Analysis on the Efficiency of Engineering Based on Engineering Structure

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Abstract

Structural simulation analysis has become an effective and general research means in engineering field. Through the finite element modeling and calculation, we can obtain the engineering performance, stress mechanism, collapse state, etc so as to guide practical engineering application. This paper attempted to respectively elaborate the characteristics of conceptual model, mathematical model, calculation model and construction idea and method by putting forward a kind of integrate system. Whether they had reached to the effectiveness index was examined through comparing the results of effectiveness experiment and simulation analysis. The accuracy of this simulation analysis was obtained through defining the effective index and comparing the results between effectiveness experiment and simulation analysis. It has provided reliable system evaluation for whether the simulation analysis results of effectiveness experiment can be applied or not.

Keywords: effectiveness, verifiability, engineering structure

1 Introduction

At present, under the great efforts of engineering researchers and scientific and technical workers, the application of engineering structure is increasingly grown up. However, the world economic development will never stopping, especially in recent years, with the globalization of economy and the rapid enhancement of computer capacity, more and more great engineering are building, and more and more engineering records were broken through. Therefore, many new engineering problems need us to study. At the same time, many various major engineering and city lifetime engineering like large-scale water resources and hydropower facilities are not only of enormous investment, but also carry the life safety of thousands of people and relate to the diazepam of whole society, thus its consequence is unbearable [1].

Therefore, we need to guarantee the security of engineering structure in each phase, including construction stage and normal use stage. Then we need to simulate and analyze the engineering structure, evaluate the safety performance of structure and put forward economical and reliable scheme based on safety [2]. The current researches on engineering problems are mainly centering on the computer simulation analysis of engineering structure. With the rapid development of computer performance and the strengthening of the function of computer analysis software, an increasing number of engineering problems are simulated and analyzed using computer software. The computation speed of computer with high performance also provides possibility for us to study complex engineering problem, and its simulation analysis is increasingly elaborate.

Currently, as for whether the result of simulation analysis of engineering structure is right and reliable is basically depend on the engineering analyst's experience and level, thus the conclusion is subject to be affected by various subjective factors and human factors. Part of engineering analyses only focus on the correctness of simulation analysis process, but neglect the correctness of simulation analysis itself, thus it has caused the problem of simulation analysis itself and then the correctness of simulation analysis result is out of the question [3].

Therefore, how to guarantee that the simulation analysis of engineering structure is correct, effective and can be verified? This paper strived to establish a complete set of effectiveness and verifiability system and procedure, with hope that this process system can put forward the safeguard measures in various stages in perspective of global planning and from higher step.

2 Realization of Effectiveness

A. CONCEPT OF EFFECTIVENESS

In simulation analysis of engineering structure, we need to make a choice for various properties according to the significance of each feature in engineering structure, since the complexity and uncertainty of practical engineering as well as the limitation from computer capacity and duration requirement. We only evaluate the significant feature. Therefore, all engineering simulation analyses are the simplification of the practical engineering. Only in this way, can we set priorities and

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reasonably allocate resources so as to obtain the available simulation analysis results in engineering.

And because all engineering analysis models are the approximate value of practical engineering structure and are restrained by limited resources, theory of mechanics, material performances and computer capacity, then how can we guarantee that these approximate analyses are reliable for the practical specific problems in engineering structure? This problem includes two aspects: one is accuracy, another is sufficient accuracy. Or in other words, one is to obtain accurate simulation analysis result, another is to reach the acceptable accuracy of these simulation analysis results for practical application of engineering. Effectiveness is used to answer the two questions. The so called effectiveness and verifiability refers to provide hard evidence through systematic organization so as to solve the whole flow of simulation analysis results of specific problems in engineering structure.

Effectiveness generally starts from the exploitation of conceptual model. Conceptual model is the expression of idealized engineering practice, which has defined the critical mechanics and physical process, determined experiment and modeling approaches and provided various hypotheses and criteria. It is the basis of simulation analysis and experiment, which also has listed the acceptable and conforming criteria between simulation analysis and experiment. The effectiveness of conceptual model is generally based on the specialists' direct or indirect comments and approvals. Only if we have proved the effectiveness of conceptual model, can the subsequent researches and analyses be significant [4]. The subsequent verification is code verification which judges simulation analysis in realizing the correctness the code algorithm, including numerical algorithm verification and software quality engineering. Next is calculation verification which is conducted through judging the accuracy of specific examples in mathematical model and also depend on the establishment of numerical fault. Finally, we conduct conforming contrastive analysis on results of simulation analysis and experiment, so as to prove the effectiveness of the model.

B. PROCEDURE OF EFFICIENCY ANALYSIS

As to the modeling and analysis of engineering structure, its effectiveness and verifiability procedure is generalized in figure 1. The procedure stated how to conduct verifiability analysis through realizing correlated calculation model and how to conduct effectiveness analysis through effectiveness experiment.

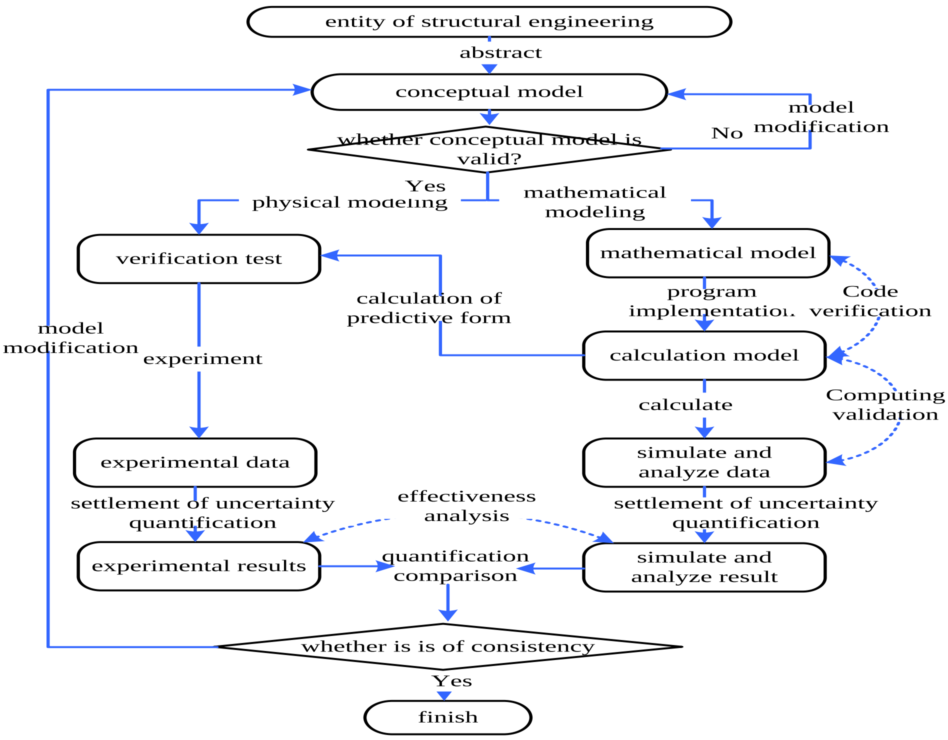

FIGURE. 1 figure of effectiveness verification

The engineering structure entity in figure 1 mainly includes the expected application of the engineering structure need to be studied and understood, and the relevant system performance need to be obtained. The expected application of the model refers to the expected reaction of real system under real operating conditions. Conceptual model is the abstract of real system. The predictive ability of the model on expected application is judged according to the interested field, important physical process and hypothesis, experimental result, modeling approach and the suitable grade need to be reached between simulation and experiment.

C. CONCEPTUAL MODEL

Conceptual model is very important to the research and develop process of whole model, since many fundamental hypotheses will affect the interpretation of simulation analysis result. These hypotheses include determining how many components or entities will be incorporated into model, and neglecting the geometry detail features, and the selection of interface and boundary type. If certain important mechanical phenomenon is not included in conceptual model, then simulation analysis result will not conform to verification criteria. Phenomena Identification and Ranking Table (PIRT) can analyze the quantification sensitivity degree. PIRT can quantitatively judge the accuracy of calculation model in major physical process, so as to help us to determine which physical processes will be experimentally verified. Example of certain PIRT is shown in table 1.

TABLE 1 Example of PIRT

phenomena	phenomenon type	significance	grade of model confidence
phenomenon A	interface	high	medium
phenomenon B	interface	medium	high
phenomenon C	load	medium	low
phenomenon D	material	low	low

In the above living example, phenomenon B will become low priority, since higher significant phenomenon will replace it; similarly, phenomenon D is low priority because of its lower significance.

The following part is the explanation taking the mathematical model of different modulus elastic theories as example. The differences of pressing different modulus elastic theories and classical elastic theory only reflect in the constitutive relation between stress and strain. In problem of pressing different modulus, the sign and direction of principal stress play the decisive role, thus the constitutive relation is expressed by relation between principal stress and principal strain.

Firstly, we need to divide stress partition. In different modulus theories, elasticity modulus can be divided into Et and Ec, according to the different signs of principal stress. There are different types of elastic relations according to the combination of various principal stress signs:

(1) $\sigma_\alpha > 0, \sigma_\beta > 0, \sigma_\gamma < 0$, principal stresses are all pulling stress;

(2) $\sigma_\alpha > 0, \sigma_\beta > 0, \sigma_\gamma < 0$, principal stresses are all pressure stress;

(3) $\sigma_\alpha > 0, \sigma_\beta > 0, \sigma_\gamma < 0$, one principal stress is pressure stress;

(4) $\sigma_\alpha > 0, \sigma_\beta > 0, \sigma_\gamma < 0$, one principal stress is pulling stress.

The above four kinds of conditions are divided into two types:

(1) The first type of region: all signs of principal stresses are the same (that is all pulling areas or all pressure areas).

(2) The second type of region: sign of one principal stress is different from signs of another two stresses.

Then relation between principal stress and principal strain is determined according to the plus or minus of principal stress:

$$\begin{pmatrix} \varepsilon_\alpha \\ \varepsilon_\beta \\ \varepsilon_\gamma \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \sigma_\alpha \\ \sigma_\beta \\ \sigma_\gamma \end{pmatrix}$$

According to the plus or minus of principal stress, determine value of it multiplies certain row: if $\sigma > 0$, then a_{il} takes $a_{il}^{\ t}$; otherwise, $\sigma < 0$, then a_{il} takes $a_{il}^{\ c}$; similarly, $\sigma_\beta, \sigma_\gamma$ is with the same process.

When $\sigma_\alpha > 0, \sigma_\beta > 0, \sigma_\gamma < 0$:

$$a_1 = \begin{pmatrix} \frac{1}{E^t} & \frac{v^t}{E^t} & -\frac{v^c}{E^c} \\ -\frac{v^t}{E^t} & \frac{1}{E^t} & -\frac{v^c}{E^c} \\ -\frac{v^t}{E^t} & -\frac{v^t}{E^t} & \frac{1}{E^c} \end{pmatrix}$$

When $\sigma_\alpha > 0, \sigma_\beta > 0, \sigma_\gamma < 0$:

$$a_1 = \begin{pmatrix} \frac{1}{E^t} & \frac{v^c}{E^c} & -\frac{v^c}{E^c} \\ -\frac{v^t}{E^t} & \frac{1}{E^c} & -\frac{v^c}{E^c} \\ -\frac{v^t}{E^t} & -\frac{v^c}{E^c} & \frac{1}{E^c} \end{pmatrix}$$

Conduct inversion of a_I under above bases, the elastic matrix of different modulus can be obtained as:

$$D_I = \frac{1}{(1+v)(1-2v)} \begin{pmatrix} (1-v)E_1 & vE_1 & vE_1 \\ vE_2 & (1-v)E_2 & vE_2 \\ vE_3 & vE_3 & (1-v)E_3 \end{pmatrix},$$

of which E1, E2, E3, Et or Ec, Et, Ec are respectively stretch and compress elastic modulus. Therefore, the final finite element solution formula is:

$$\frac{K + K^T}{2} d = P$$

It involves the geometric description, determination of computational domain and division of computational grid of engineering entity. Thus we are required to consider the construction process of conceptual model, mathematical modeling and calculation model. The obtained verification relative to calculation model may unreliable. Calculation model needs to define the detailed parameters of model so as to conduct simulation analysis.

D. MODEL CORRECTION

The correction of model can be divided into two methods: correction of parameter of mathematical or calculation model, correction of conceptual model itself. As for the analysis of engineering structure, parameter correction (such as material model constant, friction coefficient, and load size) is very common in mathematical and calculation model. There are two ways to judge the revised value of parameter of calculation model, including measurement of parameterized model, independent measurement of parameter value. According to the correction criteria of parameterized model, simulated result is more approximate to actual measurement response value. This kind of process is generally considered as “model correction”, “model adjustment”, “parameter calibration” and “parameter estimation”. The correction of conceptual model will generally cause the change of relevant mathematical and calculation model. In general, such kind of change will embody in verification experiment stage. Features of some construction reaction are inconsistent with the relevant features in model export, of which the difference is not totally attributed to the unreasonable of model parameter.

E. EFFECTIVENESS

Implementation Steps of Effectiveness

Effectiveness aims to quantize the reliability of predictive ability of model in predictive application. In other words, the predictive ability of model depends on its application conditions. When the practical application breaks away from the expected application model, then the predictive ability of model must be weakened or even cannot be predicted. The reliability of simulation analysis result is restrained to the same application range. Only in this way can the effectiveness be guaranteed. Effectiveness analysis is used to measure the consistency between simulated result and experimental data. Consistency is conducted through quantitative test data and model analysis result. The uncertainty in model analysis data and experimental data will be mixed with the deviation of measured result. Therefore, consistency is generally described using statistical form.

The main steps of complete effectiveness analysis can be stated as follows:

The first step is to determine the features of quantification and plan test procedure and verified grade based on conceptual model.

The second step is to study the effectiveness index, so as to compare simulation model result and experimental result

The third step is to design experiment, so as to guarantee that it can produce necessary data and can verify model.

The fourth step is to compare test data and simulation analysis result, quantize the model predictive accuracy, and at the same time, we should take the uncertainty factors of the two into consideration during comparison.

Finally, we need to judge the model predictive ability and examine whether it reaches to the predefined effectiveness index (accuracy threshold value). If it reaches to accuracy threshold value, then the model can be considered as effective to its expected application.

Effectiveness Index

Complex model will always produce mass of information. The screening of simulated results should be selected according to its application requirements. For example, if the maximum strain in specific position shall not exceed a certain value is what we need to study, then the effectiveness analysis of model should center on the comparison between the strain measurement in this position and strain obtained by calculation. The reflected features in results of test data and simulation analysis should be selected according to its application range [5].

The index of effectiveness is the basis of comparing test data and simulation analysis results. Effectiveness index should be in conceptual model development stage, and be established when considering the uncertainty in test and simulation process.

In effectiveness analysis, which properties are determined for comparison and how to compare are very important. Only in this way, can we determine whether the model is effective and whether it can meet the requirements of practical application under limited resources. In test work, error is generally divided into random deviation and systematic errors. Random error is fixed in test and its generated uncertainty cannot be reduced through extra test. However, deviation can be produced repeatedly or decided and reduced, though it is very difficult in most instances. The sources of systematic errors include sensor and data collection error, data correction error, specimen technique error, etc. Model developers should know all the input parameters, boundary conditions and application of load. Model developers should conduct researches on parameter and determine the sensitivity of model through the verification of model so as to design the test. In addition, the earlier test analysis should be conducted so as to remove the potential problems in test design.

Finally, we need to use mechanism to guarantee the evaluation to the model predictive ability, which requires developers to obtain results after finishing prediction. Many problems show that people are easy to adjust the estimation of high-precise calculation model so as to meet measurement requirements, since their obvious sensitivity to mechanics and numerical value.

3 Conclusion

Effectiveness aims to document the model predictive ability to its predictive application and judge whether model is suitable for its predictive application [6]. Based on test data, effectiveness definitely states the range of predictive application of simulation analysis through establishing the verification test of systematic level. Effectiveness is supported through the verification test of systematic level. In verification of predictive ability of engineering structure simulation analysis, verifiability cannot be separately treated, since the consistency between test data and simulation analysis result may be occasionally. Through systematized procedure, verifiability can guarantee the model accuracy, of which code verification is to analyze whether its mathematical operation is stable, consistent and accurate. However, calculation verification is located in the verification on the specific examples of model mathematical operation. The effectiveness of conceptual model is the precondition of verifiability. Conceptual is the idealized expression of real system, which needs to determine the key mechanical process, effectiveness test, modeling methods and its basic assumption. They are bases of test and simulation analysis which also has stated the key point of consistency between simulation analysis and test.

Only through systematized effectiveness and verifiability analysis, can we confirm whether the engineering structure analysis model is correct and effective to its predictive application. Moreover, we can also confirm whether it can meet the practical requirements of engineering, which has provided reliable system evaluation for us to judge whether the simulation analysis result of engineering structure is adoptable or not.

References

[1] Wang Lin, Zhang Wei 2014 Analysis of the Factors Affecting the Quality of Construction Engineering Based on the ISM *Mathematics in Practice and Theory* 44(14) 223-230

[2] Zhang Lin, Zhang Xuesong, et al 2013 Model Engineering for Complex System Simulation *Journal of System Simulation* 25(11) 2729-2736

[3] Wang Yong, Zhang Jianping, et al 2012 Model Automatic Transformation Methods in Architecture and Structure Designs *Journal of Architecture and Civil Engineering* 29(4) 53-58

[4] Yang Fan, Chen Bo, Wang Ganjun 2014 Model Updating of Building Structures for Safety Assessment *China Safety Science Journal* 24(5) 104-108

[5] Ma Yingjun 2013 Effectiveness Analysis of Dynamic Compaction for Foundation Treatment *Ningxia Engineering Technology* 12(4) 363-372

[6] Wang Dejiang, Ye Zhiming 2012 Dynamic Response Analysis of Interaction between Large Cylinder Structure, Soil and Wave *Journal of Shanghai University (Natural Science Edition)* 18(1) 88-91

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