BUILDING ENERGY CODE ADVISOR

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ABSTRACT

This paper presents a decision support system (DSS), named Building Energy Code Advisor, that aims to: (i) check if the early design of the exterior envelope complies with Model National Energy Code of Canada for Buildings (MNECCB) [1] requirements, (ii) provide technical advice on how to improve the design according to the code, and (iii) be a learning tool about the MNECCB. The system contains the code requirements for all building envelope subsystems such as wall, window, roof or exterior door. The impact of air infiltration rate on the annual thermal loads is also evaluated.

INTRODUCTION

Energy-efficient buildings are the results of the designer's ability to apply energy-efficient techniques into the design process. Building designers are constantly facing the problem of how to choose energy conservation options and how to implement them. In the conceptual design stage, the architect would study the requirements of clients and take decisions regarding the building type, form, structure type, etc. The definition of envelope assemblies would be made in the preliminary design stage. Thus many important design decisions that significantly affect energy performance are made in this stage.

The new MNECCB could guide designers under these circumstances and give them a systematic approach to account for building design issues. The requirements contained in the code are in the form of statements and rules. Misinterpreting or overlooking provisions of the Code would lead to building failures.

This paper presents a decision support system, named Building Energy Code Advisor (BECA), based on the MNECCB that aims to: (i) check if the early design of the exterior envelope complies with MNECCB requirements, (ii) provide technical advice on how to improve the design according to the code, and (iii) be a learning tool about the MNECCB. The system contains the code requirements for all building envelope subsystems such as wall, window, roof or exterior door. The impact of air infiltration rate on the annual thermal loads can also be evaluated, and the results are used to address the effect on the indoor air quality.

MODEL NATIONAL ENERGY CODE OF CANADA FOR BUILDINGS (MNECCB)

The compliance check paths provided in the code are shown in Figure 1. The mandatory requirements apply to all buildings in all circumstances. Minimum prescriptive requirements are used in the prescriptive compliance path. When some of the building envelope characteristics do not comply with minimum prescriptive requirements, while others do, the trade-off compliance path can be used to check the overall performance of the exterior envelope.

Building energy performance path takes every aspect of a building design into consideration when it is used to evaluate the energy performance of the entire building: the exterior envelope, the lighting system, type of HVAC system, the service water heating system and the electrical power. Although some aspects of the building design may not respect the prescriptive requirements, the proposed design is accepted if its expected energy consumption does not exceed that of a building corresponding to the prescriptive requirements. This path is not included in the BECA system.

KNOWLEDGE-BASED SYSTEM

Knowledge-based systems (KBS) are well suited for the computerization of Code requirements expressed as rule sets. The literature survey found substantial research and development activities related to the application of knowledge-based system (KBS) in both code checking area and energy-performance evaluation [2,3]. We can see several reasons why knowledge-based system is used.

- Codes contain sets of rules that indicate if a design is accepted or not.

- Unlike many conventional energy evaluation systems that use the procedural simulation approach, KBS needs less input, less calculations and can still get results with acceptable accuracy.

- KBS separates knowledge from the control process. Instead of mixing the knowledge and the control of the knowledge, it stores pieces of knowledge in the knowledge base, and use different rules to control them. The quantitative change on specific piece of knowledge does not affect the rules that control the knowledge base. Similarly, the changing of rule will not affect the knowledge representation as long as this rule still deals with the same parameters as well. This is an important advantageous in heuristic programming where changes may occur very frequently.

- Due to its heuristic nature, the KBS can track the knowledge used to generate solution and explain how the conclusion is obtained. It is also used to provide advice on how to improve the design and to better understand the code requirements.

BUILDING ENERGY CODE ADVISOR (BECA)

Overall Architecture

The integrated system that combines knowledge base, database and correlation model is developed into a CAD environment. A research prototype named Building Energy Code Advisor (BECA) is developed and presented herein. The architecture of the computer-aided design system consists of a pre-processor, the main module of MNECCB and a post-processor. The pre-processor role is to gather general design information. The post-processor displays the results at the end of a consultation session. The main module of MNECCB consists of several modules: the database, the knowledge base and the correlation model.

Pre-Processor

The use of a graphic user interface (GUI) saves time and makes operation simple. When a conventional energy evaluation system is used, the user has to write down all the necessary design information. As the working drawings are usually done in a CAD environment, the user has to quit the CAD program and open another software to input those data manually. This whole procedure is time-consuming and awkward.

There are two ways offered by the BECA system to input the required data (Figure 2): (i) input by the user, and (ii) collect information from the drawing. The shape of a window, a piece of wall in an elevation drawing, or a floor in a plan is drawn. This function requires the interface to be able to interact between the working drawing and interface system. By pushing the "Sketch the shape" button, the dialogue box disappears and the AutoCAD cursor appears to let users select some representative points on the plan drawing. After the sketch procedure is finished, the dialogue box is resumed; the value of floor is automatically calculated and displayed. This method is also applied to obtain the wall or window areas from the drawings.

Main Module

1. Database

The database can automatically generate two sets of data at the beginning of the code compliance check. One set of data, called Design Building, contains information about the proposed building design. It consists of the dimensional information, the materials used in the building envelope and their thermal characteristic values, and the lighting conditions in the building. The other set of data named Reference Building, contains information necessary to develop a reference building, with the same dimensions as the design building. For instance, it uses the prescriptive values for thermal properties of the exterior envelops (e.g. the recommended U-value for a metal stud wall) as they are provided in the energy code.

2. Knowledge Base: Object Orientated and Hypertext Implementation

The knowledge base stores the mandatory requirements and the prescriptive requirements. The proposed design is checked for compliance with the mandatory requirements (e.g. the continuity of the insulation). Then, if the user chooses to use the prescriptive compliance path, the knowledge base is used to compare the design building with the prescriptive requirements. The knowledge base also stores the code text and it is accessible at any time to the user.

Hypertext technique is used to display the code text and the explanation of technical terms. Compliance with these requirements ensures that significant design aspects and details are not overlooked. If a designer follows those requirements, his new building will have acceptable energy efficiency, but will not represent the optimum design. It is usually called "the worst design allowed by the code".

The object oriented approach views the world in a different way than the conventional procedural systems. It views the world as a set of objects (which are defined as classes in programming), each of the objects is described by a set of attributes and there is a set of rules to control the relationships between the different objects. The knowledge is incorporated into knowledge base as attributes and rules that control the relations between attributes. The use of the object oriented strategy in the developing of the knowledge base leads to a significant advantage: the modifications and expansion of the existing program are done relatively easy. If a new type of building component is needed, a new class is added. Similarly, the expansion of the knowledge base can be accomplished by adding more rules without disturbing existing rules and classes.

The different types of building envelope assemblies such as windows, walls or floors are defined as different basic classes. Through the study of code, there are eight basic building components: (a) windows and other glazed areas, (b) walls above ground level, (c) walls below ground level, (d) floors above ground level, (e) floors in contact with the ground, (f) roofs, (g) exterior doors, and (h) exterior and interior lighting system. The different considerations concerning the design of a specific building component are defined as different attributes of a basic class. The air infiltration rate is defined as a numerical attribute of window class and walls above ground level class. It is one of the prescriptive requirements in the code. The user inputs the value of infiltration rate and the overall impact is evaluated according to the code.

3. CONDENSE and VISION Programs

Thermal characteristics of a building envelope component present some difficulties in the evaluation, especially for the architects. It is hard for an architect to obtain the physical property of every material. It is even harder for them to grasp the calculation method of the overall heat transmittance when air space, studs, columns or channels are incorporated in a wall assembly, or in case of multi-glazed windows with various types of frames, color, coating, and in-fill gas conditions.

In order to eliminate this problem, two programs that calculate the U-value of opaque envelope assembly and the U-value of the window system are incorporated. The program used to calculate the opaque envelope assembly is called CONDENSE [4] and was originally designed to check the risk for condensation in the envelope assembly. It also calculates the U-value within AutoCAD environment. Another benefit of the CONDENSE software is the access of its database which contains hundreds of the physical characteristics of the building materials available on the market. CONDENSE shows the proposed wall sections in the drawing when the user chooses building materials from the database.

The second program, called VISION [5], calculates the glazing U-value and SHGC (Solar Heat Gain Coefficient). It shows the window section, with different numbers of layers, coatings and in-fill gases. The VISION program does not take window frames into consideration. Therefore, the calculation method provided by ASHRAE is used to evaluate the impact of center of glass, glazing, frame and edge. The entire system works within the design environment, which is developed in AutoCAD Autolisp. Both programs evaluate the inside surface temperature, which can be used to assess the level of thermal comfort.

4. Correlation Model

In the case of the “Trade-off Compliance Path”, the code does not prescribe detailed requirements for the design. The compliance is based on the performance level: the annual thermal loads of exterior envelope of the new building must not exceed that of a corresponding building which complies with the prescriptive requirements.

The correlation model allows to evaluate the annual thermal loads of the exterior envelope for both the design building and the reference building, as requested by the trade-off path approach. Cornick and Sander [6] developed a simplified energy model based on about 5400 simulations with the DOE-2.1E program. This model estimates the change in the energy consumption due to changes in the thermal characteristics of exterior envelope. It predicts the heating and cooling loads, as a function of orientation, climate, internal loads, and wall/window characteristics. A design is accepted if its annual thermal loads are less than those of the corresponding reference building. The simplified procedure used by this path is useful because: (a) many parameters are not available in the early design stage, and therefore only the most significant ones should be used; and (b) a time-consuming and detailed energy analysis is not necessary at this design stage, where it is more important to assess the relative performance of one design solution against others rather than the absolute value of the predicted energy consumption.

Note on Validation

Validation was performed to check if the completed prototype performs the required functions and provides results of an acceptable accuracy and completeness. Two case studies were used to test the operation of data collection, the accuracy of correlation model, and the accuracy of conclusions and technical advice.

CONCLUSIONS

The prototype BECA system works properly and can further be expanded into a useful tool for building designers. Some data related to air infiltration rates and thermal comfort will be exported to other software for further analysis.

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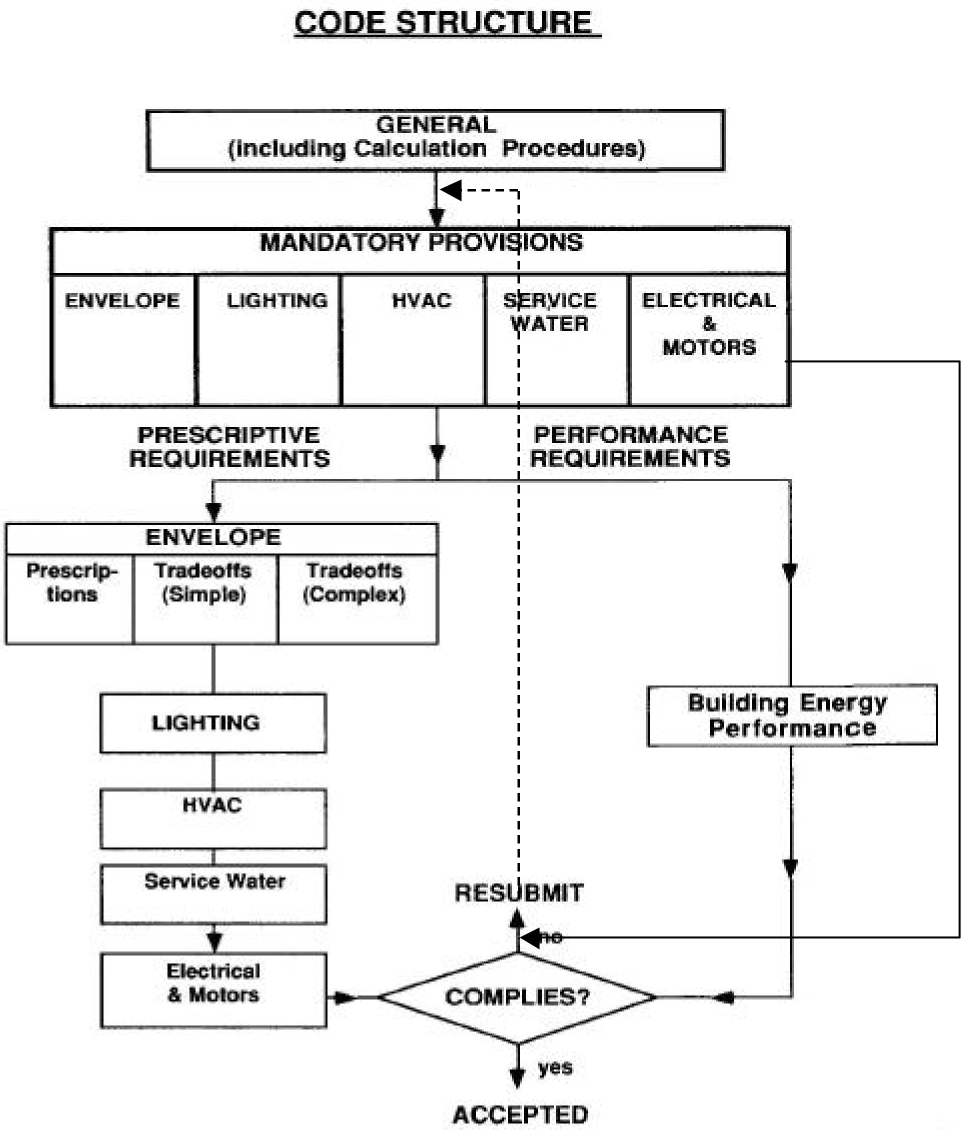

Figure 1: Compliance Paths in MNECCB [1]

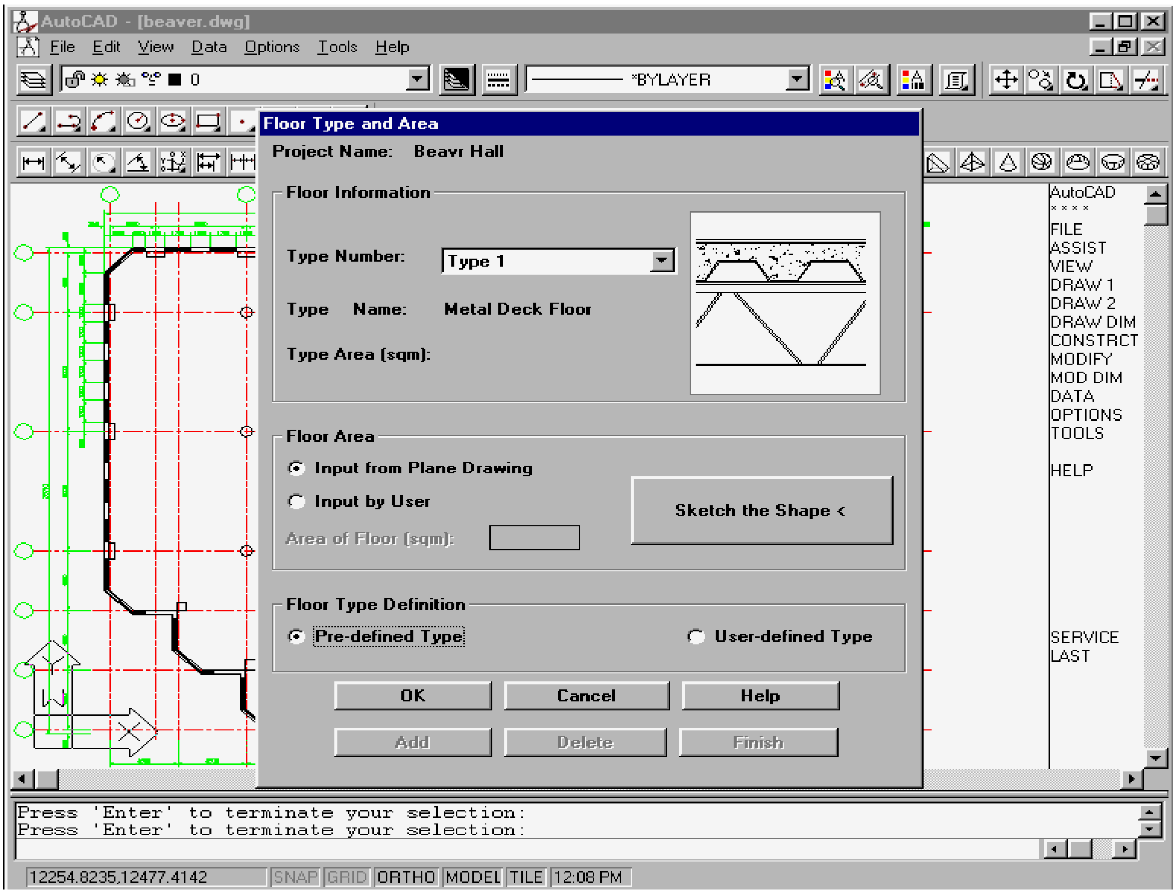

Figure 2: A Dialogue Box for Collecting of Floor Design Data