A COURSE ON COMPUTER-AIDED BUILDING DESIGN

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EDITOR: P. Christiansson

Hugues Rivard, Professor
Dept. of Construction Engineering, École de technologie supérieure, Université du Québec, Canada
also Adjunct Associate Professor in the Dept. of Building, Civil and Env. Engineering, Concordia University
email: hugues.rivard@etsmtl.ca, http://www.ctn.etsmtl.ca/hrivard

Claude Bédard, Dean of Research and Technology Transfer
École de technologie supérieure, Université du Québec, Canada
also Adjunct Professor in the Dept. of Building, Civil and Env. Engineering, Concordia University
email: claude.bedard@etsmtl.ca

SUMMARY: *Computer-Aided Building Design is a final-year undergraduate course that has been offered for more than 20 years at Concordia University. Naturally, over that period the course has evolved as fast as the technology. It started from a programming course with matrix representation of view transformations to lately, the use of off-the-shelf commercial software packages and the Internet to support project collaboration and submission. This course introduces students to the process of integrated building design. It emphasizes both computer assistance (CA) and building design (BD). Students experience the design process in teams in the context of a realistic building design project. The building is designed in a holistic manner integrating related fields such as spatial layout, structures, enclosure, energy consumption, and construction cost estimation. Many computer tools are used and integrated throughout the design process. The paper provides a brief historical overview of the course and it describes the material covered, the team-design project, and the IT portion of the course.*

KEYWORDS: *engineering education, information technology, integrated building design, computer-aided design, e-learning.*

1. INTRODUCTION

Concordia University offers a program of building engineering that is unique in Canada. This accredited engineering program is similar to architectural engineering found in many countries. The building engineering field looks at buildings in a holistic fashion integrating various aspects such as structures, envelope, HVAC, lighting, acoustics and construction. The computer-aided building design course (named CABD and numbered BLDG-459) is usually taken on the sixth out of a total of eight semesters (each four month long). The students, after covering the main theory in the various domains come to address them for the first time in an integrated fashion in the CABD course. It is also a preparation for the capstone design course given during the 7th and 8th semesters (i.e. in the final year of the bachelor degree).

The computer-aided building design course introduces students to the process of integrated building design. The course equally emphasizes both computer assistance (CA) and building design (BD). Design problems are generally characterized by: (a) incomplete specifications, requiring problem identification and definition to properly formulate the design issues involved, and (b) an open-ended solution space, where alternatives must be systematically synthesized, then analyzed and evaluated so as to recommend the "best" solution. Design is best learned by doing. Hence, students experience the design process in teams in the context of a realistic building design problem. The building design project takes into account the following fields: spatial layout, structures, enclosure, energy consumption, and construction cost estimation. Thus, the building is designed in a holistic manner integrating these fields with the help of many computer tools used throughout the process.

The objectives of the course are:

- To develop a better understanding of the building engineering design process and critical issues affecting design practice.

- To provide a methodology for approaching and solving integrated design problems.
- To assess the contributions of computer assistance in building design.
- To acquire 'hands on' experience with current commercial software for building design.

Computer-Aided Building Design has been offered for more than 20 years at Concordia University. Naturally, during that period the course had to keep pace with technology changes. After a brief historical overview, the paper will describe the material covered, the team-design project, and the IT portion of the course.

2. DEVELOPMENT OF THE CABD COURSE

Building engineering emerged as a separate discipline at Concordia University following the establishment of the Centre for Building Studies in 1977. Although it was the first program of its kind (and still is) in Canada, building engineering had existed as a distinct entity for several decades elsewhere, notably in Europe and in the US under the name of Architectural Engineering. At Concordia, it started as a Master's degree option in building studies within the Civil Engineering department, before assuming a distinct identity with its own resources and academic programs at all cycles, culminating with the accreditation of the bachelor degree in building engineering in 1981.

Conceived as a multidisciplinary program, building engineering endeavours to capture all technical aspects related to buildings in order to educate well-rounded professionals that have the ability to make informed decision about buildings, taking into account different perspectives. It was in this context of adding a specific technical expertise that the CABD course was first introduced in the building engineering curriculum at the end of the 70's. Such a course was particularly timely given the emergence of novel computer-automated drafting tools, rendered possible by the availability of dedicated graphic peripherals such as vector-based screens, flat-bed plotters of acceptable accuracy, appropriate input devices, and digital processors of sufficient speed that were readily available (workstations and mini-computers). Thus, for the first 5 to 7 years, the CABD course basically introduced students to the fundamentals of automated drafting by means of basic geometric transformations that were coded in FORTRAN in order to produce simple images on the screen, before plotting them on paper.

By the mid 1980's, the course was in a dire need of a fundamental revamping. First, technology advances had made obsolete the traditional programming of geometric transformations by means of concatenated matrices. Also, the advent of the personal computer (PC) in 1981 with a simple user-interface, which was shortly followed by the widespread availability of computer-aided drafting packages (e.g., AutoCAD) and other engineering applications designed to exploit the capabilities of the new computing platforms, had changed the engineering work environment. Interactivity also was becoming the norm, enabled by new and affordable raster-based colour screens and the mouse. These technological advances laid the background for a fundamental upgrade of the CABD course, from one based on technology to one concentrating on multidisciplinary building design. The course therefore progressively changed focus over a few years period, starting in 1986. Instead of presenting another technical topic to students, namely automated drafting, CABD sought on the contrary to introduce and assemble a variety of different technical perspectives, all computer-based, in order to improve the overall building design process. The programming of graphic entities, which covered the first month of classes in 1986, was gradually reduced to nil by the early 1990's and replaced by training on commercially available PC-based programs such as AutoCAD. The semester-long team-based design project was introduced in its new configuration as early as 1986, although students were only required to reproduce existing residential building drawings at the time because of scarce computing resources and the lack of familiarity with CAD software. The opportunity to check structural members was also introduced in 1986 by means of PFRAME, another PC-based application software. For the next couple of years, the design project required the use of a light structural steel frame because residential wood-frame construction could not be analyzed easily with PFRAME. This restriction was lifted in the early 1990's with the adoption of software introduced by the Canadian Wood Council specifically for the design/analysis of wood-frame structures. PC-based application programs were also used only for energy analysis (HOT2000) and quantity take off (QuickEst). The full complement of application softwares was arrived at by the early 1990's with the addition of a building envelope design/analysis package called BEADS and a simple tool to reproduce 3D topographies called SURFER. Several lectures were completely overhauled and dedicated to present the specifics of the building engineering design process as an integrated multidisciplinary activity. The major design project covering the entire semester was presented as the principal mean to experiment with integrated building design with the help of representative commercial application packages.

3. COURSE CONTENT AND DELIVERY

The latest vintage of CABD uses several commercially available software packages, the Internet, and a Web portal. Commercial software packages are introduced for each of the important design stages. Students are warned that this course is unlike most other engineering undergraduate course because of its unusual format and content. There are no textbook, no theory, and no formula. Thus, this course requires much personal commitment to learn by oneself. The weekly lecture covers course contents, demonstrates software, and discusses design project. Students are expected to spend significant amount of time each week to do “hands on” work with computers and to work on the design project.

There is no textbook required in this class, but handouts summarizing each lecture are provided in class and a required course pack contains a selection of additional reading materials plus some important references. An optional reference book on Canadian wood-frame house construction is also made available at the library and the bookstore [CMHC 2001].

The course BLDG-341 “Building Engineering Systems” is a prerequisite. This course introduces a systematic approach to solving building engineering problems and covers techniques such as linear and nonlinear programming, decision analysis, and optimization methods. The course BLDG-401 “Building Economics” is also a prerequisite or can be taken concurrently. This course covers the basics of economic analyses of projects such as life cycle costing, inflation, and forecasting. Students are also expected to have basic knowledge in: personal computing, technical drawing (AutoCAD LT) and writing, structural analysis, envelope analysis, and HVAC systems.

The format of a lecture is as follows. Each lecture is two and a half hours. It usually starts with a computer-based presentation (i.e., PowerPoint) to present the content of the lecture. The students can follow the material covered in notes distributed in class. This allows students to focus on listening to the lecture rather than on feverishly writing what is presented. The lecture normally ends with a software demonstration and tutorial. Active learning is encouraged in the classroom because studies have shown that the attention of students drifts away after 20 minutes of formal lecturing. It has been proven that it is easier for students to grasp concepts and theories as a result of discussion, debate, and other forms of idea testing. Instead of simply stating the definition of a complex and fundamental concept such as “design”, students are asked to come up with a definition by themselves. After giving them some time to think about the notions involved and to write down some initial ideas on their own, they are asked to discuss their definitions in small groups and to agree on a common one. Then, their findings are shared and a consensus is seeked from the whole class. After some discussion and debate, the resulting definition is usually very close to the textbook definition, which is later presented. The difference is that since they tackled the various concepts comprising the definition on their own, they can then understand and integrate it more easily.

The course content starts with a broad perspective on the construction industry in the first course. Then, the course covers all the building delivery process from the decision to build stage to the design and ends just before construction starts. The last two courses cover ethics and future outlook. The next subsections give a brief overview of the content covered in each class.

3.1 Introduction to CABD

The first lecture starts with an introduction to this unusual course by stating its objectives, plan, grading scheme, and a presentation of the project. This lecture then provides an overview of the construction industry. The lecture continues with a comparison of delivering two heavily engineered products of equivalent price: a passenger airplane (e.g., a Boeing 767) and a high-rise (e.g., the 50-stories IBM-Marathon Tower in Montreal). This comparison, shown in Table 1 below, illustrates the particularities of the building design process.

TABLE 1: Comparison between the production of a high-rise and a passenger airplane.

A High-Rise	A Passenger Airplane
A unique product.	Multiple production (4 planes/month).
Construction occurs in a unique natural environment.	A controlled manufacturing environment.
The organization delivering a building is totally fragmented among many firms.	A more integrated design and production process.
There is almost no research and development.	There are large investments in R. & D.

A large emphasis is put on the fragmentation problem and its consequences. The lecture then illustrates the importance and health of the architecture-engineering-construction industry with some key statistics and the assessment of its competitiveness is compared to that of other countries. Information technology is defined and its fast evolution is demonstrated with Moore's law. The lecture ends with some statistics on the use of IT in Canada and in particular in the AEC industry [Rivard 2000; Charles et al. 2002].

3.2 Building Design Process

The second lecture focuses on the concept of design. A working definition of design is formulated through discussion with the class. The main characteristics of design are introduced. The engineering design process is presented in terms of its main steps: problem definition; iteration between synthesis and analysis or evaluation; and documentation. More emphasis is put on the definition of design problems and its main components: the goal; the objectives; the constraints; and the evaluation criteria. A method is presented to clarify objectives [Cross 1989]. The architectural program is then categorized as a problem definition for building design. The lecture ends with an overview of the various phases a building goes through during its life span. The building delivery process has three major phases: decision (recognition of needs, architectural program, assembling team); design (conceptual design, preliminary design, and detailed design); construction (bidding, construction, and commissioning). These are followed by operation, renovation, and demolition.

3.3 Conceptual Building Design

The third lecture presents the conceptual building design stage and its importance. During this design stage, potential design alternatives are generated and roughly evaluated in order to obtain the most promising solution. At this stage, the evaluation is done using general manual methods since the alternatives are still too ill-defined for computerized techniques. The importance of this stage is illustrated by showing the impact of decisions on design, its quality, and the life-cycle performance with respect to resources and time. As this stage is a prime time for creativity, good and bad habits with respect to creativity are identified [Navin 1994]. Two design methods are presented to help in the generation of design alternatives: brainstorming and morphological chart [Cross 1989]. The weighted objectives method is presented to help in selecting the best design alternative. This topic ends in the following lecture with an introduction to space layout, building codes and architectural graphic standards. The National Building Code of Canada is introduced and some of its important articles are presented [NRCC 1995]. Additional articles are presented in subsequent lectures when they are relevant to the topic covered.

3.4 Preliminary Building Design

The preliminary building design stage brings the selected building design alternative from the previous stage to a higher level of resolution. The building design is developed in more detail and evaluated to obtain an optimal solution in terms of structure, enclosure, mechanical systems, and interior design. Here computer assistance becomes available to help optimize and improve the design. This lecture presents an overview of the preliminary design stage which is covered in greater detail in the following six lectures. An important emphasis is put on the integrated consideration during the design of the building and its sub-systems. Building design needs to consider all the following to achieve integration [Rush 1986]: buildings are made of four major systems (structure, envelope, services, and interior); there are four categories of human needs (physiological, psychological, sociological, and economical); and six performance mandates (functional/spatial, thermal, air, acoustic, visual, and integrity). Decision-making needs to consider interrelations among the above. Diagrams from the “Building Systems Integration Handbook” are provided to help students to consider some of these interrelations [Rush 1986].

3.4.1 Structural Design

There are two lectures on structural design. They review the structural design and analysis process and cover relevant articles in the building code. The design of simple residential wood-frame structures is presented in depth [CMHC 2001]. This type of construction is typical for small buildings in Canada. The history of structural engineering software is also covered [Fenves 1998]. Current structural engineering software is divided into three important categories: structural framing layout (tools within CAD packages that help in generating framing plans, elevations and annotations); structural design of components (tools that help in designing specific structural components such as beams, floors, and foundations); and structural analysis (comprehensive analysis packages that typically use the stiffness method). A first software package is demonstrated in class and in a tutorial. The software, called WoodWork Sizer, is a simple structural design software to design wood frame structures.

3.4.2 Envelope Design

The envelope is a critical component of a building, particularly in the cold climate that exists in Canada. Its purpose is to protect the indoor environment from disturbing outdoor conditions. Its composition determines the presence and magnitude of heat flow, water vapour flow and condensation. The lecture reviews the envelope design process and covers relevant articles in the building code. A second software package is demonstrated in class and in a tutorial. The software, called Condense, assists the designer in defining a section of the envelope (i.e., wall, roof, or floor).

3.4.3 Building Energy Analysis

The goal of building energy analysis is to establish how much energy is required to maintain indoor environmental conditions throughout the year. This kind of analysis helps in assessing the long term impact of decisions regarding the thermal resistance of envelope sections, the selection of windows and doors, and the choice of heating and cooling systems. This lecture introduces energy analysis of buildings, covers relevant articles in the building code, and explains a simple manual calculation method (the degree-day method) to estimate energy use [ASHRAE 2002]. Many software packages exist to carry out building energy analysis. The lecture justifies the importance of modelling buildings and describes the main characteristics of energy simulation software. It presents the five most important simulation methods (degree-day method, BIN method, weighting factor/conduction transfer function method, heat balance/conduction transfer function method, and finite difference method). It also highlights the importance of error checking and debugging as well as the limitations of building modelling. A third software package is demonstrated in class and in a tutorial. The software, called HOT2000, is a comprehensive and user-friendly program developed to assess the energy efficiency of low-rise residential buildings.

3.4.4 Cost Estimation

At the end of the preliminary building design stage, the building has been refined to a level that allows the preparation of a more accurate cost estimate. This lecture stresses the importance of cost estimating, covers the fundamentals of building cost estimating, and describes how to perform take-offs and carry out cost estimation by hand using RS Means [Means 1999]. The software Precision Estimating from Timberline is demonstrated in class and in a tutorial. This software is a comprehensive tool to assist in take-offs and cost estimating.

3.5 Ethics and Computer Use

Ethics is an important topic in engineering design. This lecture starts with a case study of the Citicorp Center in New York City. The design of the fifty-nine-story tower, completed in 1977, has a unique structural design in order to accommodate an existing church located in the corner of the block occupied by the building. Although the building was built according to current standards, the lead structural engineer, William J. LeMessurier, found out after the completion of the building that it had major structural weaknesses that could jeopardize its integrity. The way LeMessurier handled the situation is a model of ethical behaviour for students [Morgenstern 1995]. After a discussion on the case study, the lecture provides an explanation of ethics, presents some implications for professionals, and introduces a couple of examples of codes of ethics. The lectures then moves on to ethics considerations of computer use in design. Students are warned that computers provide a false sense of security and are actually quite imperfect. They are advised to always view computer results with a healthy scepticism and always check them [Emkin 1998]. The lecture then presents potential issues or difficulties that could lead to litigations: software selection; operator error; hardware defects; improper application of software or "black box syndrome"; failure to use the computer; and protecting client's rights. Recommendations for a better use of computerized assistance in building design are also provided.

3.6 Future Trends

The last lecture provides an outlook of the future in computer-aided building design. The future of hardware is discussed in terms of increased speed and power, better input/output devices, portable computers, and robot construction. The future in software is discussed in terms of Web portals for better collaboration, computer-integrated design and construction, virtual reality, support for conceptual design, and increased use of artificial intelligence. The students are introduced to the Industry Foundation Classes and how these facilitate the exchange of data between software applications from different vendors. They are also told that these are currently available in several commercial packages and data exchange with the IFC is demonstrated. The lecture ends with a demonstration of 3D Studio, a software application used to create photorealistic rendering of buildings.

4. DESIGN PROJECTS

Since design is learned by experiencing design situations, the design project is the most important component of the course. Hence, 65% of the course grade is for the design project while the remainder goes toward an individually written final test at the end of the semester. The building design project is executed by teams of three or four students. This not only adds realism to the course (since practicing engineers seldom, if ever, work alone) but it also allows students to help each other and to develop group problem-solving skills. The teams are assembled by the instructor to make sure that the composition of each team is well balanced in terms of students' interests (i.e., structures, envelope, HVAC, and construction management). Thus, the composition of the teams reflects better what happens in the industry: design specialists (e.g., architect, structural engineer, mechanical engineer, etc.) are grouped together in an ad hoc fashion based on their cost bidding.

Since this design project is the first one that building engineering students carry out from beginning to end and because it is to be done within one semester, the scope of the project is kept realistically small. It is generally a two or three story energy efficient wood-frame building to be built on a city lot of 350 to 550 m^2. The students are responsible to design the overall layout, the structure, the enclosure and the heating and ventilation system of the building. They are not responsible for the interior design (i.e., furniture plus wall and floor coverings), plumbing, electrical system, and landscaping.

The project is made as real as possible. An actual vacant lot is selected nearby and the client to the design project is someone exterior to the course. For instance, in the past, some of the clients have been a real estate agent, an artist, and an energy engineer. Taking away the client role from the instruction has clarified the relationships with students. The instructor has more of a supervising role. At the beginning of the semester, the students interview the client to gather his/her design needs; and at the end of the semester, they present their final design solutions to the client. The client is asked to select one of the projects, which is given bonus points. This gives students the chance to experience the important interaction with clients and better prepares them for their future career. Of course, the design is never actually built.

Here is an example of a design brief. The client for the last course was Mr. Eric Chartrand, a successful video game designer who had started recently his own business. He wanted to build a new headquarter for his small business in the heart of Montreal. The row building was to have three stories plus a full-height basement. The basement, ground floor, and first floor were to be used by his business while the second floor was to be Mr. Chartrand's new home. The lot was located on the famous Boulevard St-Laurent, in Montreal, near Rachel Street. The front width is 13 m and the depth is 24 m for a total area of 314 m^2. A cadastral plan of the lot and the neighbourhood is given to the students as well as pictures of the site. A front view of the site is shown below.

FIG. 1: Front view of the design project site.

The building design project consists of seven project reports, which are spread throughout the semester. The reports and the lectures are closely linked together. These seven assignments provide an opportunity for students to experiment with software presented in class. The seven assignments are described next followed by an example of a project.

4.1 Problem Definition

In this first assignment, the students are asked to clearly define the design problem. This problem definition is paramount since it guides their design and is the basis for them to evaluate their proposed design. This document states the goal of the project, design objectives, constraints and evaluation criteria. The information is to be gathered from the design brief, an interview with the client, team discussion, and any additional research that is felt necessary. This document should not present any solution yet.

4.2 Conceptual Building Design

In the second assignment, the teams generate a number of design alternatives to satisfy the client's needs. They use the design methods presented in class to initiate the design process. The potential design alternatives are roughly evaluated using the weighted objectives method in order to obtain the most promising solution. Schematic drawings prepared in AutoCAD are submitted to describe the selected solution.

4.3 Structural Design

In the third assignment, the students define the wood-frame structure of the alternative that was selected in the previous assignment. They use WoodWork Sizer to assist them in defining the load-bearing components of the structure. They need to verify the results provided automatically by Sizer. They also provide structural drawings prepared on AutoCAD.

4.4 Enclosure Design and Energy Analysis

In the fourth assignment, the teams define the envelope of the building as well as assess the energy consumption of the alternative selected. The objectives here are to determine details of the building envelope (i.e., sections of the envelope and location and type of openings) and heating system in order to minimize energy consumption, optimize envelope performance, and minimize cost of materials. To achieve these objectives, a number of design alternatives in terms of envelope construction are generated and evaluated. Two software packages are used. CONDENSE helps them in defining the envelope sections for the exterior walls, foundation walls, roof, and overhanging floors. HOT2000 assists them in determining the yearly energy consumption of the building. AutoCAD drawings are provided to define the exterior wall elevations with their openings.

4.5 Construction Cost Estimation

In the fifth assignment, the teams estimate the construction costs for the house using the software Precision Estimating. For the costs of the interior, they only consider permanent fixtures (e.g., bath, sink, WC), primer paint and no floor finishes. They check the accuracy of the cost by comparing unit costs for material and labour from other references and by comparing the overall gross cost average in $\$/m^2$ with those published in references for local house market. They are asked to set a realistic selling price for the building by considering markup, overhead and contingencies.

4.6 Oral Presentation

The teams prepare a 20-minute presentation describing their design projects. The ability to communicate ideas and plans effectively in front of an audience is considered one of the most important career skills. This exercise is intended to give them a chance to practice this skill. The objective here is to sell their design project to the client. The teams are also expected to use the computer and the overhead projector for the presentation.

4.7 Preliminary Building Design

In the last assignment, the team finalizes the preliminary design of the building and reflect on the whole project. A complete set of drawings is submitted with revisions as requested in the corrections of the previous assignments. A summary of the design for the client is provided to highlight the major technical aspects that have been addressed. The students are also asked to report on the design process itself and describe how their design evolved from the conceptual design to the final submission. They are also asked to comment on their experience with the entire project.

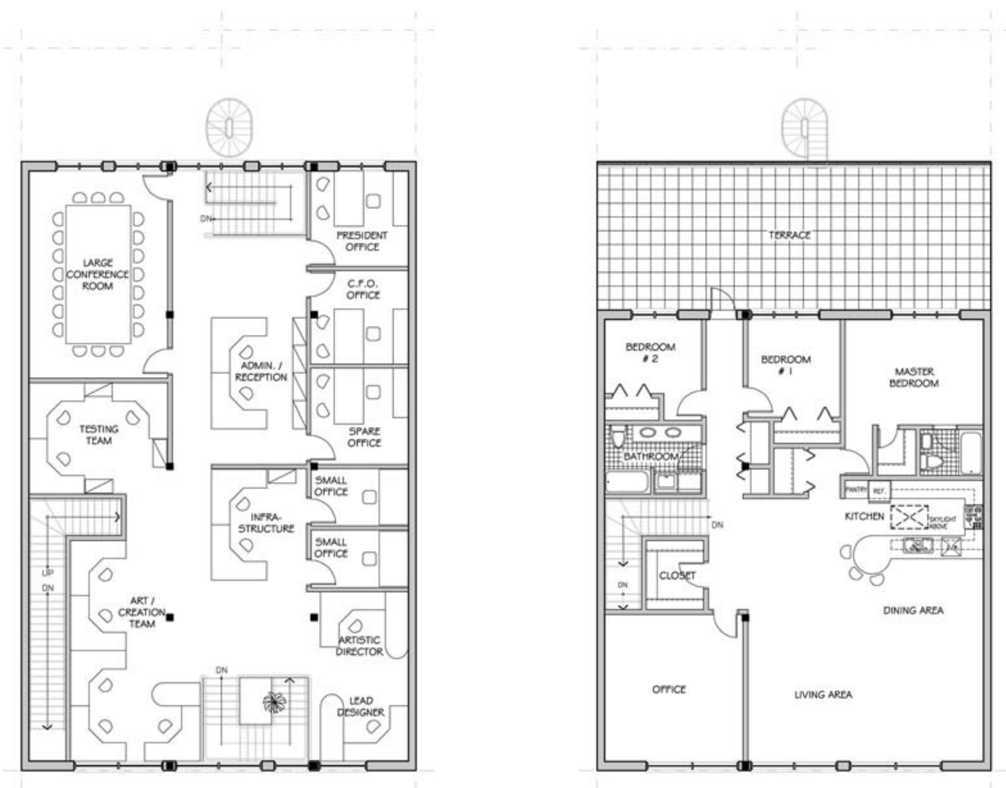

FIG. 2: Floor plans of the second floor and top floor of the design project prepared by the Building Pros team.

4.8 Design Project Example

The design from the team "The Building Pros" was the one selected by the client Mr. Chartrand. It accommodated best the 45 employees of the video game design firm as well as an apartment for four on the top floor. The basement contains services such as cafeteria, game room, presentation room and conference room. The open space ground floor contains the reception and the production department. The second floor, shown in Figure 2 above, contains the administration offices and the creation department. The top floor is an apartment with bedrooms located in the back, where noise from the street is minimal, as shown in Figure 2 above. The structure used columns on the main floors in order to have open space and the flexibility to change the space layout as the firm will mature without affecting the structure. The front façade is made of stone to fit with the neighboring buildings. The resulting design was energy efficient and economical compared to other similar constructions in Montreal.

5. INFORMATION TECHNOLOGY EDUCATIONAL SUPPORT

As its title implies, the CABD course makes extensive use of IT applications. In addition to covering IT issues in about half of each lecture, the course also makes use of several software applications, relies on a Web portal for communication, and requires students to publish their design projects on the Web. Each of these three IT aspects is described next.

5.1 Software Applications

There is no programming involved in this course. Students are introduced to commercially available software packages for each of the important preliminary design aspects. These packages were selected based on their simplicity and their usefulness for the design project. Nevertheless, these software packages prepare students to the kind of applications that are currently used in the industry. The following software packages are used (in addition to the evident Microsoft Office tools such as Word, Excel, PowerPoint, and FrontPage):

- **AutoCAD** from Autodesk is the de facto computer-aided drafting software standard in the industry [Autodesk 2003a]. Students are expected to be familiar with it and thus it is not formally introduced in the course (it is learned in a prior Building Engineering Drawing course). AutoCAD is used to prepare all drawings for the design project (e.g., floor layouts, structural drawings, elevations, and sections).
- **Woodworks Sizer 2002** is developed by Software Metrics Inc. for the Canadian Wood Council [Woodworks 2003]. This tool assists in the structural design and analysis of wood-framed structures. It has three modes: concept, beam, and column. The last two modes are used to size individual wood members for specific loading and deformation conditions. The concept mode is used to configure and design a complete wood-frame structure. The designer locates the joists, beams, stud walls, and columns graphically which are then automatically sized by the tool based on gravity loads. It is useful to obtain a quick preliminary design. Only the concept mode is used in the course. A screen shot is presented in Figure 3 below.
- **CONDENSE** [Rivard 1993] is a tool that assists in the design of building envelope sections. It can simulate envelope sections with respect to heat and vapour transfers and determine the total thermal resistance, temperature distribution, vapour pressure distribution, heat loss, risks of condensation, and an estimate of the construction costs. A section is built by adding layer after layer, from outdoor to indoor, from a selection of more than 800 building materials. This tool is used by the students for the design of the enclosure.
- **HOT-2000** is a comprehensive, easy-to-use program developed to assist builders, architects, and engineers in the design of energy-efficient low-rise residential buildings [NRCAN 2003]. It can be used to assess a house design in terms of thermal effectiveness, passive solar heating, and operation and performance of space heating, space cooling, and other working systems. The design can be revised and tested as many times as necessary. This tool is used by the students to evaluate the yearly energy consumption of different building design alternatives.
- **Estimating Extended** Edition from Timberline Software Corp. is a powerful estimating package [Timbeline 2003]. It is a popular software application in North America. It allows take offs to be done in terms of assemblies or in terms of items. It comes with extensive costs databases. This tool is used by the teams to estimate the construction costs of their selected design alternatives.

- **3D Studio Viz.** from Autodesk Inc. is a powerful rendering package that can help generate photorealistic views of buildings [Autodesk 2003b]. Students are introduced to some of its features and some of its uses such as for preparing powerful selling presentations, appearance study of alternatives, sun/shadow evaluation, as well as fly-throughs and animations. The use of this tool for the design project is optional.

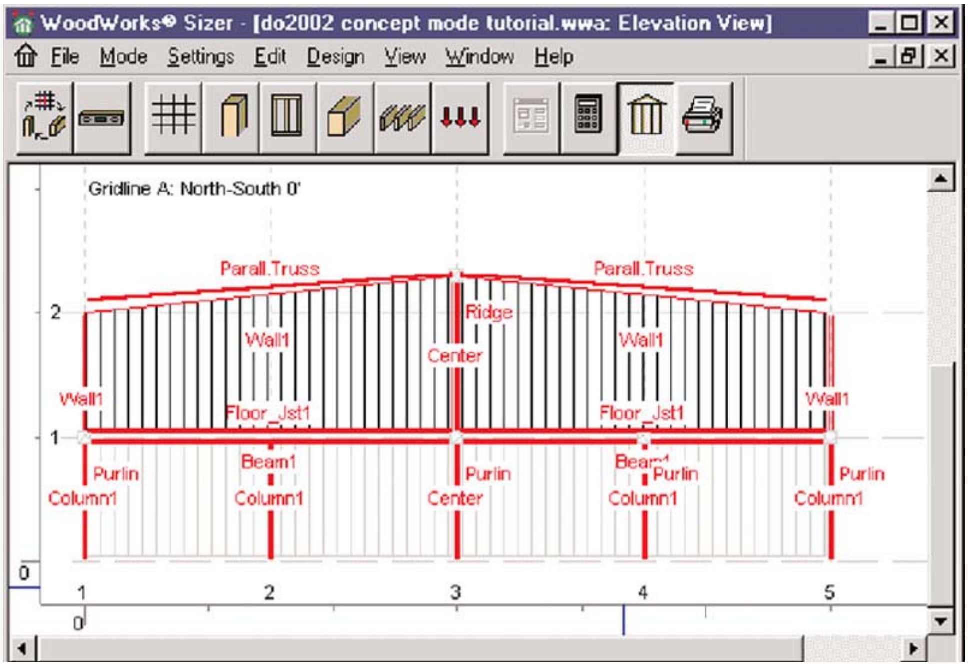

FIG. 3: Screen shot of an elevation view in the Concept mode of Sizer [Woodworks 2003].

The tools are first demonstrated in class. Then the students get hands on experience in a tutorial done in a computer laboratory made available to them with all the software applications installed and ready to use. The lecture always present the assumptions of the tools, as they limit their applicability and must be known by users, as well as manual calculation techniques to provide a mean to verify and validate the results provided by these tools. A lot of emphasis is put throughout the semester on checking the output of computers. It is known that computers give users a false sense of security [Emkin 1998]. Many engineers assume that computers always produce "correct" solutions to problems. Computers tend to become substitute for knowledge, experience and thinking. In order to avoid this pitfall, the tools' limitations are clearly presented to students as well as a means to quickly verify the results. For instance, the Degree-Day Method [ASHRAE 2001] is presented as a rough way to assess the results provided by Hot2000, or span tables for wood joists and studs [CMHC 2001] are used to check the results from Sizer.

The software user is always responsible for the work done in a software application. Most software applications have statements that withdraw any responsibilities if something wrong happens due to its use. Users must be aware of limitations and assumptions intrinsic to the software and should have sufficient technical background. They should always check the results. To emphasize the importance of checking results, they are shown disclaimers to clearly indicate that they are responsible for any design coming out of these tools. Here is an example for Sizer:

> "**Disclaimer** Woodworks should not be used or relied upon for any general or specific application *without competent professional examination and verification* of its accuracy, suitability and applicability by a licensed professional engineer, designer or architect. Every effort has been made to ensure that the information and data in the software are as accurate and complete as possible. The Canadian Wood Council *does not, however, assume any responsibility* for errors or omissions in the software nor for engineering designs or plans prepared from it." [Woodworks 2003]

5.2 A Web-Enhanced Course

The Computer-Aided Building Design course relies heavily on WebCT version 3.0 for communication, dissemination, and handing in assignments. WebCT (i.e., Web Course Tools) is an e-learning product designed to help instructors create and manage Web-based or Web-enhanced courses [WebCT 2003]. This commercially available course management system has been licensed to Concordia University and made available to professors. With this tool, students are able to send e-mail to colleagues, the instructor and the tutor; use the bulletin board; look at relevant Internet references; submit assignment; and check grades. The practice gained in using WebCT prepares students to use the emerging Web Construction portals, which are bound to become prevalent in the industry. This section describes some of the features used and provides feedback from students on their use.

WebCT can be accessed from home or from any computers connected to the Internet. The only requirement is a Web browser that supports tables, frames and Javascript, such as Netscape version 3 or higher, or Internet Explorer version 3 or higher. The university has a specific site for WebCT. The student accesses it by logging on it with a username and a password. Hence, the course home page is only available through a secured environment. After the logging process, the student gets access to a personalized home page which lists all their courses that use WebCT. The list also shows whether any courses have been updated with new information since it was last accessed. From there, the student can access the CABD home page which is depicted below in Figure 4. The features available are grouped into four categories: course materials, communication, group work, and evaluation tools. Each of these categories is described below.

- The **'course materials'** section provides access to electronically available information. It contains an electronic version of the syllabus and of each project assignments. It also contains additional information only provided in an electronic form such as digital pictures of the site and the surroundings as well as a list of potential exam questions for each lecture.
- The **'communication'** section provides three features: mail, discussion, and chat. The mail feature allows a student to send an e-mail to a colleague or the instructor. When sending an e-mail, the user can select the recipient from a pull-down menu which lists all the students registered in the course as well as the instructor and teaching assistants. The user has the option to have all e-mails sent to her WebCT account to be forwarded to her regular e-mail account. The discussion feature is a bulletin board that allows the posting of messages that everyone can see and respond to. This feature has been useful to answer questions about projects or software applications. The chat room feature allows two people to communicate live through text screen. This feature is not used much because it is not obvious to have two people logged in at the same time, and e-mail or discussion board seem sufficient to communicate.
- The **'group work'** section has some useful features to help project design teams. It provides a central repository for documents and files which facilitates the exchange of information between the different participants. It also has a bulletin board reserved only for the team to facilitate communication.
- The **'evaluation tool'** section provides a mean to submit assignment electronically. All the assignment files submitted are uploaded on the WebCT server and are managed by the system. The system records the time when the submission was made and sends a confirmation to the student. This is simpler than collecting diskettes or CD-ROM from students. The students have also access to their grades (for assignments, exams, and final grade) and can compare their grades with the class distribution and statistics.

The feedback from students using WebCT has been very positive. A survey conducted at the end of the semester in another computer related course taught by the first author is also relevant for the CABD use of WebCT. This survey showed that the students accessed WebCT three times a week on average and that they appreciated having access to the professor almost 24 hours per day, that a question needed to be answered once for every one, that it provides useful information about assignments and tests; and that they could learn from others' errors or questions. Also, WebCT allows part time students to interact with other students and shy people are less intimidated to ask questions. The survey showed that 83% of the students wanted to see WebCT adopted in other engineering courses.

FIG.

FIG. 4: CABD home page on WebCT.

5.3 Design Project Web Pages

The teams are required to submit a Web page along with each project assignment. The page is an executive summary of the assignment prepared for the web. For instance, the conceptual design page provides a brief description of the selected design alternative along with images for the front view, the main floor and the upper floor. At the end of the semester, all these pages are gathered together into a Web site for their design project. An example of the project described earlier is available on: http://www.ctn.etsmtl.ca/hrivard/CABD/main.html

As more and more publishing is done on line, getting experience on preparing electronic documents is an asset for graduating engineers. With this aspect of the assignments, the students learn to use a Web authoring tool (e.g., FrontPage), to produce multimedia documents, and to get accustomed with URL addresses. Students are thus accustomed with publishing information over the web.

6. SUMMARY

Computers have become an essential tool for engineers in a variety of tasks and more specifically in the area of building studies, their use has accelerated and improved the design and construction process. It is essential that new engineering graduates be well prepared to take advantage of this new reality. The CABD course prepares future graduates in the use of computers in building engineering design by combining commercial software applications, Web portals, and Web authoring tools with topics like fundamentals of building studies, integrated design and ethics of computer use. The CABD course is also the first course in the building engineering curriculum that integrates several domains of building studies together: space layout, structure, enclosure, building energy, and cost estimation. Topics that were covered in different specific courses are considered for the first time simultaneously in the context of a realistic building design project. The CABD course therefore gives students in building engineering a holistic understanding of buildings and the ability, with the assistance of commercially available computer tools, to produce overall best feasible design solutions.

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