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Construction Simulation Analysis of Assembled Concrete Shear Wall Structure

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Abstract: With the continuous promotion of the sustainable development strategy and the transformation of the construction industry, the green manufacturing is not limited to industry and manufacture. The modernization of the construction industry is the only way for the Chinese construction industry to get rid of the problems like shortage of labour, waste of resources, environmental pollution and accidents, etc. It is of great significance to realize green sustainable development. At present, assembled buildings in China are still in the stage of conceptual development and construction technology exploration. Taken a community as the actual background, ANSYS and SAP2000 are used in this paper to simulate a construction of assembled shear wall structures. Force and deformation of the partial shear wall and the whole shear wall are analysed in the whole construction process, which provides a reference for the construction of the assembled shear wall structure.

1. Introduction

According to the definition of green manufacturing, the area of green manufacturing involves three parts: the problem of manufacturing (including the whole process of product life cycle), the problem of environmental protection, and the problem of optimization and utilization of resources. Green manufacturing is the intersection of these three parts. The modernization of the construction industry [1] usually refers to a production mode that replaces the traditional construction industry in the decentralized, low - level, low efficiency of the handicraft production through the modern manufacturing, transportation, installation and scientific management of the production of large industries. Its main symbol is the main production methods are component prefabrication production and assembly construction, characterized by design standardization, component parts, and construction mechanization. Through the use of information technology, it can integrate design, production, and construction into the entire industrial chain. To realize the sustainable development of new building production methods that maximize energy efficiency, environmental protection and maximize life cycle value of construction products. This also indicates that under the background of sustainable development, the modernization of the construction industry is fully covered by green construction. The assembled building is not the whole of industrialization, but an important part of it. Currently, the construction industry promotes industrial restructuring to respond actively to the slogan of green energy conservation and efficient development. In order to improve the core competitiveness of the construction industry, assembled construction has become a new phase of exploration. Also, the construction of the shear wall structure has become the key research object.

2. Theoretical basis

At present, there are two theoretical sources for simulation analysis of structural mechanical properties during the construction process, namely birth-and-death element techniques and step-by-step modeling techniques. Based on the existing finite element software ANSYS and SAP2000, this paper establishes the finite element model for the construction analysis of single-story double-story shear wall and overall structure of residential building, providing a useful reference for the actual construction of the project.

2.1 The birth and death element technology

The birth and death element technology is mainly used for the simulation of welding, excavation analysis, and other directions in the current structural analysis The "birth and death" operation of the birth and death element technology does not really add or delete cells, but rather changes the element stiffness matrix. The basic idea of brith and death element simulation in finite element analysis is that according to the structural design requirements, all the elements are established at one time. Then, referring to the actual construction process, all elements to be added to the subsequent load step are "killed". Finally, the elements corresponding to each construction step are activated according to the actual construction sequence, and appropriately apply and delete the corresponding constraints and loads [2-4]. Based on the above ideas, the loading simulating of the components during the construction process is simulated, and the mechanical performance of the structure during the construction process is analyzed.

Figure 1 in this section shows the process diagram of the cantilever structure (including two sections) in birth life and death element technical analysis. It provides a numerical operation process for the birth and death element technology.

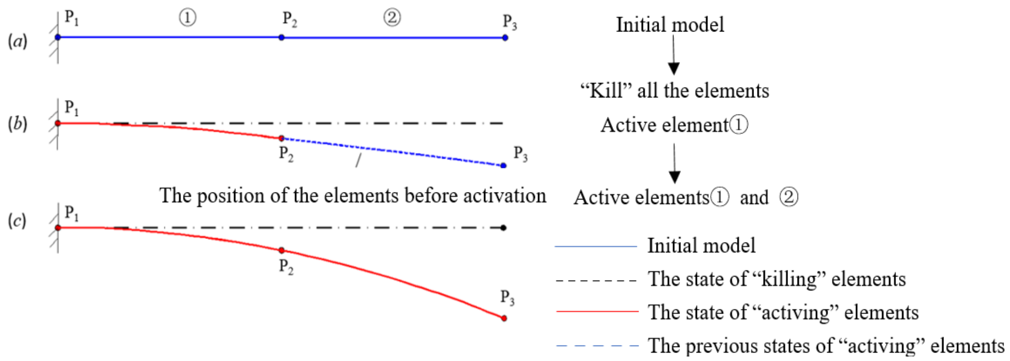

Figure 1. Analysis process of cantilever structure with element birth and death technology.

2.2 Step-by-step modeling techniques

The main simulation principle of step-by-step modeling technology [5-7] is dividing the construction steps according to the actual construction conditions and establishing the corresponding structural model for each construction step gradually. The principle of step-by-step modeling technology also means that,the finite element model was established independently of the construction step in the simulation of the entire construction process. When the complete model of each working condition is established, the birth and death order shall be re-executed, and the calculation shall be performed one by one from the first working condition and then calculated until all the working conditions (the actual construction completion status) are completed.

3 Finite Element Models and Numerical Analysis Results

3.1 Construction Process Analysis Model

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The key to construction simulation of the structure is that the model itself is consistent with the actual structure, including the structural parameters such as the stiffness of the model; the second key is making simulated construction process consistent with the actual construction. The influence of interlayer leveling on vertical deformation is ignored in the analysis of traditional multi-layer structure design, which leads to the use of one time loading method in the construction loading simulation in the design analysis. For the assembled structure, the biggest difference between the structural design and the traditional design is that the components need to be further designed considering the on-site assembly.

The completion of a structure involves the influence of many parameters. It is very difficult to do a complete equivalence simulation of the actual structure. When the application software is used to perform structural construction simulation, appropriate assumptions are generally made on the basis of actual construction, and the main factors are considered to be analyzed by simplified methods to fit the actual situation.

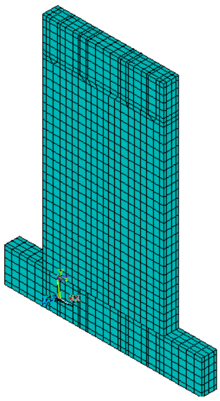
In this paper, simplified simulation analysis is conducted based on actual engineering shear wall installation .it is basically assumed that the components around the shear wall have been installed, and the specific procedures are as follows:

(1) Prefabricate cast-in- place beam firstly, and the intercalation shall be embedded on the upper surface of the ground beam;

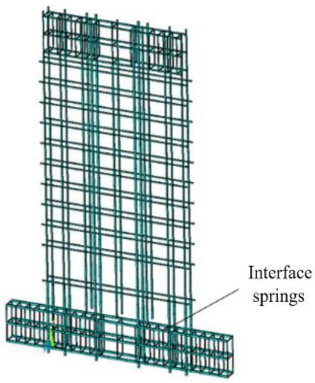
(2) The assembled walls are installed on the ground beams, and the assembled holes are connected with grouting ground beams and the first wall;

(3) The second wall is mounted on the first wall and grouted.

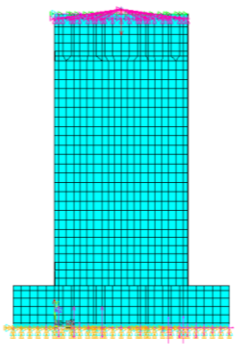
The shear wall finite element model established is shown in Figure 2.



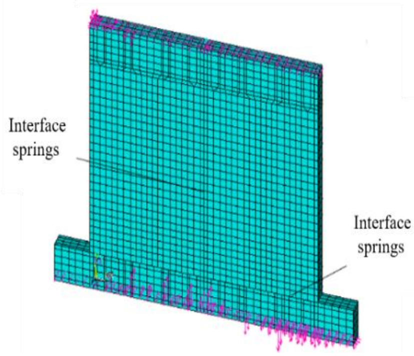
(a) Concrete element.



(b) Rebar element.



(c) Finite element model of single shear wall.



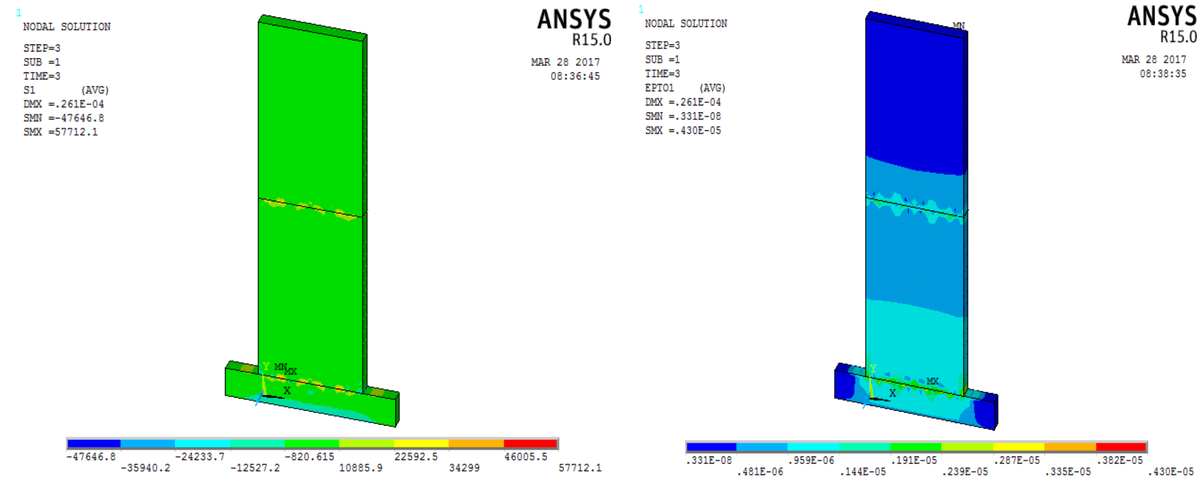
(d) Finite element model of double shear walls.

Figure 2. Finite element model of shear wall.

At the same time, the simplified simulation analysis was carried based on actual engineering shear wall installation in this paper, according to the construction pattern of the actual assembled shear wall structure, uses the layered installation procedure to carry on the approximate simulation. It is assumed that each component is defined according to the actual section characteristics. Loads in the construction stage only consider the effects of the dead load and the live load of the floor, which are selected according to the actual design load values.

3.2 Numerical results of two-story monolithic shear wall construction simulation

The simulation of the construction process to partial shear wall is realized by the birth and death function of ANSYS. The Figure 3 shows the response diagram of the shear wall to the model at the third working procedure. At this time, it is assumed that the intensity of assembled shear has reached.to that of construction before the next process.



(a) The first stress nephogram. (b) The first strain nephogram.

Figure 3. Model deformation nephogram at third procedure.

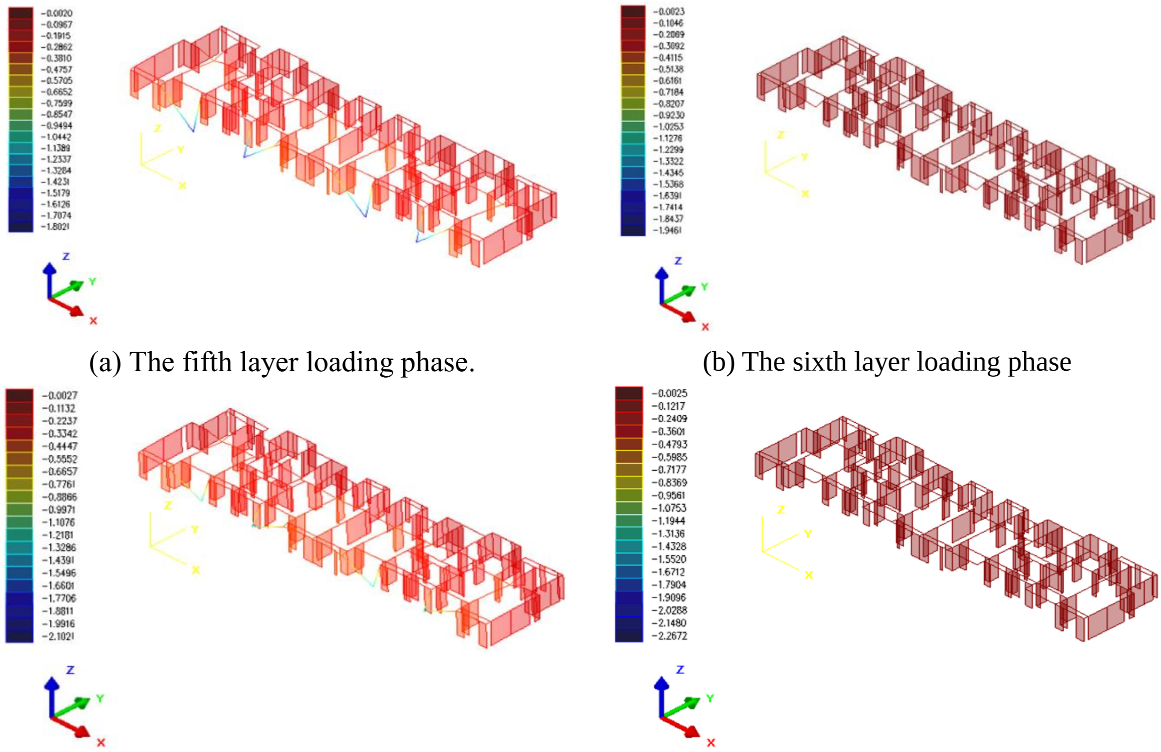
The ANSYS birth and death element technology is used to simulate the installation process of the partial shear wall components. Regardless of the transient effects of contact, the stress-strain cloud diagram of the component model can be obtained Figure 3 show that the upper and lower members are in contact during the installation of the upper shear wall. The stress value of the concrete in the middle area of the surface and the boundary area of the contact surface is the largest. After the third process is completed, top shear wall is installed. At this time, the maximum stress value at the interface between the first shear wall and bottom beam is 5,7712.1 MPa, and the maximum strain value is 0.430×10^{-5}, corresponding to the maximum. Effect force value is 315765 MPa and the maximum equivalent strain value is 0.129×10^{-4}. The maximum principal stress value of the contact surface between the second shear wall and lower shear wall is 22592.5MPa, and the most important strain value is 0.287×10^{-5}. The components are in a safe state.

3.3 Numerical simulation results of fully-assembled shear wall construction

According to the construction sequence diagram given in Figure 4, the loading construction simulation is performed. Due to limited space, the internal force and displacement response of the overall structure of the fourth floor are taken as description objects, and the results of the internal forces and deformations at each construction stage are explained. Figure 4 shows the internal force deformation response diagram of the fully assembled shear wall structure at various stages of construction.

From the displacement analysis of the fourth floor in the loading stages of the upper floors, it can be seen that the deformation pattern of the fourth layer remains the same, and the overall displacement deformation value is increasing gradually.

As shown in Table 1, the 12-axis in each construction phase corresponds to the internal force value of the fourth-floor frame. The corresponding position of each node in the table is shown in Figure 5.



(a) The fifth layer loading phase. (b) The sixth layer loading phase

(c) The seventh layer loading phase (d) The eighth layer loading phase.

Figure 4. The fourth floor displacement nephogram at load phase.

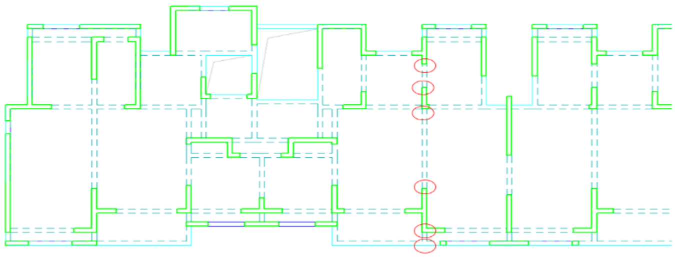


Figure 5. The location map of ridge.

Table 1. Inner force values of the forth layer at each construction stage.

Stages	Position	Column number	25	26	27	28	29	30
Layer 5 loading	4	Bottom	93.16	82.83	120.23	33.61	7.79	13.58
		Top	-90.26	-79.79	-117.33	-30.71	-4.89	10.68
Layer 6 loading	4	Bottom	139.74	124.24	180.34	53.64	11.68	20.38
		Top	-136.84	-121.34	-177.44	-50.74	-8.78	-17.48
Layer 7 loading	4	Bottom	196.32	165.65	237.45	70.14	15.57	27.17
		Top	-183.42	-162.75	-234.55	-67.24	-12.67	-24.27
Layer 8 loading	4	Bottom	234.76	216.05	317.35	89.86	19.54	34.04
		Top	-231.86	-213.15	-314.45	-86.96	-16.64	-31.14

Note: Axial force units in the table: kN

From Figure 5 and Table 1, it can be seen that the 5th layers are gradually loaded into the entire structure to complete the construction,the axial force values of each component on the 12 axis is continuously increasing, and the displacement values of both the dead load and the live load increase continuously.

Then structural analysis is performed for each construction stage, and the structural cycle is shown in the table 2.

Table 2. Structural cycle of each construction stage.

Construction stages	T_1	T_2	T_3
Layer 5 loading	0.2922	0.2636	0.1883
Layer 6 loading	0.3500	0.3238	0.2301
Layer 7 loading	0.4121	0.3908	0.2765
Layer 8 loading	0.4812	0.4667	0.3287
One-time loading	0.5034	0.4912	0.3426

T_1, T_2, and T_3 in the table represent the first self-vibration period, the second self-vibration period mainly based on the translation, and the third self-vibration period mainly based on the torsional motion.

As can be seen from the table 2, with the continuous loading of the upper floors, the overall natural vibration period of the structure continues to increase, with the first self-vibration cycle dominated by translation increasing to 0.4812, and the second mainly by translation of self-vibration cycle increasing to 0.4667, while the third period of self-oscillation dominated by torsion increasing to 0.3287. A one-time loading of a fully assembled structure is completed. The first self-vibration period with translational motion is 0.5034, the second self-vibration cycle with translational motion is 0.4912, and the third self-vibration cycle dominated by torsion is 0.3426. Compared to layered loading, the overall self-oscillation cycle of the one-time loading structure is larger.

4. Conclusions and Prospects

Based on the birth and death element technology of ANSYS and SAP2000, the simulation is taken to analyze the construction process of the local shear wall and the monolithic structure respectively. The results show that the actual construction of the shear wall member has good mechanical properties and meets the requirements of the standard design. Then the simulation of two-layer loading is taken with the same parameters. It indicates that the maximum stress and strain of the shear wall increase with the higher load, located in the interface spring area of the contact surface of the shear wall components and the edge area of the wall. For fully assembled structures, the numerical results are different between the step-by-step loading modeling analysis and one-time loading analysis.

Given that the actual construction technology of assembled concrete shear wall structures is still in exploration and development stage, various kinds of construction technology have not formed a mature construction system. In this paper, the construction simulation of assembled shear walls is simplified partially. The construction simulation of the structure is performed in a simplified cassette assembly mode for construction simulation analysis. With the development of assembled construction technology, further detailed analysis of the construction process in accordance with the actual construction process is expected to provide a more effective basis for the actual assembly.

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