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Construction Simulation Analysis of Large and Complex Structures based on Time-varying

Zeng Fankui and Hou Yanfeng
Xi'an Technological University, Xi'an, 710021, China

Abstract: The key issues that the construction of large and complex projects has brought to existing design and construction is construction mechanics analysis of the structure construction process. With the construction mechanics method, pre-construction process analysis can not only optimize structure construction schemes but also be compared with the measured data from construction synchronization to ensure that structure construction can be carried out smoothly and safely. The finite element model of DAGOBA construction process simulation analysis as well as tracking simulation analysis on the whole construction process should be established to get preset value and to plot the displacement curve of the key points of structure. And it should be compared with data of field measurement to ensure the structure safety in the construction and that the stress and deformation on the completing status meet the design requirements.

Key words: Large and complex structures, time-variation, construction mechanics, field measurement

INTRODUCTION

With the vigorous development of national economic construction and the growing of the construction scale of all kinds of projects, major projects such as new CCTV main tower, national stadium Bird Nest DAGOBA of temple FAMEN are springing up (Xu and Ma, 2008). The construction of these projects demands that we should not only consider the projects we design and build but also the dynamics and interactions of the intermediates during the construction. As a result, Construction Mechanics, a new branch of engineering mechanics, which is closely related with construction is formed by analyzing structure and works media. Construction of large and complex structure is continuous process, while the stress state is changeful. Because structure stress and displacement of last phrase must have an influence on that of latter phase, stress and strain of every phase should be tracked and computed to get exact cumulative effect of structure stress and displacement. Meanwhile each construction is changing with such factors as diversification of boundary conditions, members, temperature and pre stress of pre stressed structure.

All of these should be reflected in tracking computing to obtain exact result (Cao, 2001). According to the construction process of construction site DOGOBA, secondary development of construction process is performed on the ANSYS stage. Mechanical Behavior during construction is researched by the combination method of numerical calculation and site monitoring to provide reliable proof for the safety of structure construction.

PROJECT OVERVIEW

DAGOBA of temple FAMEN is located 10 kilometers from the north of county FUFENG of region Baoji province Shanxi. Temple FAMEN, known as worshiping Buddha' s finger relic, is 110 km from city Xi'an in the east and 90 km from city Baoji in the west. The main tower uses section steel and concrete combination structure and his hands clasp together in vertical so that conjoined structure is formed by interconnecting on the top. Main tower, 148 m in height, covers n area of 41000 sq. m. There is one floor (6456 m^2 in the area) underneath used for worshiping SAKYAMUNI Buddha's finger relic. There are 11 floors above whose

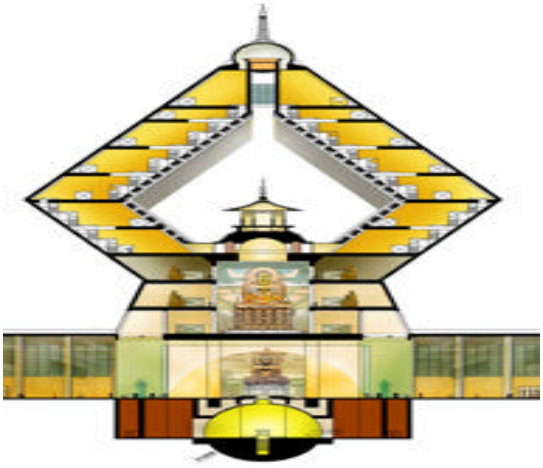


Fig. 1: Main tower sectional view

Corresponding Author: Zeng Fankui, Xi'an Technological University, Xi'an, 710021, China

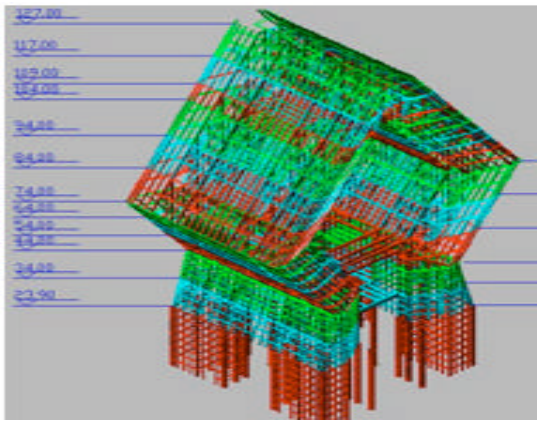


Fig. 2: Steel skeleton distribution view

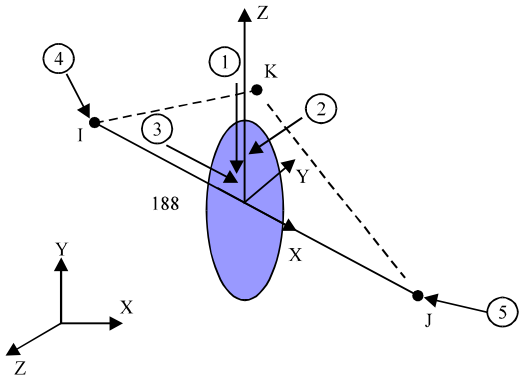
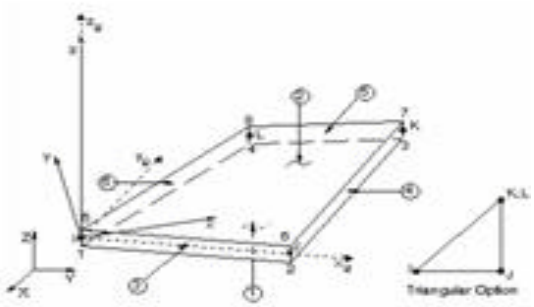


Fig. 3: Unit BEAM 188



x_{IJ} = Element x-axis if ESYS is not supplied
x = Element x-axis if ESYS is not supplied

Fig. 4: Unit shell 63

total building area is 76690 m^2 (Fig. 1). The steel skeleton is characterized by system complexity, hard to control the overall deformation and local deformation, diverse affecting factors on structure positioning and accurate measurement and big inclined cantilever in the construction. All of these bring lots of challenges to construction. The tower for the time being is the highest Buddha building under construction (Fig. 2).

ESTABLISHMENT OF FINITE ELEMENT MODEL OF CONSTRUCTION SIMULATION ANALYSIS OF LARGE AND COMPLEX STRUCTURES

In general, numerical simulation method in the construction consists of finite element method, time-varying element method, super element and finite element coupling method and so on. New CCTV main tower was built earlier than DAGOBA tower of temple FAMEN. Both are classified into inclined high-rise building. Aimed at new CCTV main tower, phased comprehensive iterative method is raised by Guo *et al.* (2007) to make a accurate calculation for deformation preset value .The computing results have been applied to the process of the machining and installation of steel structures.

Steel skeleton of section steel of DAGOBA tower of temple FAMEN consists of steel column in vertical and steel beams in horizon. The key points of establishing structure analysis model in the construction is that we should try to match the stiffness, loads and construction steps applied in analyze with that in reality as much as possible. Section-steel steel skeleton of Tower DOGOBA of temple FAMEN consists of steel skeleton column in vertical and steel skeleton beams in horizon. The key points about establishing analyzing structure model in the construction are that stiffness, loads and construction steps used in analyzing should be matched with that in reality as much as possible. Section steel skeleton uses unit BEAM 188 to simulate, as it's shown in Fig. 3. The unit is suitable for analyzing beam structure varying from slim to coarse. It is based on Timoshenko structure theory of beams and the influence of shear deformation is taken into consideration. Unit BEAM188 allows self definition on the size of cross section and support elastic, creep and plasticity model. Cross section related to this unit is allowable in using many kinds of materials. Unit shell 63 is used to simulate concrete angle barrel, arm wall, slabs as well as connected box on the top, as it is shown in Fig. 4. Shell 63, elasticity shell unit, has the properties of bending and membrane and it can stand the loads from parallel plane and the vertical plane. Each node has six degrees of freedoms: Translational degrees of freedom in the direction of X, Y and Z axis and turning degrees of freedoms surrounding the axis of X, Y and Z. This unit including the ability of stress strengthening and large deformation can choose continuous shear matrix used to

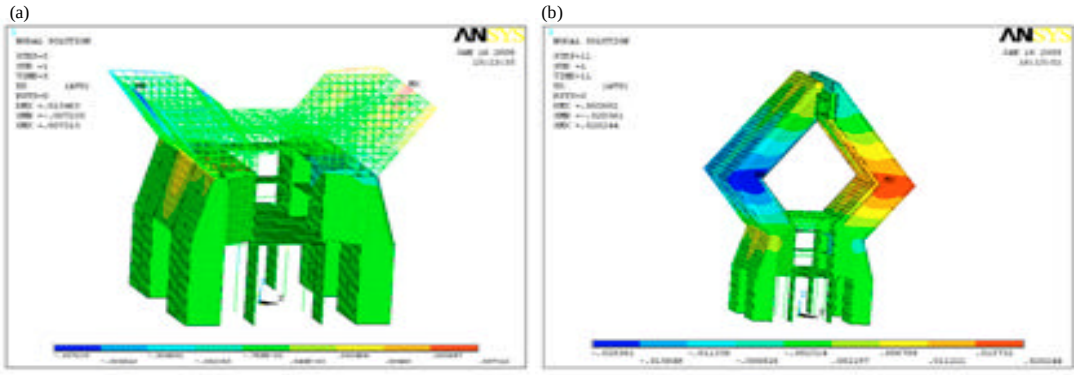


Fig. 5(a-b): Finite model of construction simulation analysis of Tower DOGABA

analyze big deformation (limited rotating). Equivalent simulation is made between the stiffness in plane and stiffness outside the plane when dealing with arm cavity wall and cavity slabs.

The basic idea of using "Life death" method of unit ANSYS to simulate the structure construction is: Establishing complete finite model of structure at one time, killing all the units, activating them according to the construction steps, applying loads of correspond construction, then tracking and analyzing the process of developing stress and varying deformation in the construction. This text made a profound research on unit life death method and finite element model simulating the construction process of the established tower DOGABA is shown in Fig. 5.

CONSTRUCTION SIMULATION ANALYSIS OF TOWER DAGOBA

The structure of this project experiences the process of complex mechanics changes in the construction. Meanwhile structure system also undergoes big conversion: Before the connection of steel truss, two palms work independently; after the connection, structure is interconnected as a whole to undertake the loads. According to the characteristics of this project, construction simulation analysis is closely based on construction procedure in reality, depending on the powerful computing function of large scale finite element software ANSYS to make an analysis of construction mechanics on tracking and analyzing of the whole process. Analyzing the coordinate of model uses the point of intersection of central axis of symmetry of structure plane as origin point. Besides, the point of ±0.000 in height in structure is taken as starting point in the vertical. And structure materials (concrete and steel)

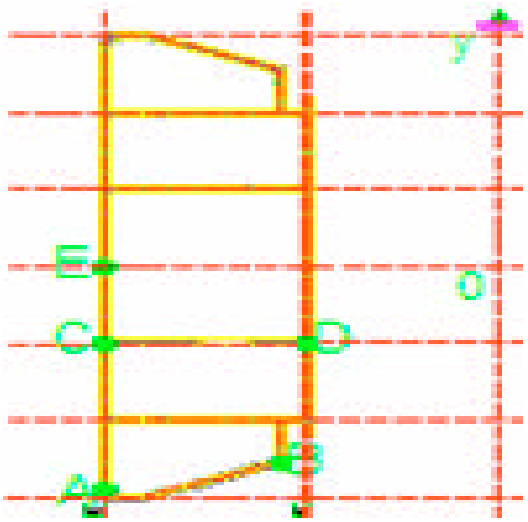


Fig. 6: Key point arrangement and coordinate of 74 m

are regarded as lining elasticity materials. When it comes to loads, the consideration should touch upon not only the loads of self weight of structure but also that of shelf, mutative loads in the construction and the loads of template of inclined wall inside and outside.

Computing result analysis on the key points of engineering structure: According to construction process schedule of this project and construction plan that steel structure is 20 m prior to civil working, displacement curve of partial points of the tower during the whole construction can be achieved by computing. Because it is basically biaxial symmetry in structure arrangement, only displacement curve of key point 74 m are shown in Fig. 7 to state briefly and clearly. Figure 6 shows the arrangement in the plane of the key point 74 m.

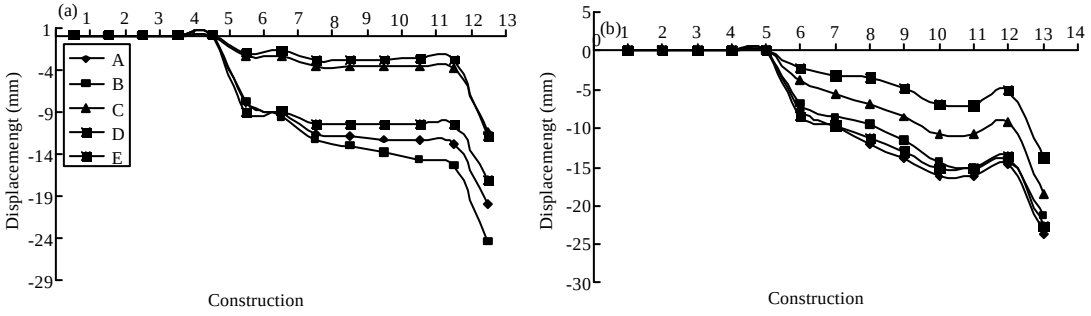


Fig. 7(a-b): Changing displacement curve in the direction of X axis of key point 74 m

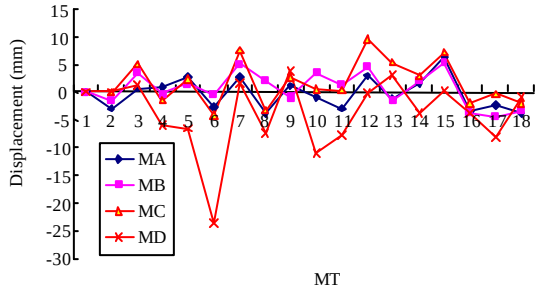


Fig. 8: Changing displacement curve for each point in axis X direction

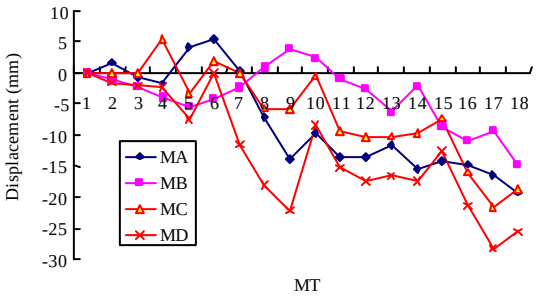


Fig. 9: Changing displacement curve for each point in axis Z direction

Analysis on measuring results of key points of engineering structure: Survey teams in the scene make measuring on the coordinate of each reflection point in a continuous way until the whole project is finished. Each construction phase includes the construction of main body steel skeleton and concrete engineering of each floor. The tower, particularly the construction of cantilevered parts, will undertake various influence caused by these factors: Structure self weight, live loads, temperature effect, wind force, creeping and shrinking of columns, relative settlement of foundation. Deformation measurement and control is mainly focused on position changes of datum column on each floor. With that, the general deformation of structure can be summarized and the result of deformation measurements and control will be achieved to recheck the accuracy of preset value. Measurement and control data can be accumulated for the following projects. For measurement and control points A (-26.3059, 43.0373, 72.7676), B (-10.0315, 43.094, 72.7783), C (7.3812, 43.1837, 72.943), D (26.3313, 43.131, 72.8393), their measuring results in the direction of X and Z axis are summarized in Fig. 8 and 9.

It is shown from Fig. 8 and 9 that after engineering construction is finished, there is small changes in displacement in the direction of horizontal axis X, which is opposite from that in vertical axis Z. Due to the characteristics of process and time varying of construction process and that there is a few of vertical crossing operations, the law of numerical curve from the measurement in the scene isn't as apparent as that of displacement curve of simulating finite element.

But both numerical curve and measurement and control curve at the same position share the same changing trend.

CONCLUSION

This text only made a shallow analysis on several mechanics problems and its resolving and analyzing method presented in the structure construction. After the comparing with data from the scene some conclusions can be reached: For large and complex projects like tower DAGOBA temple FAMEN, only with simulation construction and pre-analysis on the deformation of structure can the requirements of structure safety be satisfied. It is also shown from Fig. 8 and 9: Since concrete stiffness and strength is changing with the time of molding goes, combined structure system whose stiffness and strength are changing is formed. The stress will be distributed constantly with time passing by. Also

there are also constant changes in the direction of structure relative displacement. We can reach the conclusion that it is inclined to be unsafe for partial members using method of regular structure analysis when dealing with projects like tower DAGOBA temple FAEMN. With construction simulation, analysis of measured data and successful experience about referring construction simulation of similar project, it is practicable and reasonable to simulate the whole construction process on the platform of finite software ANSYS .

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