DESIGNING IN THE CAD STUDIO

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ABSTRACT

The "CAD Studio" is one of many design options that fourth year students may select in the College of Architecture. In this electronic environment, the students analyze and present their designs totally on the computer. The vehicle used is a fifteen week architectural problem called the "Calor Redesign Project."

The "Calor" problem requires the move of a famous residence to a hot arid climate. The residence must then be redesigned in the original architect's style so the building becomes as energy efficient as possible in its new arid environment. The students are required to use as design criteria a new building program, the design philosophy of the original architect, and appropriate passive energy techniques that will reduce the thermal stress on the building. The building's energy response is measured by using an envelope energy analysis program called "Calor."

Much of the learning comes from imposing a new set of restraints on a famous piece of architecture and asking the student to redesign it. The students not only need to learn and use a different design philosophy, but also develop new skills to communicate their ideas on the computer. Both Macintosh and IBM computers are used with software ranging from Microsoft Works, Superpaint, AutoCAD, MegaCAD, Dr Halo, to Calor.

INTRODUCTION

The "Calor" problem has grown from eight to fifteen weeks in duration. This is primarily due to the fact that students are now required to design, analyze, and present their designs on the computer. Although students are familiar with computers they have had little previous experience with the particular graphic or energy programs they will be using. Therefore, time must be spent learning CAD concepts, drawing commands, and energy input formats. The computer instruction is integrated in the design studio so students learn in an informal setting on a "need to know basis."

The seven week time increase is partially due to learning new computer drawing skills. Also, a beginner simply takes longer to do a set of drawings on the computer. In fact, if students weren't required to present their designs using the computer they could initially do the work in less time by hand. Most students are willing to spend the extra time because they believe it will
help them later in their professional career. Toward the end of the semester
the students drawing speed will equal or exceed that of hand drawing. Even at
a perceived equal stage, the students are further ahead because they have a
set of drawings that can be readily changed in response to their design review
before their final project book is due.

![Figure 1 MegaCAD & AutoCAD Drawing - Lang Residence Redesign](image)

**PROJECT GOALS**

For the students, the basis for the course is:

1. To improve data gathering abilities.
2. To develop the ability of establishing a hierarchy for decision making.
3. To broaden the appreciation of other design philosophies.
4. To develop computer-aided presentation skills for communicating process.
5. To learn energy conserving techniques for small structures.

At the beginning of the semester the students first form into 4 person teams,
move the building, and analyze it in its new location. The students also
begin their computer tutorials, learning how to draw with AutoCAD and how to
do an energy analysis with CALOR. Their specific requirements are to use
AutoCAD and draw the site plan, building plan, elevations, and wall section.
The team also constructs a 1/6" building model for a heliolum study. Finally,
the members produce an energy analysis of the building in the new desert
location. To complete the first phase, each team presents the concepts and
facts of the original building to the whole class.
DATA GATHERING

It is difficult at times to find adequate descriptive building data that can be entered into CALOR. The typical American architectural publications like Progressive Architecture do not contain adequate descriptive data like wall, roof and floor details. Even such obvious information as the wall composition and amount of insulation is usually missing. The teams, therefore, are required to become detectives and predict material composition and thickness based on the building’s date and prevailing regional construction methods.

One team of students, frustrated by the lack of material, phoned the California architect, Raymond Kappe, and spoke with him about his design philosophy for the Wattenbach House in Santa Monica, California. He was very gracious and sent the team working drawings and shared with them the history of the project. He also reflected how he would alter his design for a desert region. He admitted the original house was not as energy efficient as he had intended and suggested ways of improving it if it were rebuilt. The team members were able to incorporate his suggestions into their individual building redesigns in the second phase of the project.

PHASE II INDIVIDUAL DESIGN

The teams dissolve and the individual members begin the redesign phase. Each student by now knows how to use the basic commands in both the drawing and energy computer programs and has some strategies for the building redesign.

To insure that the students make major modifications to the residence the original architectural program is changed. Not only will the site and climate be different but also the design criteria. Each student draws six different criteria they will use in their new design. These new criteria will form the basis for their new architectural program. The choices are:

1. Site Considerations
   a. Steep slope > 15%
   b. Average slope 5% - <10%
   c. Gentle slope <5%

2. Slope direction
   a. South
   b. North
   c. East
   d. West

3. Important views
   a. City
   b. Mountains
   c. Both city & mountains
   d. None

4. Inhabitants
   a. An artist
   b. A retired couple
   c. Couple with two small children
5. Occupation
   a. Leaves home for work
   b. Works out of study
   c. Home business 10 - 15 clients / day

6. Building materials
   a. Own choice
   b. Massive
   c. Light weight
   d. Original materials

After the drawing for the criteria is completed, each student has the opportunity to "turn in" a choice and draw again. This satisfies those that felt two of the choices pose a "conflict" in design criteria. It is now guaranteed that the residences will take on a "new look" and the project will become more than just a simple cosmetic change of the existing residence.

DESIGN PHILOSOPHY

Each student begins the residential redesign using the team analysis as a guide. This includes the passive energy principles dictated by the desert and the design philosophy of the original architect. Students arrive at a project design philosophy by reading about the architect, the building, and other projects the architect has done. A reasonable consensus is reached and the philosophical design criteria to be used for the students' project is formalised.

One student remarked "I really liked this house, and had no intention of changing it. But, by having different design requirements I had to redesign it from scratch. I learned a great deal about this architect that I never would have by simply reading about him. He is really good!" In general, the students were able to "roll up their sleeves" and make the new program work.

Figure 2 AutoCAD Elevation - Lang Residence
ENERGY DESIGN ISSUES

Many residences have severe solar design problems. Small problems in a moderate climate become large problems in a hot arid climate. The major problem is too much glass. This becomes the first issue the students need to tackle. It is not uncommon for glass areas to be reduced by 50% to 75%. Unprotected horizontal skylights become taboo. The project energy goal is to balance heat gains and losses throughout the year. This is an especially difficult task because of the scorching summer sun. Some changes like glass area reduction have a substantial effect but others like surface color changes have little. Many students said they feel the computer acts as a model design critic — giving feedback at any hour of the day or night.

Students are expected to compute and bring their buildings within the +/- 3 Btu/cu ft per day range for the four seasons represented by the months of March, June, September, and December. Using the climatic data of the four seasons can reasonably predict the building’s yearly performance. The 6 Btu/cu ft range as determined from past experience is achievable. It represents a very economical passive energy structure.

PASSIVE ENERGY

Students are encouraged to develop a strategy for selecting non-mechanical passive energy methods to reduce the thermal impact on their building. The strategy is to focus on major energy problems for each month and work down to less significant ones. Student skills are generally sharpened with each new design change and a re-analysis by CALOR. It is generally apparent which surfaces are causing the major problems in each month, however, it is possible that an improvement to reduce a loss in one month may cause an unexpected gain in another month. Students eventually discover the passive energy combinations that satisfy all four seasons.

Figure 3 Passive Energy Section - Lang Residence Redesign
CALOR PROGRAM

CALOR is intended as a schematic design tool requiring only a few inputs that are calculated or found in reference books. The program is quick to identify building envelope heat transfer problems. It is not intended as a complete analytical tool to thoroughly measure building energy gains and losses. Nor is it intended to measure the peaks and valleys of the day/night temperature swing. Although these are important concepts, the idea of balancing day/night temperature swings by using mass walls is not part of this design problem.

Based on the building data input into the program, CALOR produces an analysis of heat flow through the building skin. The results express in BTUs per hour, how much heat is gained (or lost) through each building surface (i.e. walls, roof, windows, etc.). The total building gain or loss is then modified by the internal load gain. With this information in hand, the designer is able to make comparisons of all building surfaces by component and identify problem areas. The speed with which this can be done using the CALOR program makes analysis during the early design stages a practical matter for students.

HELIOLUX ANALYSIS

The heliolux is a machine designed to show shadows cast by objects at any latitude, month, or time of day. Its primary purpose is to verify the amount of sun striking glass surfaces during different times and seasons. The machine is comprised of a turntable and single light source. The table holds the building model and is rotated on a set of gimbals to a chosen latitude and time of year. The table then swings through a twelve hour day while the light remains on a stationary stand. Different times of the year can be held constant while the time of day changes, or time of day held constant with the month or latitude varied.

Students can set their house on the table and dial in 32 N, December 23, and 12:00 noon. The shadows are cast on the building facade and ground for that time of year. The latitude can be varied to see the effect of location. Students enjoy dialing in the north pole at 90 degrees north latitude to witness how the sun never rises in December and never sets in June. Students are asked to draw color coded shadow outlines on the study model to document the sun angle of the four seasons (Mar, June, Sept, Dec 21st) at 8:00 am, 12:00 noon, and 4:00 pm.

DRAWING RESOLUTION

The kind of drawings that can easily be done on the computer are different from the traditional hand rendered presentations. Only 16 colors and a few line weights were available. The resolution on the EGA screen compared to the traditional architectural rendering is comparatively low. The drawings to be "read" needed to be enlarged by "zooming". One student said this was equivalent to "looking at a set of drawings through a stove pipe". The students produced drawings that could be saved as computer slides and then called up in sequence and displayed on a color monitor similar to a slide show. The drawings tended to be simpler and more focused in content, and the
required viewing time only about 15 seconds. As a result, many more drawings were produced but their focus and content were greatly simplified.

PLOTTING AND SLIDES

One small 11" x 17" plotter is not adequate for 16 students to use. Even when everything was working well there was a "bottleneck" on due dates and the plots were small for group presentations. One solution to this problem was to photograph the screen and give presentations using slides. This was used effectively by the students and allowed them to utilize all their drawings, models, and energy graphics in a coherent presentation. When they completed the semester they also had a "handy" 35 mm format for their portfolios. With this type of presentation timing became critical. The students were forced to have the drawings ready one day early in order to have the slides processed.

COMPUTERS AS A DESIGN STUDIO FOCUS

Five IBM-60 computers workstations were adequate for 16 students. They each had time to do their projects without excessive late night sessions. Each student was allowed to check out a key and function as the room monitor to keep the computers accessible after hours. Students could sign up for certain hours and be assured of computer access each day.

The notion of an "electronic studio" was not fully realized. One problem the 16 students had was sharing the space with other beginning computer students. Another was the limited access the design students had to this space because of security reasons. The fourth year design students were not able to personalize the room and therefore did not feel like they belonged to this particular studio. The students did not have their own desk, locker, or computer. As a result, they felt it was just another computer lab and not an "electronic design studio" as had been envisioned at the beginning of the semester.

A total of three computer programs were used. All the orthographic drawings were produced with AutoCAD. MegaCAD was used to produce simple perspectives. These files could be passed back to AutoCAD and Dr Halo for drawing enhancements like the addition of people, landscape, and color shading. CADET was used to produce the basic conceptual energy analysis. The Macintoshes were used to assemble the schematic diagrams and text for the final presentation booklets.

The cohesiveness within the class was high, and many students helped the less computer literate with their drawings. Most students admitted openly that they felt they had learned a "marketable" architectural skill by producing computer drawings.

CALOR REDESIGN PROBLEM EVALUATED

At the end of the semester the students were asked to evaluate their experiences. Some students felt that redesigning a famous residence in the desert had been exciting and challenging. It gave some students a "greater
appreciation of the design abilities of the architect they had chosen. It also allowed "learning about the computer without a large complicated design task". It was "challenging to make another architect's ideas conform to the desert".

On the other hand, a residence is not an ideal type of structure for a CAD program like AutoCAD. The full power of this software is not realised on a "one of a kind" type of building like a residence. It would be better to pick a more systematic type of building that has repetitive components and a consistent set of rules. The power of the computer can better be applied to a "systems type building" like an office.

Most students felt that using computers in the design studio was a "valuable experience". Some felt a "new avenue in architecture" had been opened to them, and they were now "more attractive to a possible employer". The students also perceived that the image of the college had improved. They said it was nice to see the college "keeping abreast of a changing world" and that "the college had an open mind". It was perceived by the students that the computer had "made the design project more worthwhile".

It is debatable whether one can take an architect's design philosophy and apply it to an entirely different situation. Another positive factor was that this project provided a catalyst for endless dialogue and debate among students and faculty.

COURSE REFERENCES


Clark, K. and Payliore, P., Desert Housing, University of Arizona, 1980.


APPENDIX - CONDENSED PROBLEM STATEMENT

Architecture should respond to the environment for which it is designed, as well as for the needs of the client. Housing, in particular, is an area in which these factors become critical. The three global issues of concern are:

- Clients' needs
- Technology available
- Environmental forces

In recent years the amount of residential construction in the Southwest has increased dramatically without careful regard to the implications of the place and its climate. To many, it seems, the widespread availability and reliance on cheap fuel and air conditioning makes precise design for the desert climate of little importance.

Because of an ever-increasing dependence on energy, and over the long run, ever-dwindling supply of fossil fuels, the opposite philosophy should be true. Climatic design factors need to be considered in all types of buildings. Recent studies have shown that the application of passive solar heating and cooling techniques save the home owner considerable money over the life of the building. Local buildings which use small amounts of energy can provide insights in historic energy conservation.

Design methods should always consider the climate that will impact the built environment. Buildings may be divided into two groups, load dominated, and skin dominated. The load dominated structures are typified by building types with a large volume to skin ratio and have large requirements dominated by large internal loads such as lighting, equipment and people such as an office building. A skin dominated building has a small volume to skin ratio and is typified by low periodic internal loads such as a private residence.

A skin dominated building is more affected by the climatic. The large solar load of the desert will have a high thermal stress on the building envelope and magnify the problems of a skin dominated building.

For the style of building ought manifestly to be different in Egypt and Spain, in Pontus and Rome, and in countries and regions of various characters. For in, one part the earth is oppressed by the sun in its course; in another part the earth is far removed from it; in another it is affected by it at a moderate distance.

Vitruvius, De Architectura, 1486

Problem Part 1 - Team Analysis

In the next 3 weeks, in a 4 member team, investigate the design philosophies, concepts, and programmed space and adjacency requirements of one of the selected houses. Determine the architect's design language; what are the rules and what are the kit of parts. Move the house from its current location to the upper Sonoran life zone. The high desert which surrounds Tucson, is at 2500 feet elevation, and at 32 N latitude.

Create a model in AutoCAD showing a 2 dimensional representation of the building, i.e. plans and elevations. On 8 1/2" x 11" paper, illustrate the design language showing the isolated parts and explain the design rules.
Calculate an energy analysis of the four specified months using the "Calor" energy program and build a 1/4" study model to show a shadow analysis using the heliolux solar simulator.

The following architects and their buildings have been selected on the basis of availability of material describing both designers philosophies and building layout. The buildings are roughly the same size, although the program requirements and sites vary considerably. Select one to analyze.

Selected Architects Houses:
Le Corbusier Villa Savoye Poissy, France
Michael Graves Snyderman House Indiana
Gwathmy/Siegel Gwathmy House Amagansett, NY
Raymond Kappe Hattenbch House Santa Monica, CA
Ricardo Legorreta Gomez House Mexico City, Mex
Mies van der Rohe Farnsworth House Plano, Illinois
Richard Meier Smith House Connecticut
Charles Moore Licht House Mill Valley, CA
Richard Neutra Kaufman House Palm Springs, CA
Robert A.M. Stern Lang Residence New York
Stanley Tigerman Metal/Class House Illinois
Frank Lloyd Wright Kaufman House Bear Run, PA

Other residences by the above architects may be substituted if approved by the instructor. Choose buildings that have sufficient descriptive documentation for a complete formal and thermal analysis.

Due Week 1:
a) Design language and philosophy of Architect
b) Conceptual drawings of the given house including: site and building

Due Week 3:
c) Space analysis of original program
   List of activities
   Square footage allocation
d) Plans and elevations of the existing house at an appropriate scale
e) Heliolux model of existing house showing 4 season analysis including solar penetration diagrams of original house Scale: 1/8" = 1'- 0"
f) Typical wall and roof section(s) of existing house showing thicknesses, materials used, and building assemblies.
g) Calor energy analysis of original house at 32 N - March 21, June 21, Sept 21, Dec 21.

Problem Part 2 - Individual Analysis
Based on the information gathered by your team, you are now asked to redesign, as opposed to remodel, the original house with a new program (activities and sizes) and the original architect’s philosophy and concept as demonstrated in the design. It is expected that the design language will guide you during this portion of the problem.
In order to further demonstrate the effect of region and climate on architectural design, the new structure will be located in the Tucson basin, 32 N latitude. Students may select a specific site which matches the conditions of the site "design". Plan, structure, fenestration, form, orientation, relationship to site, materials, and color may change in response to region and climate.

A suggested design approach is to examine the program, site, philosophy, and concept from general to specific, moving from larger influences of the site to more specific details. Remember: this is a complete design problem, not just a remodel.

Presentation Requirements: These should be sufficient to explain the re-designed residence for Tucson. The original group analysis is to be available for all team members.

Objectives:
1) Preserve the original concept of the house
2) Use passive measures to reduce the heat gain and losses to a range of -3 to +3 Btu/cu ft/month.
3) Present the process and final solution to the client

Building Considerations:
1) Thermostat adjustments 68 - 80
2) Improve "U" factor - double glazing, insulation
3) Reduce surface areas - earth berms, basements
4) Reduce or reorient poor thermal performers - glass
5) Modify shading on windows - winter vs summer
6) Reorient building - optimize configuration for climate
7) Modify air movement - tight enclosure vs air washes
8) Select appropriate colors - thermal radiation
9) Night sky radiation - cooling in summer
10) Outdoor spaces - courtyards, length x width, orientation
11) Building as shading - lightweight vs mass
12) Shading devices - vertical or horizontal

Site Considerations:
1) Landscape for shade or sun
2) Wind screen or funneling
3) Evaporation for cooling - water, fountains, grass
4) Outdoor living - patios

Final Presentation
Each team is allowed a presentation time of 1 hour. This will include a short introduction to the particular residence and then each of the four individual projects. The team should provide a short introduction of the residence including major design philosophies and passive energy redesign considerations. All four presentations should be tied together with comparisons and contrasts of the different solutions. An alternative is to address different issues and use the four different projects as possible solutions. You should consider your team as an architectural office presenting four different solutions to the client for possible selection.

It may be helpful to have a moderator for each team to introduce each member.
and keep the ball rolling. It is not necessary for each team member to present all the information about their redesign. They should rather focus on the uniqueness of their design compared to the other three projects and the original design. Ten to twelve minute presentations must be concise and to the point. These presentations will start at 1:00 sharp. They should be rehearsed and timed. The equipment will be available in 207 the morning of May 6. If any team runs over they will be stopped so the next team may have their full hour. The teams should reserve one of the 1 hour slots as soon as possible.

The presentation will be up to the team members. There will be an IBM-AT raised up for audience viewing, a slide projector, and transparency projector available. Please let the instructor know your requirements prior to the presentation date. This will be a professional presentation. You may wish to invite your friends. Invitations will go out to the Dean and interested faculty and architects in town. Remember: This is a team effort!

**Project Book:**
Each individual shall submit, in 8 1/2” x 11” (laisy A) format, a book fully explaining the scope and character of the Calor Redesign Project and the proposed solution. The booklet should be thought of as a method of documenting a design process and the physical result of that process.

Use written text, diagrams, photographs, perspectives, plans, elevations, isometrics, sections, and details as needed to describe the analysis and synthesis of information and ideas explored this semester. Focus on those issues that were important to you in the design process.

You might begin the book with a photograph of the building model or a perspective. This shows the finished product and focuses attention on the scale and scope of the project. Explain your solution using background design information like concept diagrams and photographs of your heliolux model. Follow this with detailed information like plans, sections and elevations distilled on a few pages. And last, include the team analysis of the original house in the appendix as support material for the project.

Be sure to include the reference information such as: Calor runs and what they mean, original architect's philosophy and how it affected your redesign, and diagrams of the passive energy design concepts used in the design.

The game is not thickness so do not fill the pages with undigested data. Use only material that is directly relevant to the explanation of your design. In other words, show the full extent of your work - all the steps or issues you considered, but don't pad the book with issues that you didn't consider. The end of the book may incorporate team effort material, but the major part will contain only your individual work. Use the written evaluation sheet from your critic as a guide for the necessary changes that need to be made to your design. The magnitude of the redesign will depend on the quality and completeness of your building design as presented.

The presentation booklet for the Calor Redesign Project shall be of professional quality, 8 1/2” x 11” (lasy A) format, spiral bound, and about 20 pages in length.