Engineers

Grand Forks Public Library

2019 Structure and Enclosure Feasibility Study

Grand Forks, BC

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RJC No. KEL.123799.0001

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Executive Summary

This report presents results of the study of structural modifications and potential energy improvements that could be realized for the Grand Forks Library. The Grand Forks & District Public Library building is located at 7342, 5th St in Grand Forks, BC. It is a single-storey structure above grade with a flat roof, has a full height basement, and was constructed *c.* 1981.

Four possible structural alterations to the structure were reviewed at the request of the owner: (1) addition of a lift, (2) addition of a sloped roof, (3) addition of an additional storey, and (4) addition of solar panels to the existing roof. All options with the exception of option (3) were determined to be feasible with varying degree of structural upgrades required, and most required additional review of the soil capacity by a geotechnical engineer. Option (3) was deemed unfeasible as it would require extensive upgrading, likely including a substantial seismic upgrade, and would increase soil loading substantially.

Based on the current electricity usage that was provided, it can be expected that energy-efficient improvements to meet the current building code levels of insulation and air-tightness would result in significant energy savings. The overall energy demand of the building due to losses via the enclosure could be nearly cut in half. Further energy efficiencies could be realized by updating mechanical systems to match the performance of an improved building enclosure system. The option of adding photovoltaic panels to the roof would bring an improved building closer to net zero energy usage.

Opinions of Probable Cost for the building enclosure upgrades and photovoltaic installation are provided.

1.0 Introduction

This report presents results of the study of structural modifications and potential energy improvements that could be realized for the Grand Forks Library as described in Read Jones Christoffersen's (RJC) proposal dated March 6, 2019.

The structural questions raised include:

1. Feasibility of installing an elevator or lift to improve accessibility to the basement.
2. Feasibility of installing a sloped roof rather than replacing the existing flat roof with new flat roofing.
3. Feasibility of adding a second floor, which would include meeting rooms and office spaces.
4. Feasibility of adding solar panels to the existing flat roof.

Potential energy improvements explored by the study take the form of "deep retrofit" strategies. The study includes review of improvements to building thermal performance in the roof, wall, window and below-grade assemblies. In a deep retrofit program, improvements in these systems would reduce energy demand on the building mechanical systems, which could also be upgraded with the potential of being reduced in size and improved in efficiency. Taken together this approach results in synergistic benefits.

To complete this study RJC's services included the following:

- Reviewing available Architectural drawings A1-A7 provided by the City and dated June 4, 1981 to understand the current building systems and their details.
- Attending the site in Grand Forks to complete a visual review, documenting any obvious changes from the drawings and reviewing the structure for visible signs of distress.
- Review of BC Building Code 2018 criteria for each of the four structural items raised.
- Creating energy models in two software programs to calculate and to visualize energy savings.
- Preparation of a written report to summarize findings and provide recommendations for structural modifications and potential energy improvements.

2.0 Building Description

Figure 1: Street elevation of the Grand Forks & District Public Library

The Grand Forks & District Public Library building is located at 7342 5 St in Grand Forks, BC. It is a single-storey structure with a below-grade basement level, constructed *c.* 1981. The building is rectangular, 100 ft long by 60 ft wide, with an alcove leading to the main entrance centered on the west side. 5th Street runs parallel to the west elevation of the building. On the north, east and south side, the library is surrounded by parking and the road access to the neighbouring post office.

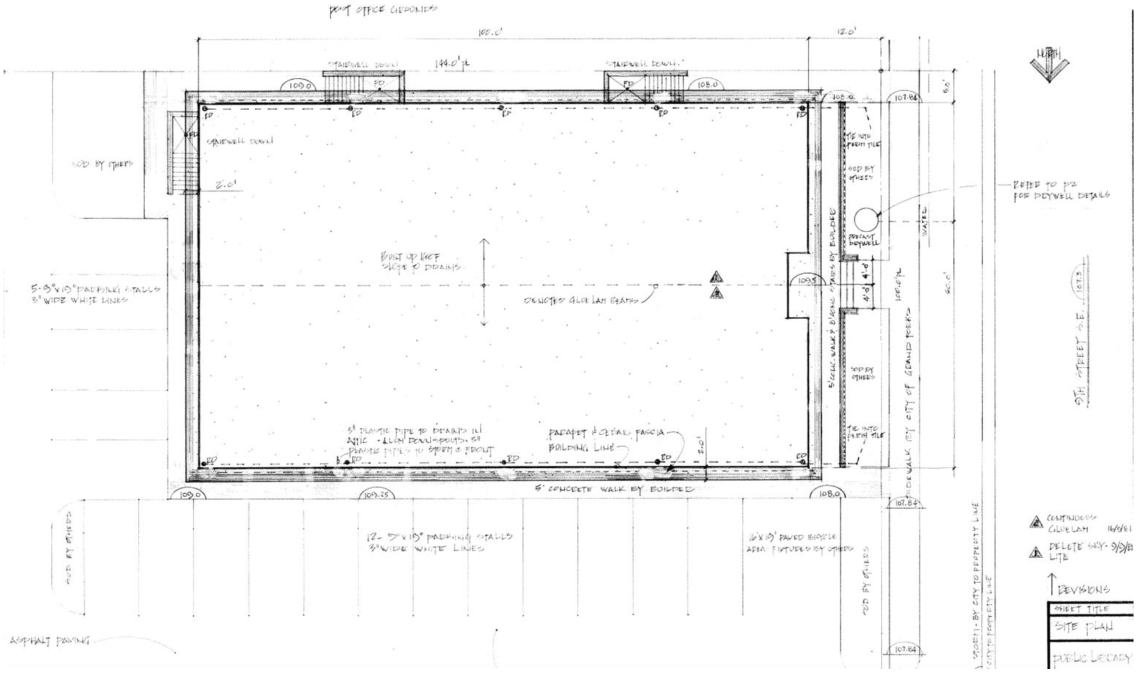

Figure 2: Original site plan dated 1981 (note: 5th Street is marked as 9th Street)

The original building drawings are dated June 4, 1981 by Chernoff Design Services of Grand Forks BC. The drawings provide both structural and architectural details. Based on the date of the drawings and in the absence of structural general notes, it is assumed that the existing building has been designed to the National Building Code of Canada (NBCC) from 1980.

According to the original drawings, the exterior wall consists of 8" clay masonry units on the north, east and south faces, and giant brick walls with large windows along the west face. The walls are insulated with core fill vermiculite; no details regarding air barrier systems are provided. The exterior basement walls consist of reinforced concrete walls—16" wide on the west face and 8" wide on the remaining faces—with 2x4 stud walls on the interior face. There are no details pertaining to a vapour/air barrier or thermal insulation in the basement walls.

The building has a flat roof with R-28 insulation and a polyethylene vapour barrier. The structure is comprised of TJL joists spanning 30' in the north-south direction between the exterior masonry walls and interior glulam beams. The glulam beams span east-west along the centerline of the building and are supported by concrete pilasters and steel pipe columns.

The main floor structure is comprised of 2"x12" joists spanning 15' in the north-south direction. The joists span between ledgers along the exterior concrete basement walls and 3 rows of interior glulam beams. The glulam beams span are supported by 16"x16" concrete pilasters at the east and west exterior walls, and a 15'x20' grid of 5" and 6" diameter steel pipes on the interior. The 6" diameter steel pipes and concrete pilasters along the centerline extend to the underside of the roof to support the roof glulam beams.

The basement floor is comprised of a 4" concrete slab-on-grade over a polyethylene vapour barrier and compacted gravel. There are pad footings supporting the steel pipe columns and 16" wide strip footings supporting the 8" basement walls along the north, east and south faces.

3.0 Structural Visual Review

RJC attended the site on March 12, 2019 to complete a visual review of the structure. Photographs taken during our review are included in Appendix B. Our observations are:

- The glulam beams, columns, ground floor joists and walls were confirmed to be in conformance with the existing building drawings
- The roof joists and foundations were not visible at the time of review, and the overall depth of the roof glulam beams could not be confirmed
- Additional door openings were located in the east masonry wall
- Enclosure structures were located above the stairs on the south face

Overall, the structural elements observed at the time of review appeared to be in good condition and generally in conformance with the existing building drawings.

4.0 Structural Feasibility Review

The following section addresses the structural feasibility of achieving the following modifications: (1) addition of a lift, (2) addition of a sloped roof, (3) addition of an additional storey, and (4) addition of solar panels to the existing roof. The review of each items was completed using the following information:

- Original architectural building drawings A1-A7 dated June 4, 1981 by Chernoff Design Services of Grand Forks BC.
- The *Geotechnical Investigation Town Square Revitalization and City Park Upgrade* report dated September 11, 2007 by Golder Associates Ltd. The bearing capacity of the subject site was assumed to be similar to "Area 3" of the report (150kPa SLS and 225kPa ULS).
- NBCC 1980 to determine design loads from the original building design.
- NBCC 2015 to determine current design loads.

The table below summarizes the feasibility of each modification and what obstructions may impede these modifications or require an associated modification.

Modification	Feasibility	Modifications required	Additional Comments
Addition of Lift	High	Existing L1 joists, L1 beams	
Alteration to Sloped Roof	Moderate	Upgrade existing glulam beams, and possibly remove existing flat roof trusses	Bearing capacity of footings on soil may require re-evaluation
Addition of Additional Storey	Very Low	Upgrade existing roof joists, beams, columns, footings, lateral load paths	Bearing capacity of footings on soil would require re-evaluation
Addition of Solar Panels to Roof	High	Upgrade existing roof trusses	Bearing capacity of footings on soil may require re-evaluation

Many of the structural upgrades involving the roof impose 2018 code snow loading on the existing gravity load structure, which is significantly higher than the code loading at the time of original design. The 16" wide strip footings under the perimeter walls are indicated as overloaded with the soils information available during this review.

4.1 Addition of Elevator or Lift

The addition of a limited use/limited application lift is a feasible modification. The lift would need to be located such that the new opening does not interfere with the existing glulam beams and the new pit does not conflict with existing strip or pad footings. In addition, the lift would require the following structural modifications:

- Addition of a shallow pit below the lift, including localized cutting and removal of the existing slab-on-grade.
- Reframing of the ground floor joists in the location of the lift to frame around the proposed opening. Joists would need to be doubled or tripled on either side of the lift with cross joists on either side of the lift. This would need to be coordinated with any existing mechanical or electrical in the joist space to avoid re-routing of services (conduits, pipes, ducts, etc.)
- Possible addition of structural walls around the perimeter of the new lift, pending the lift manufacturer's requirements. These walls could be constructed from 2x lumber or masonry block.

Specifications of the lift type and the desired location would need to be provided to RJC to provide overall structural modifications to accommodate the lift. The final location desired should be discussed to optimize structural and operational constraints.

4.2 Revision to Sloped Roof

The addition of a sloped roof can be approached in three different ways:

1. The existing roof is retained, and a sloped roof is added that is comprised of two 30' monoslope trusses that span 30' to bear on the existing exterior walls and the roof glulam beams. This option would require glulam beams to be upgraded and may not be feasible if foundation capacity values cannot be increased.
2. The existing roof is removed, and a sloped roof is added that is comprised of two 30' monoslope trusses that span 30' to bear on the existing exterior walls and the roof glulam beams. This option would require the soil capacity to be validated, but may not increase overall loading as much as option 1.
3. The existing roof is retained, and a slope roof is added that spans 60' to bear on the existing exterior walls. This option would likely exceed the soil capacity and be deemed unacceptable.

The roof loading would increase from its existing condition approximately 50% for configuration (1), and 35% for configuration (2). This increase in load is largely due to an increase in code-specified snow loads, and results in an increased demand on the footings, exterior walls, the 6 inch interior pipe columns, and the roof glulam beam.

The increased loads on the footings may warrant a site-specific investigation by a geotechnical engineer to validate soil capacity values as modifications (1), (2) and (3) would result in the strip footing loading exceeding the current allowable bearing capacity exceeded by 5%, 1% and 30%, respectively. If soil bearing capacity is deemed adequate, constructing a sloped roof can be achieved with engineered wood trusses supported by the existing structure.

In configuration (1) the addition of a sloped roof would result in the existing glulam roof beams exceeding their flexural capacity by 7% and would require upgrading the beams. This can achieved by adding a timber truss spanning parallel over the beam, or adding timber laminations, steel plates or fiber-reinforced polymer wrapping to each beam. Each upgrade option has an associated cost and level of disturbance to occupancy associated with it.

In configuration (2) the addition of a sloped roof with removal of joists would result in the existing glulam roof beams reaching approximately 95% of their capacity. This is considered acceptable.

In configuration (3) the addition of trusses which would span the entire width of the structure would reduce the overall load on the existing glulam roof beams, however the overall load increase on the existing strip footings would increase significantly.

For all three configurations, the exterior walls and columns would likely not require any modification or upgrading. It should be noted that if a sloped roof is used the 6" diameter steel pipe columns would utilize 94% and 99% of their capacity for configuration (1) and (2) respectively. This is considered acceptable.

The scope of the roof upgrade would trigger the requirement to examine the lateral capacity of this structure to the NBCC 2015 for wind forces and NBCC 2015 Commentary L for seismic forces. For the seismic review, the new and existing structure would need to meet a Level 2 seismic assessment/upgrading level, which uses spectral response acceleration values with probability of exceedance of 10% in 50 years. If the existing structure does not pass the Level 2 assessment, then it would need to be upgraded to meet a Level 3 seismic assessment/upgrading level, which uses spectral response acceleration values with probability of exceedance of 5% in 50 years.

Review of the existing building drawings for the structure indicate long reinforced masonry walls along the north, east and south faces. These walls likely have sufficient capacity to carry the increased lateral loads. A more detailed review would need to be conducted to assess the connection detailing and the overall effect of the loads on the building.

For both assessment levels, it is recommended that non-structural upgrading be conducted for the full building, including exterior falling hazards.

4.3 Addition of Second Storey

The addition of a second storey to the structure would require extensive structural upgrades as summarized by Table 1 and is therefore not recommended as a feasible option.

Table 1: Summary of element capacity exceedance

Element	% capacity exceeded
Roof Trusses	70%
Glulam	16% in Flexure
Columns	5%
Pad Footings	n/a
Wall Footings	70%

4.4 Addition of Solar Panels to Existing Roof

The addition of solar panels may be a feasible option withstanding that current assumed bearing capacity of the soil has been underestimated. Otherwise, additional loading to the strip footing would exceed the bearing capacity of the soil. An additional dead load of 6psf added to the current roof structure can be accommodated by the existing structural elements except for trusses which would need to be upgraded, or additional trusses would need to be added in between the current trusses. Solar panels less than 2.5ft high would not contribute to additional snow loading. However, the additional loading would result in current estimates of soil capacity being exceeding by 5%. This would require assessment by a geotechnical engineer.

5.0 Schematic Design Energy Model

RJC used several energy usage simulation programs to create the three models of the building. These were used to visualize and compare possible alternatives for energy related upgrades to the building. Three scenarios were established:

1. Current building as a baseline following the original building drawings provided by the city, and current records of energy usage,
2. Proposed building with flat or pitched roof, compliant with the current National Energy Code of Canada for Buildings (2011) and the 2018 BCBC Part 10, and
3. Proposed building with pitched roof beyond current energy code requirements, striving toward BC Step Code 3 for commercial buildings.

The energy model for the current building is based on the original drawings from 1981. The existing drawings show little detail regarding air barrier and thermal resistance of the assemblies, which is fairly common for early 1980s construction. According to the drawings, the roof assembly features RSI-4.9 (R-28) batt insulation placed within the truss roof structure, and a polyethylene vapour barrier and gypsum board assembly on the ceiling. The exterior walls have RSI-1.0 (R-5.9) core-fill vermiculite insulation in the giant bricks. The bricks are only partially hollow, some cells are filled with concrete and reinforcing steel, and vermiculite insulation is known to settle in the cells over time. The floors appear to be uninsulated. RJC's energy model includes assumptions about performance of the early 1980's aluminum framed double-paned windows found on site, a relatively high rate of air leakage, and an annual energy demand calibrated to the reported electricity usage.

Different software programs for energy modelling use different simplifications of inputs to calculate the overall energy loads in a building. A simpler and a more detailed model were run, and provided the following estimates of energy demand ranging from 142 to 153 kWh/m^2/year (45 to 49 kBTU/ft^2/year). The modelling results show that the building energy demand is currently heating dominated, i.e. the largest part of energy is required to heat the building. With no insulation in the exterior walls and floors (basement slabs) and probably walls, these building assemblies have the highest heat transmission losses. As a first step to saving energy in this building, adding a continuous air barrier and insulation to the building enclosure system is seen as the lowest hanging fruit. After that, energy losses due to solar gain against cooling, and transmission through the windows and doors follow.

5.1 Upgrade to Current Energy Code

For the second energy model, the building was upgraded to meet the requirements of the current National Energy Code of Canada for Buildings (NECB). The building form lends itself to an exterior air barrier with exterior insulation and new cladding, connected to a roof barrier in the new roof assembly as a feasible solution. These new assemblies would improve air leakage and the overall thermal performance of the building. Per NECB requirements, exterior walls in new construction must meet an R-value of RSI-3.6 (R-21). The roof must have an R-value of RSI-5.5 (R-31), and the floors must meet RSI-1.3 (R-7.5) in a zone 1.2 m around the perimeter of the building. Basement walls require RSI-2.6 (R-15). To allow integration of solar a flat roof is preferred, and this has been the approach included in the opinion of probable cost. If a pitched roof is desired, we recommend using batt insulation while the floors and walls below grade can be insulated from the interior using rigid insulation boards.

The windows can be upgraded to double-pane with low-e glazing. U values are mandated by the BC Energy efficiency act, and as far as overall energy use is concerned there is little benefit to improving the windows substantially above these levels. Better windows (triple glazed with high efficiency frames) would result in improved comfort for occupants near to the windows during peak winter and summer conditions

Assuming typical infiltration and ventilation rates, as well as standard values for lighting, mechanical, electrical and HVAC equipment, the upgrades to the building envelope are expected to reduce the building energy demand to between 79 and 110 kWh/m^2/year (25 to 35 kBTU/ft^2/year). The overall energy loads would be nearly cut in half and would now considered 'equipment' dominated; this means that for further improvements to the enclosure systems would have diminishing returns on investment, so focus should change to improvements of the buildings mechanical and lighting systems.

RJC's Opinion of Probable Cost (Class D[1]) for upgrade scope in this section is $900,000. The probable cost includes:

Contractor General Conditions	$110,000
Demolition (doors/windows removal)	$1,000
Detailing at Openings and Walls	$30,000
Exterior Membrane	$30,000
Exterior Insulation	$40,000
Exterior Cladding	$265,000
Roofing, Including Removal and Insulation	$180,000
New Windows	$45,000
New Doors	$10,000
Subtotal Hard Costs	*$711,000*
Design Contingency	$71,000
Construction Contingency	$35,000
Soft Costs	$85,000
Total OPC	$902,000 (rounded to $900,000)

[1] Opinions of probable cost are a Class "D" order of magnitude. A Class D probable cost is based on limited site information and probable conditions of the project. It is usually considered to be +/- 20-30% in accuracy. Actual costs are dependent on final scope and design and would be based on Tender or Construction Management costs.

The opinions of probable cost are for budget purposes only and no detailed cost material estimates were included. The Construction scope includes:

- Demolition to remove existing windows, doors, roofing.
- Preparation of exterior face of block, window and door openings,
- New liquid applied barrier,
- New external insulation (110 mm mineral wool), with new cladding,
- New interior basement floor and wall insulation,
- New double glazed windows and doors,
- New roofing with new insulation (200 mm mineral wool).

5.2 Upgrade to Beyond Energy Code

To reduce the building energy demand further, once current minimum levels of insulation are in place, a next step would be to install more energy-efficient equipment, such as heat recovery ventilation, and heat pump based heating and cooling equipment. In discussion with Stantec, RJC understands that the current HVAC systems are relatively new, and that replacement would not be planned for 15 years +/-. Stantec advised that further energy efficiencies from the existing mechanical design are limited. These include addition of CO2 sensors and consideration of economizer operations in shoulder seasons.

The Pan-Canadian Framework on Clean Growth and Climate Change strives toward highly energy-efficient buildings that rely on clean electricity and renewable energy. The suggested approach includes retrofitting existing buildings including fuel switching to reduce CO_2 emissions, as well as improving the overall energy efficiency of the built environment, appliances and equipment, with matching increases in insulation and air tightness of the building enclosure systems. For this building, to achieve a performance target near Step Code 3, this would invoke increases in insulation thickness above those listed in 5.1 above, and triple glazing of the window systems. The extent of insulation increases would be determined by calculating Thermal Energy Demand Intensity (TEDI) in coordination with the building services equipment proposed. Costs for this insulation would be incremental costs for increased thicknesses of insulation material, since most other costs for building the assemblies are included in the OPCs for upgrades in 5.1 above, and would not change appreciably.

Matching improvements for equipment efficiency could be provided by a building services engineer. The current building systems are powered electrically. Based on information provided to RJC we understand that the COP for the current mechanical units is approximately 3. Improved mechanical systems such as heat pump heating and cooling systems can achieve similar high-performing COPs. Modification to LED lighting can help reduce heat loads in summer. As noted in the introduction to this section, Stantec has advised that further energy efficiencies from the existing mechanical design are limited.

RJC reached out to a local provider of photovoltaic systems. Details of the system they suggested and a price quote are included in Appendix C. Installing this capacity of solar panels on the roof could provide about 2/3 of the building's total energy demand after the Current Code (section 5.1) building envelope upgrades. We recommend reviewing details of the installation with your building services engineer, particularly to determine if solar thermal or solar electric panels would be more effective for this building. We note that providing a similar or greater capacity of ground mounted solar panels offsite may be less costly than installing them on the roof.

If a goal of approaching near net-zero energy use for the building is desired, the building's overall annual energy use must be reduced so that the remaining energy demand can be met by generating solar power on-site. Net-zero energy buildings usually require an integrated design and planning phase to balance the building components such as the building envelope, and mechanical and electrical systems. In retrofits of existing buildings such as this one, net-zero energy is far more difficult to achieve and even approaching near net-zero energy demand is considered a success.

6.0 Closing

We trust the above meets with your current requirements. We remain available to review the results of our investigation with yourself and others as required.

Yours truly,

READ JONES CHRISTOFFERSEN LTD.

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Appendix A: Limits of Commission

Limits of Commission

Grand Forks recognizes that special risks occur whenever engineering or related disciplines are applied to identify hidden elements or portions of a building. Even a comprehensive sampling and testing program, implemented with the appropriate equipment and experienced personnel, under the direction of a trained professional who functions in accordance with a professional standard of practice, may fail to detect certain conditions. This is because these conditions are hidden and therefore cannot be considered in the development of a repair program. For similar reasons, actual conditions that the design professional properly inferred to exist between examined conditions may differ significantly from those that actually exist.

The City of Grand Forks realizes that nothing can be done to eliminate these risks altogether. As a result, we cannot guarantee the accuracy of opinions of probable cost and can assume no liability where the probable costs are exceeded.

The City of Grand Forks recognizes that RJC does not have expertise in the identification of, or health risks associated with, mould, mildew or other fungi and therefore cannot provide an opinion as to the extent to which these substances exist in the building or the associated potential health risks to building occupants.

RJC prepared this report for the use of the City of Grand Forks. The material in it reflects RJC's judgement in light of information available to RJC at the time of preparation. Any use that a third party makes of this report, or any reliance or decisions to be based on it, is the responsibility of such third parties. RJC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.