LESSONS LEARNED FROM LABORATORY TESTING FAILURES OF GLAZING SYSTEMS

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EXTENDED ABSTRACT

Introduction

Curtain walls and window walls are typically specified to meet a variety of different performance and testing criteria, some of which can be quite stringent. Such requirements are defined in specific codes and industry standards, including, but not limited to new 2015 requirements of the National Building Code of Canada, the International Building Code, AAMA 501 - *Methods of Test for Exterior Walls*, and ASTM E2099 – *Standard Practice for the Specification and Evaluation of Pre-Construction Laboratory Mockups of Exterior Wall Systems.*

Full scale laboratory mock-up testing of glazing systems can provide a valuable demonstration of a systems' ability to perform to these specified requirements. This presentation assesses the importance of lab testing as part of a quality assurance program. It presents a variety of different failures that have occurred during laboratory mock-up testing, which revealed deficiencies in the design, assembly, or installation of the glazing systems.

Glazing systems presented include full scale, multi-story laboratory mock-ups of curtain walls and window walls, as well as mock-ups that incorporated precast concrete panels. Failures presented include instances of water penetration, excessive air leakage, and structural failures. Corrective measures that were implemented in the mock-up will be discussed, as well as modifications that were made to the system design and/or assembly methods to address the mock-up failures. Potential future consequences that may have arisen had lab testing not been undertaken will also be presented.

This presentation does not address specific testing or certification that is commonly done on smaller mock-ups or panels (such as testing for thermal transmittance, condensation resistance, etc.). It instead focuses on full scale, project-specific multi-story laboratory mock-ups.

This presentation includes recommendations on when laboratory mock-up testing should be considered as part of the quality assurance program. It also identifies test procedures that should be included in the testing program and procedures that typically provide lesser benefit and may be considered optional. This presentation is intended to assist architects, developers, and façade consultants in deciding when laboratory mock-up testing should be undertaken and which tests should be included.

Typical Procedures of Laboratory Mock-up Testing

Lab test procedures vary from project to project, but comprehensive testing procedures commonly included in a lab mock-up testing program include the following:

- Air leakage testing in accordance with ASTM E283
- Static Water penetration resistance testing in accordance with ASTM E331
- Dynamic water penetration resistance testing in accordance with AAMA 501.1
- Structural testing in accordance with ASTM E330.
- Vertical interstory movement testing in accordance with AAMA 501.7
- Horizontal interstory drift testing in accordance with AAMA 501.4
- Thermal cycling test in accordance with AAMA 501.5.

Each of these tests is briefly discussed, although the focus of the presentation is on specific failures that have been observed.

Water Penetration Testing Failures

Water penetration is perhaps the most common failure that occurs during testing, as well as during the service life of cladding and glazing systems. This presentation provides examples of a variety of different failures that occurred during both static and dynamic water penetration testing of lab mock-ups, as well as corrective measures that were implemented to address these failures.

Water leak examples presented include; around the perimeter of glazing units, at mullion joinery, around fireplace vent penetrations, at operable units, at opaque spandrel panels, and through cracks in precast concrete panels.

Corrective action to address the leaks included: adjusting the methods of achieving water tight sealant continuity during assembly, modifying QA/QC procedures to ensure seal continuity, in addition to subsequent re-design and testing of operable units. In some cases, had these leaks not been discovered during the laboratory testing, leaks may have occurred during the in situ performance when the systems were subject to wind driven rain exposure. In a few cases, repairs would have been difficult or impossible to effectively execute in the field.

Structural Failures

Although typically not as common as water penetration failures, structural failures can be more significant due to potential life safety issues.

Examples of structural failures under negative wind load presented include a unitized curtain wall where an upper floor panel become disconnected from the panel below; in addition to failures of operable units, including a sliding door and awning windows.

Corrective action included re-design and retesting of the components. The structural failures that were observed could have posed a safety concern had they occurred during the service life of the systems, and would have resulted in significant costs to investigate and undertake repairs.

Excessive Air Leakage

Excessive air leakage was noted during one project when subject to negative (outward) structural load. Although the specifications did not require air exfiltration testing, this excessive air leakage revealed an error in the mullion fabrication that allowed the upper panel of a unitized curtain wall to shift outward when subject to negative wind loads, which loosened the air and water seal gasket at the interior of the stack joint. Corrective action included adjusting the fabrication of the effected mullions.

Had this defect not been discovered, excessive air exfiltration may have occurred during the service life of the glazing system. This may have resulted in wind whistling noises (as had occurred during the testing) as well as increased potential for interior condensation as interior air was able to leak through the assembly. This condition would have been extremely costly to investigate and repair in the field.

Other Lab Test Procedures

In addition to failures described above, examples are provided to demonstrate the importance or limitations of other test procedures, including lateral (seismic) drift testing, vertical displacement tests, and thermal cycling tests. Of these, the thermal cycling test is the most common that is left out of the testing sequence as it is among the most time consuming test and very rarely results in failures.

Conclusions

Undertaking full-scale laboratory mock-up testing of glazing systems can carry a significant cost that may reach into the hundreds of thousands of dollars. Strong justification of the benefits of the lab testing need to be presented in order for an owner to accept these costs.

The test procedures and sequences described in AAMA 501 and ASTM E2099 define appropriate laboratory testing requirements and most of the optional tests outlined in these standards should typically be included in the testing program.

With many building designers and owners desiring unique building aesthetics, use of customized glazing systems are not uncommon. Alternatively, modifications are made to “off the shelf” or more standardized glazing systems to accommodate specific aesthetic designs. Some of these modifications may have an impact on the performance of the glazing system. For these types of systems that have not been subject to previous laboratory mock-up testing, project specific mock-up testing is typically recommended. Consideration, however, must also be given to the extent or area of the glazing system and the lab mock-up costs in relation to the overall costs of the glazing system or project.