### The Measured Frost Penetration Depth in Korea National Road

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1. Introduction

Korean Peninsula belongs to seasonal frost area where the frost heave occurs in the ground at the temperature falling below zero in winter and is thawing in spring, resulting in deteriorating the road pavement in freezing and thawing cycle. To prevent the road pavement from being deteriorated by such freezing, an anti-freezing layer is provided and in Korea, American or Japanese-type anti-freezing design has been employed, but as such approaches were developed considering their own environmental conditions. In this study, the formula (proposal) to estimate the frost penetration depth was developed considering the frost penetration depth measured at 89 locations on national Road throughout the country and the freezing index calculated from the temperature measured by the weather agency as the function. And the analysis to identify the difference between the formulas for frost penetration depth by region and sunny side / shady side was carried out, and another analysis to identify the differences between the existing locally-available formulas and foreign formulas, with the result thereof, was performed.

2. Frost gauge

The frost gauges were installed at 89 locations on paved national highways across the nation from 1991 till 2008. The locations where the freezing indicators were buried are indicated in Fig.1 below.

3. Frost penetration depth contour map

A frost penetration contour map was developed based on freezing depth measured. As indicated in Fig.1, the depth at Inje, Hongcheon and Pyungchang in mountainous area of Gangwon region was more than 150cm(A) while Cheolwon, Hwacheon and Yanggu indicated 130cm(B) and Yeoncheon and Gapyung in northern Geonggi and Jecheon in Choongbuk and Cheongsong in Gyungbuk indicated 110cm or deeper(C). Then Yangyang and Samchuk in coast district were relatively shallower. Choongcheong, Jeonbuk and Gyungbuk in the central district indicated about 50~100cm(D) and Gyungnam region was 0~40cm(E) and Jeonnam was 0~20cm(F).

4. Relationship between freezing index and frost penetration depth

Fig.2 represents the relations between 818 frost penetration depths at 87 locations nationwide except Jeju region and the freezing indices calculated from temperature data from 44 meteorological stations.

5. Analysis by region

To identify the relations between nationwide freezing indices and depth, the relation between regional freezing indices and depth was represented. A constant C is described in Table 1.

### Table 1 C by region

<table>
<thead>
<tr>
<th>Area</th>
<th>Gyeonggi</th>
<th>Gangwon</th>
<th>Choongbuk</th>
<th>Choongnam</th>
<th>Jeonbuk</th>
<th>Gyungbuk</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>4.33</td>
<td>5.41</td>
<td>4.68</td>
<td>4.13</td>
<td>3.38</td>
<td>4.42</td>
<td>2.58</td>
</tr>
</tbody>
</table>

6. Comparison with the other formulas

Fig.3 shows the correlation curve between freezing depth and freezing index measured for years and compares the formulas of COE, Japanese Derada and KICT (Korea Institute of Construction Technology) made public in 1989. As indicated in Fig.3, COE's appeared to be similar with the curve representing the value of Gangwon region measured by KICT. And the formula by NCRI appeared to be similar with the graph indicating Gangwon region measured by KICT. But the freezing index at 400℃. day or below was higher than the values measured by region and those at 400℃. day or above was lower than the values measured. Derada formula appeared to be distributed in between the curves of Choongnam and Jeonbuk measured by KICT. In contrast, the values of the south, Seoul area and Jeju region were lower than any existing depths.

7. Comparison with the other formulas

KICT formula (proposal) to estimate the frost penetration depth was developed using the data on frost penetration depth measured in the national highways for years. This study clearly indicated that the nationwide freezing indices have varied since mid-1990s because of global warming, but the frost penetration depth measured in the road using Methylene Blue appeared to have exceeded the values measured in bare ground by NCRI, which deemed to be attributable to compaction work on the road that increased the thermal conductivity because of less air contained in the ground.

### References

1) Kim, Young Chin, Hong, Seung Seo (2008), A study on the frost penetration depth and insulation methods in pavement, Korea Institute of Construction Technology (Korean).