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MODULAR MEASUREMENT IN 1971

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Modular measure, a system of dimensioning, has saved money for the architects and engineers responsible for the design of buildings, the contractors who erect them, and the school boards, parishes, industries, and banks who finance the building projects. The savings can be proven where modular measure has been used in the design and production of drawings for the buildings.

Measurement and dimensional disciplines for building construction have been with us for many centuries. For example, Michaelangelo's capitol at Rome was designed using the proportional method of the right triangle, used later by LeCorbusier. Analysis of many classical buildings by Wolfflin and Hambidge have indicated that practically every building of recognizable esthetic values had mathematical disciplines in its erection. Probably the most famous of these is the Parthenon, analyzed by J. Hambidge in his treatise "The Parthenon and other Greek Temples—Their Dynamic Symmetry," published by Yale University Press in 1924.

The concern, however, of this paper is with a different aspect of building measurement, that is, making all building components fit each other so that they can be joined at the site of construction with a minimum of cutting and fitting. The paper also will attempt to make it possible to dimension all building plans to incorporate materials conforming to this modular measure. Historically, the first suggestion of a feasible way to introduce economies into building technology by coordinating the dimensions of building materials and products was introduced by Frederick G. Heath in his master's thesis at the University of Washington, in which he suggested a means of coordinating masonry units. Albert Farwell Bemis of Boston and Ernest Flagg of New York independently studied the problem of modular coordination. Flagg's work was mostly related to the rational relationship of architectural design, while Bemis studied modular principles as a means of reducing housing cost. Bemis, an M.I.T. graduate and a wealthy industrialist, was able to publish a comprehensive three-volume treatise, documenting his exhaustive investigation before his untimely death in an automobile accident. His work was the real start of modular coordination. The treatise was published in 1921. A modular service association was established in 1936 to develop the method further, and in 1938 the American Institute of Architects and Producers Council sponsored a project under the American Standards Association to develop and incorporate dimensional standards for 19 categories of building materials. The object was to work out standard sizes acceptable to the construction industry and to be some multiple of four inches including the space needed for joints. In 1945 American Standard A62.1 was adopted. It was entitled "American Standard Basis for the Coordination of Dimensions of Building Materials and Equipment." There is no doubt that this is one of the most far-reaching standards ever published by ASA. The industry personnel involved in the development of the standard spent seven years in the process of exploring, evaluating, debating, and finally acquiring consensus on the proposed standard. Even though this standard now appears to be ultra-simple, when stating, "The Standard Module shall be a unit of four inches," and, "The basis for the dimensional coordination shall be a standard grid based on a module four inches," it did result in tremendous changes in production, inventory, and marketing of almost every building material.

Hundreds of architects, engineers and manufacturers adopted the standard but continually ran into road blocks. In some sections of the country modular materials were not available to architects who wanted to use them, and, in others, manufacturers could not sell modular products to architects still designing non-modular buildings.

In 1957, the Modular Building Standard Association was formed with financial support from the American Institute of Architects, Structural Clay Products Association, the Producers Council, Associated General Contractors, National Association of Home Builders, a group of Architectural firms including C. E. Silling and Associates, of Charlestown, W.Va., Nollen and Swinburne of Philadelphia, Pa., Aeck and Associates of Atlanta, Ga., and dozens of others. It is extremely difficult to give credit to all of the organizations and individuals who contributed to the growth of modular dimensioning. From the Federal government were the General Services Administration, Housing and Home Finance Agency, the Department of Navy—Bureau of Yards and Docks; Department of Air Force—Directorate of Civil Engineering; Department of Army—Office of Chief of Engineers; Coast Guard—Design Branch; Federal Aviation Agency; Federal Housing Administration and the National Organizations of practically every building operation, product, industry, contract, engineering, and design membership. Credit must be given to Byron C. Bloomfield, who, as executive director of Modular Building Standards Association, guided it through the critical years when the system attained its maximum growth and set up the present availability of materials. Professor Bloomfield has been heading the Graduate School of Environmental Design at the University of Wisconsin.

Modular dimensioning was used on average of 12 percent of all projects in these formative years. The midwest was considerably ahead of the rest of the country in acceptance using the production of modular face brick in October of 1959 as an indicator. In dollar volume of construction the midwest was considerably ahead also. In 1961, under the auspices of the Industrial Education Institute, Modular Building Standards Association initiated a series of Seminars throughout the United States. These Seminars were continued by M.B.S.A., itself, after the first several series were held.

Professor Melvin W. Isenberg, professional engineer and Professor of Architectural Engineering at the Pennsylvania State University, and I were selected to conduct the seminar training sessions in 19 cities. Sessions were held in the north central area cities of Detroit, Cleveland, Milwaukee, Chicago, and Omaha. On the west coast seminars were conducted in Seattle, San Francisco, and Los Angeles; through the south in Dallas, Houston, Miami, Atlanta, and Raleigh, N.C. In the east sessions were held in Boston, Syracuse, New York City, Philadelphia, Pittsburgh, and Washington. Short sessions and luncheon meetings were conducted in dozens of other cities. Mel Isenberg, who died last year, was one of the world's outstanding teachers. He probably converted more architectural firms to this system personally than anyone else. It is regrettable that his inspiring efforts cannot be continued.

The modular movements spread to many European countries, Canada, and Australia. The primary sparkplug in Canada was Stanley R. Kent, professor at the University of Toronto, who set up a modular drafting manual for the Division of Building Research of the Canadian National Research Council in 1961.

After the seminars conducted throughout the United States, most of the supporting agencies felt that information had been adequately disseminated and reduced their support, but maintained supplies of literature for architects and engineers for several years. The final sales and teaching effort was a book entitled, *Modular Practice,* prepared under a project grant from Educational Laboratories of New York, and put together by a 30-man team headed by Robert P. Darlington, A.I.A., as chief editor, Melvin W. Isenberg, P.E., and David A. Pierce, A.I.A., a Columbus, Ohio, architect, now a professor at Columbus Technical Institute.

From that auspicious beginning and distinguished history one might suppose that every architectural and engineering firm in the country would be using this system and time could be spent reminiscing on how things were done in olden times. This wasn't exactly the case. Modular Building Standards Association ran out of funds and was phased out long before its work was completed. In fact, it was unable to lend cohesive assistance in the complex problems that we have today in our large-scale structures. For example, a lighting fixture manufacturer trying to design a group of fixtures which would be interchangeable for many types of construction and easily warehoused, was faced with problems. First, he had to design a fixture with a sufficient joint allowance to fit into acousticals, plaster, and other types of ceilings with a wide variety of suspension systems. He examined the suspension systems and found concealed systems for metal lath, sheathing, H runners, J, C and Z splines, inverted tees, snap bars, and radiant coils on the market as adjacent materials or substrates, along with semi-exposed systems of tees, splines and various panels, and exposed inverted tees. Each of these required some different specific equipment, of ceiling flanges, plaster rings, and even the construction of the troffer itself in order to fit into these ceiling systems. To add to the complexity he planned on using seven different diffusers or glare shields under the fixture, and to manufacture it in 12- and 24-inch widths for two-, three- and four-tube fluorescents. When we multiply all of these variables out, over 1,200 different fixtures would have been necessary in order to satisfy all conditions, severely complicating warehousing. Many manufacturers had to work out these details for themselves with no agency to coordinate their solutions. As a result, many products supposedly designed, manufactured, and marketed for modular coordination have disappeared due to lack of demand: plaster polyester and wood screens, "package" modular random stone, 2-4-1 plywood construction, although variations of 2-4-1 are still available. Other products have disappeared from the market because the materials themselves became antiquated, such as ornamental glass block, and then of course there are others we *hope will disappear!* There are, however, thousands of materials on the market now available which conform precisely to modular dimensioning, erect with a minimum of cutting and fitting, including some on the market since 1960.

Why hasn't the modular system been followed by architectural offices if it was so simple, so easy and so available? The answer had to be determined from casual conversations with architects throughout the country, as M.B.S.A. was out of existence and no funds were available for a national survey. Most individuals contacted, however, seemed to have approximately the same story. The prosperity of our economy, and the resulting mobility of architectural personnel have created great problems of education for new personnel coming into any office. My own office, for example, a small one, has never had more than 11 architectural employees and generally averages about six in each of our two offices, Syracuse and Gouverneur, N.Y. We have an alumni list of 55 and we're faced with the same mobility of personnel being reported in all sections of the country. As one architect stated, "We found we had to teach it all over again every six months in our office and finally gave up." Most offices still follow the basic principles. As a matter of fact, they really must, in order to use modern materials, but they can do more and save more by a closer adherence to the system. The advantages found eight to 10 years ago still hold true:

1. Almost total absence of dimensional errors on drawings and on the job.
2. Simplified detailing, reducing production costs because materials fit together much easier.
3. Far simpler additions and extensions of older structures because the module of dimension can be extended.
4. Greater standardization of details is possible.

Our own firm is still using the system in a special way described later. Having taught the system to 600 architects and engineers at seminars, to over 200 undergraduates in the School of Architecture at Syracuse University, and about 40 more in my own office, changing back would seem hypocritical.

The next question is "What is modular measure?" The "Modular Measure" is to dimension or design a space into which a unit of material, a concrete block, a door and frame assembly, a light fixture, a unit of partition, or a cabinet can be placed. Essentially the nominal size of the material should include a joint or tolerance for installation, thus the drawings define the space or to the center of the joints, not the actual face or edge of the material. In practice it is far simpler to dimension the nominal size of many materials than the actual; a common wood stud for a house is called a 2 by 4, its nominal size, much simpler than its actual dimension of somewhere between an inch and one-half and an inch and five-eighths by three and one-half inches.

Some effort must be made to make all possible dimensions a multiple of 4 inches. This effort, however, is not just for plans or elevations or a section in dimension, but a special concept wherein all dimensions defining a space or subdividing it and all of the components of the space are defined by the basic 4-inch by 4-inch module. Essentially it is thinking of our buildings as a modular volume, a cubical concept. For a long time the products that fit this system were defined by a special trademark. Most modular products can be identified even without the trademark. The 4-inch module was selected because it seemed to be the smallest acceptable increment of materials that would fit many existing products and methods and be a sound base for the thousands of materials to come. It was close to the sizes of concrete blocks and bricks, exactly right for glass blocks, acoustical tiles, plywood, wall board sheets, and wood stud spacing. Three of the 4-inch modules made a foot of space and dimensions could easily be checked.

All of you have encountered the elderly carpenter with out-of-date bifocals, measuring with a questionable folding rule to a sixteenth of an inch that he couldn't see because of the sawdust on his glasses. Obviously, a minutely divided rule or tape cannot guarantee accuracy. With tapes and rules having only three markings per foot and modular coordination we could obtain greater accuracy.

It might be interesting to note that wall board sizes, plywood sizes, and wood stud spacings derived from cutting wood laths for plastering from scrap or firewood that had been cut to the old English cord of wood, size 4 feet, then recut. Stud spacings were set at 12 inches or 16 inches to fit the laths.

Plywood and wall boards evolved to fit the stud spacings. The metric measurement used in many European countries is the 10 centimeter module, almost identical to 4 inches. All of the foot-inch countries such as England, Canada, and Australia used the 4-inch module. Materials, however, can be shipped from one country to the other and will generally fit satisfactorily.

The modular system alone makes the change to metric measure not easy but tolerable.

Measuring in all directions, horizontally and vertically, an imaginary grid of modules can be formed, usually called a planning grid. The module in itself can be any dimension divisible by 4 inches: viz, 8 inches, 1 foot, 4 feet, 2 feet 8 inches, 20 feet, 16 inches, any 4-inch multiple whatsoever, will do. The idea is simply to make it easier for the draftsman. This grid will assist in locating walls, partitions, furnishings, doors, or any element in the plan. In elevation it can so locate doors, window openings, solar screens, curtain walls, roof lines to reduce or eliminate cutting in the materials assembly. By the use of the planning grid and modular dimensions a saving is made by the architect who can produce simpler drawings with fewer drafting errors, clearer detailing and gain faster production.

Bill Markham, associate of the firm of C. E. Silling and Associates in Charlestown, W. Va., summed up their experience with the statement, "We have found that working drawings with modular measure cut total man hours approximately 15 to 25 percent on any job. This speed enabled us to get plans and elevations to our mechanical and structural engineers soon after the job started." Cy Silling credited modular methods in helping him produce 20 million a year of college buildings and hospitals with only six architectural draftsmen!

Dozens of contractors have made statements on profits and benefits on the job, reducing the job labor of cutting and fitting, less waste material, faster scheduling, closer estimating and improved construction quality. At one time, the Pennsylvania State Legislature considered modular dimensioning so important a financial saving that laws were passed requiring all public schools to be dimensioned by this method. Many governmental bodies have ranged from endorsing the method to requiring plans to be so prepared. The Veterans Administration, the Corps of Engineers, U.S. Army, were among the latter. The 85th Congress of the United States under HR-6659 which became public law 85-104 on public housing required modular measure in Section 401 on Low Rent Housing Buildings.

Architects select materials from an estimated 30 to 50 thousand different products, not counting variations in size, finish, or color. Several hundred of the items are needed for every specific new building. In a typical building of 1960, a study would quickly identify the dimensional problems facing the architect in his selection of materials and manufacturers. The various types of units, assemblies, and components were practically always supplied by different producers. Each product had attained its own dimensional characteristics as a result of the production interests of a particular trade or segment of the construction industry. Few products were sized to fit other products. Most were sized primarily to compete on an alternate basis with the same items supplied by other manufacturers. Due to their dimensional variations the materials which surrounded dimensioned components could have no fixed dimensions. For example, it was usually necessary to vary the width of piers between stock windows. Door and window heights could seldom be related to each other. Dimensional units such as masonry had to be cut to fit between building elements. Appliance and equipment items bore no dimensional characteristics similar to the building itself, and so on throughout the building. Prior to the availability of the modular materials, the architect normally would have had to review the catalogs of several manufacturers before finding the size he needed for his specific project. If five different manufacturers produced dimensionally different product lines, the architect had to select the one which most nearly satisfied his dimensional needs. By doing so he might necessarily by-pass a more durable or better designed product simply because his dimensions could not be coordinated in the project.

The window industry was one of the first to produce its products in modular sizes. That is, in multiples of 4 inches including the installation joint on either side. This dimensional increment of 4 inches was established through ASA procedures immediately following World War II. The current dimension of steel and aluminum stock sash of 3′-4⅞″, 4′-0⅞″, etc. was derived from the manufacturers using their old standard steel mullion which had a 3⅛″ width dimension, obviously one sash and a mullion became a multiple of 4 inches as long as the sash was ⅞th of an inch more than an even module, to make up for the mullion. This questionable solution has resulted in the joint between the end of a sashrun and the masonry as being 7⁄16ths on either side. Architects can ignore the problem by dimensioning masonry openings to the nominal center of joint, such as 8 foot 4 inches, 10 foot 8 inches, etc. leaving for the contractor fitting the masonry to the sash. Strangely enough we never had any difficulties. We were deliberately trying to be a test case.

With the modular system in which all products are produced in multiples of 4 inches, the architect is free to select any one of a number of manufacturers and know that his products will fit dimensionally with other items in the project.

Joining methods are worked out by the manufacturer to allow clearances for erection, tolerances for expansion and contraction, and effective joint closures. The architect then needs only to concentrate on the center to center of joint for each component which he knows will always be a multiple of 4 inches. This known consistency of product dimensions then allows accurate preliminary study for any specific project. Horizontal and vertical coordinates are multiples of 4 inches upon which each project item is graphically centered.

ASA standard A62.1 did not do everything. A tremendous amount of pressure by hundreds of architects and engineers was necessary to convince manufacturers that their best interests were served by producing their products in modular coordinated units.

Designing for modular construction generally employs a planning grid. This grid must be some multiple of 4 inches. The planning grid dimensions are selected by the designer as the optimum to fit the program and planning needs of his particular project.

Most manufacturers produce their larger items in a range of multiples of 4 inches to satisfy varying design needs. The natural selection process controls a number of sizes, stocked by manufacturers of large components to provide an adequate selection for architects. Similar items such as masonry units build-up in three directions to multiples of 4 inches. Some units such as mosaic tile may be only one inch center to center of joints and add to modular increments. Other modular units require a number of courses to equal 8 inches. Most architectural offices have used this increment as a standard for five to ten years. Sections have definite modular characteristics in profile and are usually modular in a limited range of standard lengths. They are easily cut to other modular lengths with a minimum of waste since the remaining piece is also modular in length. This would include sheet materials, corrugated materials, tubes, channels, and many others. Assemblies such as lighting troffers, door and frame assemblies, and partitions are normally produced in the factory as finished items completely compatible with a range of potentially adjacent modular material.

Concrete block manufacturers may have been the very first group of producers to actually convert to modular production. The "pre-modular" standard block was a full 8 inches by 8 inches by 16 inches. To make it modular an increment representing one half of a mortar joint was subtracted from all sides yielding a product which could be installed 16 inches on center lengthwise and 8 inches on the center vertically. The modular block acquired an immediate advantage since it could turn corners without clipping to maintain a uniform face and could be used in conjunction with other modular masonry materials to build up desired construction details. For some reason that escapes proper documentation by architectural historians, my own home city of Syracuse has adopted a standard of 7⅝ths by 7⅝ths by 17⅝ths. It may have been to get a slight additional amount of work out of the bricklayer, who normally has a built-in work-stress computer to prevent such overwork, or it may have been to simplify work for estimators as the face area of a block is exactly one square foot. In any case there is utterly no way of turning a corner with an 18-inch nominal block in Syracuse without clipping somewhere.

Modular blocks have a simple vertical and horizontal relationship to grid lines 4 inches on center. Only for purposes of illustration is the dimensional variation of approximately 3/16ths between the face of the block and the grid line ever shown. In actual practice, reference to the grid line without actually labeling the dimension would be sufficient since all modular blocks have the same dimensional characteristics allowing for a half joint at each face.

A component is the term applied to any building material manufactured in a form for which certain dimensions are specified. A component may be a unit, a section, or an assembly. A special diagram has been developed for manufacturing nomenclature purposes in sizing modular components. The manufacturer dimension must allow sufficient tolerance in manufacturing and for installation within the limits of desirable minimum and maximum joints for the component. In all cases the fixed dimension of the grid lines govern the sum of manufacturer dimension and the joint. Maximum and minimum joints must be predetermined by the manufacturer or groups of manufacturers through testing and proving experience. The architect does not normally concern himself with these exact manufacturer requirements except in the specification stage when such inclusion may be appropriate. Seldom then does he specify it. He may refer to weather tightness of joint, "dimensional creep" or other performance requirements rather than detailed requirements for sizes of the delivered products. He may include maximums and minimums in masonry specifications in order to assure desired joint sizes. Generally this is not necessary and the only requirement now is to specify modular size or in accordance with modular measure.

Joining a modular component with other modular components can illustrate the basic principle and theory of modular construction. In examples of the modular components, doors and frames can be combined with other different types of components. The exterior limits of the frame are related to modular plane in such a manner as to allow installation clearance and joint. This clearance away from the grid line is constant for the door frame and must be maintained by the manufacturer of this stock modular component. By virtue of being modular the assembly may be fitted into any modular detail with consistent dimensions and by the addition of the simple cover plate or closure item which can normally be supplied with the assembly. You might imagine just for illustration purposes that the wall is laid up solidly and the masonry units representing the door opening have been removed. Such removal would leave one half masonry joint clearance around the entire opening allowing adequate clearance for door assembly installation. In height, 7-foot-2-inch doors and 4-inch head frames to permit use of a 7-foot door have been available for some years. Either one of these will fit a 7-foot-4-inch masonry modular opening.

Since all modular materials are sized in increments of 4 inches including their joints, delineation of construction details involves the relationship of the materials to grid lines. Clearances between the grid and the actual face of the masonry are identified just for purposes of illustration. It would not be necessary to identify these actual clearances on working drawings. It is readily understood and is an accepted practice that one-half typical joint is normal clearance for modular materials. Therefore, in most room dimensions and other dimensions start or terminate at a grid line, normally leaving overall dimensions completely free of fractions and using a multiple of 4 inches. One of the best methods of expression of modular dimensioning is, any dimension to a grid line has an arrow, any dimension to any portion of the structure off of a grid line is a dot.

Most firms starting out in modular dimensioning have used a simple decal placed on the drawings for information of the contractor building the building so that he can understand the convention of arrows and dots, and to show arrow dimensions to a grid line inside of which the material is placed with its joint clearance, dots dimensioned to any point that is off a grid line. One decal is a standard printed by Stampat. Some architectural firms have felt that a little more detail should be shown or that the method that they employ is slightly different than the standard modular method. These firms have special decals for basically masonry dimensioning. Others are basically for wood frame construction with the studs in the partition normally placed in between grid lines. A special was used by Sargent, Webster, Crenshaw and Folley in Syracuse, N.Y., in which they tried to save time on their projects by the use of a slash mark instead of the arrow head so that their decal was made showing this.

Now we can explain the part that our firm played in the modular dimensioning research program. We made a special case of modular dimensioning for some years. At no time did any decal of any kind ever appear on our drawings. At no time was there ever a contractor's job meeting held to explain the modular system. At no time did we ever volunteer any information to a contractor on what we really meant, showing grid lines as needed and the arrows, dots, and other conventions of the dimensioning system. As a matter of fact, I can only recall two questions in a period of 10 years, from a contractor or masonry sub asking confirmation as to how he had interpreted the drawings. Our trial balloon was quite successful. We didn't have any problems. Construction was more accurate than we ever had under any previous dimensioning system. Errors were eliminated both on the job and, of course, in the office. We didn't eliminate all mistakes but at least we eliminated the ones associated with dimensions and without a single word of explanation necessary on the project. Consider the plan expression of a corner in cavity all construction for both 10- and 12-inch walls. A 1-inch cavity was used for many years prior to modular dimensioning. Due to modular dimensioning, the cavity has been opened to a 2-inch nominal space, actually 2⅜ths inches, which gives far more room either to place insulation or to keep the cavity clean and provide better walls, fewer mortar bridges across the cavity and simplified dimensioning. All bonuses from modular coordination. The 4-inch back-up in a 10-inch cavity wall is placed straddle a grid line. The fraction of an inch or the half joint off the grid line that the back-up is placed cannot measurably affect most room sizes.

The same half-joint principle is followed whether in plan or vertical section. Some modular materials are not always increments of 4 inches in themselves. Three courses of brick are normally required to occupy two vertical grid spaces. Either standard brick or modular brick can be used and expressed as three courses equal 8 inches. Most architects are using this convention now, and haven't had any problems.

The only question that might come up, however, is how do we add to an older building not modular. The modular grid is used on horizontal plan and ignored vertically, where it cannot be used. A few difficulties arise on door and window openings in vertical dimensioning, but adjustments with closure angles at the door heads and stone sills, cut to fit, at windows overcome the problems. Modular dimensioning saves time and eliminates plan errors.

Detailing the installation of modular components requires consideration of joint characteristics as related to the grid lines.

A modular metal window is sized to provide a flange extending beyond the "grid opening" as means of weatherproofing the installation. On most steel and aluminum sash the dimension representing the actual grid opening seldom corresponds to any identifiable physical point on the extrusion or section. The manufacturer characteristically extends the flanges beyond the grid on either side to provide a lip which can be buried in the vertical mortar joint or to provide a weatherstop at the contact with adjacent material. Usually the window is set in place before the side masonry is laid. In other cases a modular window sash may be installed after the masonry opening has been completed. Modular windows, whether they are wood, steel or aluminum, double hung or regardless of how they operate, have one characteristic in common, they are all sized and detailed in reference to the grid lines at each jamb and can be used singularly or combinations with the same relationship to the grid in every case.

Through the use of modular dimensioning it is possible to produce a fully dimensioned plan even though some details have not been completely studied. Modular measure allows the draftsman to develop details independent of the stated basic plan dimensions. In residential or frame construction some special considerations are involved. Placement of the line of studs between grid lines is a simple procedure for the builder. A carpenter can easily snap two chalk lines on a sub floor 4 inches apart. Placing the bottom plate for the partition between these grid lines is simple and can be done to an accuracy of a 32nd of an inch. There is no need, then, to display any fractions of an inch in dimensioning wood frame. By placing the line of studs between grid lines at the exterior wall, consistency of multiples of 4 inches is maintained both inside and out. Sheathing for modular spacings of 4 feet, 2 feet and 16 inches can be easily installed with a minimum of cutting and waste. Similarly, interior dry wall finish materials are easily installed.

Maintaining modular increments between corners, window jambs, door jambs, etc., simplifies both dimensioning and construction.

The use of a large-scale planning grid is common for residential work. Repetitive spacing of roof trusses or floor joists evaluated against the dimensional characteristics of interior modular finished materials may determine whether end walls should fall on the inside or outside of the planning grid. At the present time the inside grid is more frequently used.

The floor grid serves to establish vertical reference for a large-scale detail. Horizontally, the grid line at the face of the masonry foundation completes the orientation. The architect will start his detail with these two reference lines and generate the detail around them. In many cases dimensions are not required for a detail since a full grid is shown. Some architects like to show only the two principal grid references and omit the rest of the grid. Indeed, there is a tendency on the part of many draftsmen, starting out in modular dimensioning, to overload the drawings with grids which serve no purpose other than their own education.

Brick veneer construction can be simplified by modular dimensioning.

A section cut through a portion of an exterior wall often places the masonry veneer between two grid lines, leaving the stud wall to be centered on the next grid line. The resulting air space, although somewhat larger than formerly used in a veneered wall, has advantages over the smaller space in eliminating mortar bridges, improving moistureproofing and eliminating many of the problems that come from warped brick and crooked studs.

Since a grid line, then, occurs in the center line of the exterior wall studs, the locating and dimensioning of interior wood partitions is greatly simplified by using center line references throughout or to the outside face of the masonry measuring from the outside face of the foundation wall or erecting a few courses of brick up to rough floor height for measurement purposes. Many prefer not to dimension to the center line of any partition, as it is difficult for a lather, carpenter, or mason to accurately locate a partition if he places his bottom channel, plate, or block on his line, obliterating it. Accurate locations result from snapping two lines on the floor or a single line on one side of the partition.

One of the most direct applications of modular measure occurs in curtain wall construction. The simplified jointing principles are a basic premise of modular construction and modular drafting.

Fundamental responsibility of the architect is only to locate the center line of joints. The curtain wall manufacturer is responsible for establishing joint clearances, tolerances, and expansion or contraction control for his panel. By locating panel joints on grid lines a more economical and consistent construction results. The dimensional coordination of adjacent material is greatly simplified for all suppliers. Ceiling, flooring, decking, and partitions are dimensionally inter-related to the curtain wall. Two possible locations on a curtain wall assembly can be considered as the joint. Some materials, small in dimension, obviously have the center line of mullion as a joint between adjacent panels.

Even with larger mullion, the joint can be placed at the center of the mullion. A slightly different concept considers the mullion itself a 4-inch panel with the grid lines falling at the joint between the panel and the mullion. This method is particularly useful when interior partitions terminate at a curtain wall mullion and assist dimensioning aluminum or steel sash located directly above and below the spandrel panels. The details of the curtain wall construction themselves will determine the dimensioning of sills, floor intersections, and termination at the upper stories of the building.

We have five basic principles to follow for modular drafting.

Rule 1: Make use of one or more design modules in laying out the building. Just make sure they are a multiple of 4 inches. Any 4-inch multiple will do. The idea is simply to make it easier for the draftsman to convert preliminary sketches into scale drawings dimensioned in multiples of the 4 inches.

Rule 2: A detail begins with the grid lines, principally, to orient the detail and coordinate it with the plan. Only by knowing where the grid line is can the detail be accurately located, making it unnecessary to go into much detail in the plan itself. The use of the grid varies widely from one office to the other. Some use an underlay showing the grid which is useful as a guide in the detailing. Others put the grid lines in the back of the sheet. As I mentioned before there is a great tendency to use too many grid lines, far beyond those necessary for orienting the detail. Small scale drawings do not need the grid. They are generally too small to show it anyway.

Rule 3: On small scale layout drawings such as plans, building sections, elevations, give nominal or grid dimensions. The grid is still there even if it is invisible when the building is drawn at scales of 1/16-inch, 1/8-inch or even 1/4-inch scale. Use the arrow at one end of the dimension line and an arrow at the other end with a multiple of 4 inches as the dimension. Six-inch stud partitions and 10-inch cavity walls can be used. It is easier to dimension to only one side of such non-modular products.

Rule 4: Dots and arrows at the end of the dimension lines have definite significance on modular drawings. This results from the fact you do not show the 4-inch modular grid on small scale plans, sections, and elevations. In referring back and forth from one to the other, it is important to know exactly where any particular detail fits into the building as a whole. The modular grid makes this clear and simple even when the same detail occurs at several different locations. On this particular detail particular reference lines or grids are the outside of masonry and finish floor line. This rule requires that when dimensions are taken to a grid line indicated by an arrow but where dimension line terminates off the grid, a dot should be used instead.

Rule 5: Vertical dimensions are coordinated by modular dimensioning which fixes floor heights. The actual location of the grid line reference line is the architect's option. In wood frame construction, the top of the sub-floor or slab-on-ground coincides with the grid line. In structurally framed buildings the grid line can be at finish floor or at the top of structural slab or at other points designated. Application of these rules, however, will not place any limits in the actual design of your buildings. Really, just simplify it.

Basically we start with a coordinated volume such as a house plan, using a grid of some size in planning that we have determined. As a matter of fact we can combine several grids if we so desire in a pattern, creating a varying grid or rhythm in the design. Once we determine this grid we use it on our elevation sketches as well as plan sketches as a means of coordination which will be used in the working drawings. To complete this picture, we try to use this modular dimensioning as much as possible in foundations and even in concealed items. Many engineers have used a 3-inch module for increments in footing sizes. A change to 4-inch increments can be made quite easily without detriment to the integrity of the structure and will simplify dimensions. Foundations and footings can step to conform to variations in grade or in soil conditions, modular dimensions for vertical coordination should be used, however, to simplify the drawings. The savings are in simplification and we can only get the simplification by continuing it in all items.

A great many differences in foundations can be used with modular coordination still applying. The simplest of these is a wood frame on concrete block foundation used in most residential construction or perhaps bearing wall masonry with structural slabs. The grid line indicates where plan dimensions will come. In all cases 4-inch increments establish the location of the outside of the walls and the floor lines to simplify our details. Termite block and tapered foundation tops can be coordinated just as easily if there exists a 4-inch taper from top of block to floor line. The cavity wall with slab-on-grade for many simple buildings has the grid line defining the exterior of the masonry and the top of the slab.

It is possible to offset the foundation itself to achieve a shadow line at the top, a clean line for the start of masonry. The grid remains at the masonry dimension line; thus the foundation overall dimensions are precisely the same as first floor. At the corner of the foundation plan can be indicated the dimensional offset to the actual face of the wall, if desired, or the offset can be explained on a wall section and would not have to appear on the plan at all. We have tried both methods on drawings and found both successful.

Completely different problems face us when trying to establish the grid line or reference point vertically for cornices and floor levels. A criteria that we have found to work out best is merely to establish vertical references. When it occurs at the roof line or at the floor of an intermediate story, we have found the top of the main structural element to be the most favorable grid point. For a poured-in-place slab and the beam system, the top of the rough slab seems to be the most favorable point. For precast double tees or precast elements, whether they are supported on walls or on framing members, the top of the double-tee slab has been used most successfully as a point of reference; thus we have established this point as the grid line.

Where precast structural decks have been used such as Dox Plank, Flexicore, Stresscrete, or similar, the top of the slab has been our plane of reference and, therefore, established as the grid at the highest point of the building. Insulation, roofing, and other items can be installed with reference to this particular line. When structural steel is used in conjunction with bar joists, the top of the bar joist, which is also the top of secondary struts between joists supporting and bracing columns, has been the grid line and the plane of reference. In the case of steel decks regardless of type, we have used the top of the steel frame as the point of reference and established it as our top grid in the building.

Some modular principles can be more easily realized from looking at the structural elements themselves. For example, in steel frame with steel joists over the top of the frame, the most important structural element, in place, from which we can measure is the top of the steel joists. It is the top of a solid structural element, and deck thicknesses may vary depending on span and manufacture but will not disturb the integrity of our building. The top of joists, therefore, is the highest grid. In buildings where a combination of steel and bar joists are used with part of the structural system supported on steel beams and parts supported on steel joists, we would use the steel where it is supporting light slabs, Coroform or similar elements, the top of the steel joist where that occurs.

The top of steel on an intermediate floor framed into this light column is the grid point and simple dimension point for determining the floor of an intermediate story.

On these principles, where long span deck frame is placed over steel, the top of steel is the grid; in the case of joists the top of the steel joists, in the case of precast deck the top of the precast deck. If these structural elements are located in the right place it is pretty difficult to get the rest of the frame or finishes in the building in a wrong place.

Structural plans of a building can be simplified by modular dimensions from column to column, beam to beam. The arrow and dot convention should be used here just as well as on architectural plans to simplify dimensioning throughout the entire structure.

It is possible, by modular methods, to turn a normal wall section into a building section diagram. It becomes more of a cross section of location for details and can be done in smaller scale simplifying procedures and reducing costs. It gives really more information and permits detailing key points locating them quite easily by means of the grid. Curved, bevelled or facetted precast concrete panels may vary in dimensions widely. It would be ludicrous to try to dimension to the face of such panels because it would be impossible to know at which point we were actually measuring. The important point is the structural grid of the building and it is easy to measure from this grid to the back of the panel where the elements are structurally supported to cover the exterior of the building. Wide variations can be displayed in the panels themselves. In such a case the outside building line is really a nonentity, varying widely. Therefore, in dimensioning to a structural grid we establish the back of the panels as the item of primary interest and support. These are of reference to the grid line. Once the structural steel is in place we have a definite reference in the field to measure from to locate all other elements.

It isn't always that the structure or column in itself is the most important point in a building. Perhaps the integrity of the masonry, the necessity of placing it with as little cutting as possible is more important than the center line of a column. A concrete column, then, is centered between grid lines and oriented to fit the masonry. In other cases the center line of the concrete column may coincide precisely with the grid line and might be the most important element in the building. From the center line in such a column we would locate all other elements to fit the building with a minimum of cutting and fitting. Therefore, each architect has a choice, to locate the structural grid by means of the modular grid or locate masonry, whichever is most important in the building. The modular coordination method is used as a tool to help rather than as a slavish discipline to which he must conform.

It would be possible to lay out all structural elements to fit precisely in the grid. But this isn't really as important as locating the items which are to be fitted together on the job site so that their sizes, including the necessary dimension for putting the joint together, are modular in their overall dimensions whether height, width, thickness or whatever.

Early in the modular process, the installation of hollow-metal doors and frames became a primary concern. Perhaps it was because this industry worried MDSA more than any other and sent in preliminary sketches and ideas. If we located a grid at or near finish floor line and used concrete blocks or similar structural elements for our partition or wall construction, obviously, a joint came at 6 feet 8 inches above the floor, 7 feet 4 inches and 8 feet. The only way we could use a 6-foot-8 door was to drop the masonry down between the integral casings of the frame, and we had to have the joint tolerance to get it in place. This method worked out reasonably well in most partitions, although there had to be some gap between the back of the casing and the wall in order to get the wall in place. Or a multiple thickness wall or multiple wide wall a rather ugly gap resulted at the top of the casing on the inside under a raised elevated lintel. This gap could only be closed with an extra angle or caulking compound or similar poor details. The only choice was to slide the frame inside the opening, but it forced us to use a 7-foot-2 inch door with a 2-inch casing to make a modular opening 7 feet 4 inches in height or we could use a 7-foot door with a 4-inch head casing to make the same dimension. Obviously this head didn't match the jamb and took a little time for us to accept its appearance as normal.

There are dozens of other details that may prove troublesome and many that remain a problem until we have examined basic principles. Basically the grid should define the major structural elements of a building so that all the other materials could be hung on the building, on top, along side of, against, and be forced to be in the right place because the basic grid was correct. The second principle we need to remember is that we are basically locating the center of the joint between two similar or dissimilar materials and the precise distance to each of two dissimilar materials may be different because the joint they require may be different.

The discussion to this point may have appeared as if brick was the only element in our buildings; however, in a great many the interior materials are just as important as the exterior; partitions dividing or defining interior spaces may constitute a large part of the program, particularly when adding to or remodelling a building.

Ideally, dimensioning of partitions would have the two nominal faces of the partition located on grid lines, modular dimensions between partitions and the next partition defined by grid lines as well. These grid lines could be the points on the floor where a carpenter or lather or other erector snapped chalk lines to locate the partition and then placed the bottom plate or angle or channel between the lines to locate the divider accurately.

In the case of a wood stud partition this works out neatly. Almost any carpenter can place the bottom plate of a partition between two snapped lines 4 inches apart quite accurately and to within the accuracy of almost a 32nd of an inch. As a matter of fact it wouldn't take much experience to accomplish this trick.

Partitions cannot always be located quite so nicely, however, and sometimes odd dimensions between them are required by cabinet work, equipment, special furniture, or operational clearance requirements, with modular partitions still being used. We would use the arrows where the grid coincides with our grid for the building and dots where the dimensions do not fall on the grid.

Many of our partitions do conform to this modular standards. To name just a few: the wood stud that we have mentioned before, steel stud partitions with the possibilities of many different finishes applied, where the stud can be a 3⅝-inch wire or 3¼-inch pressed steel stud. If the stud is located properly by putting it inside of a shoe and the bottom is located properly it is pretty hard for the plaster, hardboard, or whatever is used for finish to be in the wrong place.

We are using more frequently, however, thinner partitions in order to garner every inch of usable space in our buildings. The 2½-inch stud can easily be located with the edge of the shoe on a grid line and we can, therefore, dimension from the, let's say, left face one partition to the left face of another to the left face of a third always placing the edge of the bottom shoe at a single snapped chalk line on the rough slab, the grid line.

One method of locating partitions that are more than the module in thickness such as 6-inch and 8-inch partitions can be done by simply using the arrow and dot designation, standard for modular coordination. Adding dimensions can be quite a chore as far as the draftsman is concerned, however, trying to remember where the grid is and mentally adding dimensions all the way across the building. It's almost as bad as trying to keep track of fractions. As it is the avowed intention of modular coordination to ban fractions, we dimension from the left side of the first partition to the left side of the second partition. Arrows would be used in both places. Just below this dimension line we can locate the 6-inch thickness of the partition. What we are actually doing is locating the chalk line on the floor, the simple single measurement necessary to accurately locate these partitions.

If we examine a cross section of several additional partition types, such as a 4-inch clay tile masonry block and 6-inch block with terrazzo or built-up base, we locate one grid line on the left side of the masonry partition, in the normal place. One chalk line on the floor could locate the block just as easily as two lines. Similarly, solid plaster or gypsum core or solid gypsum partitions can be located by placing the bottom shoe on a grid line, the chalk line, and getting the partition precisely located. No fractions, no odd dimensions, just simplicity and accuracy.

A similar simple location procedure is possible with many makes of movable partitions which are made in modular sizes. From exterior walls or from a structural element we can space out modular panels to form the enclosure for banker-height or full-height office partitions.

Even materials that are normally not considered modular, such as random stone, precast concrete, precast polyester panels, all can be placed accurately and simplified in dimensioning if we consider what are important grid points or dimension points, on the building. When using stone over block masonry, the grid is at the floor line and the backside of the back-up precisely locating the detail. In working from these dimension points we find the face of stone and the floor line. We can quite accurately dimension a pocket for radiation or the location of door and sash elements that complete the details.

It is no more difficult to utilize the same simplicity of dimensions on our plot plans. In many instances we have slavishly copied the dimensions that a surveyor has given us, using feet and tenths or hundredths.

It's extremely difficult to provide a complete list of building types that have been successfully erected with modular dimensioning. Dormitories, hotels, office buildings, churches, schools, stores, garages, apartments, houses, have all been designed with modular coordination. They have ranged from cylindrical and round structures, single story, multi-story, sloping site, flat site, to arched, angled, and of any configuration. Regardless of type, they were simpler because of modular dimensioning. The first designed in our own office was a funeral home and residence for the funeral director in 1958. We have designed a variety of buildings since. Modular measure simplified the frame of a floating slab, Maintenance Garage for Fire Engines; it speeded a Skaneateles, N.Y., fire station and community center. It helped in a telephone equipment building at Kauneonga Lake, N.Y., and on more than 75 buildings for the New York Telephone Company. It helped us use 16th-scale plans successfully for a Convention Hall Addition to the Olympic Arena at Lake Placid, N.Y. It made possible the coordination of the entire ceiling system of partition supporting grid, light fixtures, and variable volume air diffusers in a Computer Center for Continental Telephone Company in Liverpool, N.Y. Modular coordination must be credited with helping substantially in the successful wedding of lighting, air conditioning, and variable partition locations in this heat conservation structure.

Sloping lines and staggered fronts haven't been a barrier in the design of a fire station for the City of Syracuse. As a matter of fact to show belief in the system it was used in the construction of a hunting camp near Hammondsport, N.Y., built with rough timber, cut at site, and built over a reinforced concrete diving bell foundation. The camp has four levels at 8, 12, 16, and 20 feet above the slab; the A frames are 4 feet on centers and the girts 2 feet on centers to accept plywood sheathing. The 2-foot spacing follows the slope. It was not vertical spacing, but it was simple.

Immense pressure had to be put on hundreds of manufacturers by the Modular Building Standard Association, the Building Research Institute, the National Academy of Science, the American Institute of Architects, Associated General Contractors, National Association of Home Builders, and hundreds of individual architects and engineers in order to obtain the multiplicity of modular products that we have today. An early one was cast metal screen work made by one manufacturer back in 1962, modular vertically and horizontally in assembly to simplify dimensions. A modular bathtub was actually produced for a time. All tubs are still modular in length; the other dimensions didn't seem quite as important. Price Brothers of Dayton, Ohio, in designing Flexicore originally, wound up with modular widths and were, of course, able to produce it like yard goods in practically any length. The 4-inch plank and the 8-inch were definitely modular products. The 6-inch worked equally well but did require some material cutting for its installation. Later precast and prestressed plank were modular throughout their manufacturing period. Stresscrete and many other products of hollow-core plank now on the market are modular components.

Double tee sections used for roof and floor construction were modular in dimension from the time their manufacture started. Indeed, their predecessor, the precast channel roof deck, was also modular in width. The modular depth of 8, 12 and 16 inches have coursed out extremely well in bearing wall buildings, and little difficulty has been experienced with the 10- and 14-inch intermediate depths. The larger double tees now produced in 5-foot widths and the Leap giant tee with a 36-inch stem and 8-foot flange width is a modular product. Dox plank and similar products of precast concrete elements grouted or bolted together have also been modular. Can anyone ever remember when acoustical ceiling units weren't modular? As most of the original tile were stapled to wood furring strips placed 16 inches on center they had to be modular and all of their successors over the many years that such products have developed have remained so.

Remember, modules do not have to be progressions of 4 inches but merely multiples of 4 inches. A 5-foot-by-5-foot ceiling system easily adaptable for office partition location is manufactured by Conwed Corporation of St. Paul, Minn. The system combines a regressed lighting fixture, an acoustical panel, a ventilation system and a partition anchor all in one unit. Conwed also markets another adaptation of the 5-by-5 module with panels actually 30" by 60" but when combined with a light fixture adjacent, in a checker-board pattern, form a 5-foot-by-5-foot module. This latter system was used in the Barber-Coleman Office Building at Rockford, Ill. The office partitions in the building are also made by Conwed in modular increments to fit into and anchor to the ceiling system. We have a tremendous multitude of interior ceiling systems available for the interiors of our buildings without impairing the flexibility of the space. For a slightly different system than Conwed, a 5-by-5 module using a 2-by-2 fluorescent fixture in the center, regressed and including ventilation at the tee bar, is made by Donn Products Corp. and used in their own office building at West Lake, Ohio.

Another variation, an Armstrong product, of the 5-by-5 system was employed in Banker's Trust Building in New York City.

Another simple modular product is the steel and stud system of Gold Bond, U.S. Gypsum, Donn Products, Celotex, and others used with modular gypsum board, unfinished or prefinished, all parts modular, products available for interior work. Also modular were the predecessors of this system, the Stran Steel Framing System developed in 1929 by Great Lakes Steel Corporation.

As practically all of our precast panels for building exteriors are custom built including insulated, non-insulated, concrete, polyester, and aggregate based panels of many compositions, all are available in modular sizes and some are stocked only in modular sizes. Plywood for exterior and interior use has always been modular. It even can be specifically under-sized at the mill, if so desired, to avoid any dimensional creep on extremely large structures or where special H-clip joint separators are used to keep the panels in alignment. Many mosaic tiles and wall tiles have converted to modular sizes, although such tile is considered a sheet material which we normally consider cutting and fitting on the job similar to all paper, vinyl fabrics, and carpet. Let us not forget carpet squares, another modular product. The resilient floor industry is now converting to 12-by-12 tiles finally abandoning the old 9-by-9 sizes. Possibly they were led to this decision by the Markwa Company, a Vermont Marble organization, which has been producing modular wall and floor tiles for 10 years. Practically every recessed troffer and dozens of our surface mounted electric fixtures are modular in widths from 8 inches to 5 feet and with lengths of 2 feet, 4 feet, 5 feet, 6 and 8, we have everything that we could really ask for. Dozens of companies including Carnes, Titus, Tuttle and Bailey, U.S. Air Conditioning, and many others have converted their air delivery products to modular coordination in both wall and ceiling diffusers. Many manufacturers of radiation both hydronic and electric are producing their units in modular sizes. With this plethora of products asking to be used efficiently, it is ridiculous to refuse giving modular coordination a try.

Professor Stanley Kent of Toronto University, who produced the original modular standard manual for Canada, was recently contacted. Professor Kent gave a brief report, confirmed by the Department of Industry Trade and Commerce—Materials Branch, in Ottawa. This department, headed by Mr. John Dawson, stated that modular standards have spread entirely across Canada. Most products are now being produced under standards established by the Canadian Government. Conferences and seminars have been held throughout the country with over a hundred instructional sessions held for architects and engineers. All federal departments have climbed on the band wagon and now require all drawings for their facilities to be produced by modular methods. Many of the provincial governments have established similar requirements.

We do not need government sponsorship or commands in this country in order to simplify and improve our work. We can do it by individual effort, primarily because it is profitable and produces a better job.

DRAWING BY EDWARD SICHTA

Edward Sichta studied Commercial Design, Illustration, Painting, Drawing and Printmaking at the Chicago Academy of Fine Arts, the School of the Art Institute of Chicago, and the University of Chicago. After earning a graduate degree in Painting and Drawing from this University he joined the faculty of Architecture here, where he has been teaching Basic Design, Drawing and Independent Study programs for several years.