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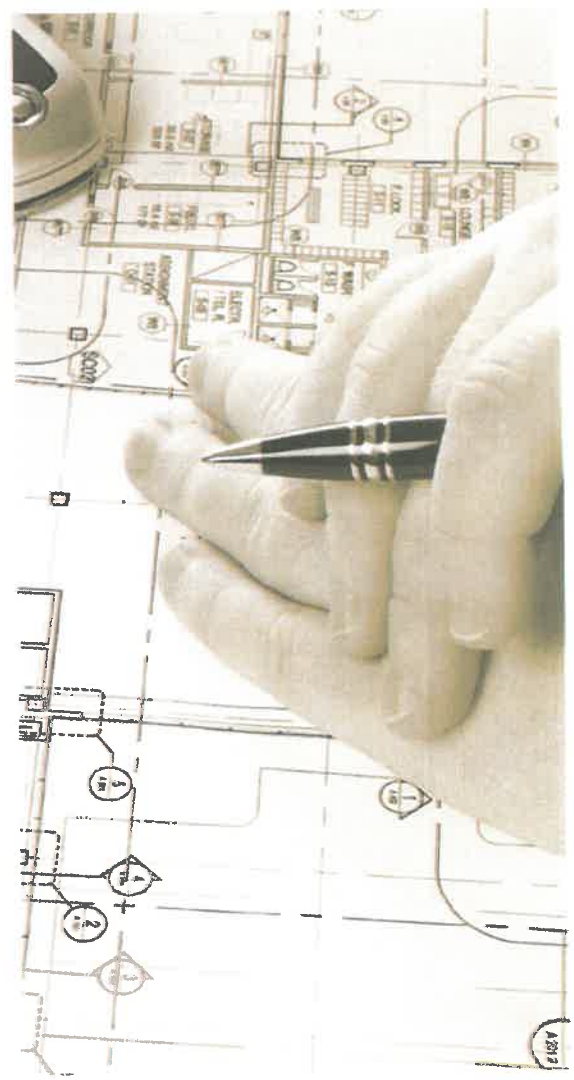
IRA CIVIC CENTER

GRAND RAPIDS, MINNESOTA



Your Client: City of Grand Rapids
Claim No.: CP44375
Date of Loss: November 13, 2017

Crane File No.: 91632
Crane Descriptor: CITY OF GRAND RAPIDS – LEAGUE OF MN CITIES – CIVIC CENTER

Prepared for:

Mr. Erik Arntsen
League of Minnesota Cities
145 University Avenue West
St. Paul, MN 55103

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

James R. Panko, P.E.
License No.: 46715
Date: December 19, 2017

SUMMARY

This preliminary report involves the investigation of issues related to a failed web member of a bowstring wood truss that is part of the roof structure for the civic center ice arena in Grand Rapids, Minnesota. Crane Engineering, Inc. was engaged on November 13, 2017 by Mr. Erik Arntsen to investigate and evaluate the cause of the failure. This report, prepared at the request of Mr. Arntsen, represents the results of our investigation performed to date.

BACKGROUND

The IRA Civic Center located at 1401 NW 3rd Avenue, Grand Rapids, Minnesota is a multi-venue facility used for various types of events. It was reported to Crane Engineering by City Officials that the west venue of the IRA Civic Center was originally constructed circa 1962. An addition to the north was completed around 1982 that added two additional trusses to the north end of the west venue. The east venue and entry was added around 1995.

The roof structure of the original 1962 building was constructed with bowstring wood trusses spaced at 20 feet on center and spanning east to west 132 feet. The wood trusses were constructed with 5 ¼ inch by 11 ¼ inch glue laminated wood timbers for the top and bottom chords. The diagonal web members for the trusses were constructed using solid wood members in varying sizes. The third diagonal web member from the east wall of the fifth truss from the north wall was discovered fractured near the upper connection on or around November 8, 2017. At the time of the inspection on November 15, 2017, the member had been temporarily repaired. The fracture web member was retained onsite for inspection. A visual inspection of the failed web member showed the member had split at the location of the holes for the through bolts at the top of the member.

A report prepared by Stuart Anderson Professional Engineering Services dated March 24, 2001 discusses a web member failure that occurred on the fifth truss from the north wall. The report indicates that the fifth web member from the east wall had bowed and fractured with a significant unbalanced snow load along the east side of the west venue roof. In addition to the fractured web member, significant bowing was also observed of multiple to several web members on the east half of the west venue roof.

INSPECTIONS

Crane Engineering performed a site inspection of the IRA Civic Center roof structure on November 15, 2017. The inspection included visual observations made from floor level and from a scissors lift. Measurements of the truss were taken using a pocket tape and a Hilti digital range meter. At the time of this inspection, the failed web member had been removed and temporarily replaced. The failed web member was retained on site and was visually observed by Crane Engineering. The failed web member measured 2 ½ inches deep by 5 ¼ inches wide. Two ¾ inch diameter holes were drilled through the width of the member at the top and bottom where through bolts were used to connect the web to the chord members of the bowstring truss. A crack was observed through the width of the member that appeared to originate at the bolt holes at the top of the member. Refer to Figure 1.

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Figure 1. Crack in 3rd web member from east wall of fifth truss from the north end.

ANALYSIS

Building Codes

It was reported to Crane Engineering by City Officials form Grand Rapids, Minnesota that the original structure was constructed circa 1962. At that time, Minnesota did not have a state-wide building code. It was up to local jurisdictions to adopt building codes into law if any were adopted at all. The original plans were not available for review. Therefore, it is not known at this time what the original roof structure was intended to be designed for. The first State Wide Building Code was adopted in 1972 and incorporated into the 1970 Uniform Building Code (UBC) by reference with state amendments. The Minnesota state amendments required all roofs to be designed to a minimum snow load of 40 pounds per square foot[1]. In 1973, the 1972 Minnesota State Building code was amended, changing the snow loading requirement to 30 pounds per square foot for Itasca County[2].

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[1] Minnesota State Regulations, *Rules and Regulations Relating to Building Code Division*. Department of Administration, October 1972 Supplement.
[2] Minnesota State Regulations, *Rules and Regulations Relating to Building Code Division*. Department of Administration, 1973 Amendments.

The subject roof structure was constructed with a curved roof referred to as a barrel roof. This type of roof is susceptible to unbalanced snow loading conditions where the windward side of the roof will be swept by wind that removes snow from the windward exposure and deposits additional snow to the leeward exposure. The 1970 UBC required trusses to be designed with consideration for an unbalanced roof load equal to the design snow load applied to half the span of the truss when such loading will result in a reversal of compression/tension stresses in the members[3].

The current building code that governs the design of buildings in Minnesota is the 2015 Minnesota Building Code which adopts the 2012 International Building Code by reference with state amendments. Under the current building code, the subject roof structure would need to be designed for 46 pounds per square foot uniform snow load and be designed for the requirements of unbalanced snow loading, as described in Chapter seven of the ASCE/SEI 7 – 10[4].

Truss Analysis

Measurements were taken of the first truss from the south wall that was adjacent to the attic/storage area. This truss was representative of all the trusses constructed as part of the original structure. Crane Engineering used these measurements to model the bowstring wood truss using Risa 3D structural analysis and design software. All wood members were modeled using properties of Douglas fir. The purpose of performing this analysis was to gain a general understanding of how loads are distributed though the truss. The analysis is not intended to be used as a guideline for a safe operating snow load for the structure. The subject truss was analyzed using two design load combinations that were based on the snow loading requirement of 30 pounds per square foot.

- Dead load + balanced snow load (30psf evenly distributed on the horizontal projection)
- Dead load + unbalanced snow load[4] (15psf at center of truss tapering up to 60psf near east eave)

The following dead loads were used in the analysis of the subject roof truss:

- TPO Roofing System: 3 pounds per square foot
- Roof Decking: 5 pounds per square foot
- Purlins and Bracing: 2 pounds per square foot
- Total superimposed roof Dead Load: 10 pounds per square foot

*Mechanical and electrical loads are negligible

*The self-weights of the individual truss members were included in the RISA 3D model

[3] Uniform Building Code (UBC) Volume 1, 1970. Part VI. Section 2305.b
[4] American Society of Civil Engineers / Structural Engineers Institute ASCE/SEI 7 – 10, Minimum Design Loads for Buildings and Other Structures, Chapter seven.

Under the dead load + balanced 30psf snow load condition, adjacent web members of the truss alternate between tension and compression members with the first, third and fifth web member in from the exterior wall as tension members and the second, fourth and sixth web members in from the exterior wall as compression members. Figure 2 shows the location of the tension and compression web members marked with a T or C respectively, when a uniform snow load is applied. The analysis under this loading condition shows the roof trusses are not capable of safely supporting the weight of a uniform 30psf snow load.

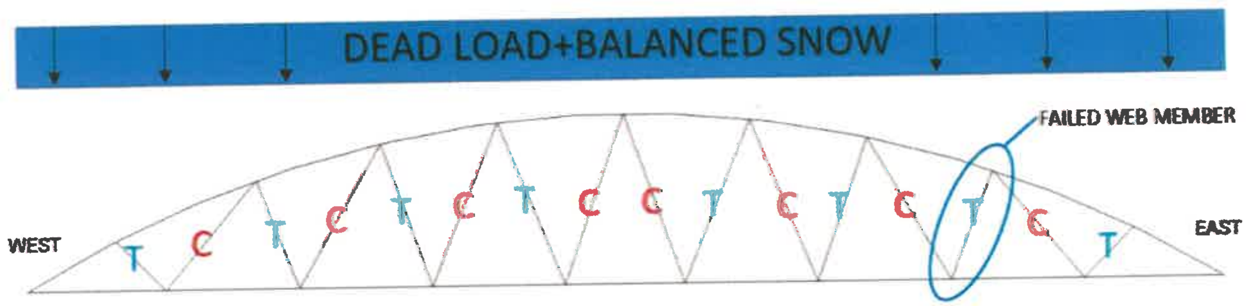

Figure 2. Tension and compression diagram of web members with balanced snow loading.

Under the dead load + unbalanced snow load condition applied to the east side of the truss using the methods prescribed in Chapter seven of the ASCE 7-10 with a 30psf snow load, the web members on the east side of the truss that were in tension under the balanced snow load condition switched to compression members. Figure 3 shows the location of the tension and compression web members, marked with a T or C respectively when the unbalanced snow load condition is applied to the truss.

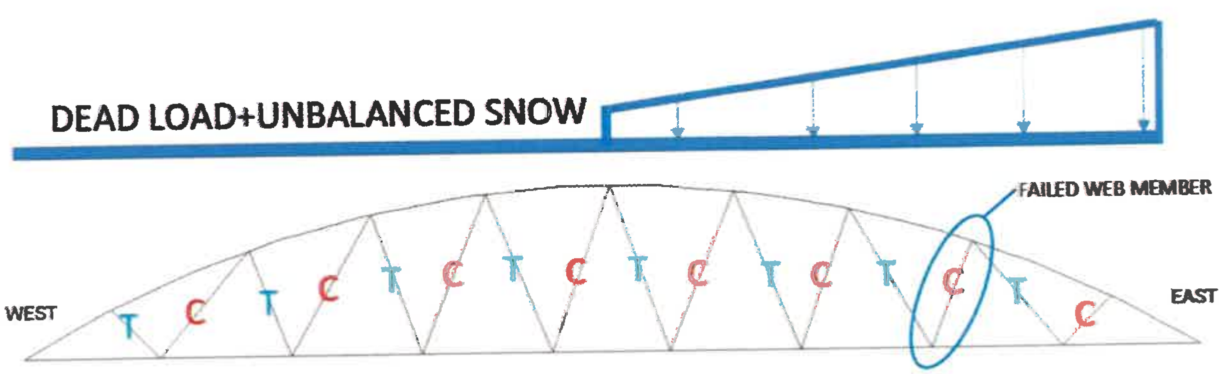

Figure 2. Tension and compression diagram of web members with unbalanced snow loading.

The analysis shows that a load reversal occurs in the web members of the subject truss when an unbalanced snow load is present along the east side of the truss. This causes slender web members that were originally designed as tension members to become compression members. The subject web member was 2 ½ inches deep by 5 ¼ inches wide, making it susceptible to out-of-plane bowing in the narrow direction under compressive stresses.

The failed web member is likely due to an accumulation of unbalanced snow along the east side of the truss that caused the slender web member to become overstressed in compression, resulting in a failure at the upper connection. It is likely that the subject web member partially fractured from a snow event that occurred in a previous season, significantly weakening the member. This caused the subject web member to completely fail during the recent snow event in November of 2017, under relatively light snow loading conditions.

REPAIR

To restore the structure back to a comparable condition prior to the loss, the failed web member can be replaced with a new member that is properly sized to the meet the loading requirements of the current building code. During this process, the subject truss will need to be properly shored up at both the top and bottom chords. The remaining roof system of the subject building should be evaluated by a structural engineer to determine how to retrofit the structure to bring it to a safe working condition.

CONCLUSIONS AND OPINIONS

Based on my education, training and experience as well as the investigation and analysis outlined herein, I hold the following conclusions and opinions to a reasonable degree of engineering certainty.

1. The as-built condition of the roof structure for the original 1962 west venue appears to be under designed to support the unbalanced snow loading conditions that are occurring on the surface of the roof.
2. The truss web member failed as a result of a load reversal from tension stresses to compression stresses caused by an unbalanced snow load condition along the east side of the subject roof.

The preliminary conclusions and opinions formulated during this investigation and presented herein are based on information available to date. Crane Engineering reserves the right to supplement or otherwise amend this report should other information become available.

Respectfully submitted,

CRANE ENGINEERING, INC.

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JRP/dke