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ABSTRACT

This paper reviews briefly the literature concerned with the use of modular components in the construction of educational facilities. Fourteen of the documents reviewed have previously been cited in RIE. The essence of the material found in the reviewed literature is organized into and discussed under the topics (1) modular components and materials, (2) systems performance, (3) applications, and (4) facility case studies. (MLF)

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Modular Components

Alan M. Baas

The use of components whose dimensions are a multiple of some common base "module" is not new. Early settlers often built their homes with "modular" wooden frames constructed in England and transported to this country in the holds of ships. Since that time, modular building components have come to be manufactured on a wide scale and are now available in a variety of dimensions.

The use of modular components can expedite the cost-effective construction of flexible school facilities. Preassembly at the factory lowers site construction time and reduces the effect of adverse weather conditions on construction schedules. In addition, specialized factory environments provide quality control over component elements. Use of modular elements also reduces maintenance and renovation costs by permitting replacement of separate units without necessitating major construction.

Today, modular components are used largely within systems building programs where, from the design stage, separate components are integrated with one another to form dimensionally related building systems responsive to a basic overall construction schedule.

The field of component manufacturing is too broad for an adequate summary in this review. Nevertheless, the documents reviewed provide a perspective for the evaluation of such performance data as may be obtained directly from component manufacturers.

Of the documents, fourteen are available from the ERIC Document Reproduction Service. Complete instructions for ordering the documents are given at the end of the review.

MODULAR COMPONENTS AND MATERIALS

Three documents published in the early 1960s provide basic information on modular components. The first (National Academy of Sciences [1960]) reviews modular standard development and discusses the status of modular practice. It also reports on the availability of modular products and describes educational programs on modular coordination.

The second (National Academy of Sciences 1961b) discusses attitudes toward preassembled components, describes component construction, and presents case studies of structural and mechanical components. The document surveys points of view held by architects, contractors, owners, labor, and building code officials. In addition, it describes preassembly techniques and presents dimensional relationships for preassembled components. Concluding sections deal with existing and potential applications of such systems.

Papers from a Building Research Institute conference (National Academy of Sciences 1961a) survey developmental problems in component construction. Ceiling and roofing systems receive attention in two of the papers. Others give attention to cooperative research within the cement industry and report on developmental aspects of structural ceramic panels.

To assist English architects and educators in relating their school design needs to prefabricated components, the Department of Education and Science (1964) describes common controlling dimensions for various building systems. Dimensions are provided for structural systems, ceiling heights, floor and roof depths, changes of level, and spacing of structural supports. The preferred dimensions are intended to set the framework for components, but not to establish actual dimensions for individual components. In addition, diagrams and sketches of building components relate the dimensional framework to construction techniques.

A second building bulletin (Department of Education and Science 1968) provides additional information on coordinating components for educational facilities. Recommendations represent a move toward establishing a national British "pool" of dimensionally related components that may be used in a variety of building types. The document's main objectives are to identify and establish the characteristics that must be standardized if components are to be shared economically by many users, and to suggest conventions for assembling those components. Discussions of performance standards and various aspects of component implementation clarify the use of modular components in the construction process.

England's Department of Scientific and Industrial Research (1965) published a history of prefabrication in Britain from the first Victorian innovations through the systems building techniques of the present. The document can assist the educator seeking an overall perspective on prefabrication as it relates to governmental and legislative action, building innovations, and general construction techniques. Schoolhouses receive attention, together with other public and private uses of prefabricated components.

The BOCA Basic Building Code published

by the Building Officials Conference of America (1967) contains nationally recognized standards for evaluating minimum safe practices and for determining the performance of materials or systems of construction. The code presents regulations in terms of measured performance rather than in terms of rigid specification of materials or methods. Areas covered include (1) administration, definitions, and general limitations; (2) special use and occupancy requirements; (3) building operation, safety, and fire protection; (4) building equipment and mechanical systems; (5) materials, construction, walls, and prefabrication; and (6) structural and foundation loads and stresses. Appendixes indicate sources used in determining the code, and an up-to-date annual supplement shows revisions between five-year editions.

SYSTEMS PERFORMANCE

In a state-of-the-art report to the architectural and educational professions, Koppes and Green (1967) agree that the logic and validity of modular design are well established and widely accepted. Present design and technological trends, particularly the systems approach, indicate continuing support for modular design and suggest its increased implementation as practical problems are resolved.

The significance of modular components is reflected in the development of modular drafting techniques with an accompanying system of computer symbols. Referring to British and American systems building projects, the authors point out the immediate advantages of modular construction in school facilities.

Mechanical building systems can be decentralized through the use of standardized modular equipment. Crossey (1969) recommends this approach instead of conventional installation of centralized mechanical units. To this end, he outlines necessary design, planning, and construction programming in terms of costs, performance, expansion, and flexibility. In addition, he suggests various strategies for implementing such systems and discusses the technological gaps between building design and construction practices.

Evans (1962) describes a system permitting construction of usual building shapes without the use of conventional concrete formworks. The technique involves development of a structural steel skeleton that is fabricated on a flat plane, sprung into final position, and coated with concrete or other sprayable materials. Photographs and diagrams illustrate the system's development and construction.

The use of prestressed concrete can provide educators with cost-effective school facilities. Lyman (1968) discusses the planning process and surveys procedures and conceptual data necessary for site development and building. Modular dimensions and the systems approach in both design and construction greatly expedite building programs.

In addition, Lyman gives information on the development of construction systems and on the integration of building systems and structures. Cost and fire resistance data supplement designs for specific functional areas. Usage data for prestressed concrete structural and architectural elements are given in terms of structural data, construction procedures, and element joinery. His presentation is enhanced with pictorial reviews of current school design and construction.

A publication of the Basalt Rock Company (1960) provides diagrammatic explanations of various concepts, processes, and potential material usages related to the construction of precast-prestressed schools. The document reviews fabrication processes, basic structural components of building systems, and building construction procedures. The use of related elements is shown for typical school plans, and information is given concerning earthquake resistance potential, headroom economy, system integration, and stadium construction. The manual employs sketches and short notes exclusively.

Weatherproofing and sealant requirements for thin shell concrete roofs and the effect of physical factors on their weatherproofing receive attention in a document published by the National Academy of Sciences (1961c). The report deals with problems and limitations imposed by such roofs and discusses properties and uses of available weatherproofing and sealant materials.

The Allied Masonry Council ([1968]) defines the compact school resulting from new educational programs as a brick structure with a flexible interior and natural light from skylights, domes, clearstories, and interior courtyards. The document provides appraisals and reactions to the physical environment, explains structural and economic effects of brick construction on school design, and gives examples of brick and tile as building materials for the compact school.

An analysis of building components is one of six major areas covered in a set of building digests published by the National Research Council of Canada (1968). In all, one hundred different topics relating to technical aspects of building design and construction receive attention, many with diagrams, charts, and sketches illustrating relevant concepts.

APPLICATIONS

Component building systems are strategic to the design and construction of many schools in Great Britain. The Ministry of Education (1964) offers a detailed summary of the main trends in the design and planning of modern English primary schools. Among major developments are the educational approach to design, the evolution of new plan forms, the adoption of new methods of plan and site analysis, and the exploration of new spatial designs for communal, teaching, and administrative spaces. In addition, the document provides photographs and brief descriptions of nineteen recent primary schools demonstrating contemporary design and construction techniques.

The New Brunswick Department of Economic Growth ([1970]) published a brief description of the planning and construction of modular component elementary schools in that province. Cost data tables supplement graphic and photographic records of the construction and results of the program.

Stull and Heder (1968) suggest prefabricated structures can assist Boston educators with their particular facilities needs. They present concepts and recommendations for a proposed system of dispersed classroom clusters or "infill schools." These small, independent urban schools would be housed in prefabricated modular component units capable of being constructed in a few weeks. The authors support their proposal with diagrams representing the interrelationship of infill schools and community resources.

In a review of the economic advantages of steel construction, The American Institute of Steel Construction, Inc. (1962) examines ten steel-framed schools. These schools do not resemble each other in size, shape, arrangement, or unit cost; some are original in concept and architecture, and others are conservative. Costs, construction data, plans, and details provide a comprehensive picture of the structural and architectural features of each school building. In addition, steel framing is compared with other available framing materials.

Koppes (1969) gives information regarding the costs of inexpensive clear-span structures that enclose recreational and athletic activity areas. His treatment includes a cost analysis of seven distinct types of readily available structures, and several variations. Initial costs as well as financing, operating, and maintenance costs are compared for three alternative annual terms of use over periods of five, ten, and twenty years. Detailed cost calculations are summarized in both tabular and graph form. Recommendations discuss the essential features of the "ideal" structure for uses of this kind.

Structural considerations in school building economy are presented in a publication by the Connecticut State Department of Education (1963). The school building, identified as basically shelter structures, consists of structural members, weather-protection elements, mechanical installations, finishing elements, and built-in equipment.

The document identifies subsoil conditions, site contours, and climatic conditions as the criteria governing the choice of building systems and examines several structural systems in terms of these critera. Weather protection elements relating to school construction cover specific aspects of roofing, flashing, siding, waterproofing, insulation, overhangs and sunshades, circulation characteristics, air and light passage, acoustical correction, and aesthetic improvement. Aspects of fire-resistivity include safety, building rating, and local ordinances. The publication concludes with miscellaneous architectural considerations and recommendations for the adoption of a modular system of dimensions.

CASE STUDIES

The use of educational specifications and component systems in the design and construction of a junior high school is discussed in a paper by Justus (1965). Showing how physical design and curriculum patterns interact, he describes the relationship between the pupil's learning environment and the component systems of the building design. The report gives an illustrated treatment of the school's instructional materials center, teacher work center, communication system, and flexible auditorium. Basic construction specifications and a brief cost analysis of the new building are included.

Kohn (1970) points out structural, functional, and design features in a photographically illustrated report on the Montessori school building in Stamford, Connecticut. The use of a precast concrete building system and a modularly designed interior enhance the flexibility of the school's learning spaces.

A flexible elementary and high school design constructed with component systems receives attention in a journal article ("Skyline Gathers K-12 Together under One Roof" 1968). The school demonstrates advantages available from modular systems designing. Large clear interior spans and movable partitions encourage open circulation. A five-foot modular ceiling integrates air distribution, lighting, and acoustics. The article also discusses various separate areas of the school, noting the use of construction techniques to meet special educational needs.

The Timber School District, one of twenty California schools cooperating with the University of California at Los Angeles and various foundations to explore educational facilities innovation, has published an illustrated report (1967) of its modular-developed school. The design concepts are related to audiovisual instruction, educational programs, curriculum, and future planning.

In separate documents, Clinchy (1960 a and b) describes two high schools built with component systems. He gives a profile of each school's component characteristics and evaluates the relationships between educational goals and physical design.

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Address requests to ERIC Document Reproduction Service, P. O. Drawer O, Bethesda, Maryland 20014.

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RESEARCH HIGHLIGHTS

Manufacturers, contractors, architects, and clients must cooperate in the standardizing of modular dimensions for building components to obtain maximum cost savings. *(Department of Education and Science 1968)*

Mechanical building systems can be decentralized through the use of standardized modular equipment, thereby effecting savings in both costs and space. *(Crossey 1969)*

Prestressed concrete can provide cost-effective solutions for school design needs. *(Lyman 1968)*

Steel frame buildings offer economical alternative solutions to design needs. *(American Institute of Steel Construction 1962)*

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