

Behind the curtain wall

Testing solutions for high-performance façades



**Add value.
Inspire trust.**

White paper

Abstract

Building façades have to withstand air infiltration, water leakage and other structural stresses. The growth of the green building market has increased the demand for façades that also support energy efficiency and noise control goals. Building owners, architects and consultants need to ensure that these high-performance façades meet clients' requirements for performance, safety and reliability from the onset.

Curtain walls and skylights have to be tested for the full gamut of design requirements at a suitable testing facility following international standards. Ideally, the testing facility should utilise computerised data gathering, and cover all aspects of performance testing, including acoustic performance, green/sustainable solutions, as well as mechanical, engineering and plumbing (MEP).

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About the TÜV SÜD expert



Tan Boon Kwee

Assistant Vice President, MEC/Building & Acoustics Group

Tan Boon Kwee is a SINGLAS Signatory for curtain wall, window and glass testing, and is also qualified as an ISO 9001:2008 Internal Auditor with TÜV SÜD PSB. Since joining TÜV SÜD, Tan has participated in the development and construction of the L10 x W14 x H16 metre curtain wall test chamber, as well as the development of a wide range of curtain wall tests. He has served on the SPRING Technical Committee since 2008.

1. Introduction



The modern façade

Like the skin of a living organism, the curtain wall safeguards the health of the building. Every façade performs many functions: it shields the underlying building from wind and water, it helps management of temperature and lighting conditions, and it controls acoustic levels. In short, every building depends on the safety and reliability of the curtain wall.

To the untrained eye, a modern building appears to be a solid, imposing edifice. But in fact, today's curtain walls are thinner and lighter

than ever before. Thanks to modern building techniques and materials technologies, advanced façades made of aluminium and glass have made high-rise structures more energy-efficient and better suited to human comfort, while weighing less. These advanced curtain walls are being put into service on larger and taller buildings, across a wide range of environments worldwide.

The untrained eye also cannot see that the building façade is under constant siege by invisible forces. While curtain walls do not carry

any dead load from the building, they must bear their own weight. Every day, environmental, climatic and seismic factors put the façade under tremendous stresses. In the rare situations when these stresses exceed the structure's tolerances, the results can be catastrophic. One of the most notable curtain wall failures occurred during the construction of Boston's John Hancock building in 1973, when strong gusts of wind dislodged more than 65 glass panels, each weighing 224 kg. Ultimately, all 10,344 panels on the building had to be replaced, at a cost of US\$7 million.

Skyrocketing demand

Unsurprisingly, the global curtain wall industry has expanded in recent years, in line with the rapid growth of cities in the developing world. Due to its booming construction market and its hunger for high-rise buildings, China has emerged as the fastest-growing curtain wall market in the world, with a CAGR of 24.6% from 2006 to 2011. It is also home to the largest manufacturers of curtain wall systems in the world¹. As curtain wall installations multiply throughout the world, a growing number of building stakeholders must ensure their safety, reliability and functionality.

Building owners, architects and consultants need to ensure that high-performance façades and skylights retain their integrity throughout the lifespan of the building, without the need for repair or replacement. Rising as high as half a kilometre

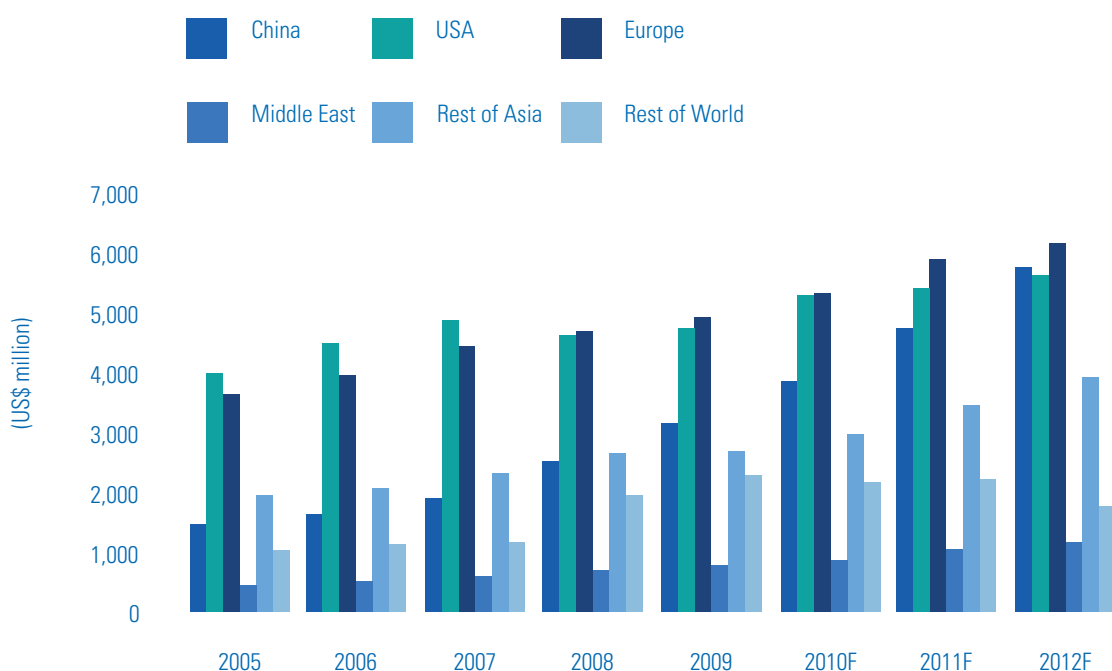


and holding tens of thousands of occupants, today's juggernauts tower over 20th-century skyscrapers such as the John Hancock building. Failure of the façade could result in injuries or fatalities, property damage, costly lawsuits and extensive brand damage. Repair work in a high-occupancy building could cause unimaginable

disruptions to business. Replacing a modern curtain wall would cost far more than the John Hancock building's US\$7 million repair bill, and on some super-tall buildings, such a feat may be flatly impossible.

For building stakeholders, failure is simply not an option.

MARKET SEGMENTATION OF THE GLOBAL CURTAIN WALL INDUSTRY (FORECAST UP TO 2012)



Source: Synovate Report

2. Safety and integrity: An invisible struggle



Many points of failure

Even if architects and façade consultants succeed in minimising the risks of failure during the design phase, there are many other points of failure during the façade lifecycle. A study in the UK building industry found that the primary cause of façade failure was poor workmanship (35%), followed by issues in design (22%), supervision (16%), fabrication (9%) and specification (9%)².

Design considerations

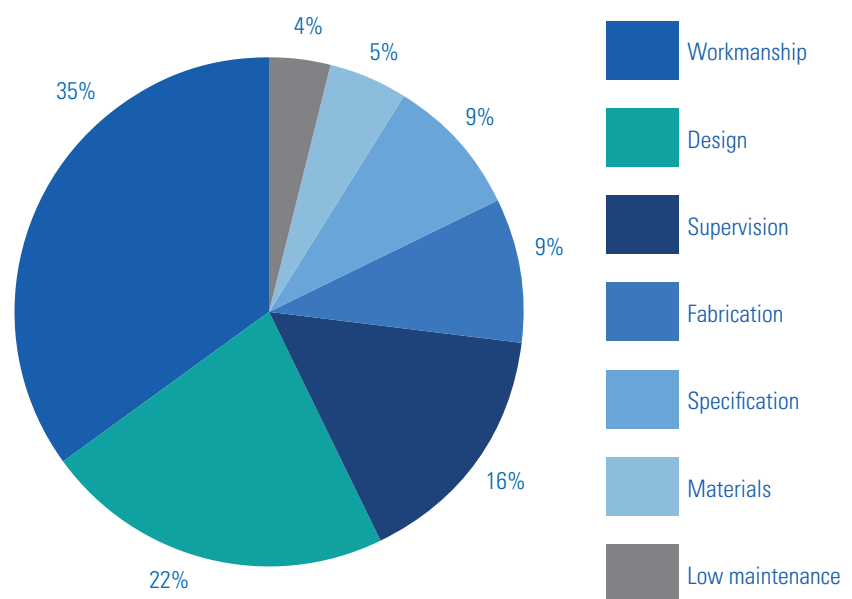
While engineers have learned much from the challenges of the past, curtain walls continue to grow more complex. Glass curtain walls of the 1970s comprised stick curtain walls, with individual mullions assembled on-site. Introduced in the 1980s, unitized curtain walls saved construction costs by being assembled in factories and installed as a unit in the field.

Today, a third generation of curtain walls incorporate energy-efficient

technologies such as triple-glazed curtain walls and solar control glass. These high-performance façades are essential to achieving energy savings in green construction

projects. Depending on the position of the building and the climate it is located in, a double façade could save between 10% and 50% of HVAC energy³.

CAUSES OF FAILURE IN THE UK BUILDING INDUSTRY



Source: WS Atkins

Future technologies such as smart windows are expected to reduce peak electricity loads in commercial buildings by 20-30%⁴.

Demand for advanced façade systems is growing: In 2012, 28% of AEC firms, consultants and owners worldwide were involved in high levels (60% or more of their projects) of green construction activities, more than twice the percentage in 2009⁵.

Material concerns

Owners, architects and consultants must prepare for a myriad of issues within the curtain wall that could lead to façade deterioration and failure. For instance, aluminium members can be prone to deflection; they deflect three times as much as steel does for a given load. Other problems to look out for include glazing failure due to excessive thermal loading or nickel sulphide inclusions, gasket and seal degradation, and various design or construction defects⁶. The slightest water penetration can result in expensive water damage, deterioration of the building structure and further façade failures.

Weathering the elements

Façades also need to be over-engineered to withstand powerful winds. Curtain walls at the topmost floors have to endure wind speeds far greater than those at ground level. Building façades in regions prone to hurricanes, typhoons or tornados must be strong enough to resist the higher pressures of storm winds as well as wind-borne impacts of flying debris. Similarly, façades must have both the flexibility and resilience to withstand building sway, particularly in earthquake zones.

PERCENTAGE OF FIRMS WITH MORE THAN 60% OF WORK GREEN IN SELECTED COUNTRIES (2012 AND EXPECTED FOR 2015)



Source: McGraw-Hill Construction, 2013

The most common type of failure in curtain walls is moisture damage, which results from water infiltration or

The slightest water penetration can result in expensive water damage and deterioration of the building structure.

condensation. Sealants in curtain walls may fail due to shrinking and cracking from aging, or because of improper installation. In either case, once water penetrates the curtain wall, the damage can be difficult to access and expensive to repair.

Workmanship and installation

Building façade stakeholders clearly need to remain vigilant during and after installation. On-site testing can help evaluate the workmanship

of the installation and prevent the occurrence of future problems. Beyond these measures, stakeholders should also employ independent testing and simulation services to verify their design choices and material specifications.

Acoustic considerations

Façades are also valued for their ability to reduce noise. As cities have grown, noise pollution has become an important issue affecting quality of life in urban areas. Since 1997, the

U.S. Census Bureau has found that Americans rate noise pollution as the number-one problem afflicting their neighbourhoods. Across Europe and Ireland, new and pending legislation is set to address noise-related concerns.

3. Façade testing: All under one roof

Ensuring all-around reliability

A comprehensive curtain wall and skylight testing solution is required to minimise risks of failure and ensure acoustic and energy performance, not just for office buildings, but also for malls, hotels, airports and other modern building projects. This solution involves tests in the lab and on-site for water and air tightness, structure and proof load, acoustical

qualities, solar optical performance and thermal performance.

Because of the façade's crucial role in building energy performance, stakeholders also require solar optical glass performance testing and energy simulation to gain a clear picture of how to reduce energy consumption and set design specifications.

Building stakeholders can achieve greater cost efficiency and save time by having all façade tests conducted under a single roof. Optimally, the third-party test provider should be a one-stop shop capable of offering the full range of air infiltration, water penetration, structural performance, proof load, vertical/lateral movement, energy and acoustic tests.



Seeing the big picture with TÜV SÜD

TÜV SÜD's experts conduct acoustic testing concurrent with curtain wall testing under the same roof, providing a one-stop service for façade stakeholders. Their wide range of expertise also covers green construction; acoustic, fire and MEP testing; and failure analysis.

Of the company's two test chambers in Singapore, one measures W10 x H8 metres while the other is a fully automated positive and negative chamber measuring L16 x W14 x H16 metres and suitable for SIROWET and AS/NZS 4284 testing. The test chambers are equipped with fully computerised test equipment.

As an internationally renowned independent third-party technical service provider, TÜV SÜD has worked on façade projects around the world. The company's experts frequently participate in building standards development committees, giving them insights into the risks and liabilities of construction projects. With over 800 locations worldwide, the company can provide programmes customised to local regulations and client needs in all major markets.

Regulatory compliance

Stakeholders operating across international borders must understand the local building codes for façades, which can differ considerably from one place to another. Many tests for curtain wall systems are designed to comply with ASTM test methods for air leakage, water penetration, and uniform static air pressure difference, as well as other national standards (AS/NZS, AAMA, SS, JIS and BS).

The unique architecture and situation of each building can lead to unforeseen problems with the façade. Stakeholders need to test the façade to the most stringent standards, taking into account the distinct features of their building design. Testing solutions should cater to additional client requirements such as acoustics, MEP, fire safety and use of renewable energy.

Energy performance

Tests can also verify the energy performance of façades. Energy performance is measured by the U value of glazing, which represents its conduction performance. Window solar control strategies also depend on the visible light transmittance (VT) of the glass as well as its solar heat gain coefficient (SHGC). To minimise



external heat gains for office buildings in warm climates, the glazing should have a high ratio of VT to SHGC – light-to-solar-heat-gain ratio (LSR). On the other hand, glazing in cold climates should have a higher SHGC and a lower LST to let in as much heat as possible.

Energy simulation

To help architects and façade consultants design a system that will last the test of time, the experts

begin with trial testing of a mock-up system to find weaknesses and areas for improvement before actual testing. Performance tests conducted

Tests conducted at the initial design stage identify weaknesses before installation.

at the initial design stage identify weaknesses in the curtain wall before installation, which minimises the risk of costly repair or replacement. The experts then conduct annual comparison tests to ensure reliable test results.

TÜV SÜD's renewable energy consultants help optimise the performance of energy-saving façades, including automated façades and façades incorporating solar photovoltaic technology.

TÜV SÜD CURTAIN WALL SYSTEM TESTING METHODS

Air Infiltration Test

- Determines the rate of air leakage through the exterior curtain wall under specified pressure difference (normally 20% of design pressure) across the mock-up.

Static Water Penetration Test

- Applies specified uniform static difference (normally 30% of design pressure) and specified water rate onto the exterior face of the curtain wall.
- Interior is checked for water leakage.

Dynamic Water Penetration Test

- Applies dynamic pressure difference (ranging from 300Pa - 720Pa) and specified water rate onto the exterior face of the curtain wall.
- Interior is checked for water leakage.

Cyclic Water Penetration Test

- Applies cyclic pressure difference (three stages) and specified water rate onto the exterior face of the curtain wall.
- Interior is checked for water leakage.

Structural Penetration Test

- Applies specified uniform static pressure difference (design pressure of the curtain wall).
- Any deflection is measured and recorded, and the curtain wall is checked for any distress or failures.
- Checks for compliance to the specified requirements (standards or project technical specification).

Proof Load Test

- Applies specified uniform static pressure difference (1.5 times the design pressure of the curtain wall).
- Checks for failure of any fixing, stop, or locking device; or dislodgement of any façade panel framing member.

Lateral Movement Test

- Simulates movement due to seismic activity (earthquake) or rocking of the main structure.

Vertical Movement Test

- Simulates movement due to a live load on the floor slab.

Curtain wall system testing methods

While curtain wall manufacturers do test their own products, building stakeholders demand stronger proof, hence the need for independent third-party tests. Façade testing providers in the ASEAN region routinely offer testing solutions for air leakage, water penetration and structural performance. Among the different tests for façades, AS/NZS 4284 – Testing of Building Façades is considered more stringent than others because of how it simulates real-world conditions.

The AS/NZS 4284/SIROWET method involves pressure testing of the external face of the curtain wall, simulating actual conditions after installation. First, a structural performance test is conducted, which may cause the façade's joints and panels to open up under air pressure changes. Next, air leakage and water penetration tests are performed to ensure that any weaknesses resulting from the structural performance test will be exploited and exposed. Most façade consultants prefer to use AS/NZS 4284 as it is more stringent compared with other testing standards.

However, most test providers in ASEAN are not capable of testing to AS/NZS 4284 and still use manual control systems instead of the newer computerised control systems. The lone exception among third-party solution providers is TÜV SÜD.

TÜV SÜD currently supports a complete range of major national and international curtain wall testing methods. These include ASTM (E 283,330,331), AS/NZS 4284, AAMA (501.1, 501.2, etc.), Singapore



Standards 381, JIS (A1515, A1516, A1517) and BS (5368, 6375).

On-site tests include the **Field Air Infiltration Test (ASTM E 783)** determines rate of air leakage through the exterior curtain wall under specified pressure difference (normally 75Pa based on ASTM

Most façade consultants prefer to use AS/NZS 4284 as it is more stringent compared with other testing standards.

Standard or as specified by the authority) across the mock-up.

The **Field Water Test (ASTM E 1105 or AAMA 501.2)**, another on-site test, applies specified uniform static pressure difference (normally 137Pa based on ASTM standard or as specified by the authority) and specified water rate (3.4L/min/m²) onto the exterior face of the curtain wall, after which the interior of the curtain wall is checked for any water leakage.

Acoustics testing

TÜV SÜD has one of the region's top acoustic test facilities, equipped with an external sample carrier that enables multi-sample mock-ups and

reduces lead time. The acoustic testing services manage general sound insulation using two key sound measurement criteria, the sound reduction index (ISO 140-3/ ISO 10140-2), a laboratory method of measuring the airborne sound insulation of building elements such as walls, floors, roofs, partitions, doors and windows, and the sound transmission loss (ASTM E90), a method of measurement that determines the Sound Transmission Class (STC) rating of architectural products to match other products with similar STC ratings.



Root cause failure analysis

The company's façade testing service is also integrated with its Failure Analysis team, which

offers root cause analysis and can provide an independent expert witness in court cases. If and when a façade fails while in operation, an independent investigation is the best way to safeguard the interests

of all stakeholders. A thorough investigation by a failure analysis expert can uncover the root cause and provide the stakeholders with recommendations on remedial and preventative measures.



4. Business benefits

TÜV SÜD's testing solution gives stakeholders confidence in the safety and integrity of their curtain wall system prior to actual installation.

The company's proven track record of independence and excellence also ensures a high level of acceptance for the building project. A one-stop test provider will enable stakeholders to save time and money by consolidating all of their façade tests under a single roof.

Stakeholders using the testing solution will:

- Gain peace of mind by ensuring the safety and stability of their system.
- Minimise the risk of façade failure and the ensuing reputation damage and legal costs.
- Enjoy wide acceptance of tests performed by an impartial and independent solution provider.
- Save time and costs through a convenient one-stop testing and certification service.
- Benefit from an expert partner using state-of-the-art testing equipment and methods.

5. Conclusion

Markets around the world are driving demand for green buildings, not only in Europe but also in rapidly developing countries such as Brazil and South Africa. These projects utilise a wide variety of high-performance façades to manage energy, lighting and ventilation needs. TÜV SÜD is the only test provider with the expertise and facilities to provide not just basic tests but also the preferred AS/NZS 4284 or SIROWET method as well as acoustic testing, all within one company. In addition, its test chambers are equipped with fully computerised test equipment, ensuring that accurate test results can be collected.

The company's one-stop solution provides a full range of tests for the safety, reliability and performance of curtain walls and skylights against stakeholder specifications. The tests provide accurate and independent verification of a system's ability to resist water penetration, air leakage and other potential causes of failure. Its positive and negative test chamber, computerised data acquisition equipment and on-site acoustic lab can support testing and assessment needs under a single roof. The company also provides green building, MEP and renewable energy expertise; fire safety testing; and

integrated failure analysis services. To date, the company has tested over 375 curtain wall systems for clients throughout Asia over the past 15 years since the establishment of its curtain wall testing facilities.

GLOSSARY OF ACRONYMS

AAMA – American Architectural Manufacturers' Association
AEC – Architects, Engineers and Contractors
AS/NZS – Australian/New Zealand Standards
ASTM – American Society for Testing and Materials
BS – British Standards
CAGR – Compound Annual Growth Rate
HVAC – Heating, Ventilation, and Air-Conditioning

JIS – Japanese Industrial Standards
LSR – Light-to-Solar-Heat-Gain Ratio
MEP – Mechanical, Engineering and Plumbing
SHGC – Solar Heat Gain Coefficient
SIROWET – CSIRO Wall Evaluation Test
SS – Singapore Standards
VT – Visible Light Transmittance

FOOTNOTES

- [1] China Construction Curtain Wall Industry Report, 2012-2013.
[2] Durability of the Façade, Diego Alves, 1997.
[3] A critical review of the energy savings and cost payback issues of double facades, Stribling, et al, 2003.
[4] Window Systems for High Performance Commercial Buildings, Lawrence Berkeley National Laboratory, 2006.
[5] World Green Building Trends, McGraw-Hill Construction, 2013.
[6] Preventing and Treating Failure in Glazed Curtain Wall Systems, Journal of architectural technology, Issue 2/2012, Volume 29.

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Find out more about TÜV SÜD's curtain wall testing solutions

www.tuvsud.com/buildings

realestate@tuvsud.com

Add value. Inspire trust.

TÜV SÜD is a trusted partner of choice for safety, security and sustainability solutions. It specialises in testing, certification, auditing and advisory services. Since 1866, the company has remained committed to its purpose of enabling progress by protecting people, the environment and assets from technology-related risks. Through more than 24,000 employees across over 1,000 locations, it adds value to customers and partners by enabling market access and managing risks. By anticipating technological developments and facilitating change, TÜV SÜD inspires trust in a physical and digital world to create a safer and more sustainable future.

TÜV SÜD AG
Westendstr. 199
80686 Munich Germany
+49 89 5791 0
www.tuvsud.com