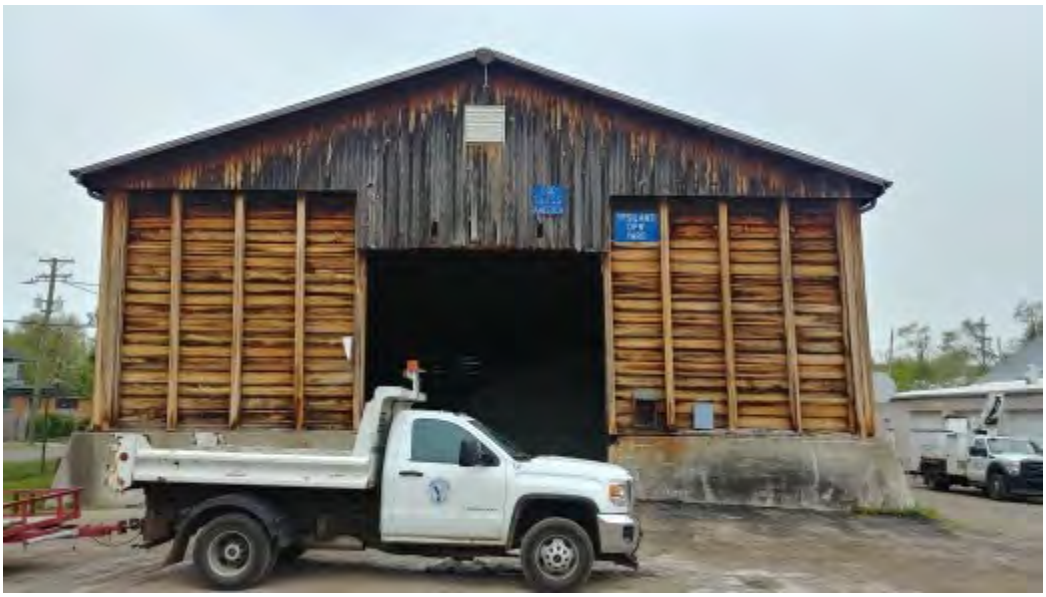
Salt Barn Structural Evaluation

City of Ypsilanti Public Works Yard
14 West Forest Avenue
Ypsilanti, MI 4897



Prepared For:
City of Ypsilanti Department of Public Services
ATTN: Bonnie Wessler

Date: 31 May 2023

Prepared By: Adam Wagner, P.E.
Wagner Engineering, LLC
Order Number: 2023-071

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Project Location: 14 West Forest Avenue, Ypsilanti, MI 4897

1.0 Introduction and Scope of Evaluation

I conducted a structural assessment, on May 19th, 2023, of the Salt Barn located within the City of Ypsilanti Public Works Yard at 14 West Forest Avenue, Ypsilanti. This assessment was done at the request of Bonnie Wessler, Director of Public Services. The purpose of this structural assessment is to provide my opinion on the overall stability, current structural risks associated with the structure, and methods for mitigating the risks for continued use. The scope of this evaluation is limited to the Salt Barn structure only and is based on a visual inspection from ground level. It is also based on the condition of the structure at the time of my visit and assumes no further deterioration.

2.0 Existing Structure Description and History

The salt barn was built sometime in the 1960's. It is approximately 50' wide and 160' long with a wall height of 15'-6". The barn is a wood post framed structure. The posts are 6"x10" and spaced every 4' on center. The roof is a metal plate connected wood truss also spaced every 4' on center with OSB sheathing and asphalt shingles. The posts bear on a wood sill plate, and are fastened to the sill with steel angles and bolts. The walls bear on a 48" tall by 12" thick concrete stem wall. The wall framing is sheathed on the interior face with 2x10's. There is no exterior wall sheathing or siding. There is a vehicle entry opening on the south end, and there was a previous a vehicle opening on the north end that has been framed in. The barn is primarily used for storing bulk deicing salt.

3.0 Observations

3.1 Wall Framing

The structure is racking to the west by about 2" over a 4' length, or about 2.4 degrees. The west wall framing has the most deterioration. Nearly all the posts ends and sill is rotten as shown in Figure 1.

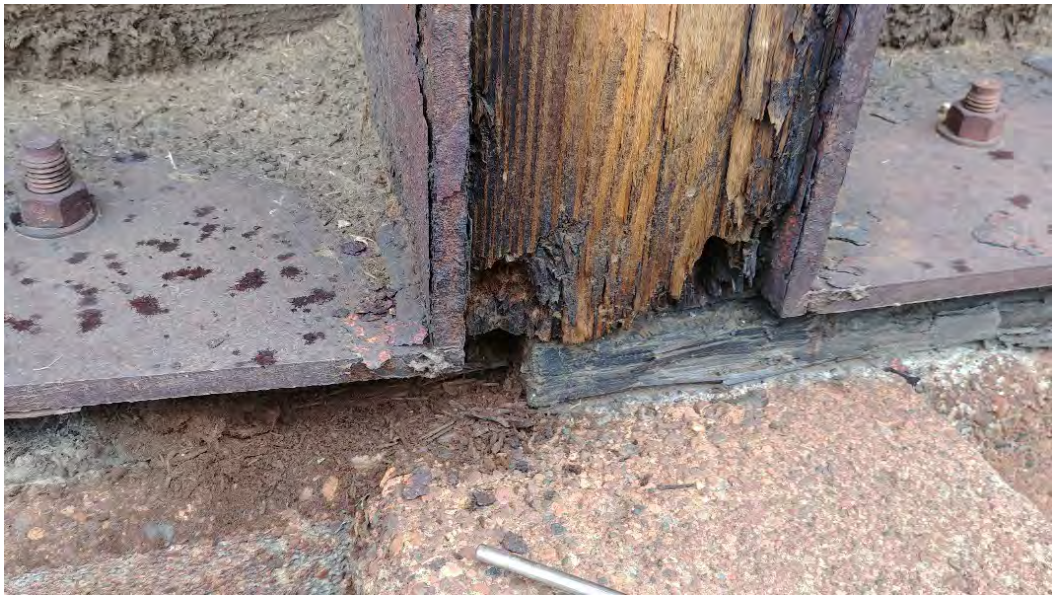

Figure 1: Typical Post End and Sill Plate Rot Damage

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Additionally, most of the steel angles and fasteners have corroded completely and are no longer providing any fastening power between the post and the foundation. Figure 2 shows a typical state of the steel angle brackets and fasteners on the west wall.

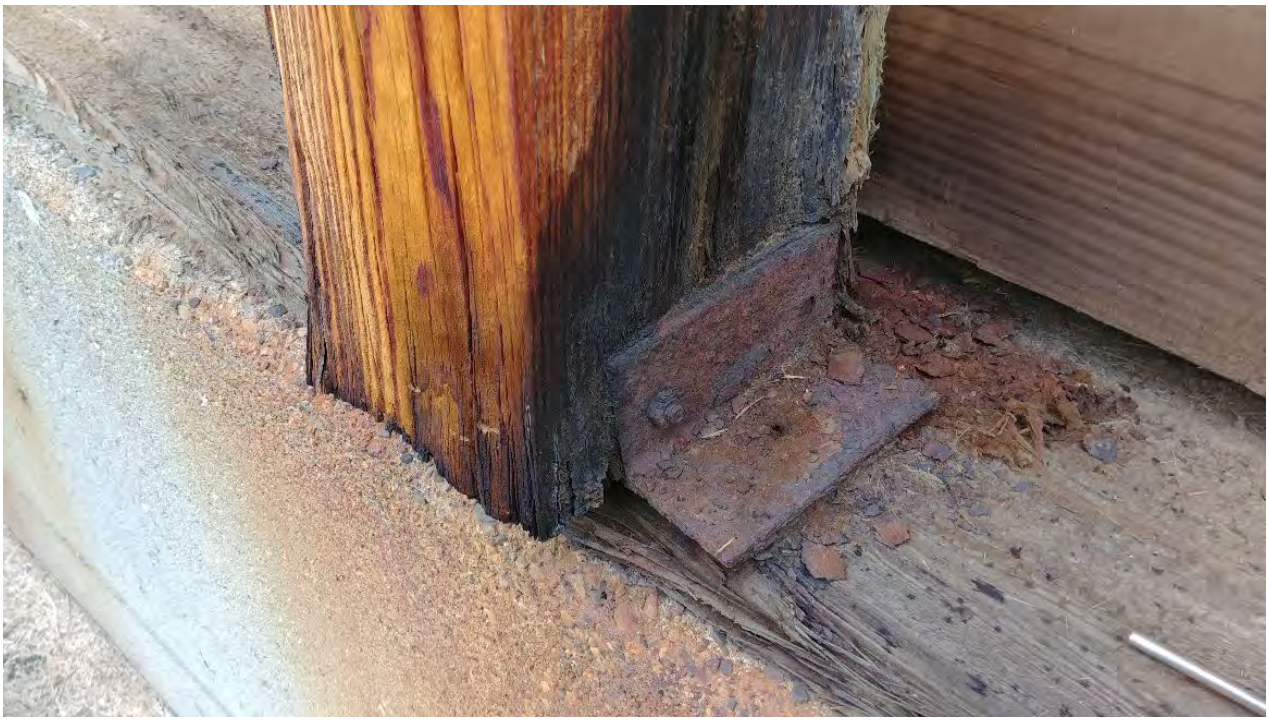

Figure 2: Steel Angle and Bolt Corrosion

The east, south, and north walls have minimal rot and bracket deterioration. The east wall has evidence of previous repairs; namely some of the original brackets have been replaced and several of the posts have been shored with new timber fastened to the original posts as shown in Figure 3.

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Figure 3: Previous Repairs to Columns and Replacement Bracket

3.2 Vehicle Strikes

There are two wall locations where vehicle strikes have damaged the structure: at the east side of the vehicle main entrance and at the northwest corner of the barn. The entrance damage is to the edge of the concrete stem wall, which has exposed the interior steel reinforcing. The damage to the north wall has buckled two of the timber columns. Figure 4 shows the vehicle damage at the two locations.

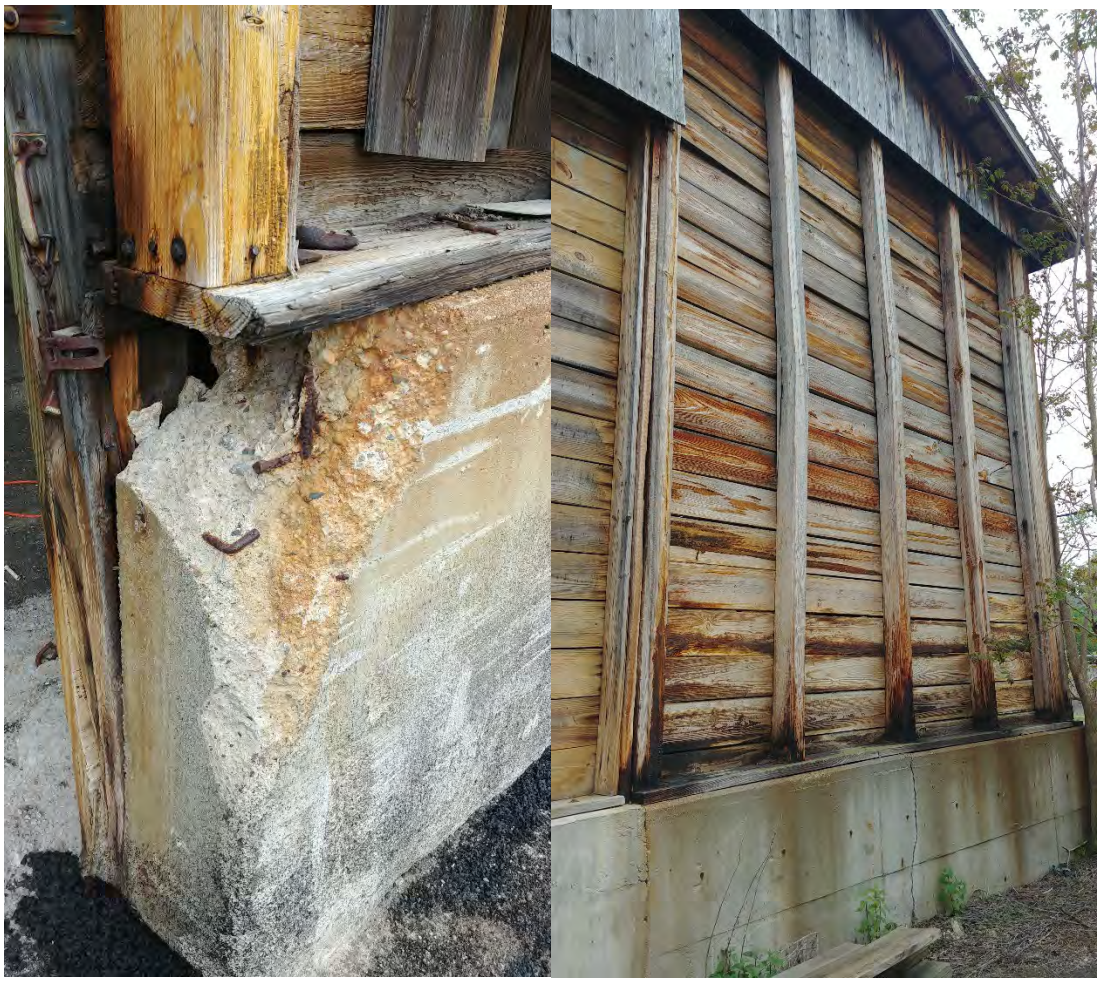

Figure 4: Vehicle Strike Damage to the Entrance and North Wall

3.3 Foundation

The concrete stem wall has periodic vertical cracks about every 8 feet that penetrate the entire wall thickness. Many of the cracks occur at the interface between the stem wall and the exterior concrete buttresses. Additionally, there is a tree growing next to the foundation at the northwest corner of the structure. Figure 5 shows a typical foundation crack and the tree.

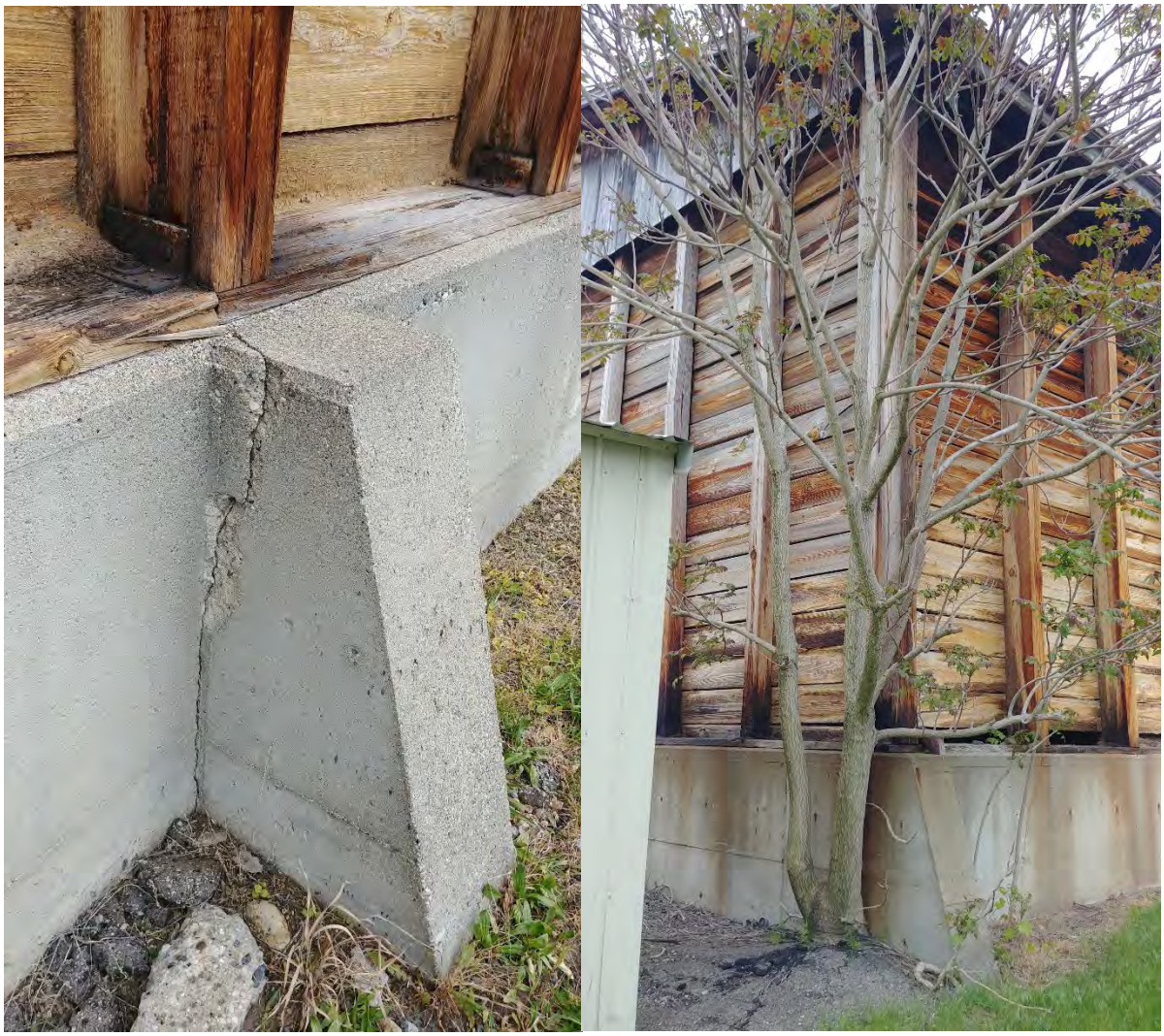

Figure 5: Typical foundation cracking and tree at northwest corner.

3.4 Roof

The roof is of typical metal plate connected wood truss construction. The most of the original roof sheathing has been replaced with OSB panels. Several truss bottom chords have been shored with new 2x framing. The bottom chords were likely damaged during salt transfer or loading operations.

4.0 Analysis

The structure is reaching the limit of its useful life without structural corrections. The structure could be rehabilitated, but in discussion with City staff the Salt Barn does not meet the current needs of the city and is slotted for replacement.

I believe the structure racking is primarily due to the piling of salt against the walls. The staining and board replacement pattern of the west wall interior sheathing indicates that salt was piled nearly to the top of the wall framing. The structure was not designed as a retaining wall and therefore does not have adequate lateral strength to resistance the forces of the salt piles. The self-weight of the structure helps counteract any lateral forces imposed on the structure, and any lean lessens that effectiveness. The structure is rather top heavy given the ratio of roof to wall. Any further lean increases the risk of the structure toppling from its own self weight.

Additionally, the salt creates a highly corrosive environment for both the wood framing and all ferric based fasteners and connectors. All the deterioration on the west wall framing I attribute to the salt pile against the wall mixing with precipitation.

The cracking in the foundation I attribute to the lack of control joints and likely inadequate amount of steel reinforcing. The stem wall likely was likely formed in a monolithic pour. The heating and subsequent cooling during the curing process created stresses the concrete could not intrinsically resist. This would also explain why most of the cracks are at the inside corners of the buttresses, which would be an area of stress concentration. Overall, the foundation is functional and performing adequately. However, the cracks allow the stored salt to corrode the interior steel reinforcement.

5.0 Failure Modes and Structural Risks

Because of the issues noted above, the Salt Barn is not very resilient to external lateral forces acting upon it. The primary mode of the structural failure would be the wood framing portion collapsing by continuing to lean to the west. This could be caused by salt pile force on the wall, wind forces on the walls and roof, or an equipment striking the wall or roof assembly with enough force to topple the structure.

A secondary failure mode would be the wood frame structure separating from the concrete stem wall and shifting horizontally until it is no longer bearing over the concrete. This failure could happen to due salt pile forces, wind, equipment strike, or during a flood event.

Categorizing the likelihood of failure and accompanying risk is difficult. Nonetheless, for the structure to fail will require an external horizontal force acting on the Salt Barn. It is unlikely the barn would experience a “sunny day” failure unless the existing lean continues to increase. The salt piles against the structure are the most likely to cause a failure followed by equipment strike then by wind forces.

6.0 Risk Mitigation Methods

Since the structure is seldom occupied and primarily used for bulk storage, the consequences of failure are mostly economic with only slight risk to life safety. The following are several mitigation methods to reduce the risk of further damage to the structure and extend its usual life.

Salt Piles: Do not pile salt against the walls. The weight of a salt pile on the walls is the most likely contributor to the current lean. Continued piling against the walls could lead collapse or shifting the barn off the foundation.

Equipment/Vehicle Strike Preventive Controls: Add process or administrative controls to limit the risk of vehicle or equipment striking the structure during salt loading operations. This could include adding bollards or other obstructions near the walls to act as guards, or additional training for staff. This also includes preventing loading equipment from contacting roof framing.

Periodic Inspection: Periodically inspect the lean of the walls to determine if it is further deteriorating. This can be done using a 3' or 4' long level held plumb and measuring how much the lean is over the length of the level. The current lean of ½" per vertical foot is about the highest amount of lean that would be permissible.

Seal Foundation Cracks: Use concrete joint sealant to seal the cracks in the foundation. This will help prevent salt from attacking the interior reinforcing steel

Tree Removal: Remove the tree at the northwest corner. The root ball can remain if the tree is preventing from resprouting.

7.0 Structural Shoring

The structure requires basic shoring in order to add some resiliency is the structure is expected to remain in service for more than a year. The following should be done as soon as time and budget allows:

Timber Column Shoring: Add 4' lengths of pressure treated 2x10 shoring on both sides of any rotted timber columns like the previous repairs done to the east wall. The west wall should be the primary focus since nearly every column is rotted. In addition, replace any rotted sill plate at the column locations.

Steel Bracket Replacement: Replace any corroded steel angle brackets and refasten to the concrete foundation at any point, but specifically along the west wall.

Repair Vehicle Strike on North Wall: The timber columns that have buckled should be replaced, or full length 2x added to both sides of the columns. Any broken or buckled sheathing should be replaced and refastened to the timber columns.

8.0 Conclusion

The Salt Barn has several structural issues identified above. As it currently stands, the structure is not very resilient to external lateral forces imposed on it. Some basic shoring and risk mitigation strategies can extend the useful life of the structure until a replacement structure can be designed and built.

The existing foundation could be reused for a temporary interim replacement structure. However, it is not recommended to reuse the foundation for any permanent structure.

The lean of the structure could be corrected, which would greatly decrease the chances of collapse. To do so, the wall sheathing on the north and walls should be removed. The structure could then be

straightened, and new sheathing added to the north and south walls to lock into place. This would should be a done a by an experienced and qualified construction firm.

If you have any questions, please feel free to contact me directly at 734-392-7034 or Adam@WagnerEngineer.com.