

By JAMES WILKINSON, P.ENG.

In August 2003, a large racking structure collapsed at a major cold storage facility in Brampton. The collapse triggered an extensive progressive collapse of the racks throughout the freezer area, including major structural members of the building. An employee working in the building at the time of the collapse was killed from falling debris.

Two and a half years later, in March 2006, a similar racking structure collapsed at another cold storage facility north of Toronto. Miraculously, there were no significant injuries from this collapse, as the worker was able to escape from the collapsing structure above him.

The social cost of injuries and loss of life from these types of structural failures cannot be measured; however, the direct economic impact to the industry from loss of property and business interruption is in the millions of dollars.

A number of contributing factors led to these rack failures; however, two significant factors contributed to both:

- design features of the rack structures; and
- lack of in-service structural maintenance.

On October 16, 2006, a coroner's inquest was held to probe the circumstances surrounding the accident that killed the cold storage worker, with the purpose of making recommendations to prevent similar racking accidents in the future. After hearing 15 days of testimony, the jury made comprehensive recommendations, many of which involve PEO and professional engineers.

The coroner's jury strongly recommended that the design, installation, structural repair and modifications of racking systems be engineered and certified by a professional engineer and that regulations be amended to make this requirement mandatory.

The jury also recommended\* that:

## The engineer's role in preventing racking system collapses

Recommendations from recent racking system collapses, one involving the loss of life, provide lessons for engineers. Professional engineers can take a lead role in the prevention of these potentially tragic structural failures.

- the Ministry of Labour clarify the application of pre-start health and safety reviews to rack repairs and modifications;
- a review of the Canadian Standards Association (CSA) standards for rack structures be undertaken and the standard be adopted into the regulations;
- rack structures be considered "designated structures" under the *Ontario Building Code*; and
- all organizations involved with racking systems work together to promote awareness of the hazards associated with storage rack systems.

### Pallet storage racks

As material handling equipment has become more sophisticated with high-load and reach capabilities, pallet storage racks have also developed into highly efficient steel structures.

Pallet racks generally comprise a system of steel-frame columns and adjustable beams connected to uprights. Unlike conventional steel structures, most rack structures use a proprietary design for the beam-to-column connection, so that beam elevations can be adjusted by warehouse owners.

Steel rack structures are generally manufactured from either cold-formed steel components or hot-rolled steel conventional shapes. Cold-formed steel has allowed manufacturers to design a wide variety of proprietary components and connections, while the heavier structural shapes normally use bolted connections.

Most rack manufacturers and designers do not incorporate diagonal bay

bracing into their designs, so lateral or down-aisle stability must be provided by beam-to-column connections. These semi-rigid connections are critical to the overall stability of the rack structure.

### Applicable design codes

A number of design codes and guidelines are used by rack designers and manufacturers.

### Rack Manufacturers Institute

Pallet storage racks in North America have generally been designed to the specification published by the Rack Manufacturers Institute (RMI), an independent American trade association affiliated with the material handling industry.

The RMI published its first *Minimum Engineering Standards for Industrial Storage Racks* in 1964, which was subsequently rewritten in 1997. The specifications are offered as a guideline only.

The 1997 edition, *Specification for the Design, Testing and Utilization of Industrial Steel Storage Racks* has been referenced by the Ministry of Labour in its *Guideline for Pre-Start Health and Safety Reviews*. The RMI publication is considered a "current applicable standard" under the requirements of the Regulation for Industrial Establishments.

### Canadian Standards Association

The Canadian Standards Association published the first Canadian rack standard in August 2005, CSA Standard A344.2-05, *Standard for the design and construction of steel storage racks* and a companion guide

for users, CSA A344.1-05, *User guide for steel storage racks*.

The design provisions of the CSA Standard A344.2-05 essentially mirror the RMI specification; however, the Canadian structural steel design codes are referenced as the basis for detailed design methods.

Both the RMI specification and the CSA A344.2-05 standard allow designers to use non-braced frames in the down-aisle direction, thus the overall stability of the rack relies entirely on the stiffness of the beam-to-column semi-rigid connection. The RMI standard requires that these connections and bracing be designed to resist nominal horizontal forces; however, both standards give a great deal of latitude to the designer and manufacturer to use any rational analysis method or testing to determine various parameters, such as connection performance, effective length determination and joint spring constants.

### Federation Europeenne de la Manutention

Probably the most comprehensive standard for rack structures is published by the Federation Europeenne de la Manutention (FEM).

The FEM publishes a comprehensive series of standards for the design, testing and use of racking systems, and is emerging as the international standard for racks. Section 10 of the series, entitled *The Design of Static Steel Pallet Racking*, recognizes and addresses many of the unique characteristics inherent in the design, fabrication and installation methods of pallet racks that are not addressed by the RMI specification or CSA Standard A344.2-05.

One of the most significant design requirements of the FEM standard involves a specified out-of-plumb condition that takes into account frame imperfections and the inherent looseness of the beam-to-column connection. This is particularly significant in the case of racks designed with a bolted connection, as the joint is prone to slippage at service loads, causing a down-aisle tilt or sway that may cause horizontal forces to exceed those specified in the RMI and CSA standards.

The FEM standard specifies:

- material fracture toughness, which is a significant factor in low temperature environments, such as cold storage facilities;
- tolerances for fabrication, assembly and installation;
- allowance for minor impact with mechanical equipment; and
- global analysis of the overall structure that takes into account frame imperfections and initial sway conditions.

Designers and manufacturers of pallet storage racks must be aware of the significance of these design requirements and provide information to users, including:

- installation instructions and erection tolerances;
- impact protection from mechanical equipment; and
- rack inspection and maintenance procedures.

*A pre-start health and safety review is required when a racking system is installed or modified at a workplace and the review must be conducted by a professional engineer*

### OHS legislation

On October 7, 2000, amendments to section 7 of the *Regulation for Industrial Establishments* regarding pre-start health and safety reviews came into effect.

Racking structures are referenced in section 7, which specifies that a pre-start health and safety review is required when a racking system is installed or modified at a workplace and the review must be conducted by a professional engineer.

Employers and warehouse owners must have documentation that their racks have been designed, manufactured and installed in accordance with the current applicable standard, and have not been modified or

had structural repairs subsequent to the original review document.

Although the RMI publication is considered a “current applicable standard” under the requirements of the *Regulation for Industrial Establishments*, professional engineers must be aware of the significance of the unique characteristics of rack structures and understand how these characteristics are addressed in other, more comprehensive, standards.

### How can engineers help?

Professional engineers can take a lead role in preventing potentially deadly rack collapses through good engineering design practices, evaluation of existing and potential rack damage, preparation and oversight of proper repair techniques, and the development of good care and maintenance procedures for employers and plant owners.

Engineers must understand the unique structural behaviour of racks and, in particular, the structural joints and proprietary connections used by some manufacturers. Connection characteristics can have a significant effect on the safety and performance of the structure. Simply meeting the minimum legislated requirements may not be enough to address the hazards associated with racks.

The Ministry of Labour and other organizations have been sent the recommendations of the coroner’s jury for their appropriate action.

Professional engineers in the regulatory authorities, academic and research institutions, consulting engineering firms and manufacturers can collectively develop the codes, standards and mandatory legislation to prevent a recurrence of these tragic, and preventable, workplace accidents.

\*Note: Further information regarding the jury recommendations is available from the Office of the Chief Coroner of Ontario, 416-314-4000. ❖

James Wilkinson, P.Eng., is a former senior engineer with the Ministry of Labour and has been the chief investigator of many rack collapses. He is currently an independent professional engineer in partnership with HITE Engineering Corporation, an engineering consulting firm specializing in the rack industry.