3D Visualized RC Structure Durability Analysis

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Abstract. Building Information Model (BIM) is used to share and exchange information between different applications for considerable processes of Architecture, Engineering and Construction (AEC) projects, and it is the key technology to manage information throughout the entire lifecycle of a building, solve the problem of information silo and improve the productivity of AEC project. This paper proposes a new method to extend the BIM technology, which makes it possible to integrate durability factors into design, durability analysis and residual life of building structures prediction. Based on the combination of the national durability code and achievements of RC durability study, a 3D Visualized RC Structure Durability Analysis is developed, which is verified to be capable of improving lifecycle management of AEC projects, upgrading durability level and optimizing the lifecycle cost structure of building projects by a case study.

1. Introduction

IFC is the definition of sets of classes and interface restrictions with the object-oriented describing computer language EXPRESS, and is being upgraded by the members of IAI committees worldwide. It has been studied for many years. The Bentley company developed Building Information Sharing System based on a central information model database; with the aim of improving facilities management and maintenance, Kevin Yu et al proposed FMC (Facilities Management Classes) by extending the entities and regulations in IFC standards, and utilized FMC to develop a CIFM (Computer Integrated Facilities Management) system. It is commonly accepted that the exchanging and sharing of building information will be more convenient by the application of BIM in more disciplines and stages in AEC/FM project life cycle, resulting in the upgrading for the informatization level and the growing of the building industry producing efficiency. The lifecycle information of an AEC/FM project is generated since the beginning of the planning stage, and will be continuously extended, modified and rearranged in the design, construction, commissioning and operation stages. As described above, BIM and IFC technology has been used in the fields of draws checking, loads calculation, construction planning and facilities maintenance etc. Lifecycle information has significant impact on decisions made during the rest period of the building life cycle. With the popularity for giant AEC/FM projects, the management of project information is required to be more efficient and accurate. Consequently, the notion of BIM (Building Information Model) is proposed as an adequate product modeling and information exchanging tool by implementing object-oriented (OO) technology. Information technology has been utilized to facilitate the product expression, data exchanging and project management for decades of years, storing data by means of spreadsheets, documents and 2-
dimension drawings with basic geometry elements, such as points, lines and surfaces. BIM is essentially an OO modeling methodology for AEC/FM products and activities. With the help of BIM technology, the AEC/FM project information can be archived and processed in hundreds of hierarchy and interactive objects, and the problems of lifecycle data exchanging and sharing can be addressed efficiently. The BIM technology transforms the traditional project managing framework with less overlap and more linkage of information. As a result, the information extraction, semantics applying, data integration and files creation are conducted by manual work, which is essentially composed of frequent man-machine interactions. Obviously, the information technology at present merely contributes the AEC/FM industry in the level of information storage, without realizing the automation and collaboration of data exchanging and sharing as expected.

However, the RC durability analysis consists of lifecycle knowledge management and complicated analysis, therefore, the implementation of BIM in this field is of great challenge. In this paper, a 3D Visualized RC Structure Durability Analysis based on BIM technology is developed for durability design automation of newly constructed building and safety analysis for existing building.

2. IFC data interface
At present, the IFC standard is used in the areas of loads analyzing, drawing outputting, construction management, real estate maintenance, etc. An IFC file is the combination of project information covering geometry, material, process etc., which is generated through the whole lifecycle. The IFC file is used to store, exchange and share building project information. With the help of the IFC standard, massive project data can be archived in a unified format and managed efficiently. Massive project data can be freely retrieved, modified and extended according to the definition of IFC. In this research, the IFC application is further extended to be utilized in the area of durability analyzing for RC structures by developing an IFC data interface. The data from IFC is first loaded into the memory, and is analyzed by the IFC data interface to check its integrity for durability analyzing. For the incomplete data source, the original IFC data structure is extended according to the IFC definition to reserve in advance the memory for more durability information; for the complete data source, the project data is directly abstracted and loaded into instances of durability information model for the local database as the later functional modules’ data source; after durability appraising, the data in local database is processed and updated, and the IFC data interface will format the project data into new IFC file. The IFC Engine toolkit developed by TNO is adopted to retrieve IFC files. The IFC Engine toolkit is composed of interface functions to retrieve and manage IFC codes. As mentioned above, the IFC data interface is mainly in charge of loading IFC file into memory, analyzing IFC data, reforming and saving IFC file. In the following section, an example of analyzing geometry data from IFC file is elaborated to demonstrate the application of the developed IFC data interface, since the geometry data is the most complicated compared to other ones. IFC file is operated at the level of source codes by IFC Engine toolkit. Compared with other IFC tools which deal with IFC file at the level of entity, it is of more flexibility and can achieve more sophisticated targets. The typical geometry data of building project includes geometry dimension, reinforcement arrangement, elevation and span length, which are all encapsulated as properties of the IFC entities in the IFC file. The IFC file is traversed by the function sdaiGetEntityExtentBN (model, “IFCCOLUMN”) to pick out all of the entities of the type “IFCCOLUMN”, and an array of IFCCOLUMN entities is generated. The first parameter “model” of the function is the memory address of a specific IFC file, and the address of the generated array is stored into a temporary variable objects; after the address of entities is got, the element with the index number of i can be retrieved by the function engiGetAggrElement(objects, i, sdaiINSTANCE, &object), whose address is stored in the output parameter object; the properties of components can be got by the address of entities, and the hierarchical structure of IFC standard can be analyzed layer by layer until the target data is reached. Fig.1 shows the first and last part of the space coordinate retrieving process for the space vertices of a specific component.
As shown in Fig.1 the property Representation (IFCPRODUCTDEFINITIONSHAPE) is first retrieved by function sdaiGetAttrBN(), and the address of the instance is stored in the temporary ntemp_2; Similar operations are conducted in the middle part and at last the instance pointed by ntemp_2 is retrieved by function sdaiGetAttrBN() to get the instance of IFCCARTESIANPOINT: Polygon, whose address is stored in the temporary ntemp_1. The geometric coordinates is finally reached by retrieving the properties of x, y and z of the instance pointed by ntemp_1. The IFC data interface can initialize the local database by abstracting project information from IFC files as the data source for durability appraising module. Similar to the analyzing method mentioned above, the extension, formation and storage of IFC file can all be achieved by adopting corresponding functions from IFC Engine toolkit.
3. Application module of durability

The durability appraising module is the programmed implementation of durability theories and utilizes the data from the local database founded by IFC data interface to achieve the requirement model. The application of durability theories in building project can be classified into three typical types: durability design, durability appraising and residual life prediction. The software system is developed according to the three types of requirement and the related functions are achieved.

3.1. Durability design

The problems caused by lack of durability have been increasing for decades worldwide and additional cost must be spent on the repair and maintenance. The durability of structure is mainly affected by the phase of design, which has been focusing on safety without consideration of durability ever since. The result of design is only adequate to the safety and suitability, so the structure will deteriorate with time and break down before the design serving life. As a result, the durability must be considered by the designer as a crucial standard. The Code for durability design of concrete structure was issued in 2008 in China to standardize the design process with durability requirements. However, since the design software system and method those are most adopted have not considered the requirements in the code, the process of durability code checking must be conducted manually for massive project data. To improve the efficiency of code checking, it is necessary to automate the code check with the help of computers, so the system developed in this paper integrates the Code for durability design of concrete structure into the durability design module, which can check whether the data from IFC file have enough durability according to the criteria from the code. The data that is not suitable is highlighted and some suggestion of modification will be given by the system. The modified data can be put into IFC file to update the old one. Fig. 2 is presenting a normal distribution curve of concrete carbonization depth at the age of 22 years. This curve is given by the analysis of the system according to the environmental actions, loads and spot detected information. As shown in Fig.2, the expectation of carbonization depth is 6.25mm and has enough durability according to the durability code.

3.2. Durability appraising

Durability appraising is defined as grading the safety level of structure, which includes the grading of components, floors, units and structure according to the factors such as the ratio of resistance and internal force, structure function, environmental condition et. As literatures stated, the component resistances of bending, pressing, torsion and shearing are the key factors for grading of components and structure. The practical method adopted most at present is to detect the structure on spot and the data detected is utilized by operators to remodel and analyze the structure, and the Standard for appraiser of reliability of civil buildings is adopted as the criteria to grade the structure. The durability appraising module of the developed software system is able to load data detected on spot, remodel the structure and analyze the data together with the data abstracted from the durability information model.
According to the results of the analysis, the grade of component and structure is determined by the Standard for appraiser of reliability of civil buildings which is integrated into the module and the appraising result can be stored into the IFC file. As mentioned above, the automation and integration of durability appraising is realized by the developed function module.

3.3. Residual life predicting

The result of residual life predicting is the key reference for repairing and maintaining of existing structures. The residual life of existing structure is mainly determined by the current damage, degrading speed and limit state of durability. The module in this paper integrates the popular theory models, and predicts the residual life of structure based on the mentioned theory models. The limit state of durability is determined before predicting according to the type of component, usage and the environment level and typical limit states are input into the system, including carbonization depth, crack width, erosion ratio of reinforcement; the current damage of structure is investigated and detected on spot, and the results including carbonization depth, corrosion ratio of reinforcement, crack width, deformation are input to the system through user interface. The residual life of component and structure can be analyzed according to the local project information and theory models. Fig.3 shows the bending resistance deterioration curve of a beam taking into account factors of carbonization, chloride ion aggression, reinforcement corrosion and environment conditions. According to the deterioration curve, it is concluded that the residual life is 40 years by the limit state of 140kNm. The three modules elaborated above are the essential function components of the developed system.

4. Conclusion

With the help of the durability information model developed, IFC tool and durability analysis tool, an appraising module is proposed, and the technology of BIM is used to enhance the RC durability analysis. Additionally, the IFC is utilized with the help of IFC Engine toolkit. The cooperation through different IFC depended functions is proved to be efficient by case study. The methods system described in this paper can also suit the situation of IFC implementation in other building industry fields.

Acknowledgement

This work is part of the research projects: Forecasting and Monitoring Technology for Urban Slow-Changed Geological Disasters Based on Distributed Optical Fiber System (MS12017027-3) and 3D Visualized Operation System for Smart Airport Terminals Based on BIM (SBK2019042774). The authors gratefully acknowledge the support from the projects.

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