COMPUTER MODELING OF THE BUILDING DESIGN
WITH THE COMPUTER-AIDED ENGINEERING/ARCHITECTURAL DESIGN SYSTEM

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ABSTRACT-The United States Army Construction Engineering Research Laboratory (USA-CERL), a laboratory of the Army Corps of Engineers, has been developing the Computer-Aided Engineering/ Architectural Design System (CAEADS) for several years. CAEADS is a collection of integrated computer systems that provide the architect and engineer with automated tools to interactively build a model of the building concept design in an integrated computer data base. The power and speed of the computer can then be utilized to simulate conditions that the building will encounter when built. These include energy usage, structural loads, environmental conditions, and life safety violations. USA-CERL's current work and future plans are presented.

INTRODUCTION

The Corps of Engineers is field-testing a prototype of CAEADS in preparation for Corps-wide distribution of the system's first version. So far, this field test has verified the feasibility of using computer modeling in the building design process by permitting architects and engineers to test several alternatives to achieve a more efficient, safer design. The tests have identified several problem areas where further research and development are needed. These include improved data base design, interfaces between CAEADS and commercial drafting systems, and applications of artificial intelligence methods to the building design process.

THE CAEADS SYSTEM

The CAEADS system (see Figure 1) is an integrated set of automated design tools. The word "integrated," as used in this context, requires explanation. Briefly stated, it means (as indicated in Figure 1) that all disciplines involved in the design process will use as input the same data base that contains the model of the building as conceived by the architect. Each discipline will contribute additional data to the data base model. The data base is initiated by the architect during the planning and programming phases of the design process, using libraries of standard designs, user requirements, criteria, code requirements contained in the PDB and LAYOUT subsystems, and employing a graphics-driven interactive computer-aided design system called ARCH. As the design is conceived by the architect and drawn on the graphics screen using bitpad and cursor, CAEADS captures the required information

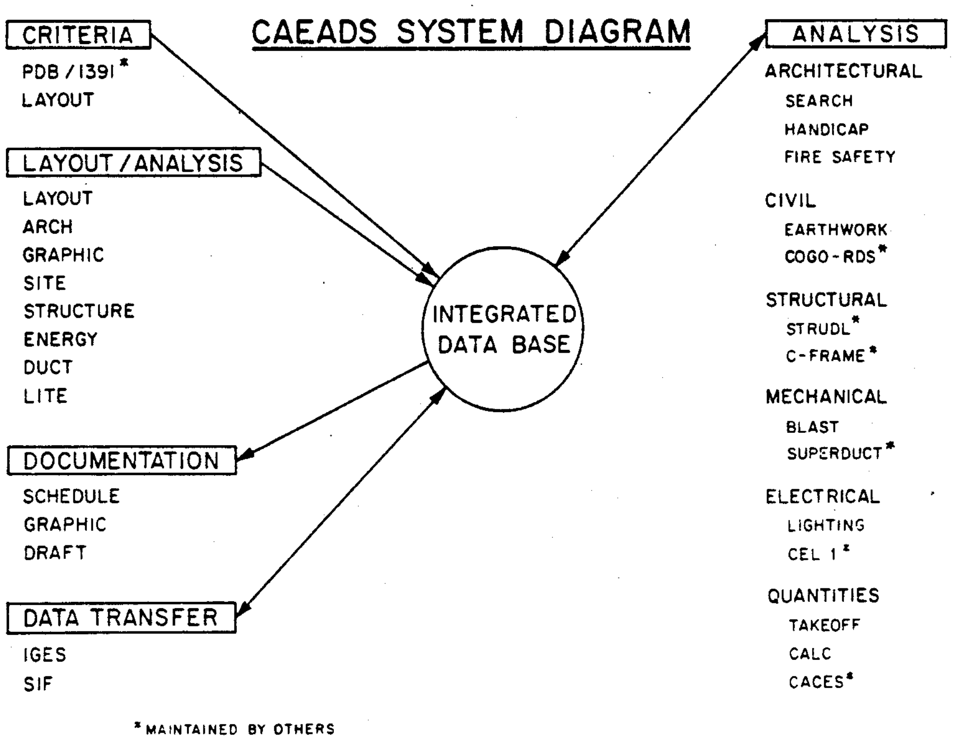

Fig. 1. The CAEADS system.

to begin constructing a three-dimensional model of the building in the data base.

The model is built in three-dimensional Cartesian space; each nodal point and line entered has a position relative to the origin in topology of the world coordinates. This property, among others, distinguishes ARCH from most commercial drafting systems; the spatial connectivity of the model is retained in the data base. Thus, entering the design into ARCH is similar to the architect building a physical scaled model of the design on a table display. With the model available, architects and engineers can perform detailed studies and analyses of the design.

The current version of CAEADS is intended for use at the early stages of design, primarily in the functional layout and analysis phases. CAEADS will help designers and engineers organize project information, lay out design alternatives, analyze for compliance to functional requirements, evaluate energy consumption and costs, estimate direct project costs, and produce scaled drawings. In addition, CAEADS will provide three-dimensional data from which final design can be initiated. This data can also be transmitted electronically to commercial drafting systems via the IGES translator subsystem of CAEADS for automated production of construction drawings.

ENERGY SIMULATION

Using the design model entered into the CAEADS data base, the designer (or engineer) can out and evaluate alternative heating/cooling systems. By using the ENERGY subsystem of CAEADS, thermal zones can be defined and associated with an air-handling system and a heating and air-conditioning system. (See Figure 2 for an example of a zone display on a floor plan.) An operating schedule for the building and a simulation period can be selected. (Weather data based on project location are available on tapes.) The ENERGY program then automatically creates a run deck for the BLAST (Building Loads Analysis and System Thermodynamics) program to give the designer an energy budget summary. Evaluations can be made based on either peak loading (design day) or an annual simulation.

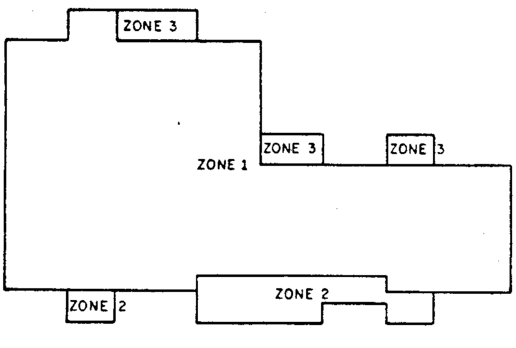

Fig. 2. Thermal zone display on a floor plan.

If the energy budget for the design is unacceptable, the designer can make selected changes to the design model and get another BLAST energy budget summary. These changes can be stored in the original data base, or an alternative data base can be created. Because compute execution time is brief, the repeated use of BLAST is inexpensive. Alternative designs can be evaluated, modified, and reevaluated, helping to ensure that the final design is energy-conservative.

As a subsystem of CAEADS, BLAST requires little additional user input to perform an energy budget for the concept design. The information in the integrated data base supplies the necessary building description information, thus removing the requirement that the designer reenter the information. This reduction in manual handling of data reduces the probability of errors. The common data base provides a vehicle for communications between architect and engineer because changes made to the data base by one of the participants in the design process are immediately transmitted electronically to the other participants.

INTEGRATED BUILDING DESIGN

The planning process for a building system, whether it be structural, electrical, or mechanical, involves the study of system alternatives within the context of a unique set of program criteria. Obviously, the planning process should have the goal of selecting the most appropriate, efficient, and economical system that satisfies the program criteria while integrating the mechanical requirements and maximizing the intended aesthetic. The planning process is most effective if initiated during preliminary design, when major decisions regarding form, function, and aesthetics are being firmly established. Collaborative effort between architect and engineers at this stage of design can result in totally synthesized and cost-effective solutions.

Integrated computer-aided design is an excellent tool to establish and encourage this collaboration. The favorable results achieved during testing of the integration of the CAEADS data base of the building design to the BLAST program offers proof of this. Not only is the designer able to significantly reduce the time required to generate an energy budget summary, the architect and mechanical engineer are also able to collaborate on the most efficient design during the planning stage.

The CAEADS data base has also been integrated to a structural design system, a duct design system, a cost-estimating system, and an electrical design system (see Figure 1). Test results indicate potential savings in these areas equal to the savings achieved in the energy area.

Preliminary considerations of the anticipated critical engineering issues will eliminate the potential surprises encountered during preparation of construction documents. Examples would be fixing the location of wind bracing or deciding how to fit ductwork in ceiling spaces that were guessed at and fixed prior to engineering review.

If the facts so clearly favor the inclusion of engineering planning so early in any project's development, the question may be raised as to why it is not more universally practiced. From the architect's point of view, the answer usually centers around his/her fee, as defined by contract and proportioned among basic services. There is generally no thought of a stipulated budget for engineering input during schematic design. Also, most architects underestimate the time required for this highly creative, research-oriented phase that totally influences all the remaining phases in the architectural design process.

It is not uncommon for the engineer to have the architect hand him/her a design that is substantially complete, or one that requires fitting a structure or mechanical system within the building fabric. This is possible only if the architect is completely conversant in engineering issues and has consciously allowed for it. The rapid growth of knowledge in the technological area of building design makes this unrealistic today for all but a few rare individuals. The "renaissance" person has been replaced by a team of specialists. There is strong evidence that the tools of the renaissance person must be supplemented with computers and appropriate software to assist this team of specialists.

CURRENT STATUS OF CAEADS

An initial version of CAEADS has been installed at six Corps of Engineers district offices for operational use and testing. In FY84, CAEADS was tested at the Sacramento District Office by a team of architects and engineers.

The results of that test were so promising that the decision was made to distribute the software to five additional district offices. More districts wanted to participate, but limited funds permitted only five to be selected.

These tests are providing USA-CERL with valuable user input for improvements to the system. CAEADS is also proving to be an excellent tool for training practicing architects and engineers in the concepts of computer-aided design.

USA-CERL discovered early in the CAEADS training sessions that there was a significant lack of awareness among practitioners that integrated computer-aided design and computer-aided drafting are complementary functions--that they do not perform the same function.

CAEADS is not a drafting system. Graphical representation of the design model entered into the CAEADS data base can be transmitted to the drafting systems through the IGES subsystem to produce annotated production drawings. When wed through IGES in this manner, the two concepts complement rather than compete. CAEADS is a computer system intended for use by the professional architect and engineer.

FUTURE WORK

It is becoming evident to most researchers in the field of computer-aided design in the building process, and to an increasing number of practicing architects and engineers, that the time for integrated computer-aided design and modeling is rapidly approaching. The developers of CAEADS at USA-CERL have only partially achieved their primary objective of a completely integrated computer-aided design system. Much research and development remains. Future plans call for continued development of the CAEADS system. More district offices will be trained on the current system to provide more user feedback.

The CAEADS development team at USA-CERL is aware of the challenges that exist in the application of computers to the building design process. These include the education, training and continued exposure of design professionals to the fundamentals of what the systems are attempting to accomplish. Sound engineering and architectural judgment can never be replaced by a computer system. In fact, a properly designed computer-aided design system should give the professional more time to exercise sound judgment.

Designer creativity should not be compromised as a result of using a computer-aided design system. USA-CERL's approach to research is the seeking of fundamental knowledge and the application of this knowledge to systems development. The systems developed at USA-CERL are the results of specifications written by leading experts in the field working with computer systems developers and end-users of the systems.

The quality of the design should not be reduced as a result of using the computer. A quality design should not be replaced by a "cookbook" solution that could be developed quickly with computer aids. A good computer-aided design system should be able to report to the user a measure of the quality of the design when the design is compared to knowledge contained in the system data base. Methods of artificial intelligence are being investigated to determine if this can be achieved.

CAEADS, as it exists today, is not an end product, it is an experimental tool that is assisting researchers and users in learning about the requirements of a final product. An added benefit is that it is increasing productivity in the design arena, especially in the area of energy conservation. It is but a first step. The next step should be easier because of what has been learned from CAEADS.

SUMMARY

CAEADS is an extensive set of computer systems based on the concept of integrated design that addresses every aspect of the building design process at the concept design level. It is an ongoing research and development project with a primary objective of giving the building design professional a tool that serves both as a data management system and a vehicle through which the designers and engineers can collaborate at all phases of design.

CAEADS research at USA-CERL has spawned operational prototype systems which are proving that the concept of integrated computer-aided design in the building design process is a viable concept.

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