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22 October 2012

Wayland Historical Commission
Wayland Town Building
41 Cochituate Road
Wayland, MA 01778

Attention: Elizabeth Von Goeler

Reference: Old Stone Bridge, Wayland, MA

Dear Liz:

On 10 August 2012 we performed an investigation of the Old Stone Bridge in Wayland. This included visual observations from the top, sides, and undersides of the bridge, two test pits, and several samplings and probes.

The following is a summary of our observations and findings.

Structural Description

The Old Stone Bridge was constructed around as an east-west crossing of the Sudbury River on the former alignment of what is now Old Stonebridge Road, which continued west into what is now Potter Road.

According to historical research, the present bridge is the final replacement of several wood-framed permutations that were built before it. This being said, no conclusive evidence as to the date of its construction has been found, but it is thought to be no older than the Old Stone Bridge, which was apparently built in 1848. I find this surprising because the dry laid stone construction is very primitive for a time when water resistant mortar materials were commonly available.

During the 1950s the river was widened and straightened and the western approach and buttress were removed and replaced with a stone faced concrete pier that juts out to the edge of the re-directed river flow, creating a dead-ended structure.

The Old Stone Bridge is approximately 70-feet long by 15-feet wide, and has four barrel vault arch spans of approximately 14-feet across. This combined with the added end pier which is approximately 10-feet long and an angled wing wall at the southeast corner makes the total length of construction approximately 95- to 100-feet.

Based upon our visual observations, test pits and probes, the Old Stone Bridge is an entirely dry laid stone masonry structure. The bridge was constructed as follows:

1. A combination of buried rubble and solid cap stones were dry laid as footings within the riverbed, and then 3-feet wide by 15-foot long vertical piers were dry-stacked atop the footings from which the arches would immediately spring up from each side. The riverbed was of variable depth, with exposed bedrock under the east end of the bridge, and a muddy bottom at the center. One still to this day detects a decrease in depth as one approaches the bridge’s west end, as this was the original west embankment before the main flow was re-directed further west.

2. Arched wooden forms were then constructed between the piers to support the construction of single wythe rough cut stone arches that were chinked and dry laid on top of them.

3. The wedge-shaped “valleys” between the arches were partially filled in with angular stone rubble to help stabilize the arches, and wedge shaped trust blocks would have been created at the ends to help prevent the line of arches from spreading. After some initial filling, the wooden arch forms could have been removed.

4. Using the completed arch spans as a base, the parapet walls were constructed along the sides and splayed wing walls were constructed to create approach ramps at the ends.

5. Earth was then placed over the arch structure up to the tops of the parapet walls in order to create the level surface for a roadway. According to our test pits, little or no attempt other than chinking (wedging of small, usually angled stones into joints) seems to have been made to seal the stone construction against pass-through water flow and sifting of soil. This being said, the original builders seem to have been at least marginally successful in containing the soil as there are few detectable sink holes on the surface.

6. The modern-era pier at the west end appears to have been constructed by building a three-sided "box" of semi wet laid stone walls within dunnage or containment forms, with the fourth side of the box being the far abutment of the westernmost arch. This box was then filled with bar reinforced concrete. The stone masons were clever to hold back the mortar from the outer faces of the stone walls to that they so one would not easily detected it when viewing the partially mortared pier and the unmortared bridge together as a whole.

7. Dimensional, sawn wooden fence railings presently bound the grassed-in top surface of the bridge which now serves as a small park. These are probably a several-generations-later replacement to the original railing system.

Noted Conditions

The following conditions were noted during our investigation:

- The vertical sides of the bridge are irregular and have undergone out-of-plane deviations as the parapet walls are bulging and the sides of the bridge are spreading apart. In some places, these movements, which include the vertical edges of the arches themselves, are more than 6- to 8-inches.

- On the introdos (underside) of each arch one can see oriented widenings of head joints that follow lineal orientations that run circumferentially to the arch. These are in essence longitudinal structural "cracks" in the unmortared structure that directly correspond to above-noted out-of-plane deviations of the side walls. Some of the widenings total more than 8", which again correspond to the summed widths external deviations.

- Where the widenings occur, there is a loss of chinking and an eventual loss of soil. We experienced such soil loss first hand when we excavated one of our test pits near but not directly over one of these widenings and encountered a cavity within the soil at the side of the test pit that quickly turned into a sink hole.

- In addition to the overall spreading movements, there are localized bulges in the sidewalls where the stonework has become unstable and has moved out. The worst of this is along the south side of the bridge where there is massive vegetation growth.

- There are also places where stones are missing or chinkers have fallen out, revealing cavities within the arch and sidewall construction.

- At the west end's concrete pier, stones are becoming detached from the north face and, to a greater extent, south face (the far west face seems basically intact). Behind the fallen stones, one can see concrete and a few rusted rebars. At the south face, a significant patch of stones has moved out by as much 12" creating an earth filled pocket that is supporting the base of a tree.

- In addition to the structural masonry issues, the residential grade split rail wooden fencing the circles the top of the bridge is insufficient, rotting and in places falling over. This does not meet code and is a potential hazard to anyone who might lean on it.

Discussion

Based upon the above conditions, it seems that the primary damage involves the lateral spreading of the bridge and outward bulging of the parapet walls under soil pressures. If the Old Stone Bridge has one basic construction flaw, it is its lack of transverse resistance to the lateral pressures from the soil fill that is retained by it. This would have been magnified during its years of vehicular service by the outward spreading of wheel loads, and it is possible that much of the movement took place during its past.

According to our rough calculations, the structure is sufficiently robust to retain the existing 2- to 3- foot maximum depth of soil. However, wheel loads of even half of today's truck loads, which they might have been sustained near the end of the roadway's service life, create lateral pressure that is four times greater than the soil load alone. Therefore, it is seems likely that most of the spreading occurred as a result of heavy wheel loads, not longitudinally compressing the arches so much as laterally spreading them under the soil pressures applied under the roadway. This has resulted in a series of longitudinal circumferential “cracks” forming within the arches, which are basically linked lines of severely widened joints between arch stones.

The most immediate effect of these widened joints is the fact they act as funnels through which the retained fill can sift, creating hidden sink holes that grow from below until they eventually reach the retained fill surface. A way of transversely tying the bridge and retaining the soil mass must be devised, but it must allow the bridge to continue acting as a dry-laid masonry structure that allows the soil mass to freely drain.

The secondary effect is fact that the parapet walls and edges of arches lean, and will continue to do so until they reach a point of instability. This has already started to occur at the south face of the bridge, where stones are buckling outward from parapet and edges of the arches. All portions of the bridge that are approaching instability must be dismantled and reconstructed.

At the far end of the bridge there is a totally different type of construction, and a totally different behavior. There the stones are becoming unbonded from the concrete mass that was placed against their back surfaces and need to be reapplied.

Recommendations

Considering the existing construction and its present condition, we recommend that repairs be done in a way that is sympathetic to the original construction while providing the needed improvements in longevity and repair while allowing the bridge to structurally function in the same manner that it traditionally has.

This can be done in the following manner:

Throughout-

Remove vegetation and soil fill.

1. Remove all vegetation biological matter from the sides and top of the bridge, especially at the south, upstream face. This will inevitably result in the partial collapse of some of the facing stones in the parapet walls and end pier.

2. Remove the existing soil mass down to the top of the stone and concrete bridge and pier structures.

<u>At the Dry-Laid Arch Sections</u>-

Restore dry-laid masonry arches and lower walls.

3. Fully document and dismantle the bulged and leaning parapet walls and ends of arches.

4. Wet-chink and partially underpin the ends of the piers to restore solid bearing.

5. Re-chink the remaining piers from the outside, the remaining walls from both sides, and the arches from above, and replace stones that are missing.

6. Reconstruct the dismantled masonry elements to match their original configurations, up to the top of the lower top course of the parapet walls.

7. Cover the structure with filter fabric that turns up against the side parapet walls to create containment for fill.

<u>At the West Pier Section</u>-

Restore west-end pier.

8. Document and remove all loose and shifted stones.

9. Inspect and repair exposed portions of the concrete core, cleaning and coating or removing rusted reinforcing and grout injecting cracks.

10. Reinstall all removed and missing stones, wet bonding and pinning them back into place.

11. Additionally pin any other potentially loose stones and grout any voided collar joints encountered.

12. Create a surface bonded mortar topping layer over the concrete to positively pitch the top of the pier into unmortared westernmost arch construction, and cover the parging with a pre-formed drainage composite.

<u>Throughout</u>-

Reinforce the soil mass to counter the spreading effects on the bridge, provide proper drainage, and restore parapet walls, top grade and railings.

13. Place 6” to 12” of compacted structural drainage fill over the entire structure with the top to roughly align with the bottom parapet course and

lay a biaxial geogrid over the top of the fill and allow extra grid length to fold up over the top of the lower parapet course.

14. Place additional compacted structural fill up to the top of the lower parapet course and flop the biaxial geogrids up over the top of the fill and add a transversely oriented uniaxial geogrid atop the flopped uniaxial grid ends, extending out to onto the lower parapet course.

15. Wet-lay the top parapet course over the lower course and the uniaxial geogrid with grids and mortar recessed by 4”.

16. Compact 6” of structural fill over uniaxial geogrid and then add up to 6” loam.

17. Replace removed wooden guard rails with aesthetically appropriate but properly structured wooden guards designed that meet code.

Please see the attached elevation and section drawings that graphically layout the scope of work.

Associated Costs

[redacted]

Thank you for the opportunity to provide this evaluation of this very interesting structure and important historical resource. Please contact me if you have any questions or would like further clarification.

Respectfully Yours,

John M. Wathne, PE, President
Structures North Consulting Engineers, Inc.