CROSS US
COLLABORATIVE REPORTING FOR SAFER STRUCTURES

SEI STRUCTURAL ENGINEERING INSTITUTE ASCE

CROSS Newsletter

CROSS-US Newsletter 3 | **May 2021**

Collaborative Reporting for Safer Structures (CROSS)

Roof collapse of warehouse structure under rainwater ponding | Report ID 969

Channel slab roof deck collapse during reroofing | Report ID 970

Share knowledge to help create a safer built environment

Editorial

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With this newsletter we are pleased to introduce CROSS's new look and feel, web presence, and report format, which results from a major UK initiative to expand the capability and reach of the CROSS system. More than a year in the making, the CROSS upgrade includes an entirely new web interface and content management database. A new comprehensive CROSS taxonomy will allow sophisticated and targeted searches of CROSS data. All existing reports have been reformatted and retagged. The web structure will allow us to add searchable resources on failures, safety, and quality in the built environment. We can create dedicated pages for specialized content. The new system better guides a correspondent through the process of submitting reports.

A feature of the new report format for which we have received enthusiastic feedback is an introductory section in each report that summarizes lessons learned by various stakeholder groups. This allows readers of different roles and backgrounds to quickly grasp the salient points relevant to them.

Formerly Confidential Reporting on Structural Safety, CROSS now stands for Collaborative Reporting for Safer Structures. The new name emphasizes the collaborative nature of CROSS, as well as the expansion of CROSS-UK into fire safety. Overall the CROSS upgrade represents an exciting step increase in CROSS's power and usability that should enable the expansion of CROSS for years to come. Further information on the evolution of CROSS is available in the article, Collaborative Reporting for Safer Structures – US, found on page 3 of this newsletter.

This newsletter edition includes five instructive reports, two of them involving roof collapses and three about failures or accidents during construction. The many lessons learned share common themes of the need for clear communication, collaboration, and setting of expectations and roles on projects. These themes have recurred over the sixteen-year history of CROSS and must not be forgotten.

The CROSS system requires the participation of all involved in the built environment. We need your experience in the form of submitted reports. Please use CROSS, individually and in your organization, as a learning tool to minimize the incidence of failures and improve safety. And please spread word of CROSS to others.

We hope you enjoy the new report format and find our new web presence more user-friendly and enabling. As always, we welcome your comments and suggestions.

Glenn and Andy

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Reporting to CROSS

Your report will make a difference. It will help us to create positive change and improve safety.

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Visit:
www.cross-safety.org/us

Email:
team.us@cross-safety.org

Collaborative Reporting for Safer Structures (CROSS)

News

CROSS helps professionals make structures safer. We do this by publishing safety information based on the reports we receive and information in the public domain.

Our secure and confidential safety reporting system allows professionals to share their experiences to help others.

Origins and Development of CROSS

CROSS-US was established by the Structural Engineering Institute of the American Society of Engineers (SEI/ASCE) in 2019, as a new unit in a growing international network of CROSS entities. Background on the development of the CROSS system follows.

In 1976, the Institution of Structural Engineers (IStructE) and the Institution of Civil Engineers (ICE) in the UK established the Standing Committee on Structural Safety (SCOSS). Like the US-based ASCE Technical Committee on Forensic Engineering established in 1983, the main function of SCOSS was to identify in advance trends and developments which might contribute to an increased risk to structural safety. General findings were published periodically, along with publications on specific matters of interest.

In 2005, SCOSS implemented a system for the collation of data on matters of concern relating to structural safety. The system was named Confidential Reporting on Structural Safety (CROSS). It was based on the success of confidential reporting in the US aviation industry developed by NASA.

CROSS allowed professionals to confidentially share their experiences to help others. It aimed to improve safety by publishing information that would not otherwise get into the public domain.

As CROSS's positive influence on safety culture was demonstrated in the UK, its use expanded, and the vision for an international network of CROSS units emerged. CROSS-Australasia was added in 2018; CROSS-US in 2019; further international CROSS units are planned.

To date, CROSS has received over 1,000 safety reports on topics ranging from issues with domestic buildings to major structural collapses. Each report contains information from which the industry can learn to make structures safer.

The Grenfell Tower Fire leads to the expansion of CROSS-UK into fire safety

There was a major and tragic fire in 2017 at the Grenfell Tower in London with multiple fatalities. This led to Dame Judith Hackitt's being appointed by the UK Government to carry out an **Independent Review of Building Regulations and Fire Safety>**.

Evidence was given by CROSS-UK based on reports received through its confidential safety reporting system that illustrated the depth and extent of safety issues within the building industry. The final Hackitt report stated:

'...the current CROSS scheme should be extended and strengthened to cover all engineering safety concerns...'

As of April 2021, CROSS-UK therefore embraces fire safety in addition to structural safety. The new name, Collaborating Reporting for Safer Structures (CROSS), reflects the integrated way in which professionals engage for a common purpose.

Our secure and confidential safety reporting system allows professionals to share their experiences to help others.

While CROSS-AUS and CROSS-US have yet to undertake fire safety, they both operate with CROSS-UK in an international system with the new name.

Reporting to CROSS

Our secure and confidential safety reporting system allows professionals to share their experiences to help others.

CROSS-US therefore welcomes reports about structural safety issues related to buildings and other structures in the built environment. Reports should aim to include information that will help others to learn from the safety issue identified.

Reports typically relate to concerns, near misses or incidents, and our confidential reporting system can be used by professionals who work with buildings and other structures. This includes anyone with an interest in, or responsibility for, structural safety.

If you would like to know more about **reporting to CROSS-US>**, we have further guidance on our website.

Benefits of safety reporting

The aim of reporting to CROSS is to make structures safer and to ultimately save lives and reduce injuries. Safety reporting helps to achieve this by:

- **Promoting a culture change:** to encourage professionals to identify and report safety issues that occur during the design, construction and occupation or operation stages.
- **Sharing lessons learned:** to identify key lessons to be learned from safety reports to help professionals make structures safer.
- **Identifying pre-cursors:** to identify and provide an opportunity to address pre-cursors that might result in a risk to life safety in similar circumstances if not addressed.
- **Identifying shortfalls:** to identify and provide an opportunity to address shortfalls in the design, construction and occupation or operation stages.
- **Improving competency:** using published safety reports as training and learning tools will form a key part of increasing the competency levels of all professionals.

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- **Supporting regulatory activities:** information from analyses of the reports can be used for enforcement and wider regulatory activities such as planning future activity, publishing guidance, and providing training and advice.
- **Supporting industry activities:** safety reports can be used by industry bodies as a learning resource for their members. Trends identified from reports can be used by industry to publish guidance and provide training.
- **Assisting with horizon scanning:** culture change and improved competency will help professionals and others to look ahead and predict likely future safety risks that have not yet been identified. These include low probability but high consequence safety incidents.

The CROSS-US Expert Panel

Our Expert Panel is at the heart of what we do. The members are all volunteers.

The CROSS-US Expert Panel comments on reports we receive. They use their experience to help you understand what can be learned from the reports. Where possible, they aim to identify the underlying causes and make reference to other publications. Blame is never apportioned. The aim is to enable lessons to be learned so that similar situations can be avoided.

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The Expert Panel has a number of other roles, including maintaining a continuing review of matters affecting safety in the built environment and helping to write other safety information for CROSS. You can find out more about the **CROSS-US Expert Panel>** on our website.

How to become part of the CROSS-US community

We want all professionals in the built environment to be part of our community. Here are some practical ways that you can get involved:

- **Share safety information for others to learn from.** Professionals who work with buildings and other structures can do this by using our secure and confidential reporting system. You can find out more on our website.
- **Use the information on our website to make structures safer.** Here are some practical ways that you can use the information:
  - As part of your continuous learning and development
  - Improve your knowledge of safety for the projects you work on
  - Keep up to date with emerging safety issues
  - Find out more about best practices
  - Share it with your team and others
- **Get in touch with us if you would like to collaborate.** We are always interested in exploring opportunities to work with others to make structures safer.
- **Encourage others to get involved with CROSS-US.**

Roof collapse of warehouse structure under rainwater ponding

CROSS Safety Report   Report ID: 969

Overview

This report highlights the structural risk caused by rainwater ponding on relatively flat roofs.

It highlights the collapse of a flat roof warehouse structure.

It demonstrates how ponding was caused by inadequate roof drain design exacerbated by changes to parapet scupper screens.

Key Learning Outcomes

For structural design engineers:

- Although drainage design is normally not part of the structural engineer's scope of work, it is good practice to coordinate roof drainage with other members of the design team, especially on relatively flat roofs.
- Understand how the performance of roof drainage that may be designed by other disciplines affects rainwater structural design loads.
- While typically not required by building codes, it is advisable to indicate the assumed rainwater design loads on the structural design drawings.

For architects, mechanical engineers, and other designers of roof drainage systems:

- Roof drainage design and roof rainwater design loads require careful coordination amongst disciplines.

For contractors:

- Consult the drainage design professional of record before modifying roof drainage systems.

For building owners and managers:

- Consult a qualified drainage design professional before modifying roof drainage systems when the building is in service.
- Maintain drains, scuppers, and plumbing to be free of obstructions.

R Full Report

Structural system

The project was designed and constructed in 1985 at a cost of $5M. The structure is a concrete tilt up wall building that is typical of warehouse construction in Texas, both when it was built, and now. The building is rectangular in plan, 748 ft (228 m) long (E/W) by 330 ft (101 m) wide (N/S). The roof structure was designed to slope at 1/4 in/ft (21 mm/m) to the north and south walls from an east-west ridge that is located 150 ft (46 m) north of the south wall. The design live load was 20 psf (0.98 kPa). The concrete tilt-up wall panels are 12 in (30 cm) thick, nominally 24 ft (7.3 m) wide, and extend 37 ft (11 m) from drilled pier foundations to the top of parapet, about 13 in (33 cm) above the roof. The column grid is 30 ft (9.1 m) (N/S) by 36 ft (11 m) (E/W). In the north-south direction, steel roof deck is supported by 16H6 open-web steel joists spaced at 6 ft (1.8 m) on center. In the east-west direction, the joists are supported by 40G 6N 6.3K joist girders spanning between 6.5 in (17 cm) diameter pipe columns. The drainage system was not addressed by the Structural Engineer of Record (SEOR), since it was not within the structural scope of work.

During the storm, three roof bays collapsed adjacent to the south wall and pulled four wall panels inward.

Partial roof collapse

In May 1989 the building experienced the effects of a severe rainstorm. Meteorologists estimated a peak rainfall intensity of 4.0 in/hr (10 cm/hr) at the building site. During the storm, three roof bays collapsed adjacent to the south wall and pulled four wall panels inward, crushing the rack area where electronics were stored. The floor of the warehouse was covered with several inches of water, which caused many tall stacks of boxed appliances to topple. Ultimately, the owner filed a $26 million insurance claim, including $1 million of building damage and $25 million of inventory loss. The SEOR learned of the collapse two days after it occurred and rushed to the site. The air in Texas is dusty, and the dust settles on building roofs. When rainwater accumulates, the dust floats and leaves behind high water marks on building parapets. The SEOR observed and documented consistent watermarks indicating that at least 12 in (30 cm) of water had accumulated on the roof at the parapets, more than three times the design live load.

Drainage system

Codes then and now require primary and secondary roof drainage, with scuppers restricted to secondary drainage. Despite the code requirements, the architect provided only scuppers spaced at 48 ft (15 m) on center along the north and south parapet walls. Each scupper is 9.5 in (24 cm) wide by 4.25 in (11 cm) high, with an invert elevation of 2 in (5 cm) above the roof. The roofing system is a rubber membrane under 1.5 in (3.8 cm) of river rock ballast. To prevent the ballast from washing through the scuppers, the architect specified hardware cloth gravel guards spanning across all scupper openings. In some locations, the contractor or owner apparently substituted a steel plate with a matrix of drilled holes in lieu of hardware cloth. Along the south parapet wall, there were a total of sixteen scuppers to drain an 112,200 sf (10,424 m2) watershed. Simple analysis using weir equations indicates that the scuppers were wholly inadequate, even before considering any blockage by the gravel guards.

Aftermath

Due to the size of the claim, extensive testing of the structural and drainage systems was undertaken. Ultimately, all parties concluded that the failure was due to the drainage and not to the structure. Repairs included the removal and replacement of eight bays of roof framing and six concrete tilt-up wall panels. No changes were made to the original structural design. New intermediate scuppers were retrofit in the north and south parapet walls. Each new scupper was approximately 30 in (76 cm) wide. This effectively increased the roof drainage capacity by more than 400%.

Lessons learned

Even though it is normally beyond their scope of work, structural engineers should pay attention to roof drainage, especially on relatively flat roofs. This is not limited to traditional considerations of ponding. A structural engineer should also verify that there are separate primary and secondary drains, properly sized and meeting code requirements. Why? If there is a roof collapse, the SEOR will almost always be named as a party in any resulting litigation.

C Expert Panel Comments

The principal cause of the roof collapse was inadequate roof drainage, a not uncommon source of problems, particularly in light roof structures. Flow restriction from modification of the primary scuppers by the installation of steel plates with drilled holes compromised the already inadequate original design. The lack of adequate primary and secondary drainage was a code violation and critical factor in the failure.

The principal cause of the roof collapse was inadequate roof drainage, a not uncommon source of problems, particularly in light roof structures.

Design of drainage systems typically is not the primary responsibility of the structural engineer. Drainage is generally designed by a mechanical engineer (particularly in the case of roof-mounted drains) or the architect (common for parapet scuppers).

The awareness and involvement of a structural engineer in roof drainage design has been the subject of much recent discussion and appears to be an evolving issue. For example, the American Society of Civil Engineers Standard **ASCE/SEI 7-16>**, Commentary, Para. C8.2 notes 'Roof drainage is a structural, architectural, and mechanical (plumbing) issue. The type and location of secondary drains and the hydraulic head above their inlets at the design flow must be known to determine rain loads. Design team coordination is particularly important when establishing rain loads.' No similar statement exists in the predecessor to ASCE 7 current at the time of the building's design, **ANSI A58.1-82>**. The author of **Roof Drainage Design and Analysis: Structural Collapses, Responsibility Matrix, and Recommendations>**, published in 2005, suggests 'The subject of roof drainage design should be a required item of discussion at the design review meetings between architects, mechanical engineers, and structural engineers.'

Drainage considerations can impact rainwater loads, so the structural engineer should consider the implications of the expected drainage system performance on roof loads. For example, roofs must be designed for the weight of rainwater assuming the primary drains are blocked. For the structural engineer, the rain load includes the static (depth of water to the invert) and hydraulic head (depth of water above the drain invert). Ponding load due to deflection of the structure is in addition to the rain load, and that is determined by the structural engineer for the specified system.

On most projects, roof drainage design and roof rainwater design loads require careful coordination amongst disciplines. While at present the International Building Code does not explicitly require that the structural design drawings indicate the assumed rainwater design loads, some consider this to be advisable practice.

Drains and scuppers should not be modified by an owner or contractor without the consultation of qualified professionals. Building owners and managers should maintain drains, scuppers, and plumbing to be free of obstructions.

Additional information may be found in:

- **Two Roof Failures Due to Water Ponding and Related Code Requirements>**
- **The Roof Drainage Epidemic>**
- **Roof Drainage, Not my problem . . . Maybe>**
- **Steel Joist Institute Technical Digest 3 - Structural Design of Steel Joist Roofs to Resist Ponding Loads>**

Drainage considerations can impact rainwater loads, so the structural engineer should consider the implications of the expected drainage system performance on roof loads.

Submit Report

Submit Feedback

Channel slab roof deck collapse during reroofing

CROSS Safety Report   Report ID: 970

Overview

This report highlights the structural risk caused by machinery during reroof a project.

It describes the partial collapse of a roof (consisting of precast concrete ‘channel slabs’) of a 45-year-old manufacturing building that occurred during reroofing.

Key Learning Outcomes

For structural design engineers:

- Consider reviewing guidance documents before assessing the condition of existing structures for reroofing since it can be challenging, especially in older structures that have deteriorated. See suggested guidance documents referenced in the Expert Panel’s comments below.
- Specifications for reroof work that contain project-specific requirements will help avoid the contractor’s overloading or damaging the structure.

For contractors:

- Conduct a thorough survey of existing conditions prior to commencing work.
- Use care to not overload or damage the structure during reroofing operations.

For building owners and managers:

- Consider retaining a qualified independent professional to monitor reroofing work.

R Full Report

In 2020 an existing roof deck experienced a partial collapse during a reroofing project. The subject facility was a manufacturing plant, originally built in the mid-1950s. The existing roof deck consisted of conventionally reinforced, conventional structural lightweight precast channel slabs (not autoclaved-aerated concrete). Each channel slab is approximately 2 ft (0.61 m) wide and spans approximately 8 ft (2.4 m) between supports. The channel slabs were reinforced with a single reinforcing bar in each flange (two total per channel slab) and a wire mesh within the web of the channel. A non-composite lightweight insulated topping slab was installed atop the precast channels slabs and provided support for two separate roofing systems, including various layers of insulation and roofing membranes. The total thickness of the roof assembly varied from 14 to 18 in (36 to 46 cm) atop the precast channel slabs. The roof was flat with no slope. Long term roof leaks had led to the deterioration of some precast channel slabs. This deterioration generally included cracking and spalling over reinforcing steel at these locations. This cracking and spalling was generally isolated and extended from approximately 1 to 3 in (2.5 to 7.6 cm) along the length of the precast channel slabs.

Prior to the reroofing project an engineering study was undertaken, which included limited observations of the precast channel slabs, chemical and petrographic analysis of the existing concrete material, and infrared scanning of the roof to determine the approximate extent of the roof leaks. There was no indication that the reinforcing steel within the precast channel slabs had debonded from the channel slabs as the distress was limited in length. It was determined by the engineer that, absent any deterioration, the structural roof deck consisting of the precast channel slabs was generally capable of supporting the new roof in accordance with Section 705.2 of the International Existing Building Code (IEBC). During the reroofing operation, debris containment netting was provided over select portions of the facility to catch small portions of spalling concrete and other construction debris that might fall through the joints between precast channels slabs during the reroofing project.

During tear-off of the existing roof, a channel slab collapsed and fell to the ground. No one was injured in the collapse. Workers atop the roof were able to get off the failing panel as it began to collapse. No occupants were in the portion of the building at the time of the collapse. Reports from the workers atop the roof at the time of the collapse indicated that the channel slab 'suddenly snapped in half' while a worker was sweeping debris off a portion of the roof in preparation for the new roof installation. Later investigation revealed that the roofing contractor was using concrete demolition hammers (jackhammers) to remove portions of lightweight insulated concrete topping which was installed above the precast channel slabs.

A review of the debris including the broken panel revealed that reinforcing bars had debonded and separated from the precast channel slab, leading the channel slab to act as an unreinforced concrete section causing a flexural failure under service loading. No corrosion or rust-staining was present on either the reinforcing steel or the concrete debris. It was determined that the collapse was likely the result of inappropriate equipment use during roof tear-off.

Care must be used in extrapolating 'limited' observations and probes to an overall assessment.

C Expert Panel Comments

This case highlights two important topics (1) the challenges of assessing the capacity of an existing structure in building repair and maintenance projects and (2) a contractor's obligation to not overload or damage the existing structure.

It was difficult for the engineer specifying the reroof project to assess the existing conditions. The building was old, and the roof planks exhibited some, but apparently limited, distress. The extent of any potential debonding of the planks' reinforcement could not be directly determined. Care must be used in extrapolating 'limited' observations and probes to an overall assessment. The post collapse observations of the absence of rust or staining on reinforcing steel or concrete debris suggest the engineer made a reasonable judgement in assessing existing conditions. The lack of redundancy in the planks' structural capacity caused by simple spans with no reinforcement at the plank ends is not uncommon in roof decks of various materials, but it meant that a midspan flexure failure would result in sudden collapse with little warning. One potential avenue in the preconstruction assessment of capacity may have been to load test a representative sample of the planks. ASCE's Guideline for Structural Condition Assessment of Existing Buildings (**SEI/ ASCE 11-99>**) offers additional guidance.

Contractors must use care not to overload or damage the structure during their operations. The reroofing provisions of the **International Building Code (IBC 2018)>**, Section 1511.2 Structural and construction loads, requires, 'Structural roof components shall be capable of supporting the roof-covering assembly and the material and equipment loads that will be encountered during the installation of the system.' The **NRCA Roofing Manual: Membrane Roof Systems – 2019>**, Chapter 9 – Reroofing states, 'The structural integrity of the roof assembly must be maintained during reroofing operations, including loading on the roof attributable to workers and material being present during this special time.' It is common in reroofing projects for the project specifications to include specific provisions to avoid overloading and structural damage.

There are similarities between this case and failures of reinforced autoclaved aerated concrete (RAAC) planks reported in a **May 2019 SCOSS Alert>**, although the planks of this case were not AAC.

Submit Report

Submit Feedback

Inappropriate material storage causes collapse of ceiling of a truck dock mezzanine

CROSS Safety Report   Report ID: 983

Overview

This report describes the collapse of an overloaded framed ceiling.

It relates that the ceiling above a mezzanine at a truck access dock was inappropriately used for material storage and caused it to collapse.

Key Learning Outcomes

For architects:

- Consider discussing the use of the structure with the building's owner, especially when the intended use of a space may be unclear or subject to misinterpretation.
- Design strategies for avoiding overloading of structures include (1) functional design that precludes access to the space, (2) direct design for worst-case loads, and (3) posting load limits.

For structural design engineers:

- Consider, within reason, any foreseeable conditions that may exceed the code-prescribed minimum requirements.
- The structural engineer, however, is not obligated to design for misuse of the structure.

For contractors:

- It is good practice to follow design documents and not to improvise.

For building owners and managers:

- It is good practice to monitor use and loading of your structures.
- Consult with qualified design professionals before modifying or adding to the structure.

For building authorities:

- It is good practice to look for ways in which the structure may be subject to overload when reviewing plans and during inspections.

R Full Report

The subject facility is a parts storage building associated with an automobile dealership. A storage mezzanine, which is used to store extra parts, is located adjacent to the exterior wall. A portion of this storage mezzanine is located over the parts receiving garage. According to onsite workers, this receiving garage is normally left open overnight to receive overnight deliveries without allowing access to the rest of the parts storage facility. During the original construction, a wood and gypsum panel ceiling was framed approximately 5 ft (1.5 m) above the mezzanine elevation for the purpose of air-sealing the parts storage building when the receiving garage is open. The ceiling is located above the mezzanine level to permit a delivery truck access into the receiving garage and is constructed using 2x4 (4x9 cm) ceiling joists at 2 ft (61 cm) on center supporting a plywood top and a gypsum board bottom. This framing was nailed using wood nails to the exterior wall. Over time, this ceiling adjacent to the storage mezzanine was utilized for additional parts storage.

Eventually this ceiling collapsed, separating from the exterior wall and causing the ceiling and the parts stored above the ceiling to fall to the floor below. Unfortunately, the collapse led to the hospitalizations of two workers, who were located under the ceiling at the time of the collapse.

Designers need to be cognizant of how spaces will be used and especially careful when heavy live loads are involved. In this case, extending the wall up to underside of the roof structure would have prevented the top of this ceiling from being used as storage at a minimal additional cost.

C Expert Panel Comments

It is unclear from the report whether a structural engineer or other design professional specified the subject ceiling. Regardless there are useful lessons here for design professionals, code officials/inspectors, and building owner/operators.

Designs must meet the minimum requirements of the applicable code. While the International Building Code (**IBC 2018>**) has specific live load requirements for 'attics' of residential structures, there are no similar provisions for storage warehouses, as typical warehouses do not have attics. Building codes specify minimum requirements and, where necessary, it is incumbent on the design professional to consider reasonably foreseeable conditions that may exceed the code-prescribed minimums. (**ASCE/SEI 7-16>**, Para. 4.3.1 states, 'The live loads used in the design of buildings and other structures shall be the minimum loads expected by the intended use or occupancy but in no case be less than the minimum uniformly distributed loads required by Table 4.3-1.' This begs the question of what conditions are reasonably foreseeable and what are not. The structural engineer is not obligated to design for abject misuse of the structure. A 2017 Structure magazine article **Failure of Imagination>** discusses the dilemma of misuse and design for unforeseen conditions.

Where the intended use of a space may be unclear or subject to misinterpretation, it is advisable for the design professional to discuss the use of the structure with the building's owner. In this case the inclusion of plywood atop the ceiling joists may have suggested to a user that the ceiling was intended for storage. Safeguards can include:

1. Arranging the structure to preclude overloading. In this case that might have included walling off the space above the ceiling as suggested by the reporter.

2. Designing for a maximum likely foreseeable load under the intended use.

The structural engineer is not obligated to design for abject misuse of the structure

3. Posting signs prohibiting unintended loading or stating a maximum design capacity. OSHA 1926.250(a)(2) requires, 'Maximum safe load limits of floors within buildings and structures, in pound per square foot, shall be conspicuously posted in all storage areas, except for floor or slab on grade. Maximum safe loads shall not be exceeded.' A risk with sign postings is that they might be removed or ignored.

Problems may occur if owner agreements and understandings made at the design stage are not passed on to the building's managers and operators. Code officials and inspectors should be on alert for possible misunderstandings as well. Regardless of the above, building manager/operators should monitor use and loading of their structures.

Submit Report

Submit Feedback

Steel column erection anchoring connection failure injured worker

CROSS Safety Report   Report ID: 992

Overview

This report describes how a construction worker was injured during the erection of a steel column due to shortcomings in erection procedures and inadequacies in a column base connection.

Key Learning Outcomes

For all built environment professionals:

- Be mindful that accidents caused by instability are not uncommon in structural steel erection.
- The erector is, generally, responsible for the method and sequence of erection. Be aware that in unusual cases, design contract documents may prescribe or control certain aspects of erection methods and sequence.
- Some industry standards, particularly OSHA 1926, have specific requirements for steel erection.

For steel erectors:

- It is good practice to review and assess the capability of column base connections.

For structural design engineers:

- It is good practice for design contract documents to be clear in defining responsibility for steel column base details. This includes defining design responsibilities for both in-service conditions and erection conditions. Be aware that responsibilities may vary from project to project.

For fabricators and their detailers:

- It is good practice to understand the project requirements for column base connections, including definition of responsibility for the connection design.

R Full Report

The column was a TS 6x6 (15x15 cm tube), two-stories tall. The design of the anchoring system consisted of four 3/4 in (1.9 cm) diameter all-thread bolts embedded into the concrete foundation and welded to a leveled base plate. The column had a 1 inch (2.5 cm) thick base plate welded to its end. This base plate had two 1-1/4 in (3.2 cm) (nominal 1 in) holes to receive two 5/8 in (1.6 cm) diameter bolts that the contractor field welded to the leveled baseplate. The column was temporarily secured with 1-3/4 in (4.4 cm) diameter by 1/8 in (3 mm) thick washers and 5/8 in (1.6 cm) nuts. The column base detail is shown in Figure 1.

During steel erection, while a worker was halfway up the column for the purpose of connecting a beam, the column fell over (possibly pulled down by the crane) injuring the worker not only from the fall, but the column landed on his legs.

During steel erection, while a worker was halfway up the column for the purpose of connecting a beam, the column fell over

There are multiple ways this accident could have been avoided. First, the steel erector did not secure the column with bracing. Second, the project was in an area of the country where the structural engineer does not design steel connections. However, the design drawings contained a detail that provided the contractor with the option to field weld the two 5/8 in diameter erection bolts to the embedded plate. Thus, the engineer accepted some responsibility for the design of the connection and for the contractor means and methods of erection. The provided shop drawings, reviewed by the engineer, contained the suggested detail without sufficient information to evaluate its capacity. The responsibility for determining the adequacy of the connection fell into the gap between the engineer and the fabricator/erector. The failure of the bolt weld was the weak link in the connection detail. Moreover, both the fabricator/erector and engineer failed to recognize the OSHA requirement that 'all columns shall be anchored by a minimum of 4 anchor rods (anchor bolts).' While four anchor bolts may not have prevented the accident, the designer of the connection should have been aware of the OSHA requirement.

C Expert Panel Comments

Steel erection accidents like the one reported herein are not uncommon. Responsibilities amongst designers, fabricator/detailers, and erectors can be complex and may be unclear. Consequently, written standards of practice such as OSHA 1926 and the AISC Code of Standard Practice (**ANSI/AISC 303-16>**) have become more detailed and definitive with time.

Generally, and unless the contract design documents prescribe otherwise, responsibility for erection means and methods resides with the erector. Where erection stability depends, in part, on the strength and configuration of connections, as in the case of column base connections, responsibility can be obscured. There is insufficient detail in the report to precisely ascertain the responsibilities for the final column base detail design amongst the structural designer, the fabricator, and erector in this case. While CROSS has a no-blame culture, numerous learning outcomes can be drawn.

OSHA 1926.750 has extensive provisions for steel erection. 1926.755(a) requires that:

- 'All columns shall be anchored by a minimum of 4 anchor rods (anchor bolts).'
- 'Each column anchor rod (anchor bolt) assembly, including the column-to-base plate weld and the column foundation, shall be designed to resist a minimum eccentric gravity load of 300 pounds (136.2 kg) located 18 inches (0.46m) from the extreme outer face of the column in each direction at the top of the column shaft.'
- 'Columns shall be set on level finished floors, pre-grouted leveling plates, leveling nuts, or shim packs which are adequate to transfer the construction loads.'
- 'All columns shall be evaluated by a competent person to determine whether guying or bracing is needed; if guying or bracing is needed, it shall be installed.'

If the design of a column base connection is shown fully on the design documents, the connection must have four anchor bolts as required by OSHA. Normally then, the structural engineer will design the connection, as a minimum, for the eccentric gravity load required by OSHA, as well as the in-service loads. If the structural engineering design professional intends for the fabricator/detailer or its structural engineer to design the connection, then the contract documents must clearly state so, including specification of the required design capacity. The fabricator/detailer must also design the connection for erection conditions, again, as a minimum for the OSHA prescribed eccentric gravity load.

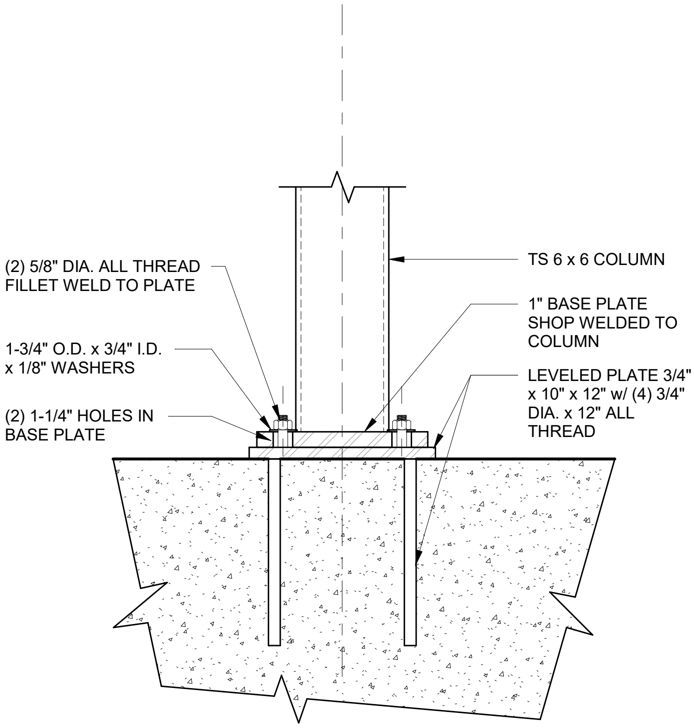

Figure 1: Column base detail showing base plates and anchors. Figure drawn by REM Arch LLC.

In the case where the fabricator/detailer designs the connection, final responsibility for the connection's adequacy depends, again, on the requirements of the contract documents. Often responsibility for a connection's design adequacy remains with the structural engineering design professional regardless of who performs the function, but this is not always the case. See, for example, Option 3 of AISC/AISC 303-16 referenced above, in which connection design is delegated to another registered professional engineer who works on behalf of the fabricator/detailer.

Clarity of responsibility for column base connection design in contract documents is critical.

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Failures of cold formed steel floor systems during construction

CROSS Safety Report Report ID: 997

Overview

This report describes numerous collapses during construction of cold formed steel floor systems caused by lack of bracing/fastening and overloading of an incomplete structure.

Key Learning Outcomes

For structural design engineers:

- It is good practice to include in the project design documents the requirement that cold formed steel joists be properly braced before loading.

For contractors:

- It is good practice to not load cold formed steel joist systems until properly braced.

For code and standards writers:

- Consider the addition of prescriptive requirements for bracing cold formed steel floor systems, similar to those adopted in New York City.

R Full Report

The correspondent reports that in recent years there have been collapses during construction of cold formed steel floors. This is not just a recent trend, as several accidents of this type have been recorded since 2005. Although not very numerous, these accidents have led to serious injuries and even fatalities. Almost all had a common cause: floor overload during construction. Manufacturers' instructions clearly define the allowable floor loads, but these refer to a system where the joists are properly attached to decking and braced. In some construction operations such bracing and fastening does not immediately follow the installation of the cold formed joists, leaving them in a potentially unstable condition. Of course, construction loads should not exceed manufacturer's specifications, but several incidents have occurred when a lower load of construction material was deposited, and collapse occurred because the floor was unbraced. Collapses have occurred under a variety of loading, including depositing CMU, studs bunched together, or concrete being cast. In some cases, the depositing of the construction material occurred when the material was delivered by a lumber yard. Commonly the load might not have been extreme, but it was concentrated over a small area at mid-span.

The potential of local instability of cold formed floor joists is such that one should consider a cold steel formed floor as a one way spanning system. Despite this the IBC 2015 does not include specific requirements for special inspection of bridging.

Almost all had a common cause: floor overload during construction

The New York City Buildings Department issued a **recent bulletin>**, with numerous and specific instructions, with the intent to curb these types of accidents. Through this bulletin, the following provisions related to special inspection of cold formed steel were added to the New York City Building Code.

From Table 1704.3.4, Cold Formed Steel Light-Frame Construction, Bracing

'5.a. Verify that temporary bracing, shoring, jacks, etc., are installed, and not removed until no longer necessary, in accordance with the approved construction documents and approved erection drawings.

5.b. Verify that permanent bracing, web stiffeners, bridging, blocking, wind bracing, etc., are installed in accordance with the approved construction documents and approved erection drawings.'

Experience has shown that because this special inspection might occur at a late date, the requirements are not capable of detecting missing or improper bracing before construction operations take place and allow accidents to happen.

C Expert Panel Comments

Cold formed steel joists are increasingly employed nationwide, especially in multifamily residential and hotel construction. The stability of traditional wood framing is less critical because of the dimensions (material thickness) of typical wood joists. Wood joists are inherently more stable.

OSHA 1926.750 contains extensive provisions for steel erection, which include cold formed steel framing. 1926.754(a) requires that 'Structural stability shall be maintained at all times during the erection process.' While OSHA 1926.750 contains specific provisions for metal decking, column anchorage, beams and columns, open web joists, and system engineered metal buildings, there are no similar specific provisions for cold formed steel framing.

The American Iron and Steel Institute Code of Standard Practice for Cold-formed Steel Structural Framing 2020 Edition (**AISI S202-20>**), Section F6 Temporary Bracing, requires, 'The installer shall determine, furnish, and install all temporary bracing for the cold-formed steel structural framing. This temporary bracing shall secure the framing against loads that are expected to be encountered during installation.'

Given the increasing use of cold formed steel joists in floor construction, the incidence of problems, and the evolving nature of codes and standards, it may be prudent for structural design specifications and drawings to make special note of the need to properly brace such floor systems before loading.

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