STRENGTHENING AN ADIRONDACK HIPPED ROOF

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ABSTRACT

Constructed in 1896, the Keene Valley library has a reading room with a hipped roof and a central lantern for light and ventilation. This most elegant public space in a small rural community is 8.3 m × 8.3 m and the lantern is 3.7 m × 3.7 m. The library building is in the Adirondack Park which is a protected area that includes the Adirondack Mountains. The park in northeast New York is the largest in the United States and the largest National Historic Landmark. Traditional Adirondack hipped roofs had internal supports, a design where the roof loads were primarily carried by posts and walls. The library's reading room, on the other hand, is a clear span structure with no internal supports; all loads are carried by the perimeter walls. While the roof maintained the hipped configuration, structurally it acted more like a dome structure. This fact apparently was not clearly understood by the local designer-builders. Rather than a timber frame, the library roof was framed with light wood framing. This was daring for the day in this region. Light framing facilitated the construction, but removed some inherent redundancy typically provided by timber edge beams. During the one hundred years since construction, the lantern sagged and the exterior walls of the room bowed outward by as much as 15cm at the eaves. Structural safety became a concern due to the high snow loads typical for the area. Correcting and overcoming the structural flaws in the library roof, while preserving the original design and craftsmanship, were unique challenges. This paper will discuss the structural concept, the evaluation of the light-framed roof system of the Reading Room of the library, the design of the strengthening system, and the restoration of the reading room that left the historic character and historic fabric of the hipped roof and lantern intact by introducing modern materials hidden within the original structure.

Keywords: Light wood framing, Hipped roof, Lantern, Strengthening

1. INTRODUCTION

1.1. History

The library was established in 1885 with a gifted collection of 167 volumes for adults and children, housed in a residence next door to the current library. The Keene Valley Library Association was organized in 1891 and community fund raising efforts enabled the construction of the original library building in 1896, consisting of a Main Reading Room flanked by an Alcove and an entry porch. A Children's Room was added to the original building in 1923 and the “fireproof” Loomis room for archives was constructed between 1931 and 1936. With the major east addition in 1962, followed by a 1985 three-room addition along the south wall, the library attained its current configuration. Throughout its history, the building has retained its original use as a community library and the Main Reading Room remains the architectural and cultural heart of the library. [1].

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1.2. Description of Main Reading Room

The original building consisted of the square Main Reading Room, flanked by two small wings, containing an interior room on the southwest corner and an open entry porch on the northwest corner. The resulting composition, therefore, was visually balanced but not actually symmetrical. The exterior of the building was sided with scalloped wood shingles as well as half-logs below the window sills, the latter replaced with shingles in 1923. The entry porch was a log structure and the entire building had wood shingle roofs. While very rational in plan, the articulated massing and rustic materials combined to give the building a picturesque appearance. If a style were attributed to the building, it would be closer to the Shingle Style than any other; but the Library is a singular design, a successful synthesis of simple parts into a whole, of which the most distinguishing feature is the visually complex roof form.

The Main Reading Room is a square footprint of about 82 m², with a large bay window that has unusual rectangular diamond panes. The room has a hipped roof surmounted by a lantern that also has a hipped roof. Clerestory windows in the lantern light the center of the room from above. Originally the Reading Room had a fireplace on the east wall and a stone chimney (Fig. 1) penetrating the lantern roof. Most of the east wall, as well as the fireplace, were removed to expand the building in 1923 and a post and beam structure installed (Fig. 3). This was the only major alteration to the space over the years, though changes of lesser magnitude have also taken place. Most notably, the original stained
beaded board ceiling had been painted to lighten up what was a dark space, and a Plexiglas lay-light had been installed below the lantern (Fig. 4).

Fig. 3 Reading room interior in foreground; before recent restoration.
The post and beam separates the reading room from an addition

1.3. The Restoration Project
In 1997, a local engineer reported structural problems with the Reading Room roof. At the same time, the building was suffering exterior deterioration. In 1998, Argus Architecture & Preservation prepared a comprehensive Existing Conditions Assessment[1] for the building and a project for the rehabilitation of the 1896 and 1923 sections of the building was developed, including the correction of structural problems, new roofing, handicapped access, restoration of the lantern, new lighting and other repairs. With respect to the rehabilitation of the Reading Room, the architects insisted that any structural work be completely hidden and that any original finishes removed for repairs be salvaged and reinstalled. The work was completed in 2001.

Fig. 4 Lantern; before restoration

2. MAIN READING ROOM STRUCTURE

2.1. Original construction
Traditional Adirondack hipped roofs were built of heavy timber framing and had internal supports; the roof loads were primarily carried by posts and walls (Fig. 5 shows another building with post and beam construction). The Reading Room structure provides a clear span with no internal supports. While there was a fireplace and chimney, the roof structure was only supported by the perimeter walls.
The perimeter wall framing is 50 mm × 100 mm (2 × 4) spaced at 400 mm (16 inches) and is supported on a stone foundation. The tops of the wall studs have a double plate of 2-50 mm × 100 mm (2 – 2 × 4) that connects the studs. The wood plates are lap spliced and nailed at random locations. Overall the studs are 3.2 m tall. All light wood framing is spruce, which is native to the Adirondacks. The wood roof rafters are 50 mm × 200 mm (2 × 8) at 400 mm (16 inches) for the lower roof and the lantern. The lantern has wood-framed awning windows that support the upper rafters; the lower rafters frame into a header constructed of 2-50 mm × 200 mm (2 – 2 × 8). Inside, the ceiling of the lantern has 50 mm × 100 mm (2 × 6) framing which acts as a diaphragm to partially support the lower roof as a compression ring (Fig. 6).

The lower ceiling is light framed as well. The curved sloped interior ceiling shape was formed by 50 mm × 100 mm (2 × 4) wood rafters that were ripped to form the curved inside shape. The horizontal ceiling support was hung from the sloping rafters. The sloping ceiling and the lower horizontal ceiling were covered with wood beadboard paneling that in combination with the roof sheathing created diaphragms of the roof. The bead board paneling was also used on the walls and stiffened the walls in-plane as did the exterior wood siding of half-logs.

The lantern is a stable structure supported by the upper ceiling headers at the top of the lower roof. Below the lantern, the sloping rafters of the lower roof act as both flexural and compression members and provide support to the upper ceiling headers. The roof sheathing stiffens the overall roof structure to resist these combined forces.

2.2. Structural problems
During the 1997 inspection, the engineer reported the upper ceiling headers had deflected downward. Subsequent observations also indicated the north and south walls had deflected outward (Fig. 7 shows the deflected shape) by 44 to 48 mm on the north and south walls, respectively. The ceiling headers
had dropped unevenly by as much as 100 mm. Even though the roof framing had been functioning for over one hundred years, the preliminary report identified that the roof framing had insufficient capacity for the current code-mandated loadings and needed to be strengthened.

**Fig. 7 Structure deflection**

While not included in this paper, there were other structural concerns with the stone foundation and framing in the additions. Each concern was addressed in the overall repair and restoration project.

3. **DIAGNOSIS AND ANALYSIS**

3.1. **Diagnosis**

The diagnosis is a result of determining the load path of the forces through the roof structure. Fig. 8 shows the load path for ¼ of the roof structure from the lantern, through the lower roof rafters and into the wall studs. The outward forces developed by the upper rafters (Pt. A) are resisted by the top plates above the lantern windows. No lateral spreading was identified at these locations.

At the upper ceiling header (Pt. B), the header had deflected downward as noted in Fig. 7. The vertical support to the headers is provided by the sloping rafters in compression. The horizontal component of the rafter loads must be resisted by the ceiling headers in lateral bending causing them to perform as a compression ring at the base of the lantern.

The compression forces in the lower rafters resolve into lateral forces at the top of the walls (Pt. C) as well as vertical loads to the studs. Thus, the wood plates at the top of the wood studs were placed into tension as well as lateral bending. The splices in the plates were unable to support the tensile forces. The wood sheathing of the roof provides diaphragm stiffness, but was not able to provide redundant tension resistance for the top plates. This resulted in the outward spread of the tops of the walls and subsequently, the downward deflection of the upper ceiling headers.

Thus, the diagnosis is that the roof was acting as a dome-like structure but that the original design and construction were not adequate. Tension continuity at the tops of the walls was missing. While the upper ceiling header was not constructed specifically to act as a compression header, it apparently performed adequately. The ceiling may have provided some redundancy as well, aided by diaphragm action of the lower roof sheathing. While the original construction included a chimney opening through the lantern, it did not provide lateral support to the headers.

**Fig. 8 Load path**
3.2. Analysis of the existing structure

Fig. 9 and Fig. 10 show the joint forces at Pt. B and Pt C based upon the original construction. The ceiling header receives biaxial bending and compression from the lantern (Fig. 11). The top plates of the wall studs receive lateral bending and tension (Fig. 12). The outward forces at the hipped corners induce tension into the plates and their splices.

![Diagram of forces at Pt. B and Pt. C](image)

4. RESTORATION DESIGN

4.1. Concept

In concept, selecting a restoration method should be simple. Strengthening should provide a reliable tension ring for the structure at the top of the walls and reinforce the compression ring at the upper ceiling headers. In addition, the roof structure should be raised to remove the deflection at the upper ceiling headers and the tops of the walls pulled inward to return the walls to plumb. However, this proposed strengthening would require significant modifications to the wall plates and the connections of the roof rafters to the top plates. Those modifications were not desirable because they would significantly affect the aesthetics and cause great disruption through removals. Therefore, an alternate solution was desired.

The solution selected required converting the structure to a modified post and beam structure. Fig. 13 schematically shows a steel framework that was installed to supplement the wood framing. All sections were tube material except the tie rods were steel rods. The ceiling header supports the vertical loads from the upper and lower roof (Fig. 9 and Fig. 11). The ceiling headers are supported vertically by the diagonal posts rather than the existing wood rafters. The diagonal posts are then supported by the corner posts. The horizontal forces developed by the diagonal posts are taken by the ceiling header at the top and the tie rods at the bottom. The tie rods were designed to limit the elongation and future spreading of the roof.

The strengthening frame was designed to support all the code related forces [2]. The net result was the wood rafters no longer have to take the compression from the lantern loads. In addition, the tie rods tie the diagonal and corner posts from spreading outward without modifying the wall plates.
4.2. Construction problems to be overcome

There are several issues in dealing with a 100 year old structure. The wood structure deflected over many years and reached a new equilibrium. Connections of nailed joints do not return to their original position upon reverse loading. In addition, the old wood is very dry and precautions had to be taken not to cause any sparks near the wood framing.

Strengthening light wood framing can be accomplished using additional wood framing that would increase the overall section size and affect the aesthetics. Instead, steel members were used to provide strengthening within the depth of the light wood framing.

The roof was jacked to level the lantern and partially reduce the outward bow in the walls. The jacking allowed the walls to be pulled inward approximately 22 mm leaving them still out-of-plumb by approximately 24 mm. This was acceptable and a practical compromise to avoid damaging the remaining structure.

4.3. Details

Structural hollow tube sections (200 × 150 × 10 mm) were selected for the upper ceiling headers to take flexural and axial forces. A tie rod (28 mm) was chosen to provide the tension ring between the diagonal posts. Once the lantern was jacked and the walls partially plumbed, the tie rods were tightened to hold the structure in place.

The diagonal posts (150 × 75 × 6 mm) also strengthen the hipped rafters. The corner posts are 75 × 75 × 10 mm tubes. All member sizes were detailed to fit within the existing structure with the exception of the upper ceiling headers. Fig. 14 shows the detail of the upper ceiling header. The tube was covered with trim. The revised trim work at the base of the rafters was selected for architectural reasons and was not needed to hide any structure. The tie rods were hidden within the ceiling space.

Fig. 14 Strengthening section  Fig. 15 Tie rod detail

The contractor was required to take excessive precautions and wet the wood in
the area of welding, provide welding blanket protection, and provide a constant fire watch during the welding stages and for hours after.

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**Fig. 16** Upper ceiling headers and diagonal post  
**Fig. 17** Tie rods at diagonal post

### 5. CONCLUSIONS

In the 1890s, the light wood framing system used in the Keene Valley Library was still relatively new to the Adirondack region, used primarily in simple structures, and not as well understood as the traditional heavy timber framing of post and beam. In this context, the articulated, clear span roof structure of the Reading Room was an ambitious design. Nevertheless, and despite its structural flaws, the roof structure performed reasonably well for over 100 years and remained sound enough to effect *in-situ* strengthening to stabilize and preserve it for the future.

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**Fig. 18** Completed restoration  
**Fig. 19** Completed restoration

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### REFERENCES