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Research on Lateral Shift Features of Diagrid Structure

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Abstract: The diagrid structure system is analyzed, based on the traditional general diagrid structure system. Compared with the vertical structure, it is more necessary to restrain the overturning moment due to the gravity for the tilted angle diagrid structure system. Two types of basic model and five kinds angle of the titled-diagrid model were made and analyzed, the shear lag effect and the lateral load resistance abilities were also analyzed in this paper.
Keywords: Diagrid System; Lateral Behavior; Shear lag effect.

1. OVERVIEW

1.1 Research background and purpose

The diagonal frame structure, as a high-effective structural system fully exploiting structural spatial potentials, uses various forms of vertical frame structures the skeleton of the outer envelope wall of the high-rise building, encloses the spatial grid-like simplified structure, and combines the vertical bearing and the anti-side force structure. At the meanwhile, the grid-like fashion of the diagonal frame structure has a strong geometric law, with a special architectural visual effect to be obtained.Two types of basic model and five kinds angle of the titled-diagrid model were made and analyzed, the shear lag effect and the lateral load resistance abilities were also analyzed in this paper.

1.2 Research method

A 60-layer general included framed tube structure and diagrid finite model is used in this research, which has a structure similar to that of the diagrid and includes 7.5 modular units (8 layers as a unit). This model is also analyzed. The shear lag efficient of the bottom plays an important role in the whole shearing lag of the building, so the shear lag coefficient is calculated and analyzed via the stress of the column at the bottom of the model and the results are compared in this paper.

The architecture model is established and analyzed by using the finite element analysis software MIDAS GEN 8.00 in this research.

2. SHEAR LAG PHENOMENA

The structure section in the structure will not observe the general beam theory in the structure of the framed cylinder under action of the horizontal load. The flange and web in the structure will bear the most bending moment and shear, so the positive stress of the corner column will increase and will gradually decrease at the middle under the shear deformation of the beam and bending deformation lag of the beam and columns, so it forms the curve distribution, which is different from the line distribution of the traditional bent structures. Such phenomena is called as the shear lag effect. The positive stress of the corner column will be less than the positive stress inside the column of the flange frame at the top of the structure. Such phenomena is called as the negative shear lag.

The axial force inside the cornet column will increase and the column stress remote from the corner column reduces, so it leads to high concentration of the corner column stress in the frame structure. Shear cannot be effectively transferred, so the web and flange frame are absorbed by the web and flange frame, shear lag occurs, and the flange frame is destructed.

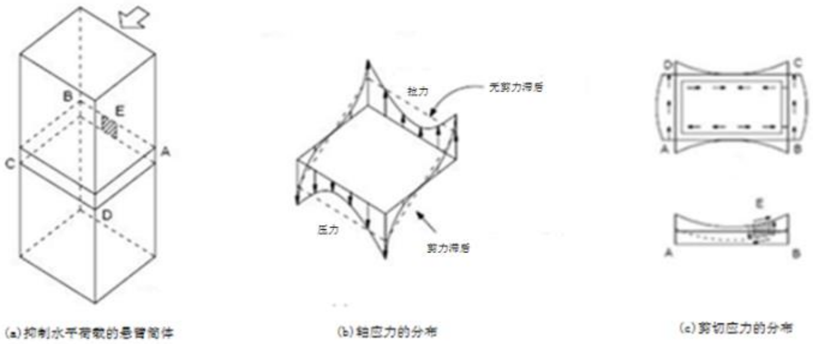

Figure 1 Shear lag effect

To better describe distribution of the internal column and corner column stress in the shear lag effect, the shear lag coefficient shall be used for data analysis. The equation is described as follows:

Shear lag coefficient=stress of internal column beam/stress of edge column beam

$$\text{shear lag coefficient} = \frac{\text{stress of inernal column beam}}{\text{stress of edge column beam}} \tag{1}$$

The shear lag coefficient of all columns under a cylindrical structure with certain height is 1. When the height is higher than it, the shear lag coefficient will exceed 1. If the shear index of the frame is 1, the shear resistance strength of the beam column shall be limitless based on the plain section assumption of the beam, so the shear lag coefficient at the bottom of the frame structure shall approximate to 1. It is difficult to reach it in actual framed cylinder structures. When the coefficient is about 0.7, generally the structure can effectively support the horizontal load.

3. MODEL OVERVIEW

The basic model used in this paper belongs to the inclined framed cylinder structure and diagrid structure. With 36×36m square as the plane, the gap between external columns is 3m, the floor height is 4m, total height of 60 floors is 240m and the finite element model has 6.7 slenderness ratio.

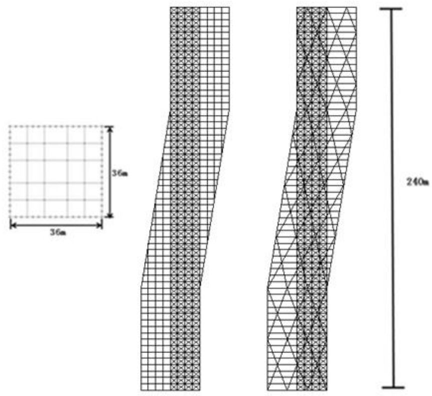

Figure 2 Tilted tube & Tilted diagrid model

The reference paper points out that the efficiency is maximal when the inclined crossing angle in the general inclined grid structure system is between 60° and 70°. The inclined crossing support angle of the model is set as 69.3° in this paper. The material section of the diagonal bracing and column is of box type and the beam section is of H type. The diagonal bracing is set with 8 layers as a unit and the layer number is 60. To easily describe the analysis results, we call the diagrid structure model as TD and calls the inclined framed cylinder as TT. We also establish the diagrid structure models with same section and different inclination angle for easy comparison and analysis. With calculation, the figure 3 is divided into five forms from whole structure inclination to partial inclination, which correspond to 4°, 7°, 9°, 13° and 20°. The kernel cylinder is set in the model. To keep the vertical position of the kernel cylinder not change, the model is established by continuously decreasing the floors of the inclined part in this paper.

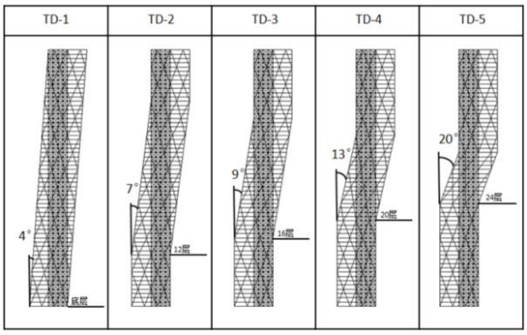

Figure 3 5 five kinds angle of the titled-diagrid model

4. RESULT ANALYSIS

4.1 Analysis on shear slag effect

The shear lag effect analysis aims to calculate the shear lag coefficient based on the stress of the vertical structures on the foundation after the model analysis.

The calculation results are shown as the figure 4. The shear lag coefficient of the inclined framed cylinder structure is 0.37. The stress of the vertical structures at the edge is about 3-time higher than that of the central structures.

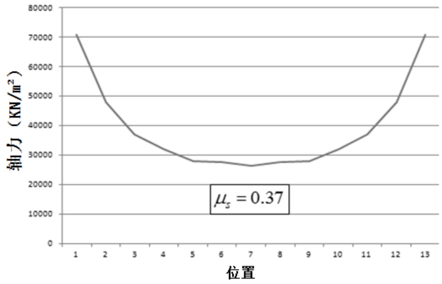

Figure 4 TT model axial force distribution of first floor

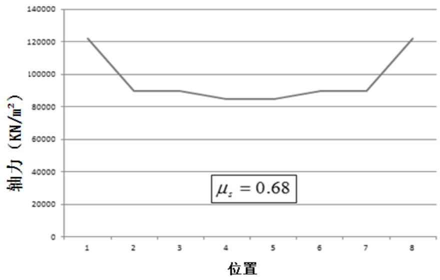

Figure 5 TD model axial force distribution of first floor

The shear lag coefficient of the diagrid structure model is 0.68. Shown as the figure 5, the ratio of the central structures of the diagrid structures to the external structures reduces by about 54% compared to the framed cylinder structure. For general inclined framed cylinder structure, the diagrid structure features better stress distribution effect.

4.2 Analysis on shear lag effect

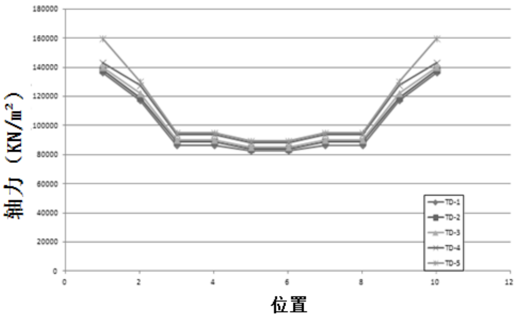

Figure 6 models axial force distribution of first floor

With change of the whole inclination angle of the model, distribution of the bottom vertical load stress of the diagrid structure model TD-1, TD-2,TD-3, TD-4 and TD-5 is shown as the figure 6. The shear lag coefficient can be calculated from data in the figure, shown as the table 1.

模型	TD-1	TD-2	TD-3	TD-4	TD-5
剪力滞后系数	0.43	0.61	0.68	0.66	0.56

Table 1 5 models' shear lag effect Coefficient

With change of the whole inclination angle of the model, distribution of the bottom vertical load stress of the diagrid structure model TD-1, TD-2,TD-3, TD-4 and TD-5 is shown as the figure 8. The shear lag coefficient can be calculated from data in the figure, shown as the table 1.

From the TD-1 model to the TD-3 model, the shear lag coefficient will increase to the maximum. Later the TD-5 model will gradually decrease. With TD-3 model as the benchmark, the shear lag coefficients of the model TD-1, TD-2, TD-4 and TD-5 decrease by 37%, 9%, 3% and 18% compared to the model TD-3. It shows that the gravity load distribution also changes continuously with continuous change of the model angle. The axial stress at the edge reduces and the axial stress at the middle increases, so the shear lag coefficient continuously grows. The shear lag coefficient of the model TD-3 approximates to 1 to most extent under same diagonal bracing gap, so the shear resistance strength of the TD-3 model is maximal in five models with different inclination angles.

In a word, the shear lag suppression effect of the TD-3 model with 9° whole inclination angle is the excellent under the action of the horizontal load such as wind load in case of five different whole inclination angles.

4.3 Analysis on lateral shift

The applicable ranges of the maximal lateral shift of five diagrid structures with different forms are compared and analyzed under action of the wind load. The results are shown as the figure 7. Except TD-4 model from 12th floor to 48th floor, the lateral shift range of other models does not exceed the maximal lateral shift range. It indicates that the structures without rigid sections can satisfy the requirements of the maximal applicable shift (H/400). On the contrary, for the floors above 60th floor, the building will approximate to a super-high building and the lateral shift resistance of the structural system shall be considered.

For the same inclined crossing angle 69.3°, the lateral shifts of five models with different inclination angles are compared. Based on the TD-3 model, the resistance effect of the lateral shift of TD-1, TD-2, TD-4 and TD-5 respectively reduces by 3.2%, 6.5%, 2.6% and 1.4%. The upper part and lower part of the kernel cylinder model are linked with the external structural system to form the integrated change. On the whole, the lateral shift from the TD-1 to TD-2 model grows. The lateral shift of five models reaches the minimum in the TD-3 model, so the TD-3 model can resist the lateral shift in the diagrid structural system to the most extent and can effectively suppress the lateral shift.

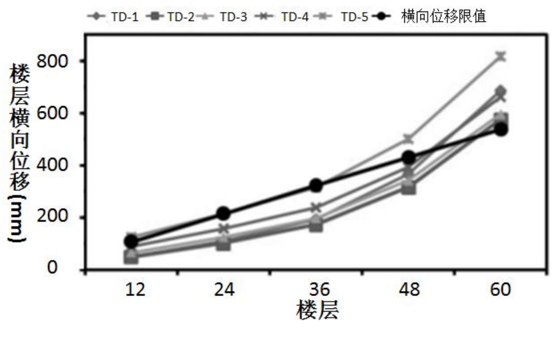

Figure 7 Maximum lateral displacement range of each model

4.4 Analysis on lateral shift of seismic load

Generally analysis on the seismic load of buildings aims to analyze resistance of buildings to the horizontal seismic load. Generally the analysis methods include the static analysis and dynamic analysis. The Korean modern anti-seismic benchmark points out that static force and dynamic force will be analyzed for buildings. The response spectrum and time history analysis are frequently used in the dynamic analysis, but generally the high-order vibration modes have significant influences in the super-high structures. If the response spectrum is used, no accurate peak structure can be obtained. The time history method is used for analysis in this paper.

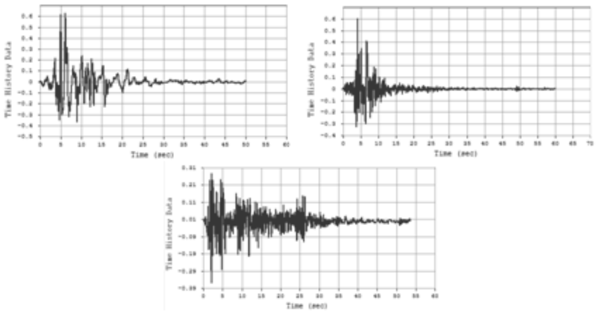

Figure 8 Northrige, Hyougoken, El centro Seismic wave

To analyze the time history of the dynamic forces, we select three seismic records suitable for Korean architecture benchmarks (KBC2009). The seismic wave such as Northrige, Hyougoken and El Centro are regulated and used according to anti-seismic design. 5% seismic damping ratio is assumed and the time history of the dynamic forces is analyzed.

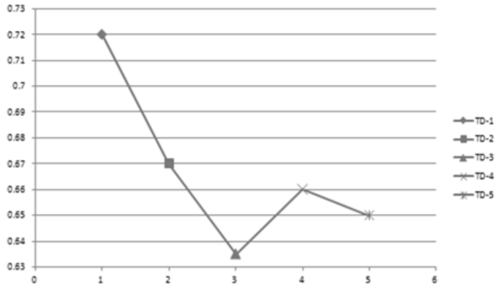

Figure 9 The top placement of 5 models

Shown as the figure 9, for five models with different inclination angles, the TD-3 model has the minimal top floor lateral shift and the top floor lateral shift of the TD-1, TD-2, TD-4 and TD-5 model increases by 15.3%, 7.6%, 6.2% and 4.5%. On the whole, the lateral shift will grow from the TD-1 model to the TD-3 model and the lateral shift of the model TD-3 reaches the maximum. Although the lateral shift of the TD-4 model increases little, the lateral shift of the TD-5 model reduces again, but the lateral shift of the TD-3 is minimal.

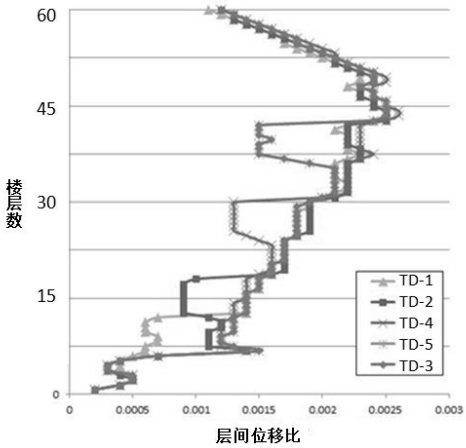

Figure 10 Story drift ratio of 5 models

Shown as the figure 10, the lateral shift of five inclination models does not exceed the limit 0.015 for the inter-floor shift ratio regulated in the anti-seismic regulations. when the whole inclination angle of the model continuously grows, the maximal inter-floor shift ratio will also grow from 3.5% to 5.3%. in a word, the TD-3 model has the top anti-seismic capabilities in five inclination models.

5. CONCLUSION

(1) The force distribution of the diagrid structure along the inclined support is more uniform compared to the inclined framed cylinder structure under the same whole inclination angle, so it can improve the deformation control of the structure under the force status and distribute forces better. Although the lateral shift of the two structures exceeds the limit 600mm under the wind load, the inclined grid structure has a smaller top floor shift and features stronger resistance to the lateral shift.

(2) For five same models with different inclination angles, with growth of the inclination angle and reduction of floors, the TD-3 model with 9° inclination angle can better suppress the shear lag. The shear lag coefficient approximates to 1 most and the structure can bear the force better.

(3) Although the models with five inclination angles do not exceed the inter-floor shift ratio 0.015 regulated in the anti-seismic regulations, the top floor lateral shift of the TD-3 model is minima and features stronger resistance to the horizontal load compared to other structural models, so the diagrid structure with 9° whole inclination angle is an excellent structure.

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