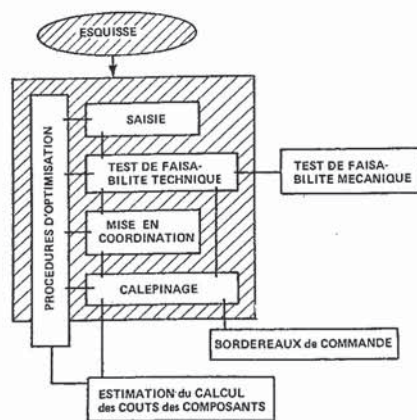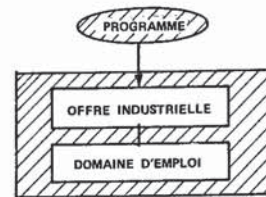Fig.1

Fig.2

Fig.3

Computer-Aided Engineering and Architectural Design System
Test Results

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KEYWORDS

Computer-aided Design, Energy Analysis, Structural Analysis, Computer Graphics, life-cycle Costs

ABSTRACT

Concept CAEADS is being developed by the U.S. Army Corps of Engineers, Construction Engineering Research Laboratory (USA-CERL) to support the design of military facilities. Concept CAEADS is an integrated set of automated tools to support data development in conducting studies in the early concept design process. The CAEADS programs inteface standalone programs, such as energy analysis, structural analysis, and drafting systems. The programs have been and continue to be tested at six Corps of Engineers District offices. This paper describes the results of field testing.

Système de Design d'Ingenierie et d'Architecture
Assisté par Ordinateurs (CAEADS) Résultat des Tests

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Mots-clés

système de design assisté par l'ordinateur, l'analyse de l'énergie, l'analyse structurelle

Sommaire

Le concept CAEADS est en train d'être mis au point par le Laboratoire de Recherche d'Ingénierie de Construction du Corps d'Ingénieurs de l'Armée Américaine (USA-CERL) pour appuyer le design des batiments militaires. Le concept CAEADS est un ensemble intégré d'outillage de design automatisé fonctionnant actuellement par des services à temps partagé. Il a été créé pour appuyer des études sous-producit, des quantités et des graphiques servant le point de départ pour le design définitif. Les programmes CAEADS constituent une doublure pour les programmes indépendents tels que l'analyse de l'énergie, l'analyse structurelle et les système de rédaction. En réduisant le montant des entrées de données superflues dans ces programmes indépendants, un jeu d'outillage devient plus efficace au point de vue du temps pour mener à bien des études de design originales. Les programmes sont actuellement testés dan 6 districts. La communication décrit les résultats des tests dan 6 districts.

INTRODUCTION

The concept design phase offers the opportunity to develop and evaluate alternative schematic project designs, and select major design features to result in near-optimal facility life-cycle costs. Major concept design decisions involve functionality, structural configurations, and expected operating energy costs. More careful study should be made of the interdependence of choices regarding architectural layout, structural configuration, and energy saving measures. The objective of the concept CAEADS tests was to determine the practicality of using automated tools in early design for conducting life-cycle cost studies.

Concept CAEADS, is a group of inter-related programs which provide common files for sharing data among design disciplines: architecture, mechanical, structural, site civil, and lighting. These interfaces provide formatted data for input to BLAST (Building Loads Analysis and Thermodynamics), CEL1 (Naval Civil Engineering Laboratory lighting), SUPERDUCT (Automated Procedures for Engineering Consultants duct sizing), CFRAME (Corps of Engineers Frame analysis), IGES (Initial Graphics Exchange Specifications), CACES (Computer-Aided Cost Estimating System), as well as other standalone analysis programs. The interface programs are discipline-oriented, layout programs which allow specification of designed information. The interface programs were developed by USA-CERL under contract to the University of Michigan Architectural and Planning Laboratory, as well as by in-house staff. Fig. 1, "CAEADS System Diagram," illustrates the standalone programs and interfaces. The interface layout programs are shown on the left side of the diagram and include programs, such as, ARCH, facility layout system. The programs shown on the right are the commonly-used analysis programs, such as, CFRAME. The layout programs, e.g., ARCH, are intended to provide a convenient representation of the facility design features and materials of construction. They are not automated design tools like BLAST which can automatically size heating/cooling plants. The users of the layout programs are the engineering disciplines performing the design studies. The architect may use the programs to study alternative building envelopes.
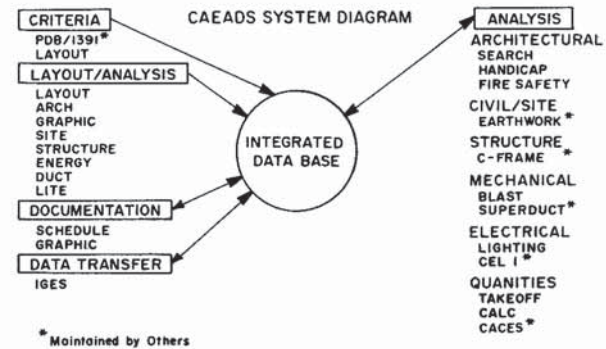

Fig. 1 CAEADS System Diagram

Background

During 1982-1984, The US Army Engineers District, Sacramento, applied a number of computer programs in conducting various concept design studies on twenty-six projects. These studies included:

life-cycle energy (passive/active)
site planning and layout
natural day-light studies
artificial lighting
structural framing
architectural

The interface programs, e.g., ARCH, SITE, ENERGY, were developed in coordination with the designers testing the programs. This method of system development, called "prototype" testing[1], allows better fitting of software to the needs of the users. At the Sacramento District, all design disciplines used the various analysis programs. The results of these initial tests of using interfaced analysis programs (BLAST, SUPERDUCT, CEL1, and drafting) were promising. The advantage of shared data among the architectural and mechanical/electrical designers proved to be sufficient to meet schedules. In addition, the designers reported conducting more alternative studies. The estimated impacts of this early test[2] showed that interfaced analysis programs do, very slightly, increase direct design productivity. The results showed that designers conducted more studies (energy, scope, costs). These studies, reported the designers, yielded more optimal plans, especially relating to passive energy features.

Adding More Test Sites

To determine whether this initial test at one District was representative, tests at five other Districts were conducted. These included Savannah, Mobile, Omaha, Kansas, City, and Tulsa. In 1985, the designers at these Districts were provided training and tested the mechanical/electrical applications, including BLAST, SUPERDUCT, a simple lighting analysis program, and IGES interfaced to a commercial CADD system. A users group meeting was held in late 1985, at which time, the Districts provided feedback on the applications of these tools at each of their offices.

TEST RESULTS

Results of these tests showed increased usage of interfaced analysis by the mechanical engineers. Within a span of several months, at most of the Districts, mechanical

[1] Alvavi, M., "An Assessment of the Prototyping Approach to Information Systems Development," Communications of the Association for Computing Machinery, 27, (7), pp. 556-563, (1984).

[2] Spoonamore, J., "CAEADS and the Sacramento District", The Military Engineer, 77, (502), pp. 430-431, (1985).

engineers began using ARCH-ENERGY-BLAST, as well as starting to use lighting and duct sizing programs. In the other disciplines, especially architectural, the results are clouded by a number of issues. Recognizing these issues and the supporting facts behind them is crucial for successful development and implementation of a truly integrated computer-aided design system. It is important to note that concept CAEADS is not a drafting system, although an interface via IGES allows transfer of data to those commercial CADD systems supporting IGES. Prior to the introduction of these tools at the Districts, designers may have confused CAEADS with a drafting system, since graphical displays and output are provided in some of the CAEADS interface programs. Evidence of this confusion is shown in the responses of some of the District staff.

District - 1

The office reported their objective was to test the utilization of CAEADS interfaces as a design tool in their production environment. They tested the interfaces to BLAST, SUPERDUCT, lighting analysis, and the IGES interface to the INTERGRAPH system. Two projects consisting of five buildings were tested. They reported problems were encountered due to program size limitations. For instance, care must be taken to minimize wall detail in describing architectural plans so as not to exceed the maximum allowable BLAST heat transfer surfaces. Further, at that time, the IGES interface provided only the minimum entity set, not allowing useful minipulation later in the INTERGRAPH system. The district reported that this initial use of these programs was disruptive to schedules and normal operation.

This District reported that training on only the mechanics of running the programs was insufficient and indicated that additional training on the concepts of computerized design is required. Computerized designs require a better understanding of how the whole design goes together, and each designer must understand how the parts they are doing will be used by others. This District reported overloaded hardware, which limited the availability of computer time for the designers.

In summary, the District reported that CAEADS has the potential to assist design personnel in producing superior building designs, by reducing owning and operating costs. For them, a key requirement, for their effective utilization of CAEADS concept tools, is the full integration with their CADD system, using more intelligent features of IGES.

District - 2

This District, because of overload on computer hardware, was unable to complete tests on any of their projects. They reported experimenting with the ENERGY and BLAST, and that they supported the idea of the CAEADS programs. An architect at this District reported that his schedule is so tight that he does not have sufficient time to conduct lengthy studies.

District - 3

This District reported that the mechanical engineers used the interface programs for BLAST. Other disciplines had not used the system. They suggested the architects want production drawings and a way to get the data from CAEADS interface programs

into final design drawings. At the time of testing, the office did not have a computer-aided drafting system. The designers reported that management is committed to the system, but thinks it needs to evolve more before using it in other areas beyond mechanical engineering.

District - 4

This District reported that the mechanical engineers used the interface program for BLAST. They reported that an architect investigated different furniture locations using the ARCH interface, but they stated that the architects are not getting anything from CAEADS. They suggested more co-ordination between CAEADS and CADD. At the time of the testing, this office did not have a computer-aided drafting system. Further, they stated that they did not receive timely support during the tests. They maintain a commitment to concept CAEADS.

District - 5

This District did not formally report on the test. However, in conversations with the designers, they have tested some of the programs. Further, they report on using PC-based energy analysis, as well as experimenting with several of the interfaces to the analysis programs.

District - Sacramento

Having tested and used concept CAEADS interfaces for several years, Sacramento, by this time, had used various programs on forty projects. As an example, the educational facility, illustrated in Fig. 2, "Education, Training, and Employment Facility," resulted in expected operating energy costs of nearly fifty percent savings over allowed budget. They met their schedules, but this required planning. Sacramento suggested many program improvements. They reported their continued commitment to the ideas of CAEADS.
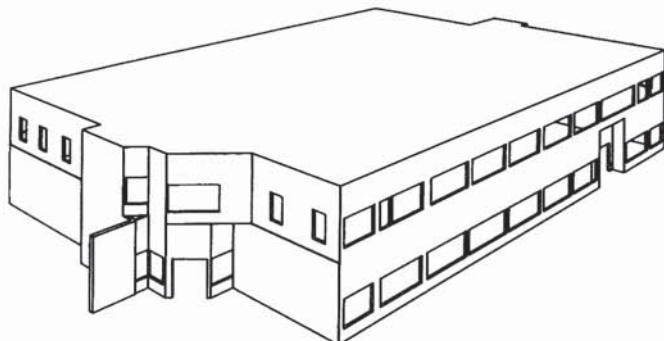
South West Perspective

Fig. 2 Education, Training and Employment Facility

ISSUES

Two major issues are illustrated. Firstly, hardware resources were not available when needed by the designers. Pre-empting computer resources from the designer decreases the efficiency of conducting analysis studies. The ideal hardware environment, under the control of the designer, is the personal computer. Currently, low cost hardware, responsive to the architectural and engineering computational needs is available and is rapidly being introduced into the design offices. The second major issue deals with the critical efficiency of the architectural process in early design. This is a major software issue.

Architectural Productivity

The major concern surfacing from the feedback from this test is that the interfaces are too time-consuming for the architects to easily maintain productivity and meet schedules. The architectural activities are on the critical path during concept design. Each alternative floor plan must be completed before the supporting disciplines can proceed to design their parts. Even though these disciplines may report time savings, it is insufficient to recover the extra time taken by the architects to conduct several rigorous envelope, scope, and cost studies. By careful planning, as indicated by Sacramento District, the schedules can be met. However, more efficiency is needed.

Superior Designs

For the design team to give the owner a reduced owning and operating costs design, the architect must be involved in the "integrated" process. However, he must have a true "architects" system. This system must support the architectural activities efficiently, even more efficiently than for other disciplines, while, at the same time, providing other disciplines the analytical model required for their analysis.

CONCLUSION

The District design staff are committed to the concepts of integrated design and early life-cycle costs optimization. The tests at the District sites were successful enough to show the potential of integrated concepts. The introduction of computer tools for use in conducting early design studies is disruptive in two ways. Firstly, it introduces new work for the designer in performing more studies, likely not a part of his current practice. Secondly, it requires learning computer tools, diverting his time away from normal duties. For the building project, integrated computer-aided design focused on early design decisions has great potential for improving the quality of design: improved functionality, reduced construction and operating costs. This test shows that multi-discipline approaches, allowing more rapid development of alternative plans, selection of materials, and life-cycle costs analysis are being used effectively by the supporting disciplines. Based upon the progress made during this short test period, as well as the wider availability of PC-based software, it is anticipated that the supporting engineering disciplines will increase their use of interfaced and standalone, analytical tools for conducting studies. Lower costs computer-aided drafting systems will assure accessibility of these tools to more of the engineering and architectural staff. The designers at these offices tested rather rudimentary and incomplete "integration" and found sufficient benefits to commit to more extended applications.

RECOMMENDATIONS

In an international survey[3], conducted in 1985 within Working Commission W-78, Integrated Computer-Aided Design, it is reported that only three systems, of forty-five systems responding, provide tools for handling early design programming requirments. The major areas, supported by the respondents, include drawing production and engineering analysis tools. The responses do not show clearly how interfaces and/or integration are provided in these systems. The results of this test and the evidence of the survey lead to the recommendation that we must carefully and fully investigate the architectural design process to identify the architectural information handling tasks and invent new, innovative, and highly responsive and efficient automated approaches. Everyone must directly benefit from an "integrated" approach for it to be fully and successfully used. The results of the tests show the need for computer-aided drafting to precede computer-aided design, especially in the case of the architect. Further, design tools for the architect will not be the "analysis" tools that the engineer uses. Rather, the tools will provide support for organizing building program information for use in design, organizing layouts and specifications, conducting conceptual-level life-cycle cost studies, and preparing drawings.

The computer software industry, as well as public research institutions, should now recognize, from these test results, the receptiveness of the building design community to utilize these integrated computer-aided design technologies. Research into the topic of computer-aided architectual design, as well as development of new systems, can now be conducted very cost-effectively using lower-cost micro-based equipment. If the value and importance of "integrated" life-cycle costs studies are widely recognized, over the next few years, the industry will accomplish major strides in providing software products tailored to the needs of the architectural process.

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[3] J.Spoonamore, D. Vanier, P. Christiansson, "A Survey of Integrated Computer-Aided Design Systems", presented at CIB W-78 Integrated Computer-Aided Design Symposium, Rotterdam, 16-17 September 1985.

Multistorey building drainage network analysis: a computer aided approach to drainage design

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Summary

Flow in a building drainage network may be described as free surface, unsteady pipe flow. Wave action steepens or attenuates inflow profiles depending upon both the system parameters and the shape of the initial profile itself. Appliance discharges are therefore modified by wave action during their passage along the system. Inclusion of wave action in the prediction of system loading provides an enhanced design capability quantifiable in terms of increased loading, the potential use of smaller diameter pipes, and the ability to deal with specific building designs and usage patterns. Current fixture unit design methods cannot do this as they employ steady flow criteria and are based on appliance peak discharge. The equations governing wave action are presented and solved via the computer based finite difference method of characteristics. Computing techniques representing both wave action and the range of initial and boundary conditions to be encountered in a multistorey building drainage network are presented, together with the laboratory results of full scale validation experiments and examples of computer model applications to both U.S. and U.K. design cases. The paper concludes that the application of computer aided engineering to the design of building drainage networks is both feasible and beneficial.