BUILDING ENVELOPE TESTING SCOPING GUIDELINES

1.0 GENERAL GUIDELINES

2.0 BUILDING ENVELOPE SCOPING GUIDELINES

3.0 BUILDING ENVELOPE TESTING

3.1. Introduction

The following 'Building Envelope Testing Guidelines' are provided to assist the AEOR with identifying the appropriate non-destructive testing (NDT) methods for each project and with selecting targeted locations to include in the scope of work. Understanding the construction of the subject building as well as the information desired from the testing will be critical to the success of the NDT, as different roof systems and wall types require different methods. Just as appropriate testing can yield useful results and lead designers towards the correct solution to a problem, inappropriate testing can produce misleading results and lead to incorrect or inadequate repairs to a building. In general, testing of any kind should not be performed without a clear statement of understanding of the problem, justification for the specific test method being recommended, and a discussion of how the results will be used. Rather than submitting paperwork of forms describing the tests, a written description of the testing justification and goals should be submitted for review along with the initial walkthrough field report containing "Damage Mapping". Refer to the CIP Project Manual and Building Envelope Scoping Guidelines for a description of the Building Envelope Scoping Process and expected deliverables.

The intent of a Building Envelope Project is to perform repair or replacement of deficient system component(s) in the building envelope, related to water infiltration, safety and other issues. It is important that all building envelope components are inspected so that when the project is complete, there will not be any ongoing water infiltration, safety or other envelope concerns. This poses a significant challenge in larger buildings due to the potentially high number of leak sources, and the varying severity of leaks from different sources. However, it is common for problems to be isolated to a specific area of the building, such as a recent or past addition with unique construction, or related to a specific repeated component such as a certain type of window. In both cases, a thorough review of the conditions and discussion of the history of problems with school personnel are critical to understanding the extent of the issues.

3.2. Gathering Background Information

3.2.1. Existing Drawings and Repair History

The designer must review existing drawings and any documents outlining past repairs. It is important to understand the different systems and assemblies. For example, test methods and/or testing durations vary for solid masonry vs. cavity wall construction. Similarly, test methods vary for conventional roofing systems vs. **protected** roof membrane assemblies (PRMA). Given the age of many existing school buildings and the number of prior repair campaigns that may have occurred and may have changed the design approach from the original design, understanding what systems are installed, and where, is a critical first step.

3.2.2. Meetings and Site Investigations

The designer must meet with the school's Custodian, Principal, and other designated school staff during the investigation to identify existing Building Envelope problems or hazards and

review the status of outstanding building violations related to the Building Envelope and other renovations or additions being planned that may impact the funded project. The designer must interview the school personnel and identify deficiencies during the investigation to determine if any of the conditions outlined in the relevant Scoping Guidelines exist and include their findings in the Scope Report.

Perform a room-by-room survey with the Custodian to identify areas of water infiltration and interior damage. While this can be time consuming in larger buildings, it is critical to evaluating the potential scope of work for a project. *This includes the basement for signs of ground water or other subsurface water infiltration*. In particular, identify with the Custodian any areas that experience recurring water infiltration that may have been recently repaired and are not showing visible signs of deterioration. This is critical, as many custodians are extremely diligent about repairing finishes and repainting after damage occurs. Take note of water staining which may be attributed to plumbing leaks, as well as, damage to interior finishes with no history of bulk water infiltration that may then be attributed to water vapor migration rather than leakage. The designer shall annotate a set of plans and elevations indicating the extent of exterior defects, water infiltration and related interior damage to include in the Scope Report. Damage should be generally described to identify areas of simple staining or reported prior leakage (without current leakage) vs. areas with clearly failed finishes or other evidence of water leakage. As discussed in the related scoping guidelines, visual "Damage Maps" are very effective in evaluating the nature and extent of leakage issues, as well as ascertaining whether leaks are discrete/isolated conditions or more widespread/systemic.

3.3. Water Testing

The intent of NDT is to replicate previously observed or currently evident leakage and identify possible causes of leakage. The need to identify the exact cause of leakage and to have a better understanding of the design intent versus the installed condition may justify performing probe openings, especially if drawings of the existing building or renovations are not available*. Water testing is rarely cost effective, or even reliable, if used to attempt to locate uncertain (or suspected, but without evidence) leaks or, as is often the case, determine if a particular component or systems "will leak under normal conditions".* This relates back to the need for specific justification for testing (including, but not limited to water testing and probes); if the proposed testing is not appropriate for the intended purpose, it should not be performed. Ideally, the NDT firm will only perform water testing at locations identified as having bulk water leakage.

It is important to note that on occasion the stored water in the system will produce a leak to the interior a day or two after water testing. If the building damage is indicative of water leakage to the interior but no leaks are witnessed during water testing, it is important to explain to the building maintenance staff that they should keep an eye on the tested locations. The designer or NDT firm should verify with the building maintenance staff that the documented locations did not leak stored water after the testing. If possible, arrange a visit for a final inspection of the test location interiors.

3.3.1. Horizontal Elements Testing Methods (i.e. roofs, areaways, plaza decks)

3.3.1.1. General

Water testing, infrared scanning, or a combination of these or other NDT techniques may be used to help locate the source of infiltration if it is not obvious. It is important to evaluate whether the parapet or other roof structures are the source or are contributing to water infiltration, as leaks in the "field" of the roof away from detail areas are

relatively uncommon. Many times leaks can come from two or more sources and if only one is addressed, leaks will continue. It is important to understand the limitations of various NDT techniques used for roofing. **It is also important to note that the NDT methods can be used to determine if a membrane has been compromised and needs to be replaced, even if there is not an active leak to the inside of the building at the time of the testing.**

It is critical to select test methods that are appropriate to both the leakage being reported and the roof system type at the building. Review specific test methods with the SCA and Forensic Consultant (NDT firm) prior to finalizing any testing plans to avoid unnecessary or (as in the case of flood testing a membrane-over-insulation roof) potentially damaging tests.

If roof cuts are intended, coordinate the timing of roof cuts so that they occur directly after completion of water testing. This will help limit false results and can allow for documentation of trapped water between roofing layers (which may migrate to lower layers or dry to the interior if too much time passes between the leak and the roof cuts). Roof cuts are not permitted on roofs with a roof warranty still in effect without approval from the warrantor (typically the roofing manufacturer or occasionally the roofing contractor).

3.3.1.2. Flood Testing

In numerous incidents where active water leaks are reported in rooms below roofs that are still under warranty, flood tests are often performed to test the water-tightness of the roof(s) in question. Where the roof passes the flood test and no leaks are detected, it is likely that the water infiltration may not be related to roofing but attributed to parapets, exterior masonry, leaks within roof-top equipment locations or other sources. If a vented base sheet was used below the existing roofing assembly, lateral migration of water through this layer may disguise the origin of water infiltration. In this situation, the roof warranty will not always address these deficiencies, since they may not be considered “roof-related” problems. The AEOR must be careful in making a determination of the source(s) of leaks by making efforts to relate the location of interior defects to those that appear in roofs, roof top structures or at parapet locations, when the source could be related to building envelope components other than roofing. As noted above, visual damage maps are required, since they are useful in identifying the general nature and location of leaks.

It is important to note that roof manufacturers may have different criteria for determining when a roof is eligible for warranty service, which may or may not include water testing. This determination needs to be made prior to performing any tests or openings on warranted roofs. The AEOR must check the SCA Roof Database and confirm warranty of roofs.

Large-scale flood testing of roofs must not be performed for general assessment, or in areas with only minor or diffuse evidence of leakage due to the risk of creating more damage in the roof assembly. Flood testing of large areas of membrane-over-insulation roofs is potentially damaging to the roof, as even small leaks may allow a significant amount of water to enter the system and damage roof insulation, etc. far from the leak site. Conventional roofs with vapor barriers are at most risk of this testing, as the vapor barrier may prevent leakage to the interior and allow water to accumulate within the assembly unnoticed. Localized testing around drains or other areas with visible interior

damage poses less risk, as the interior damage suggests that leaks are visible on the interior and not concealed (i.e., leakage will enter the interior before too much roofing/insulation has been damaged by the test). Thus flood testing should only be performed in localized areas, or on **protected** roof membrane assemblies where the membrane is installed directly over the structural deck and the risk of concealed damage is minimal.

When localized damage is evident at drains, the drain itself should be tested first by allowing water to flow into it, since often the source of leakage is a plumbing line segment. Then the drain should be blocked to test the drain bowl. Finally, the membrane around the drain should be tested.

3.3.1.3. Low-Voltage Electric Integrity Testing (LVEIT)

LVEIT is a technology that uses low voltage electric fields to locate leaks in roofing and waterproofing systems. Electric Field Vector Mapping (EFVM®) by International Leak Detection is the most well-known system of this technology but there are other companies now that have gained the experience to utilize the methodology. The primary advantage is that it can be used on protected membrane roofing assembly (PRMA) systems or gravel-surfaced built-up roofs without the need to remove gravel. This can be very useful for existing plazas or accessible roof decks where removal of overburden would be prohibitively difficult or expensive. This method cannot be used on conductive roof membranes, which typically include EPDM membranes or aluminized/reflective coatings installed over asphaltic roofing.

Note that this method does not test roof drain perimeters or the drain bodies for leakage. Flood testing can be performed in conjunction with **LVEIT** to test the drain locations.

Similar to the general discussion of testing areas without known leaks, **LVEIT** testing requires a direct path for water between the membrane surface and the building interior. As such, testing of roof systems without known leaks, or with vapor retarders that can trap water above the roof deck, will likely be inconclusive. Some newer roof systems include a “grounding screen” below the roof membrane that is intended as a workaround to this issue, in which case the testing can be done as a quality assurance measure.

3.3.1.4. High Voltage Electronic Leak Detection (HVLD)

High voltage leak detection (HVLD) is a relatively new method for detection of leaks, but is similar to **LVEIT** testing. The primary difference between the two methods is that HVLD must be performed on a dry, fully exposed roof membrane. As such, it is limited to exposed membrane roof systems **and thus ineffective on gravel-surfaced built-up roofs and PRMA systems.**

3.3.1.5. Infrared (IR) Thermography

This technique uses an IR camera to visualize surface temperature differences on the roof which can indicate the presence of wet materials below. On a sunny day, the roof and underlying materials absorb heat during the day. After sundown and as temperatures drop, that heat is released. Wet materials have higher moisture storage

capacity than dry, so wet areas cool off more slowly and will show up as warm areas on the IR scan. This technique should only be performed on conventional (membrane-over-insulation) roofs with exposed membrane surfaces, such as mineral surfaced modified bitumen or single ply systems without ballast, **though some firms have effectively used it on non-insulated roofs**. Effectiveness will be limited on the typical gravel-surfaced built-up roofs found on older buildings as even a small amount of gravel surfacing or overburden can mask the temperature differences below and prevent accurate readings in most cases. On PRMA systems, with pavers/gravel and insulation outboard of the membrane, the technique is completely ineffective. In all cases, secondary verification (roof probes) should be performed rather than relying on the IR scan alone.

Conditions during the scan, including temperature and wind speed, will impact the results and must be considered. Lower temperatures and higher wind speeds will cause roof areas to cool more quickly, making timing of the scan critical. Any solar gain on the roof will cloud results, requiring that scans be performed after sundown. Standing water or snow on the roof will also impact results. Most importantly, the scan must be performed after a moderate rain event, under the right conditions, before water from the leak has dissipated.

3.3.1.6. Electrical Inductance (EI)

EI testing uses a specialized device to measure the combined capacitance and resistance of roof insulation, which will change depending on whether the material is wet or dry. In the majority of cases, the measurement device must be in close or direct contact with the roof membrane surface to obtain accurate measurements. This means that gravel surfacing can interfere with the interpretation of readings. This method is most effective on modified bitumen or singly-ply roof systems. On built-up roofs with gravel, the gravel needs to be removed in representative locations at the time of the survey to ensure the gravel and membrane below are dry. This method is wholly ineffective on roofs with pavers and with PRMA systems.

3.3.1.7. Summary Table

	Flood	**LVEIT**	HVLD	IR	**EI**
Large-Scale Testing		*	*	*	*
Pinpoints Actual Leak		*	*		
Effective on insulated gravel-surfaced built-up roofs	*	*			*
Effective on non-insulated gravel-surface built-up roofs	*	*			*
Effective on Conventional Single Ply Roof Systems **without ballast**	*	*	*	*	*
Effective on **insulated mineral-surfaced** Modified Bitumen Roof Systems	*	*		*	*
Effective on non-insulated mineral-surfaced Modified Bitumen Roof Systems	*	*		*	*
Effective on PRMA Systems **or built-up roofs with pavers**	*	*			
Effective on Conductive Roof Membranes (i.e. EPDM, **aluminum coated**)	*			*	

3.3.2. Vertical Elements Testing Methods (i.e. walls, parapets, fenestration)

3.3.2.1. General

Water infiltration that may appear to be attributable to the windows may actually be attributable to the surrounding masonry (including lintels, flashing, etc.). Thus, the NDT investigation needs to be carefully coordinated with the investigation of exterior masonry and testing done systematically to check each item separately. This is especially true at window head leaks, which may be caused by leakage from window sills or other elements on the floor above (specifically in areas with band courses or other horizontal projections above, which can catch water).

Testing must determine whether leakage is due to window units, perimeter conditions, or a combination of the two. If access to the exterior can be provided during testing, then testing by masking off specific parts of the system to isolate those elements can be performed.

Prior to any testing, verify age of windows and warranty.

3.3.2.2. Spray Rack Tests

A spray rack is a testing apparatus that delivers water to the exterior surface of the building. Spray racks are often calibrated to deliver a specific amount of water (typically approximately 5 gallons per square foot per hour, per ASTM Standard E1105) to the test area to produce a consistent film of water over the exterior. The contractor typically provides the spray racks and positions them at the test locations based on the NDT firm's direction. Spray racks at the exterior wall tests are usually hung from the roof parapet.

3.3.2.2.1. Windows

A combination of water testing using spray racks in general accordance with ASTM E1105 and interior probe openings is usually the best practice. If leakage is only reported during wind-driven rain events, an interior chamber for applying negative air pressure should be used. Test pressures should be selected using historical weather data and procedures described in AAMA 511 - Voluntary Guideline for Forensic Water Penetration Testing of Fenestration Products. Spray racks should extend at least 12 in. past the window perimeter to test perimeter joints, and separate tests should be run at the sill and head (beginning at low points, working upwards). If exterior access is available, a hand held nozzle may be used to isolate leakage paths. Interior openings may be required to confirm specific leakage paths, especially in areas where new windows were installed in existing openings, over weight pockets, etc.

It is important to note that window assemblies, which are non-absorptive, allow water to penetrate relatively quickly and any leakage contributed directly to the windows will typically surface quickly.

3.3.2.2.2. Masonry

Spray racks combined with interior IR testing are typically effective in determining the general source and path of water infiltration, although probe openings are typically necessary to confirm these findings.

It is important to note that leakage through solid masonry wall systems can often take several hours of saturating conditions or require wind-driven rain to activate. This is due to the high water storage capacity of masonry materials, as opposed to lightweight materials such as window frames, which are also non-absorptive and allow water to penetrate relatively quickly. In some cases, water infiltration is more significant under more severe conditions than can be created during spray testing (i.e., wind-driven rain). Additionally, thick masonry walls have significant water storage capacity; it may take time for water to find an opening and travel to the interior of the classroom/building.

Field testing for surface absorptance of masonry walls, such as using "Rilem Tube" tests, rarely yields any useful information about the source(s) of leakage in a wall system, and can produce misleading conclusions about the quality of the brick/stone and mortar on a project. These tests should not be used for diagnosis of water leakage or evaluation of exterior mortar and masonry. (For additional information see Section 3.4 Laboratory Testing of Masonry.)

3.3.2.2.3. Other Cladding

Testing of alternate cladding systems, including metal panels and single-wythe brick veneer, is performed in a manner similar to solid masonry, but tests are generally shorter in duration due to the lower water storage capacity of lightweight cladding systems. However, the presence of weather resistive barriers (WRBs) within newer cladding systems can complicate testing, as it may take a longer test to deliver enough water through the cladding to the WRB surface to cause a leak, especially if the WRB defect causing the leak is small. In these tests, where the cladding is separate from the cavity wall (as opposed to solid masonry wall systems), probe openings are often necessary to isolate the cause(s) of leakage since the leak source may be relatively far from the site of leakage on the interior.

3.3.2.2.4. Below-Grade

There are no specific test methods designed for testing below-grade walls for water leakage. Tests often include localized flooding or filling of test pits adjacent to foundations to expose the walls to water, but these methods can be inaccurate as they do not directly wet the wall and may not produce wetting in all leak locations. Depending on the nature of the leak(s), excavation of larger areas of the walls may be necessary for an accurate diagnosis. Check the basement, perimeter foundation drains, piping to sump pits, site/yard drains & piping, areaway drains, drywells near foundations and roof storm line (leaders and gutters).

Testing of walls in areaways should utilize spray rack methods described above, as the exposed wall areas can be wet directly.

3.3.3. Selecting Locations

As noted previously, water testing should be used to recreate leaks that have been observed during rain events, not for general "proof testing" of installed components or systems. When choosing locations for water testing, consider the number of different conditions where water damage is present. In most circumstances, testing two or three of each condition is sufficient for finding the leakage path or identifying the condition of the system. As stated previously, w*ater testing of every potential leakage source, or every similar condition where water damage is evident, is typically a waste of resources and does not provide any useful input to the project.* Water testing is a systematic process in which a process of elimination allows for the water infiltration source to be targeted. Start from the lowest possible point of water infiltration and work up to the roof and parapet. If access is possible, it is beneficial to block off adjacent systems.

3.4. Laboratory Testing of Masonry

3.4.1. General

The long-term durability of brick and stone masonry CANNOT be determined from the typical tests that are requested, such as water absorption and compressive strength. There are lab tests available that can better assess the risk of long-term degradation based on other material properties; these should be considered if the durability of the masonry is in question. The initial cost and time associated with the testing will always be significantly smaller than the potential cost of recladding a building, especially in the case where recladding is not warranted based on the masonry conditions.

3.4.2. Compliance with ASTM C216

Testing for compliance with ASTM C216, specifically grade "SW" (severe weathering), is often requested on projects where the quality of the exterior masonry is in question, and designers are considering a full re-cladding of a building. As noted above, testing for this compliance will not produce meaningful results on the actual cause(s) of water leakage into a building, causes of deterioration of the masonry, or help to evaluate the long-term durability of the masonry itself. The only potential use for this test is on newer buildings where the quality of the masonry is debated, and where testing could show whether or not the installed material meets the specified performance (typically SW based on ASTM C216). However, this becomes more of a comparative exercise than an evaluation of an actual performance issue.

3.4.3. Long-term Durability

The long term durability of a masonry sample (brick, terracotta, or stone) is a function of many factors, including pore size and distribution, mineralogy, water absorption, and the location on a building. These tests may require a specialty testing laboratory as well as a qualified technician (or geologist/petrographer) to perform and evaluate. The location on a building is also critical, as weaker, less freeze-thaw resistant brick or stone may provide sufficient performance in sheltered exterior applications or as the inner wythe of a multi-wythe wall. Consult with SCA's forensic firm for project-specific recommendations if long-term durability of particular masonry components is in question.

It is best not to check for whole building durability based on discrete samples of wet and severely exposed locations. Sample a variety of exposed masonry. Results of testing must

be reviewed with consideration for the specific sample locations and conditions around the building.

3.4.4. Other Testing

See Exhibit A attached to these Scoping Guidelines for additional information on other laboratory tests available and their applications.

3.5. Supplemental Testing

3.5.1. Video Pipe Inspections

Damage mapping can often indicate the presence of plumbing leaks. If damage in the field of ceiling is visible at lower floors, far from walls and roofs, it is likely caused by a plumbing leak. Video pipe inspections of these drains can assist with resolving plumbing leaks. Video pipe inspections can also be used to inspect the full length of a cavity wall at flashing laps, end dams, and terminations if the thickness of the cavity is sufficient (i.e., video equipment may not be able to navigate small cavities or those clogged with mortar).

3.5.2. Locating Steel Reinforcement

Ground Penetrating Radar (GPR) will aid in determination of locations for selective demolition probing (See Section 3.6 below) by determining the location (spacings and depths) of embedded reinforcing steel. Note that it is limited to concrete surfaces that are readily accessible for up-close access for GPR.

3.5.3. Borescopes/ Endoscope

Boroscopes/endoscopes can assist in visually inspecting further than the eye can see. The size of a probe opening can be adjusted in the field based on a scoping of the perimeter conditions. If for example, something is noted adjacent to a probe opening (i.e. corrosion of steel) then the opening can be expanded and that condition can be viewed closer. Likewise, probe openings can remain small if there is nothing different to note from the adjacent spaces. They can also be useful in inspections of interior probing.

3.5.4. Additional Structural Testing

There are many test methods and standards available. A comprehensive list of test methods and their implementations can be found in Exhibit A.

3.6. Probe Openings

Identifying the exact cause of leakage or getting a better understanding of the design intent versus an installed condition may justify performing probe openings, especially if drawings of the existing building or renovations are not available. *Generally, one or two openings at typical conditions in the location of damage are sufficient for understanding the conditions, identifying the cause, and gathering information to design a repair*. This relates back to the need for specific justification for testing and performing probes; if the proposed probing or testing is not appropriate for the intended purpose, it should not be performed. If rusting steel is found to be a major issue, more probes may be necessary to determine the extent of the deterioration at the different locations and determine the repairs required to be detailed.

Ground-Penetration Radar and other techniques outlined in Appendix A, can assist in determining probe locations and limiting the number of required probes. *Make sure to select at least one probe location where masonry is in a satisfactory condition so the condition of masonry can be compared*

with other probes. Coordinate probe openings both with the probe contractor and with the NDT firm, as applicable.

Probe openings should be observed as they are being made in order to adjust the opening, as required, based on in-situ observations. Use a combination of probes and NDT to assist in determining the source of moisture infiltration as well as reasons for bulging of masonry or cracking of stone work. Take note of the condition of collar joints in the masonry (See Exterior Masonry Scoping Guideline for additional information). Probe openings should occur *up to 72 hours after water testing* to prevent false leakage reports; note that water stored within the first or second wythe in a solid masonry wall is not indicative of leakage as mass walls will absorb water and slowly dry out if there are no voids to create a path of travel to the inside of the building.

4.0 EXHIBITS

A. **Exhibit A: List of Building Envelope Tests**
B. **Exhibit B: Building Envelope Map/Test Guidelines**

End of Building Envelope Testing Scoping Guidelines

Test Description	Test Standard / Reference	Test Indicates	Test Implementation
Visual Assessment / Remove Coating	ACI 201.1R-08	• Detection of visible concrete distress and deterioration, including at areas currently obscured by coating.	• Limited to concrete surfaces that are visible. • Limited to areas of the concrete where the coating is removed. • (Requires assistance from contractor to remove coatings, if present.) • (Coatings should be tested prior to removal for hazardous materials, if present.)
Hammer or Rotary Percussion Sounding	ASTM D4580-12	• Determine near-surface (non-visible) delaminations in the concrete. • Detection of near-surface delaminations caused by corroded embedded reinforcing steel. • Sounding will aid in determination of locations for selective demolition probing and half-cell testing.	• Limited to concrete surfaces that are readily accessible for up-close sounding. • (Will require assistance from contractor for access.) • (May require assistance from contractor to remove coatings, if present.) • (Coatings should be tested prior to removal for hazardous materials, if present.)
Ground-Penetrating Radar (GPR)	(None)	• Determine the location (spacings and depths) of embedded reinforcing steel. • GPR will aid in determination of locations for selective demolition probing.	• Limited to concrete surfaces that are readily accessible for up-close access for GPR (must be in contact with the surface). • Requires selective demolition probing for calibration. • (Will require assistance from contractor for access.)
Selective Demolition Probing	(None)	• Selective demolition probing (coupled with sounding) will allow observation of various conditions of embedded reinforcing steel. • Allows direct observation of condition of reinforcement at probe locations.	• Should be coupled with sounding for maximum benefit. • Requires small portions of the concrete covering embedded reinforcing steel to be removed and then repaired / replaced. • (Will require assistance from contractor for access.) • (Will require assistance from contractor for coating / concrete removal, if present.)
Half-Cell Testing	(None) / ASTM C876-09	• Allows determination of the corrosion state of larger areas of concrete with minimal demolition.	• Requires some probe areas to make an electrical connection to the reinforcing steel and to calibrate readings. • (Will require assistance from contractor for access.) • (Will require assistance from contractor for coating / concrete removal, if present.)
Impact-Echo Testing / Impulse-Response Testing	ASTM C1383-15 / ASTM C1740-10	• Impact-echo testing can be used to determine the presence of any voids or deep delaminations (of significant size) on the far face of the wall or slab being tested. • Impulse-response testing can be used to make a general characterization of the quality of concrete in an area.	• Will require two staff to perform testing on site and full up-close access. • Can be used to determine the quality of the concrete deeper within the wall or slab (complementary to visual assessment and hammer sounding). • (Will require assistance from contractor for access.) • (May require the localized removal of the coatings, if present.)
Coring ASTM C42-13	Petrography: ASTM C42-13 / ASTM C856-14	• Will provide information through most of the thickness of the wall or slab being tested. • Provides information on concrete condition and quality (including its components and any potential mechanisms of deterioration).	• Requires removing core(s) from wall or slab (stopping prior to reaching inside face of wall or slab). • Requires core samples to be shipped to laboratory for further testing. • (Will require determination of concrete wall or slab thickness). • (Will require extensive assistance from a specialty contractor.)
	Chloride Content: ASTM C42-13 / ASTM C1218-15 / ASTM C1152-04(2012)e1	• Chloride content testing will allow for the effects of external chlorides (chlorine) at different depths in the core samples to be quantified and evaluated.	
Compressive Strength of Concrete ASTM C39-16	ASTM C39-16	• Compressive strength of cylindrical concrete specimens. • Specimens shall be extracted and shipped to laboratory according to ASTM C42-13.	• Requires removing core(s) from wall or slab (stopping prior to reaching inside face of wall or slab). • (Will require determination of concrete wall or slab thickness). • (Will require extensive assistance from a specialty contractor.)
Chemical Composition of Coating(s) using (FTIR) / (SEM)	(none)	• Can be used to determine the chemical composition of coatings and the number of layers (different coatings) applied to the pool wall. • (Provides no information about the structural condition.)	• Will require the removal and packaging of coating samples. • Will require off-site laboratory analysis. • (Will require assistance from contractor for access.) • (Will require assistance from contractor for coating sample removal.) • (Coatings should be tested prior to removal for hazardous materials.)

Compressive Strength of Masonry ASTM C1314-16	ASTM C1314-16 (ASTM C1532-12)	• Compressive strength testing of prisms obtained from field-removed masonry specimen. • Specimens shall be extracted and shipped to laboratory according to ASTM C1532-12.	• Will require selective demolition to remove specimens. • (Will require extensive assistance from a specialty contractor.)
Flexural Bond Strength of Masonry	ASTM C1072-13	• Flexural bond strength of non-reinforced masonry by physical testing of each joint of masonry prisms. • Specimens shall be extracted and shipped to laboratory according to ASTM C1532-12.	• Will require selective demolition to remove specimens. • (Will require extensive assistance from a specialty contractor.)
Weldability Analysis of Steel Beams (A)	ASTM E350-12 AWS D1.1	• Chemical analysis of steel sample and carbon equivalent calculation to determine whether an existing steel structure can be welded.	• A test coupon 1x1 in. must be cut from the existing structure. • This coupon must be saw cut and care taken not to overheat the sample.
Tensile Testing of Steel Beams (B)	ASTM A8-15	• Tensile testing of coupon to determine strength and ductility of existing steel structure.	• A test coupon 12x2 in. must be cut from the existing structure. • This coupon must be saw cut and care taken not to overheat the sample. • (Will require extensive assistance from a specialty contractor.)
Tensile Testing of Steel Beams	ASTM A370	• Charpy testing of coupon to determine toughness of an existing steel structure that may be subject to impact loading.	• A test coupon 3x3 in. must be cut from the existing structure. • This coupon must be saw cut and care taken not to overheat the sample. • (Will require extensive assistance from a specialty contractor.)
Qualification of welding procedure for AWS D1.1	AWS D.1.1	• Qualification of welding required for structures welded accorded to AWS D1.1. • Mechanical testing of test weld coupon. • Metallographic testing of weld section. • Weld inspection by AWS-qualified personnel.	• A coupon (typically 12x12 in.) is required for testing. • (Will require extensive assistance from a specialty contractor.)
Thickness Determination by Ultrasonic Testing	ASTM E797	• Thickness measurement of metal using ultrasonic testing. • To be used for structural integrity surveys.	• Thickness measurement of metal piece >0.025 in. thick. • (May require assistance from contractor to remove coatings, if present.)
Corrosion Failure Analysis	n/a	• Corrosion analysis of corroded metal. • Structure can include bolts, pipes, beams, etc. • Determination of corrosion mechanism. • Evaluation of corrosion rate. • Determination of structural integrity and remaining lifetime.	• Site inspection by corrosion engineer. • Removal of corroded specimens for laboratory analysis. • Water testing and/or swabbing to determine chemicals and microbes in the environment. • (Will require extensive assistance from a specialty contractor.)
Fracture/Fatigue Failure Analysis	n/a	• Failure analysis of cracked/fractured metals. • Structure can include bolts, beams, welds, cables etc. • Determination of failure mechanism (fracture, fatigue, fretting etc.) • Structural integrity calculations.	• Site inspection by metallurgical engineer. • Removal of corroded specimens for laboratory analysis. • (Will require extensive assistance from a specialty contractor.)

Building Envelope Map/Test Guidelines – Exhibit B

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Category/Test		Site Work (Brick/ Stone/ Mortar/ Conc.)	Building Envelope Referred Items: Roofs – BUR Roofing	Roofs – Metal Roofing	Roofs – Conc. Slabs (Roof/Floors)	Parapets – Masonry / Stones	Parapets – Concrete	Exterior Façade – Masonry / Stones	Exterior Façade – Concrete Beams / Columns	Exterior Façade – Steel Beams /Columns	Ext. Doors	Windows	Flood Elimination (Masonry/ Concrete walls)	Map/Test Guidelines: Map/Test Indicates	Map/Test Guidelines: Map/Test Implementation
Damage Mapping Survey														**Map Indicates**	**Map Implementation**
DAMAGE MAPPING	Damage Mapping Survey to prepare by Architect/Engineer of Record to determine scope of testing.	Req'd (R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	• Physical observed conditions on building envelope components • Visible defects such as distress, deformations, slants, subsidence, movements, cracks, displacements, leaks, bulging, deflections, sags, settlements at exterior envelop and interior damages as result of exterior conditions (including plaster and paint deterioration)	• Each referred Item to have initial damage mapping survey, prepared by design engineer and/or architect for any test request. • Use drawings from SCA database, if no documents available, prepare hand sketches and markup observed conditions on sketches. • A final damage mapping survey drawings shall be included in Appendix 2 of the Scope Report. • Include initial damage mapping survey along with initial field report for assigned project.
Exploratory Probes														**Test Indicates**	**Test Implementation**
EXPLORATORY PROBES	Selective Exploratory/Demolition Probing	PDT		IEH roof cuts	-						_	_		• Selective demolition probing (coupled with sounding) will allow observation and verification of the presence and condition of components hidden within the assembly, as well as observation of how the overall assembly was constructed. Components of interest may include structural steel, anchorage, flashing, etc., • Exploratory probes in Mortar types, Brick, Terracotta, limestone for anchorage and corrosion examination. • Exploratory core cuts in roof slabs/walls will allow to know unknown details regarding depths and material compositions.	• Designer to provide plan/elevation drawings including a table showing probe numbers, probe locations, description and photos. • Should be coupled with sounding for maximum benefit. • Requires small portions of the concrete covering embedded reinforcing steel to be removed and then repaired / replaced. • (Will require assistance from contractor for access.) • Will require assistance from contractor for coating / concrete removal, if present. • Limit number of probes/core drills to minimum. Do not probe at areas of similar observed damages and same underlying masonry /concrete issues. • Sounding and/or GPR scanning is recommended prior to probing/core drilling.

Exploratory Probe Notes:

1. Designer to coordinate with probe contractor, NDT firms and school custodial officials to avoid any miscommunications which might delay on the project schedule
2. Designer to note probe openings in walls/parapets are taken within 72 Hours after completion of NDT water testing.
3. A temporary weather-tight covering is provided over the probes holes until probes are reviewed. When closing up probes, new material must match existing material in size and color.
4. General Probing locations: a) For Masonry at window sill, window head, Jamb and damaged areas. b) For steel/encased steel structure at member mid span and at member end connection and other suspected/bulging areas.
5. General probing sizes: a) Face brick probe= 2 brick stretchers x 5 brick course high (16"W x 16"H). b) Face brick probe at terra-cotta window jamb= 2 bricks wide x 5 brick course high x 2 Wythe deep (16"W x 16"H x 8"D)
6. Other probe sizes: Probe size may vary between building envelope items, based on what is being observed and/or the wall assembly, multi-wythes and extent of underlying problems.

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Test Description														**Test Indicates**	**Test Implementation**
CORROSION TESTS															
Hammer or Rotary Percussion Sounding ASTM D4580	PDT/NDT		–	–	–						–	–		• Determine near surface (nonvisible) delaminations in the concrete elements. A hollow sound indicates areas where concrete has separated from rebars. • Detection of near surface delamination/voids caused by corroded embedded reinforcing steel. • Sounding will aid in determination of locations for selective demolition probing and half-cell testing. • Determines depth/thickness of concrete/masonry/stones	• Limited to concrete surfaces that are readily accessible for up-close sounding.
Half-cell Testing ASTM C876	PDT / NDT		–	–						–	–	–		• Partial destructive probing is needed. • Allows determination of the steel corrosion state of larger areas of concrete with minimal demolition in concrete slab/wall elements. • Corrosion investigation and mapping of risk of corrosion. • Determines the probability rebar is under corrosion.	• Partial destructive probing is needed. • Requires some probe areas to make an electrical connection to the reinforcing steel and to calibrate readings. • Will require assistance from contractor for access to remove coatings and hazardous material samples for testing. • If concrete is dry or has been coated for a long time, do not test as test results will lead to inaccuracy.
Carbonation Depth (Per PCA PL911)	NDT		–	–	–	–		–		–	–	–		• Measurement of average & peak depths of carbonation in the body of the element. • Loss of alkalinity and reduction in **pH** values in concrete/cement may promote corrosion and subject to carbonation of the concrete.	• A chemical solution spray on exposed concrete surface shows pink color when concrete is not carbonated or no color on carbonated concrete portion. • Collect and send samples to Lab testing for further investigations.
Chloride Ion Content: ASTM C1218	PDT/NDT		–	–	–	–		–		–	–	–		• Chloride ion content testing will allow for the effects of external chloride ions at different depths in the core samples to be quantified and evaluated in concrete elements. • Chlorides are not consumed in corrosion process but they act as catalysts and causing concrete debonding, cracking and spalling. • Concrete parapets and walls (exposed to marine atmosphere). • Corrosion investigation and determining chloride content from drilling dust or core drilling.	• Collect and send samples to Lab testing

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	Detection of Concealed Ferrous Anchors/Wall ties using Pachometer (ASTM D7046)	NDT		–	–						–	–	–		• Detects spacing of anchors and wall ties. • Approximate measurements of cover thickness and detect presence of steel embedment in concrete, determine approximate rebar spacing and length	• Unrelated metal (flashings, structural steel, railings) can interfere with reading the metal of interest. • Metal must be conductive to be detected. • Certain grades of stainless steel masonry ties do not register in test.
STRUCTURAL FORENSICS TESTS	Impact Echo Testing ASTM C1383 or Impulse Response Testing ASTM C1740	NDT		–	–	–					–	–	–		• Impact echo testing used to determine the presence of any voids or deep delamination's (of significant size) on the far face of the wall or floor slab being tested. • Impulse response testing used to make a general characterization of the quality of concrete in an area.	• Will require two staff to perform testing on site and full up-close access. • Can be used to determine the quality of the concrete deeper within the wall or slab (complementary to visual assessment and hammer sounding). • Will require assistance from contractor for access. • May require the localized removal of the coatings, if present.
	Ground Penetrating Radar (GPR)	NDT		–	–						–	–	–		• Determine the location (spacing's and depths) of embedded reinforcing steel. In concrete elements • GPR will aid in determination of locations for selective demolition probing, coring & drilling. • Indicates presence of rebar's in concrete beams. • Indicates voids in concrete and grout in masonry blocks	• Limited to concrete surfaces that are readily accessible for up close access for GPR (must be in contact with the surface). • Requires selective demolition probing for calibration but not always necessary. • Will require assistance from contractor for access.
STRUCTURAL FORENSICS TESTS	Coring ASTM C42	PDT		–	–						–	–	–		• Will provide information through most of the thickness of the wall or slab being tested. • Can determine condition of existing constructed materials.	• GPR scanning is recommended before drilling to clear and avoid utilities, conduits & reinforcement. • Requires removing core(s) from wall or slab (stopping prior to reaching inside face of wall or slab). • Requires core samples to be shipped to laboratory for further testing. • Will require extensive assistance from a specialty contractor.
	Petrography ASTM C856 (for concrete) Petrography ASTM C1324 (for mortar evaluation)	PDT/LAB		–	–						–	–	–		• Provides information on concrete condition and quality (including its components and any potential mechanisms of deterioration). • Determines the "make-up" of concrete. Mortars and stone masonry. • Evaluation of mix designs, air content, void ratio, general mix design data, porosity of materials.	• **Very time consuming and Expensive test, the request must obtain approvals from DPM/DCS.** • Collect and send samples to lab testing

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															• Alkali Silica Reaction (ASR) in concrete is also found from petrography testing. • For mortar Evaluation test using ASTM C1324 which includes both petrographic examination ASTM C856 as well as chemical analysis based on ASTM C1084)	
STRUCTURAL FORENSICS TESTS	Freeze-Thaw Durability Test - Brick Masonry ASTM C67	PDT/NDT		–	–	–					–	–	–	–	• When masonry surface is suspectibile for flaking, spalling, chipping, cracking and disintegrating and resulting loss of surface on masonry units. • Lab test measures critical degree of saturation where masonry material will fail. • Reveals microscopic and macroscopic deterioration in masonry material as result of freeze and thaw actions.	• This test to be used only when brick surface is flaking and becoming risk of structural integrity of masonry façade.. • This test is not definitive test method as field conditions cannot be created as exact assembly condition but it gives an assessement if masonry can be repaired or replaced as entire face.
	Freeze-Thaw Durability Test – Concrete/Cast stone ASTM C666 CMU-ASTM C1262	PDT/NDT		–	–	–	–		–		–	–	–	–	• This test to be used only when concrete surface is flaking, spalling, chipping, cracking, disintegrating, loss of surface and corrosion risk of rebars. • Lab test reveals microscopic and macroscopic deterioration in concrete due to freeze and thaw actions.	• This test to be used only when concrete surface is flaking heavily and becoming risk of structural integrity of concrete façade/spandrels/columns.
	Thickness Determination by Ultrasonic Testing ASTM E797	NDT	–	–	–	–	–	–	–	–		–	–	–	• Only for structural retrofit (reinforcement) projects • Existing steel beams/columns • Thickness measurement of metal using ultrasonic testing. • To be used for structural integrity surveys.	• Thickness measurement of metal piece >0.025 in. thick. • (May require assistance from contractor to remove coatings, if present.)
	Ultrasonic test (UT)	NDT	–	–	–	–	–	–			–	–	–	–	• ASTM C597 for Masonry, ASTM E797 for concrete. • Detects cracks, discontinuity detection and internal conditions of materials.	• Surface must be accessible to probe. • Thin parts may be difficult to inspect.
	Magnetic Particle (MT)	NDT	–	–	–	–	–	–	–	–		–	–	–	• Detect surface and near surface flaws and seams in steel	• Only ferromagnetic material can be inspected
	Dye Penetrant (PT)	NDT	–	–	–	–	–	–	–	–		–	–	–	• Test can confirm suspected cracks, locate cracks,	• Requires surface to be cleaned prior to test.
	Electro Magnetic (ET)	NDT	–	–	–	–	–	–	–	–		–	–	–	• This test includes Eddy Current Testing (ECT), Alternating current field measurement and Remote field testing.	• Only conductive materials can be inspected. • Surface finish and roughness may interfere.

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STRUCTURAL FORENSICS TESTS	Radiography	NDT	–	–	–		–	–				–	–	–	• Can inspect almost any material for surface and subsurface defects. • Detects flaws and voids in welds.	• Access to both sides of structure is usually required. • Field inspection of thick section can be time consuming.
	Fracture/Fatigue Failure Analysis	PDT/NDT	–	–	–	–	–	–	–	–		–	–	–	• Failure analysis of cracked/fractured metals. • Structure can include bolts, beams, welds, cables etc. • Determination of failure mechanism (fracture, fatigue, fretting etc.) • Structural integrity calculations.	• Site inspection by metallurgical engineer. • Removal of corroded specimens for laboratory analysis. • (Will require extensive assistance from a specialty contractor.)
	Sounding/ Tactile Inspection (Hammer tap test for stones/steel) By boom truck	NDT		–	–	–					–	–	–	–	• To measure surface hardness and identifying variations in masonry and stone units for hollowness and material uniformity. • Stone deterioration conditions can be found using visual, audible and tactile inspections. • Stone sounded hollow to some degree when acoustically tested with delamination detection testing (ASTM D4580) • Exfoliation or corrosion of steel.	• Test the stones for moisture-content when significant amount of stone are spalling.
	Stone Consolidant treatment testing for strengthening (Performance or compatibility of patch materials)	PDT/NDT		–	–	–		–		–	–	–	–	–	• Performance requirements for treatment material to restore cohesion, physical properties, and appearance of a deteriorated stone to near its original condition. • Assessment of effects of different audio tactile “tapping sound conditions”. • Consolidation treatment that stabilizes masonry/stone by replacing the natural binding materials lost/damage due to weathering and anchor corrosion. • Evaluates the physical and chemical characteristics of the substrates to confirm whether consolidation is possible.	• Treatment materials to be in compliance with state EPA VOC regulations.

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			BUR Roofing	Metal Roofing	Conc. Slabs (Roof/Floors)	Masonry / Stones	Concrete	Masonry / Stones	Concrete Beams / Columns	Steel Beams /Columns					
MATERIAL LOAD TESTS	Compressive Strength of Concrete by ASTM C39 and/or Slab byRebound Hammer (ASTM C805) /Schmidt hammer or Windsor probe test (ASTM C803)	PDT/NDT	–	–		–		–		–	–	–		• Compressive strength of cylindrical concrete specimens. • Specimens shall be extracted and shipped to laboratory according to ASTM C42 • Determine Strength using Rebound Hammer. • Accuracy of test results for rebound hammer,/Schmidt hammer/Windsor pin are within 20% • Windsor probe test may claim to have reliable test results top core testing.	• Requires removing core(s) from wall or slab (stopping prior to reaching inside face of wall or slab. • Will require determination of concrete wall or slab thickness. • Will require extensive assistance from a specialty contractor.
	Compressive Strength of Masonry ASTM C1314 Removed usingASTM C1532	PDT/NDT	–	–	–		–		–	–	–	–		• Only for loadbearing walls when required. • Compressive strength testing of prisms obtained from Destructive removed masonry specimen. • Specimens shall be extracted and shipped to laboratory according to ASTM C1532	• Will require selective demolition to remove specimens. • (Will require extensive assistance from a specialty contractor.)
	Flexural Bond Strength of Masonry ASTM C1072	PDT/NDT	–	–	–		–		–	–	–	–		• Only for loadbearing walls when required. • Flexural bond strength of non-reinforced masonry by physical testing of each joint of masonry prisms. • Specimens shall be extracted and shipped to laboratory according to ASTM C1532	• Will require selective demolition to remove specimens. • Will require extensive assistance from a specialty contractor.
	Tensile Testing of Steel Beams as per ASTM E8 Or ASTM A370	PDT/NDT	–	–		–	–	–	–	–		–	–	• Only for structural retrofit (reinforcement) projects For existing spandrel beams • Tensile testing of coupon to determine strength and ductility of existing steel structure (flexural/tension capacity) • Charpy impact testing of coupon to determine toughness of an existing steel structure that may be subject to impact loading.	• Test ASTM E8 is similar to ASTM A370. • TEST A test coupon 6x3 in. or 3x3 inch is saw cut from the existing structure, do not overheat sample • Will require extensive assistance from a specialty contractor.
	Covermeter (BS1881-204) or GPR (ASTM D6432)	NDT	–	–	–					–	–	–		• Indicates reinforcing bar spacing and locations and depth of cover in masonry and concrete units.	• For a covermeter to determine rebar size, the spacing must be known or vice versa. • GPR can provide rebar spacing and depth but does not provide size.

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				BUR Roofing	Metal Roofing	Conc. Slabs (Roof/Floors)	Masonry / Stones	Concrete	Masonry / Stones	Concrete Beams / Columns	Steel Beams /Columns				Map/Test Indicates	Map/Test Implementation
																• For both methods, overlying rebar or ties can obscure readings of deeper reinforcement.
	Strength of Anchors in Concrete or Masonry ASTM E488	PDT		–	–	–					–	–	–		• Provides pull-out strength of post-installed or cast-in-place anchors	• There are many failure modes that can occur (e.g bond, shear, etc.), but failure can also be defined by a displacement.
	Proof Loading Test (In-Situ Structural Concrete /Brick/ Terracotta Arch Slabs)	IN-SITU (FIELD)TEST	–	–	–		–	–	–	–	–	–	–	–	• Structure or system is subjected to loads and respond is measured. • Check load carrying capacity for additional loads on slabs. • Check existing arch floor slab capacity constructed of cinder/brick/terra-cotta arch slabs	• This Test request must be approved by DPM/DCS. • Arch ceiling plaster to be non-ACM for this test. • Load test during holidays when there are no students and faculty in the school. • All survey and loading steps must be supervised and monitored by a registered professional engineer. • May cause damage to the structure,
DEFICIENCY TESTS	Optical Magnifications	PDT/NDT	–	–	–	–		–		–	–	–	–		• Flaw dimensions can be readily measured.	• Instrument needs to be calibrated
DEFICIENCY TESTS	Fiberscope (Endoscope)	PDT/NDT	–	–	–	–		–		–	–	–	–		• Direct visual inspection of otherwise in accessible parts is possible. • Fiberscope composed of bundle of flexible optical fibers with lens and illuminating system is inserted into small bore for viewing through interior cavities. • Borescope assist visual inspection of internal conditions	• Probe holes must be drilled • Probe holes must connect to a cavity. • Need to use high intensity light source,

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			BUR Roofing	Metal Roofing	Conc. Slabs (Roof/Floors)	Masonry / Stones	Concrete	Masonry / Stones	Concrete Beams / Columns	Steel Beams /Columns					
VERIFICATION TESTS	Qualification of welding procedure for AWS D1.1	PDT/NDT	–	–	–	–	–	–	–	–	–	–	–	• Structural retrofit reinforcement projects • Qualification of welding required for structures welded accorded to AWS D1.1. • Mechanical testing and metallographic testing of weld coupon and weld section. • Weld inspection by AWS qualified personnel. • A weld coupon is created using the weld procedure and sent out for testing to confirm procedures satisfied.	• A coupon (typically 8” linear inch) is required for testing. • Will require extensive assistance from a specialty contractor.
	Chemical Composition of Coating(s) using (FTIR) / (SEM)	PDT/NDT		–	–	–					–	–	–	• Can be used to determine the chemical composition of coatings and the number of layers (different coatings) applied to same surface. • (Provides no information about the structural condition.)	• Will require the removal and packaging of coating samples. • Will require off-site laboratory analysis. • Will require assistance from contractor for access. • Will require assistance from contractor for coating sample removal. • Coatings should be tested prior to removal for hazardous materials.
	Adhesion Tester ASTM D4541 and ASTM D7234	PDT		–		–					–	--		• Indicates pull out strength from the base material ASTM D4541 for metal or other rigid substrates; ASTM D7234 for concrete substrate) • Test is applicable to coatings, self-adhering membranes, and air-barrier materials.	• A larger surface area of dolly is required for accuracy results.
	Coating Thickness Measurement ASTM E376	PDT/NDT	–	–		–	–	–	–	–			–	• Measurement of coatings in ferrous and non-ferrous metals using a non-destructive gage device. • Coating can be removed for test using knife, tape, pull off and scraping methods.	• Accuracy of measurement depends on the instrument and calibration.

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			BUR Roofing	Metal Roofing	Conc. Slabs (Roof/Floors)	Masonry / Stones	Concrete	Masonry / Stones	Concrete Beams / Columns	Steel Beams /Columns					
MATERIAL ALLOY TEST	Weldability Analysis of Steel Beams (A) ASTM E350 AWS D1.1	PDT/NDT	–	–	–	–	–	–	–	–	–	–	–	• Only for structural retrofit (reinforcement) projects where field welding is required on existing steel. For roof/floor slab • Existing spandrel beams • Chemical analysis of steel sample and carbon equivalent calculation to determine whether an existing steel structure can be welded.	• A test coupon 1X1 in. must be cut from the existing structure. • This coupon must be saw cut and care taken not to overheat the sample.
GEOTECHNICAL TESTS	Borings (Mostly outside of existing building)	PDT	–	–	–	–	–	–	–	–	–	–	–	• Collecting soil samples and having Geo-tech to evaluate boring logs for soil classification, blow counts, moisture, and depth of groundwater, settlement calculation and Full Geotech Report. • Well monitors can be installed in borings to study ground water level fluctuations.	• Borings to be taken outside the building and away from existing building foundations. GPR scanning is recommended to avoid existing utility pipe for proposed boring locations.
	Test Pit (Mostly outside of existing building)	PDT	–	–	–	–	–	–	–	–	–	–	–	• A pit or trench is dug manually or with an excavator to depth desired in order to visually observe subsurface soil conditions including adjacent footing visible sizes.	• Test pit depth not to undermine existing foundations.
	Soil Permeability/ Percolation Test	PDT/ NDT	–	–	–	–	–	–	–	–	–	–	–	• It is measurement of the soil's ability to allow water to flow through soil pores or voids. The test can be conducted in field or lab to determine the coefficient of permeable soils,	• It is difficult to get a reliable value of k with conventional lab testing methods because of boundary conditions of in-situ and lab.

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	Below Grade Ground (water test/piping and sewer investigation)	PDT/NDT	–	–	–	–	–	–	–	–	–	–		• No specific test, excavate pit • Do test pit to see existing foundation wall construction and obtain wall/footing data • Record water level if ground water encountered • If water test is Chlorine positive, it indicates drinking water and likely its plumbing leaks • If water test is Coli bacteria positive, it indicates sewage waste line and likely sewer leaks not ground water issue. • If water test is negative, it indicates most likely groundwater and storm water.	• Water testing and/or swabbing to determine chemicals and microbes in the environment. • Test leaking water for Chlorine & Coli bacteria.
ROOF ASSEMBLY TESTS	Roofing Cuts	PDT (IEH)	–		–	–	–	–	–	–	–	–	–	• Roof membrane cuts to determine number of roof membrane piles and if material is asbestos containing material. • Indicates the fill condition as dry or wet. • A small number of roof cuts or cores can provide verification and spot check of the accuracy of other NDT methods to correctly detect moisture.	• Roof cut request through IEH or IEH clearance required. • Roof cuts to be patched after collection of sample and data.
	Roof Cores	PDT	–	–	–		–	–	–	–	–	–	–	• The core drills through roof Fill & Screed and its thickness. • Indicates the fill & screed quality, sample can be tested for suspected ACM.	• IEH clearance required. • Roof core holes to be plugged solidly with structural repair concrete after collection of sample and data.
	Roof Contour Mapping (using laser level system)	NDT	–		–	–	–	–	–	–		–	–	• To determine “Pitch to drain”	• Presence of dust and other type of coating on laser can affect the performance of the device.
	Roofing Fastener Withdrawal Test (ANSI/SPRI FX-1)	PDT	–	–	–		–	–	–	–		–	–	• Indicates pullout capacity of fastener.	• Roof repair required after withdrawal of fastener testing.

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	Category/Test		Building Envelope Referred Items											Map/Test Guidelines	
		Site Work (Brick/ Stone/ Mortar/ Conc.)	Roofs			Parapets		Exterior Façade			Ext. Doors	Windows	Flood Elimination (Masonry/ Concrete walls)	Map/Test Indicates	Map/Test Implementation
			BUR Roofing	Metal Roofing	Conc. Slabs (Roof/Floors)	Masonry / Stones	Concrete	Masonry / Stones	Concrete Beams / Columns	Steel Beams /Columns					
ROOF LEAK TESTS	Flowing water Flood test and/or Flood test using containment assembly per ASTM D5957	NDT	–		–	–	–	–	–	–	–	–	–	• Where active water leaks reported in rooms below roofs that are still under roof warranties. • Effective on Insulated gravel surfaced built-up roofs • Effective on Non_Insulated gravel surface built-up roofs • Effective on Conventional Single Ply roof systems without ballast (gravel) • Effective on Insulated/Non_Insulated mineral surfaced Modified Bitumen Roof Systems • Effective on PRMA Roof Systems or Built-up roofs with pavers • Effective on Conductive Roof Membranes (i.e. EPDM, Aluminum coated) • Flood and Deluge testing and leakage mapping. • Waterproofing failure detection of roofing. • Flood and deluge testing for leakage mapping on roof.	• This test must be justified and must obtain approvals from DPM/DCS. • Large scale flood testing of roofs must not be performed for general assessment or in areas with only minor or diffuse evidence of leakage due to risk of creating more damage in the roof assembly • Flood testing of large areas of membranes over insulation roofs is potentially damages the roof system. • Temperature must be above freezing during the flood test. • Must block drains during containment flood test • If a leak occurs, a large volume of water could flow into the building. • Does not test higher portions of roofing where it turns up at the perimeter and at penetrations. • Flood test loads be less than roof design live loads and this test must be approved by EOR/AOR
	Infrared (IR) Thermography Following ASTM C1153	NDT	–		–	–	–	–	–	–	–	–	–	• Large scale roof testing which detects the thermal signature of wet insulation under a membrane. • Effective on Conventional Single Ply roof systems without ballast (gravel) • Effective on Insulated/Non_Insulated mineral surfaced Modified Bitumen Roof Systems • Effective on Conductive Roof Membranes (i.e. EPDM, Aluminum coated) • Roof moisture survey, missing insulation, detects patterns of differential heating that indicates potential voids or water retention in assembly system.	• Depends on an interior/exterior or a night/day temperature differential, so is less effective in some seasons • Roof pavers prevent use of this method • Gravel ballast interferes with this method • Often used in conjunction with EI • Variations in insulation thickness, variations in the type of roofing surface, surface dampness, or areas of soiling can confuse results • Per ASTM, results should be verified with roof cuts at regions of indicated high moisture and low moisture.

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		BUR Roofing	Metal Roofing	Conc. Slabs (Roof/Floors)	Masonry / Stones	Concrete	Masonry / Stones	Concrete Beams / Columns	Steel Beams /Columns						
Electrical Impedance (EI) Following ASTM D7954	NDT	–		–	–	–	–	–	–	–	–	–	–	• Large scale roof testing detects moisture under roofing membrane. • Effective on insulated gravel surfaced built-up roofs • Effective on non_insulated gravel surface built-up roofs • Effective on Conventional Single Ply roof systems without ballast (gravel) • Effective on Insulated/Non_Insulated mineral surfaced Modified Bitumen Roof Systems. • Roof moisture survey, missing insulation, detects patterns of differential heating that indicates potential voids or water retention in assembly system. • Note that Infrared Thermography (IR) and Electrical Impedance (EI) can often be used together for verification and that for reflective roofs, EI is more appropriate than IR	• Often used in conjunction with IR testing • Limited use when gravel ballast or gravel protection course is present – gravel must be removed to perform test and residual moisture in the gravel fines must dry out completely • Results from impedance testing should be verified by roof cuts – at a region of high reading, intermediate reading, and low reading, per the ASTM standard • The method is sensitive to small changes in roof membrane thickness, and does not provide consistent results near metal roof penetrations, drains. and perimeter flashings. • Method will not detect moisture deeper than approximately 6” to 8”
FAÇADE LEAK TESTS	RILEM Tube Test (Absorptance test)	NDT	–	–	–	–		–		–	–	–	–	• Measures Moisture resistance to wind driven rain water intrusion in Masonry units and Mortar joints • Provides a rough estimate of initial rate of water penetration of brick units or masonry joints, which may correlate to porosity, or to voids and cracks .	• Do not test on walls that are already in state of leaks. • RILEM tube is a quick and simple test and results can vary greatly depending on the exact position of the tube on a masonry wall • To provide an estimate of the rate of water penetration over a larger area, ASTM C1601 testing evaluates a 12 sq ft region of masonry.
	Initial Rate of Absorption (IRA) of brick (ASTM C67	NDT	–	–	–	–		–		–	–	–	–	• The power of brick to absorb water and is measured by the initial rate of absorption (IRA). • Determining IRA of brick may help evaluate the cause of poor brick/mortar bond and increased water penetration of the masonry	• High IRA brick which was not wetted before use or not combined with a mortar with high water retention can result in a poor bond and increased water penetration of the masonry • Brick with high IRA will absorb water from the mortar and must be wetted before use • High IRA brick should be combined with mortar with high water retention, and low IRA brick should be combined with mortar with low water retention.

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															• Mismatch between brick IRA and the amount of water retentivity in the mortar may result in poor bond, increasing water penetration
Absorption of dimension Stone (ASTM C97)	PDT/NDT(LAB)	–	–	–	–		–		–	–	–	-		• Absorption and specific gravity of stone. • Moisture can become trapped below the surface and may lead to spalling.	–
Water Vapor Transmission of Materials (ASTM E96)	NDT	–	–	–	–		–		–	–	–	–		• Evaluates the water vapor transfer through semi-permeable and permeable porous stone materials (including plastic films, fiberboards, gypsum, plaster products, woods and plastics)	• Used to determine material properties for use in hygrothermal / dew point analysis
Water testing ASTM C1601 chamber apparatus field setup (Water penetration on masonry wall surfaces)	NDT	–	–	–	–		–		–	–	–	–	–	• Evaluates the resistance of the outer surface of masonry to water penetration under simulated wind-driven rain • Tests a 12 sq. ft. area at once, and tests both the masonry units and mortar joints • Can test single wythe, multi-wythe, cavity walls and on composite walls • Evaluates the workmanship and material performance to prevent water infiltration at the surface • Can also evaluate the effectiveness of repointing, coatings, or surface treatments by testing before and after • Provides secondary benefit of generally evaluating how well the wall system manages water after it passes the surface of the masonry	• This test consists of sealing a chamber to the face of a masonry wall and applying a constant, uniform sheet of water and positive pressure to the face of the masonry within the chamber, then measuring over time how much water is lost due to the absorption of water at the surface. It does not necessarily evaluate whether the entire wall will resist water penetration to the interior. A wall with a high initial penetration rate at the surface may perform well if the internal flashings and drainage are able to manage that water and allow it to dry or drain to the exterior. • Similar to RILEM test, but with more consistency and reliability
Spray Rack Water Testing (modified ASTM E1105 apparatus)	NDT	–	–	–	–		–		–	–	–	–	–	• Diagnostic water testing method used to investigate water infiltration • Used to replicate locations of known water infiltration, and determine the water infiltration path through a building enclosure	• Water applied by spray rack, typically from low to high regions, while monitoring the interior by IR thermography for water infiltration • Often combined with plastic sheet masking to improve diagnostic certainty

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														• Attempts to determine if the exterior initial entry point is related to masonry, fenestrations, roofing, etc., or the interface between these elements	• Combine with probe openings after completion of testing to verify suspected infiltration paths and locate specific defects allowing water infiltration to occur
Investigation of water leakage in building walls (Masonry/cladding/ skylights/ windows/doors/ interior finishes) ASTME2128	NDT	–	–	–	–	–	–						–	• It identifies the root cause of an active water intrusion and helps designer to choose appropriated and targeted repairs.	• Test covers a variety of investigative techniques, including intrusive, disruptive, destructive, and non-destructive ways to determine the cause and origin of water intrusions. • This standard covers: review of project documents, evaluation of design concepts, determination of service history, inspection, investigative testing (multiple methods), analysis, and report.
Water testing on Cavity wall (masonry wall drainage testing) ASTM C1715	NDT	–	–	–	–		–		–	–	–	–	–	• Test documents the ability or inability of water to exit the wall system via the weep drainage holes. • Test used to identify failures in the flashing systems, document cause and origin of water infiltration, determine the effectiveness of thru-wall flashing. • Test also provides quality assurance during commissioning of New Building.	• Primarily intended to evaluate cavity wall masonry with a drainage system. • Ports are drilled into the head joints of the masonry veneer to introduce water directly to the masonry cavity. The flow rate is determined based on the tributary area of the masonry above each port and either an assumed or tested water penetration rate of the masonry wall (often determined using ASTM C1601)
Forensic Water Penetration Testing of Fenestration Products – AAMA 511 (Air & Water leakage resistance of Windows and Doors)	NDT	–	–	–	–	–	–	–	–	–			–	• To perform a systematic forensic investigation of observed & known leaks. • Air & Water leakage resistance of in-place windows and doors. • AAMA 511 also expands on the investigative process set forth in ASTM E2128.	–

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DEFECT DETECTION TESTS	Patch Detection	NDT		–	–		–		–			–	–		• Indicates patch or repairs depth using a Ultra-violet lamp to create fluorescent patterns.	–
	Push Camera Survey/Video Pipe Inspection	NDT	–	–	–	–	–	–	–	–	–	–	–		• Use for Storm Pipe inspection • Plumbing pipe leaks	–
REMOTE MONITORING TEST	Structural Vibration Monitoring (NYC TPPN 10/88)	NDT	–	–	–	–	–	–				–	--		• This test requires prior approvals from DPM/DCS. • Remote vibration monitoring of adjacent foundations during construction using Geophones.	• Vibration monitors must be secured where accessible to students / public.
	Structural Crack Monitoring	NDT		–	–							–	–		• For walls using Telltales/crack monitors. • Cracking can be tracked to determine if movement is ongoing, and in which direction	• Small crack monitors are attached to each side of a crack and checked periodically. • Crack monitors must be secured if accessible to students / public
	Parapet Movement Monitoring	NDT	–	–	–	–			–	–	–	–	–	–	• This test requires prior approvals from DPM/DCS. • Remove monitoring of suspect parapet movements using Proprietary wireless inclinometers.	–

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TIMBER TESTS	Ultrasonic Testing	NDT												• To detect strength defects such as knots, slope of grain, decay of wood. • Detection of internal defects	• For timber structure
	Radioscopy/Radar Scanning	NDT												• To investigate the wood degradation due to fungal attack	• For timber structure
	Resistance Drilling	PDT												• Drill resistance to determine the density and decay in timber.	• For timber structure

OTHER FORENSICS SERVICES	**Whole building** Only when no existing building information is available through records of EOR/AOR/SCA alchemy files/DOB files/School custodians and other documents. **The request for preparation of documents must have SCA Director's Approvals**	**Map/Test Indicates/Test implementation**
Aerial Surveys	Mapping with drones Only upon SCA DPM/DCS approvals	• Mapping/Making measurements from photographs using drone technology where site accessibility and visibility is limited and/or unsafe conditions.
As-Built Existing Structural Surveys	Only upon SCA DPM/DCS approvals	• To determine the structural framing layout, framing members, columns including measuring the physical sizes of members. • It helps to investigate the additional load carrying capacities of the existing structure in retrofit structural projects.
As built documentation using Hper-Pixellation photography		• Documentation of Facades
Structural Condition Survey	Only requested when delegated to another professional to assist the main designer	• Examination of building structure, type, pattern distress, cracks and etc.,
Delamination Survey	Only requested when delegated to another professional to assist the main designer .	• Surveying concrete slab by sounding to determine delamination in the concrete.
Elevation Survey	Only requested when delegated to another professional to assist the main designer	• Floor to Floor, Floor to Ceiling elevation measurement.
Unknown Foundation Investigation	Only requested when no structural/foundation information available	• Determine of foundation type and length of piles.
`Miscellaneous/Secondary Test Methodologies	Only requested when no construction documents are available in SCA database (including alchemy, project directories & custodial office) or from building department archives.	• Acoustical testing in occupancy where noise issue is of concern. • Protection against outside acoustic environment

Notes:

1. Designer to coordinate with probe contractor, NDT Consulting Firms and School Custodian Engineer to avoid any miscommunications and scheduling issues that may impact delays on the project schedules.
2. Designer to note probe openings in walls/parapets must be taken within 72 Hours after NDT water testing performed