast and the northwest, the topog-
raphy accelerated the wind-an amplifying effect. This was because a canyon was formed in be-
tween the Mt. Ilbong and the Mt. Iibong and the streamlines in the canyon converged or con-
tracted. The topographic factor reached 1.83 at the wind direction of N300. Figure 6 shows the
topographic factors with height at the locations of the transmission tower #142. In the case of
N10, the topographic factors were less than 1.0-shielding effect. However, as the wind direction
changed, the #142 location that received shielding from the mountain encountered amplified
wind in another direction. The topographic factors reached 1.38 in the wind direction of N280.

5 DISCUSSIONS
Korea Electric Power Corporation (KEPCO) applies KEPCO’s design guidelines[8] to estimate
design wind loads on a transmission tower. Current KEPCO’s guidelines do not consider wind
exposure and topographic effects over hills or escarpments. The results of wind tunnel experi-
ments were compared with major codes/standards, which are ASCE-7-02[9] and AS/NZS1170.2-
2002[10]. These major codes/standards assuming that a single hill or mountain exists on a flat
land. However, actual topographic conditions are not the same as the ideal topography. Only AIJ
Recommendations [11] comments wind-tunnel tests or reasonable numerical methods to estimate
the topographic effects over 3-D hills or mountains.

The topographic factors from the wind-tunnel experiments were compared with those from
the major codes and standards for a specific wind direction as shown in Figure 7. The selected
wind direction was the case that the topographic factor was the maximum value. The topographic
factors from the experiments were greater than those from the codes and standards. This is be-
cause the codes and standards are not easy to reflect the actual complex topography that is not
isolated single hills or mountains. The topographic factor of the experiments reached 1.83 at
about 40m and gradually decreased with height as shown in Figure 7. This quantity is about 1.5 times greater than those of ASCE and AS/NZ codes and standards. Since wind load is proportional to the square of wind speed, the wind load of the structure can be about 225% wind loads estimated by ASCE and AS/NZ codes and standards. The transmission towers designed by KEPCO could be exposed to failure because the wind load may be 335% the designed value.

<table>
<thead>
<tr>
<th>Location</th>
<th>#141</th>
</tr>
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<tbody>
<tr>
<td>s</td>
<td>0.23</td>
</tr>
<tr>
<td>Ly</td>
<td>295m</td>
</tr>
<tr>
<td>h</td>
<td>136m</td>
</tr>
<tr>
<td>x</td>
<td>85m</td>
</tr>
<tr>
<td>Wind dir.</td>
<td>N300</td>
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</tbody>
</table>

Figure 7. Comparison of topographic factors of simplified hill from experiments and codes

6 CONCLUSIONS

The speed up effects over 3-D complex hills with transmission towers collapsed during typhoon passage were presented. It can be concluded that the topographic influence on wind speed in complex terrain is wind direction rather than site elevation; and that 3-D effects, such as channeling and downslope acceleration phenomena through valleys, can be significant.

The topographic factor from the experiment at the location #141 was 1.83 for a specific height. Since wind load is proportional to the square of wind speed, wind load on the transmission tower can go up to about 3.3 times as much as that encountered by the same structure on a flat area in the same region. The topographic factors from the experiments are greater than those from the codes and standards. This is because the codes and standards were based on a single isolated hill. Therefore, the structural engineers should be careful in using codes and standards for the actual complex terrain, especially for the canyon built by two or three hills.

REFERENCES


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