A STUDY ON THE BEHAVIOR OF CONCRETE WIND POWER TOWER

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Abstract- Recently, in the world, efforts to reduce greenhouse gas emissions is expanding. Such as research and development of renewable energy is enabled as a policy for that. Currently, the towers are mostly used, many steel tower drawback to complement these parts, must develop a high-strength concrete tower is one of the options. Therefore, in this study, in order to analyze the behavior of the concrete tower, was studied with a commercial software (MIDAS Civil2009). The safety factor of the strength of the concrete tower by placing a reference to 2 is performed to determine whether to resonate through the natural frequency, By utilizing the thickness of the tower recalculation is concrete, we examined the buckling stability with axial load. As a result, run the research, by analyzing the behavioral characteristics associated with it, there is intended to be utilized in basic research.

Keywords- High-Strength Concrete Tower, Strength Safety Factor, Natural Frequency, Buckling Safety

I. INTRODUCTION

Entered into force Tokyo Protocol based on the climate treaty of 2005, efforts have expanded on greenhouse gas emissions around the world. Currently, South Korea as number 9 of carbon dioxide emissions the world, accounting for 1.8% of the world's carbon dioxide emissions Become a reduction obligations countries of greenhouse gases to discuss the reduction measures since 2013 it is leading. As a policy for the energy efficiency of research, such as research and development of renewable energy is enabled. Wind energy is the one field of renewable energy in it, has the advantage of a point is capable of pollution-free power generation that is developed for energy Development Institute wind, Footprint of the facility required to produce the same amount of power is also reduced as compared to coal or sunlight, It is possible to semi-permanent power generation without any special effort after installation. Furthermore, wind power generation cost is low compared to other renewable energy, as only gradually efficient that can be used primary energy source area, is showing an annual high growth rates. Tower with the rotor and blade gradually large to another effort for the development is also large.

In such a situation, wind power generation technology, such as the 12 leading companies in Europe and some of the developed countries have accounted for the majority 95% of the market share, High foreign technology dependent, it may be that it is necessary in the field current of the wind power market.

Today, the towers for wind power generation have been rarely used as a steel type of steel tower According to The Economics of wind energy (2009, EWEA), and a large percentage of about 26% of the total manufacturing cost of the wind power generator. Thus, wind generators, large cost of the generator of the tower so that it can be stable during the life cycle to calculate the maximum energy and had if determined height and diameter. Currently, the nature of the atmosphere, and in an attempt to win the quality of wind for wind speed increases as away from the floor, is also used more Tower 100m. However, an increase in a simple tower height induce many problems. Especially in the case of steel tower, because there is a high possibility that local buckling occurs more you larger, Since the thickness of the steel pipe to attempt to prevent this thicker than necessary there is a disadvantage that is uneconomical in the price of steel is continued to rise continuously. In this way, the higher the wind generator is to be large in size, there is a need for solutions for safer tower structure and price competitiveness. There is a tower of high-strength concrete in such alternative. As expected effect on this, can reduce construction costs and maintenance costs, it is determined that those with a competitive price in buckling and fatigue failure prevention and affordable cost. Also, there is an advantage to be able to install without the diameter of the restriction when the cast-in-place.

Therefore, in this paper, by analyzing the behavior characteristics of the concrete tower, there is a purpose of the basic research for the development of tower with high-strength concrete.

II. WIND POWER TOWER

Tower for a wind turbine is an important component blade and the hub and the gear box, prepare to a cylinder at regular intervals as a structure component supports all assembled nacelle such as the generator, and a flange at each end bolts, which are manufactured in the form of nut assembly. Tower features, as can be seen from the structure of the tower, and thrust the blade occurs while rotating, as a passage for the roles and tasks and power cooperation with its own weight

and the tower with the nacelle and the blade weight to support a load received by the wind by the role is very simple compared to the elements of the other machines which constitute the wind power generator.

However, other very large loss induced damage compared to the elements constituting the wind power generator, since higher unit cost of the tower itself and accounts for 26.3% of a large wind turbine cost, economy and safety it is very important to develop a tower that will highlight.

2.1 The design concept of the tower
Tower, load characteristics and shape given its structural role, manufacturing process, material, must meet various design requirements, such as by the use environment. Also, a relatively simple but is form, the optimal design for high unit price and weight, weight, simplification of the manufacturing process, while ensuring price competitiveness and improved installation ease, structural stability simultaneously it is an important element for enhancing the commercial value of ensuring the sex.

2.2 The design method of the tower
2.2.1 Natural frequency analysis
The most important thing in the natural vibration design and analysis, would avoid the resonance with the rotational speed of the most important dynamic load-induced chain wind turbine blades in the wind turbine. To this end it is necessary to satisfy the equation (2.2) equation (2.1) which defines the GL is presented.

$$\frac{f_R}{f_1} \leq 0.95 \qquad (2.1)$$

$$\frac{f_{R,m}}{f_n} \leq 0.95 \text{ or } 1.05 \leq \frac{f_{R,m}}{f_n} \qquad (2.2)$$

This, f_R= Maximum frequency of the rotor during operation
f_1= Primary natural frequency of the Tower
$f_{R,m}$= pass frequency of m rotor blade
f_n = N-th natural frequency of the Tower

This, Equation (2.1) means that the rotation speed of the rotor in a state of normal operation (normal operating range) is less than 95% of the primary natural frequency of the tower, Equation (2.2), all of the natural frequency of the tower, means that you must get out blade passing vibration frequency 5% in consideration of the number of blades in all operating conditions.

2.2.2 Design load analysis
In order to design the tower, it is important to accurately apply a load on the tower. Design load of the tower is generally obtained through aeroelastic analysis.

Design load, various design load situation that may wind generator occurs (DLCs, design Load Cases) development of state of the failure in the power generation, start-up state, depending on the progress of the time normal stop, etc. is calculated.

2.2.3 strength interpretation
strength interpretation is to interpret whether the strength of the tower structure is sufficient for extreme (ultimate) load applied to the tower. For strength interpretation, all the parts that make up the tower to be designed to have a sufficient safety factor margin (margin of safety) for the extreme loads. Result of the design through the strength interpretation, it is necessary to satisfy the following equations (2.3) and equation (2.4) Equation (2.5).

$$F_d = \gamma_f F_k \qquad (2.3)$$

$$f_d = \frac{f_k}{r_m} \qquad (2.4)$$

$$\gamma_f F_k \leq \frac{1}{r_m} f_d \qquad (2.5)$$

This, F_d= Design load value
γ_f= The partial safety factor for load
F_k= Characteristic load value
f_d= Design values for the material
γ_m= Partial safety factor for the material
f_k= Characteristic values for the material properties

Equation (2.6) and (2.7), in order to ensure safety design values for uncertainty and variability of the material and the load, must apply a partial safety factors as described above. Partial safety factor of concrete materials are presented in GL provision is 1.5.

2.2.4 fatigue strength analysis
Fatigue loading for the fatigue strength analysis, the average stress load came out several DLCs in rainflow counting method, to obtain the number of repetitions for each size of the repeated stress, using a Minor's rule and configure the Markov matrix calculate. Fatigue loads used for the fatigue strength analysis of the tower is calculated on the basis of 20 years of the life of the wind power generator, The target time of the fatigue load analysis to fit the type class wind power generator, and then to be converted into actual number occurring for 20 years. Furthermore, the scale value any mean stress, with the magnitude of the repeated stress, the cumulative damage fatigue load damage coefficient indicating the damage for generating the materials and components forming the parts of the structure ($\frac{n_i}{N_i}$) is accumulated If you do not cause fatigue damage to be those seeking Miner sum (D) indicating a coefficient, it must satisfy the conditions, such as equation (2.6). In equation (2.6) N_i can be obtained from the fatigue life equation SN lead.

$$D = \sum_i \frac{n_i}{N_i} \leq 1 \qquad (2.6)$$

This, D = Miner sum, cumulative damage factor

n_i= Can repeat load at any of fatigue load

N_i= Cycle life at any fatigue load

2.2.5 Buckling stability analysis

Wind power tower, must ensure that there is stability against buckling against axial load as one of the pillars. Buckling stress limit, the shape of each section (section) to form a tower, the thickness of the shell varies depending on the material, such as the tower diameter.

III. CONCRETE TOWER SELECTION

3.1 Concrete tower selection

The materials used in the concrete tower selection of this study was to go analyzed using the f_{ck} = 50MPa as <TABLE3.1>. According to the provisions of GL, partial safety factor of concrete materials, are given in (r_m) 1.5

Therefore, 33.3MPa is applied to the design strength 50MPa was considered ultimate strength.

In general, concrete structures, but are designed with strength design method, in this study, we apply the allowable stress design method, which is a tower system, In order to reflect the brittle fracture characteristics of the concrete material, Coulomb - have been applied mower theory (Coulomb-Mohr theory).

TABLE 3.1 Concrete material property

design strength (f_{ck})	50Mpa
ultimate strength (=f_{ck}/1.5)	33.3Mpa
Poisson's ratio	0.18
Unit mass	2500kg/m3
elastic modulus (E_c)	32876Mpa-KCI2007

The diameter of the concrete tower was applied similarly in order to use the extreme load, such as an existing tower structures. By utilizing the application diameter, the section diameter is expressed by equation (3.1), is expressed by the diameter and thickness of the section as the section modulus of section equation (3.2). Then the section star stress can be calculated by the equation (3.3) using the load and section modulus acquired earlier.

1) The diameter of the cross section

$$d_x = d_a + (d_b - d_a)\frac{x}{H} \quad (3.1)$$

This, d_x : The diameter of the cross section

x : Distance from the tower top portion

H(Tower height) : 77m

d_a : Top diameter

d_b : Bottom diameter

2) Section modulus

$$S_x = \frac{I}{C} = \frac{\pi(d_x^4-(d_x-2t_x)^4/64}{d_x/2} = \frac{\pi(-16t_x^4+32d_xt_x^3-24d_x^2t_x^2+8d_x^3t_x}{32d_x} \quad (3.2)$$

This, S_x : Any of the section modulus

I : Moment of inertia

c : Distance from Neutral axis

t_x : Any cross section thickness

3) Sectional stress

$$\sigma_x = \frac{M_x+P_x}{S_x} = \frac{32d_x(M_x+P_x)}{\pi(-16t_x^4+32d_xt_x^3-24d_x^2t_x^2+8d_x^3t_x)} \quad (3.3)$$

This , σ_x : Sectional stress

M_x, P_x : Maximum moment, maximum load in each section

Ultimately, the thickness of the concrete tower section stars are, maximum moment of each and the diameter of the cross-section section, it is possible to express in the ultimate strength. To determine the thickness of the section is can be represented by the solution of equation 4, such as equation (3.4).

$$-16t_x^4 + 32d_xt_x^3 - 24d_x^2t_x^2 + 8d_x^3t_x - S \times \frac{32d_xM_x}{\sigma_y\pi} = 0 \quad (3.4)$$

To obtain the maximum moment in the section bottom end, by substituting equation (4.4), the result of the calculated thickness of the tower of the concrete, it can be seen by calculating the same value as <TABLE3.2>.

TABLE 3.2 Thickness of the initial concrete tower

Section	Hegiht(m)	Load Case	Tower thickness(m)
1	0~10	DLC6.1	0.564
2	10~26		0.518
3	26~48		0.416
4	48~77	DLC1.3	0.167

3.2 natural frequency analysis

3.2.1 Modeling and analysis results

Method used in making concrete tower modeling was used Element1540 pieces Shell. Lowest portion was applied to a thickness of the initial concrete according to the height is fixed.

Natural frequency of the modeling tower, was interpreted as <TABLE3.3>. This frequency is, the maximum frequency of the rotor during operation (= 0.255Hz), to satisfy the conditions in accordance with the provisions of GL you try to determine whether the resonance of the pass frequency rotor blade at the time of the m = 3 at startup it is I found.

TABLE 3.3 Natural frequency of the initial concrete tower

Primary	0.547
Secondary	2.287
Third-order	6.507

TABLE 3.4 Determine if the resonance of the initial concrete tower

Maximum frequency of the rotor during operation	15.3RPM(=0.255Hz)
m-rotor blade passing frequency	6.0RPM(=0.1Hz)
The number of blades	3
Primary natural frequency	0.547
Secondary natural frequency	2.287
$f_{R,3}/f_1$	0.466 < 0.95 (ok)
f_R/f_1	0.548 < 0.95 (ok)

1-3 natural vibration mode shape of the modeled tower, is as <Fig1> ~ <Fig3>.

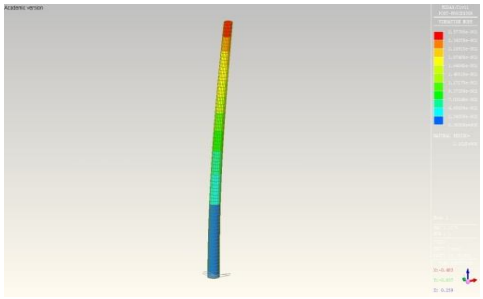


Fig.1 natural vibration mode shape of concrete tower

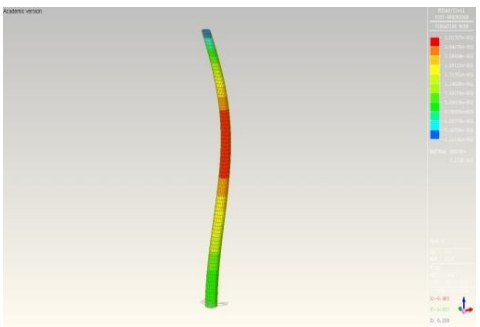


Fig.2 natural vibration mode shape of concrete tower

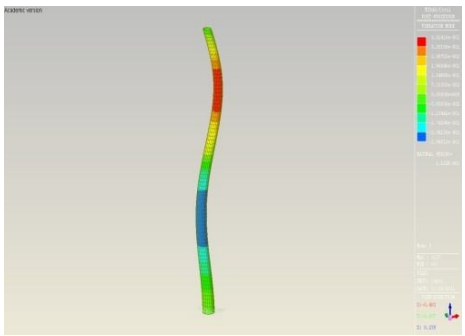


Fig.3 natural vibration mode shape of concrete tower

IV. MODELING ANALYSIS

4.1 Strength Analysis

4.4.1 Coulomb-Mohr theory

In this study, the brittle material at a reference for predicting the destruction, there are many differences reference to a determination of ductile materials such as metal. In the case of ductile materials, it is whether the stress at a particular point in the object exceeds the yield stress as a reference for destruction, In the case of brittle materials, whether reached to determine stress as a reference for destruction. In the case of brittle materials, not only the tensile, fracture occurs by compressive load.

There are three of large brittle failure criteria, the simplest theory is exactly the maximum normal stress theory therein. Among them Coulomb-Mohr theory is based failure criteria, such as <TABLE 4.1>. Therefore, in order to determine the safety against concrete tower destruction, Coulomb-Mohr theory is tried to be apply.

TABLE 4.1 Coulomb-Mohr theory based on the destruction

case	The maximum principal stress		Required criteria
1	Both in tention	$\sigma_1 > 0$ $\sigma_2 > 0$	$\sigma_1 < \sigma_t$ $\sigma_2 < \sigma_t$
2	Both in compression	$\sigma_1 < 0$ $\sigma_2 < 0$	$\sigma_1 < -\sigma_c$ $\sigma_2 < -\sigma_c$
3	σ_1 in tension, σ_2 in compression	$\sigma_1 > 0$ $\sigma_2 < 0$	$\frac{\sigma_1}{\sigma_t} - \frac{\sigma_2}{\sigma_c} < 1$
4	σ_1 in compression, σ_2 in tension	$\sigma_1 < 0$ $\sigma_2 > 0$	$-\frac{\sigma_1}{\sigma_c} + \frac{\sigma_2}{\sigma_t} < 1$

(Ultimate tensile strength) : 33.3/10 =3.3MPa
(Ultimate compressive strength) : 33.3MPa

4.4.2 Analysis of results

Depending on the height of the concrete tower, was applied to extreme loads. In order to see the safety factor of strength, and extracted the maximum stress of any large values of • on the finite element analysis during the shell element. Maximum stress in each section is the same as <TABLE4.2>.

section1, the maximum stress of 15.5MPa revealed at the height of 42 times the element upon application of a load of 10m in section2, maximum stress of 15.7MPa revealed in 281 number of elements at the time of application of the load of the height of 26m. And, the maximum stress of 16.4MPa has appeared in

elements of the 829 number at the time of application of the load of the height of 48m in section3, In section4, I got the maximum stress of 19.3MPa at 1251 times the element at the time of application of the load of the height of 77m.

TABLE 4.2 The maximum stress in the initial concrete tower

Section	Hegiht(m)	Load Case	Tower thickness (m)	σ_{max} [Mpa]
1	0~10	DLC6.1	0.564	15.5
2	10~26		0.518	15.7
3	26~48		0.416	16.4
4	48~77	DLC1.3	0.167	19.3

Such are as <TABLE4.3> you tried to calculate the safety factor($\gamma_m = 1.5$) specific for the ultimate strength of the maximum stress applied to partial safety coefficients in each section.

TABLE 4.3 Strength safety factor of initial concrete tower

Section	σ_{max} [Mpa]	σ_y [Mpa]	Safety ratio
1	15.5	33.3	2.15
2	15.7	33.3	2.12
3	16.4	33.3	2
4	19.3	33.3	1.73

First, when we look at this value, and calculate the thickness to match the safety factor 2 more specific thickness calculation formula of the above (3.4), has been applied to extreme load of concrete, safety factor of strength , the error of 0.15 to 0.27 has occurred.

The reason is that because it does not take into account the weight and other other load by thickness, it is estimated that there is an error. Also, when obtaining a solution by using a fourth-order equation has no established, it is expected that because looking convergence value close to 0 is an error.

Stress distribution in each section at the time of application of the ultimate load in accordance with the height is the same as <Fig4> ~ <Fig7>.

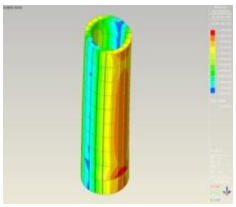


Fig.4 Stress distribution in the section 1

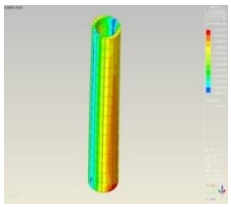


Fig.5 Stress distribution in the section 2

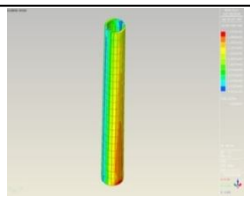


Fig.6 Stress distribution in the section 3

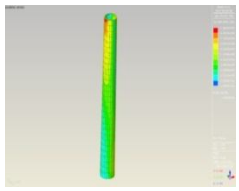


Fig.7 Stress distribution in the section4

However, even as a safety factor as described above came out in two or more, concrete because it is brittle material, Coulomb-Mohr theory is tried to ensure safety to destruction by applying. Maximum and minimum principal stress is I tried to check the elements that occur in each section to <TABLE4.4>. As a result, it was possible to know that it is an element that generates only tensile or compressive stress to the failure criteria case1 or case2. In addition, as a result of was applied to the fracture criterion of Coulomb-Mohr theory, Although the results to be safe in the compression side in every section out, beyond the failure criterion of the tension side, and leaving it results that it is not safe.

TABLE 4.4 Maximum value of the initial concrete tower of elements and minimum principal stress

section	Shell elements		Maximum and minimum principal stress [Mpa]	Judgment results
1	Tensile	42	11.7,1.34	NG
	Compression	142	-14.52, -1.67	OK
2	Tensile	265	12.14, 1.36	NG
	Compression	425	-14.78, -1.67	OK
3	Tensile	609	12.89, 1.37	NG
	Compression	829	-15.31, -1.63	OK
4	Tensile	989	6.39, 0.51	NG
	Compression	1279	-9.07, -0.66	OK

Next <Fig8~Fig11> is a diagram showing the maximum and minimum principal stress from section1 to section4.

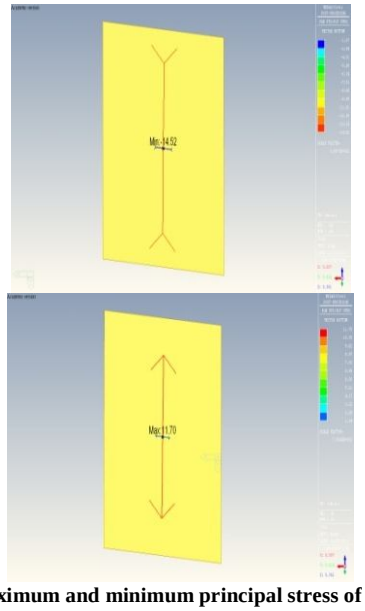


Fig.8 maximum and minimum principal stress of section 1

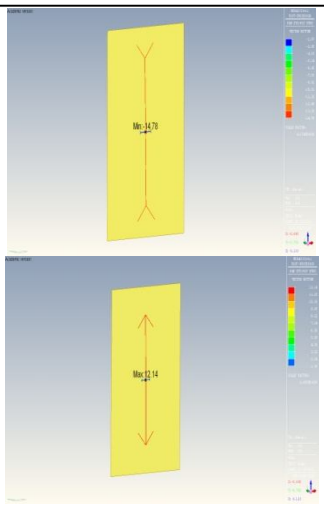


Fig.9 maximum and minimum principal stress of section 2

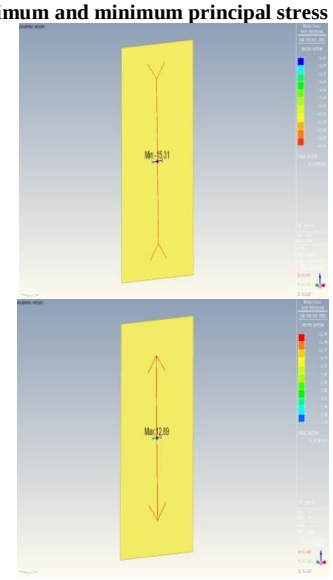


Fig.10 maximum and minimum principal stress of section 3

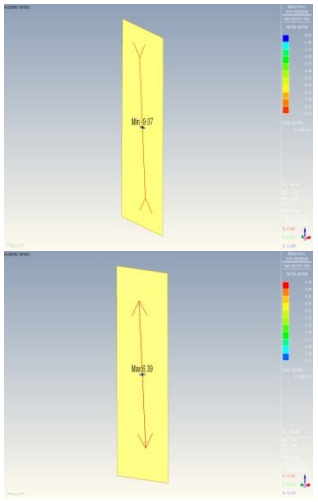


Fig.11 maximum and minimum principal stress of section 4

4.2 Buckling Stability Analysis

Concrete tower is to grasp the seat boundary load of the tower that has been modeled, was to determine whether the stability is based on the relationship between the maximum axial load. As a result, it has received the critical buckling load, such as <TABLE4.5>, it was confirmed stability against buckling. <Fig12~Fig14> is in the form of buckling in the primary order mode to 3 of the concrete tower, is expressed as follows.

TABLE 4.5 Seat buckling world load of initial concrete tower

n	P_{cr}(KN)	P(KN)
1	108153	
2	584664	2008
3	1558197	

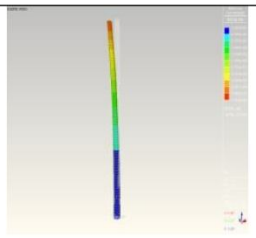


Fig.12 first Mode buckling form of concrete tower

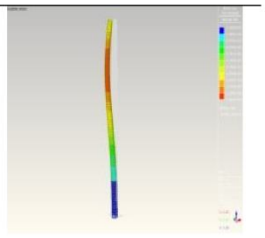


Fig.13 first Mode buckling form of concrete tower

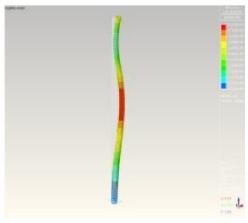


Fig.12 first Mode buckling form of concrete tower

4.3 Recalculate of the concrete tower thickness

The thickness of the concrete tower, placed in the reference 2 is the basis of the safety factor of the mean values shown in <TABLE4.3>. Was performed to fit the criteria Trial & error method with 0.5% error rate 2. Thickness is Recalculated are as <TABLE4.6>.

TABLE 4.6 Recalculate of the concrete tower thickness

Section	Tower thickness (m)	σ_{max} [Mpa]	σ_y [Mpa]	Safety factor
1	0.535	16.3	33.3	2
2	0.500	16.3	33.3	2
3	0.416	16.4	33.3	2
4	0.198	16.3	33.3	2

And in order to confirm the safety for destruction, it was applied the Coulomb-Mohr theory. As a result, as <TABLE4.7>, but the compression side at all section out to be stable results, results in not stable comes beyond the failure criterion of the tension side.

The concrete tower was not stable beyond failure criterion can be expected because it was not considered a rebar that will receive the tension.

TABLE 4.7 Maximum and minimum principal stress of Recalculate has been the tower of concrete elements

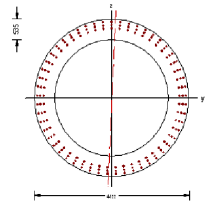
section	Shell elements	Maximum and minimum principal stress [Mpa]	Judgment results
1	Compression 142	-15.2, -1.74	OK
2	Compression 425	-15.27, -1.71	OK
3	Compression 829	-15.35, -1.63	OK
4	Compression 1279	-7.76, -0.59	OK

Prior to calculating the rebar, it was considered as the average diameter of inheritance ▪ bottom from each section. Strength reduction factor was applied to partial safety factor of 1.5 of concrete material that is presented in the provisions of GL. Rebar used was I was using the SD500. As a result, has been calculated is rebar amount such as <TABLE4.8>.

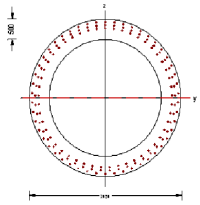
TABLE 4.8 Use rebar amount of tower of Recalculate has been concrete

section	Hegiht(m)	Steel bar arranement	Using reinforcement
1	0~10	Three reinforcement /159-H32	126277.8 mm^2
2	10~26	Three reinforcement /148-H32	117541.6 mm^2
3	26~48	Three reinforcement /125-H32	99275.0 mm^2
4	48~77	Three reinforcement /49-H22	18967.9 mm^2

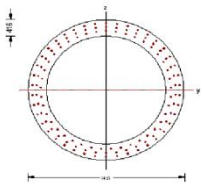
Concrete tower cross section reinforcement is considered based on the <TABLE4.8> can be expressed as follows.



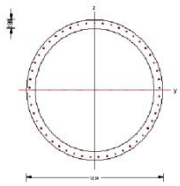
Section 1



Sectopm 2



Section 3



Section 4

Fig.13 Concrete tower cross section reinforcement is considered based on section1 to 4

V. COMPARED TO THE ANALYSIS OF CONCRETE TOWER ANALYSIS

I put the standard to 2 strength safety factor of concrete tower. Appropriate to me was carried out in two with 0.5% error rate in Trial & error method. Thickness is Recalculate was the same as <TABLE5.1>.

TABLE 5.1 Increase or decrease of the concrete tower thickness

Section	Initial model [m]	Re model [m]	Thickness of the increase or decrease [m]
1	0.564	0.535	-0.029
2	0.518	0.500	-0.018
3	0.416	0.416	equation
4	0.167	0.198	+0.031

5.1 natural frequency

By utilizing the thickness of the tower recalculation is concrete, in order to determine whether the resonance, and tried to analyze the natural frequency. Tower modeling was performed as those initial modeling. The total weight was made in the 822ton 4.5ton increased compared to the initial model. I tried to comparison with the initial model natural frequency of <TABLE5.2>.

Comparison result, the primary and third-order natural frequency is reduced, the natural frequency of the secondary can be seen that it has increased. Possibility of resonance of the tower is recalculated was analyzed to have the possibility of resonance of up to about 60% by the primary natural frequency.

TABLE 5.2 Comparison of the natural frequency of the concrete tower

n	Initial model	Re model
1	0.547Hz	0.530Hz
2	2.287Hz	2.323Hz
3	6.507Hz	6.487Hz

5.2 Buckling stability

By using the thickness of the tower of the re-calculation has been concrete, and gave a buckling stability analysis by axial load. <TABLE5.3> the

initial model and re-calculation has been critical load of the tower I tried to compared. As a result of the comparison, I was increased in all orders. These reasons, the seat buckling field load is determined to have increased by the total weight increase, while re-calculate the thickness. Moreover, re-calculated by concrete tower, the first-order mode, showed about 105% of the buckling resistance performance compared to the initial model.

TABLE 5.3 Comparison of the seat buckling world load of concrete tower

n	Initial model	Re model	P(KN)
1	108153	113643	
2	584664	634495	2008
3	1558197	1726261	

VI. RESULT

In this study, after interpreting the concrete tower in order to examine the behavioral characteristics of the concrete tower, was studied. Specifically, using the commercial software(Midas civil 2009) to satisfy the strength safety factor 2 with respect to the concrete tower, were calculated the appropriate thickness. In addition, to determine whether resonates through the eigenvalue analysis through each modeling, I examined the buckling stability against axial load. Therefore, the conclusions that have been derived through this research I was organized as follows.

First, the primary natural frequency of the concrete tower that is re-calculated were interpreted by 0.530Hz. If this is the possibility of resonance of the concrete tower is 60%. High strength concrete tower as compared to the existing tower is determined to have a particularly excellent performance whether resonance.

Secondly, as a result of a comparison of the natural frequency of the increase or decrease in response to the thickness of the increase or decrease, The primary natural frequency, regardless of the material was analyzed as the thickness of the bottom of the tower is the greatest effect. Then, the secondary natural frequency was analyzed that the thickness of the upper end of the tower is the greatest effect. Therefore, the tower design, to solve first order natural frequency of the problem, to be considered the thickness of the bottom of the tower in top priority is determined to be advantageous.

Third, re-calculated by the buckling threshold load value by the axial load of the concrete tower, was calculated to 113643KN in the primary mode. This concrete tower is obtained some beneficial results for buckling stability as compared to the existing tower. Therefore, concrete tower for buckling considering the load of the wind turbine, it is determined to be suitable than the existing tower.
However, in this paper, and developing a concrete tower, and the wind power tower basic research was performed to analyze behavioral characteristics associated with it, Additional research on effects of fatigue loading of concrete tower and more load assessment is determined to be necessary.

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