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SEVEN METRIC CASE STUDIES

The National Institute of Building Sciences recently completed a preliminary case study report for the Army Corps of Engineers, the General Services Administration, and the Department of Veterans Affairs on seven federal metric projects. As of the report's publication in January 1994, three projects were in design, one was out for bid, one was under construction, and two had been completed. The report's findings are as follows:

Design Costs. The design fees for two of the seven metric projects examined were slightly higher than they would have been had the projects been non-metric. In both cases, the fee increases were granted because government standards had not yet been converted to metric and the architect/engineer had to make the necessary conversions. Fee increases also may be justified when projects are changed from inch-pounds to metric after design work has begun.

Construction Costs. It is premature to draw firm conclusions about construction costs since only three of the seven projects have been awarded to date. Two were well below the government cost estimate, following a bid pattern similar to that for current non-metric projects. The third, located in a remote area, was awarded slightly above the government cost estimate. These cursory data appear to indicate that market conditions play a much greater role in determining construction costs than does conversion to metric.

The Metric Learning Curve. An additional effort was required on the part of designers and builders to use metric, resulting in a temporary reduction in productivity until everyone "got up to speed." Specifying and using metric required extra time, care, and attention to detail. Rethinking familiar practices, particularly in the early stages of a project, was necessary and time had to be allowed for this.

After the initial learning period, however, the advantages of metric became evident: it was easier to use and resulted in fewer errors. As the construction industry becomes accustomed to working in metric, there may be a net increase in productivity.

Although it was not critical to have someone with metric experience on the project team, it helped. Experienced personnel gave everyone more confidence in making the many small decisions involved in the conversion process and their guidance reduced the impact of conversion on productivity, project costs, and schedules. On one project, for instance, the contractor's superintendent had previous metric experience and was able to help subcontractors interpret construction documents and prepare shop drawings.

Project Selection. An organization's initial metric projects should be as large as possible because large projects provide time for everyone on the job to learn metric thoroughly (in fact, they cannot avoid learning it). Large projects also provide the volume orders required to purchase metric products without a cost premium. Small projects may not offer these advantages. The cutoff point varies depending on the nature of the project, but the GSA Philadelphia Region indicates that projects of a few hundred thousand dollars often can be executed in metric without difficulty. Projects under one hundred thousand dollars also are feasible if they do not require the small amounts of metric materials (e.g., block or drywall) that could carry a premium price.

Architectural Design. Architects had little difficulty learning to design in metric. The preparation of specifications, however, took more time and effort because the availability of metric products had to be researched and non-metric product specifications had to be converted. As architectural firms convert their in-house specification systems and product manufacturers convert their literature, this problem should disappear.

Structural Engineering. There were no reported problems in the area of structural design. Some firms performed calculations using inch-pounds, converted the answers to metric, and then completed the structural details.

Mechanical Engineering. There were no reported problems in the area of mechanical design. A number of firms reported using mechanical design software programs that performed calculations in metric.

Cost Estimating. A conversion error in an early cost estimate for one project was the only reported problem associated with cost estimating.

Computer-aided Design and Drafting. Computer-aided design and drafting (CADD) programs were reported to be quite useful in producing metric drawings since CADD allows users to work in metric scales and units. CADD also allows designers to evaluate alternative approaches to rounding from inch-pound to metric dimensions.

Metric Guidance Documents. The National Institute of Building Sciences' (NIBS) *Metric Guide For Federal Construction* and the General Services Administration's *Metric Design Guide* were the two most commonly used guidance documents. The GSA guide was cited as being particularly useful to designers and project managers.

Codes and Standards. Few problems were encountered in this area since most codes and standards contain metric units. In one case, a building inspector was reluctant to review metric plans. In another, it was found that a set of requirements was based on tests of inch-pound assemblies, which resulted in the need for extra research on the part of the specifier.

Trade Union Training. On one of the large projects, government representatives are helping the local trade unions begin metric training before the project goes to bid. On the job, the metric training responsibility will be assigned to the general contractor's project safety office with little or no additional cost to the project anticipated. Similar outreach efforts are recommended whenever possible and consideration should be given to requiring them in the general conditions of the contract.

Metric Tools. Metric measuring tapes were not provided to the trades on one project, causing confusion and delays. Provision should be made to ensure that metric tools are always available. On one project, the contractor supplied the metric measuring tapes and insisted that metric terms be used in all job-site discussions.

Reverse Conversion. A mistake by a contractor in converting metric dimensions back to inch-pounds led to a significant ordering error on one project. Continuous effort is needed to eliminate unnecessary reverse conversions in the field.

Shop Drawings. Government project managers consistently demanded metric-only submittals for shop drawings. A slightly higher rate of shop drawing rejections and a significant number of metric-related mark-ups have been reported. In a few instances, subcontractors submitted metric shop drawings but used drawings with dual notations in the field. A metric orientation program for subcontractors prior to the beginning of the job can reduce such problems.

Converting and Rounding Numbers. When rounding metric numbers, the effects of repeating a rounded dimension over a large area must be considered since the cumulative effect of such rounding may be significant. Lack of care in rounding also may lead to errors in shop drawings and in-place work. There are no rules of thumb to replace the need for attention to details and rechecking calculations. The designers and builders who devoted special attention to such details avoided problems.

Building Products. Some project participants were concerned that metric modular products (brick, block, drywall, plywood, suspended ceiling components, and floor tile) might not be available locally or be produced by enough manufacturers to promote competitive bidding. However, all product availability concerns were resolved without causing project delays or increasing costs.

A limited number of metric construction products may cost more due to a relatively low level of competition or production capacity. It is best to deal with this issue by contacting suppliers during the design stage to ensure that the products being considered are locally available. The GSA Philadelphia Region's *M2: Metric Design Guide*, Third Edition, contains a listing, by manufacturer, of metric products and associated minimum order requirements.

Some concern was expressed regarding whether to allow contractors to substitute soft metric for hard metric products. Experience has shown that most hard metric materials are readily available and that substitutions should not be allowed unless there will be a clear and overriding benefit to the government.

Building product data often are available in metric. Some manufacturers who produce for both the domestic and foreign markets have metric data available. Others have begun to add metric data to their catalogs and advertising literature. Discussions with manufacturers during the development of product specifications help ensure a competitive supply of metric components.

Effective communication among designers, managers, contractors, subcontractors, and manufacturers and the identification of critical metric dimensions will reduce requests for changes in product specifications during construction.

Systems Furniture. Office furniture systems are manufactured in inch-pound modules but will work in metric layouts if care is taken in choosing the appropriate module sizes. Problems can be minimized by avoiding shortcuts and checking calculations.

Utilities. Local government and utility records are not maintained in metric units and local authorities may require submittals in inch-pound units. On one project, there was some resistance to reviewing metric drawings, but no problems were reported on the other projects.

Clients and Tenants. Clients and tenants often have difficulty understanding space requirements when metric is used. Allow for the extra time needed to assist them in this regard.

Federal Commitment. Many study participants emphasized the need for the federal government to show an unequivocal commitment to metric. Only a strong federal commitment will provide the necessary incentive for the construction industry to convert rapidly to metric.

Positive Approach. A positive approach to metric construction seems to work best. It involves:

- Making a firm commitment to learning metric,

- Choosing projects of significant size,

- Using available CADD technology,

- Conveying a positive message about metric to all project personnel and constantly reinforcing it,

- Providing metric orientation for construction trades,

- Accepting the increase in effort needed to ascend the metric learning curve,

- Devoting extra attention to details and checking calculations, and

- Requiring metric-only usage in the provisions of all design and construction contracts.

Canadian Metrication. The Canadian construction industry converted to metric in the late 1970s. It found that the conversion process was much less difficult than anticipated and that there were no appreciable cost penalties associated with the change.

[The above findings are excerpted from *Seven Metric Construction Case Studies: Preliminary Assessment*. The full report is available for $12 (including shipping and handling) from the National Institute of Building Sciences, 1201 L St., N.W., Suite 400, Washington, D.C. 20005; phone 202-289-7800. Major credit cards and phone orders are accepted. Also available from NIBS are the *Metric Guide for Federal Construction* ($15) and the *M2: Metric Design Guide*, Third Edition ($12), both mentioned herein.]

METRIC FACTS: PRESSURE AND STRESS In the inch-pound system, pressure and stress areexpressed in many ways, including pounds per square inch (psi), inches of mercury, and inches of water. In the metric system, the unit for pressure and stress is the ***pascal*** (rhymes with rascal). One pascal is defined as the force of one newton exerted over an area of one square meter. In symbolic language, this is shown as $Pa = N/m^2$.

One psi equals 6894 pascals. Since the pascal is such a small unit, pressure and stress are often given in kilopascals (kPa) or megapascals (MPa).

Problem: The operating pressure in a boiler is 125 psi. Express this in pascals with a convenient prefix.

Solution: $125\ lb/in^2 \times 6894\ Pa/lb/in^2 \times k/1000 = 892\ kPa$

By Oscar Fisher; used with the permission of the American Society of Mechanical Engineers.

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The National Institute of Building Sciences is a nonprofit, nongovernmental organization authorized by Congress to serve as an authoritative source on issues of building science and technology.

The Council is an outgrowth of the Construction Subcommittee of the Metrication Operating Committee of the federal Interagency Council on Metric Policy. The Construction Subcommittee was formed in 1988 to further the objectives of the 1975 *Metric Conversion Act*, as amended by the 1988 *Omnibus Trade and Competitiveness Act*. To foster effective private sector participation, the activities of the subcommittee were transferred to the Council in April 1992.

Membership in the Council is open to all public and private organizations and individuals with a substantial interest in and commitment to the Council's purposes. The Council meets bimonthly in Washington, D.C.; publishes the *Metric Guide for Federal Construction* and this bimonthly newsletter; and coordinates a variety of industry metrication task groups. It is funded primarily by contributions from federal agencies. For membership information, call the Council at the above phone number.

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