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Improving Anti-seismic and Collapse-Resistance Ability of Building Structure Based on Building Information Model

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Abstract: Building information model plays an irreplaceable role in strengthening anti-seismic ability of building structure, it can form automatically by applying Finite Element Analysis Software and Open System for Earthquake Engineering Simulation. Conducted effective structure analysis model according to international basic-class industrial file and select targeted information data. The angle and prospectiveness of model analysis can be developed continuously so that anti-seismic and collapse-resistance ability of building structure can be strengthened constantly. Relevant sub-model transfers various information data in order to improve accuracy of model data analysis. Finite Element Analysis Software and Open System for Earthquake Engineering Simulation positively promote constructing information model; at the same time, they actively strengthen digital construction of model, reasonability and systematicness of information data analysis. Wish this study can provide useful data and theory support for further exploring work. Hope building information model can be applied more in enhancing anti-seismic and collapse-resistance ability of building structure.

Keywords: Building information model, ilding Structure, anti-seismic and collapse-resistance ability, study and application.

1. INTRODUCTION

From another layer, continuously strengthening anti-seismic and collapse-resistance ability of building structure can reflect constantly improving scientificity of building project design and conduction. Building information model analyzes all kinds of parameters of building projects, adds up seismic damage data effectively and conducts comprehensive analysis. Model construction is based on digital construction and scientific application of software, so scientificity of analysis of building parameters can be improved. The paper analyzed seismic damage, required data, IFC expression needed for anti-seismic analysis data, design of model transformation program and specific examples for testifying efficiency of model transformation. Accuracy and efficiency of model were testified fully and solid theoretical foundation was provided for building information model.

2. ANALYSIS OF SEISMIC DAMAGE AND DATA REQUIREMENT

Normally, in construction and design, fiber beam model is used for steel reinforced concrete constructions, it is the basic calculation model used for vibration resistance statistic and analysis of relevant data in construction and design. Many software have relevant calculating abilities, they positively influence data analysis; two software are considered as classic: Finite Element Analysis Software (Marc) and Open System for Earthquake Engineering Simulation (OpenSees) [1].

Individual building is important basis for most city buildings. In this study, C++ was used in conducting model program and relevant transformation. Digital model was built through relevant individual building (steel reinforced concrete structure), necessary information for analysis of seismic damage was selected effectively so the models mentioned above could form automatically. Testifying of both models showed that seismic data analysis responded to relevant model transformation, specific process was shown in Fig. (**1**).

2.1. Marc and OpenSees Software

Finite Element Analysis Software has all kinds of characteristics and data analysis function; it also has high-grade angle for nonlinear geometric analysis. In this paper, analysis of anti-seismic capability design was introduced briefly, analysis of data simulation result was idealized gradually, and requirement of anti-seismic data analysis for most building project could be satisfied.

During fiber model construction, secondary development of joint was conducted through Finite Element Software, Nonlinear Program Analysis Software was developed, fiber model data analysis of steel-reinforced concrete structure was carried out through Finite Element Analysis Software. Nonlinear Program Analysis Software divided basic section of steel refined concrete structure into 36 concrete fibers and 4 steel fibers, the area of each fiber depended on its size and other elements [2]. So it was possible to conduct structure analysis on fiber definition of each steel-refined concrete structure, high precision and accuracy of analysis data could be assured. The biggest characteristics of Open System for Earthquake Engineering Simulation were: its effective analysis on anti-seismic capability of building structure, codes

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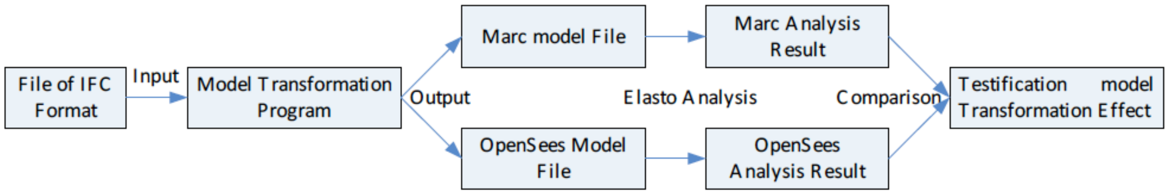


Fig. (1). I-seismic Elasto analysis process of building based on IFC standard.

Table 1. The requirement of building anti-seismic analysis.

Project	Data Requirement of Building Anti-Seismic Analysis
Unit	Unit No., Total Number, Nodes of Unit.
Node	Node No., Total Number, Coordinate
Steel-reinforced Concrete Material	(Core Zone and Protective Layer) Elastic Modulus of Concrete, Stress Strain Relation, Thickness of Concrete Protective Layer, Sectional Reinforcement, Elastic Modulus of Steel, Yield Strength, Corresponding Unit No. of Sectional Reinforcement.
Geometric Quality of Section	Section Size, Direction of Partial coordinate of section -- X-axis in the whole coordinate system, Corresponding Unit No. of Geometric Quality of Section
Support Constraint	Constraint of Support Freedom Degree, Constraint Title and Corresponding Unit No.
Load	Constant Load, Live Load, Other Loads, Corresponding Unit No.

could be kept comparatively transparent, operation mechanism of steel reinforced concrete structure could be effectively controlled, effective secondary developments could be conducted according to actual requirement of different projects. On basis of discussion mentioned above, a conclusion could be achieved: Open System for Earthquake Engineering Simulation was an important tool for evaluation and study on building seismic damage.

From discussion and study on two models, we can see that both models can effectively evaluate anti-seismic effect of construction engineering steel-reinforced concrete structure, process and angle of seismic damage analysis could be kept extremely full-round, transparentness of software itself could be assured as well.

2.2. Data Requirement of Building Seismic Damage

Data analysis and management were the most important part; relevant data of concrete model was combined in comprehensive analysis.

Analyzed anti-seismic model with two software and got relevant result, it suited specific structure and operation requirement of model, intuitive representation was shown in Table **1**.

3. IFC EXPRESSION NEEDED FOR ANTI-SEISMIC ANALYSIS DATA

3.1. Introduction of IFC Standard

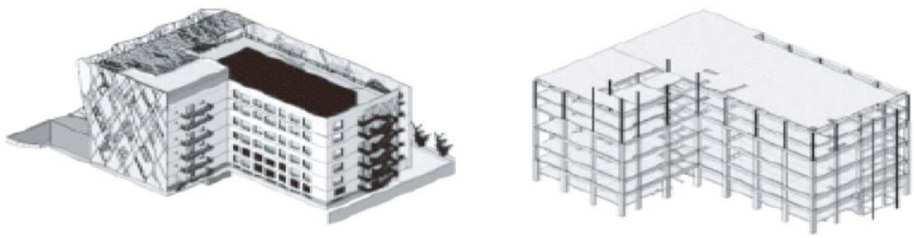
International basic-class industrial file are specific standards of building information model construction; its main edition changes correspondingly with practices; the latest edition is IFC4.

International Basic-class Industrial File 4 consists of building type, building entity, basic function of value engineering, rules of construction engineering, basic set of properties, relevant magnitude and other specific elements. Building entity refers to specific category of construction object; however, properties represented in each building entity can be one single piece or multi-piece. Each single property particularly refers to specific data in category set [4]. Therefore, property expression of building entity is more realistic and specific. Concept of property set was effectively insert into international basic-class industrial file, each property set was analyzed through relevant operation mechanism of connected entities, connection of building entities was achieved and entity properties could be further expended.

Specific identification of International Basic-class Industrial File 4 was represented in both particular description of building model construction and effective description of model structure analysis. In process of constructing structure analysis model, representation of one same beam was IFC Structural Curve Member, it was formed by two vertexes and lines which linked vertexes effectively, this entity showed specific difference from former model. Comparison of a particular building model and its structure analysis model was shown in Fig. (**2**) [5].

3.2. Application of IFC Standard in Structure Analysis

Presently, IFC is widely used and studied in building design and construction, but not so much in structure analysis. Difference was found through comparing required information of Structure Analysis Software SAP2000 and information described by IFC 2X2 Standard; with the difference, WAN and others analyzed support degree of IFC Standard to



(a) Building model (b) Structure Analysis model

Fig. (2). Comparison of building model and its structure analysis model.

Table 2. Test of IFC file's exporting capability of some software.

Software for test	Geometric property	Material property	Structure analysis model Entity	Steel Information	Load	Support constraint
Revit Structure 2013	√	√	×	×	×	×
Etabs 9	√	×	√	×	×	×
ArchiCAD 16	√	√	×	×	×	×
SAP2000 v15	√	×	×	×	×	×
Tekla Structures 18.1	√	√	×	√	×	×
IFC4 Structure Analysis Sub-information model	√	√	√	√	√	√

Note: "√" means capable, "×" means not capable.

structure analysis model; it was found that IFC could provide simple basic load, static work condition and mechanical property of partial materials, and that it could not describe certain information like bending moment release and cutting capability of materials.

Although IFC Standard could be used to describe basic structure analysis model, its application was not mature enough; IFC model's exporting effect of normal building design software and structure analysis software was shown in Table **2**, the highest edition of exported IFC file was IFC 2X3. Table **2** indicated that IFC structure analysis model's exporting capability of current software was poor and could not satisfy demands of structure anti-seismic and elastic analysis.

3.3. IFC 4 Structure Analysis Sub-information Model

Because critical data of building structure anti-seismic and elastic analysis was short in IFC file exported by normal software, so it was necessary to build an analysis model with complete IFC structure, like shown in Table **2**. Sub-information model refers to sub-set in the whole IFC Standard system. IFC was a general data standard for building products, it provided plenty building description methods in order to suit for various requirements, however, it became extremely complicated at the same time [6].

Reinforcement property was added for beam through custom property set, it expressed flexibly, meanwhile, information could be derived for programming conveniently. Complication of IFC was the reason to limit its development and to interfere normal software in exporting IFC file which were required for anti-seismic analysis. Therefore, on basis of inspecting IFC 4 System thoroughly, IFC 4 Structure Analysis Sub-information model was built based on parts which were used most often. For example, only method was kept in description of reinforcement. Although IFC would not be as comprehensive and complete as before, it still could describe critical information required by anti-seismic analysis, its practicability was improved. The most convenient software to describe IFC sub-information model was EXPRESS-G, part of the software was shown in Fig. (**3**).

3.3.1. Description of IFC 4 Structure Analysis model

Only one IFC project building entity is needed for basic file of all International Basic-class 4 models. Therefore, in each sub-information model, there is one IFC project entity; this is the specific characteristic of each building project. In International Basic-class Industrial File 4, IFC Structural Analysis Model entity which consists of model properties of itself, whole coordinate system and load condition is usually used to represent a complete structure analysis model. So-called Load condition can represent sub-category of IFC Structural Load Group through IFC Structural Load Case. There are two kinds of properties represented by building entity: load type and form. One IFC Project may correspond more than one analysis model, their inner connection is represented through IFC Rel Declares relation entity. Expressing form of EXPRESS-G is shown fully in Fig. (**4**). Not the whole building entity is shown, only part of it is shown here in gray field.

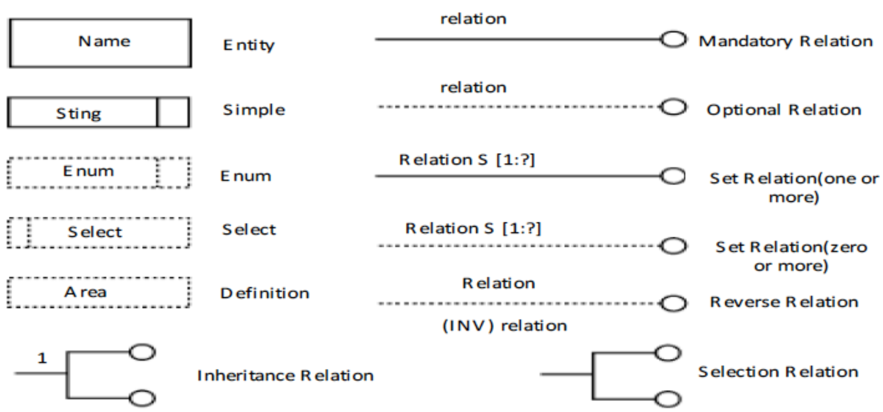


Fig. (3). Part legend of EXPRESS-G.

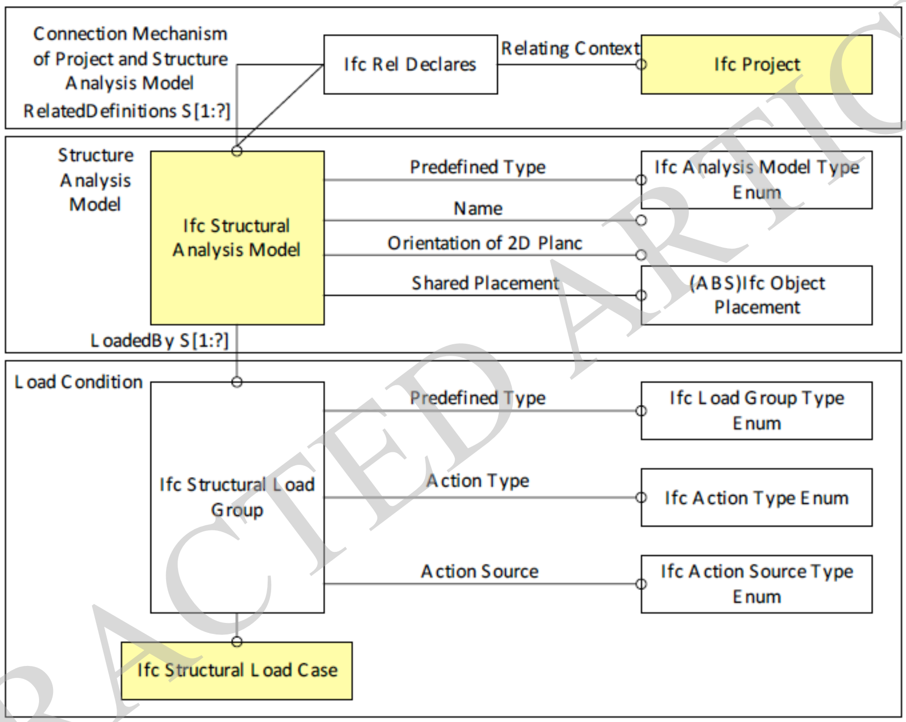


Fig. (4). Description method of IFC 4 structure analysis model.

3.3.2. IFC 4 Description Method of Other Building Anti-seismic Analysis Data

In the paper, relevant data was described with IFC 4 through effective analysis of building construction characteristics. Take load as example, from Fig. (**5**) we can see that, properties of entity were not represented fully or specifically, only distributed loads which had changed linearly were described by IFC 4, aggregation information seemed simpler. These loads were transferred effectively and equivalent distributed loads could be obtained and be described by IFC Structural Linear Action Entity.

4. DESIGN OF MODEL TRANSFORMATION PROGRAM

After frame was studied, complete international basic-class industrial structure analysis model was built according to specific anti-seismic requirement. C++ Language was used for relevant program writing and transferring, relative files of international basic-class industrial model were analyzed, Finite Element Analysis Software and Open System for Earthquake Engineering Simulation formed automatically.

International basic-class industrial structure analysis model was defined with specific language, it was represented as pure text form through computer encoding system. Therefore, international basic industrial file must be analyzed and recognized specifically so that file codes could display corresponding data information. Normally, IFC Engine.dll is a basic tool for international industrial basic file analysis and a free data installation package, but it requires programmer to have high capability in understanding international industrial basic file.

From Table **1** we can see that node, unit and other three aspects were designed and classified according to actual data demands of building seismic damage. The container in

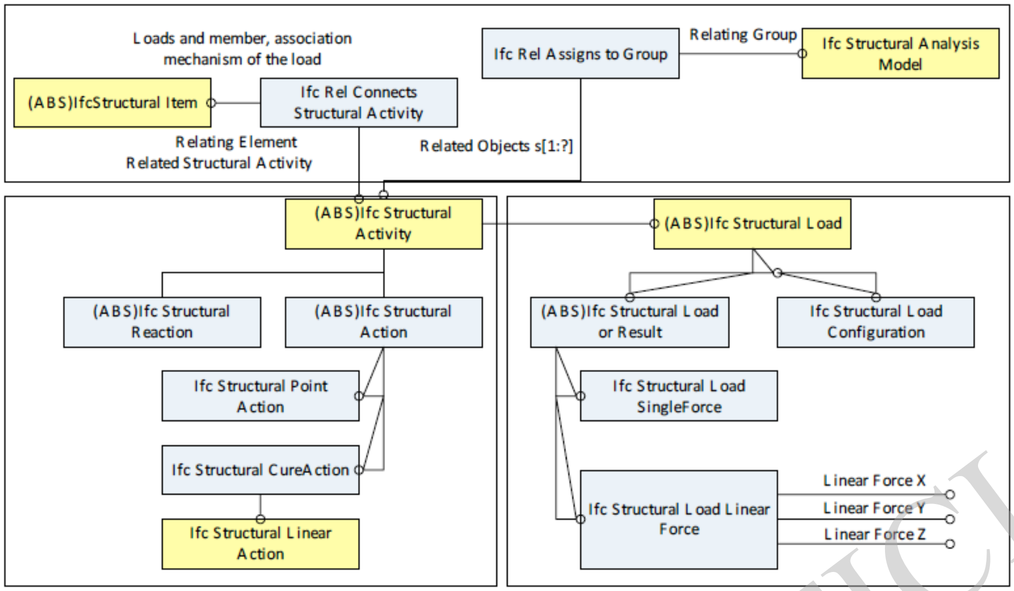


Fig. (5). Description method of load information in IFC 4.

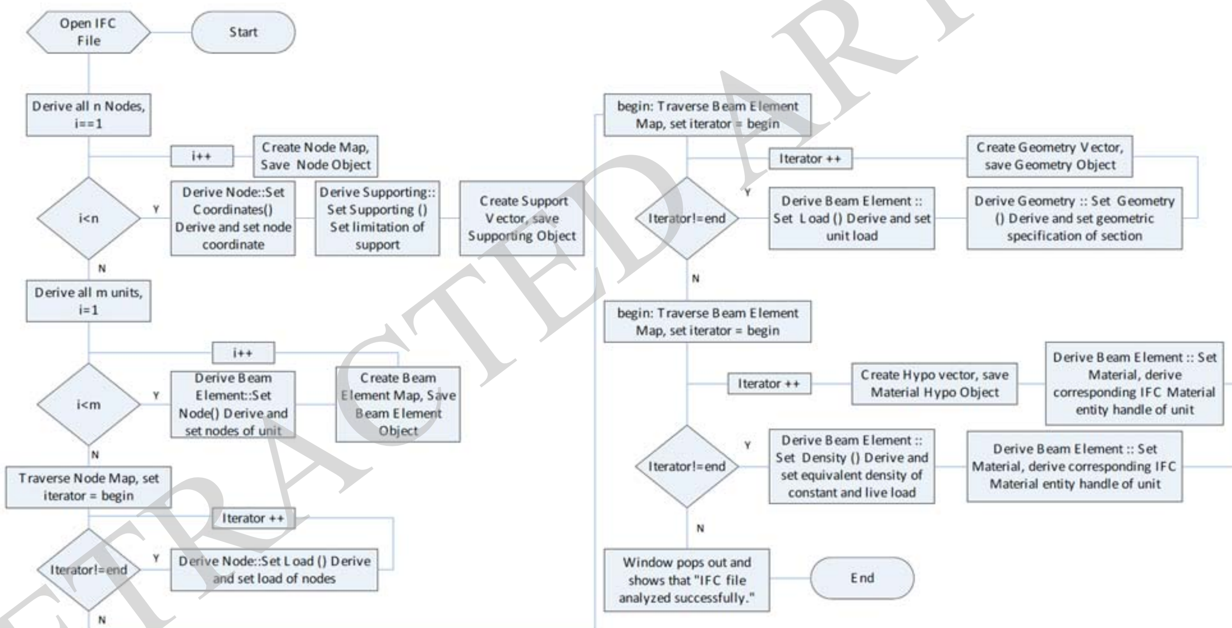


Fig. (6). Analysis and data derivation from model transformation program.

standard program library connected and organize corresponding data, member functions were selected and analyzed in program input model, so data of international basic industrial file could be derived effectively, and required information data could be provided to corresponding data member [7]. For example, at Node, Set Coordinate was applied, node coordinate was set, international basic industrial file data information could be derived correspondingly in model transformation like showed in Fig. (**6**).

In writing model transformation program, program data and structure designing process were ideal, model could be used conveniently and fast. Container was traversed separately, regular output point, unit material and other data information were analyzed effectively while models of both software were constructed, so models could form automatically.

5. SPECIFIC EXAMPLE TESTIFIED MODEL TRANSFORMATION EFFECT

During process of testifying accuracy of model program transformation, a steel reinforced concrete structure model was built with IFC as its basic standard, the model was built from Main Building in Tsinghua University, it's a ten-floor and 3-meter span cross plane structure. Side span length was 7.5 meters, middle span length was 3.5 meters and total height was 45.05 meters. However, after international industrial basic model was transformed, model interface was not presented obviously and was not presented at all in some

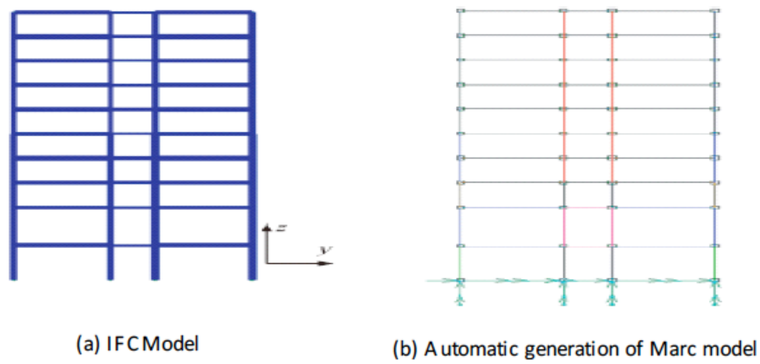


Fig. (7). Model and automatically formed marc model.

Table 3. El analysis comparison of marc and opensees.

Analysis software	1st Stage circular frequency /s-1	2nd Stage circular frequency /s-1	3rd Stage circular frequency /s-1	Basic cycle / s
Marc	4.07	11.48	21.69	1.53
OpenSees	4.11	11.57	21.82	1.54

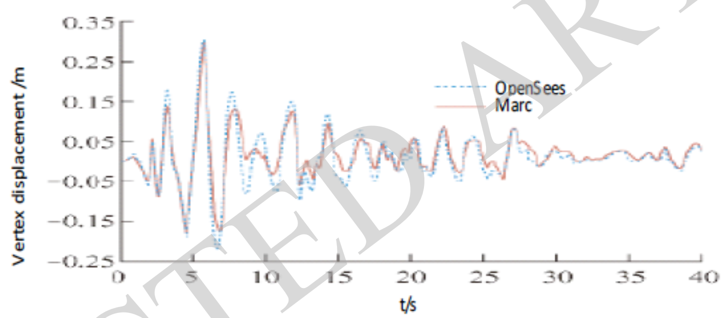


Fig. (8). Comparison of Marc and OpenSees elastoplasticity time history analysis results.

parts. From Fig. (**7**) we could see that high accuracy could be assured for category transformation of unit and nodes, basic parameter of model and data transformation of base plane.

Model analysis was conducted through two softwares. Difference of circular frequencies in first three stage vibration types was below 1%, as shown in Table **3**.

In analysis and evaluation of elastoplasticity, effectively input vibrational acceleration on Y direction and analyzed elastoplasticity with two software mentioned above [8]. El Centro Seismic Wave was used for data record, the peak value acceleration was assumed as 400 Gal. Fig. (**8**) showed displacement curves of the apex, we could see strong consistency from it.

A conclusion could achieved in model analysis with two software mentioned above, process and result of analysis were highly accordant, it showed that model unit and every parameter of material could convert effectively, accuracy could be guaranteed fully.

CONCLUSION

In this study, application of building information model in improving anti-seismic and collapse-resistance ability of building structure was studied and discussed, IFC expression and specific experiment model transformation required by anti-seismic analysis were discussed. Therefore, process of model constructing was clear and effective, practicability of its application was presented fully. Wish obvious promoting function can be played for application and effect of building information model through this study and for improving anti-seismic and collapse-resistance ability of building structure.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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