STUDY ON TALL BUILDING STRUCTURE ANALYSIS

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ABSTRACT

TBSA (Tall Building Structure Analysis) is a three-dimension analysis program for tall buildings based on a member structure model. In the program, beams, columns and braces are defined as space bar members, with 6 freedoms on each end. Shear walls are defined as thin-walled column members with buckling, with 7 freedoms on each end. It is assumed that floors have infinite in-plane stiffness and no out-plane stiffness. Version 6.0 is a new version based on new Building Codes of China. In version 6.0 there are many new features added to enhance the usability and quality. This paper illustrates some of the new features and discusses some points that should pay attention to when we analyze tall building structures with the program.

KEY WORDS

tall Building, analysis, space bar, thin-walled column, infinite in-plane stiffness.

1. NEW FEATURES

1.1. INTRODUCTION

TBSA (Tall Building Structure Analysis) is a three-dimension analysis program for tall buildings based on a member structure model. In the program, beams, columns and braces are defined as space bar members, with 6 freedoms on each end. Shear walls are defined as thin-walled column members with buckling, with 7 freedoms on each end. It is assumed that floors have infinite in-plane stiffness and no out-plane stiffness.

The program has no specific requirements on structural system. The structures may be unsymmetrical and non-rectangular in plan. TBSA can analyze not only general frame structures, frame-shear wall structures, tube structures, but also those more complex such as multi-tower structures, Staggered floor structures and connected buildings.

For nearly 20 years, the program has been used in thousands of buildings all over the country.

Version 6.0 is a new version based on new Building Codes of China. In version 6.0 there are many new features added to enhance the usability and quality.

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1.2. NEW GRAPHICAL USER INTERFACE

The graphical user interface is used to model, analyze, and display the results for your structure.

Figure 1 shows the main window of the new graphical user interface. This window may be moved, resized, maximized, minimized, or closed using standard Windows operations.

The main title bar, at the top of the main window, gives the program name and the name of the data file. The menus on the Menu Bar contain almost all of the operations that can be performed. The buttons on the toolbars provide quick access to many commonly used operations. Status Bar shows the information about what the program is currently doing, the coordinates of the mouse cursor, the current floor and the current standard floor.

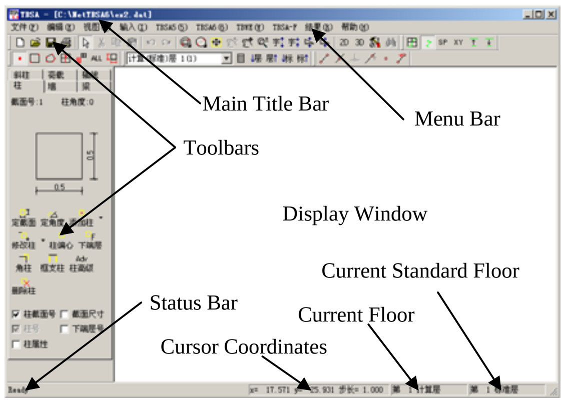

Figure 1. new graphical user interface

Display window shows the geometry, loading, or analysis results of the structure in 2D or 3D view. A 2D view shows a single floor. A 3D view shows the entire structure in an orthographic projection.

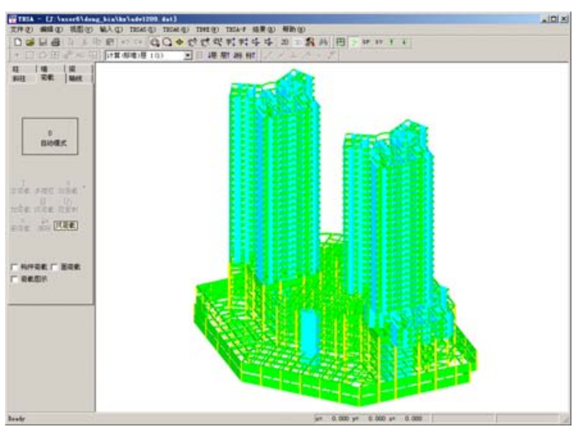

Figure 2 . OpenGL rendering

The OpenGL rendering feature depicts the structure in realistic 3D lighting and texture. The animate feature allows users to graphically view displacements, mode shapes in an animated mode.

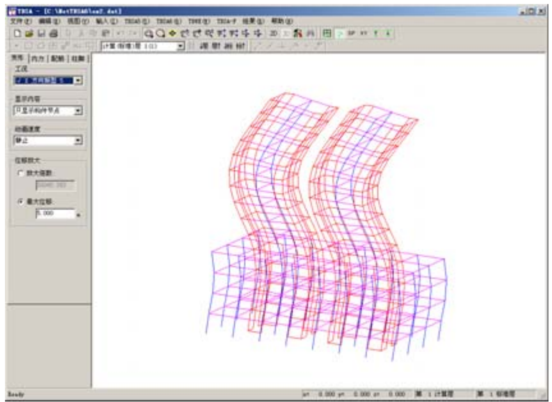

Figure 3 mode shapes in an animated mode

1.3. NEW ANALYSIS FEATURES

Version 6.0 can analyze steel structures, profile steel concrete structures and special-shaped column structures in addition to the reinforcement concrete structures and steel tube concrete structures that previous version can do.

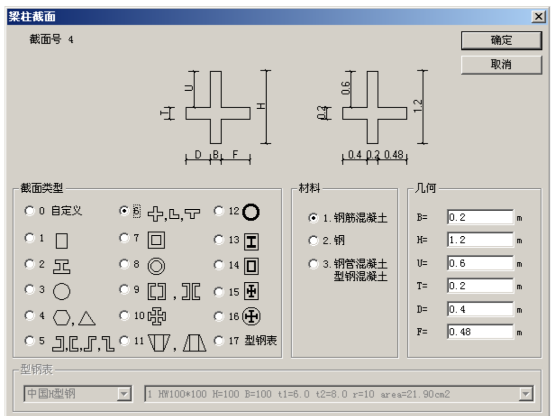

Figure 4 . sections

Dead load and live load can be input and calculated separately.

Properties of members such as material and earthquake-resistance class can be assigned individually. It makes the design work more accurate.

Version 6.0 offers the options that the following factors may be considered in analysis:

Basement with or without lateral restraint.

Bi-directional seismic load.

Random decentration effect.

Independent members and nodes.

P-Delta analysis.

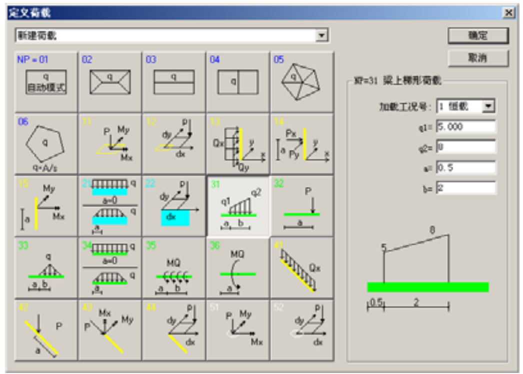

Figure 5. loads

2. POINTS THAT SHOULD PAY ATTENTION TO

Analysis is an important part in the procedure of tall building structures design. The analysis results have great influence to the dimension and reinforcement of the members, as much as, to the project. So we think much of analysis. Now we discuss some points that should pay attention to when we analyze tall building structures with the program.

2.1. SELECTING ANALYSIS MODEL

The first step of any structure analysis is to select an appropriate analysis model that can objectively represent the stress of the structures.

In mechanics, the accuracy of a model needs two preconditions, first the displacement must be continuous, secondly the load transfer path must be correct. Most of the buildings with regular plane and elevation layout can meet the requirements. But for those with irregular elevation, they can hardly make the displacements continuous.

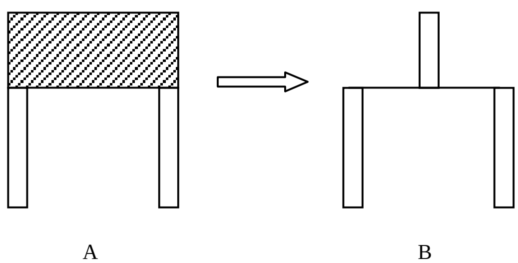

Figure 6 . frame-supported shear wall

For example, in a frame-supported shear wall structure, a single piece of shear wall supported by a beam as shown in figure 6A. Actually, the load of the shear wall distributes uniformly onto the beam then transfers to the columns. According to the simplified model shown in figure 6B, the load of the shear wall applies as a concentrated force to the frame-supporting beam then transfer to the columns below. This simplification ensures that the load transfer correctly. To make sure that the displacement of the model approaches that of the real structures, the stiffness of the frame-supporting beam should be considered larger than it is. When modeling, we can assign the beam's width as its actual width and assign its height as half of the story.

If it is a multiple shear wall on the frame-supporting beam, we can select the column that most close to the shear center of the shear wall as loading transfer point, connect each frame-supporting column by deep beams, to make sure that the load of the shear wall be supported by these columns together.

2.2. Shear force adjusting of multi-tower frame-shear wall buildings under seismic load

To adjust shear force of single-tower frame-shear wall buildings, we first find the maximum value of total shear force of all frame columns in each story, then multiply this value by 1.5, compare the result with 20% of basis shear force, get the less one. This adjustment is made for the horizontal seismic load.

To adjust shear force of multi-tower building, which consisting of several towers rising from a common base, we should take notice of that the adjustment is made in each tower separately and the 0.2Q0 refers to basis shear force of each tower.

2.3. Basement with lateral restraint

The program is for superstructures of tall buildings considering the base of building as fixed. It offers the options that the coactions of the superstructure and the basement may be considered.

The users can input the number of stories of the basement, wind load of these stories will be set to zero, the height of each story for wind load will be counted from the story above the basement.

The users can also input the number of stories of the basement with lateral restraint, the lateral displacement of these stories will be set to zero. The height of these stories will be removed from the height of the building. Load combinations are applied with the new height of building.

2.4. Random decentraction and bi-directional seismic load

According to the new code for seismic design of buildings, the torsional effect of horizontal bi-directional seismic loads should be considered. In the new technical specification for concrete structures of tall buildings, the random decentration effect should be considered while calculating single-directional seismic loads

If we analyze a building with random decentration and bi-directional seismic loads considered simultaneity, the reinforcement may be much more than reasonable. Therefore, if the bi-directional seismic loads are calculated, the random decentration effect may be ignored.

2.5. Construction sequence loading

In most analysis of tall buildings, it is assumed that the structure is not subjected to any load until it is completely built. In reality the dead load of the structure is continuously being applied as the structure is being built. The vertical members such as the columns and the shear walls continuously deform axially during the construction. Their force should be calculated in the case that dead loads are applied floor by floor as shown in figure 7.

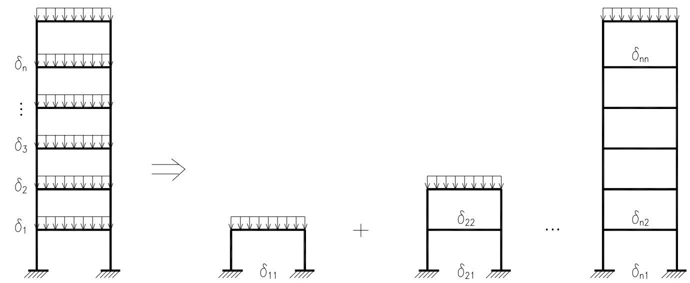

Figure 7 Construction sequence loading

However, after the building is built, the dead loads applied on it are long-term, moreover, the columns have larger values of axial compression ratio than the shear walls, their time deformations are obviously larger than that of the shear walls. After redistributed, the internal forces of the structure approach to the results of one-time loading. So the internal forces of the structure are intermediate between these two situations.

The program introduces an approximate construction sequence loading method as shown in figure 8. The stiffness matrix is completely formed at one time and the loads are applied floor by floor. In other words, when the loads are applied to a certain floor, the deformations of this floor and the floors below are effected by the stiffness of this floor and the floors above.

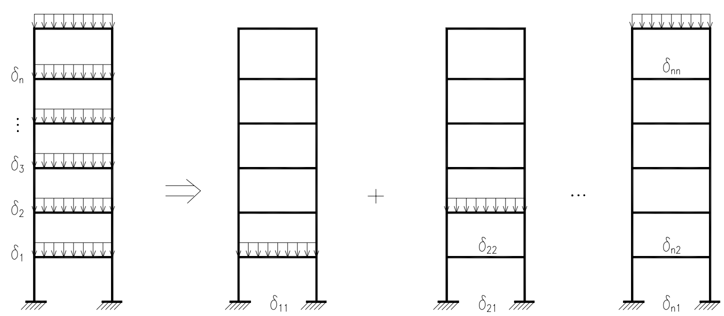

Figure 8 Approximate construction sequence loading

For those complex buildings such as multi-tower buildings, the users may specify different construction sequence loading in the program according to the different construction sequence in reality.

2.6. ENLARGING SEISMIC LOADS OF WEAK FLOORS

It is prescribed in the code for seismic design of buildings and the technical specification for concrete structures of tall buildings that the seismic shear force of weak floor should be multiplied by a factor of 1.15.

Here is the definition of “weak floor”. According to definition of vertical irregular structure in the code for seismic design of buildings, a floor meets one of the following conditions will be defined as weak floor:

(1) The lateral stiffness of this floor is less than 70% of that of the adjacent upper floor or 80% of the average of that of the adjacent upper three floors.

(2) The shrinkage in horizontal dimension of this floor is large than 25% of the dimension of the adjacent lower floor, except that this floor is the top floor or it is in a multi-tower building.

(3) The internal forces of the vertical members resisting lateral loads transferred by horizontal transferring members.

(4) In a structure resisting lateral loads, the shear bearing capacity of this floor is less than that of the adjacent upper floor.

Besides, the seismic shear forces of the floors with staggered or connecting structures or with large cantilever members also should be enlarged appropriately.

In the program, the lateral stiffness of each floor and the stiffness ratio of adjacent floors are given. The designers select the weak floors according to the situations of their projects, the program enlarge the seismic shear forces of the selected floors.

REFERENCES

The Ministry of Construction of China, Code for Seismic Design of Buildings.

The Ministry of Construction of China, Technical Specification for Concrete Structures of Tall Buildings.

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