Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

TECHNICAL SUPPORT DOCUMENT

TSD-51-17

USE OF PRE-ENGINEERED BUILDINGS FOR SCHOOLS AND OTHER BUILDINGS

February 1987

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Technical Services and Contracts

Services techniques et marchés

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THE APPLICATION OF PRE-ENGINEERED BUILDINGS

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1.0 INTRODUCTION

1.1 Purpose

This document supports DRM 10-7/51, Building Design. Its purpose is to assist designers and administrators in selecting the type of building system or method that best suits their needs (pre-engineered or conventional), and to outline the characteristics of pre-engineered buildings so that their suitability for various projects may be assessed.

1.2 Users

This publication is intended for those who are engaged in the development of projects and are considering the use of pre-engineered buildings. These include project managers/officers, regional administrators and designers, Public Works Canada (PWC) staff and private consultants engaged by the Department, a band and/or PWC.

1.3 Definition

Pre-engineered building systems are usually metal buildings, in which component parts for the structure and envelope are designed and produced in a controlled factory environment, and then assembled at the construction site. Whether the completed building is one of the metal building industry's standard models or a special design, the components are formed, fitted, pierced, painted and, in some instances partially assembled, before leaving the factory. Pre-engineered building packages do not usually include the foundations, or the mechanical or electrical systems.

1.4 Present Development

During the last 25-30 years, the metal building industry has progressed from galvanized sheeted shells to more sophisticated structures because of controlled factory conditions and the use of industrial technology and computers for design and engineering applications. The quality and performance of pre-engineered buildings has improved greatly and a much wider range of applications is now possible provided certain limitations are recognized.

2.0 CODES AND STANDARDS

In addition to provincial and national building codes, the following standards apply:

Canadian Sheet Steel Building Institute Publication No. 38.4 "Standard for Steel Building Systems".

CSA S16.1-1974, "Steel Structures for Buildings - Limit States Design".

CSA-S16.1S2-1981, "Supplement No. 2 to S16.1-1974, Steel Structures for Buildings - Limit States Design".

CAN3-S16.1-M84, "Steel Structures for Buildings (Limit States Design)".

CAN3-S136-M84, "Cold Formed Steel Structural Members".

CSA W59-1982, "Welded Steel Construction (Metal- Arc Welding)".

3.0 PRODUCTS

3.1 General Characteristics

In North America, pre-engineered buildings are steel frame, steel-clad building systems. The suppliers offer rigid-frame, beam-and-column and truss-frame structural configurations, with thoroughly worked out details.

These structures are likely to be competitive in most parts of the country particularly for large-span, single-purpose buildings such as gymnasiums, rinks and warehouses.

The use of pre-engineered buildings can cut down the on-site time needed to achieve a weatherproof enclosure. The main advantage, however, is that they are coordinated systems with standardized, well worked out erection procedures.

Manufacturers can also supply two and three storey structures for light loadings, that is, a live load of about 4.8 kPa (100 lb./ft.^{2}) on a span of 9 m (30 ft.), 3.8 kPa (80 lb./ft.^{2}) on a span of 10.5 m (35 ft.), and 2.9 kPa (60 lb./ft.^{2}) on a span of 12 m (40 ft.).

The major suppliers all show examples of buildings that have a non-industrial appearance. However, if stone, brick and wood are used extensively to modify the steel-panel appearance, the initial cost advantage is reduced or eliminated.

There are also examples of pre-engineered buildings where the industrial character is not disguised but rather expressed and used as an opportunity for innovative design.

The design of pre-engineered buildings requires special consideration of sound and thermal insulation. It is virtually impossible to eliminate all thermal bridges between the outer skin and the structure of the building, and improper installation of air-vapour barriers causes condensation and frosting, especially in cold regions. There may also be a problem with sound transmission between rooms.

3.2 Cost and Time Factors

The pre-engineered building package includes only the structure, cladding, insulation and roof. In conventional construction this is 25 to 30% of the building costs. Other elements, such as foundations, interior finishes, mechanical and electrical systems, and overhead and profit should remain approximately the same. Departmental experience has shown that, typically, in an urban or rural location a completely pre-engineered school costs 20% more than a wood frame school with a shingle roof and 10% more than one of brick and block with steel joists and built-up roof.

The logistics of getting a pre-engineered building to a remote site should be carefully considered although not dismissed as it is often possible to reduce the components to transportable sizes. However, the costs involved must be compared with alternative approaches.

When the supplier has adequate lead time, the construction time can be significantly reduced by using a pre-engineered building instead of brick and block. For a six-classroom school the time required may be as much as four weeks shorter. The time savings would probably be smaller if compared with wood construction. For a simple, one-purpose building such as a warehouse, the time savings might be greater.

A premium of up to 100% on affected parts may be charged for any modification of the manufacturers' stock sizes and details, for example, 6 m or 7.2 m (20 ft. or 24 ft.) bays and 3.6 m to 7.2 m (12 ft. to 24 ft.) heights in 0.6 m (2 ft.) increments.

It is usually quite impractical to get a true cost comparison between conventional and pre-engineered buildings as only comparative tender calls will do this. However, where time permits, bids can be invited for both pre-engineered and conventional buildings, assuming that all the requirements are flexible enough to be met by both types of building. It is important to obtain at least three bids to ensure a true comparison. The proposals must be based on complete and well prepared documents so that accurate and valid comparisons can be made. The documents should, if possible, be prepared by independent consultants. As an alternative to preparing several sets of documents, the design-build method of construction may be used to achieve this (see 5.2).

3.3 Design Limitations

On an unrestricted site, it is reasonably easy to use the manufacturer's stock sizes, but where more restrictive site conditions or other factors require a departure from the standard panel module, clumsy detailing may result.

It can be difficult to get a pleasant effect with stock windows and doors. The more attractive examples shown in manufacturers' brochures are usually those that use non-stock elements for feature areas like main entrances, for example, brick or fieldstone walls, or a glass curtain wall cantilevered out from the structure. While the use of these materials helps disguise the steel-panel character successfully, the anticipated cost and time savings are obviously affected and the advantages diminished.

One positive feature of these buildings is the roof--which can be attractive and trouble-free, providing both a long life and a wide range of colours. However, avoid piercing it with vents and chimneys, if possible, as this can lead to awkward detailing and future problems with leaking.

Available standard sandwich panels for walls and roofs do not provide enough insulation to meet the standards outlined in the current edition of Measures for Energy Conservation in New Buildings. In a 5000 Celsius degree day (9000 Fahrenheit degree day) zone, the standards require an RSI value of 2.5 (R17) for walls and 4.7 (R32) for roofs. The best standard panel is RSI 1.8 (R10). The most economical insulating technique is to drape insulation blankets between the purlins and the outer skin. This approach permits the mechanical and electrical services to stay on the warm side and avoids awkward fitting around the wind bracing rods.

Where there is no suspended ceiling, in a gymnasium for example, insulation blankets can be faced with a vinyl scrim which gives vapour control, light reflectance and sound absorption. It is also reasonably attractive. A pad of rigid insulation on the purlins is required to avoid thermal bridging.

To avoid the loss of insulation where the batts are compressed over the purlins, an insulating strip must be used between the roofing and the purlins. Another way of avoiding thermal bridging at the purlins is to add spacers on top of the purlins.

Protect doors and entrances by recesses or overhangs to prevent them being blocked by falling snow or endangered by icicles.

3.4 Maintenance Factors

Pre-engineered buildings do not appear to require extra maintenance. The light gauge panels are, however, susceptible to mechanical damage, and if damaged, usually have to be replaced. This should be considered where vandalism could be a problem. Panel material that is galvanized before painting is unlikely to rust. The paint can be maintained almost indefinitely by an annual program of inspection and touch-up. The use of a 2 m high masonry lower wall around the building prevents most mechanical damage to the panels but increases costs.

Great care must be taken during construction to ensure that the insulation and air-vapour barrier are installed continuously without breaks, although this can be difficult to accomplish on walls. Such breaks permit heavy condensation and resultant building damage.

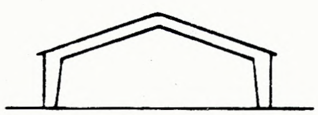
3.5 Basic Types and Elements of Structures

3.5.1 Rigid Frame

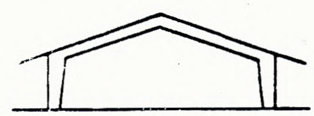
The rigid frame is the most common type. Columns and rafter beams are either welded plate members with tapered web or parallel flange, or mill sections. Widths of structure are available from 7.6 m (25 ft.) to 12.2 m (40 ft.) in 1.5 m (5 ft.) increments, and from 12.2 m (40 ft.) to 36.6 m (120 ft.) in 3 m (10 ft.) increments.

Standard roof slopes of clearspan rigid frames are 1:48 and 1:12. Pre-engineered buildings have traditionally had a pitched roof for drainage, but a steep roof pitch is not essential. Roof slope should be based on space requirements and desired appearance.

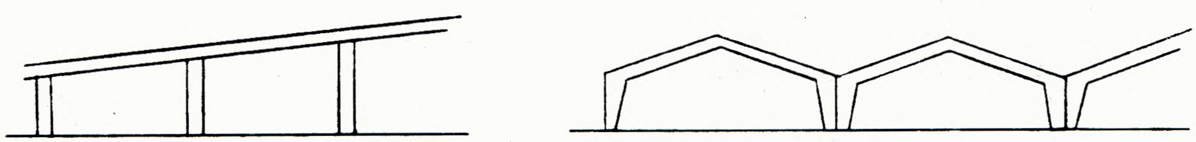
Examples of Rigid Frame:



Single-span (clear span)



With roof overhang



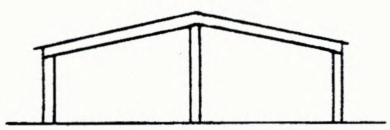
Multi-span

* Great care must be taken with this type of design. It is not suitable in areas where heavy snow and ice damming occur as the roof is likely to collapse.

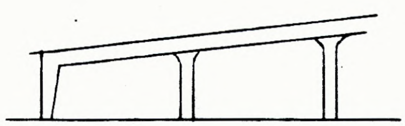
3.5.2 Beam-and-Column

The beam-and-column frame is used for buildings that exceed the available width of rigid frame structures, or those in which interior columns are not objectionable. Beam and column construction is generally cheaper than rigid frame construction, especially for tall buildings (see Building Construction Cost Data 1985). Standard spans are 12 m (40 ft.), 15 m (50 ft.) and 18 m (60 ft.).

Examples of Beam-and-column frame:



Two-Span



Multi-Span

3.5.3 Truss Frame

Truss frame construction has open web trusses for the beams and usually has parallel flange columns. This structural system is typically used for large industrial projects or gymnasiums and is often used with concrete or masonry walls. Column and truss structural frames are available as clear span or multiple span. The interior columns may be:

a. welded plate;

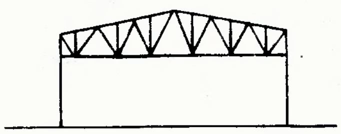
b. rolled structural shapes; or

c. hollow, round or square, structural sections.

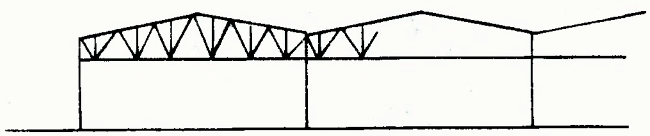
The roof slope of this structural system is generally 1:48.

Standard spans are 18 m (60 ft.) to 36 m (120 ft.) in 3 m (10 ft.) increments.

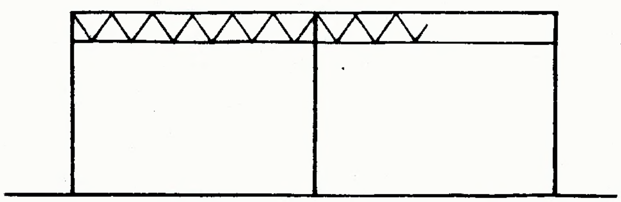
Examples of Truss Frame (for use in gymnasiums):



Single-span



Multi-span



Space Grid

3.5.4 <u>Secondary Framing</u>

Standard bay sizes are 5.4 m (18 ft.) and 7.2 m (24 ft.). Purlins and wall-girts are usually very efficient roll-formed sections in a "C" or "Z" configuration, designed for a spacing of about 1.5 m (5 ft.) for normal loads.

Lateral stability is normally achieved by diagonal bracings in some bays on all four sides and the roof.

Connection holes for all structural bolts, including connections of purlins and girts to the primary framing members, should be factory punched or drilled. This ensures the proper alignment of framing members which is essential to roof panel alignment. Improper alignment will result in roof leakage.

3.5.5 Wall System

There is little functional difference between the single skin metal wall panels of major manufacturers, but differences in configuration provide some variety in appearance. The profiles are usually 25 mm to 40 mm deep (1 in. to 1 1/2 in.), though there are some deeper ones for large-scale industrial applications.

Deviation from the manufacturer's standard colour selection usually adds to cost and delivery time. Each manufacturer offers about 12 well-chosen colours.

There are also standard factory-insulated 'sandwich' panels available. These panels combine the outside skin, insulating material and an inside liner panel. Sandwich insulated panels are approximately three times more expensive than single-skin, uninsulated panels, yet they do not provide enough insulation to meet energy conservation standards or a means of concealing wind bracing or mechanical and electrical services. They are most suitable for arenas, firehalls, etc. where services do not require concealment.

3.5.6 Roof Systems

The roof used most often is the ribbed or corrugated panel, with lapped side and end joints and slotted or sliding-clip connections to the purlins. Joints are pre-caulked.

Standing seam roofs with mechanically-crimped side- laps and sliding-clip connections to the purlins are an improvement, in that no fasteners pierce the roof. End joints, rarely necessary due to the long lengths available, are lapped.

Skylight panels are available. Vent curbs and roof jacks are also available which are compatible with the roof system. It is important that mechanical requirements are properly coordinated with the roof design so that these curbs and jacks are provided.

A 20-year guarantee is available on some of these roofs.

3.5.7 Finishing

Although the pre-engineered building manufacturers offer demountable partitions in steel panels or metal-stud with gypsum board, and suspended ceiling systems, conventional construction is probably easier. If block partitions are appropriate and competitive in a particular situation, they have the advantage of providing a sturdy surface and good acoustical separation. Otherwise conventional stud partitions can be designed to give the required acoustical and fire separation.

Suspended dry-wall or lay-in tile ceilings are both independent of the building system. For those parts of the ceiling and sidewalls that are out of reach in large open spaces such as gymnasiums and rinks, vinyl-faced insulation blankets, which are part of the "package", are cheaper and have an adequate appearance.

Outside walls must usually be furred for the wall finish on their inner side to conceal and protect the insulation and wind-bracing. Under some circumstances columns can be left exposed between rooms to provide a strong design feature; but to cut sound transmission from room to room, they usually have to be furred, insulated and covered. Getting services past the protruding columns is difficult, but small pipes and conduits can pass through drilled holes.

Insulate the outside face of the column to avoid thermal bridging.

4.0 ENGINEERING ASPECTS

The normal engineering principles for conventional buildings must be followed with particular attention given to soil analysis, foundation design and snow loads.

If the designer understands the configuration of the structure, there should be no difficulty integrating the mechanical and electrical services. With blanket insulation between the structure and the outer skin, there is usually a furred space on the warm side to conceal small pipes and wiring. Electrical, plumbing and heating mains can run in a basement or crawl-space, or be buried in the floor slab.

If the ceiling space is insulated between the purlins and roof-skin, it may be used for ducts and vents. Use factory-built accessories where roof penetrations must be made, and make sure that the complete assembly carries the same guarantee as the roof itself and that the roof guarantee is not compromised by the penetrations.

Avoid sandwich panels with a metal inner skin, which necessitate surface mounted pipes or raceways, unless such features are acceptable in the particular circumstances.

5.0 METHODS OF CONSTRUCTION

5.1 General Contract

For the reasons mentioned in 3.2, it is usually unwieldy, time-consuming and impractical to try to take tenders on a pre-engineered building as an alternative to conventional construction in the same contract package. Decide on the best approach before tendering, and design accordingly. An exception to this is the use of the design-build method (see 5.2).

As the pre-engineered portion of a building only makes up about a quarter of the total cost, a pre-tender for the shell (structure, skin and insulation) could be considered for later integration with the general contract.

When a pre-engineered building package has been chosen, ensure that at least three major suppliers are willing and able to bid, and that substitutions are permitted in places where their products vary.

5.2 Design-build Procedure

Design-build is the contracting procedure by which a firm (usually a contractor) is retained to both design and build a facility under one contract. When this procedure is used a clear, concise performance specification is essential. It should adequately describe the scope and quality of the project, as well as list all applicable policies, standards and guidelines. This is the document that outlines the design-build firm's obligations.

When this process is used, insist that an architect be part of the design-build team. An independent architectural opinion should be included as part of the process where either engineering and architecture staff responsible to the project manager or an independent consultant provide:

a. an evaluation of the proposals including actual design; and

b. supervision of the work.

5.3 Day Labour

Pre-engineered buildings can be built by local labour if the supplier provides appropriate supervision, equipment and key personnel. It should be noted that cranes are usually required.

5.4 Winter Work

Unless the permanent enclosure complete with insulation and vapour barrier can be installed before the beginning of winter, it is recommended that the project be postponed to the following spring. Otherwise, frost formation on the steel structure and skin will cause serious damage to the insulation and finishes. As an alternative, costly heated temporary enclosures could be used, however, they are not usually cost-effective.

6.0 CONSIDERATIONS IN THE USE OF PRE-ENGINEERED BUILDINGS

Single source responsibility, which makes pre-engineered buildings attractive to private customers, can be a disadvantage for public building projects for the following reasons:

a. There is limited public competition.

b. Public money is committed to a system that cannot be readily interchanged with any other one during the course of a contract.

c. The local economy receives less stimulation as structural and cladding elements usually come from elsewhere.

Also, a greater degree of design care and on-site supervision is required to ensure that wall and roof seals, insulation and air-vapour barriers are installed correctly. Deficiencies in pre-engineered buildings tend to have more severe consequences and be harder to correct than in conventional buildings. The reason for this is that the steel skin forms an effective vapour barrier, with the result that any moisture that gets through the insulation cannot escape and condenses on the inner surface. Conventional wood or masonry surfaces permit vapour to dissipate.

Pre-engineered buildings do, however, have three considerable advantages:

a. quick on-site erection time;

b. efficient, sometimes even elegant, structure; and

c. attractive and trouble-free roofs.

Furthermore, for structure and roof, the three major suppliers can bid against each other because their packages are virtually interchangeable. Enclosing walls and other accessories sometimes introduce unnecessary complications because of cumbersome connecting systems, however, the pre-engineered structure and roof could be incorporated into the design as part of a general contract.

Pre-engineered buildings can offer advantages in terms of erection time and the degree of control over quality, time and cost. In a situation where quick erection of the building shell will allow interior work to proceed more quickly and thus help achieve earlier completion of the project, overall savings can result. However, considerations such as the quality of construction and the life span of the building must be carefully compared with those of conventional buildings.

In the past pre-engineered buildings were typically more expensive than conventional construction. However, in two recent building projects, substantial savings in time and money have been achieved through the use of pre-engineered buildings and the design-build procedure. One of these was Chief Poundmaker School, Saskatchewan. This six-classroom school was delivered nine months ahead of schedule at a cost less than the approved budget. In the other project, Thunderchild Technical Institute, Saskatchewan, residential and educational requirements were combined. This project was also completed on schedule and under budget. However, it is difficult to determine whether the quality of these projects is equivalent to conventional construction or to give a precise analysis of the relative contributions of the type of construction used (pre-engineered systems) and the contracting procedure (design-build).

In order to determine the viability of using a pre-engineered building for a particular project, a careful assessment of all the variables must be made. These include familiarization with local assets and constraints such as materials, labour skills, transportation and quality of supervision available as well as the scheduling of supply and delivery. Whether this type of building is appropriate for its intended use must also be considered. This includes the range of bay sizes, the geometry of the building, the length to width ratio and the materials available - all factors which affect the function and aesthetics of a building. The involvement of an architect in an examination of these issues is essential.

Ideally, the pre-engineered building should be considered as one possible approach for providing good design at a reasonable cost rather than as an excuse for ignoring the normal design considerations. Good design and low cost can best be achieved when a team approach is used. A team which includes an architect and a general contractor, who is also the pre-engineered building supplier and construction manager, can achieve good planning, design, scheduling and cost control.

Pre-engineered buildings tend to be best suited for single purpose, or simple and repetitive buildings where deviations from standard components are less likely to be required.

7.0 RELATED PUBLICATIONS

7.1 Departmental Publications

EA-HQ-84-46. Capital Project Evaluation Poundmaker School, Saskatchewan

7.2 Other Publications

American Institute of Steel Construction, Inc. Modern Steel Framed Schools. 101 Park Ave, New York 17, N.Y.

Canadian Sheet Steel Building Institute. Sheet Steel Data. Willowdale, Ontario.

National Research Council. Associate Committee on the National Building Code. 1983. Measures for Energy Conservation in New Buildings, No. 22432. Ottawa.

Public Works Canada. Ontario Region. Pre-design Study for School Addition, Sandy Lake Ontario. Toronto: 1977.

Robert Snow Means Company, Inc. 1984. Building Cost Construction Data 1985. 43rd Edition. 100 Construction Plaza, Kingston MA 02364, US.

Johns, Barry. June-July 1983. "Pre-engineered System: Has its time come?" The Canadian Architect.

"Award of Excellence". Dec. 1982. The Canadian Architect.

The designers' manuals produced by Butler, Armco and Stran Steel are very useful, as is other trade literature.