R E P O R T   R E S U M E S

ED 016 369 EF 001 287

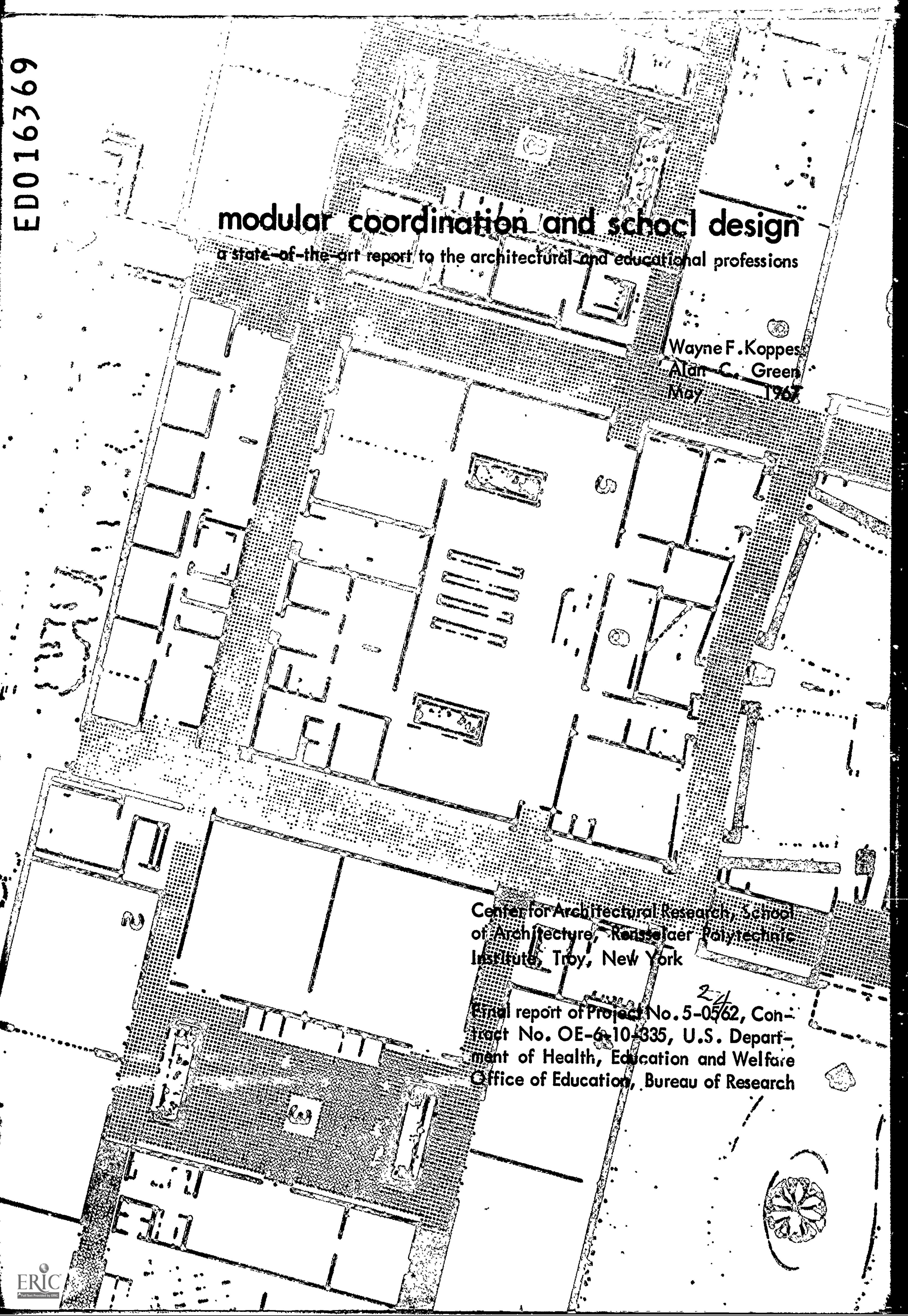
MODULAR COORDINATION AND SCHOOL DESIGN, A STATE-OF-THE-ART REPORT TO THE ARCHITECTURAL AND EDUCATIONAL PROFESSIONS. FINAL REPORT.

BY- KOPPES, WAYNE F. GREEN, ALAN C.
RENSSELAER POLYTECHNIC INST., TROY, N.Y.

REPORT NUMBER BR-5-0562-FR PUB DATE MAY 67
CONTRACT OEC-6-10-335
EDRS PRICE MF-$9.50 HC-$4.16 102P.

DESCRIPTORS- *BUILDING DESIGN, *MODULAR DESIGN, *SCHOOL CONSTRUCTION, *SCHOOL DESIGN, STRUCTURAL SYSTEMS

THE OBJECTIVES OF THIS STUDY WERE--(1) TO DETERMINE THE INFLUENCE OF MODULAR COORDINATION OF BUILDING DESIGN, (2) TO INVESTIGATE CURRENT ATTITUDES OF THE BUILDING INDUSTRY TOWARD THE MODULAR CONCEPT, AND (3) TO EVALUATE THE CONCEPT'S SIGNIFICANCE, MERIT, AND IMPLICATIONS IN TERMS OF SCHOOL BUILDING DESIGN. THESE OBJECTIVES WERE REALIZED BY A LITERATURE SEARCH, CONTACT WITH KNOWLEDGEABLE PERSONS, SURVEYS, AND INVITATIONAL SEMINAR, COMPLIMENTARY GRADUATE AND UNDERGRADUATE PROJECTS, AND BY RETAINING CONSULTANT REVIEWERS. THE VALIDITY, LOGIC, AND MERITS OF MODULAR DESIGN ARE WELL ESTABLISHED AND WIDELY ACCEPTED, AND PRESENT DESIGN AND TECHNOLOGICAL TRENDS SUGGEST ITS SUPPORT AND RESOLUTION OF PRACTICAL PROBLEMS FOR INCREASED IMPLEMENTATION. THE USE OF THE GRAPHIC TECHNIQUE OF MODULAR DRAFTING DEPENDS ON THIS ACCEPTANCE. A SYSTEM OF COMPUTER SYMBOLS AND LANGUAGE WILL LIKELY BECOME THE COMMUNICATION MEDIUM. THE DEVELOPMENT AND DEMONSTRATION OF SUCH A SYSTEM SUGGESTS SCHOOL BUILDINGS AS BEING AN APPROPRIATE VEHICLE. (MH)



modular coordination and school design

a state-of-the-art report to the architectural and educational professions

Wayne F. Koppes
Alan C. Green
May 1967

Center for Architectural Research, School of Architecture, Rensselaer Polytechnic Institute, Troy, New York

Final report of Project No. 5-0562, Contract No. OE-6-10-335, U.S. Department of Health, Education and Welfare Office of Education, Bureau of Research

Photographic Credits

Harvey Rabinowitz and Alan Jensen,
School of Architecture, R.P.I.

Staff of Office of Institutional Research,
R.P.I.

Lawrence S. Williams, Inc. (page 61)

modular coordination and school design

a state-of-the-art report to the architectural and educational professions

Wayne F. Koppes
Alan C. Green
May 1967

The final report of Project No. 5-0562 (Contract No. OE 6-10-335) undertaken by the Center for Architectural Research, Rensselaer Polytechnic Institute, Troy, New York

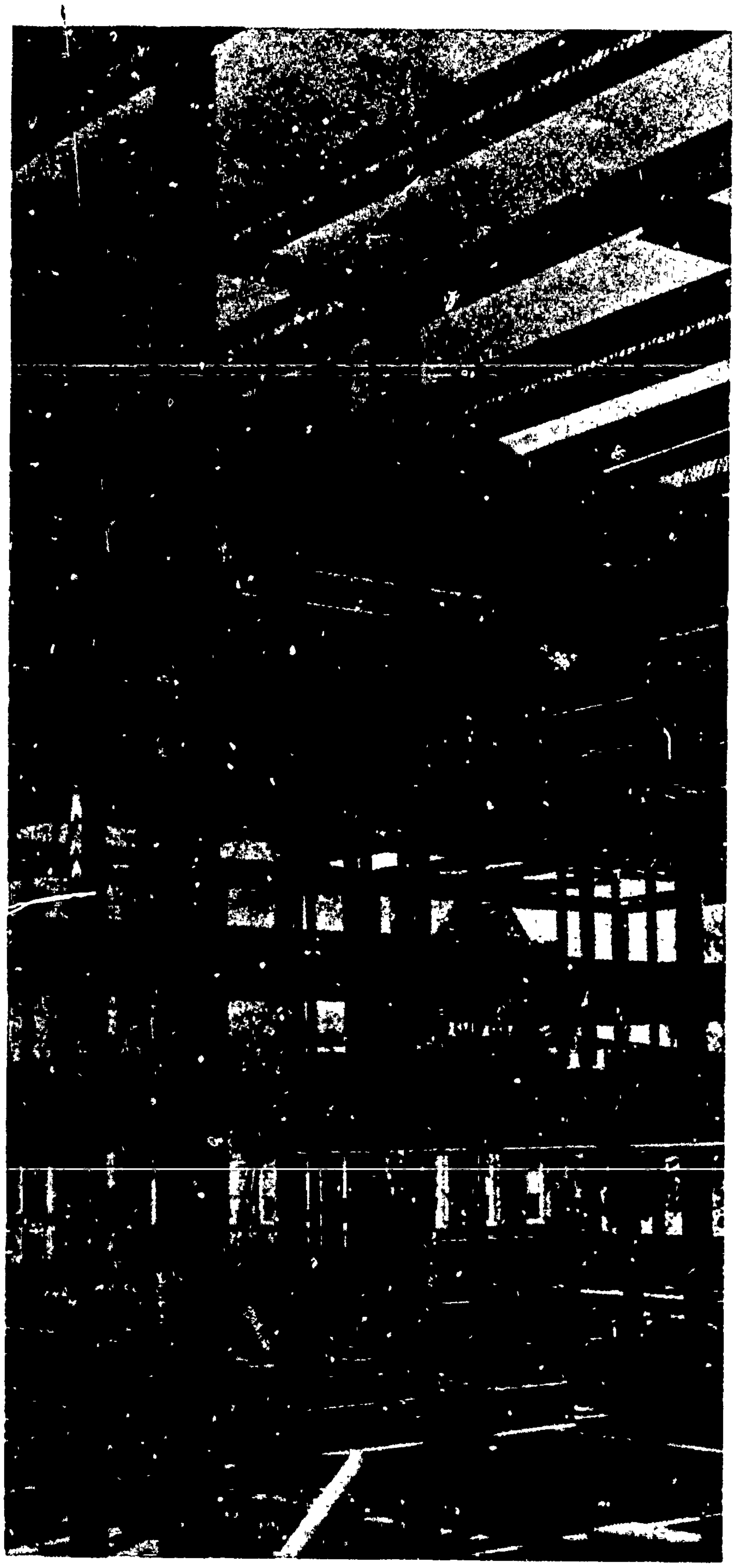
The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

contents

the challenge

The current level of spending for new construction of elementary and secondary schools in the United States is in the range of $5 billion yearly. To meet this level of building need with efficient and purposeful schools without over-burdening the taxpayer is one of the great educational challenges of the day.

Many innovations in planning and construction have been promoted, and some have helped in meeting the challenge. One innovation is modular coordination. Taken in its broadest concept and in light of today's technology, modular coordination is here being re-examined to better determine its potential in also helping to meet the challenge.



1

orientation

Modular design of buildings is not really a new concept. Broadly speaking, it may be said that the Greeks and Romans - and even the Egyptians - employed it, at least in some degree, in their architecture. In its dictionary meaning, a module is simply a unit of measure, whose dimensions may be either large or small. So any building in which a certain dimension such as that of column spacings, is used repetively, may said to be of modular design.

Until the advent of the machine, the module was used chiefly as an esthetic or architectural tool, but in the era of industrialization its practical values have become equally if not more important. Modular

ORIENTATION

design today often implies the predetermined dimensional coordination of manufactured components, or modular coordination - a concept dating back less than fifty years. For several decades this more complex concept has been promoted by various agencies both here and abroad, and with fluctuating degrees of activity and enthusiasm, as an aid to more efficient building.

PURPOSE OF STUDY

This report is the result of a recent study undertaken on behalf of the U. S. Office of Education to investigate the potential importance of modular planning and modular coordination in school design. The principal objectives of the study, therefore, have been:

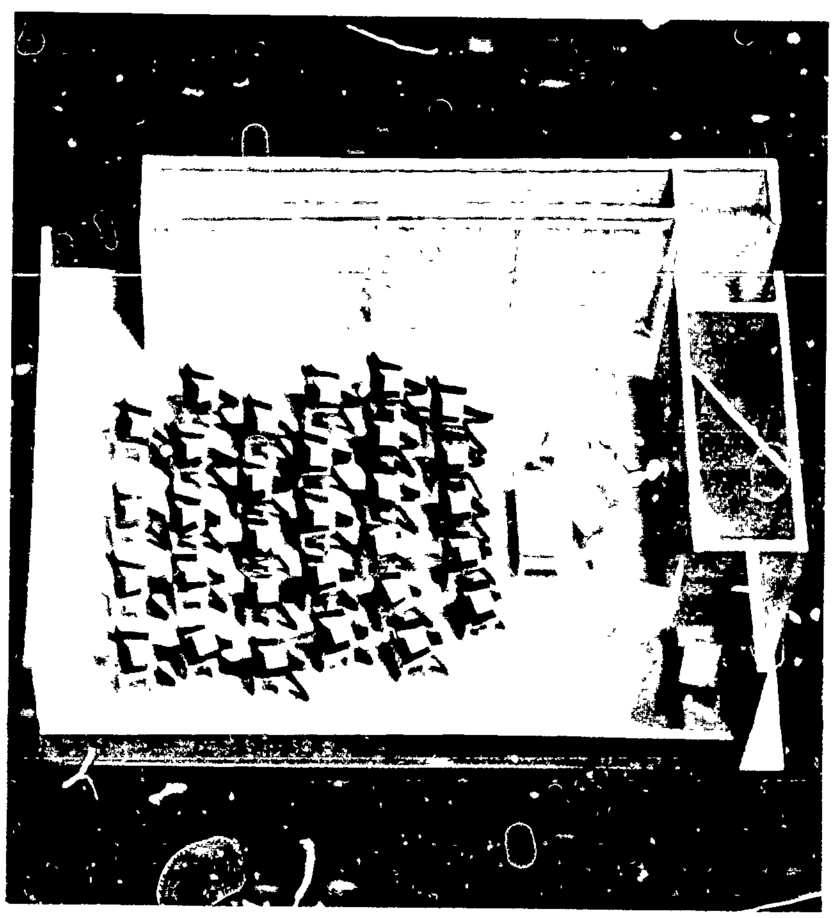
- o to determine the current status of modular coordination as an influence in building design
- o to investigate current attitudes on the part of the building fraternity in respect to the modular concept
- o to evaluate, in general terms, its significance and merits, and
- o to assess its implications, particularly in reference to the design of school buildings.

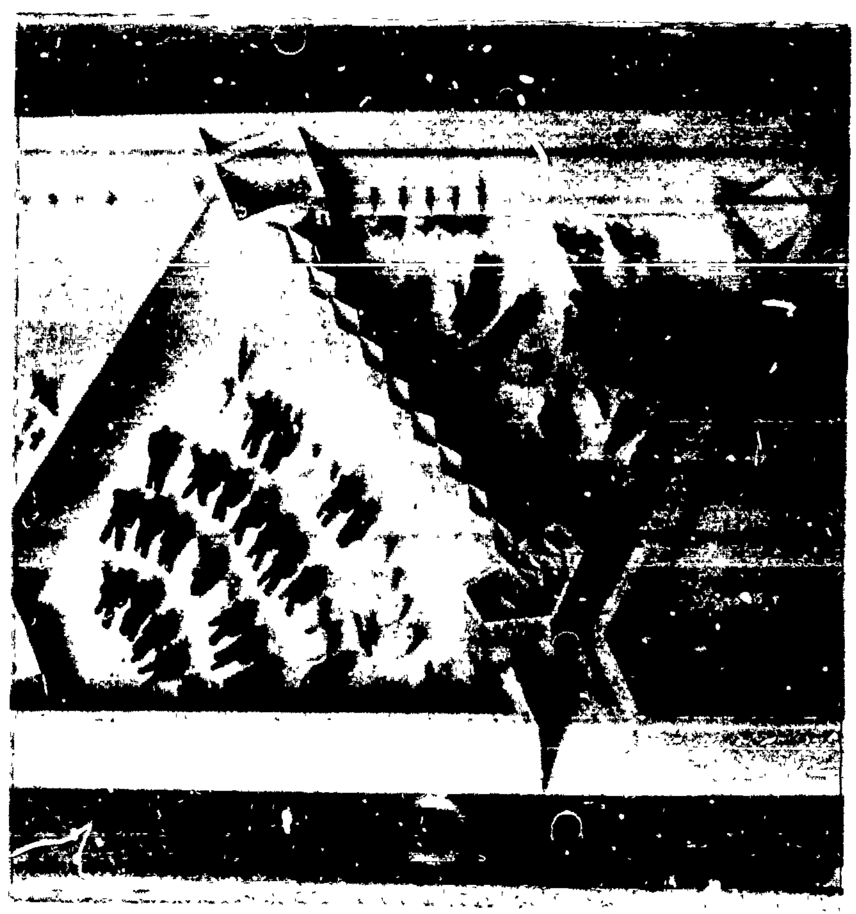
Although the study has necessarily been school-oriented to some degree, its larger purpose has been an objective review of the whole case for modular coordination - its merits, its problems, its status and its premise. This report, representing that study, is not intended as a comprehensive exposition of the subject - which would require volumes - but as a summary of the current "state of the art" and its indicated potentials. As such, it is hoped that it may be of interest to many segments of the architectural and planning professions.

CLARIFICATION OF TERMS

At best, it's a rather nebulous area with which we are dealing, because concepts and meanings are not clearly defined. Some of the principal terms in common use appear to have no commonly accepted precise definitions; as will become evident, they often mean different things to different persons. One party, in commenting on this situation, observed that "You can find just about any definition you want, depending on whom you talk to".

It is essential at the outset, therefore, that the intended meaning of several key terms, as used in this report, be clarified. The definitions offered not only reflect the concepts in the minds of the authors, and seem logical, but are believed to represent the most commonly accepted meanings of these terms. They are all subject to question, of course,





and some disagreement on the part of some readers is inevitable, but in the context of this report, the following definitions apply:

Modular design: Orderly planning, so arranged as to make logical and extensive use of a repetitive module or dimension of at least a foot or more.

Comment: The planning module may be determined by the size of functional units such as rooms or spaces, or by the optimum dimensions of component materials, or both. It is usually reflected in the spacing of structural supports and/or the width of wall elements. It may be any appropriate dimension, but usually is between 3'-4" and 16', 4' and 5' being commonly used. In most cases this module is a multiple of 4", but this is not mandatory under the definition given.

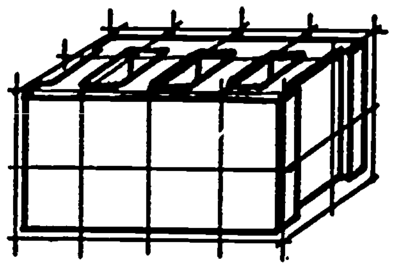
Modular coordination: The establishment of both building dimensions and building material sizes as multiples of a common base module, to facilitate the assembly of materials according to plan with a minimum of modification at the site.

Comment: The base module is much smaller than, and a factor of, the planning module used in modular planning. The unit most commonly used is a 4" cube, and unless otherwise indicated, wherever the term "modular coordination" is used in this report, this unit is implied.

As explained in Appendix "A" and mentioned elsewhere in the report, several other definitions for "modular coordination" are found in the literature, and all have their proponents. These have been carefully considered, but in the opinion of the authors they do not adequately describe the concept.

Modular drafting: The drafting technique developed and promoted by the Modular Building Standards Association, employing grid lines and using the dot-and-arrow symbols on dimension lines.

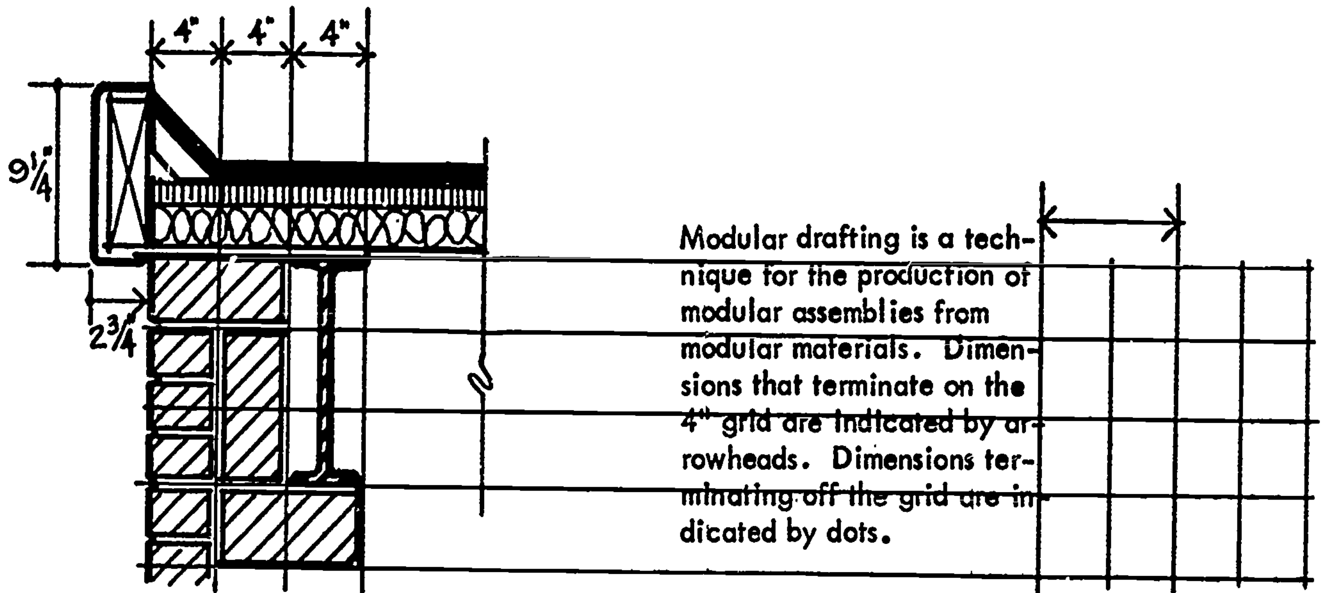
Comment: The use of modular drafting is an optional matter, even when employing modular planning or modular coordination. Often a modified or compromise system is employed, making use of grid lines, but not the dots and arrows.



4" grid continuous in three dimensions

Modular materials are nominal increments of a 4" base module. The actual dimensions are something slightly less depending upon the method of jointing.

MODULAR MATERIALS

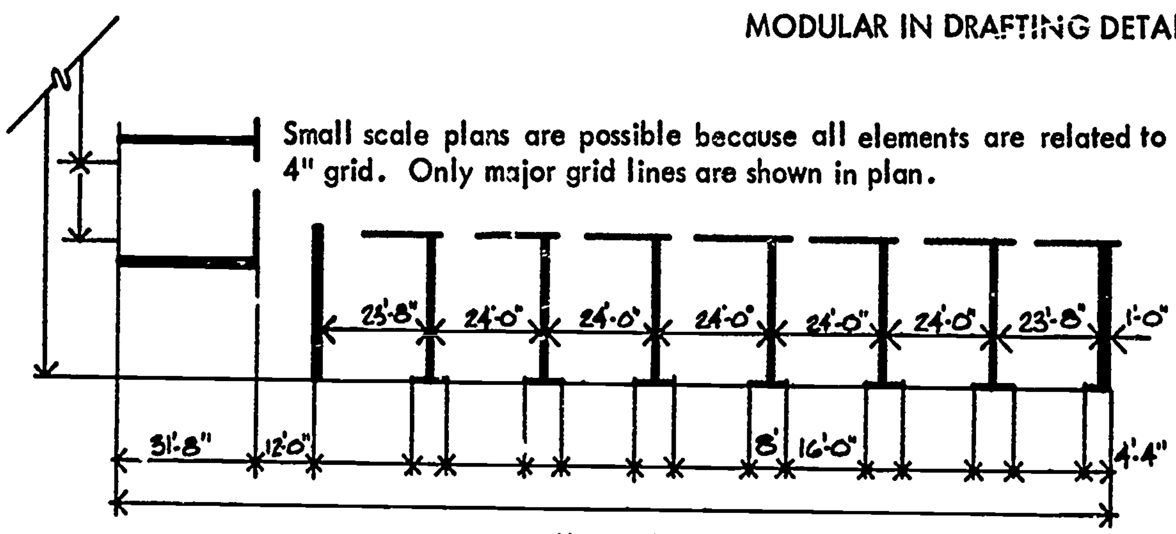


Modular drafting is a technique for the production of modular assemblies from modular materials. Dimensions that terminate on the 4" grid are indicated by arrowheads. Dimensions terminating off the grid are indicated by dots.

large scale detail grid lines need not be shown

MODULAR IN DRAFTING DETAILS

Small scale plans are possible because all elements are related to the 4" grid. Only major grid lines are shown in plan.



overall modular dimension

MODULAR IN PLANNING

Although these three terms are of course related, the practices they represent are not necessarily inter-dependent. In a sense, these practices might be regarded as three different stages of optional involvement. Many architects use modular design, but relatively few consistently practice modular coordination, and still fewer use modular drafting. Conversely, those who do use modular drafting are necessarily proponents of modular coordination, and those who employ modular coordination in their work are producing modular designs.

2

overview of the modular concept

HISTORY OF MODULAR COORDINATION

The concept of dimensional coordination in building is generally considered as having originated in 1921, when Albert Farwell Bemis began his work in this field. His primary concern at that time was to update the housing industry, which he felt had failed to keep abreast of developments in industrial technology. Noting that nearly every other aspect of living had benefited from the efficiencies of industrialization, Bemis sought a method for a more rational production of building materials and components. This rationalization, he thought, could be found in an examination of the physical structure of the building.

OVERVIEW

In 1933 Bemis published the first of three volumes entitled "The Evolving House", in which he described in great detail his proposal for developing a building system based on a three-dimensional module. This "cubical modular method" was to provide the basis for both the efficient production and the efficient use of building elements. After exhaustively studying a number of logical possibilities, he adopted 4" as the dimension of this cubical module.

Although reduction of waste was the principal objective in proposing his modular method, Bemis emphasized that it would also provide the very important advantages of:

- a common unit of measure
- the reduction from many sizes to a few standard sizes
- the economies of using repetitive details, and
- dimensional compatibility of accessories, equipment and furnishings.

Bemis did not live to see the fruits of his work. Following his death in 1936, however, his heirs, with the cooperation of the American Standards Association, established the Modular Standards Association (MSA), to promote the concept of dimensional coordination throughout the building industry. The joint efforts of these associations led to the adoption, in 1945, of the 4" module as an American Standard applying to the sizing of building materials, and equipment. Instructions for the dimensioning of certain products, along with recommended installation details, were published the following year in the "A-62 Guide". The measures thus advanced were somewhat broader in scope than Bemis' original proposal, being designed to encourage:

- less construction waste
- a minimum of on-site cutting and fitting, and
- more pre-assembly of components.

It was during this period that some parts of the building industry, notably the brick manufacturers, began to respond to the need for modular products by making them available. The use of modular sizes and materials was also encouraged by the publication of "Grid Lines", a technical periodical aimed at informing the architect about modular practice.

Recognition of the importance of informing the architect led to the sponsorship of educational programs by the HHFA,* in the belief that increased interest in modular coordination would stimulate a demand for more modular products. In a series of excellent HHFA publications, the principles of modular coordination were clearly explained, and its potential advantages to the architect were also emphasized. Among the benefits postulated were:

- less drafting time required, because working drawings would be simpler and fewer
- fewer drafting errors, because of the elimination of fractional dimensions
- improved intra-office coordination, through the use of a common dimensional standard.

Funds available to the MSA became exhausted in 1946, and the organization was disbanded. During the next ten years various agencies became randomly involved in promoting modular coordination. The AIA ** took over the publication of Grid Lines and established its Section on Modular Coordination to promote the work; HHFA contracted with the National Academy of Sciences to investigate the obstacles to its wider acceptance; NAHB and the Producers Council added their support to the A-62 program, and the Veterans Administration adopted the policy of recommending the use of modular coordination in the design of all VA hospitals.

In 1957, active interest in modular coordination was renewed with the formation of the Modular Buildings Standards Association (MBSA) under the joint sponsorship of the AIA, the Producers Council, the National Association of Home Builders and the Associated General Contractors. This organization served as the sole instrument for the promotion of modular coordination until 1963, when its activities too, were discontinued because of the lack of financial support. Since then, there has been no one agency responsible for promoting modular coordination in this country.

---

* Housing and Home Finance Agency
**American Institute of Architects

an outline of the development of modular coordination

DATE	IN THE UNITED STATES	IN OTHER COUNTRIES
1921	Albert Bemis began his work on modular coordination.	
1933	Bemis published the first volume of "The Evolving House".	
1936	On Bemis' death, his heirs established the Modular Service Association.	
1938	With MSA help, ASA held an industry conference, resulting in the organization of ASA Project A62 for the Coordination of Dimensions of Building Materials and Equipment.	
1939	ASA Sectional Committee was organized with AIA and PC as co-sponsors.	
1942		France adopted a "modulation standard" and 10cm became the preferred module. In Germany, Professor Neufert developed the 10cm and 12.5 cm modules for use as war construction standards. In Sweden, Bergvall and Dahlberg, under direction of the Swedish Standards Association, established a 10cm module as a basis of window sizes.
1945	ASA formally adopted the 8" module.	
1946	The "A62 Guide" was published by MSA.	
1947	With MSA's funds exhausted, the Office of Technical Services, at PC's request, provided funds for continuing its work another year. Publication of "Grid Lines" was started by MSA.	
1948	MSA was disbanded, and sponsorship of A62 reverted to AIA and PC. AIA took over the publication of Grid Lines. HHFA initiated educational programs promoting the use of modular coordination in housing. Fred Heath began the publication of his "Moduletter".	
1949	ASA-sponsored conference inspired new financial support by industry, and AIA established its Section on Modular Coordination, taking over the publication of Heath's Moduletter. Under an HHFA-BRAB contract, A.D. Little Company made a survey of the status and potentials of modular coordination.	
1950	William Demarest appointed AIA Secretary of Modular Coordination and secretary of ASA Committee A62.	
		In Canada, the Division of Building Research, NRC, held a conference to explore the merits and application of modular coordination.
	NAHB joined AIA and PC as a sustaining sponsor of the A62 program.	

1951 In Germany, Standard Din 4172 established the 12.5 cm module for brick construction and the 10cm module for interior dimensions, in publicly subsidized building.

1953 Project 174 of the European Productivity Agency was initiated, to promote the modular concept. In England, a private organization, The Modular Society, promoted the use of the 4" module, initiating its publication of a periodical, the "Modular Quarterly".

1954 In the USSR, the "Building Standards Regulations" supported the use of the 1000mm module to govern the dimensional inter-relationship of space units. The Danish National Institute of Building Research reduced module sizes from 60 and 48cm to 10cm.
BRI held its first conference on Modular Measure.

1955 Building Bulletin No. 8 dealing with the development of modules for school construction, was published in England.

1956 AIA's Section on Modular Coordination was discontinued.
The first phase report of EPA Project 174 was published.

1957 The Modular Building Standards Association was established under the joint sponsorship of AIA, PC, NAHB, and AGC, with Byron Bloomfield as executive director.

1958 In Yugoslavia, the Centre for the Improvement of Building established the 10cm module as standard for interior furnishings.

1959 Southwest Research Institute completed its study on the "Development of Standard and Correlated Dimensions of Material Components in School Construction", sponsored by the Texas Educational Agency.
The Canadian Standards Association published Code A31, establishing the use of the 4" module.

1960 The International Modular Group (IMG) was founded (in Copenhagen) to carry on the work of EPA Project 174.

1961 The second phase report of EPA Project 174 was published.

1962 "Modular Practice" was published by MBSA under a grant from the Educational Facilities Laboratory.

1963 MBSA funds became exhausted, and its activities were discontinued.
The National Research Council of Canada held conferences on Modular Coordination, in Toronto and Montreal.

1966 In response to recommendations by the Institute for Applied Technology, supported by the findings of an investigating committee representing industry, a new A62 Project for the "Pre-coordination of Building Components and Building Systems" was initiated, and the A62 Sectional Committee was reactivated.

OVERVIEW

Meanwhile, during the past twenty-five years, many European countries have also been studying the matter of dimensional coordination. France adopted a "modulation standard" as early as 1942 and in the same year, Bergvall and Dahlberg developed a 10 cm module for window sizes in Sweden, while in Germany dimensional coordination came into use as a war-time construction standard. Russia adopted a "Building Standards Regulation" in 1954. In all of these cases, 10 cm, the approximate equivalent of 4", was chosen as the base module.

The motivation for, and application of these European standards have been somewhat different however, from those related to the American standards. Most of them involved also some compatible larger module or "preferred size", to be used along with the 10 cm base module. These larger modules are generally related to planning dimensions appropriate for the particular building type, e.g. the 40 cm planning module for residential construction, and the much larger 3m module for industrial buildings. Furthermore, most of the European standards resulted from pressures within the housing industry. In countries where skilled labor is scarce and the cost of materials is relatively high, pre-coordination and pre-assembly have been found to save materials and speed erection at the site.

Great Britain, on the other hand, has been concerned with a growing shortage of school facilities, and most of its work in dimensional coordination has been directed at this problem. The components for British school systems, too, have been based on relatively large planning modules, such as 3'4" (width of door and frame) and 99" (1/3 the sum of a 24' classroom plus a 9" block wall). Concerned not only with industry-wide application but with fundamental principles, Great Britain sponsored a series of number pattern studies. These studies, conducted by the Building Research Station, dealt with numbers relationships as they might apply to the dimensional aspects of building design. An interest in addibility (e.g. sill height plus window height equals ceiling height), and the compatibility of component sizes, led to involvement with certain number relationships such as the Fibonicci doubling and tripling series, in the belief that the use of such principles might facilitate greater coordination.

Canada's interest in dimensional coordination is relatively recent, actively beginning in 1959 with the adoption of Code A31, establishing the 4" module. Like the United States' A62 Standard, this Code is designed to provide industry-wide coordination and standardization. More recently, the National Research Council has sponsored several important international conferences promoting interest in, and the use of, modular coordination.

Probably the most significant difference between modular standards development in the United States and those in other countries has been the absence here of specific legislation requiring modular coordination in building construction. The success of Sweden's modular housing is due, in part at least, to the requirements imposed as a condition of eligibility for government subsidy, and the British school building systems have succeeded largely because of the central control exercised over their development and application. This control, for the most part, has grown out of greater need than has as yet existed in the United States. In other countries the demands of post-war reconstruction, and the problems of underdeveloped industrial capacity, have undoubtedly spurred the general acceptance of modular standards.

The International Standards Organization (ISO) has been concerned with dimensional coordination, but since 1960 the chief responsibility for developments in this area has been assumed by the International Modular Group (IMG), an organization formed to continue the work begun by the European Productivity Agency Project 174. Although general agreement exists as to the nominal size of the base module, the 1.6% difference between 10cm and 4" is intolerable in many applications. The task of international integration is a complicated one, and despite the substantial progress already made, a great many problems still remain to be solved.

CURRENT STATUS AND ATTITUDES

One of the basic concerns in this study has been to investigate the present status and usage of modular concepts and current attitudes of the building fraternity regarding their validity and promise. It was felt that, to be meaningful, such a "pulse-taking" should include all segments of the industry having an interest and stake in the matter, contractors, manufacturers, and government agencies, as well as architects.

Obviously, a complete and comprehensive survey of all interested parties - or even all architects - was far beyond the scope of this project, and would not likely be worth its cost anyway. Instead, it appeared that limited surveys involving properly selected samplings of the various types of interest, supplemented by contacts and conferences with knowledgeable and interested representatives of these interests, would provide reliable and adequate indicators. These were the techniques used, and the information resulting is presented in the following summaries.

Manufacturers

Modular coordination necessarily concerns building products and materials, and therefore involves the manufacturer as much as the architect. In this sense, it's a two-legged concept, which cannot stand on one leg alone. The concept was borne of the machine, and owes its origin to the fact that materials were no longer being shaped at the job site, but manufactured off-site and delivered preformed to the building.

From its beginning, therefore, the progress of modular coordination has depended upon the availability of modular products. And, conversely, the manufacturers' interests in supplying modular products has been proportional to the architects' demand for them. As a rule, a changeover to the production of modular sizes involves costly re-tooling, which manufacturers do not undertake unless a proven demand for these sizes warrants the expense. Historically, for this reason, it's been a chicken-and-egg situation, with the architects saying that they'd like to use modular coordination but can't get modular materials, and the manufacturers replying that they can't afford to produce modular sizes because there isn't enough demand for them.

A few industries have consistently lent their support to modular coordination since the earliest days of its organized promotion. Most prominent among these has been the brick industry, the Structural Clay Products Institute having been one of the most active and influential sponsors of the movement since the initial organization of ASA Project A62. Others who have cooperated actively include the producers of concrete masonry units and clay tile, and the manufacturers of windows, doors, glass block, plywood and insulation board. In none of these industries, however, not even the brick industry, has there been by any means complete acceptance of modular standards, and in some, the ready availability of modular sizes is still the exception rather than the rule.

A survey of the U.S. brick industry, made in 1959 by SCPI, revealed that while modular brick were readily available in most of the central plain states, the southwestern and southeastern states, they were not being produced except on special order in the more populous states east of the Mississippi and north of the Mason-Dixon line, in the Northwest or in the Los Angeles area. Recent information indicates that essentially the same situation still exists today in this industry. The impression gained as a result of random inquiries (unsupported by factual survey) is that, with the possible exception of certain types of steel doors, the number of modular products generally available from other industries has likewise increased very little during the past six years.

To obtain expressions of current attitudes on the part of manufacturers, a simple questionnaire was sent to 26 building industry associations, inquiring as to their policy regarding the adoption of modular standards. Of the 24 replies received, 9 reported that they actively promote the use of these standards. In response to further inquiry, the reasons cited for taking this position included the following:

- to meet architectural specifications
- to satisfy building trade requirements
- to provide for design flexibility
- to save costs in production, inventory and replacement
- because the industry had historically produced modular sizes.

Although there seems to be general agreement that dimensional coordination would "be good for the industry", there was no expression of the conviction that it might offer common advantages to all concerned. Even those associations which promote modular sizes point out that in some instances modular sizes are inappropriate and inapplicable. Some representative comments, both pro and con, indicate common attitudes:

> "Modular sizing in the brick and tile industry has not, as a general rule, reduced the prices of the material. We are convinced, however, by statements of reliable contractors, that modular masonry units result in lower costs and better quality than similar non-modular construction".

> "It would be of some benefit in design and standardization, but would have some disadvantages to the trades".

> "A change of sizes was considered to be of no special advantage".

> "The concept (of modular coordination) is a narrow one as presently conceived and practiced".

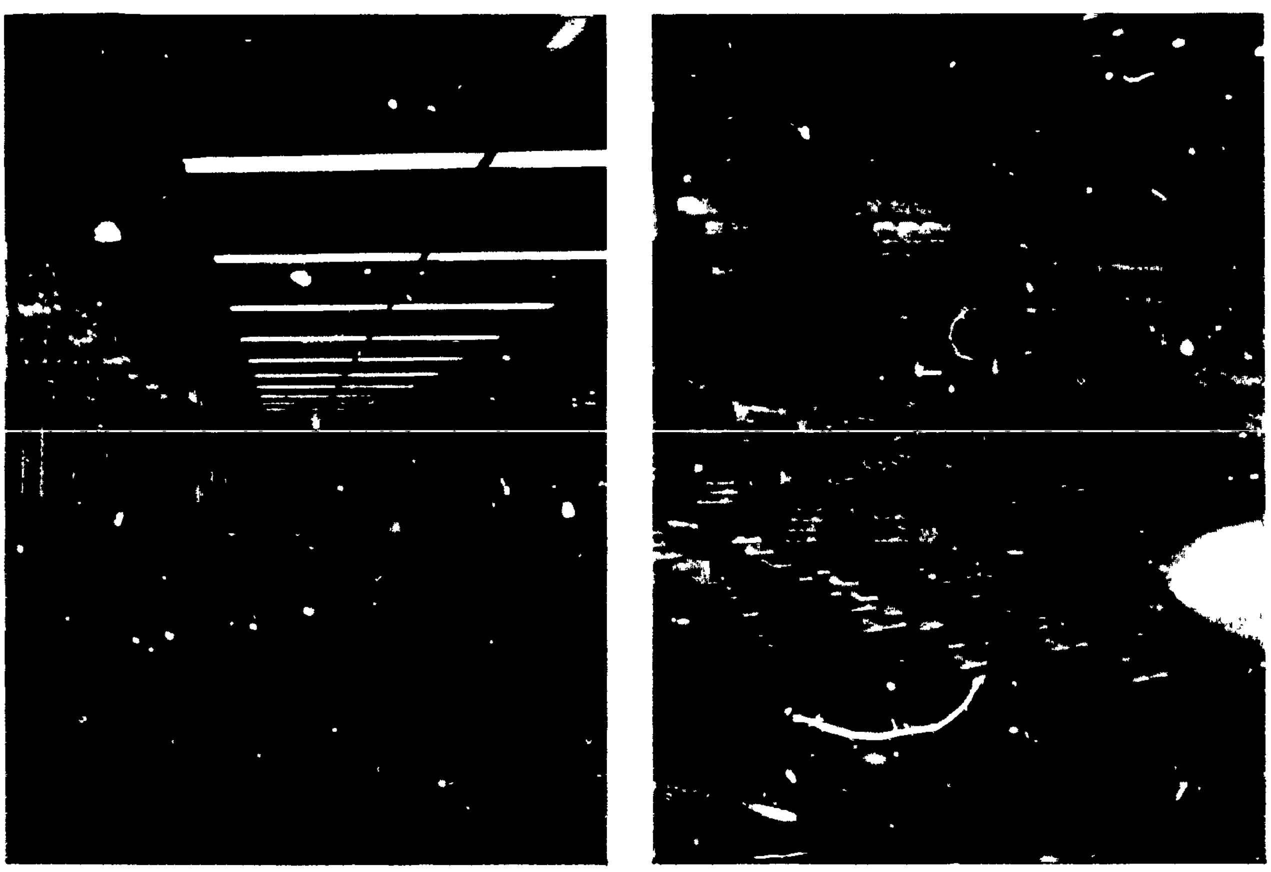
> "(Modular sizing) is effective only in double-hung windows in our industry. There are too many complications due to hardware and design for other uses".

Some replies stated that their industry is already producing coordinated sizes, though not necessarily in 4" multiples; others expressed the opinion that there is not yet sufficient need for modular sizes. The clay tile manufacturers, who have standardized on a 4-1/4" size for wall tile, explain that this size is based on a geometric relationship which allows for diagonal patterns within a 6" square, and point out that pre-mounted tile patterns are available in rectangular blocks of 12" multiples, which are compatible with modular design.

Four of the associations indicated that they recognize the value of modular coordination, but do not currently promote modular sizes, either because it doesn't concern all segments of their industry or because other matters currently have higher priority. One reply commented, "We can certainly see that there is merit and potential in the use of modular systems in the construction industry. At the moment, however, it does not affect us, but this is not saying that we would not give it due consideration as the modular sizes become more and more important".

Other associations indicated that they do not promote modular standards, either because their products do not lend themselves to modular dimensions or because they've found no advantages in modular sizes. Very few feel that modular coordination offers any cost advantages.

Other indications of current attitudes have also been expressed during the course of the study by individual representatives of industry. These, too, reflect both sides of the question. On the one hand, there is obvious agreement as to the need for standardization, and the economic advantages inherent in reducing the number of sizes to be produced and handled. "Dimensional coordination is necessary, if you're going to use manufactured components, the only way you can really stop it is to stop the machine". But on the other hand, there is understandable opposition to costly changes in product sizes unless and until the demand for them is sufficient to warrant the expense involved. As one representative observed, "To get the optimum out of mass production, you can't simply look at the great big umbrella of modular coordination. You have to consider each material by itself to see what the advantages may be". Another observed, "I find that our people making floor tile and ceiling tile are, for the most part, only dimly aware of modular coordination and modular sizes. But I'm sure that if you asked them to start making them in different sizes there would be screams of agony".



equipment and furniture offer opportunities for modular coordination

Two factors appear to be the chief determinants affecting the progress of modular coordination: 1) the extent of demand by architects for modular products, and 2) the economic incentive offered by the use of standard sizes. If architects were to consistently demand modular sizes, and reject all else, the manufacturers would provide them. But in the experience of many of the larger architectural firms, at least, there's often little if anything to be gained by "sticking to standard sizes". On many jobs the quantities required are sufficiently large that they can obtain special sizes of their own choosing at small or no extra cost. In any case the premium, if any, is usually small, and the fact that there's often more profit in special sizes obviously does not lead the manufacturers to discourage their use.

A significant illustration was provided by a former industry executive, in recalling his experiences in the production of steel sash: "After the war, we brought out a new line of windows. We were thinking modularly, so we set up a series of about a dozen sizes. It was a seller's market, so we informed architects that 95% of the windows supplied on any job would have to be one of these standard sizes, and we would supply a maximum of 5% in non-standard sizes. This worked fine - for a while. But as it changed from a seller's to a buyer's market we had to increase this 5% to 10%, then later to 20%, and eventually to 50%. To satisfy architects' demands, the proportion of standard sizes dropped to half, and the total number of sizes increased tremendously. Where the ratio stands now, I don't know, but I think this illustrates the point that the laws of supply and demand certainly have to be taken into account in promoting the modular concept".

The importance of modular sizing appears to be proportional to the number of units normally required of any material in building construction. This is perhaps the chief reason why brick, a highly repetitive material, was the first to be "modularized", and after that, modular sizes were considered for doors and windows. This suggests, too, that perhaps there is a practical limit to which modular sizing should be carried; that it may not be necessary for all of the pre-sized components used in building, particularly those used in small numbers.

Further pursuit of this line of reasoning has led to the preparation of the "Checklist of Dimensional Characteristics" shown on pages 22-23. The purposes of this admittedly sketchy and by no means comprehensive listing is twofold: 1) to investigate what proportion of the principal materials commonly used in a typical school building need be modularly sized, in order to achieve modular coordination, and 2) to indicate approximately what proportion of these are already available in such sizes.

The significance of this information depends largely upon what is accepted as the definition of a "modular size". Assuming that 4" is the accepted base module, does it mean that the actual dimensions of the product are multiples of 4", or that the product is so sized that it will "lay-up" to joint spacings of this dimension? Obviously many brick and concrete blocks meet the latter criterium, but how about 12x12 acoustical ceiling tile and 4x8 plywood sheets? It seems that the term "modular" is loosely applied to products sized according to either of these definitions, but the accuracy of this practice is questioned. In the checklist here shown, this rather loose concept of modular sizes has been used, for the sake of expediency. In spite of the probable inaccuracy thus involved, however, the information disclosed is believed to be significant.

Approximately 90 items have been listed. Of these, somewhat more than 10% are supplied in bulk or roll form, and their dimensions are of little or no consequence in any case. Materials supplied in roll form have arbitrarily been grouped with the bulk materials because their width, although dimensional, is seldom if ever critical.

In preparing this checklist it was postulated that the importance of modular dimensions varies with different materials, depending on how they are used, and accordingly, all products have been classified as to the "Relative Importance of Modular Dimensions". Those classified as items whose dimensions are of "Great Importance" are those which 1) are used in such ways that orderly and compatible jointing patterns are esthetically important, and/or 2) are not easily amenable to cutting and fitting on the job. The items classified as of "Small Importance" dimensionally include: 1) those whose jointing patterns are inconspicuous or concealed in the finished building, 2) those which are easily adjusted or sized to meet requirements. The materials checked under the "Possible" heading are those which are considered as frequently falling in the category of "Small Importance", but might be used in such ways that their dimensions would be quite important.

Of the 80$\pm$ "dimensioned" items, approximately half are thought to be used in such ways that their dimensions are of "Great" importance. For about 2/3 of the other half, dimensions have "Possible" importance, and for about 1/3 (or approximately 1/6 of all dimensioned items), dimensions are thought to be of "Small" importance. Of those whose dimensions are highly important, it appears that about half are commonly available in modular sizes, and an additional quarter are available in some modular sizes from some manufacturers or may be obtained in modular sizes on special order.

checklist of dimensional characteristics

of Major Representative Materials
Used in Typical Flat-Roofed Elementary School Building

Building Material or Product (*=bulk or roll materials)	Relative Importance of Modular Dimensions: Great	Possible	Small	Estimated Availability in Modular Sizes (see key)
FRAMING MATERIALS:				
Steel		x		3
Poured concrete*		x		-
Lumber		x		3, 5
EXTERIOR WALLS:				
Brick, common, and face	x			1, 2
Brick	x			2
Concrete block	x			1
Claybackup tile	x			1
Stone (ashlar)	x			1
Glass block	x			1
Metal curtain wall	x			1
Precast wall units	x			1
Windows, metal	x			2
Windows, wood	x			2
Doors, metal	x			2
Doors, wood	x			2
Door frames, metal	x			2
Door frames, wood	x			2
Copings, stone		x		1
Copings, metal		x		3
ROOF CONSTRUCTION:				
Bar joists		x		3
Steel deck		x		1
Corrugated from sheet			x	1
Flexicore units	x			3
Precast concrete plank		x		1
Fiber-cement plank	x			3
Gypsum plank	x			5
Poured gypsum on tees*		x		6
Wood beams, solid		x		6
Wood beams, laminated		x		2
Wood plank			x	6
Precast concrete joists		x		-
Insulation*			x	4
Roofing, built-up*				-
Roofing, plastic*				-
Flashing*			x	4
STAIRS:				
Metal		x		2
Concrete*		x		1

1) Some tubular sections modular. 2) Laminated members may be modular. 3) Varies with locality. 4) The spacing is dimensional but not modular.

KEY TO AVAILABILITY SYMBOLS

1 - Either commonly available in modular sizes or sized to order as standard practice.
2 - Modular sizes offered by some manufacturers; generally available from others only on special order.
3 - Standard sizes include some that are modular, many that are not.
4 - Easily cut or adjusted to required size in the field.
5 - Only length dimensions (not thickness or width) are modular.
6 - Standard sizes are not modular.

Building Material or Product (*=bulk or roll materials)	Relative Importance of Modular Dimensions: Great	Possible	Small	Estimated Availability in Modular Sizes (see key)
FLOOR CONSTRUCTION: (Above Grade)				
Bar joists)				
Corrugated form sheets)				
Flexicore units)				
Precast concrete plank) see Roof Construction				
Precast concrete joists)				
Wood beams)				
Wood plank)				
Metal lath			x	4
PARTITIONS:				
Steel studs		x		6
Wood studs		x		5
Metal lath – see Floor Construction				
Gypsum tile		x		6
Gyosum lath			x	1
Plaster board	x			1
Concrete blocks – see Wall Construction				
Brick – see Wall Construction				
Structural clay tile	x			3
Structural facing tile	x			1
Plaster*				-
Doors and frames – see Wall Construction				
Folding partitions	x			1
Demountable partitions	x			1
FLOOR FINISHES:				
Asphalt tile		x		3, 4
Cork tile		x		1
Rubber tile		x		3, 4
Vinyl tile		x		3, 4
Vinyl – asbestos tile		x		3, 4
Linoleum (roll)*			x	4
Vinyl (roll)*			x	4
Quarry tile	x			3
Ceramic mosaic tile			x	4
Wood strip			x	4
Wood parquetry		x		3, 4
Carpet*			x	4
LIGHTING FIXTURES:				
Surface mounted			x	6
Recessed	x			1, 2

Building Material or Product (*=bulk or roll materials)	Relative Importance of Modular Dimensions: Great	Possible	Small	Estimated Availability in Modular Sizes (see Key)
CEILINGS:				
Metal furring			x	4
Metal lath – see Floor Construction				
Plaster – see Wall Construction				
Acoustical tile	x			1
Luminous or integrated systems	x			1
WALL FINISHES:				
Plywood	x			1
Ceramic tile	x			3
Plaster – see Ceilings				
Sheet vinyl*			x	4
Paint*				-
Trim, wood		x		6
Trim, metal		x		6
PLUMBING FIXTURES:				
Water closets			x	6
Lavatories		x (width)		6
Urinals		x (width)		3
Sinks (classroom)		x		3
Toilet stalls	x			1
Shower stalls	x			1
Drinking fountains	x (recessed)		x (surf. mtd.)	1, 2
HEATING EQUIPMENT:				
Ductwork		x		1
Unit ventilators	x			2
Grilles and registers		x		2
FURNISHINGS & EQUIPMENT:				
Chalkboards	x (rec.)		x (s.m.)	1
Bulletin boards	x (rec.)		x (s.m.)	1, 2
Tack boards	x (rec.)		x (s.m.)	1
Clothes lockers	x (rec.)		x (s.m.)	2
Desks			x	6
Chairs			x	6
Tables			x	6
Carrels		x		2
Book stacks	x			2
File cabinets	x (rec.)		x (free stdg.)	6

sizes from some manufacturers or may be obtained in modular sizes on special order.

This rough check, then, seems to point to two conclusions:

- It is not essential that all materials and products have modular dimensions, in order to achieve modular coordination; there are many whose dimensions are relatively unimportant.
- A large share of those whose dimensions are critical are already available, to some degree, at least, in modular sizes.

Contractors

Theoretically, the contractor benefits substantially when he has the opportunity to build from designs that are based on modular coordination and can work from architects' drawings made with modular drafting conventions. Because these drawings are simplified, his take-off and estimating work is said to be easier, and with less likelihood of his overlooking items, he can reduce his catch-all contingency allowance and submit a lower, more accurate bid. Furthermore, modular drawings supposedly facilitate his field layout work, and the use of modularly coordinated materials in construction reduces the amount of cutting and fitting required, thus minimizing waste. Savings realized in these ways should not only benefit the contractor, but should also, in part at least, accrue to the owner.

It was one of the purposes of this study to investigate to what extent these theoretical advantages have been experienced by contractors who have built "modular jobs". Samplings of contractors' opinions were gathered from discussions with architects, interviews and correspondence with contractors, and from comments made at an invitational seminar held in Washington*. Their opinions regarding the merits of modular coordination appear to vary widely. Some feel that "a dimension is a dimension", and that the 4" module has no special significance, while others think that modular coordination offers inherent savings which may "trickle on down to even the smallest sub".

Contractors do agree, however, that their business is highly competitive, and that anything which can reduce their costs deserves attention. Some of those interviewed expressed the opinion that modular coordination properly used could provide some cost advantages, but implied doubt that such advantages would be adequate to cope with the problems faced in the rising costs of labor and equipment and increasing competitive pressures.

As was pointed out at the invitational seminar, the proportionate cost of site labor, relative to total building cost, has decreased greatly since Bemis originally proposed his concept of modular coordination. Forty years ago it accounted for perhaps two-thirds of the total cost, but now it represents only one-third or less. This decrease has not brought any substantial benefit to the contractor, however. Although the number of man-hours at the site has been greatly reduced, the rates for skilled labor are much higher and the amount of capital that must be invested in heavy equipment has mushroomed. These increases have cancelled out any possible savings in the cost of doing business.

*Appendix A

OVERVIEW

Often an important factor in successful bidding, and even in the contractor's ability to stay in business, is the margin of safety that he includes in his bid. This amount, in turn, depends upon how well he can understand and interpret the architect's drawings. Consequently any device or technique that aids in clarifying the intent of the contract documents will generally result in a lower bid. As one contractor observed, "We're not all equal when it comes to interpreting the intent of the architect's plans. And the less we understand the, the higher our bid".

Some contractors point out that the potential savings attributable to the use of modular coordination may be small as compared with savings which might be realized by other measures. Among the alternatives considered equally if not more important were 1) the choice of a propitious time for inviting bids, and 2) a careful selection of bidders, to insure fair and equitable competition. It was pointed out, too, that unless all materials are modular, equipment is still needed at the site for cutting and fitting, and as long as it's needed, it's more economical to get full use from it.

Other reactions to the claims made for modular design vary widely, as might be expected. On the negative side, some of those contracted said that they had had experience with modularly designed jobs, but hadn't noticed that the use of a modular system made any difference, as far as their work was concerned. A good many architects observed that contractors didn't understand the modular system, were confused by it, and didn't like it. To quote one such comment, "On one of our jobs - a $3 million high school - before the contractor moved any equipment to the site, he put three draftsmen to work redrawing our modular contract drawings. He had them eliminate all grid lines, and substitute arrows for dots, because the superintendent refused to take any responsibility 'with dots on the job'. And he did it at his own expense". Another architect observed, "We can talk modular coordination all we want, but unless the man who puts the building together is thoroughly familiar with the system, he has as much trouble reading a modular set of plans as with any other plans".

On the other hand, some contractors strongly commend the use of modular design and drafting techniques. A Pennsylvania firm which has worked from modular drawings on school jobs states, "The modular design and modular grid-line drawings usually simplify layout and field checking, and also simplify construction. We have constructed projects by various architects who use modular design, and have found that in most cases construction costs are greatly reduced". Another contractor stated that, in his opinion, the use of modular coordination reduced the cost of estimating by at least 25%.

There are differences of opinion, too, as to whether the use of modular coordination actually results in lower building costs, with economic benefits to the owner. Some are convinced that it does, but the majority appear to be doubtful. No positive factual evidence could be found to support either view. A prominent west coast architect, who consistently applies the space module concept to all of his major work, is sure that he achieves lower costs in this way. He points to the fact that one contractor in the area who has done much of his work and has learned to recognize the practical advantages inherent in this design philosophy, is consistently a low bidder. But more frequently the experience seems to have been more like that of another architect, who put it this way: "It seems to me the subcontractors who recognize the efficiencies inherent in the system would tend to be the lower bidders, but it hasn't worked out this way. This is what has disappointed me most. I thought that would surely be the result, when they caught on, but it hasn't been"

It appears quite obvious, as a result of this investigation, that there are relatively few contractors who have had any significant experience with working from modular drawings, and still fewer who have positive reactions regarding their practical advantages. In view of the small number of architects using modular coordination, this is readily understandable. By searching in the areas where the architect-proponents of modular design are practicing, such contractors may be found, and among them are those who have recognized and endorse the advantages claimed for it. But there are other contractors who, having had similar, though perhaps less extensive experience, have not found these advantages, some feeling that it only complicates their work.

It must be recognized, however, that the terms "modular designs" and modular drawings" are rather nebulous, including various techniques and covering a wide range of quality. Modular drawings may be vague and confusing or clear and concise, just as with "conventional"drawings. Undoubtedly contractors' opinions and evaluations have been influenced in most cases, by the quality of the documents provided by the architect, and because of this variable, no valid conclusions as to the merits of the basic principles can be drawn from a sampling such as this.

OVERVIEW

Governmental Agencies

As major clients for design and construction servies, various agencies of the Federal Government should stand to gain significantly from the potential benefits of modular planning and coordination. Consequently, a number of federal agencies have made real efforts to encourage the uses of modular coordination, but with no lasting results either in terms of widespread adoption by architects and builders or any demonstrated savings of time and money. The following points are significant:

- most federal efforts were initiated during the mid-1950's when MBSA was particularly effective in promoting modular concepts.

- although regulations have been promulgated dealing with uses of modular, no strict enforcement has been attempted.

- although savings in time and money have not been demonstrated, better designs, in terms of the agencies' needs, have often resulted. An example is the "flexible office" developed by GSA.

The Housing Act of 1948 authorized the HHFA to standardize dimensions and methods for the assembly of homebuilding materials and equipment. Subsequently FHA attempted to encourage the use of modular coordination in building programs for which they had a responsibility, by the development and dissemination of reports and publications directed at architects, developers, and building contractors. The actual effect of this form of encouragement is hard to assess although one FHA official has expressed the opinion that, "A lot of housing is designed utilizing modular materials, even if not dimensioned that way". To date, the Minimum Property Standards of the FHA have not included regulations concerning the use of modular, and no formal attempt is being made to promote it.

In 1955 the U.S. Army Corps of Engineers issued a bulletin stating that principles of modular coordination would be employed, whenever feasible, in the design of military buildings. Background information on the development of modular coordination and basic references were provided, together with a list of confirmed advantages. This regulation was reenforced by subsequent documents in 1961 and 1962. Certainly the repetitive nature of some military building types, and often the unique concerns with transportability and speed of erection, would tend to make some military buildings particularly appropriate for modular design.

Although the Corps of Engineers askes for modular coordination, they report that they don't get it very often, and its potential has not been realized.

Beginning about eight years ago, the Veterans Administration issued a Design Standard which encouraged the optional use of modular coordination by their contract architect-engineer firms in planning VA hospitals. A number of firms tried it, but gave it up for the typical reasons - problems of training draftsmen, extra time required to implement a modular approach, non-availability of modular materials, and lack of proven savings. The VA planning staff also has tried modular coordination on "in-house" work, but has not used it consistently. At no point has the use of modular coordination or drafting been specifically required.

Like other Federal agencies, the U.S. Public Health Service also explored the application of modular coordination ten to fifteen years ago, but took no formal action toward requiring or promoting it.

The "Drawings Requirements Handbook" of the General Services Administration contains the following statement, "The dimensioning method in accordance with the Modular Building Standards Association practice may be used at the option of the contract engineer-architect". Thus the GSA tries informally to encourage architects to use modular dimensioning, preferably on a 4" base module. As of yet, very few projects have employed modular dimensioning, and this is attributed to the fact that architects lack the familiarity with it, and GSA is therefore reluctant to require its use.

GSA does require the use of a planning module, however, in the layout of general office space in federal office buildings which it operates. Generally this is a 5' module, and it determines the location of columns, fenestration, ceilings, corridors and partitions, in accord with instructions in a "Design Data Sheet" provided to the architect by GSA. This use of a standard planning module provides buildings with flexible interior space, permitting the relocation of office partitions. The contractor bids on a total length of partitions, without regard to their final arrangement. GSA feels that such use of the planning module results in long-term dollar savings by providing space that maybe readily and inexpensively reorganized by relocating partitions. As for the merits of complete modular coordination, it is felt that the initial construction savings are there, but very difficult to assess.

OVERVIEW

The National Institute of Mental Health has no regulations requiring the use of modular coordination in the construction of community health facilities, but it does try to encourage it. To date, only a few projects have attempted to use any modular coordination whatsoever.

Although not in the position to be a long term client for design and construction, the National Bureau of Standards has taken a very real interest in the development of modular coordination and its ramifications for the industrialization of the building process. The Institute of Applied Technology of the NBS is assuming the staff responsibilities and general coordination for the revised A-62 Committee. (See page 42).

One interesting development brings together two federal agencies. The General Service Administration has contracted with the Institute of Applied Technology of the NBS to explore the development of an industrialized building system for a standard, repetitive GSA building type. This effort is just getting started, and its significance cannot yet be assessed.

Architects

Since the early days of the MSA, over thirty years ago, the proponents of modular coordination have maintained that the use of modular drafting techniques not only simplifies the architect's work but substantially reduces his production costs. More recently, by way of underlining this contention, the major effort of the Modular Building Standards Association was directed toward explaining to the architect the techniques and advantages of modular drafting. This was done in the conviction that wider use of these techniques by architects would not only benefit the profession, but would automatically create a demand for more modular products. An important objective of this study has been to determine what real effect these missionary efforts have had, and whether architects who have used modular drafting substantiate the advantages claimed for it.

In 1959,, The Modular Building Standards Association surveyed architectural firms in 40 states to determine the extent to which modular materials and modular drafting techniques were being used. Of the 918 firms responding (54%), 290 stated that they "incorporated modular materials whenever possible", and 102 reported that they were using modular drafting. When considering appropriate sources of information for this project, it appeared that information regarding the current practices and opinions of this latter group would be significant. A simple questionnaire was therefore sent to most of them, inquiring whether they still use modular drafting, and if not, their reasons for abandoning it.

In response to the questionnaires sent out, 52 replies were received. In summary, these disclose that:

- approximately half of these firms still use the modular (dot-and-arrow) drafting technique, though most of them say they have found the lack of modular materials a handicap.
- most of the firms still using modular drafting use it on at least 75% of their work.
- 21 of the 52 firms responding stated that they encourage the use of modular products, though 10 of the 21 no longer use modular drafting, for reasons which will be indicated.

Another source of pertinent information was disclosed as a result of inquiries in another direction. In response to a questionnaire sent to State Education Departments in all 50 states, it was learned that the work of certain architects in many parts of the country consistently reflects the use of modular principles. From the list of architects so identified, 40 additional firm names were selected and contacted, using a questionnaire similar to that sent to the firms mentioned above; 26 replies were received, a 65% response, and two-thirds of these stated that the dot-and-arrow convention is used on from 75% to 100% of current jobs. Interestingly, 5 firms say that their use of modular drafting has declined in the past 5 years, 5 say that their use of it has increased, and 7 indicate that its proportionate use has not changed much during this period.

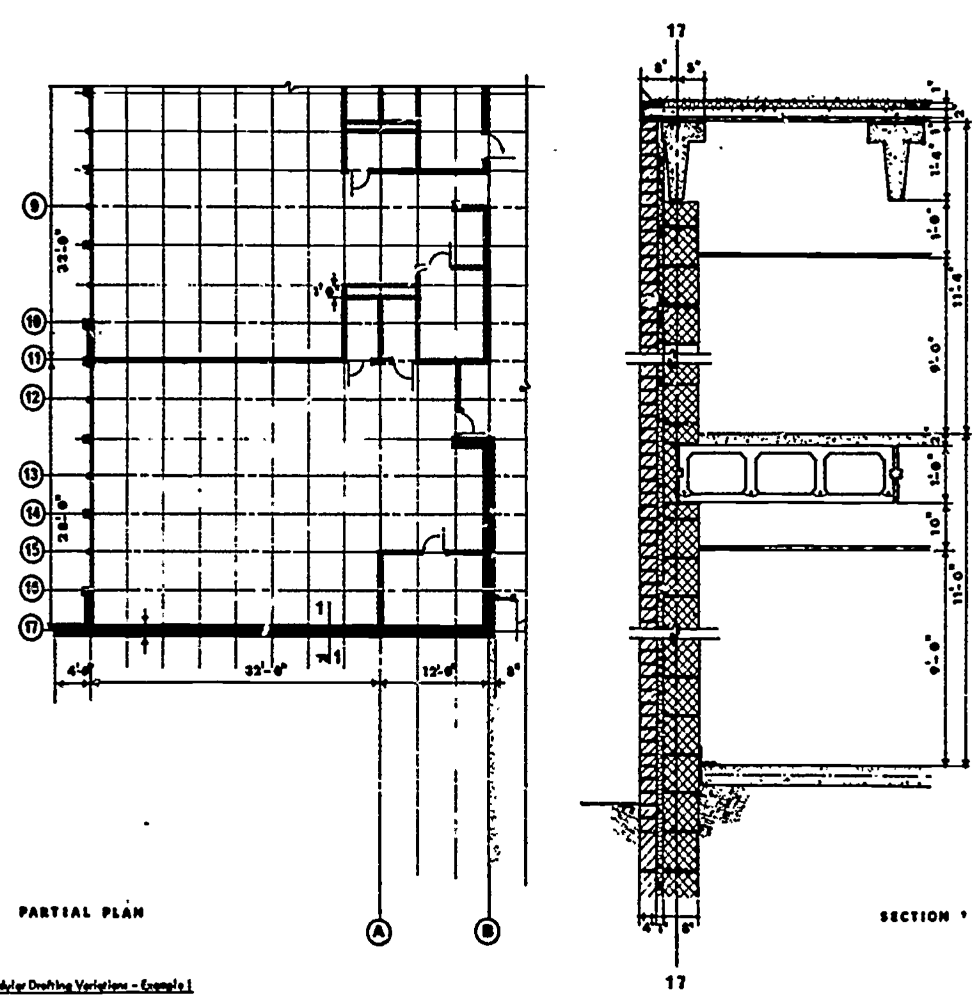
The extent to which modular design is being used appears to be considerable and is closely related to the individual's design philosophy. As for modular coordination, the surveys indicated no general agreement in regard to its merits or specific advantages. Some architects suggest that it represents nothing more than a carefully studied approach to design, respecting material sizes as an important parameter. Others are convinced that increased industrialization and consequent standardization make its use inevitable, and some even suggest that modular coordination can provide the breakthrough in converting to the metric system.

Opinions and comments have been solicited from many architects regarding the various concerns of this study. Some of these were gleaned from the surveys and from personal contacts; others were expressed at the invitational seminar conducted in connection with the project. The following representative cross section of views expressed, presented here in paraphrased form, is believed to indicate current attitudes regarding some of the more important issues.

On the philosophy of modular design:

> "I believe most of us would like to standardize for greater and more economical production. But the tremendous influx of new materials, systems, technology and concepts tends to relegate this, along with CPM and other things, to the limbo of good intentions".

> "The sooner we recognize that handicraft methods have no place in the construction acitivites on the site, the better off architects and the building industry will be. I think the craftsman-artist should have a place somewhere in architecture, but not in the process of putting materials together to enclose space".



<u>Modular Drafting Variations - Example 1</u>

Arrowheads represent dimensions terminating on the 4" grid. Dimensions terminating off the 4" modular grid are indicated with a dot. The basic 4' module (a modular dimension) is shown to the centerline of interior walls. In section the structural "T" beam is centered on the grid, consequently the centerline of the exterior wall does not coincide with the modular grid. Instead the face of the exterior wall becomes a modular "on-grid" dimension. In all instances fractional dimensions have been eliminated from the drawing.

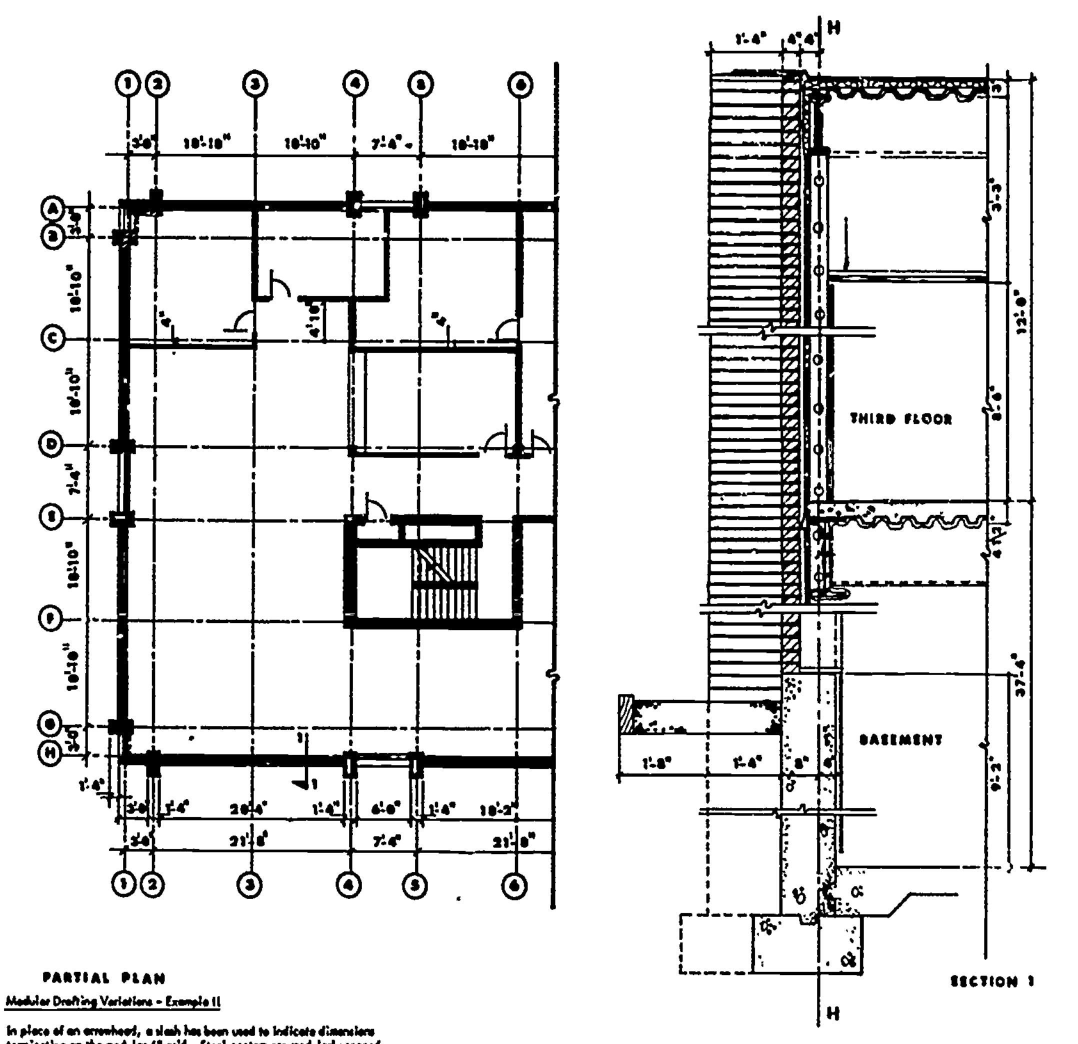
Hempdin Elementary School, Mechanicsburg, Pennsylvania
Bender Benell Associates.

On the use of planning modules:

"For nearly fifteen years we have used modular materials and have dimensioned to the module line rather than to the face of the material, but we have never shown a four-inch grid or used the dot-and-arrow convention".

"We use modules much larger than 4" and clearly indicate them with center lines. This major grid differs with different jobs, depending on the nature and scale of the building. We number and letter the grid lines and tie all dimensions to them".

"We encountered problems with the 4" module and dot-and-arrow, and now use larger modules of 4' and 5'. These are directly related to the project at hand, as well as to standard materials and appropriate column spacings. Both horizontal and vertical height modules are determined by the specific project".



PARTIAL PLAN

Modular Drafting Variations - Example II

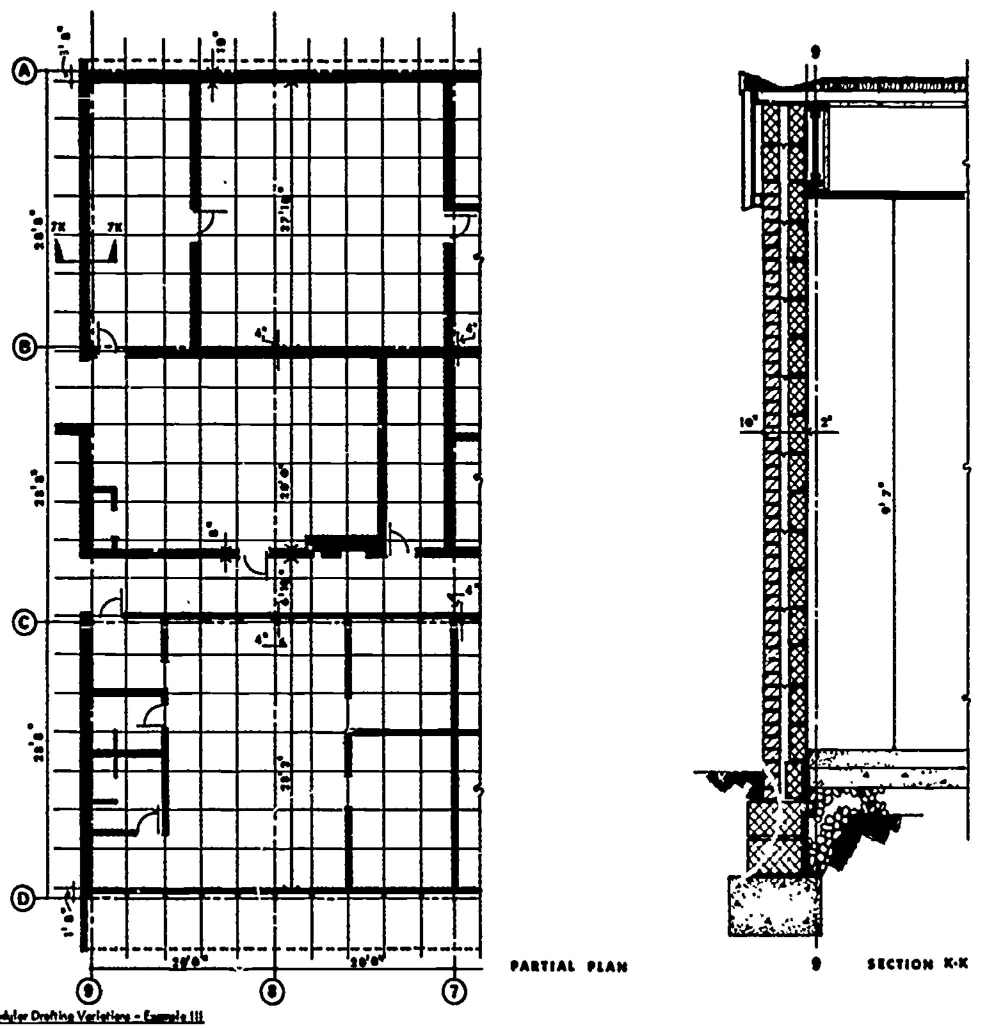
In place of an arrowhead, a slash has been used to indicate dimensions terminating on the modular 4" grid. Steel centers are modularly spaced. The structural grid provides the reference points for other building elements. The face of the exterior wall is shown as an "on-grid" dimension. Offsets for interior partitions are held to modular dimensions and are referenced by the modular structural grid.

Administration Building, State University of New York at Cortland, Syracuse, New York
Sargent, Webster, Crenshaw and Folley.

OVERVIEW

On the availability of modular materials:

> "We would be glad to avail ourselves of what should be the economic advantages of modular coordination if there were modular materials available for use in structures of good architectural design".
>
> "One of the perplexing aspects of modular coordination is that modular brick and flue linings are almost impossible to obtain in this area".
>
> "Manufacturers of such materials as ceramic tile, partitions, resilient flooring and some wood windows seem to have completely ignored modular coordination in respect to their products".
>
> "The biggest problem, material-wise, is to get items such as masonry made to exact dimensions. Unfortunately, we've had to reject many brick shipments because of this, and at such times the system (modular coordination) is defeated due to time lost in re-manufacture".



Modular Drafting Variations - Example III

Arrowheads and dots are used to indicate modular and non-modular dimensions. The 4" module is located 2" to either side of a 4' grid. This 4' grid is the centerline reference for moveable interior partitions. The interior structural members are offset from the 4' partition grid so as not to interfere with partitions. The centerline of masonry interior partitions coincides with the 4' grid, but, the face of the wall lies on a 4" gridline. Consequently interior room dimensions are also modular.

Office Building, Sparrows Point, Maryland
Christie, Niles and Andrews (formerly Wilson and Christie, Associated Architects), Towson, Maryland.

On the use of modular drafting:

"This office has used modular drafting for about eleven years for all work except remodelling, which requires matching with existing work. We have received many compliments for the accuracy, clearness and ease of interpretation of our plans from contractors and their superintendents. In several instances, superintendents with negative reactions to modular drawings were converted to full acceptance after using our plans and being instructed by our field force".

"We consider modular drafting to be the best method, and we insist that suppliers conform or their products will not be used. We have better response from contractors in their bidding than do other offices because there is less waste in building the modular way".

"I believe in it, but haven't been able to get the draftsmen to use it".

"We have long designed our work on a modular basis, but have never adopted the modular drafting system because of the difficulty of acquainting contractors and consultants with the system".

"Modular coordination is fine for general planning, but in detailing it increases the required time by 10%. We also found that we ended up with too many dimensional errors, and the manufacturers' draftsmen seemed to have the same problem.

"Using the 4" module and the dot-and-arrow convention adds ten percent to drafting time, and it adds to the confusion of contractors and suppliers".

"We do not use the complex techniques of the dot-and-arrow grid method because cont[illegible]rs tend to be confused by it. We dimension in the conventiona[illegible] way to the nominal modular measurement".

On construction economies:

"We use modular design to reduce the contractor's cost. We are satisfied that it helps to produce lower bids, at least on a second or later job that a contractor does for us, but we couldn't prove it very easily".

"I can't cite facts to prove cost reduction, but builders frequently comment on how easy it is to build when the 4" module is used in planning. They have said that this system results in both labor and materials saving".

"We doubt whether most contractors in this area take modular planning into consideration when preparing bids. It is our opinion, therefore, that the owner does not benefit from lower costs".

"Job superintendents usually comment on the increased efficiency and reduced material waste. The entire success or failure of the system rests with this man".

"It seems practically impossible to eliminate on-job cutting of materials. For most materials it is cheaper to cut and waste than to stock many different sizes. On jobs costing $500,000 or more we've often found that custom made doors and frames are just as cheap as those of standard sizes".

In assessing the significance of these opinions it must be remembered that they represent only a small sampling, but perhaps the most interested and most vocal segment of the profession. The majority of architects have probably not given much thought to modular coordination and very few, relatively speaking, have even experimented with modular drafting.

Summary

Obviously there are major differences of opinion regarding the merits of modular coordination. Manufacturers of building products, although divided in their views and varying widely in their support of the idea, generally seem to endorse the concept in principle, but don't intend to upset production to change product sizes unless or until the demand so dictates. The government agencies, while appearing to favor it, have, for the present at least, abandoned all efforts to make its use mandatory. Probably the widest divergence of opinions is found among the architects and contractors. Members of both these groups have their views not only about the broader concepts of modular design, but also about the practical advantages of modular coordination.

Perhaps these divergent views can best be summarized by listing the principal arguments both pro and con, again recognizing the importance of distinguishing between the three concepts defined in the introduction to this report.

Modular Design

Pros: Discipline is a fundamental essential of good design, and discipline calls for orderly organization, employing a common dimensional unit as far as practicable.

The increasing use of factory-produced building components of larger dimensions is inevitable, and, for economic reasons, variations in such components should be limited. If this is duly recognized in planning, the use of repetitive dimensions (modules) necessarily follows.

Modular planning offers many advantages to the architect, builder and owner alike, chief of which are order, flexibility and economy.

Cons: Being restricted to any established pattern or standards curtails the designer's freedom.

Designs using repetitive modules may become stereotyped and monotonous.

Observation: It appears that in the architectural profession the proponents of modular design far outnumber the opposition, and the majority of architects use it.

Modular Coordination

Pros: By providing a common dimensional framework for design it promotes more orderly thinking and facilitates intra-office coordination and communication.

It insures that pre-sized materials from different sources are going to fit together properly in the building.

For many manufacturers, it reduces the number of product sizes to be produced and handled.

It minimizes cutting and fitting on the job, thus reducing waste.

Cons: It handicaps design freedom; the module becomes all-important, and dimensions demand too much attention.

It's difficult to get some materials such as masonry made to reliably exact dimensions.

It's impractical, because 1) there are relatively few modular products available, and 2) on large jobs there is usually no advantage in sticking with standard sizes. If the order is big enough, special sizes of our own choosing are no problem.

Unless there's a big demand for modular products, manufacturers can't afford to change over production processes to produce them.

Observation: The theoretical merits of modular coordination are widely acknowledged, but many practical problems still stand in the way of its wider acceptance, and present progress is minimal. With several notable exceptions, the building products industry, in general, sees no need as yet to convert to modular sizes. And while many architects "encourage the use of modular materials", relatively few consistently use modular coordination, because of the problems encountered.

Modular Drafting

Pros: Working drawings can be made at smaller scale, with details keyed in by grid lines.

It facilitates contractors' take-off for estimating and simplifies lay-out of the work at the site.

The elimination of fractions on small scale drawings reduces errors and simplifies checking.

Cons: True modular drafting, using the dot-and-arrow convention, increases drafting time. (Note: This is denied by a few of the more ardent proponents).

The training of draftsman in its use is a problem, particularly where personnel turnover is high.

It's confusing to most contractors, and few are interested in trying to understand it.

Observation: True modular drafting (dot-and-arrow) is used by very few architects, and the number appears to be declining. The use of a modified type of modular drafting, using a planning grid, but conventional dimensioning, is quite common, however, and seems to be on the increase.

CONTRIBUTING INFLUENCES AND TRENDS

Both building methods and production methods, like our habits and tempo of living, are changing more rapidly and significantly now than during any previous era in history. To assess the validity and potential merit of the modular concept, one must therefore not only consider to what extent this concept is compatible with current building practices, but also whether it is consistent with the more obvious of foreseeable developments. Among the many factors which might be considered as affecting the acceptance and use of dimensional coordination, several trends are particularly worthy of note.

Industrialization of Building

Probably the most significant of these trends is the rapidly increasing industrialization of the building process. The meaning and implications of this term should perhaps be clarified, because they are likely to vary with the interests of the person using it. To some, it is essentially synonymous with "prefabrication", implying the factory production of standardized buildings, while in the minds of others it suggests precast concrete units, or the use of a tower crane at the building site. But in its broader basic sense as used here, the term "industrialization" means the replacement of hand skills by the work of the machine in all phases of the building operation, both in the factory and at the site.

Considered in this sense, greater industrialization appears inevitable, in view of the building needs ahead. Unquestionably more and larger parts of the building, eventually nearly all parts, will be produced off-site, where the quality of the work and the working environment can be accurately controlled. Site construction will cease to be a manufacturing process, becoming instead essentially an assembly process, using a minimum of manual labor. It is already apparent that this course will be dictated by the combination of a decreasing supply of skilled labor and spiralling wage scales. Handicraft methods in building are fast becoming a luxury that few can afford.

"For creative architects to be mere assemblers of various erector sets is not a pleasant prospect. A true work of art must be designed down to the last detail in order to be complete. Why, then, do we look favorably on the concept of fabricated buildings?

"First of all, we doubt that there are enough truly creative architects who can design systems that are superior to what prefabricated could produce. Secondly, there will not be enough architects of any description who could properly design all the details of the fantastic volume of buildings that will be needed in the future. And thirdly, prefabrication might be the solution to the problems created by stylistic incoherence in our environment resulting when individual architects constantly strive to outdo each other, although the few 'foreground' buildings each community needs could still be 'custom-made' by the truly gifted masters".*

The factory production of increasingly more and larger parts of the building has obvious impolcations for dimensional coordination. Economic production depends on a mass market; seldom are the requirements of one project or even a joint venture sufficient to support it. The parts produced must be so designed that they are appropriate for use in many buildings, in many locations, in combination with a variety of other factory-produced parts, and with a minimum of size adjustment. It follows, therefore, that dimensional coordination of all such parts, whatever their size or material, is essential. And, as the industrialization of building expands, a common module will become necessary.

---

* Jan C. Rowan, in an editorial in Progressive Architecture, October 1964.

The Demand for Flexibility

Another significant trend, affecting the design of many types of buildings, is the growing demand for flexibility of spatial arrangement within the building. This, too, is a recognition of our rapidly changing ways of life, and reflects the anticipation of needs which cannot yet be defined. In schools, hospitals, laboratories and office buildings in particular, built-in provision for future changes is frequently a program stipulation; for many industrial buildings, requirements often include not only interior flexibility of space, but the ready relocation of exterior walls to accomodate expansion.

These requirements of flexibility call for interchangeable parts which can be quickly demounted, moved and reassembled with a minimum of dirt and confusion. Often the process may involve the substitution of a number of compatible new parts for outworn or obsolete old parts. These requirements of interchangeability and compatibility can best be served by using dimensionally coordinated units in a modular design.

Computer-Aided Planning and Design

Another highly significant trend concerns the organization of the planning and construction processes. Architectural practice is changing, and architectural services are expanding to include greater concern with building programming. Often this involves the development of systems, as well as the more conventional planning and design. Both architects and contractors are developing new tools for controlling the construction process. Critical path techniques (CPM) and similar approaches (such as PERT, PERT/COST and the proprietary resource allocation packages) attempt to bring efficiency to the process through scheduling, budget control, and resources management.

The concern with efficiency in architectural practice manifests itself in the production of contract documents by use of preprinted standard details and building elements, and in the use of various forms of standardized, simplified, and computer-generated specifications. The planning process more and more involves a large team of specialists; rarely does a single man carry the design process from beginning to end. All of these factors seem to point in the direction of simplifying of building procedures and the standardization of building parts. The inter-relationship of component parts is a vital concern in achieving more efficient and economic programming, planning, design, and contracting procedures. Modular coordination provides the logical base for many of these innovations.

The high speed computer brings to design and construction a tool of vast and complex potential. If buildings can be thought of as an assembly of large-scale components precisely located within some sort of three-dimensional grid, it is possible to "build" them in computer memory long before the design is finalized. Once components are selected and placed in the grid, the total design concept can then be checked for weight, areas, lighting, ventilation, structural integrity, code violations, costs, and other pertinent requirements. Changes in components and layout can be made, and the impact of such changes evaluated. Finally the computer can provide lists for manufacturing, fabrication, shipping, and assembly.

Experimental versions of such computer models of buildings are already in existence*. They promise great potentials, both for assisting in the production of successful solutions (through advance simulation and evaluation), and for freeing the designer from many of his less-than-creative tasks. It is highly significant that these potentials can be realized only if the designer can use a convenient planning module, and if he can find modular materials that are compatible with it. It appears inevitable therefore that new pressures for modular design will brought to bear by developments such as these.

Reactivation of A62 Committee

Since the activities of the Modular Building Standards Association were discontinued four years ago, no single force at the national level had been promoting modular coordination in a professional sense until the A62 Committee was recently reactivated through the efforts of the Institute of Applied Technology of the National Bureau of Standards. Although the work of this committee is just getting started, it appears that their basic concern will be the formulation of standards to encourage the development and use of modular products while avoiding "closed

*Two examples of such attempts include the IBIS System demonstrated at the 1964 Industrialized Building Systems and Components exhibition, and a "Computer-Aided Building Design and Cost-Analysis System" being designed by Arthur Cogswell Associates as part of a Low Income Housing Demonstration Program grant in Chapel Hill, North Carolina.

systems". Greater interchangeability of building components is, therefore, a long range objective, and this promises real dollar savings in construction. As recommended standards are developed for various kinds of construction elements such as masonry units, metal and wood doors, prefabricated masonry panels, structural wood, and structural steel, these will be recommended for adoption by the United States of America Standards Institute.

In addition, this committee is interested in coordinating the development of a series of projects having objectives such as:

- o the classification of components according to their function
- o the classification of building systems accordint to type and placement of the marginal grid
- o the development of preferred sizes and slopes of modular roof tresses
- o the development of standard details for relating loadbearing structures, floor slabs and components to the grid.

It is obvious that the efforts of this committee can make a significant contribution to the promotion of modular coordination in the design of many building types.

3

modular principles and school design

In the two decades since World War II we have seen revolutionary changes in the design of school buildings. Not only has their character changed radically, but their efficiency, attractiveness and architectural quality have been greatly improved. Yet the cost of building them has increased far less, in proportion, than that of other building types. Credit for this is due largely to the ingenuity and hard work of a rather small number of dedicated and highly talented architects across the country, who have concentrated their principal efforts on school design.

Changes and improvements continue to characterize school design. It is generally agreed, in fact, that change is the most consistent factor in

SCHOOL DESIGN

American education today, and this is necessarily reflected in its buildings. The quest for better design and more efficient buildings continues apace, and the necessity of controlling costs becomes greater with every increase in the building cost index. Every potential approach to cost savings deserves to be fully explored, and among the more promising of such possibilities are modular planning and modular coordination.

MOTIVATIONS

There are many factors motivating the achievement of greater efficiency, not only in the educational system, but in the buildings that house it. Most of these have often been explored and discussed in depth elsewhere, and there is no need to re-examine them all here. It's sufficient to recall that among the most important factors ot urgency, as most taxpayers have already come to realize, are these:

Steadily increasing enrollments, due not only to a growing population, but to the general need for more education.

Widespread critical interest in the quality of education.

The obsolescence and need for replacement of many school buildings, particularly in the urban areas.

The constantly rising costs of building and financing.

APPROPRIATENESS AND POTENTIAL OF MODULAR DESIGN

In general, the validity and benefits of using modular design principles in building design are proportional to the extent to which repetitive units or dimensions are involved. Most building types are characterized by repetitive dimensions to some degree, at least in their structural system, but there are some types which are typified also by a large number of similarly sized rooms or spaces. Among these are hospitals, dormitories, apartment buildings and those schools, at least, of the more conventional types containing a series of classrooms.

While the school building is perhaps not uniquely amenable to modular planning, as compared with the other building types mentioned, modular principles can very readily and appropriately be applied to most school building plans. In some of the newer schools, repetitive "classrooms" are replaced by "learning spaces" of a range of sizes, and, in a few cases, by bulk loft space affording a maximum flexibility of spatial arrangement. Even in these, however, structural bays are usually repetitive. The use of repetitive space units is encouraged, too, by the fact that in many localities state aid is based on specific space allowances for the various functions.

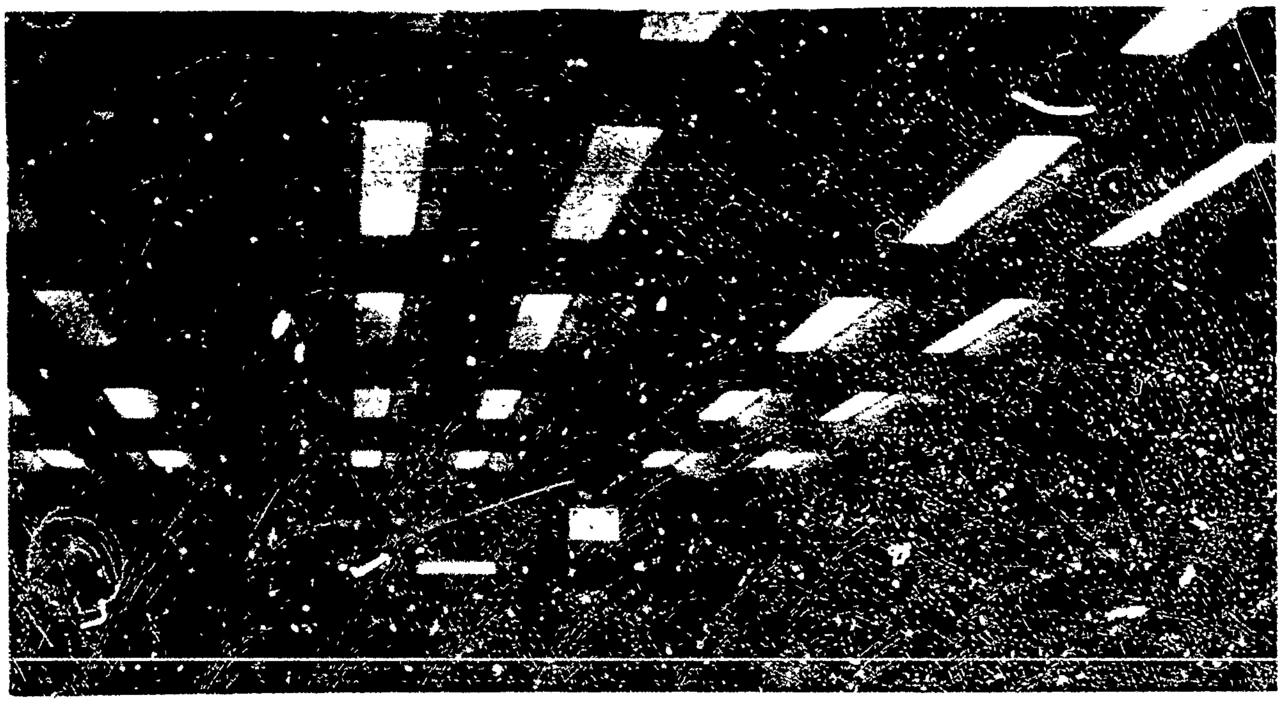
Thus the appropriateness of modular planning in school design has long been recognized. Modular principles have consistently been observed by most of the competent school architects, and the majority of contemporary school plans reflect their use at least to some degree. The use of modular coordination, however, with its more rigid dimensional disciplines and its requirement of modular products sized to a common basic unit, is still comparatively rare.

flexibility through operable walls

Changing concepts of the use of space within the building contribute to the desirability, if not the necessity, of using modular design. In this respect school buildings are, perhaps, unique. A common requirement, in most of the new schools, is that of "flexibility", the capability of changing the spatial arrangement with a minimum of time and effort.

This built-in capability of rearrangement, interchangeability and replacement is, in fact, often a specific program requirement. Student groups of various sizes must be accommodated; large groups are subdivided into small groups, and small groups are combined for certain activities or may be dispersed for individual study. This calls for multifunctional space, and the extensive use of interchangeable components - a requirement that virtually dictates the use of modular design principles.

The appropriateness of modular principles applies not only to the building structure but also to its furnishings and equipment. It is in this area, in fact, that the greatest potential for cost reduction through standardization probably lies. Some of the more costly equipment, such as plumbing lines and ductwork, is concealed from view and could well be standardized without criticism on esthetic grounds; other equipment and furnishings in classrooms, offices and auditoria have considerable esthetic importance, and might well be better coordinated for that very reason.



opportunities for coordination of ceiling elements

Consider, for example, the benefits that might accrue from the logical application of modular principles to the layout of toilet rooms and plumbing line assemblies. There appear to be no valid architectural reasons why toilet room arrangements for various age groups should not be completely standardized on a modular basis and largely factory assembled. Except for the problems of labor jurisdictions, which admittedly are considerable, it would seem entirely logical to preassemble the supply and waste lines to standard modular patterns, either on or off site, instead of treating each installation as a hand-crafted custom job. Eventually these things will have to be done, and when they are, it will be essential that the work be dimensionally coordinated by reference to a common base unit.

In the furnishings of the classroom or learning space, too, a wider application of modular principles of design offers attractive possibilities. Not only the seating, but the chalkboards, display areas, projection screens, casework and other furnishings might well be related dimensionally to a common base module, with benefits both esthetically and economically. Considering the size of the market represented by the tens of thousands of classrooms built each year, the potential economy of greater standardization in the design of such items seems quite obvious.

APPLICATIONS AND DEVELOPMENTS

There has already been a number of significant programs and developments which have demonstrated and served to promote modular principles in school planning. The earliest, and perhaps most significant work was done in England, where various systems of prefabrication have been used for school construction since 1947. More recently there have been some important developments in this country, serving to validate the use of modular components in school planning. It must be assumed that the reader is generally conversant with most of these developments. A brief summary of the general nature and significance of the more important ones, however, may help to place them in perspective.

British Systems of School Construction

After the second World War, England was faced with an unprecedented task of school building. The urgency of the need was due to several factors; damage to schools during the war, a sharp increase in the birth rate following the war, and the construction of new towns, as well as the expansion of existing cities. To compound the problem, building materials were in short supply, and there was an acute shortage of skilled building labor.

This combination of circumstances led to the decision by the Ministry of Education to encourage and promote the development of prefabricated systems of school construction. A number of such systems, using various materials, were developed by architectural teams in the offices of district educational authorities. The results were generally quite satisfactory, and by the 1950's, about 20% of all the new schools being built throughout England and Wales were of factory-made components. The system generally considered most successful was that developed in the County of Hertfordshire, immediately north of London.

example of a British school component system

A significant and mandatory characterisitic of all these British schools is that they do not have standard plans, but are all individually designed by architects, using a choice of standard components. Consequently each school has its own individual character. Moreover, they are all permanent structures of high quality construction, in no way to be confused with emergency make-dos.

Modular planning is necessarily the basis of any such system. All parts must be dimensionally compatible, and similar parts must be readily interchangeable. Various planning modules have been used. In the earlier stages of development, 8'3" was favored, but later developments have favored a smaller module, and 3'4" has now become widely accepted. The fact that the latter is a multiple of the internationally established base module of 4" (or 10cm) has no doubt influenced this preference. Significantly, the compulsory acceptance of this modular discipline, whatever the module, does not seem to have seriously limited the freedom of architectural expression.

Industry-Sponsored Systems in the United States

Various producers of building materials, steel in particular, have from time to time promoted proprietary systems of school construction in the United States. While these systems, for the most part, have not been notable for their architectural merit, and the number of schools represented has been relatively small, such developments deserve recognition for their influence in promoting modular concepts.

In one category are the low-cost "temporary" and "portable" prefabricated school buildings provided by several reputable companies such as Armco and Butler, and extensively used to relieve overcrowded conditions in burgeoning urban areas. Although receiving little recognition in architectural circles, many such buildings have been used and will probably continue to be in demand. In general, they appear to serve their purpose quite well. Being factory-produced units, assembled from standard components, all such systems are of course modular in design.

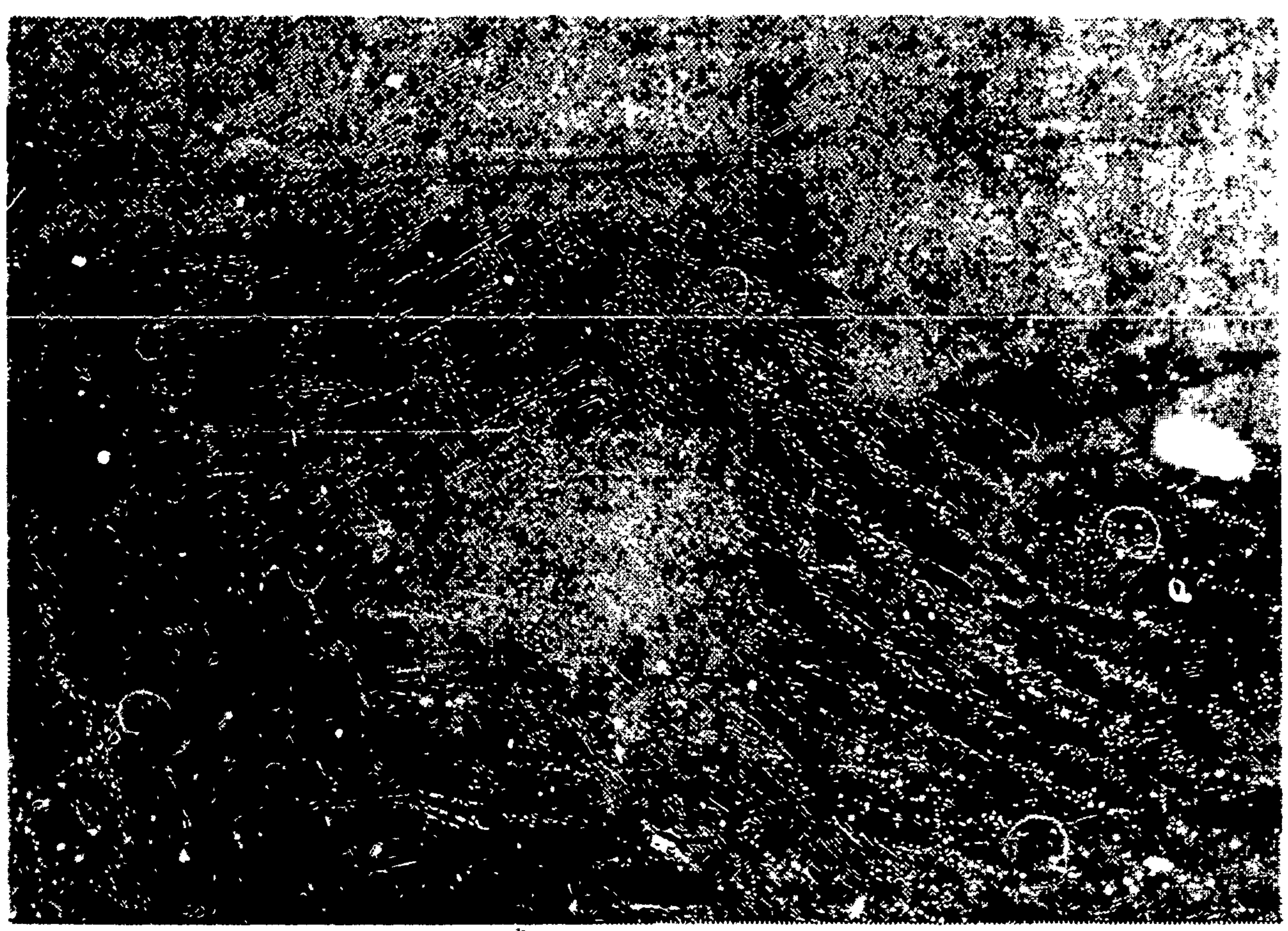
In another category are several skillfully designed systems of superior architectural quality, which, at various times have been built experimentally, in the hope of wide acceptance, but have not been commercially produced. Among these, perhaps the most noteworthy have been the Unistrut system and the woodframed system sponsored by National Homes. The Unistrut system, developed by the School of Architecture at the University of Michigan, under a research grant from the Unistrut Corporation, employed a framing system of proprietary light steel members, and a planning module of 49". The National Homes schools were developed by architects Charles Goodman and Walter Scholar, and employed wood framing bents on 8' centers.

Another structural framing system, intended primarily for schools, is the Schoolmaker System, used in a number of schools in Michigan. This uses essentially standard light structural members and steel decking to provide framing bents on 5' centers.

Perhaps the most important development in factory-built schools of a permanent nature, as opposed to temporaries, portables, and experimental designs, has been that known as the AmBridge System. This system had its origin in 1955, when an organization known as Structor School Systmes was formed to produce components for low-cost pre-engineered schools. This group made and marketed, with only limited success, curtain wall units and light structural framing elements to be used in school buildings of certain types and designs.

In 1958, the American Bridge Division of United States Steel, having participated in this program and become interested in its potential, acquired the rights to the Structo System and greatly expanded its concept. The successor AmBridge System offered a larger "product package" of compatible school building components, including not only structural framing and exterior wall panels, but joists, roof deck, interior partitions and erection services as well. And instead of these being related to preconceived building designs, as was the case with Structo, the system was marketed as a variety of "coordinated building components" for use by architects in creating their own designs. Another feature of the system was its appropriateness not only for schools, but for many other types of buildings as well, including even high-rise structures.

The AmBridge System has been used by various architects in building approximately 150 school buildings of many types throughout the eastern part of the country. Early in 1966, however, United States Steel discontinued its production of wall and partition components and made the decision to withdraw its AmBridge System from the market.



Modular Study by Southwest Research Institute

The development of a system of dimensional coordination appropriate for school construction was undertaken in 1957 by Southwest Research Institute, under a research contract with the Texas Educational Agency. This work, like previous work in modular coordination, was predicated on the thesis that "spaces, elements and materials can be linked dimensionally and made commensurable" by use of a proper reference system. But it was further postulated that the appropriate base module or modules were still to be determined. It was also recognized that, because of differences in design philosophy and differences in program requirements from one region to another, a dimensional reference system, to be generally accepted, must provide maximum flexibility.

This study extended over a period of three years. It involved a comprehensive review of the development of modular theory, an examination of pertinent numbers theories, and a detailed dimensional analysis of 127 plans for contemporary school buildings in many parts of the country. The resulting findings and recommendations were published in 1960, in a report to the sponsor, entitled "Development of Standard and Correlated Dimensions of Material Components in School Construction".

This report advocated the use of the three base modules, 3, 4, and 5, rather than the single 4" module. Among the reasons leading to this recommendation were 1) the recurrence of multiples of 3, 4, and 5 as the principal dimensions in the school plans analyzed, and, more importantly, 2) the far greater dimensional flexibility offered by such a system. The three base modules were to be considered non-scaler; that is, depending on its usage, the module might represent inches, being designated as "m", or feet, designated as "M". In essence, it was demonstrated that under this system, by using additive and/or multiple combinations of the three base units, all whole inch dimensions of 3" or greater would become modular.

The proposed system has had little, if any, application. In the opinion of most authorities who have reviewed the proposal, the complexities involved in its use would outweigh any advantages of dimensional flexibility to be gained. Moreover, the difficulties already experienced in obtaining modular products related to a single 4" base would undoubtedly be proportionately increased if the number of base modules were to be tripled.

SCHOOL DESIGN

The Space Module Concept

The "three-dimensional, self-contained and self-energized unit of space" is an important concept in modular planning which has been explored and used to some extent by a number of forward-looking architects. San Francisco architect Ernest Kump is generally credited with having most fully developed this concept over a period of years, having consistently employed it in many of his building designs.

The concept is basically that of a three-dimensional unit of space which is used repetitively, with a minimum of variation, to build up the total organism of a building or group of related buildings. It's applicable to many types of buildings, but architect Kump seems to have had schools particularly in mind in developing it, and has used it most extensively and effectively in his school designs.

lack of dimensional coordination results in poor details

The size of the space module varies from job to job, being determined by various factors: the requirements of the program, the functions to be accommodated, the nature of construction materials considered most appropriate to the site and region, and even the furnishings to be used. In general, the module is at least as large as a conventional classroom, perhaps several rooms, and its dimensions are usually multiples of 4 feet.

Several important advantages appear to be offered by this approach to planning. Esthetically, it results in a logical, orderly arrangement and pleasing relationships, properly scaled, both inside and outside. There are said to be important economic advantages, too, to both the client and the architect. The extensive use of repetitive dimensions reduces the cost of major components and simplifies scheduling, deliveries and site work, while the concept of dealing with repetitive units of space permits streamlining the production of drawings to the extent that computer techniques can be profitably employed.

The Systems Concept: A Consortium Approach

The dictionary defines a consortium as "a combination of institutions for carrying into effect some financial operation requiring large resources of capital". In view of the fact that school building requires large capital outlays, and schools have many physical features in common, it is not surprising that school authoritirs in various localities have adopted or are considering the consortium approach as a logical course of action. It appears likely that, by pooling resources, planning and buying power, better buildings can be obtained at lower cost.

This approach was pioneered, in effect, by England's Ministry of Education in developing the British school construction systems already discussed. And the success of that development no doubt inspired the first true consortium in this country organized specifically to provide better school construction. This was the School Construction Systems Development program, organized in 1961 by thirteen California School districts, with the aid of a substantial grant from the Educational Facilities Laboratories and under the direction of a competent technical staff, guided by a group of able advisors.

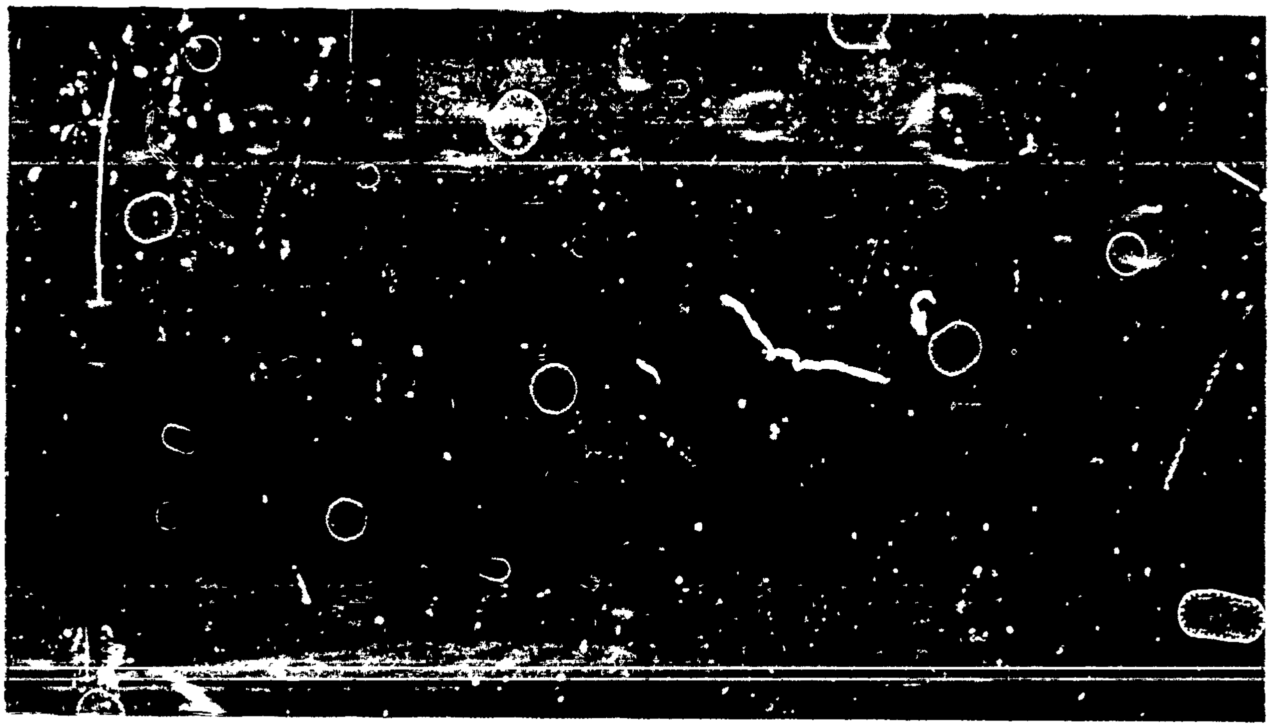
The objective of the SCSD program, just as in England, was to provide, not school building plans, but appropriate building parts, eminently suitable for their purpose, which architects could employ in their own designs. But the methods employed were unique in several respects.

The first step was to establish comprehensive design criteria for the school structure, based on a thorough study of the requirements of the participating districts. For several good reasons, it was decided not to include the entire school building in the design program, but to concentrate on those elements which play a minor role in establishing architectural character, yet account for a large share of the building cost. Those selected were: 1) the structural framing and roof system, 2) the ceiling and lighting system, 3) the interior partitions, and 4) the mechanical system. The planning modules established by the staff for these elements, after due deliberation, were 5'0" as a plan module and 1'0" as a vertical module.

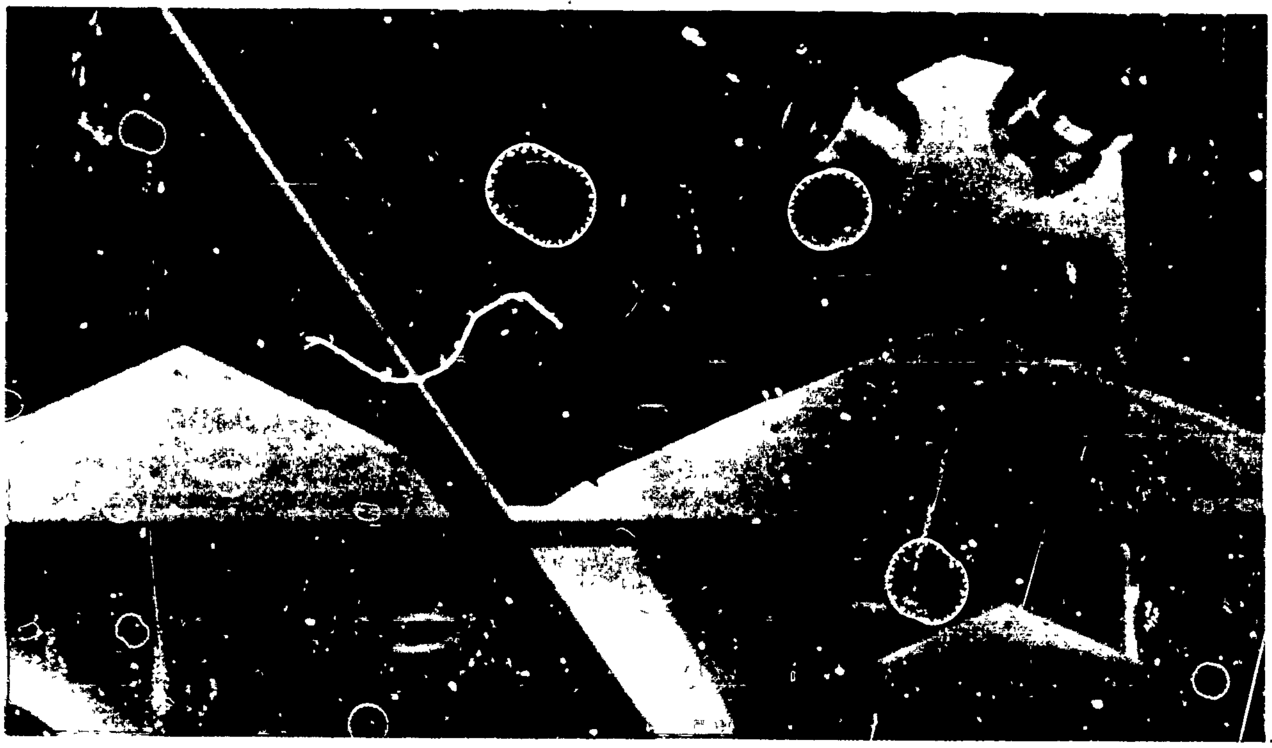
Designs for these elements were not developed by the project staff, however. Instead, comprehensive performance specifications were developed for each component, and industry was invited to cooperate by preparing its own designs, based on these specifications, and then to submit bids based on these designs. Furthermore, the basic requirement that all components be compatible necessitated close cooperation between companies bidding on the various elements. Both of these procedures represented new and commendable concepts aimed at involving industry more effectively in the creative aspects of building. The underlying design concept of the SCSD criteria was the requirement of total flexibility of interior space arrangement without effecting the environmental conditions of the resulting spaces.

The response from industry, assured of a guaranteed market as a reward for its efforts, was gratifying. Following a six months' period of intensive development work, a number of bids were submitted, and contracts were awarded to the successful bidders in January, 1964. After the building and exhaustive testing of a full-size mockup structure, and the inevitable period necessary for "debugging", construction of the first California schools using the system was begun in the fall of 1965. At this writing, 7 schools have been built by the cooperating districts, using SCSD components, and 6 more are scheduled for completion by the end of 1968. In addition, several schools have been built in other states, using components developed under the SCSD program.

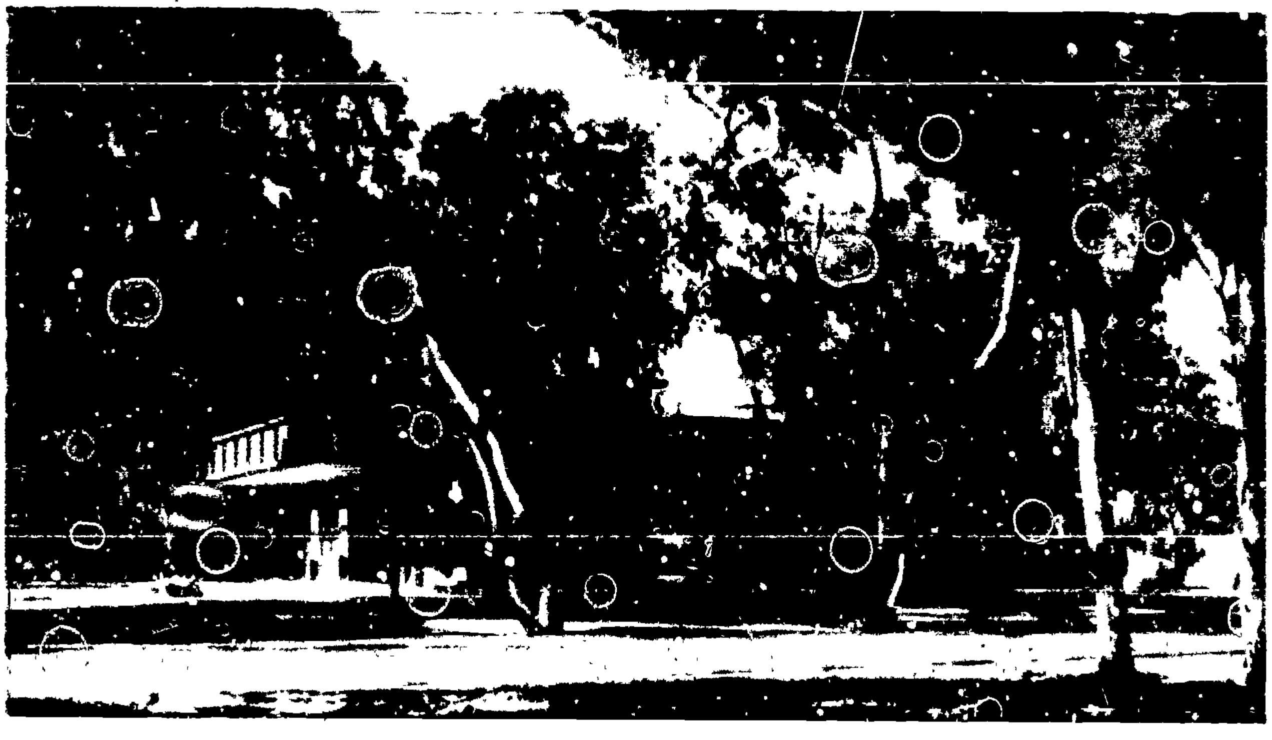
The "systems concept", aimed at achieving flexibility and economy in construction by the use of standardized modular components, has attracted wide attention in other areas. The Pennsylvania State Department of Public Instruction, recognizing the merits of this concept, authorized a comprehensive study exploring the feasibility of applying the "SCSD approach" to school building needs in that state. And, as a result of affirmative conclusions, it has received a $50,000 grant from EFL to initiate its own systems development.



the four basic SCSD components



the ceiling, lighting and air-handling units



the SCSD pilot structure at Stanford University

Another consortium of school districts in the Mid-Hudson region of eastern New York State also initiated and sponsored an exploratory study to investigate the merits of this approach in relation to its special needs, but concluded that present circumstances favor consortium action of somewhat different type.

The Metropolitan Toronto School Board, with a projected 5-year outlay of about $250 million for new buildings, is reported to be initiating the development of a construction system comparable in principle to the SCSD system.

An the University of California, faced with burgeoning enrollments, is actively developing, with substantial EFL assistance, a system of components for dormitory buildings.

Whether or not, in any of these projects, the consortium approach has proven wholly successful in achieving its original goals is not yet clear. There is no doubt, however, that there is widespread and rapidly growing interest in the potential advantages of using factory-made building components to provide at least a substantial part of not only school buildings but other types of buildings as well. Since dimensional coordination is a basic essential of all such systems, all such projects, whether or not they fully meet all of their objectives, have greatly advanced the cause of modular planning.

"Modular Practice"

The book "Modular Practice", published in 1962 under a grant from the Educational Facilities Laboratory, was the first formal attempt to deal comprehensively with the application of modular design and drafting techniques to school design. Written under the auspices of the Modular Building Standards Association, it not only demonstrates the practicability of this design approach, but is intended to serve also:

- as a text for students
- to promote interest in modular design
- to educate architects in modular coordination and the use of modular drafting techniques.

After numerous interviews with school designers throughout the country, the authors of this book established certain procedures for the application of modular principles, beginning with preliminary drawings and proceeding through the production of working drawings. In all cases the 4" module is shown to be applicable in plan, section and elevation.

The major contribution of the book is a clarification of the mechanics of modular drafting, using a 4" base module. A number of illustrative examples is presented, demonstrating how this module can be applied to plans which either have no basic planning module or which utilize an incompatible planning grid.

Although the overall theme of the book is a plea, not only to architects but to engineers, contractors and manufacturers to "think modularly", the mechanics of modular drafting receive the major emphasis. With the ultimate objective of promoting modular coordination, the authors take the view that modular working drawings are the first requisite, and that a knowledge of modular drafting techniques is the primary essential in promoting the development and use of modular products.

Design Regulation at the State Level

With the knowledge that state authorities in at least one state, Pennsylvania, had adopted a regulation requiring that schools be designed "on the principles of modular coordination", a survey was made to determine what other states, if any, have instituted or may be contemplating similar action. A simple questionnaire designed to obtain this information was sent to the regulating authority in each of the 50 states as well as in the District of Columbia, Puerto Rico and the Virgin Islands. Replies were received from all except one state.

The information resulting from this survey may be summarized as follows:

- Of the 50 states, only Pennsylvania has adopted this type of regulation. This was done in 1960, but the requirement has subsequently been relaxed, as will be explained.

- Puerto Rico reports having adopted a similar direction in 1954.

- o Two states, Delaware and North Dakota, report that they are considering the adoption of such regulations.
- o Thirty-four of the agencies report that in their observations architects are, of their own volition, using modular planning in school design; fifteen report no evidence of this trend.
- o Twenty-five of the thirty-four so reporting believe that modular planning is on the increase; two of them think that the practice is decreasing.

Many of the replies included interesting comments and opinions regarding the merits of modular design and the trends being observed. The following quotations are representative:

> "This office has been active in promoting the use of modular components in school design. We feel that the use of 'custom' design elements may add materially to the construction cost of the building with little or no educational advantage accrued. Our only hesitancy in this matter is the misconception that equates modular design with standard plans. We fully believe that each school should be specifically designed for the program, and needs of the specific district. To the extent that modular design can adequately fulfill such needs, we are in full accord".

> "We estimate that 90 percent of the states' school architects use it to some degree. We have been encouraging this procedure for the past decade or more. It is close to, if not actually, a must in effective school design and economical construction". (Ed. opinion: the speaker was referring to modular design, not modular construction).

> "We have been unable to recognize any appreciable savings in cost of construction. The matter was and still is controversial".

> "There appears to be more advantages to architects than to owners. It probably reduces dimensional errors. I find it a deterrent as the manufacturers have not generally adjusted to this".

The reasons for Pennsylvania's Department of Public Instruction requiring the use of modular coordination, and the difficulties which were encountered in enforcing this requirement are worthy of note.

When the regulation was adopted, in 1960, the costs of school building in the state had been under scrutiny by the legislature, just as in many other states, and regulations were being considered to reduce and control them. Several of the prominent school architects in the state, convinced of the merits of modular coordination, proposed its mandatory use as the most logical course ot the achievement of cost economies, and the legislature accepted this recommendation. The regulation required that "each project involving new construction hereafter approved ... shall be planned and designed on the principles of modular coordination ... including the 4" module, as adopted by the Modular Building Standards Association". It stated also that the Bureau of School Buildings would not process plans not complying with this requirement.

As a mandatory requirement, however, the regulation was short-lived. Some architects favored the policy, while others at least accepted it, and several schools were designed and built in strict conformity with the principles of modular coordination. The majority of architects, however, while generally favoring the use of modular principles, objected to having modular coordination and modular drafting techniques forced upon them. They pointed to the difficulties, and often the premium costs, involved in obtaining modular materials, as well as the burden of training their personnel in new drafting techniques. Opposition to the regulation was further strengthened by the fact that membership in the MBSA, at an annual fee of $100, was a prerequisite to architects receiving technical instruction in the mechanics of modular drafting. Consequently, after a short trial period, the regulation was relaxed. While the use of modular design was still strongly recommended by state authorities, the mandatory requirement that modular materials and modular drafting be used was rescinded.

SCHOOL DESIGN

A recent review of school plans being processed by the office of the architect for the Department revealed none in which the modular (dot-and-arrow) drafting technique, as promoted by MBSA, was used. Some plans, however, are decidedly modular in character, with numbered grid lines shown on the plans, usually on 4' centers, with all details referenced to these lines, and with a conspicuous lack of fractional dimensions. The large majority of plans are of the same character as found in any other state. Many of them use repetitive planning modules, but without overall grid lines, and in general there seems to be no evidence of any special effort to avoid fractional inches.

On the basis of current information, it appears doubtful that the use of modular coordination or modular drafting will be advanced by legislative action. State authorities can do much to encourage the use of modular design, and probably more states will do so. But until the technology is further advanced, it will be impractical to require a specific drafting method or even to dictate the use of a specific base module.

IMPLICATIONS OF MODULAR PLANNING

A review of the history of various applications of the modular concept suggests that its utilization has been rather segmented and limited. Architects have employed modular drafting in an attempt to simplify office procedures and to reduce the expense of producing contract documents; some contractors have found that modular coordination can simplify their work and reduce their costs; and educators have been interested in modular design only if it can reduce the amount of time and dollars required for school construction.

However, it's important that we consider the benefits of a common dimensional base in school planning throughout the <u>entire</u> process of programming, planning, construction, and operation of the school plant. It is this concept of modular coordination and planning as a basic, underlying principle governing the entire process that offers the greatest potential not only for cost savings, but for better school designs.

The diagram opposite illustrates the several roles that modular planning can play at each stage in the process of developing a school plant, from early conception to construction and operation. In the programming stage, for example, a planning module may serve as a communicative tool for

MODULAR COORDINATION DURING THE BUILDING CYCLE - SOME ADVANTAGES

PROGRAMMING
- programs expressed in terms of planning modules may be more meaningful to both client and architect.
- construction costs can be predicted based on modules of space.

PRELIMINARY DESIGN
- communication between architect and client, if based on planning modules, may be improved.
- dimensions of materials and equipment are correlated.

STRUCTURAL DESIGN
- structural dimensions relate to equipment and material dimensions.
- structural systems can be made compatible with mechanical systems.
- economical standard structural systems are possible.
- modular can be important means of communication between architect and engineer.

EQUIPMENT LAYOUT
- various types of equipment can be readily integrated in design.
- combinations of equipment can be organized and integrated.

WORKING DRAWINGS
- small scale drawings are appropriate.
- fractional dimensions are reduced.
- details tend to be repetitive and simplified.
- school administrators' understanding of plans is facilitated.
- drawings can be produced faster.
- mechanical means of producing drawings can be employed.
- drafting errors can be reduced.
- referencing can be simplified.

ESTIMATING
- take-offs are less subject to error.
- estimating can be faster and more accurate.
- allowances for waste can be reduced.
- estimating can be more systematized and machine-aided.

SHOP DRAWINGS
- repetitive details can reduce number of drawings.
- checking can be simplified and completed quicker.
- errors can be reduced.

JOB LAYOUT AND SUPERVISION
- grid lines serve as convenient reference lines.
- dimensions are easy to total and check.
- repetitive units can make job layout less complicated and more accurate.
- long dimensions subject to error are reduced.
- workmen's errors are reduced.
- at each stage of construction, dimensions can be easily verified.

ERECTION
- on-site cutting and fitting reduced.
- waste of materials is minimized.
- work can be organized in concurrent segments.

EQUIPMENT INSTALLATION
- equipment and casework fit rough openings without adjustment.
- connections can be made with a minimum of cutting and fitting.

ADDITIONS AND ALTERATIONS
- materials can be replaced with a minimum of alterations.
- provision for integrating fixture equipment and casework is facilitated.
- additions fit the framework of the original building.

both owner and architect. Often classrooms, offices, laboratories and other facilities defined in terms of "modules of space" can have more meaning and significance than when expressed simply in square footages. During the preliminary design stage, the use of a planning module greatly simplifies the work of the architect, both in developing preliminary studies and in communicating the concepts of these studies to the client. The preliminary study becomes a more direct translation of the building program and, is expressed in units of space that are readily understood.

As the design is developed, the discipline of a planning module serves also to simplify structural design, and facilitates fixture and equipment layout, and in general, simplifies and accelerates the production of working drawings. Further advantages of modular design appear when bids on the work are invited. Contractors note that the "take-off" of titles for estimating pruposes is simplified when a repetitive module is used, and that this results in more accurate bids. For school work the speed of estimating and the ability to "sharpen the pencil" are major benefits.

As noted in the diagram, the use of the modular concept offers advantages also in the preparation and checking of shop drawings, the actual layout of the job at the construction site, the supervision of construction, and finally the installation of finished materials, equipment, and fixtures. All of these processes can be accelerated, with less waste of time and materials when modular design is used consistently throughout the project.

A further advantage not generally recognized is the fact that later additions and alterations to the building are also facilitated. The matching of of structure and materials, as well as equipment and fixtures, can be simplified and can result in a more unified total school plant if modular design has been used initially as well as for the addition. In other words, school building obsolescence can be more easily remedied if the school plant is design-based on modular coordination. Obsolete equipment, furniture, materials, and finishes, can be removed and readily replaced if both the original and the new have been planned and specified within a coordinated dimensional system.

In summary, then, the use of modular planning and modular coordination throughout the entire process of school building, from early programming through planning and construction, to maintenance and addition should provide benefits to the taxpayer, to the school administrator, and, most importantly, to the children occupying the school.

4

observations and conclusions

In assessing the merits and potentials of using modular principles in design, it's important to keep in mind the distinction between the two related terms "modular design" and "modular coordination", as defined at the outset. These terms too often are used indiscriminately, though their true implications are quite different. To minimize confusion, each must be considered separately.

Modular design is widely accepted as an essential of good contemporary practice, and is already being used extensively in many types of buildings. It offers undeniable advantages in the planning and construction of schools, resulting in more orderly arrangement, greater flexibility of space usage, and increased facility of reorganization and replacement.

The use of modular design and planning will inevitably increase, in all building types, as more and larger building components are factory-produced, skilled labor becomes scarcer, and the proportion of on-site work is reduced.

Modular coordination is a more complex concept, and its future is debatable. It might be considered as a universal pattern for modular design, requiring the establishment of detailed dimensional standards, and necessarily involving the policies of the manufacturer as well as the practices of both the architect and the contractor. The use of modular coordination appears to be growing, but at a very slow rate. The inevitable application of computer technology to building design, already in its exploratory stages, will undoubtedly hasten the process.

Modular coordination, being a refinement of modular design, is believed to offer the further advantages of facilitating estimating, expediting site layout work and minimizing the waste of building materials. These advantages are yet to be proven convincingly, however, and the availability of modular products must be improved before the concept can be widely accepted.

Among the chief advantages historically claimed for modular coordination has been that of cost savings. It was expected to reduce the architect's production costs by simplifying his drawings, benefit the manufacturer by lowering his handling and inventory expenses, save the contractor time in estimating and field layout work, and therefore result in lower building costs for the owner. It is difficult to establish, however, that such advantages have been realized with any degree of consistency. This study, though admittedly limited in scope, failed to disclose any buildings whose costs are proven to have been reduced by the use of modular coordination.

This should not be interpreted, however, as proof that the economic benefits claimed are not valid. It only means that they have not yet been proven. Experience to date has obviously been limited, and modular coordination can scarcely be said to have had ample opportunity to prove its value. It may well be that with wider acceptance and use, definite savings will result.

There appears to be some confusion as to the meaning of the term "modular size". Certain products such as plywood and acoustical ceiling tile are classified as modular, by some parties at least, because their actual dimensions are multiples of 4". Other products such as brick and concrete blocks are considered modular because their cumulative actual dimensions plus joint widths are multiples of 4". Only the latter concept, reflecting Bemis' original intent, appears valid, if true modular coordination is to be achieved. The three-dimensional modular grid must be considered as a pattern for locating joint centers, not the actual faces or edges of the material units themselves.

To establish the modular size of a product requires, therefore, that a standard joint width, as well as standard relationships to other products or materials, be established. This requirement is often found objectionable by designers, on the grounds that it inhibits design freedom in detailing. As applied to expanses of masonry wall, such restrictions may be quite acceptable, but when they dictate how a window or door frame must be set in the wall there is understandable opposition. For reasons such as this, there may well be definite limits to the practical value and application of modular coordination.

If the use and acceptance of modular coordination is to be accelerated, action along several lines appears essential:

- The concept must be actively promoted, not only among the "suppliers" of buildings - architects, manufacturers and contractors - but also among the "consumers" - the building owners. Such promotion should reflect not only its potential benefits to the suppliers, but must also emphasize the overall implications of the concept, from initial programming to occupancy and replacement. It must necessarily be the responsibility of some agency representing both suppliers and and consumers at the national level - perhaps the National Bureau of Standards (IAT) or the Building Research Institute.

- Its economic advantages, as reflected as actual building costs to the owner, must be clearly established. These advantages might be quantified by a controlled demonstration building project involving, for example, two identical schools, one designed to take full advantage of all the implications of modular coordination, the other designed "conventionally". Such a project might well serve to demonstrate for schools such potentials as have been revealed by the GSA-IAT cooperative work in the planning of office space.

CONCLUSIONS

- The criteria of modular sizing must be better defined, and more products must be readily available in such sizes. It is not essential, however, that all ingredient products and materials be modular, to obtain a high degree of dimensional coordination.

Obviously, these efforts must be concurrent and inter-related, rather than sequential. With the limited availability of modular products, the demonstration of their advantages may be handicapped, but until these advantages are proven, the promotion of modular coordination will be difficult and the availability of modular products will not likely be improved.

In summary, then, this appears to be the situation:

- The validity, logic and merits of modular design are well established and widely accepted, and present trends in building technology point inevitably to its increasing use.

- The acceptance of modular coordination, however, in spite of its theoretical advantages, has progressed very slowly, if at all, during recent years. To accelerate its usage, its benefits and full implications must be clearly demonstrated and it must be actively and objectively promoted in its broadest concept.

- The extent to which modular drafting is used will depend, of course, on the acceptance of modular coordination. Quite likely, however, the graphic techniques now identified as modular drafting will be replaced by a new vocabulary of computer symbols and language, not yet developed.

As to school buildings, they do not appear to be sufficiently unique as a building type to warrant the consideration of any special "system of dimensional coordination" intended specifically for use in school design. The already established system, based on a single module of 4" or the metric equivalent as an international standard, offers ample latitude for most design requirements. To introduce and promote any system having other base modules would seem ill-advised and would likely accomplish nothing of constructive value. It would, however, add to the doubt and confusion already existing in this area, and would probably impede the wider acceptance of modular coordination as a workable concept.

In the light of these observations, it is recommended that the Office of Education confirm as its policy the endorsement of modular principles in school design. To implement this policy, it is further recommended that appropriate measures be taken to:

- commend and promote the use of modular planning in school design,
- impress upon those responsible for school programming, planning and adminstration, the full import of modular principles in all aspects of facilities procurement and operation, and,
- encourage and support the further development and extended application of modular coordination as an aid to modular planning. Such support should favor the generally accepted system based on the 4" module, rather than any competitive system intended specifically for school design.

APPENDIX A
summary of invitational seminar

APPENDIX B
bibliography

APPENDIX C
methodology

appendix A

summary of invitational seminar

To explore at first hand the views of knowledgeable and informed persons regarding the status and merits of modular coordination, an invitational seminar was held in Washington, D.C., on June 23, 1966. Ten invitees, including a representative of the Office of Education, (see roster of participants following), met with the project staff to discuss developments in this field and exchange opinions concerning the potentials offered, particularly in school design.

Most of those participating had had extensive background experience, either directly or indirectly, in the promotion and/or use of the modular planning concept, and the group was selected to represent a cross section of the various interests involved. Three of the participants were practicing architects, three represented the building products industry, one was a member of a prominent firm of building contractors, one an educator and consultant, and one a planning director for educational facilities. Each contributed significantly to the discussion, candidly expressing his views on various aspects of the subject in response to questions posed both by the project staff and by their fellow participants.

Interesting differences of opinion were expressed on some of the questions, though on matters of basic concern there appeared to be general agreement. On the whole, the sense of the meeting seemed to point up the fact that while modular coordination is generally, though intuitively, favored, and is, in fact considered to be an inevitable development, yet the concept is rather nebulous, meaning different things to different people. Its merits are not clearly demonstrable, it is still far from being generally accepted, and there appear to be no clear-cut paths to clarifying or improving the situation.

As a means of orienting the thinking of the group, the first ten minutes of the meeting were devoted to the question of an appropriate definition of the term "modular coordination". Four different "definitions", taken from the literature dealing with the subject, were presented to the group, and each participant was asked which, if any, of these definitions best expressed his concept of the meaning of the term. The four definitions presented were:

a) A system of dimensional coordination using the standard modular space grid of 4 inches.

b) A keyboard for design which provides flexibility while using standard products.

c) A system of organizing dimensions, using a basic module, to enable components to be used together on the building site without modification.

d) The establishment of both building dimensions and building material sizes, by use of a basic module, so that materials may be assembled according to plan with a minimum of modification.

None of these definitions met with unanimous approval. Some, for various reasons, preferred one, some another, and some thought that none of them were adequate. One of the architects stated, "To me, it doesn't mean any of these things precisely; it means a combination of all of them". It was suggested that most of these definitions put too much emphasis on numbers, and don't recognize the basic value of modular coordination, which is design discipline. And another participant observed that "you can find just about any definition you want, depending on whom you talk to. There really isn't any <u>specific</u> definition". A rough tally indicated, however, that definition "d" found greater acceptance among the group than any of the others, the industry representatives in particular favoring it. Furthermore, there seemed to be general agreement that modular coordination concerns both building and product dimensions, that a basic dimensional unit is essential, and that one of its chief objectives is to minimize modification of material sizes at the building site.

Prior to the meeting, each invitee had been asked to be prepared to present an informal summary of his views regarding three matters in particular:

a) The benefits, if any, of modular coordination in school planning and construction.

b) Recent or current developments that significantly affect the status of modular school design.

c) Future prospects for the use of modular coordination in school design.

Following the brief consideration of definitions (without attempting to resolve this question), these presentations were made, and there followed several hours of discussion and interaction touching on many aspects of the subject. In the course of these discussions certain pertiment questions were posed by the project staff, and others were raised by the participants themselves.

The gist of the opinions and views expressed on a number of topics is presented in the following summary. In most cases, the remarks are not quoted verbatim, but have been paraphrased for brevity and clarity, and authorship is not indicated. Such "pulse-taking" is always debatable, and some participants may question that the feeling of the group has been fairly represented in all cases. But these highlights are summarized with the intent of reflecting the views expressed in respect to the various topics considered, and are thought to be eminently worthy of presentation, in spite of the hazards involved.

<u>Concerning the influence of the machine:</u>

Bemis recognized that the machine was becoming an essential part of the building industry, and that sooner or later the building industry would be getting into mass production. If you begin to think of the problem in that light, you soon realize that once you get into mass production you begin to reduce sizes; it's the nature of the machine to reduce variations. And still the crux of our problem today is the failure of architects to realize the limitations which the machine puts on their designs.

"After all, modular coordination came about only because we are manufacturing building products and materials".

Modular coordination is necessary, if you're going to use manufactured components. The only way you can really stop it is to stop the machine.

Concerning the merits and significance of modular coordination:

"Probably the chief benefit of modular coordination is its value as a design discipline. Architects, as a general rule, are too prone to not want to be organized. They don't want to do things with a logical discipline, as they did when they built the Parthenon. They need more uniformity in their detailing, and modular coordination helps this".

"As Corbusier has said, to the sensitive designer, modular design can be an assist, but to the mediocre, it is either a crutch or a straight jacket".

In the designing and detailing stages, the architect must think more in detail, and must study more thoroughly the use of materials, if he uses the modular concept. It will not necessarily result in more drafting, but it will result in more intelligent thinking.

An architect: "If modular coordination saves money and gets things out of the way so I don't have to worry about them and allows me to do something I would like to do in school design, and also satisfies client requirements, then I'm all for it. But if I have to constantly compromise what I think is good, to use something that might save a buck or two, then I'm not interested in it".

An architect: "I feel that if my architecture is going to have any order at all in any form, I have to impose upon myself some sort of order, call it discipline or any other name. Merely the superficial super-imposing of grids, dots and arrows on the drawing does not make it modular".

Speaking of orderly thinking, all architects should ask themselves at least these four questions:

- What are the purposes of dimensions - why do you have them?
- What are the necessary dimensions on a job?
- How are they established - by function of the structure or by the materials themselves?
- How are they maintained, both in the factory and at the site?

An architect: "I'm sure there must be benefits, but I haven't been able to put my finger on what they are. Modular coordination is like home and mother; we're all for it. But unless there are some tangible benefits, I don't think the architectural profession is really going to grab it".

Another architect: "I think that our reliability in the production of our product is increased by insisting on modular dimensioning and coordination, but this may be a subjective opinion. I can't prove it. I'm not sure, either, that we have a working system that insures this great design discipline or produces a building at less cost. We have too many architects who aren't using modular coordination, and too many contractors who aren't. But the smart contractor who recognizes it and uses it will certainly turn in lower bids".

A building contractor: "The benefits of modular coordination and construction, particularly in school work, are many. If we include the manufacturers, the subcontractors and the general contractor, it probably requires 1000 man-hours of labor to properly estimate the cost of a 200,000 square foot high school. At $10 to $15 per hour, the cost of estimating could easily run $10,000, maybe $20,000. If modular design and drafting is used on such a job, I believe this cost is likely reduced by one-third - or at least by one-fourth".

A manufacturer: "Standardization in itself won't save a nickel. Only when it leads to mass production will it start to save money. When you can turn out thousands of products all the same size, you will save money not only in production, but in warehousing, and also in sorting of materials on the job".

"We seem to have come to the general conclusion that certain benefits may accrue at various stages, but that none of these can be guaranteed".

SEMINAR

Concerning progress in the application of modular principles:

Most architects, either consciously or subconsciously, "place the restraints" of modular thinking on their work much more toady than they did 10 or 15 years ago.

Most buildings that are designed by intelligent and capable architects will have certain dimensional uniformity and will take advantage of the sizes in which materials are being produced. This is taking place today on a very large scale.

A lot more attention is given to dimensional relationships in building today than was done 20 or 30 years ago. This is being done through organized methods, and the dimensional relationships between materials are much better today than in the past.

In Canada, school boards are now joining together administratively to investigate common problems and eventually develop some sort of similarity in the building process. The most heartening thing about modular development is this recognition at the political level of common problems and being prepared to do something about them.

Concerning the present status and problems of modular coordination:

There was considerable interest in modular coordination in the early days of the A62 Guide. That went into most every architect's office, and a good deal of effort was devoted to applying the concept. Why didn't it take hold? We don't really know, but perhaps it was because it was too complicated. The problem seems to be to find more simplified non-proprietary methods that everyone will use.

The system has to be flexible enough that we can design to it, and simple enough that contractors can bid it advantageously. It has to be so simple that people just automatically adopt it. When it's so complicated that one virtually has to go to school to learn how to use it, it's not going to be accepted.

An architect: "I have been very interested in this thing for years, and I'm concerned because I don't think we've gotten very far with it. Maybe the reason it doesn't really work is that although we at the upper technical level, shall we say, understand it, this understanding doesn't filter down through to the others. I think we have to go back and rethink what we are trying to do with this concept before we can convince others that it is both workable and worthwhile".

Another architect: "It seems to me the subcontractors who recognize the efficiencies inherent in the system would tend to be the lower bidders, but it hasn't worked out this way ... This is what has disappointed me most. I thought that would surely be the result when they all caught on, but it hasn't been".

"It's surprising that modular coordination is still being used as much as it is. The typical architect and designer is opposed to it; he thinks it takes away his creativity, you know. He thinks it limits his ability to express himself, and that this is not good from an architectural point of view".

An architect: "I'm surprised, too, that we still have this thing around. I'm almost ready to give it up. The day the Modular Association went out of business we had an office meeting and spent half a day discussing what we should do. The decision was to stay with it, no matter what. I still think it has many benefits, but with the turnover we have in drafting help today, the training of draftsmen to use it properly is a big problem.. We're the only architects in our area that are using it, and when I ask contractors, they seem to have a don't-care attitude".

One handicap seems to be that many product manufacturers make more profit on special items than on standard products.

Concerning the choice of the module:

The establishment of a module should not be limited to some preconceived idea as to what the module is, but should grow from the need of the use of the space.

We should not limit our thinking to four inches, but let the building activity, or use of space determine it.

If we are going to have to deal with materials that are non-modular in their own right, we are going to have to keep our so-called modular system flexible enough to take advantage of these materials. We may use one module on one building, and a different module on others.

A manufacturer: "The only answer for the hard goods product producer is the single module. You set your grid lines on that module, whatever it may be, and then you must take into account your interface problems. From there you work out the dimensions of the products themselves".

Concerning the inter-relationship of materials:

The interfacing of materials is important; it's the thing that has to be faced up to next. Perhaps modular coordination could be applied with greater design freedom if we were to establish specific sizes for those materials in whose production dimensions are critical, and take up variations in those materials for which size is not important.

One of the things that has been slighted is the inter-relationship of materials - the interfacing of adjoining products. This is a problem that needs a tremendous amount of work.

Perhaps one of the important things that the reactivated A62 Committee should do, instead of concerning themselves with the proper module dimension, is to take up the question of interfaces and their relationship to the grid line. This will require a lot of cooperative effort on the part of the different trade associations; the brick people are going to have to get together with the metal people and the concrete people to solve this problem.

Concerning the availability of modular products:

There appears to have been little change, during the past six years, in the availability of modular brick. In the Midwest, both modular and non-modular sizes are readily available, but if you want modular brick in the northeastern states, you'll probably have to ship it in, and pay a premium for it. In the Southwest, the situation is quite the reverse. If you want non-modular brick there, it will cost you extra, because modular brick is all that they make in that area.

Modular dimensions are naturally most important for the products that are "most repeated", or used in greatest quantity in typical building. That's why it was desirable to start with brick, and after that, attention turned to windows and doors.

In general, it seems that the limited availability of modular products poses no serious problem even to architects who consistently use the modular concept of design. Having more modular products "might open up some avenues", but on many jobs the quantities required are large enough that they can establish their own modules and can obtain special sizes, if necessary, at little or no additional cost.

Concerning the extent of applicability of modular sizes to building products:

There is certainly not much modularity about a load of premixed concrete, but modular dimensions may be very important in the framework that will contain it. And roll roofing is so easily sized to the job that it is probably unimportant whether it's modular or not. But when you consider the products that come prefabricated to the job in materials that cannot be easily altered, modular dimensioning may be very important.

To get the optimum out of mass production, you can't simply look at the great big umbrella of modular coordination. You have to consider each material by itself to see what its advantages may be.

There may be a limit to which modularity would apply under ideal conditions, but it probably isn't apparent as yet. As the use of modular coordination grows, it will likely be found that more and more benefits will accrue from having additional materials dimensionally coordinated.

Concerning the relationship of modular coordination to computer technology:

There is a possibility that the use of electronic data equipment for improving the effectiveness of manpower in preparing drawings and specifications, and even in the development of design concepts, may give a special significance to establishing some kind of coordinate grid by which the machine itself unifies information.

An architect: "We're spending more money than we should, trying to see what the application of the computer is in our profession. So far we haven't done too much. But I want to be there the day somebody finds it, and I feel that modular discipline and this type of approach to design will be with us more and more".

Concerning the merits and significance of modular drafting:

It's doubtful that this method of putting lines on paper simplifies the architect's work any. There's probably only one architect who can demonstrate that it saves him a lot of money. Most of those who have tried it have become so intrigued with the mechanics of the system that they've spent more money on working drawings than they should.

One Michigan firm, in particular, who experimented with modular drafting had cause for regret. They thought they'd found the solution to all of their drafting problems, but bingo! When they computed their job costs on certain school jobs they found their drafting had cost them 30% more. And they had grids, dots and arrows all over the place.

Are we kidding ourselves by worrying about details of drafting and doing these things because we like the intellectual exercise, or because they offer some real benefit?

An architect: "I found that the contractor's men on the job threw their folding rules away when they found out how the system worked, and what those lines on the paper meant. They started using them as references, and everybody was happy. It was wonderful"!

Another architect: "On one of our jobs, a $3 million high school, befor the contractor moved any equipment to the site, he put three draftsmen to work redrawing our modular contract documents. He had them eliminate all the grid lines and dots and put in arrows, simply because the superintendent refused to take any responsibility 'with dots on the job'. And he did it at his own expense".

We can talk modular coordination all we want, but unless the man who puts the building together is thoroughly familiar with the system, he has as much trouble reading a modular set of plans as any other plans.

One of the biggest benefits to the architect is to be able to put the plans for a large building on one sheet of paper at 1/16" scale, instead of on four sheets at 1/8" scale, and this is possible.

If modular drafting is regarded as simply a technique for saving drafting time, and the architect doesn't put the effort into the real basic thinking he should be doing, we haven't accomplished a thing except to make it easier for people not to think too much.

Concerning "catalog design" and design freedom:

An architect: "I use modular coordination in my own office, and I think I've made it work. But I hope that I'll never get into the catalog design attitude or atmosphere. I hope I'll always have a modular concept, but also a flexibility of design attitude".

Another architect: "I don't think we can ever end up taking all of our designs out of a catalog. One of our problems is that our clients don't appreciate the fact that there may be some savings in this (modular) system. They are willing for you to use it as long as it doesn't interfere with their own ideas".

The modular concept does not provide a stereotyped or patent solution to a design problem. Just as with any logical design process, it means taking the program, the objective, the budget, and your own personality, and devising an appropriate solution.

Concerning the future potentials and significance of modular coordination:

An architect: "I'm not being a religious prophet or fanatic, but I say the only salvation of custom design in building is going to be a modular concept, regardless of whether you use a grid, dot or arrow. The projected demand on the construction industry is so great that we cannot do the job during the next 40 years by present methods".

As researchers create more responses to the demands of the building market, their solutions will likely employ the component concept. And when the performance specification requires that some of these components be maintained for 15 years by their producers, this will lead to a role reversal, the producer assuming the role and responsibilities of the architect in the design of his product. It won't be long until there will be catalogs of such products with such guarantees on the architect's desk, with all costs spelled out and all guesswork eliminated.

It's been suggested that by the year 2000 land will be so scarce and expensive that it won't make much difference what you build on them. Buildings, by comparison, may be so cheap that they may be much more frequently replaced. Perhaps the same thing will apply to the schools; portability or replaceability of parts may be much more significant than now.

We are getting so many people in this country that in order to live with each other we have to accept some discipline. There are modules of speed limits, for example, which you have to live with; you don't have complete freedom in design either.

There probably is some way to structure an anlysis of actual experience so that meaningful comparisons could be made to determine the cost benefits of using modular coordination, but there's no obvious method and it probably wouldn't be easy. This is the kind of information that's needed - not just talk around a conference table. It seems that the only way we can find where we're going is by looking back. Maybe that's the best we can do, but we should be able to find a better way.

How can you have the benefits of the components and systems concept in building design unless they <u>are</u> related to some basic module?

Ultimately we will gain momentum, and the architect's office that is ready to take advantage of this concept of thinking when the real demand comes will be on top of the heap.

If the modular system can contribute to a solution of problems facing the typical school board by giving them a more valid method of construction to ask for, a basis on which to plan their schools, or more predictable costs, it will be great value to them.

The modular concept will help in keeping school construction costs down, and is an absolute necessity if we are going to do a job for education.

A poll of the seminar participants revealed that, with one abstaining vote, all favored the concept of modular coordination and felt that it should be promoted in school design and construction. The point was made, however, that school construction alone is not adequate to support it; if it doesn't apply to all parts of the building industry, it won't work.

<u>Concerning the question of leadership in promoting the concept:</u>

It seems that in the building industry we have some 20,000 or more building designers. In the automobile industry, design is controlled by about four men. They may not be doing all of the actual design work, but they can fire the designer who designs an Edsel. We must find some way to bring the building industry together so that we can communicate, and we need some decision makers with authority to determine whether such concepts as this - or other reforms in the building industry - should be put into effect.

If we don't have some central organization that is continually pushing the advantages of modular coordination, what can it do but eventually die out? It seems that some architects continue using it because they're intrigued with the idea, but when we lose these firms, what's going to happen then?

An architect: "I feel very strongly that the architectural profession is denying its own responsibility if it does not take a certain amount of leadership in pushing manufacturers into doing a better job of modular coordination of their products".

Modular coordination requires serious thought on the part of the architect right at the drawing board. If he doesn't think of it, the fabricator, the manufacturer and the contractor can't help him one bit.

With very few exceptions, modular coordination, and the appreciation of this concept, isn't taught in the architectural schools. Some absolutely refuse to have it in the curriculum. This being the case, how long can the concept endure? You have to have some sponsorship for it. Some think the AIA should be responsible for promoting it, or at least seeing that some organization is, but it seems that at present the AIA has no official interest in it.

When architects take the leadership in promoting modular coordination they will have the cooperation of the manufacturers. But they have to provide this leadership before the manufacturers are going to follow.

PARTICIPANTS

William Gillett
Consultant to the Director
Building Research Advisory Board
2101 Constitution Avenue
Washington, D. C.

Harold Horowitz
Architectural Services Staff
Division of Institutional Programs
National Science Foundation
Washington, D. C.

Professor Stanley Kent
Consultant
Division of Building Research
National Research Council
Ottawa, Canada

David A. Pierce, A.I.A.
Architect
140 Fairlawn Drive
Columbus, Ohio

Herbert H. Swinburne, F.A.I.A.
Nolen, Swinburne and Associates
Architects
1601 Locust Street
Philadelphia, Pennsylvania

John W. McLeod, F.A.I.A.
McLeod, Farrara and Ensign
Architects
1705 DeSales Street, N.W.
Washington, D. C.

SEMINAR

Ancle Tester
Vice President
John Tester and Son, Inc.
General Contractors
Clinton, Maryland

Alan H. Yorkdale
Construction Engineer
Structural Clay Products Institute
1520 18th Street, N.W.
Washington, D. C.

John S. Parkinson
Research Director for
Government Liaison
Johns-Manville Research and
Engineering Center
Manville, New Jersey

U.S. OFFICE OF EDUCATION REPRESENTATIVE

Dwayne E. Gardner
Administrative-Instructional Support Branch

PROJECT STAFF

Alan C. Green
Associate Professor of Architecture

Wayne F. Koppes
Adjunct Professor of Building Research

Alan C. Jensen
Student Technician

appendix B

bibliography

Books and Reports

A62 Guide
Adams, M.W. and Bradley, P., (ed.)
Modular Service Association
Boston, Massachusetts
1946.

Building Better from Modular Drawings
Demarest, William Jr.
Division of Housing Research
Housing and Home Finance Agency
U.S. Government Printing Office
Washington, D. C.
January, 1954.

Controlling Dimensions for Educational Building
Department of Education and Science
Her Majesty's Stationary Office
London, England
1964.

Dimensional Coordination of Building Materials and Equipment on the Modular System
Industrial Research and Development Division
Office of Technical Services, Department of Commerce Washington, D. C. 1948.

BIBLIOGRAPHY

Doors and Frames
Bloomfield, Byron C.
Modular Building Standards Association
Washington, D. C.
1963.

Innovation in Building
International Council for Building Research
Studies and Documentation - CIB
Elsevier Publishing Company
New York, New York
1962.

Modular Coordination
British Standards Institution
Report B.S. 1708
Building Divisional Council
London, England
1951.

Modular Coordination
Division of Standardized Building Codes
Housing and Home Finance Agency
U.S. Government Printing Office
Washington, D. C.
1949.

Modular Coordination in Building
The European Productivity Agency
OEEC
Paris, France
1946.

Modular Drafting Manual
Kent, S.R.
Division of Building Research
National Research Council
Ottawa, Canada
August 1961.

Modular Measure
Building Research Institute
Washington, D. C.
June, 1955.

The Modular Method in Dwelling Design
Division of Housing Research
Housing and Home Finance Agency
U.S. Government Printing Agency
Washington, D. C.
1951.

Modular Organization for Building Efficiency
Jensen, Alan
Rensselaer Polytechnic Institute
May, 1966.

Modular Practice
Darlington, Robert P., et al. (ed.)
Modular Building Standards Association
John Wiley and Sons, Inc.
New York, New York
1962.

Module, Proportion, Symmetry, Rhythm
Kepes, Gyorgy, et al.
George Braziller, Inc.
New York, New York
1966.

Potential Economies in School Construction
Koppes, Wayne, et al.
The University of the State of New York
Albany, New York
1958.

SCSD - An Interim Report
Educational Facilities Laboratories
New York, New York
January, 1964.

The Co-ordination of Dimensions for Building
Martin, Bruce (ed.)
Royal Institute of British Architects
Stephen Austin and Sons Ltd.
Hertford, England
November, 1965.

The Current Status of Modular Coordination
Building Research Institute
Publication 782
National Academy of Sciences
National Research Council
Washington, D. C.
1960.

The Evolving House, Vol. I, II, III
Bemis, Albert F.
The Technology Press
Cambridge, Massachusetts
1936.

The Modular
Le Corbusier
Peter de Francia, trans.
The Harvard University Press
Cambridge, Massachusetts
1958.

The Modular Method in Dwelling Design
Housing and Home Finance Agency
Washington, D. C.
May, 1951.

The Modular Number Pattern
Ehrekrantz, Ezra D.
Alec Tiranti Ltd.
London, England
1956.

BIBLIOGRAPHY

Articles and Pamphlets

A31 Code for Modular Coordination in Building
Canadian Standards Association
Ottawa, Canada
1959.

Abstract of Proceedings from Sectional Committee A62
American Standards Association
Washington, D. C.
1960.

Accomplishments, Developments and Need for Standard Activities in the Building Industry
American Standards Association Conference
New York, New York
October, 1960.

American Standard Sizes of Clay and Concrete Modular Masonry Units
American Standards Association
New York, New York
1946.

Architectural and Engineering News
"Systems - Basis for an Integrated Building Industry"
Halle, Roger
September, 1965.

Architectural Forum
"Components for Schools"
Time, Inc.
New York, New York
February, 1964.

"Ernest Kump's Environmental Control Grid"
Vol. 117: 110-11
August, 1962.

"How to Make Things Fit Together; Flexible Modular System"
Vol. 113: 114-17
August, 1960.

"In Office Designs, What Decides the Module?"
Vol. 117: 118-21
November, 1962.

"Modular Framing Reduces Cost, Components, Site Work"
Vol. 111: 53-4
November, 1959.

"New Hope for Standardization; Modular Dimensioning"
Vol. 109: 146-9.

Architectural Record
"Components Program for California Schools"
Vol. 135: 167-9
January, 1964.

"Materials Systems Differ in Four Displayable Schools"
Vol. 113: 182-5
February, 1963.

"Modular Coordination and How It's Done"
Vol. 125: 44
March, 1959.

"Modules for Texas Schools"
Vol. 124: 230
October, 1958.

"School Components Designs' Cost Revealed"
Vol. 136: 165
July, 1964.

"Turreted Modules for Ultra-fine Manufacturing"
Vol. 136: 165
July, 1964.

Chemical and Industrial Research
"Industrialized Building Systems and Component Exhibition"
August 1, 1964.

Chemical Engineer
"Modules, Big and Small, Hike Engineering Efficiency"
Vol. 70: 54+
January 21, 1963.

Code of Standard Practices
Metal Building Manufacturers Association
Cleveland, Ohio
1965.

Controlling Dimensions for Educational Building
Department of Education and Science
Her Majesty Stationary Office
London, England
1964.

Coordination of Dimensions of Building Materials and Equipment
American Standards Association
New York, New York
1957.

Coordination of Masonry
American Standards Association
New York, New York
1945.

Development of Standard and Correlated Dimensions of Material-Components in School Construction
Texas Education Agency
Austin, Texas
1960.

Dimensional Co-ordination for Industrialized Building
Ministry of Public Building and Works
Her Majesty's Stationary Office
London, England
1964.

Directory of Architectural Firms Using Modular Practices and Products
Modular Building Standards Association
Washington, D. C.
undated.

Electrical Construction and Maintenance
"Flexible Power for a Modular Industrial Complex"
Vol. 61: 84-7

Engineering News
"Modular Steel Systems Promise Cost Cuts"
Vol. 168: 120
April 26, 1962.

"New Code Simplifies, Expends Cost Estimating by Computer"
Vol. 172: 30+
May 14, 1964.

BIBLIOGRAPHY

Illuminating Engineer
"Influence of the Building Module on Illumination"
Vol. 59: 612-13
September, 1964.

Journal of the AIA
"A New Architecture for Man"
Kump, Ernest J.
November, 1957.

"The Strange Case of the New Idea"
Bloomfield, Byron C.
February, 1959.

Magazine of Standards
"Story of Modular"
Vol. 30: 228-33
August, 1959.

Many Ways to Market
Proceedings of the 44th Annual Meeting of the Producers' Council
Louisville, Kentucky
1956.

MBSA Reports #1, 2, 3, 4,
Modular Building Standards Association
Washington, D. C.
undated.

Mechanical Engineer
"Modular Offices in Union Carbide's New 52 Story Building"
Vol. 82: 74
May 1960.

Modular Coordination
Conference Proceedings Bulletin No. 3
Legget, Robert F.
Division of Building Research
National Research Council of Canada
Ottawa, Canada
1965.

Modular Coordination in Building Project 174
European Productivity Agency
OEEC
Paris, France
1961.

Modular Dimensioning Practices
Symposium at the National Housing Center
Structural Clay Products Institute
Washington, D. C.
1959.

Modular Drafting Manual - A Guide to the Application of Modular Coordination in Design
Technical Paper No. 123
Kent, Stanley R.
Division of Building Research
National Research Council of Canada
Ottawa, Canada
1961.

Modular Measure Works for Architects, Producers, Builders
Modular Building Standards Association
Washington, D. C.
1958.

Plant Engineer
"Building with Modular Design"
Vol. 15: 114-16
September, 1961.

"New Prefab of Paper Honeycomb; Modular Building System"
Vol. 14: 144-5
December, 1960.

Producers' Council Bulletin No. 89
"Modular Measure"
Silling, C. E.
1959.

"Modular Practice in Residential Construction"
Bloomfield, Byron
March, 1959.

Progressive Architecture
"Geometry of Space in Schools"
Vol. 45: 134-47
February, 1964.

"Modular Co-ordination Research for Schools"
Vol. 40: 162
April, 1959.

School Construction System Development Report No. 2 - British Prefabricated School Construction
Lauritus, James D., et al.
Educational Facilities Laboratories, Inc.
New York, New York
undated.

Space Module Schools
Kump, Ernest J.
Palo Alto, California
July 11, 1957.

Standard Steel Doors and Frames for Modular Construction
Steel Door Institute
Cleveland, Ohio
undated.

The Five Fundamentals of Modular Drafting
Demarest, William, Jr.
Modular Building Standards Association
Wahington, D. C.
1955.

The Magazine of Standards
"Clay Tile Sizes Have Always Been Modular"
Fitzgerald, J. V.
April, 1956.

The School Executive
"A Basic Space Module Solves a District's Problem"
Engvall, Willard R.
February, 1958.

Unicom Manuals #1 and #2
National Lumber Manufacturers' Association
Washington, D. C.
1964.

appendix C

methodology

Although the research leading to this report involved no unique procedures or methods, it may be of interest to the reader to know what types of inquiry and investigation led to the findings and conclusions presented. The research methodology, characteristic of the field of architecture, may be summarized as follows.

Literature search: Published literature on the subject of modular coordination consists chiefly of conference reports and articles in technical journals; relatively few books dealing with the subject have been published. In the more specific area of modular coordination and its relationship to school design, several useful books and reports are available, evidencing the fact that the application of modular coordination in school planning has been given some previous thought. As evidenced by the bibliography (Appendix B) many of these publications were reviewed as references sources at various stages in the project.

METHODOLOGY

Invitational Seminar: Early in the course of the work, a one-day seminar was held in Washington, D. C. to explore the implications of modular principles in design, with particular reference to schools. Invitees included representatives of the various interests primarily involved - architects, contractors, product manufacturers, and educators: all contributed freely with an interchange of information and opinions. A summary of the thoughts expressed is presented in Appendix A.

Contacts: The investigations included many contacts, both in person and by correspondence, with individuals well qualified by experience to express impartial opinions pertinent to the investigations. These included prominent architects in various parts of the country who have experienced or been involved in the promotion of modular coordination, a number of contracting firms who built buildings from modular designs, several educational administrators, a half dozen authorities in the field of building research and particularly building systems, state educational authorities, and representatives of federal agencies having large building programs. Of particular importance were contacts with the authors of "Modular Building Practice" and the Southwest Research Institute report "Development of Standard and Correlated Dimensions of Material Components in School Construction", and the former officers and officials of the Modular Building Standards Association.

Making the contacts and eliciting the expert opinions required several field trips including visits to New York, the Washington metropolitan area, Newport News and Virginia Beach, San Francisco, Los Angeles, and several communities in Pennsylvania.

Surveys: Some aspects of the attempt to contact expertise in a subject area were more systematized. For instance, all state education departments in the country were contacted to establish their individual interest in and promotion of modular coordination in school building. These contacts in turn led to a survey of a number of architects recommended by these departments who have been known for their work in the use of modular coordination. Another group of architects were contacted by mail to establish any change in their use of modular and their attitudes towards modular since the time of the MBSA survey in 1961. Finally, a survey questionnaire was sent out to building manufacture and equipment trade associations to solicit their interest and promotion of modular coordination in the design and manufacture of building materials, equipment, and case work.

METHODOLOGY

Consultant-reviewers: Since an important resource for this project was the SWRI report previously mentioned, a panel of five consultant-reviewers were retained to each independently review the report and relate its contents to the current status of modular coordination and this project. Together with the reviews by the two principle investigators, these seven independent opinions have been reflected at a number of points in the development of this report.

Student projects: Because this project was conducted within a school of architecture, it became the appropriate subject for several independent student investigations. A group of three senior students worked as a team to explore the various roles of industrialization in construction today, and one student then took the particular applications of modular coordination as his thesis topic. The interaction of the project staff and the students undertaking these projects was helpful in testing ideas and exploring concepts.

Draft report: At several stages in the development of the first draft of the final report, particularly knowledgeable people who had been contacted previously during the project were asked to review and comment on the drafts. Not only have these reviews been important for testing the accuracy of the information, but also in eliciting further opinions and information.

OE 6000 (REV. 9-66)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF EDUCATION

ERIC REPORT RESUME

ERIC ACCESSION NO.				
CLEARINGHOUSE ACCESSION NUMBER	RESUME DATE	P.A.	T.A.	IS DOCUMENT COPYRIGHTED? YES ☐ NO ☒
	6-12-67			ERIC REPRODUCTION RELEASE? YES ☒ NO ☐

TITLE

Modular Coordination and School Design - a state-of-the-art report to the architectural and educational professions

PERSONAL AUTHOR(S)

Koppes, Wayne F. - Green, Alan C.

INSTITUTION (SOURCE)

Rensselaer Polytechnic Institute, Troy, New York

SOURCE CODE

REPORT/SERIES NO.

OTHER SOURCE

SOURCE CODE

OTHER REPORT NO.

OTHER SOURCE

SOURCE CODE

OTHER REPORT NO.

PUB'L. DATE 30 May 1967 — CONTRACT/GRANT NUMBER OE-6-10-335

PAGINATION, ETC.

99

RETRIEVAL TERMS

Modular Coordination and planning
school planning, design and construction
assessment and evaluation of current status
implications and potential benefits

IDENTIFIERS

ABSTRACT

The objectives of the study were to determine the current status of modular coordination as an influence in building design, to investigate current attitudes on the part of the building fraternity towards the modular concept, and to evaluate its significance and merits, and its implications, in reference to the design of school buildings. These objectives were accomplished by conducting a literature search, contacts with knowledgeable persons, surveys, an invitational seminar, complementary graduate and undergraduate projects, and by retaining consultant-reviewers.

The validity, logic and merits of modular design are well established and widely accepted, and present trends in design and building technology point inevitably to its increasing use. The acceptance of modular coordination has progressed very slowly, if at all, during recent years. As the modular concept of design gains support, the use of modular coordination will probably also expand, but first there are inherent practical problems to be resolved, and progress, even if capable direction is provided, will undoubtedly be slow. The extent to which modular drafting is used will depend on the acceptance of modular coordination. Quite likely the graphic techniques now identified as modular drafting will not be widely used; a new vocabulary of computer symbols and language, not yet developed, will more likely be the communication medium. All of this must be actively promoted and demonstrated, and school buildings are highly appropriate for such demonstration.

INSTRUCTIONS FOR COMPLETING ERIC REPORT RESUME

The resume is used to identify summary data and information about each document acquired, processed, and stored within the ERIC system. In addition to serving as a permanent record of the document in the collection, the resume is also a means of dissemination. All fields of the form must be completed in the allotted spaces, but inapplicable fields should be left blank. The following instructions are keyed to the line numbers appearing in the left margin of the form:

TOP LINE. ERIC Accession No. Leave blank. A permanent ED number will be assigned to each resume and its corresponding document as they are processed into the ERIC system.

LINE 001. Clearinghouse Accession No. For use only by ERIC Clearinghouses. Enter the alpha code and 6-digit document number.
Resume Date. In numeric form, enter month, day, and year that resume is completed. *(Example: 07 14 66)*
P.A. Leave blank.
T.A. Leave blank.
Copyright. Check appropriate block to denote presence of copyrighted material within the document.
ERIC Reproduction Release. Check appropriate block to indicate that ERIC has permission to reproduce the document and its resume form.

LINES 100–103. Title. Enter the complete document title, including subtitles if they add significant information. Where applicable, also enter volume number or part number, and the type of document *(Final Report, Interim Report, Thesis, etc.)*.

LINE 200. Personal Author(s). Enter personal author(s), last name first. *(Example: Doe, John J.)* If two authors are given, enter both. *(Example: Doe, John J. Smith, Ted)*. If there are three or more authors, list only one followed by "and others."

LINE 300. Institution *(Source)*. Enter the name of the organization which originated the report. Include the address *(city and State)* and the subordinate unit of the organization. *(Example: Harvard Univ., Cambridge, Mass., School of Education.)*
Source Code. Leave blank.

LINE 310. Report/Series No. Enter any unique number assigned to the document by the institutional source. *(Example: SC-1234)*

LINE 320. Other Source. Use only when a second source is associated with the document. Follow instructions for Line 300 above.
Source Code. Leave blank.

LINE 330. Other Report No. Enter document number assigned by the second source.

LINE 340. Other Source. Use only when a third source is associated with the document. Follow instructions for Line 300 above.
Source Code. Leave blank.

LINE 350. Other Report No. Enter document number assigned by the third source.

LINE 400. Publication Date. Enter the day, month, and year of the document. *(Example: 12 Jun 66)*
Contract/Grant Number. Applicable only for documents generated from research sponsored by the U.S. Office of Education. Enter appropriate contract or grant number and its prefix. *(Example: OEC-1-6-061234-0033)*

LINES 500–501. Pagination, etc. Enter the total number of pages of the document, including illustrations and appendixes. *(Example: 115p.)* USE THIS SPACE FOR ADDITIONAL INFORMATION PERTINENT TO THE DOCUMENT, such as publisher, journal citation, and other contract numbers.

LINES 600–606. Retrieval Terms. Enter the important subject terms *(descriptors)* which, taken as a group, adequately describe the contents of the document.

LINE 607. Identifiers. Enter any additional important terms, more specific than descriptors, such as trade names, equipment model names and numbers, organization and project names, discussed in the document.

LINES 800–822. Abstract. Enter an informative abstract of the document. Its style and content must be suitable for public announcement and dissemination.