June 3, 2024

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Re: Civic Centre Arena, 719 Vernon St., Nelson, BC
Arena Roof Structure Assessment Report

This report summarizes the results of our roof structure assessment for the existing Civic Centre Arena Roof. We were directed to complete this work by Sam Ellison and Colin Innes of the City of Nelson in December, 2023.

We have completed this assessment in general accordance with the professional practice guidelines published by Engineers & Geoscientists British Columbia (EGBC): *Structural Condition Assessment of Existing Buildings.*

General Building Description

The existing building was constructed around 1935 and has a footprint of approximately 200' x 188', and consists of two general areas:

- Theatre & Gymnasium (south area, upper roof)
- Arena (north area, lower roof)

The Theatre & Gymnasium area has a footprint of approximately 70' x 180' and is located above the existing theatre, stage, and gymnasium areas. The upper roof is supported by timber purlins, timber roof trusses, and reinforced concrete walls & foundations.

The Arena area has a footprint of approximately 130' x 200' and is below, and located to the north of the Theatre & Gymnasium area. The Arena roof is supported by timber purlins, steel roof trusses, and reinforced concrete walls, columns & foundations.

Structural Analysis Methodology

The existing arena building structure was analyzed, in accordance with the British Columbia Building Code (BCBC) 2018, and material codes referenced within (concrete, steel, wood and timber). The following design loads and parameters were used to analyze the structural capacity of the existing structure:

Nelson, BC:

Snow:	Ss =	3.9 kPa	(NOT 4.2 kPa - used site specific data)
Rain:	Sr =	0.1 kPa	

Gravity Design Loads:

Area	*Dead Load (Design)*	*Snow Load (Part 4) / Live Load*
Roof	DL = 0.9 kPa (18 psf)	SL= 3.2 kPa (67 psf)

The gravity loads shown above include dead, live and snow loads. Dead load includes the weight of the permanent roof structure that does not move, including asphalt shingles, plywood, wood decking, purlins, steel trusses, sprinklers, and electrical wiring. Snow load includes the weight of snow and rain on the roof. We have not allowed for snow drift loads on the roof in this analysis (this is discussed in further detail below).

This building is not considered to be a “post-disaster building”, as defined in the BC Building Code 2018 (as agreed with Sam Ellison and Colin Innes).

Existing Arena Roof Structure Analysis Completed by Access Engineering

As directed by the City of Nelson, we have retained Access Engineering to complete a detailed structural analysis of the existing arena roof structure. This analysis was completed in December, 2023, and we provided a preliminary email report to Sam Ellison and Colin Innes on December 20, 2023.

Note that our structural analysis of the existing arena roof structure was based on the following information that was provided by the City of Nelson:

- Original Building Design Drawings prepared by McCarter and Nairne, from 1935
- Structural Steel Shop Drawings prepared by Dominion Bridge Co. Ltd, from 1935
- Reinf. Steel Shop Drawings prepared by Dominion Bridge Co. Ltd, from 1935

Where discrepancies existed between the design drawings and the shop drawings, we assumed that the shop drawings were correct.

Access Engineering has created a detailed structural model of the existing arena roof that includes the appropriate dead loads associated with the following roof build-up: asphalt shingles, ½" plywood, 2 ½" thick wood decking, timber purlins and steel roof trusses.

As discussed in our above-noted email on December 20, 2023, the results of our structural analysis are as follows (taken from email):

1. Existing roof decking: 2 1/2" thick wood decking, D.Fir No. 2 (assumed grade)
   * **Capable** of supporting current design snow load of 3.5 kPa (73 psf).
   OK
2. Existing roof purlins: 4x18 D.Fir No. 1 (assumed grade)
   6x18 D.Fir No. 1 (assumed grade)
   8x18 D.Fir No. 1 (assumed grade)
   * **NOT Capable** of supporting current design snow load of 3.5 kPa (73 psf).
   * **Capable** of supporting approximate snow load of 1.0 kPa (21 psf), or 10" of snow.
   NOT OK
3. Existing steel roof trusses: Steel trusses
   * **NOT Capable** of supporting current design snow load of 3.5 kPa (73 psf).
   * **Capable** of supporting approximate snow load of 1.0 kPa (21 psf), or 10" of snow.
   NOT OK

Note that these results are based on a consistent roof snow load on the roof of 3.5 kPa (73 psf). As discussed with Sam Ellison, it would be appropriate to design this roof for a reduced snow load of 3.2 kPa (67 psf), which corresponds to a site specific snow load that was given by Environment Canada for another site located on Vernon Street, in Nelson, BC.

We have also noted that the arena roof should actually be designed for a snow drift load that would be caused by the proximity to the adjacent upper roof (theatre roof). The design snow drift load (specified in the BC Building Code) on the arena roof is substantially higher than the snow loads that are noted above. The snow drift load is further discussed later in this report.

Existing Building Seismic Analysis Completed by Access Engineering

As directed by the City of Nelson, we have also retained Access Engineering to complete a detailed seismic analysis of the existing building structure. They have created a model of the existing building using ETABS which is one of the industry standard software for this type of structural analysis.

Access Engineering has provided the results of their seismic analysis of the entire building including the theatre and the arena based on the following general parameters:

- Seismic Site Class D (per the geotechnical report prepared by Atkins Realis, dated Dec. 22, 2023).
- Level 1 or Level 2 seismic upgrades as per NBC 2015 Commentary L.
- Original design drawings by McCarter & Nairne, from 1935.
- Assumed concrete strength of 35 MPa, except specific columns with a concrete strength of 45 MPa (based on site testing by Glade Material Testing).
- Existing structure is in generally good condition, with no signs of distress.

We have reviewed and discussed (with Sam Ellison and Colin Innes) the following concepts that are consistent with the provisions of NBC 2015 Commentary L, for seismic upgrades to Level 1 or Level 2:

1. Load path for the shear force resisting system (SFRS) for seismic forces, including any obvious deficiencies such as weak stories, discontinuities in the SFRS, connections between walls and diaphragms, restraint of potential falling hazards from chimneys or parapets, etc...

2. Review of specific deficiencies that have been identified include:
   A) Weak storey within the arena on grid G (see attached plan).
   B) Missing roof plane X-bracing at the north edge of the arena roof (2 locations).
   C) Inadequate connection of the arena roof diaphragm to the existing concrete walls.
   D) Inadequate connection of the theatre roof diaphragm to the existing concrete walls.
   E) Inadequate connection of the (new) theatre ceiling diaphragm to the existing concrete walls.
   F) Missing lateral support for the theatre concrete walls, at the ceiling level above the existing stage area (2 locations: North wall and South wall).

3. Proposed seismic upgrade strategies for the building to address identified deficiencies, including minimum voluntary seismic upgrades to Level 1 or Level 2.

In order to validate the results of the complex ETABS model that has been created by Access Engineering, we have compared these results with hand calculations completed with the assistance of Jabacus (Seismic Load - Equivalent Static Method). The compared results proved to be relatively similar, so we have confidence in the ETABS model created by Access Engineering.

Based on the results of our seismic analyses, we have decided to complete seismic upgrades that are consistent with a minimum voluntary seismic upgrade to a seismic force Level 2. This decision was made in consultation with Sam Ellison and Colin Innes, and provides the City of Nelson with a reasonable level of seismic protection for this building, in accordance with the provisions of NBC 2015 Commentary L.

Note that we have reiterated the results of our seismic analysis in this report because these results have allowed us to reasonably proceed with the emergency structural repairs of the theatre roof, which is currently under construction.

Furthermore, the results of the seismic analysis indicate that the existing arena roof and supporting structure are generally capable of supporting the seismic loads associated with a minimum voluntary seismic upgrade to a seismic force Level 2 (assuming a consistent roof snow load of 3.2 kPa throughout with no snow drift loading).

Please refer to the flow chart on the following page (excerpt from NBC 2015 Structural Commentary L) which identifies our rationale regarding seismic upgrades for the emergency roof repairs that are currently under construction. The path that is highlighted in yellow represents the emergency roof repairs to the theatre roof that are currently under construction, which also include minor seismic upgrading to the arena roof structure. The path that is highlighted in orange represents a possible future path that could be used to renovate the building in the future, once the current project has been completed.

It is important to note that the decision to complete a voluntary seismic upgrade to a seismic force Level 2, was made in consideration of the following factors:

1. The existing building is generally capable of resisting Level 2 seismic forces with only minor seismic structural upgrades.
2. The cost of these minor seismic structural upgrades was deemed to be within the available budget for this project.
3. The existing building is not capable of resisting Level 3 seismic forces without extensive structural upgrades, which were deemed to be cost prohibitive.
4. Future renovation options may exist for this building once it meets seismic force Level 2, as noted in orange on the flow chart on the following page.
5. Future addition options may also exist for this building once it meets seismic force Level 2, as noted in the flow chart on the following page.
6. BC Building Code 2024 (which came into effect on March 8, 2024) contains significant changes to seismic design for buildings.
7. The changes to seismic design in the BC Building Code 2024 have now been postponed until March 9, 2025.

Excerpt from NBC 2015 Structural Commentary L

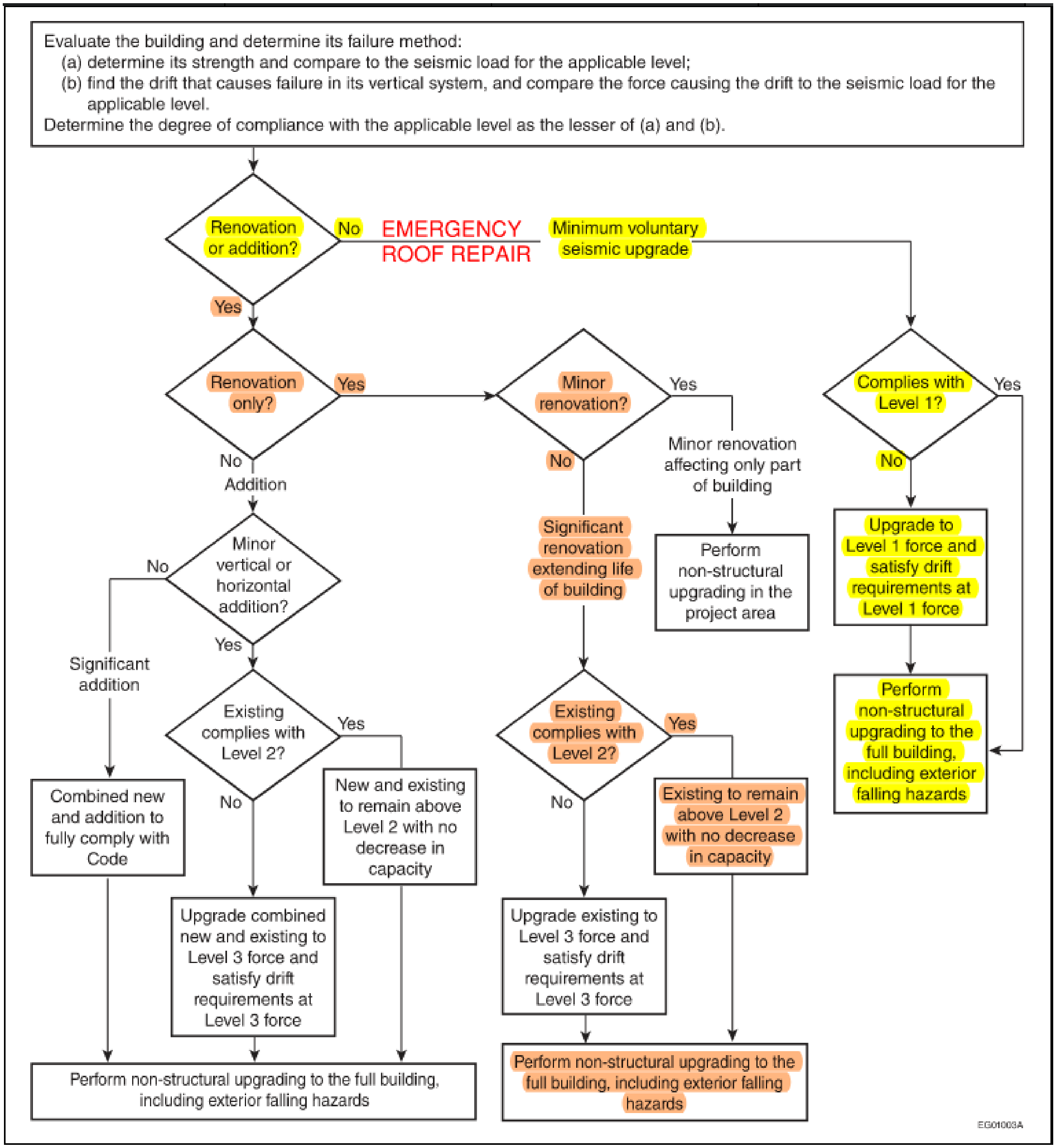

Figure L-1
Flow chart for the seismic assessment and upgrading of existing buildings

Arena Roof Structure Condition Assessment

As directed by Sam Ellison, we also completed a visual review of the existing arena roof structure on Feb. 2, 2024. In order to confirm the existing roof structure composition and condition, we utilized a telescopic boom lift on the arena ice surface to gain access to the existing roof structure. Our visual review of the existing roof structure was focused at the east end of the arena, where we confirmed the size and approximate condition of the existing structural roof members that could not be accessed from the ground, ice or bleachers.

In general, the existing arena roof structure appeared to be constructed in accordance with the original building drawings and shop drawings. We did identify several members that were not constructed as per the original design drawings such as timber purlins, steel bracing between the steel roof trusses, and the mid-span bottom chord members for the steel roof trusses. We eventually confirmed that the mid-span bottom chord members for the steel roof trusses were actually constructed in accordance with the shop drawings, which did not match the original design drawings.

The arena roof structural members were generally found to be in good condition for their age. We noted minor water stains on the wood decking and on many of the timber purlins, however we did not see any significant signs of deterioration of the wood members. The steel trusses were also found to be in good condition, and we did not see any signs of distress in the steel trusses, steel bracing, and steel connections.

We also examined the steel roof truss bearing conditions at both ends of the trusses, including the fixed bearing condition at the east end of the roof trusses and the sliding bearing condition at the west end of the roof trusses. These connections appeared to be in good condition for their age, and we did not see any signs of distress.

We did note that the existing roof decking appears to be creeping down the slope within each structural bay. The amount of lateral deflection (down the slope) was difficult to determine, but it was visible at several locations. This was also visible by sighting along the length of the purlins, which also appeared to be laterally bending (down the slope). It is our understanding that the existing roof deck was overlaid with new plywood when the asphalt shingles were replaced in the last 6 years or so. The new plywood would likely help mitigate this long-term distortion of the roof diaphragm.

Additional Structural Considerations

NBC 2015 Structural Commentary L provides guidance for the evaluation of existing buildings that were designed prior to Canada's first National Building Code which was published in 1941. This document was extensively consulted throughout our structural condition assessment and analysis, including the concepts that are listed below:

Evaluation Based on Satisfactory Past Performance

This clause is commonly referred to as "Grandfathering", and includes the following general conditions:

1. No evidence of structural damage, distress or deterioration
2. Structural system (load path) is theoretically acceptable
3. Building has demonstrated satisfactory performance for 30 years or more
4. No significant changes to the building in the past 30 years, and no such changes are contemplated

Reduced Load Factors and Load Combinations Recommended for Evaluations

These clauses allow for reduced factors of safety when evaluating historic structures, in consideration of reliability levels, risk categories, occupant types, occupant loads and records of past performance.

Historic Arena Precedence

We have briefly examined 5 different historic arenas throughout BC and Canada, to determine if there are other such arena structures in use at this time. These arenas were selected based on similar dates of construction and similar roof structural systems to the Nelson Civic Arena. The 5 selected historic arenas are:

1. **Kelowna Memorial Arena - Kelowna, BC (circa 1945)**
   Designed after the first National Building Code, NBC 1941
   Similar size to Nelson Civic Arena
   Roof design load is unknown
   Still in use today
2. **Kamloops Memorial Arena - Kamloops, BC (circa 1948)**
   Designed after the first National Building Code, NBC 1941
   Similar size to Nelson Civic Arena
   Roof design load is unknown
   Still in use today

3. **Varsity Arena - Toronto, ON (circa 1926)**
   Designed before the first National Building Code, NBC 1941
   Larger than Nelson Civic Arena
   Roof design load is unknown
   Still in use today
4. **Galt Arena Gardens - Cambridge, ON (circa 1922)**
   Designed before the first National Building Code, NBC 1941
   Larger than Nelson Civic Arena
   Roof design load is unknown
   Still in use today
5. **Prince George Arena – Prince George, BC (circa 1939)**
   Designed before the first National Building Code, NBC 1941
   Similar size to Nelson Civic Arena
   Roof design load is unknown
   Collapsed in 1956 under high snow loads

It is our understanding that some of these arenas have undergone significant renovations, however it is unknown if these renovations included modifications to the roof structure. No further research has been completed on these arenas at this time.

Consultation with Access Engineering and Entuitive Consulting Engineers

We have consulted with senior structural engineers at both Access Engineering (based in Prince George, BC) and Entuitive Consulting Engineers (offices in Canada, US and UK), about the Nelson Civic Arena roof structure.

All of the structural engineers that we discussed this project with agreed that we must recommend immediate action be taken to ensure the safety of the public. Knowing that the existing roof structure is only capable of supporting less than 30% of the design snow load on the roof, we have concluded that the existing roof structure requires structural upgrading.

Recommendations

Based on the results of our structural investigation and analysis work to date, it is our opinion that the existing Civic Arena Roof requires an emergency repair for the existing roof structure above the arena. As per NBC 2015 Commentary L, it is our opinion that these emergency repairs do not constitute a renovation or addition, as defined in Commentary L, therefore we believe that the minimum voluntary seismic upgrade that is required is a **Level 1** seismic upgrade (we have actually elected to complete a voluntary seismic upgrade to **Level 2**, which is currently under construction).

As previously noted, it is our understanding that the existing reinforced concrete walls generally have the necessary structural capacity for a voluntary **Level 2** seismic upgrade, with the exception of the foundation and concrete wall work that is currently under construction at the SE corner of the arena.

The emergency roof structure repair for the Civic Arena roof will likely involve the following general upgrades:

1. Connect the existing roof diaphragm to the existing concrete walls (this repair work has already been designed and tendered as a part of the repairs to the theatre roof).
2. Strengthen the existing timber roof purlins using timber or LVL beams.
3. Strengthen the existing steel roof trusses using steel members as required.
4. Strengthen the existing steel truss connections to the existing concrete building.
5. Strengthen the existing reinforced concrete columns as required.
6. Strengthen and/or increase the size of the existing reinforced concrete footings as required.

Feel free to contact our office if you have any questions.

Sincerely,

EffiStruc Consulting Inc.
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Don Willems, P.Eng, LEED AP
Structural Engineer

Key Plan