A study on the development of the greenhouses in reclaimed land

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Abstract

This study was carried out to find out adequate greenhouses to be installed in reclaimed lands. The area under reclamation for general horticultural complex in South Korea would be about 2,185 hectares by the year 2020. The reclaimed land was generally known it had weak foundation so that the greenhouses needed the special foundation to keep the ground from having been sinking. In this study, two venlo types of greenhouses were developed, including the design of the ground foundation. The greenhouses considered here had the two-span width of 6m(=3mx2 spans) and 8m(=4mx2 spans). One of them was built in a reclaimed land of the southern region and has been continually investigated whether the greenhouse has some problems such as the land subsidence especially after strong winds blew and heavy snowfalls came down. The FEA predictions showed that the 6m wide greenhouse with given specifications of the pipe had a safety wind speed of 41m/s and the 8m wide greenhouse had a safety wind speed of 25m/s and a safety snow-depth of 40cm, respectively. As for the ground foundation of the greenhouses, the spiral pile could be used for a SPT N-Value of 2 and a cohesive soil so that it could satisfy the pulling resistances and the compressive forces acting on columns and rafters. The specification of the foundation, a spiral pile used in the study, was found out to be with $\phi$100xt9xL1,500mm on columns for the 6m greenhouse and $\phi$125xt9xL1,850mm on columns for the 8m one.

Keywords: greenhouse, ground foundation, reclaimed land, structural stability

1 Introduction

The area under reclamation for horticultural complex will be presumed to be about 2,185 hectares by the year 2020 throughout the country. Therefore various kinds of greenhouses including both single and multi-span greenhouses with coverings of PE film, fluoroplastic film and glass and also with diverse widths for the vast reclaimed land have been requested to be developed. The reclaimed land was located on the coast so that strong winds including typhoons from July to September stroke and sometimes heavy snowfalls came down in winter. So, there have been needs to develop anti-disaster greenhouses as well. Therefore this study was carried out to find out adequate and economical greenhouses including the ground foundation suitable for the reclaimed land. However, the reclaimed land was generally known it had the soft ground so that the greenhouses had to have a special ground foundation to keep the ground from having been sinking. As the first step of the development of the greenhouses suitable for the soft land, the application validity was appraised for two greenhouses with a covering of PE film.
2 Materials and methods

2.1 Structural analysis

Structural stabilities of the 6m- and 8m-wide two-span greenhouse with a truss structure as shown in Fig. 2 and 3 were predicted by using finite element analysis (FEA) through modeling as the 3-D steel frame structure. The structural stabilities were analyzed for the pipe specifications shown in Table 1. The criterion of the stability was based on the allowable design guide. The material of steel pipes was SGH400 and the steel frame was modeled by using the BEAM188 element in the FEM code, ANSYS. The rafters were constrained on the ground by using translational and rotational stiffness as real constants of the COMBIN7 element but the columns by the fixed constraint. The formula of snow load was $S(\text{kg/m}^2) = \rho \times D \times a$ where $\rho(\text{kg/cm}^2)$ denoted the averaged unit weight of snow, $D(\text{cm})$ the snow-depth and $a$ the roof coefficient. In the study, $\rho = 1.0 \text{ kg/cm}^2$ for $D \leq 50\text{cm}$. The wind load applied was $P(\text{kg/m}^2) = c \times 0.0604 \times V^2$ where $c$ as the wind coefficient took the value of 0.8, 0.5, 0.6, 0.4, 0.2, 0.4 from the inflow side to the outflow one in sequence, $V(\text{m/s})$ the wind speed.

![Figure 1](image1.png) Figure 1: Some representative reclaimed lands along the coastline of South Korea.

![Figure 2](image2.png) Figure 2: The three dimensional FEA model and design loads applied on steel frames of the model.

![Figure 3](image3.png) Figure 3: The 6m wide two-span greenhouse with a length of 24m which was installed in a reclaimed land on the basis of structural analysis.

<table>
<thead>
<tr>
<th>Model</th>
<th>Greenhouse specification (W×H)</th>
<th>Pipe specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rafter</td>
</tr>
<tr>
<td>Venlo (Multi-span)</td>
<td>6,000×3,800 (3m×2 span)</td>
<td>$\odot 31.8\times1.5t$ @600</td>
</tr>
<tr>
<td></td>
<td>8,000×5,200 (4m×2 span)</td>
<td>$\odot 31.8\times1.7t$ @700</td>
</tr>
</tbody>
</table>
2.2 Design of the foundation and ground subsidence

The reclaimed land considered in the study according to a geological survey was known to be a SPT N-value of 2 and the soil represented CH (Clay and High compressibility), a kind of cohesive soil. The ground foundation was designed by using a spiral pile according to the N-value known beforehand as well as lift and compression forces acting on columns and rafters of the greenhouse, where forces were calculated through structural analyses for a wind speed of 35m/s and a snow-depth of 25cm which were the design loads of the reclaimed land. Regarding the foundation, a spiral pile was designed so that it could satisfy both the pulling resistances and the compressive forces acting on the steel frames. In order to investigate the ground subsidence, measuring tapelines were attached on three columns inside as well as a reference point outside, at which point the subsidence was judged to be the least.

Figure 4: Measuring tapelines put on a reference point outside and three columns to check out the ground subsidence.

3 Results and Discussions

The FEA predictions showed that the 6m wide greenhouse with a rafter of φ31.8×1.5t@600mm and a column of □60×60×2.3t@3,000mm had a safety wind speed of 41m/s and the 8m wide greenhouse with a rafter of φ31.8×1.7t@700mm and a column of □100×50×2.3t@4,000mm had a safety wind speed of 25m/s and a safety snow-depth of 40cm, respectively. As for the 8m wide greenhouse, the safety wind speed did not fulfill the design criterion of the region so that it was needed to reinforce the structures in the near future. The lift and compression forces calculated through FEA were shown in Table 2 and 3, respectively.

Figure 5: Distribution of von Mises stress for a wind speed and a snow-depth.

Table 2: Lift and compressive forces acting on columns and rafters(wind walls) for the 6m wide greenhouse.

<table>
<thead>
<tr>
<th>Wind wall(L)</th>
<th>Reaction force(㎏f) for the design wind speed</th>
<th>Wind wall(R)</th>
<th>Reaction force(㎏f) for the design snow-depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; col.</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; col.</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; col.</td>
</tr>
<tr>
<td>+135.9(Col)</td>
<td>-390.5</td>
<td>-571.9</td>
<td>-575.6</td>
</tr>
<tr>
<td>+59.4(Inter)</td>
<td>-390.5</td>
<td>-571.9</td>
<td>-575.6</td>
</tr>
</tbody>
</table>

The design criterion of the region considered is a wind speed of 35m/s and a snow-depth of 25cm.
Table 3: Lift and compressive forces acting on columns and rafters (wind walls) for the 8m wide greenhouse.

<table>
<thead>
<tr>
<th>Wind wall(L)</th>
<th>1st col.</th>
<th>2nd col.</th>
<th>3rd col.</th>
<th>4th col.</th>
<th>Wind wall(R)</th>
<th>1st col.</th>
<th>2nd col.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-69.2(Col)</td>
<td>+12.0(Inter)</td>
<td>-191.0</td>
<td>-1,123.6</td>
<td>-1,084.5</td>
<td>-378.1</td>
<td>+60.2(Col)</td>
</tr>
</tbody>
</table>

The specification of the spiral pile for two greenhouses could be found out according to the limited bearing power of spiral pile on a cohesive soil and acting forces. First, for the 6m wide greenhouse, the spiral had a specification of $f_{100}\times t_9\times L1,500\text{mm}$ (the pure spiral length of 1,000mm) for columns and $f_{50}\times t_9\times L900\text{mm}$ (the pure spiral length of 400mm) for rafters every three meters, where the steel piles were welded on the bottom of all the inside columns and the main rafters. As for the 8m wide greenhouse, it showed that the spiral pile had a specification of $f_{125}\times t_9\times L1,850\text{mm}$ (the pure spiral length of 1,350mm) for columns and $f_{75}\times t_9\times L900\text{mm}$ (the pure spiral length of 400mm) for rafters. The ground subsidence has been measured since the greenhouse was installed at the end of August in 2013. The investigation showed that the subsidence was not clearly observed yet but it needs continuous investigations especially after strong winds blow and heavy snowfalls come down on the greenhouse.

Figure 6: The schematic drawing and shape of the spiral pile welded on columns and rafters of the greenhouse.

4 Conclusions

Two greenhouses with a width of 6m and 8m were developed in order for them to be economically applied to the reclaimed lands. The ground foundation could be designed by using a spiral pile with a specification of $f_{100}\times t_9\times L1,500\text{mm}$ for the 6m wide greenhouse and $f_{125}\times t_9\times L1,850\text{mm}$ for the 8m wide one. The material used in the study was SGH400 but later on it have to be changed to STK400 and so on covered well with molten zinc plating in the light of corrosion, while maintaining the same or more than the strength. In addition, further research is needed on the optimal design of roof openings and also the distribution of air temperature and humidity in the greenhouses.

5 Acknowledgements

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6 References


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