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A Study on Analytical Methods for Installing Soundproof Walls

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Abstract—

A temporary soundproof wall is a device installed to prevent noise or dust around a construction site. However, in order to install a temporary soundproof wall, pile construction is performed on the ground using a file driving machine, which is the cause of noise, and cement construction is essential to form the ground foundation. In addition, when the temporary soundproof wall is removed, a large amount of construction waste is accompanied, which causes environmental pollution. Therefore, this paper intends to build a ground foundation using the developed screw-type pile instead of using a driving machine when installing such a temporary soundproof wall. Therefore, since the temporary soundproof wall structure must be designed with a structure that can withstand external wind pressure, in this study, the screw-type pile was intended to act differently from the method of constructing the ground foundation by applying the existing concrete. If a screw type is applied to install a temporary soundproof wall, environmental problems caused by installing or removing the ground for the soundproof wall can be solved. On the other hand, there is a demand for a temporary soundproof wall to be a safe and optimal structure that can withstand external wind pressure. Therefore, in this study, the CAE analysis technique is applied to perform an optimization analysis on the structure, so that it can prove an eco-friendly construction method that is superior to the existing ground composition method.

Keywords—Wind load, Soundproof wall, CAE (Computational Aided Engineering), Stress

1. INTRODUCTION

The noise source that has the greatest impact on environmental noise is road traffic noise. As of July 2021, the number of cars is 24.7 million, which is a cause of increasing environmental noise. To reduce traffic noise, we try to eliminate the cause by installing low-noise asphalt or low-noise car tires, but there are technical limitations, and the effective method is to install a sound barrier. However, a considerable amount of noise from construction equipment is generated even in the process of installing soundproof walls, and a considerable amount of noise is generated in the process of installing concrete piles on the basis of soundproof walls [1].

On the other hand, the acoustic performance status of temporary soundproof walls was analyzed and basic data for performance improvement was provided. Temporary soundproof walls made of metal and plastic have a sound insulation performance of 18 to 31dB, and metal temporary soundproof walls have a sound insulation performance that is about 5dB higher than that of plastic. In the case of attaching a sound insulation sheet to the rear panel, which is a member, in order to improve the sound insulation performance of the temporary sound insulation wall, the improvement in sound insulation performance by 3dB was not significant. As a result of measuring the insertion loss to examine the actual effect of the temporary soundproof wall construction, the insertion loss tends to appear higher as the location of the sound source and the sound pickup point is located closer to the temporary soundproof wall.[2]

Meanwhile, temporary soundproof walls are installed to reduce noise caused by construction at construction sites including roads. In order to reduce the noise generated from the construction site, construction companies are taking measures such as installing soundproofing facilities adjacent to the sound source or installing temporary soundproofing walls at the boundary of the construction site. In order to reduce noise, various measures are being sought, such as increasing the temporary sound insulation wall, thickening the thickness of the sound insulation wall, or applying a sound absorbing agent. [3-7].

Although research on low-noise equipment is in progress, it was not easy to reduce the noise of construction equipment. There are complaints about noise during construction in downtown areas. To solve the work noise of construction equipment, portable soundproofing facilities are installed and installed around the noise source, but they are not easy to move due to their own weight and often interfere with construction progress. The basic sound absorption and insulation performance of materials applicable to the manufacture of portable soundproofing facilities was evaluated and noise reduction performance was evaluated. In addition, in order to reduce noise sources such as breaker work and engine noise, formwork dismantling noise, and asphalt cutter noise, a portable soundproofing facility was developed and applied to the site to evaluate insertion loss. [8]

The domestic acoustic performance standards related to soundproof walls are as follows. For the purpose of noise reduction, it is stipulated that the soundproof wall transmission loss should be greater than or equal to the value obtained by adding 10dB to the diffraction attenuation value at the receiver's location, or to have sound insulation performance of 25dB or more at 500Hz and 30Hz or more at 1000Hz (Ministry of Environment Notice No. 2009-221). In addition, the sound absorption coefficient of the sound-absorbing soundproofing plate is regulated as 70% or more of the average (noise reduction coefficients, NRC) of the sound absorption coefficients for sounds of 250, 500, 1000, and 2000 Hz. On the other hand, when looking at the acoustic performance standards for temporary sound barriers, the standards have not yet been established, but according to the existing literature, the sound insulation performance is 20 dB at 500 Hz and 25 dB at 100 Hz, and the average sound absorption rate for sounds at 250, 500, 100, and 2000 Hz is 50. % or more are also being investigated [9,10].

The noise reduction effect was quantitatively analyzed through simulations of the change in the height of the soundproof wall and the change in the installation conditions of the roof board during the underground construction based on the type of equipment and the number of equipment input for each stage of construction. By classifying the noise impact on adjacent buildings during urban construction by construction phase, the noise distribution was predicted by dividing the noise horizontally and vertically assuming the noise source used in the above-ground retaining construction and in the above-ground and underground civil works where the maximum noise damage is expected. As a result of predicting noise under three conditions of noise barrier height of 6m, 10m, and 8m (6m+2m), the expected noise reduction effect was calculated to be about 50m from the ground, and the noise reduction effect shielded by the soundproof wall was about 12dB~13dB was calculated as such. In addition, it was calculated that there is an additional reduction effect of 0.3~2.4dB according to the shape change of the upper part of the soundproof wall. [11]

In the case of soundproof wall installation in construction sites, in case of soundproofing facilities in construction sites, if the noise before and after the soundproofing wall is 7dB or more, the height is 3m or more, and noise reflection is concerned, it is necessary to install a sound-absorbing soundproofing wall according to Article 33(5) of the Enforcement Rule of the Noise and Vibration Control Act is stipulated. The performance of sound barriers varies depending on the overall structure, but the thickness of the back plate is generally considered as a design variable, and the thickness of the back plate should be considered as an important variable controlling the sound insulation performance. In general, a temporary soundproof wall made of metal (galvanized steel sheet) or plastic material is used for the rear panel, but metal material is widely used because of its high sound insulation performance and durability compared to plastic. On the other hand, since the sound barrier is a structure that connects the pieces, it is also necessary to develop a sound barrier structure that minimizes the gap between the connecting parts. On the other hand, it helps to improve the sound insulation performance according to the type and characteristics of the sound insulation material. [12].

On the other hand, the performance evaluation of the sound barrier was obtained numerically by using the two-dimensional boundary element method. The validity was verified by comparing with the experimental values obtained by the model scale experiment and the Lam model in a silent room. The installation effect was evaluated as the insertion loss, which is the sound pressure level difference, at the sound receiving point before and after the installation of the sound barrier, and the change in the insertion loss according to the height and shape of the sound barrier and the orientation characteristics were analyzed. In the case of vertical sound barriers, the insertion loss increased by 1dB per 0.4m height for the reflective type and 2dB for the sound-absorbing type. In the case of T-shape, the higher the height, the higher the insertion loss in the high-frequency region. In the case of the sound-absorbing type, the insertion loss was larger than that of the vertical type in the case of the sound-absorbing type, but there was no significant difference in the case of the reflective type. In the case of the T-shaped type, the insertion loss was larger in both the reflective type and the sound-absorbing type than in the vertical type. [13, 14]

Most of the noise generated at the construction site is the movement of the construction equipment, and not the static noise, but the impact noise. Construction companies are also reluctant to invest in soundproofing facilities by spending a lot of money, and it is not easy to install fixed soundproofing facilities, which causes complaints in neighboring areas. Although construction companies are installing and operating temporary sound barriers with their utmost efforts, it is difficult to operate temporary sound barriers as an effective noise reduction measure due to the lack of effective analysis and operation methods for the installed temporary sound barriers. In order to present the operation plan of the temporary soundproof wall, noise is measured according to the type of construction and the installation method is suggested, and the installation standard of the temporary soundproof wall is presented.[15]

Temporary soundproof walls are temporary structures in the form of barriers installed for the purpose of minimizing damage from noise and dust around the construction site and protecting the living environment. In this study, the foundation of the temporary soundproof wall is manufactured in the form of a screw pile and press-fitted through rotation to form the foundation for the ground, thereby reducing the noise and construction environment waste and to develop an eco-friendly construction technology to minimize carbon dioxide emissions.

As a manufacturing method, a prototype was produced based on the drawings. Then, dynamic load simulation was performed on the temporary soundproof wall based on the screw pile. After 3D modeling was performed for structures with dimensions (height X spacing) of 3X3m and 6X2.5m, wind pressure conditions were applied to analyze the impact of the structure. In addition, simulation was performed by applying the two types of fastening method, namely, the integral type and the bolt method. As a result of structural analysis, in the case of 3mX3m, the maximum displacement of the bolted type increased by 4mm compared to the integrated type, but the maximum stress was almost the same. On the other hand, in the case of 6X2.5m, the maximum displacement of the bolted type increased by 30mm and the maximum stress increased by about 40MPa compared to the integral type, but it was structurally stable at 82% of the yield strength (275MPa) of the H-beam.

2. NUMERICAL ANALYSIS

2.1 3-D ANALYTICAL MODELLING

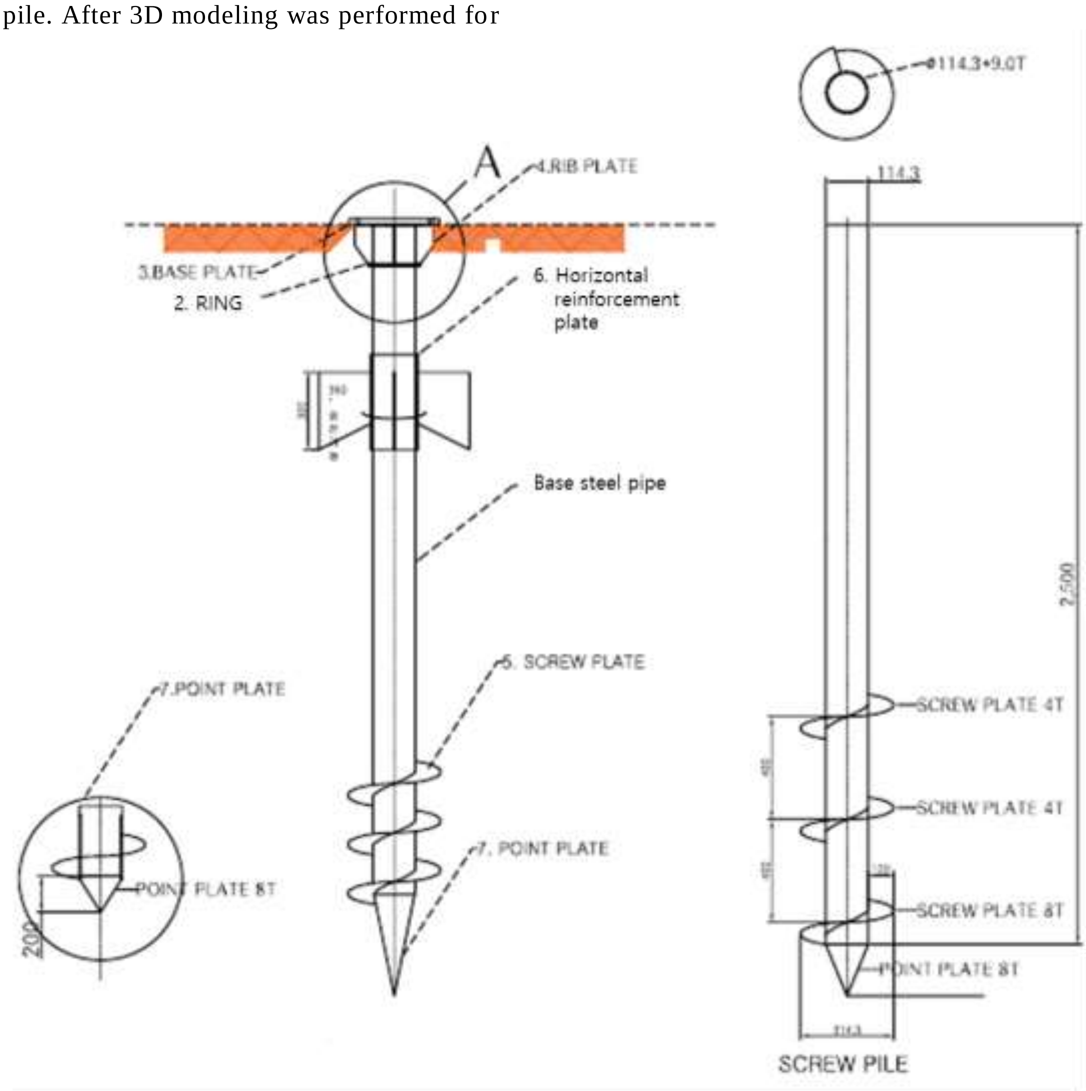

Fig. 1 Manufacturing drawing for screw pile

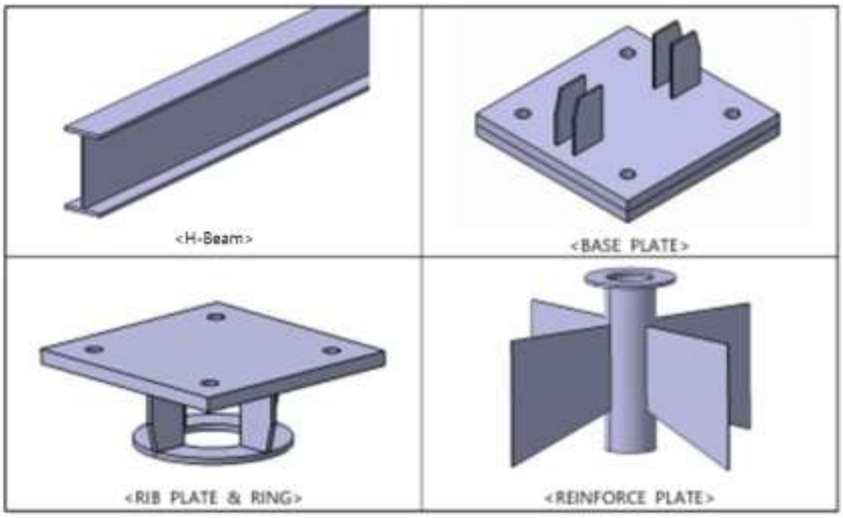

Fig. 2 3-D modeling of screw parts

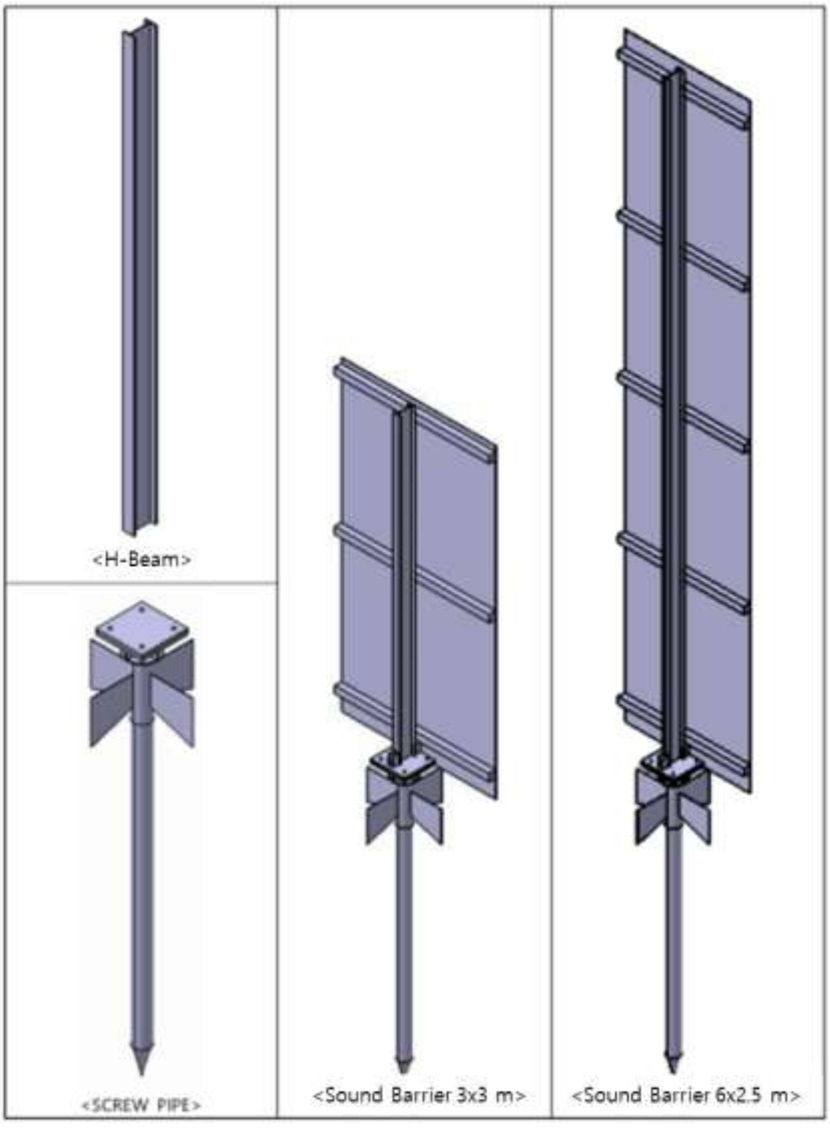

Fig. 3-D modeling of H-beam steel, screw pile and sound barrier assembly

The subject for CAE analysis in this study is a screw pile type self-supporting H-beam sound barrier structure developed by Jinbang E&C. Compared to the existing buried structure, this screw-type self-supporting pile has the advantage of being easy to install because it can be immediately installed on the ground without using cement when installing or removing the structure. In this study, CAE analysis was performed to identify the problems with the stability of the temporary soundproof wall structure to which the screw pile was applied according to the maximum external wind pressure. CAE analysis was performed on the entire structure by applying the self-standing screw pile type developed by Jinbang E&C to the 3m and 6m soundproof walls. [Fig. 1].

In order to secure 3D CAD modeling of the self-supporting H-beam soundproof wall structure required for structural CAE analysis, 3D-CAD modeling was performed by referring to the temporary soundproof wall structure design and screw pipe production drawing provided by Jinbang E&C [Fig. 2, 3].

2.2. CAE ANALYSIS PROCESS

2.2.1 MATERIAL PROPERTIES

In order to perform structural CAE analysis, information on mechanical properties such as Young's Modulus, Poisson Ratio, yield strength, and tensile strength of each part is required.

In the case of a freestanding H-beam sound barrier structure, the sound barrier is made of PVC reinforced plastic and polyurethane, and other parts such as H-beam steel and pipes are all made of structural steel. In general, the modulus of elasticity of structural steel is 205 to 215 GPa, and the Poisson ratio is defined equally according to about 0.28, and information on the mechanical properties of each part is provided in Table 1.

Table I. Material mechanical properties

Material	SS275(H-Beam Steel)	STP550(File)	SGT275(Transverse Pipe)	PVC
Modulus of Elasticity GPa)	210	210	210	3
Yield Strength(MPa)	275	355	275	45
Poisson’s Ratio	0.28	0.28	0.28	0.4
Tensile Strength(MPa)	400	500	410	45
Density	7800	7800	7800	1400

2.2.2 MESH GENERATION

In this study, the Finite Element Method was used among various CAE analysis methods. Finite Element Method was used. The Finite Element Method is a method to perform analysis by dividing the geometrical area of an object into a finite number of elements, i.e., creating an element network. The element network is composed of nodes and elements.

A dense mesh configuration improves the accuracy of CAE analysis compared to a coarse mesh, but if it is too dense, it requires excessive analysis time by performing unnecessary numerical analysis calculations.

In this study, considering the size of each shape, the mesh size was set to 40mm for sound barrier, 20mm for H-beam and transverse pipe, and 10mm for the remaining pile and plate parts, and the number of divisions was set to 10. The mesh generation result is shown in Fig. 4 and Fig. 5 are presented

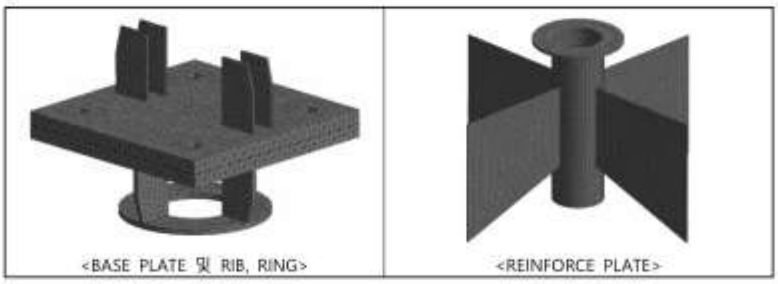

Fig. 4 3-D modeling of base plate and reinforcement plate

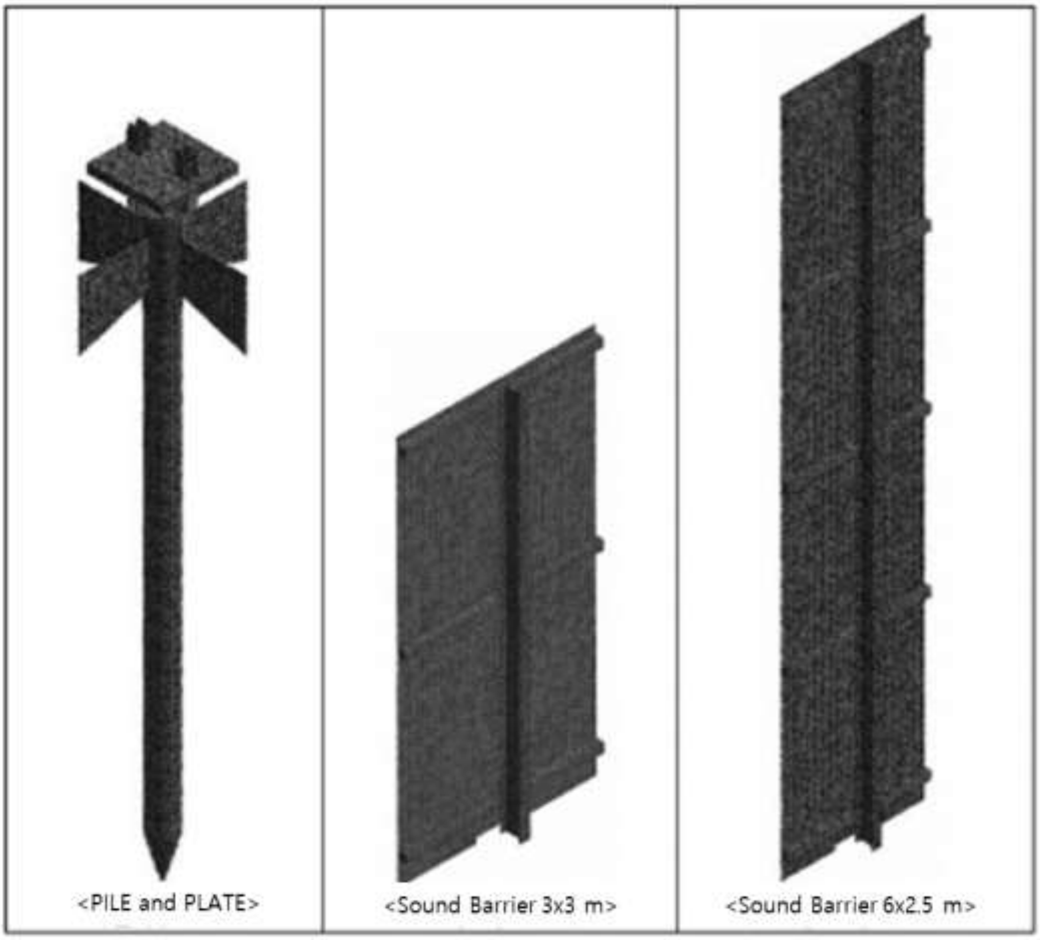

Fig. 5 3-D modeling assembling pile plate, H-beam and sound barrier

2.2.3 APPLIED LOAD BY WIND PRESSURE AND BOUNDARY CONDITIONS

Table I shows the coefficients for the design standard wind speed and wind load. Therefore, the design wind speed, design speed pressure, and design wind pressure were calculated as follows.

Design wind speed (V_d) = Vo * K_{zr} * K_{zt} * l_w = 28 * 1 *1.1 * 0.745 = 22.95m/s

Design speed pressure (q_z)=0.05 * ρ * Vd^2 = 0.05 *12.25 * 22.952=322.6 N/m^2

Design wind pressure (P_f) = q_z * G_f * C_f = 322.6 * 1.9 * 1.2 = 735.54 N/m^2

Since the maximum pressure acts in the normal direction of the soundproof wall, the uniformly distributed pressure (735.54N/m^2) and the gravity of the structure are given as load conditions in the x-axis, which is the normal direction, as shown in Fig. 6. In addition, the finite element method to be implemented in this study is given a degree of freedom necessary to realize the behavior of an object. As for the degree of freedom, three constraint conditions for movement in the x, y, and z directions at a node and three constraint conditions for rotation around the x, y, and z axes were given, so a total of six degrees of freedom were applied.

Since the actual width of the sound barrier is continuous, only half of the total width of the sound barrier was 3D modeled based on the H-beam, and symmetrical constraints were applied to both sides of the sound barrier and the transverse pipe. Assuming that the vertical bearing capacity and the vertical bearing capacity of the pile are in the elastic section, only displacement constraint conditions were applied to the pile, but rotation constraint conditions were not applied.

Table II. Wind speed and wind load factor

Wind velocity(m/s)	28
Topographic coefficient (Kzt)	1.1
Topographic coefficient (Kzr)	1
Importance factor (Iw)	0.745
wind pressure coefficient (Cf)	1.2
Gust influence factor	1.9
Air density(N/m^3)	12.25

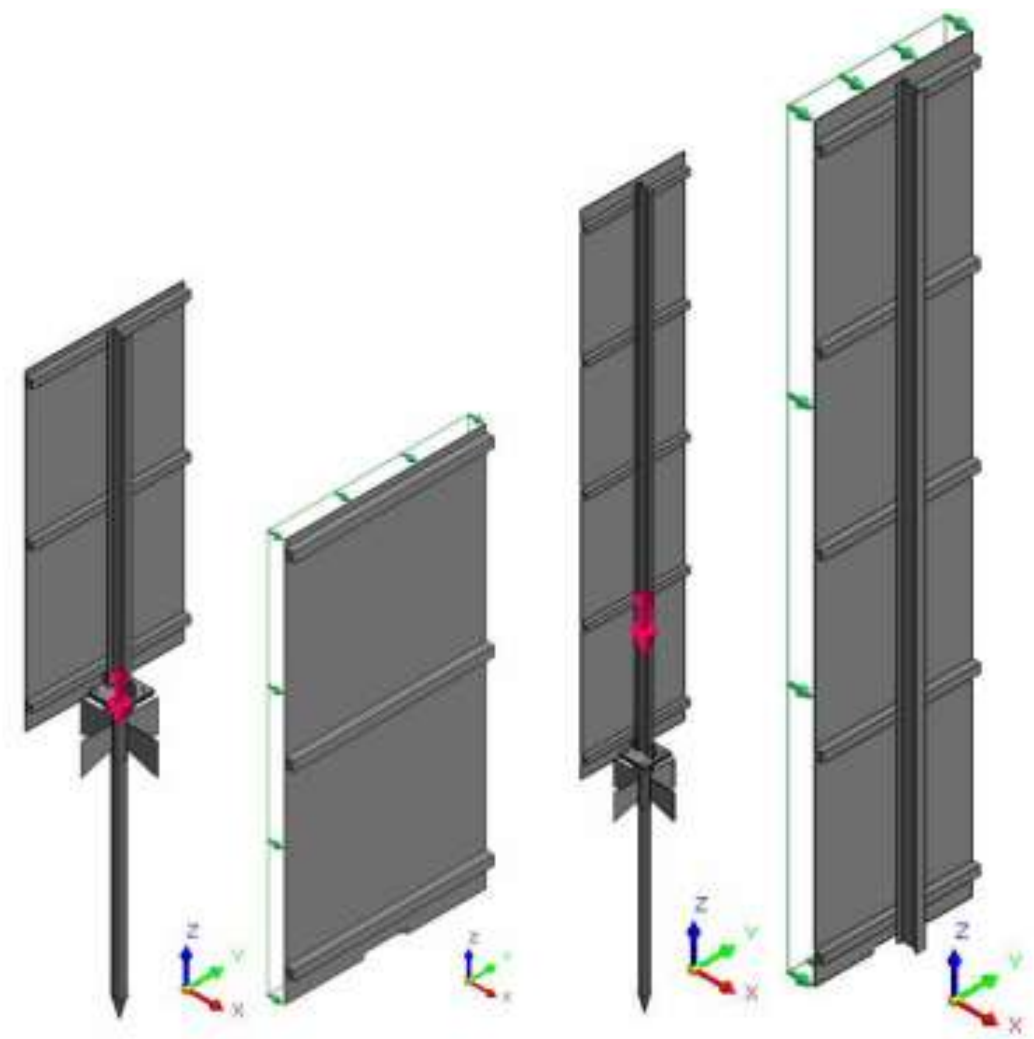

Fig. 6. Wind pressure and gravity loading conditions

2.2.4 ANALYSIS OF THE CONTACT SURFACE BETWEEN PARTS

In structural CAE analysis, the definition of the contact surface is divided into integral motion contact, bidirectional sliding contact, rough contact, and separable integral contact according to the contact friction force. In this study, analysis was performed for two cases, i.e., integral type and bolt type, according to the base plate fastening method, and the results were compared. That is, in the case where the soundproof wall is completely fixed to the transverse pipe and H-beam with clamps and is in contact with the integral movement, and in the case of the bolt-type case in which bolt conditions are applied to the bolted part between the upper and lower plates of the base plate of the independent H-beam soundproof wall structure. In order to find out the maximum amount of displacement and stress according to the constraint conditions for each structure, the constraint conditions for the base plate on the upper and lower plates are as shown in the Fig. 7.

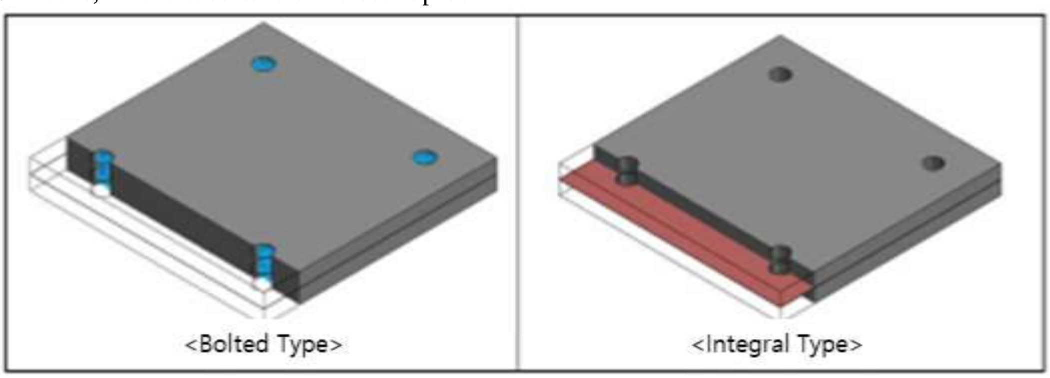

Fig. 7. Contact conditions of base plate top and bottom

3. ANALYTICAL RESULTS

In this study, structural analysis was performed on two models of a self-supporting H-beam sound barrier structure (3mx3m) and a structure (6mx2.5m). Structural analysis was performed for two cases: when the upper and lower plates of the base plate of each structure were bolted and integral.

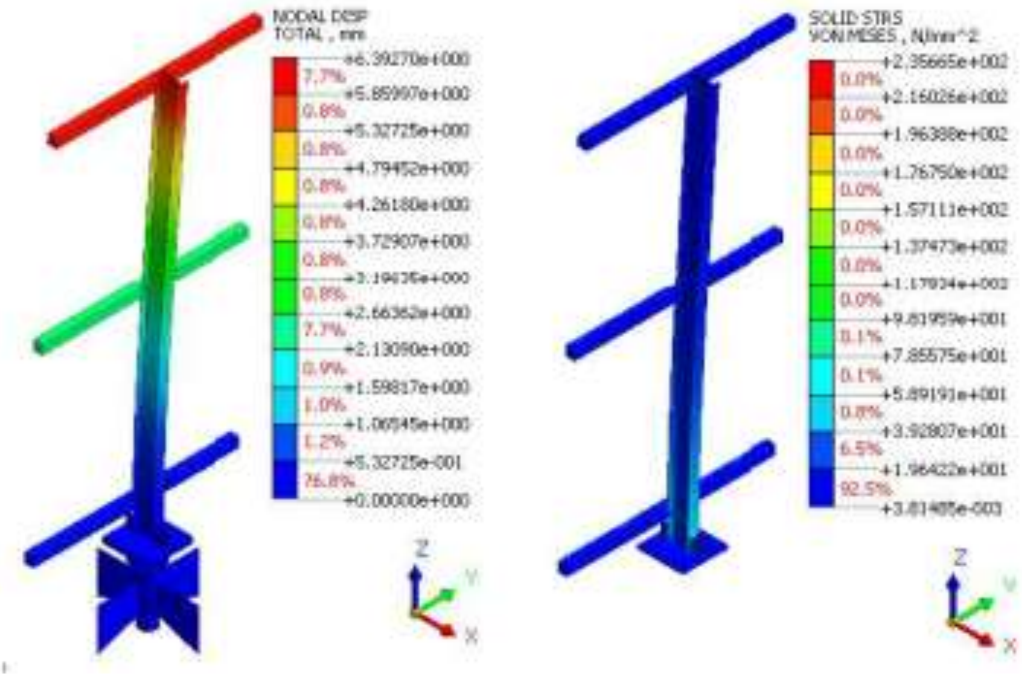

Fig. 8 Integral type structure (3X3m) displacement and stress distribution diagram

Structural analysis was performed when the wind pressure acting in the tangential direction to the soundproof wall was 735.54N/m^2, the height of the soundproof wall was 3m, the H-beam spacing was 3m, and the upper and lower parts were integrated. As a result, the displacement distribution and stress distribution are shown in Fig. 8.

Structural analysis was applied when the wind pressure acting in the tangential direction to the soundproof wall was 735.54N/m^2, the height of the soundproof wall was 3m, the H-beam spacing was 3m, and the upper and lower parts were bolted. As a result, the displacement distribution and stress distribution are shown in Fig. 9.

Structural analysis was performed when the wind pressure acting on the soundproof wall in the normal direction was 735.54N/m^2, the height of the soundproof wall was 6m, the H-beam spacing was 2.5m, and the upper and lower parts were integrated. As a result, the corresponding displacement and stress distribution diagrams are shown in Fig. 10.

Structural analysis was performed when the wind pressure acting on the soundproof wall in the normal direction was 735.54N/m^2, the height of the soundproof wall was 6m, the H-beam spacing was 2.5m, and the upper and lower parts were bolted. As a result, the displacement distribution and stress distribution are shown in Fig. 11.

Table III shows the maximum displacement and stress in each case as a result of structural analysis.

Table III Maximum displacement and stress by structure and constraint method

Type	Constrain Method	Maximum Displacement (mm)	Maximum Stress (MPa)	Stress Ratio to Yield Strength (%)
3mX3m	Integral Type	6.39	98.19	35.7
	Bolted Type	10.81	98.29	35.7
6mX2.5m	Integral Type	88.39	88.59	68.6
	Bolted Type	118.65	226.69	82.4

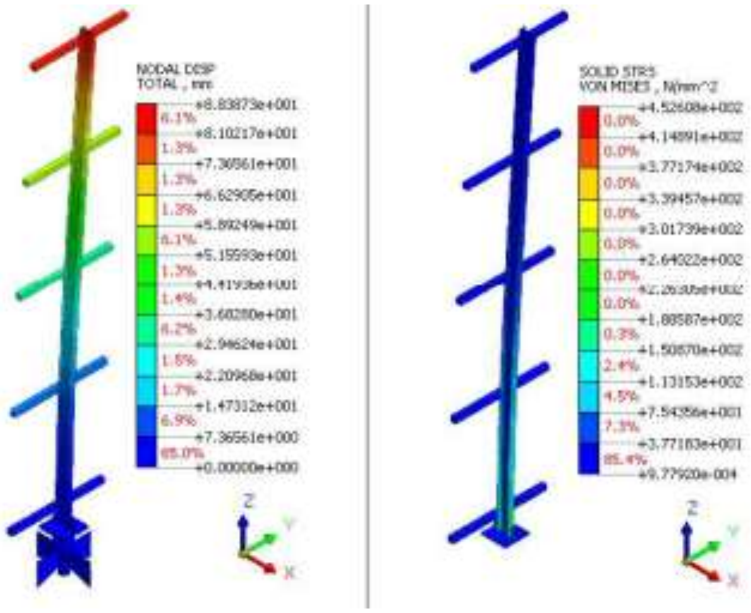

Fig. 9 Integral structure (6mX2.5m) displacement and stress distribution

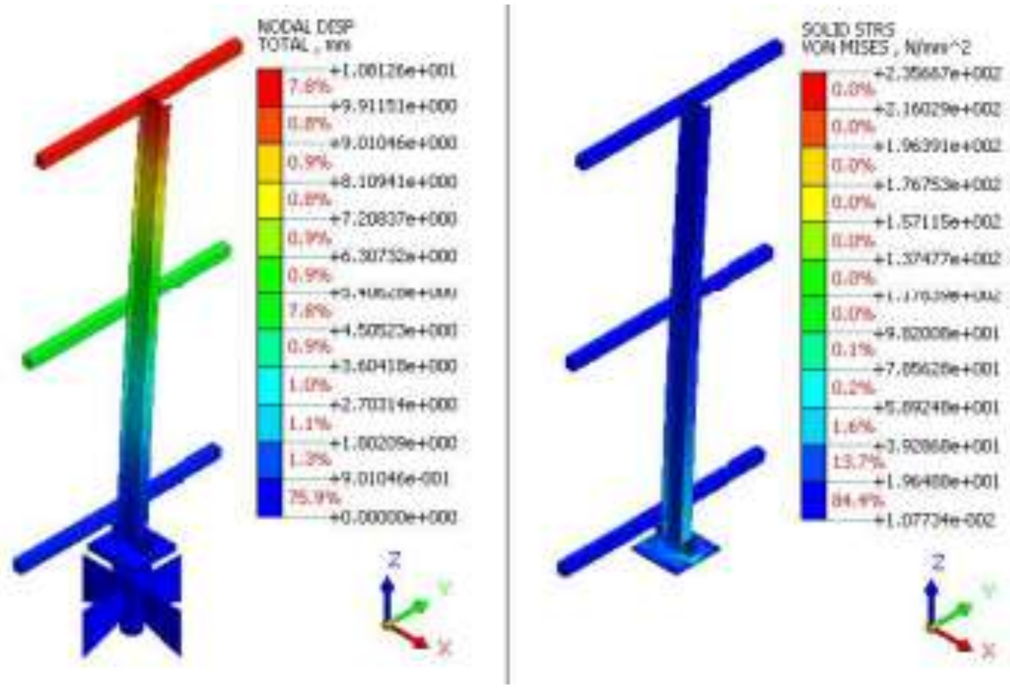

Fig. 10 Displacement and stress distribution of bolted structure (3mX3m)

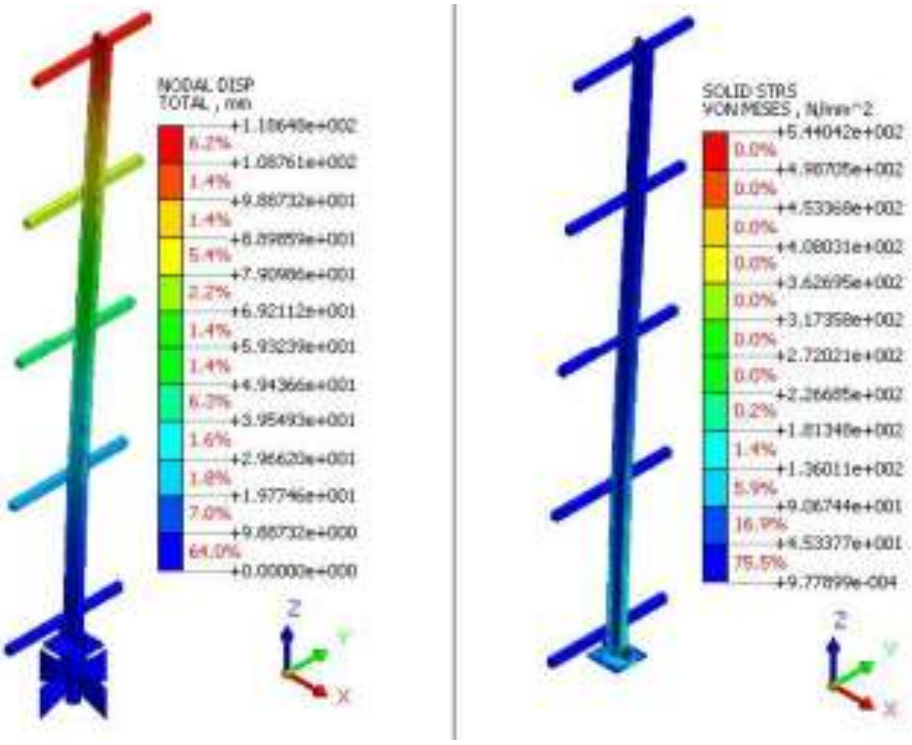

Fig. 11 Displacement and stress distribution of bolted structure (6mX2.5m)

4. CONCLUSIONS

In this study, CAE analysis was performed on the structure to understand the structural stability of the self-supporting H-beam sound barrier structure of Jinbang E&C Co., Ltd. CAE analysis was performed and analyzed by applying a screw type file to two structures with soundproof wall dimensions (height X spacing) of 3mX3m and 6mX2.5m.

The wind pressure applied to the sound barrier was calculated as 735.54N/m^2 and was evenly distributed in the normal direction. In addition, in order to compare and analyze with existing buried structures, two cases of bolt fastening method and one-piece method were applied, and structural analysis was performed for each structure for comparative analysis.

In the case of the 3mX3m structure, the maximum deformation of the H-beam increased by about 4.4mm compared to the integral type, and in the case of the 6mX2.5m structure, the maximum displacement of the H-beam increased by about 30.1mm during bolting compared to the integral.

In the case of a 3mX3m structure, there is no difference in the maximum stress of H-beams of integral type and bolted type, and the yield strength (275 MPa) is about 36%, so it is considered to be structurally very stable.

In the case of the 6mX2.5m structure, the maximum stress of the H-beam increases by about 38.1 MPa when bolted compared to the integral type, but it is structurally stable at about 82% of the yield strength (275 MPa).

Compared to the 3x3m structure, the displacement and stress of the 6mX2.5m structure increased as the load increased due to the uniformly distributed wind pressure acting on the sound barrier, which is thought to be due to the load applied to the bolted part of the base plate.

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