A look at some of the issues involved with steel-framed industrial structures and how to overcome them.

conference preview

INDUSTRIAL BUILDINGS AND NONBUILDING STRUCTURES: DESIGN CHALLENGES

BY KRUNAL K. PATEL, S.E., P.E., JOHN A. ROLFES, S.E., P.E., JAMES L. RYAN AND WILLIAM N. SCOTT, S.E., P.E.

INDUSTRIAL BUILDING DESIGN involves many of the issues faced by designers of more typical commercial buildings.

But they also come with additional challenges. Here, we'll discuss and present ideas to address three of them: steel design for cold operating temperatures; nuances in finite element modeling of industrial structures; and changes slated for the next edition of a design guide for manufacturing facilities with overhead cranes.

Below Freezing

First is the issue of how framing in steel structures reacts to lower temperatures. Industrial structures or buildings with exposed structural steel, unheated or uninsulated buildings or buildings used for cold storage may be subject to service temperatures lower than the steel's ductile-to-brittle transition temperature for significant amounts of time. Steel that is regularly exposed to temperatures lower than the material ductile-to-brittle temperature and subjected to tension, bending or highly constrained connections may require extra attention regarding design provisions, fabrication details and material selection.

Structural steel in cold-temperature service should be selected with some consideration of fracture resistance and notch toughness. The potential for brittle fracture depends mainly on the following factors:

- Steel strength
- Material thickness
- Loading rate
- Minimum service temperature
- Material toughness
- Type of structure element
- Members or connections with notches, stress risers or constraints from thermal growth

Control of discontinuities is equally important to specifying materials with appropriate toughness. Connection details should be designed to minimize stress raisers such as sharp corners and abrupt changes of stiffness resulting from changes in cross section. Thick or high-strength materials are generally more susceptible to cold cracking in the heat-affected zones of welds and in areas of high residual stresses. In such cases, the choice of appropriate welding procedures is as important as the selection of the material. Material thicker than ¾ in. may be ultrasonic tested for laminations and inclusions.

Materials meeting extreme low-temperature specifications are generally available only from mill orders or heat treating stock available from service centers. The designer should determine availability of steel before specifying material. Generally, shapes produced to ASTM A572 or ASTM A992 can be normalized by heat treatment for low-temperature service, though normalizing




Krunal K. Patel (krunal.k.patel@sargentlundy.com) is a project associate with Sargent and Lundy, **John A. Rolfes** (jrolfes@csd-eng.com) is a vice president with Computerized Structural Design, S.C., **James L. Ryan** (jryan@bechtel.com) is principal engineer with Bechtel Corporation and **William N. Scott** (wnscott50@hotmail.com) is the owner of Scott Engineering.

An update to AIST Technical Report 13, which focuses on overhead cranes, will soon be available.

may double the cost of the steel material and introduce distortions. Heat treatment such as normalizing will also change both the yield and tensile strength of the material, so those properties should be tested after heat treatment to assure they still meet the required levels. Plate produced to ASTM A572 can be produced to -50 °F requirements or may be normalized. The required Charpy V notch test temperature may be specified at 35 °F higher than the lowest anticipated service temperature to account for a difference between expected load rates and CVN test load rates.

Also, welds may contain discontinuities causing stress concentrations, which make welded metal more susceptible to brittle fracture. Thus, it is appropriate to perform welding qualification test to AWS D1.1, Clause 4 to match the toughness requirements of the base material. Connections shown in AISC 360, Appendix 3 for cyclically loaded members are also designed to consider stress concentrations and can be considered for low temperature applications.

Nuanced Analysis

Next, let's take a look at the role of finite element analysis in the design of steel-framed industrial structures. As finite element analysis and design programs become faster and with greatly expanded design capabilities, the combined structural analysis and design effort is an automated process performed in a very short period of time. While such advances are welcome, some nuances may be missed, leading to either over-conservative design or nonconservative design relative to an optimized design. These nuances include:

- Assuring effective work points in horizontal diaphragms with underside diagonal bracing (in grating floors).
- Providing both adequate lateral restraint and lateral-torsional restraint to columns
- Optimizing unbraced lengths for repetitive floor beams supporting grating.
- Assuring consistency between brace assumptions at roof trusses and the temporary construction condition, along with special consideration to web vertical configurations.
- Other miscellaneous analysis and design aspects—e.g., deck attachment considerations and concrete ponding considerations.
- Assigning boundary conditions (fixed, pinned, etc.) to members in finite element models that accurately match installed conditions.

Industrial structures involve their own set of challenges in addition to the general issues faced by all steel-framed buildings.

- Assuring consistency between work points used in finite element models versus actual conditions to apply loads from connection design.
- Keeping sight of the final deliverable (e.g., 2D drawings) while working with a 3D finite element analysis.

Looking Up

Lastly, concerning top-running cranes, a new resource will soon be available. AIST (Association for Iron and Steel Technology) Technical Report 13: *Guide for the Design and Construction of Mill Buildings* is a recognized reference for the design of mill buildings and heavier-duty manufacturing facilities with top-running cranes. The last edition of this document was issued in 2003 and, although still a valuable resource, is not consistent with the current design specifications and building codes. The committee responsible for this document is close to completing a revision to this document that is expected to be published this year. This guide has been enhanced to include and/or address the following items:

- Loading criteria and load combinations are now presented in both ASD and LRFD format and recommendations are provided for load combinations, consistent with the current requirements of the *International Building Code* and ASCE 7, but including crane loadings.
- Design requirements have been revised to be consistent with the requirements of the current steel and concrete design specifications.
- Design requirements have been updated to reflect continued lessons learned relative to the nature of crane loadings and crane runway structures, recognizing the constraints and tolerances associated with steel fabrication and erection.
- Additional commentary is provided to explain the rationale of the recommendations contained in the guide.
- Appendix C of this document has been significantly enhanced to provide more thorough and specific recommendations on inspection requirements and maintenance for these buildings. Due to the heavy use and common abusive nature of the activities within these facilities, the committee recognized this to be a significant topic that is extremely important to the owners of these facilities.

This article is a preview of Session N58 "Industrial Buildings and Nonbuilding Structures: Design Challenges" at NASCC: The Steel Conference, taking place April 13-15 in Orlando. Learn more about the conference at www.aisc.org/nascc.