THE BUILDING OF RESEARCH:
A Center for the Study of Educational Facilities

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Introduction

According to a 1996 General Accounting Office study, “More than 14 million children are being taught in school buildings needing significant repairs to restore them to good overall condition” (GAO/HEHS-96-103). Since then that number has grown significantly. As much as $112 billion will be spent with little research or documentation to assure those problems of the past 40 years will not be repeated (GAO/HEHS-95

). Another study by The Council of Educational Facility Planners International has identified a need for over $200 billion in school construction in the United States. They cite cities “like Las Vegas and Miami, where the populations are increasing at a rate of 5,000 people per month, find that they don't have time to think about designing schools in new, more effective ways. Instead, they defer to obsolete models of learning environment configuration; perhaps housed in new skins, but essentially designed on old models of teaching and learning.” In addition there are numerous new and threatening conditions of which science and health officials are now aware, that can be inadvertently designed into educational facilities. Many of the nation’s schools were designed in the 1950’s and 60’s and are facing serious deterioration. Those that still have value need renovation while others need to be completely replaced.

The current trend in new schools is to select previously designed buildings. These are often from localities in completely different climatic zones, site conditions and construction markets. This process is so prevalent and rapid that many of the previously designed buildings have not been used long enough to determine particular problems such as energy use or indoor air quality consequences that may be constructed again in their reuse. It is not uncommon to hear of school districts repeating problems in several new buildings in the same year.

The growing body of research linking student achievement and behavior to the physical conditions and environments of school buildings is significant. Consequently with the millions of school children affected and the billions to be spent, there needs to be a comprehensive center for the study of physical design criteria. This center would require a facility that supports specific technical research into many arenas. Where as the building could demonstrate the appropriate applications of some of the areas, it would also provide the necessary support structure to research others.

A research complex that can support the study of existing and proposed educational facilities would need to support at least 14 inter-related research areas:

- Site analysis issues
- Natural system compatibility
- Structural systems
- Materials and finishes
- Indoor air quality including VOC’s, temperature, humidity and ventilation
- Acoustics
- Envelope (roof, walls, fenestration and slab)
- Mechanical systems
- Electrical and technology systems including power, lighting, security and other ‘smart systems’
- Building delivery systems
- Design and Construction Contract implications
- Facilities Management
- Software modeling for predictive results
- Industrial design of building components and furniture

Critical Research Areas

The 14 research areas mentioned above are preliminary but adequate for planning purposes. Ehrenkrantz (Ehrenkrantz 1989) writes that his research found that, “designing a single stock plan and fitting it to a variety of different sites where slope, orientation, and configuration differed…the costs of adapting any given plan to a variety of special situations were higher than they would be starting from scratch with a completely new design.” The primary reason school boards tend to go the ‘stock plan’ route is to avoid or reduce architectural design fees. Since they usually have to hire a local architectural firm just to make modifications to the drawings to fit their specific intents and then to conform to the site conditions, the fees are ultimately equal if not higher than a design from the beginning. The end result is often higher site construction costs due to massive amounts of earth movement and higher design modification costs. A building not designed for a specific climate and site usually has a higher energy cost associated with it as well. To redesign the stock plan to accommodate natural ventilation or daylighting would often require massive changes to the design.

A Center that serves as a clearinghouse of information on evaluations of actual constructed facilities could offer a performance track record of decisions. It could employ modeling and simulation to evaluate new designs for specific sites in a wind tunnel or daylighting dome as well as have important full scale assemblies constructed for validation. Following each school’s construction, data acquisition systems could be located to collect critical performance information.

Daylighting has been known for its significant contribution to environmental quality and energy conservation since the ‘30’s. There have been trends in education and in early forms of energy conservation that attempted to counter that position. Now it is well known to both contribute to student achievement and to the education of students regarding environmental consciousness.

Educational Facilities Laboratories (EFL 1967) , “decided that a 60 foot span, or more, rather than the traditional 30 foot one, would be most useful, that many interior partitions should be demountable,…” In the late 60’s this might have been state-of-the-art, but now that needs to be reviewed. Educational trends towards open classrooms have shifted back to more acoustically controlled classroom environments which can dramatically change the appropriate bay size. When daylighting and natural ventilation are considered, the interior dimensions may vary and consequently, change the structural bay dimensions. Innovative structural conditions or systems may also have cost and durability circumstances that need to be evaluated. Structural issues are integral to successful, cost effective educational facilities and need to be studied in the context of the other issues listed.

Secondary schools are subject to heavy wear and tear and of course vadalism is always an issue. The materials, finishes and hardware are subject to heavy use and occassional abuse. There are many products available that can possibly lower maintenance and repair costs. There are also products that can enhance daylighting while reducing glare, increase solar heat absorption and to simply improve the interior or exterior environment.While significant progress has been made through regulation, many products still release volitile organic compounds (VOC) into the indoor air. These often contribute to serious health hazards and post occupancy law suits to correct the problems.

Schools of the future need to be designed with integrated mechanical and natural systems with control strategies that assure high indoor environmental quality (IEQ). IEQ includes thermal, luminous, sonic and indoor air quality. If the temperature is too warm, students will tend to become drowsy, if there is too much noise, concentration and communication is disrupted and if the artificial lighting system is poorly designed than veiling reflections can cause eye strain. The proposed facility would provide for controlled laboratory experimentaion, field monitoring and computer simulation to analyzize IEQ issues.

The envelope of the school is the critical filter for conserving energy, providing natural illumination and ventilation, reducing maintenance costs and protecting the occupants in the case of disasters such as fire and earthquakes. Full scale mock-ups provide the opportunity to structurally and materially test wall, roof and slab assemblies for thermal and energy transfer performance. In addition, wall sections can be constructed to test for daylight illumination and mechanical integration.

Heating, ventilating and air conditioning systems have many components that each have both energy and indoor air quality issues. Specialized filtering systems can reduce both VOC's and other airborn pollutants. Particular system configurations can vary with individual school designs. Each can have positive or negative reprocussions. If the system has duct work, whether the ducts are lined on the inside or the outside, perforated or not, are all conditions that affect the health of the delivered air. Cooling and heat exchange components can breed microbial diseases such as Legionairs and pnneumonia. Proper installation proceedures and construction practices can help reduce or eliminate the pollutants. Ventilation efficiency can drammatically affect the comfort of the occupants by the removal of indoor pollutants. A full scale classroom could be constructed in the mock-up space to test variable air volume cooling systems, displacement ventilation systems, reconfigurable heating and cooling systems and various computer based control algorithms. The same classroom mock-up could be used for electrical studies.

The classroom could be used to study various lighting strategies, lighting retrofits, and ventilation delivery methods relative to lights. It could also be used to study lamps, dimming ballasts, light shafts and photocells. In addition to lighting issues, power delivery methods could also be explored. These might include power strips, desk or lab table outlets, under carpet wiring, overhead cable trays, power poles, etc. Schools need to have special security systems to protect the property with surveillance and to protect faculty, administrators and students. The integration of these security systems into school design is both visual and power integration issues. The integration concerns also include the integration of world-wide web connection systems. Classrooms need to be wired for instant internet connections to minimize lost classroom time and increase library use efficiency. The access for the student is both an industrial design and an architectural design concern. Both can be studied in the context of an appropriate classroom mock-up.

With a Building Construction department being part of the College, access to study construction delivery contracts and methods is natural. As mentioned earlier in the introduction, school boards assumming that they are saving money by using stock plans and the lowest bid contractor, are often incorrect. A new design with construction management may in many cases appear to be the best approach but it can vary with specific conditions. With actual wall section construction and a classroom mock-up, a construction estimate can be very accurate and if too high, alternatives can be studied and proposed.

There are many software development opportunities for the study of ventilation distribution, lighting design, acoustic studies, thermal and heat loss studies, and of course for modeling interior environments, complete with furniture. Engineering firms, such as Ove Arup, have state-of-the-art software available for simulating specific environmental conditions. These would be utilized along side the physical model to achieve maximum accuracy. In addition to physical model evaluation, human subject response can often provide the most important data and can be collected in a mocked-up classroom.

Finally, with an in-house Industrial Design program, the furniture, human factor relationships and other important interior design issues would be studied in the mock-ups alongside the other previously mentioned environmental criteria.

Figure 1. Proposed Educational Facilities Research Center

The proposed educational facilities research center shown in Figure 1 above would include a multidisciplinary team of researchers that could evaluate existing designs or proposed school designs relative to all or selected issues. This K – 12 focus would position the facility and team to be a valuable resource to designers and governmental bodies on well-designed, healthy environments for learning.

Establishing Criteria

As Ezra Ehrenkrantz writes in Architectural Systems, any attempts to obtain a consensus on physical requirements from all the school boards and other governmental agencies building schools, would be fruitless. The different concepts of education would want to shape different requirements for the schools. Consequently, a flexible research complex that could afford a wide range of important research activities is necessary. Since the research performed would give designers the range of performance particular systems or component combinations would have, it is incumbent that there be spaces for prototypes and other full-scale environmental tests be provided.

Consequently two mock-up spaces for full-scale prototypes would be included. The spaces would have at least 18' high clearance and have overhead crane capability. With exposed HVAC systems and cable trays, environmental flexibility could be obtained. Natural daylighting through north facing skylights would provide balanced lighting conditions. If direct sunlight is required the mock-up could be rolled out to the staging area through overhead doors.

There are several demands that could be measured on mock-ups. These might include construction material and assembly, moisture transmission, solar heat gain, aesthetics, etc. The assembly would require shops capable of working in various materials. Therefore there would be three primary shops, one each for wood, for metal and for fiberglass. Nearby facilities allow for concrete and masonry construction. This combination of material fabrication capabilities would position the researchers to construct a wide variety of building components, HVAC systems and many other test assemblies.

Researchers would need offices and since educational support would be needed, there would be classrooms. There would also be support facilities for circulation, mechanical distribution and toilet rooms. Model testing would be necessary for many different lighting or ventilation studies so a wind tunnel and daylighting dome would be necessary. Most important is to retain flexibility and allow the primary spaces to change over time.

Figure 2 below illustrates a section through the proposed facility. It shows the two-story mock-
up space, office and classroom. The detail is of one

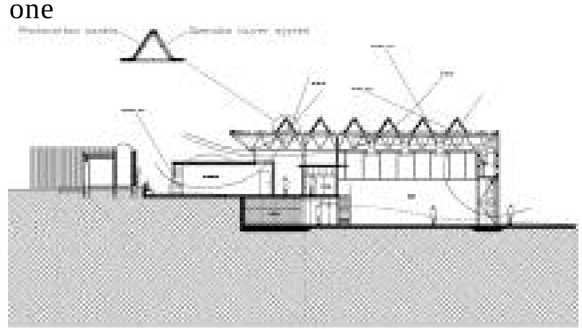

Figure 2. Section through proposed facility

of the monitors on the roof. Each monitor has a photovoltaic array to the south and a clearstory to the north.

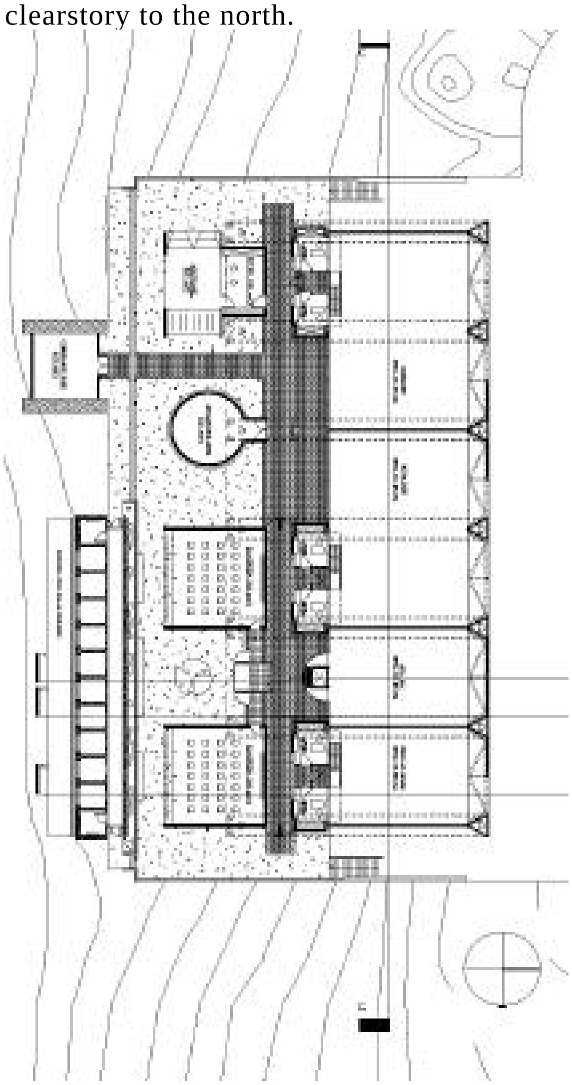

Figure 3. Plan of proposed facility.

Figure three illustrates a proposed plan reflecting the programmatic criteria just discussed. Shown are two 30-person classrooms, six offices, fiberglass shop, wind tunnel, daylighting dome, wood shop, metal shop and two mock-up spaces. The long cellular structure on the left is an existing test cell facility. This facility has two instrumentation rooms at both ends and ten 8'x8' cells with an open façade facing due south. These cells are for testing façade assemblies for solar gain, ventilation, daylighting and moisture penetration. The cells may be heated or cooled as necessary to determine thermal transfer. These can be wired for remote data transfer to a main instrumentation room in the nearby existing Research + Demonstration Facility. The three buildings would work together to provide a comprehensive research complex.

At least one of the mock-up spaces would be a climate-controlled environment. This would require enthalpy, relative humidity, CO2 and temperature sensors with a sophisticated thermal comfort controller. Some work currently on-going at the Research + Demonstration Facility relative to the design of a pediatric hospital room has shown that for full scale mock-ups to provide valid data for the duration of the research, they need to be in similar climate controlled environments.

In the other mock-up space, envelope assemblies could be tested for thermal transfer, moisture migration and air leakage factors. This would require humidifiers, pressurizing fans with variable frequency drives, pyranometers, a solar simulator, heat flux sensors and an overall system controller with a data acquisition dedicated computer. This equipment would allow different wall, roof, and slab assemblies to be studied.

The wind tunnel would be designed for model studies and would require a site built platform and housing. In the housing would be a variable frequency in-line fan with speed controller, pressure and velocity transducers smoke wand, and adjustable lighting system

The daylighting dome would likely be a stainless steel silo top with access door. Inside the surface would be modified to match a hemisphere dome. A motorized viewing platform with solar lamps and a sun simulator would be required. Also required would be a digital video camera with display system and a data acquisition dedicated computer for control.

The wood and metal shops would have equipment suitable for heavy construction as well as furniture fabrication. Areas for welding and spraying and painting booths would also be provided.

Summary

The origins of this facility lie in the fact that there is no one center that is an authoritative source for all issues affecting the design and construction and evaluation of K through 12 educational facilities. The Jefferson Center at the University of Virginia is a well-respected center for the study of pedagogical issues regarding K – 12 education. This center aims to have the same reputation for the study of physical design criteria through the design of a facility capable of handling the previously mentioned 14 criteria.

Figure 4 to the right shows an isometric of the facility. The new Center for the Study of Educational Facilities would be adjacent to an existing Test Cell facility and the Research + Demonstration Facility, both of which would expand the research resource capabilities.

Figure 4. Isometric of proposed facility showing structural elements

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