



December 18, 2015

City of Broken Arrow, Oklahoma
Attn: Thomas Hendrix, PE
Tim Robins, PE
485 North Poplar Avenue
Broken Arrow, Oklahoma 74012

RE: Repair Recommendations for Retaining Wall at Hillside Park
Broken Arrow, Oklahoma
Olsson Project No. 015-1894.300

Dear Mr. Hendrix,

Olsson Associates (*Olsson*) previously evaluated the wall design and visually observed the condition of the existing reinforced modular block wall at the Hillside Park site in Broken Arrow, Oklahoma. This analysis is contained in our report titled "Geotechnical Evaluation of Retaining Wall at Hillside Park", dated August 6, 2015.

Based on our analysis of the design and visual observations of the wall, we concluded that the existing wall design does not meet the minimum standards per the National Concrete Masonry Association (NCMA). The design deficiencies included the following:

- The blocks do not provide enough resistance to resist internal sliding, pullout and facing stability failures.
- At the taller sections, the tensile capacity of the geogrid does not provide an adequate factor of safety against breakage.
- Our global analysis indicates there is an inherent risk for an internal compound stability failure.

This letter provides our opinions and recommendations on several options for repairing or retrofitting the existing wall. In addition, we have provided preliminary anticipated costs associated with each option. Our cost estimates are based on conversations with local contractors and our experience with similar projects. However, given the unique nature of repairing the wall of this height, actual costs could be substantially different. The prices provided herein should be used for planning purposes only in evaluating the various options. We have listed the options from the anticipated highest cost to lowest cost.

Option 1 – Repair w/ Tiebacks and Shotcrete Facing

This repair option includes leaving the existing wall in place and installing tiebacks or soil nail anchors at regular intervals both horizontally and vertically across the wall face. The tiebacks or anchors would then be connected to a permanent reinforced shotcrete facing. The shotcrete facing can be customized for aesthetic purposes.

This solution would eliminate the need to remove the existing wall (ie. no haul off) and would require no significant realignment of the existing wall. However, this solution is the most complex in both design and construction and would require a specialty contractor to install the tiebacks/anchors and facing.

Based on our conversations with contractors who specialize in this type of construction, the cost to repair the wall with tiebacks/anchors and shotcrete facing would be between 150 and 250 dollars per square foot of wall face. Because of the number of unknowns associated with this type of wall, such as length and type of tiebacks and thickness of shotcrete facing, the cost listed herein could increase significantly.

Option 2 – Reconstruction

The reconstruction option would be to completely remove and replace the existing wall. This would require disassembly of the blocks and complete removal of the reinforced material and geogrid. It may be possible to reuse the existing blocks in the shorter wall sections. However, in the taller wall sections, a heavier, solid block would be required. The existing reinforced material (clay/clayey shale) would not be acceptable for reuse. In our opinion, granular backfill should be used within the reinforced zone. Based on our initial analysis, the wall would likely need to move forward slightly (less than 10 feet) from its existing position in order to keep grading and removal of vegetation above the wall to a minimum.

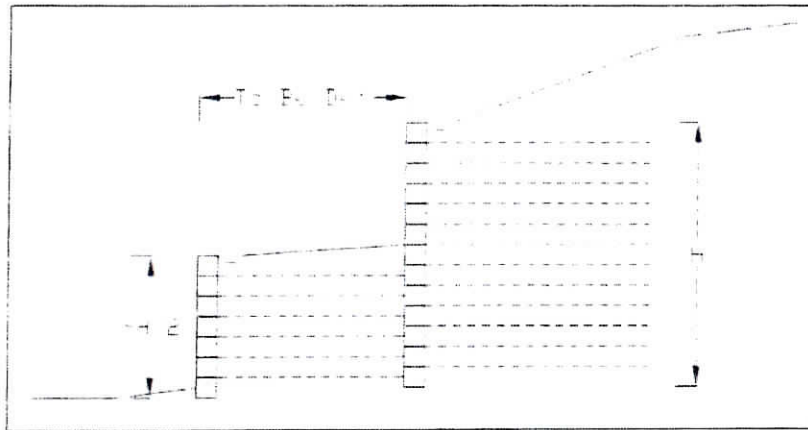
Per our contacts with local contractors, the cost to completely remove and replace the wall would be in the range of 80 to 150 dollars per square foot of wall face. Additional costs may be incurred if the existing reinforced material has to be removed off-site and/or if the existing blocks are not reusable.

Option 3 – Construct Wall in Front of Existing Wall

An additional supplemental wall could be built in front of the existing wall. This option would also leave the existing wall in place, but would require occupying additional real-estate in front of the wall. Several different wall types could be considered, but the most cost effective being a similar reinforced modular block wall a distance (to be designed) in front of the existing wall. That distance would vary based on the height of the wall and the block used, but would likely be in the range of 7 to 20 feet from the face of the wall.

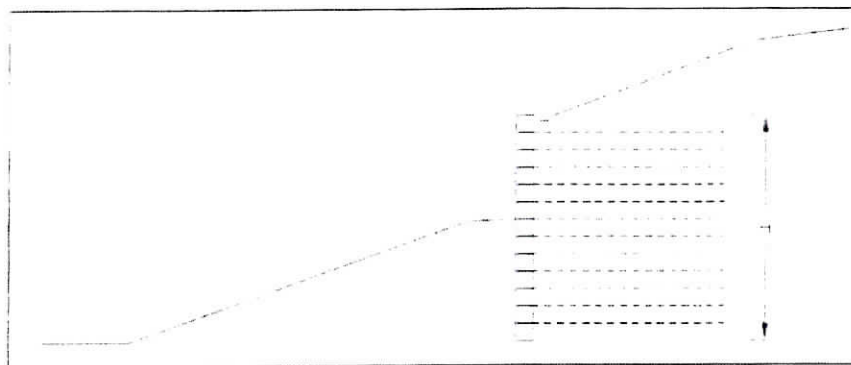
We performed preliminary calculations to determine at what height the existing wall would need to be buried in order to conform to current NCMA requirements. Our preliminary calculations indicate that the wall would need to be reduced to approximately half of the existing height across most of the wall length. The figure below presents a general cross-section of the

proposed option. We estimate the cost for option 3 to be between 50 and 100 dollars per square foot of new wall face.



Option 4 – Construct Slope in Front of Existing Wall

Similar to option 3, a soil berm and slope could be constructed in front of the existing wall. This option would be reduced the current height of the wall to approximately half of the current height in order to conform to the NCMA requirements. In lieu of a supplemental wall, soil fill would be used to reduce the wall height. This soil fill would need to be imported to the site. We estimate the fill in front of the wall would extend between 5 and 10 feet laterally out (depending on the height of wall) and slope down to the existing ground surface at a 3H:1V slope. A general cross-section of this option is shown in the figure below.



This option would occupy more space than the other options, but would be the simplest to construct and the most cost effective option. The cost for this option would vary depending on the availability and proximity of fill material, but would be significantly less than the other option listed previously.

Option 5 – Leave Wall in Place and Monitor

The final option would be to do no remedial work to the wall. In our opinion, this option should only be considered if funds are unavailable. This option would provide the greatest amount of risk to the project. If this option is being considered, we recommend a clear zone with temporary fencing be installed in front of the wall to a minimum distance equal to the height of the wall. In

addition, we recommend the wall be monitored for movement both horizontally and vertically. To do this, survey points and possibly inclinometers should be installed at regular intervals at both the top and base of the wall. Olsson can assist at locating these points. These points should be read on a monthly basis and analyzed for movement by an Olsson Engineer. Once funds become available, we recommend one of the above four options be implemented.

LIMITATIONS AND CLOSING

This geotechnical letter is based on information provided to Olsson and our understanding of the project as noted in this letter. This report was prepared under the direction and supervision of a Professional Engineer registered in the State of Oklahoma with the firm of Olsson Associates. The conclusions and recommendations contained herein are based on generally accepted, professional, geotechnical engineering practices at the time of this report, within this geographic area. No warranty, express or implied, is intended or made. This report has been prepared for the exclusive use of The City of Broken Arrow, Oklahoma and their authorized representatives for specific application to the proposed project described herein.

We trust this letter will assist you in the proposed project. Olsson appreciates the opportunity to provide our services on this project and looks forward to working with you during the final design phase and construction. Should you have any questions please do not hesitate to contact us.

Respectfully submitted,
Olsson Associates



Ian Dillon, PE
Geotechnical Engineer

A handwritten signature in blue ink, appearing to read "James Landrum".

James Landrum, PE
Senior Engineer