Structural Forensics

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Periodic Inspection of Retaining Walls

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In the wake of a major retaining wall collapse, the New York City Department of Buildings (DOB) examined the condition of numerous retaining walls within the city's boundaries and concluded there was a need for a regulation mandating periodic condition assessment of retaining walls. This article presents the ensuing local law that became effective in 2014. While several federal and state highway authorities require such inspections, this is the first such law enacted by a large municipality. It was developed based upon local experiences with periodic condition assessments and concerns with the city's high pedestrian and vehicular densities. Usually the introduction of such laws requiring a new particular type of periodic condition assessment induces some engineers and firms to specialize in such inspections.

Figure 1. Collapsed retaining wall at Castle Village.

Accident

On May 12, 2005, a 200-foot section of a 65-foot high retaining wall collapsed over a major New York City highway (*Figure 1*). At that time, a city program of surveying arterial retaining walls was already in place, but it covered only retaining walls under the purview of city and state transportation agencies. The collapsed retaining wall was an 80 year old, privately owned, rubble wall.

New York City has over 2,000 retaining walls, most of which are owned by various governmental transportation and park authorities. This accident brought into focus the existence of a number of retaining walls that are inside private lot lines and, as such, are privately owned. The New York City Building Code had provisions that placed the responsibility for wall maintenance on private owners, but it did not set specific mandates for professional reporting on their condition.

To analyze the causes of the accident, a Board of Inquiry was established by the DOB. The Department also proceeded to survey the condition of privately owned retaining walls. Using an ad-hoc inspection methodology for rapid assessment, a large number of walls were evaluated. The rapid inspections revealed many conditions that required maintenance or repair (*Figures 2*, *3* and *4, page 20*). Several walls had to be immediately stabilized. It became clear that the stock of retaining walls, mostly dating from the first half of the 20th century, was showing signs of aging and neglect. Poor conditions also had been identified in a previous survey of arterial retaining walls performed by Gandhi Engineering, on behalf of the New York City Department of Transportation (NYC DOT). Taken together, the findings demonstrated the need for a proactive program.

It was not the particular causes of the May 2005 collapse, but the findings revealed by the rapid inspections that led the Board of Inquiry report to recommend: "*The Department of Buildings should propose legislation to require owners to engage a New York State licensed architect or engineer to perform periodic inspection of retaining walls that front a public way*."

In conjunction with the American Society of Civil Engineers (ASCE) Metropolitan Section, the Department organized meetings with leading local consulting engineering specialists – civil, structural and geotechnical. The discussions included the methods and findings of the inspections, the classifications of retaining walls, and the development of the most appropriate program to safeguard the public.

Local Law

The DOB drafted a proposed rule to address the concerns of the Board of Inquiry. Following public hearings, a rule mandating periodic condition assessments of retaining walls was adopted in 2013, i.e. the Rules of the City of New York (RCNY) 103-09. It covers all publicly or privately owned retaining walls within the city limits that front a right of way and are taller than ten feet. Basement walls and vault walls that are part of a building, underground structures and swimming pools are exempt. As recommended by the Board of Inquiry, the rule uses as a model the New York City façade inspection local law. It lists the requirements for wall specific assessment programs and report content. The law defines and allows only four categories for evaluation – "Safe", "Safe with Maintenance and Repair", "Safe with Repair and Engineering Monitor", and "Potentially Unsafe". A registered professional engineer with three years of specific experience is deemed qualified to perform the inspection and make all technical evaluations.

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Figure 2. Cracked and leaning retaining wall brick veneer.

Figure 3. Leaning segment of retaining wall.

The requirement to inspect only retaining walls *fronting public right of ways* is similar to the text of the façade inspection Local Law 10 of 1980. (As an aside, this local law was later expanded in 1998 by Local Law 11 to include all sides of a building).

As a consequence of the city's extreme pedestrian and vehicular traffic densities, the ratings focus on the urgency to protect and to mitigate. The rating categories do not allow for differentiation based upon severity or extent of deterioration.

The condition assessments are required to occur on a five year cycle, with the reporting staggered by boroughs. The first phase is now in progress. It is expected that, aside from providing a higher level of safety, this first cycle of reporting will help increase the accuracy of the inventory of walls and help establish a solid baseline for future cycles. A potential complication is the fact that many retaining walls extend over several lots and, as a result, the responsibility for maintenance and repair is shared by different owners. If these adjoining owners chose different professionals to assess, the repair recommendations may differ and may create the need for conflict resolution.

Correlation with Façade Local Law

The experience gained with the façade condition inspection Local Law 10 provided a strong basis for formulating the retaining wall inspection program. Deterioration of a retaining wall's face, similar to the deterioration of a building's façade, may be the result of extended exposure to adverse weather conditions. Many symptomatic conditions indicating potential hazards – delamination of concrete, corroded reinforcement, missing mortar or cracking of stone units, etc. – are common to both facades and retaining walls. This is especially true when the face of the retaining wall is only an architectural veneer of thin stone or brick. The façade local law had demonstrated that a five year cycle of inspection is effective for observing advances in material weathering and such periodicity was thus maintained.

Even in the absence of original drawings or design criteria, an inspector can discern most changes from the façade's original architectural aspects – deviations from vertical or horizontal positions, separations or gaps in the continuity of the envelope, unexpected departures from symmetry, etc. Such elementary observations might not be indications of disrepair when examining some types of retaining walls. Verticality, a benchmark for façade reliability, is not necessarily a given for retaining walls as they might have originally been built with a batter. Not all masonry retaining walls have regular coursing. Dry retaining walls might have been originally built with gaps between stones. Many, if not most, of the structural features ensuring the safety and serviceability of a retaining wall are not visible from the outside, e.g., condition of tensile reinforcement in concrete walls, condition of soil anchors, condition of fill to allow water drainage, depth of embedment of foundation base, and thickness of wall stem. Because inspections of retaining walls, especially older ones, have to overcome a high level of uncertainty, the law makes clear that this assessment cannot be merely visual. "*The methods used to assess the retaining wall in question must permit a complete condition assessment of the wall, including, but not limited to, selective probes, cores and measurements of wall dimensions, including, but not limited to, thickness.*" Collectively, these, together with other reporting provisions (e.g. providing wall sections), insure that a baseline for future inspections is created.

Facades and retaining walls have different functional purposes, and the mitigation of their potential failures is usually different. A distressed façade condition might reveal the potential risk that some of its constitutive elements will fail and fall. In the vast majority of cases, the public can be safeguarded by the installation of temporary protection, typically a sidewalk shed that will be in place until the condition is remedied. Some distressed conditions of retaining walls may indicate the potential of failures that could include the collapse of large wall segments together with the retained soil. The forces in play are such that simple interventions, such as the installation of sidewalk sheds, might not be sufficient to safeguard the public.

As a consequence, the category "Safe with Repair and Engineering Monitor" was introduced to designate the cases where "*a retaining wall is found at the time of assessment to be safe but requires repair within the next five years to correct minor to severe deficiencies in order to*

minimize or delay further wall deterioration and to remain safe." This rating applies to walls that require repairs and provides a differentiation from walls that require only maintenance work. The completion of the repairs indicated in conjunction with this evaluation has to be certified by the inspecting engineer and cannot be postponed to a subsequent cycle. The rating also can be applied to walls that are deemed safe at the time of the inspection, but have some features that require the inspector "*to regularly monitor and/or investigate further the retaining wall to determine the nature or cause of observed distresses and what action may be required.*" This monitoring needs to be performed by the responsible engineer following a clearly detailed plan. The stability of the walls in this category has to be demonstrated by an analysis which reports a factor of safety.

Figure 4. Severe crack in stone retaining wall.

Other Programs of Condition Assessment

About the same time that the RCNY 103-09 was being developed in New York City, the Federal Highway Administration and the National Park Service were collaborating to launch a Retaining Wall Inventory and Condition Assessment Program (WIP). Compared with the RCNY 103-09, the WIP program uses a wider definition of retaining walls as it also includes structures such as culverts, slope revetments and sea walls. This procedure uses a numerical condition rating system from 1 to 10 for the wall elements and a separate *Wall Performance* rating that refers to the overall functionality of the entire wall and the relational performance of different components. The numerical systems can be interpreted as "Excellent" (rating 9 or 10), "Good", "Fair", "Poor", and "Critical" ratings. The WIP manual provides specific and systematic instructions for what elements to observe, together with a summary guidance on grading. The final rating is based upon the aggregation of the various element and wall ratings, including the reliability of observations. The "appropriate wall action" is decided based on considerations that involve the final rating, the consequences of wall failure, the reliability of engineering of the original design and the need for additional investigations. The possible outcomes are (in order of importance): "No Action", "Monitor", "Maintenance", "Repair Elements", "Replace Elements" and "Replace Wall". The "Critical" rating indicates a high severity of distress and is an indication that the "*wall is in imminent danger of falling catastrophically, requiring… the roadway be closed.*" The WIP recommends an inspection cycle of ten years maximum. Shorter cycles should be used for some particular wall types or for walls that have lower prior ratings.

An example of a slightly different inspection program is the Gandhi arterial highway retaining wall condition assessment program that started in 1999. Prepared for a transportation authority (NYC DOT), the program was derived from this authority's long experience of periodic road and bridge inspections. It uses ratings from 1 to 7, as recommended in the New York State Department of Transportation (NYS DOT) *Bridge Inspection Manual* section for retaining walls that adjoin abutments. The inspectors are expected to evaluate general stability indicators, wall elements (e.g. exposed faces, weep-holes) and structural deterioration. The numerical condition rating is translated into "Poor", "Fair", "Good" and "Very Good" categories. These four categories represent an indication of the need and urgency of repairs. The "Poor" condition rating is intended for walls requiring close monitoring or immediate action, and triggers a detailed evaluation. Some of the experience gained with this program was used in the creation of RCNY 103-09, which in turn influenced later NYC DOT inspection methodology.

The WIP and the Gandhi programs require reporting that is for the benefit of governmental agencies with the purpose to maintain public safety, and also to budget and schedule repair or replacement construction work. These reporting methods, employing numerical ratings, have a large number of evaluation categories and thus allow for a more refined classification. The RCNY 103-09 relies on evaluations made by engineering practitioners that are experienced in the use of industry standards. The RCNY 103-09 is intended for various types of owners, including private property owners who might not have a technical background and, as a consequence, provides categories that are expressed in terms that make clear when an owner's property poses potential risks to the public and when it is in need of repair. Due to the extraordinary traffic density in New York City, any potential risk to the public needs to be abated, irrespective of the severity or extent of the deterioration. As a consequence, the RCNY 103-09 incorporates within the category "Safe with Repair and Engineering Monitor" conditions that reflect concerns regarding wall stability as well as face deterioration.

The RCNY 103-09 also gives a higher consideration to potential changes in loading conditions, especially those resulting from rapid water accumulation, a factor associated with several wall collapses. The RCNY 103-09 requires the assessment of the adequacy of the entire water management system around walls, and not only the proper functioning of weepholes.

An interesting review of various other retaining wall inspection programs can be found in National Cooperative Highway Research Program (NCHRP) Project 20-07, Task 259.

In essence, the RCNY 103-09 is focused on the urgency of action to protect the public while the WIP and the other similar programs include detailed prescriptions of the methodology of condition assessment.

Conclusions

The fact that during the past fifteen years several programs of systematic inspection of retaining walls have been developed indicates that various authorities have recognized a new domain of public protection. It will take several cycles to determine the advantages of each program and what adjustments or improvements these programs may need. It is quite likely that, in time, these programs will influence each other. The New York City 1980 law, requiring periodic inspections of facades, led some engineers to develop specific expertise and to form companies offering these specific services. Several other cities have followed New York City's example and have enacted similar façade inspection ordinances. One can expect the New York City retaining wall inspection law will have similar effects as more jurisdictions realize the potential risk posed by an aging stock of retaining walls.▪

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