# FULL SCALE FACADE PERFORMANCE UNDER WIND ACTION

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## Summary

Facade performance involves the exclusion of wind, water and temperature extremes. It is complicated by other mechanical factors associated with the interaction between the facade and the supporting structure.

Testing methods are still being evolved to realistically test prototype facades and to predict on-site performance. Testing facilities capable of simulating the complex inter related variables are now becoming available.

Building facades are complex skins enclosing a reasonably stiff frame structure of the building within. Curtain wall facades consist primarily of a thin membrane made of an interlocking series of structural supports including mullions and transom systems. These in turn support glazing and other thin panels for example, aluminium, or thin masonary panels. Composite facades incorporate heavy structural sections, for example, insitu or precast concrete panels as well as a framing and glazing system for view panels. Both facade systems involve a number of stiff mounting points or mounting edges, supporting or adjacent to the reasonably flexible view glass and curtain wall systems.

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As a scheme for consideration, imagine the building structure within responding in its first bending mode as a global or uniform response. Compare this with an imagined loading consisting of a number of smaller localised forcing pressure cells evoking a very non-uniform deflection. The main wind induced loadings will be the wind pressure component perpendicular to the glazing itself. Components parallel to the facade system, induced by wind forces, will include the building sway. Under test conditions this is represented by in-plane shear, induced between successive floor systems. Under these conditions the facade wall panels become a series of inter related but partly independent stiff panels moving within a restraining lattice system that is deflecting in a parallelogram fashion. Secondary loadings on the facade include thermal forces of growth of elements directly exposed to sunlight irradiation, especiallt aluminium constraining members, and of differential temperature growths induced across glazing and facade panels, especially those in part sun and part shade. Other secondary effects include building creep and building shrinkage. Thus, there exist in practice, a number of non-uniform forcing functions dynamically influencing local and global facade responses.

Against these external loadings applied to the facade, the performance tasks of maintaining water tightness and air sealing must remain. The obvious primary task of the facade system is to maintain internal comfort conditions in occupied spaces. It must also provide for eventualities such as glazing failures, fire sprinkler flooding, and other events inside the building. Because of this most facade systems are designed to catch any residual water inside and shed this to the outside of the facade. This requires that the facade is in fact penetrated for the drains. These in turn will allow air to penetrate the building. Similarly within glazing systems themselves, there are a number of cavities and channels around the glass and infill panels that themselves must be drained to outside to shed any accumulation or leakage during storms.

These two sorts of draining can be tested under full scale test conditions. The separation of the locations where external water is shed from the facade, and where wind pressure is prevented from entering the building, is the principle of drained joint design, so eagerly persued and expounded by CSIRO's Division of Building Research. It is easy to consider drained joints applying on thick facades, it is a little more difficult to contemplate on thin walled facade samples with their narrower cavities and channels.

Quantification of the appropriate criteria for testing is found in a number of Standards. The Australian version is AS 2047 of 1977. Similar American and European Standards also cover the issue. They are however limited to considering testing of weather tightness under static pressures. It is put here that the static testing requirement may seriously underestimate the on-site performance of facade elements because of the very static nature of the test. It is suggested that the pressurising of intermediate volumes within the facade system will lead to significantly higher local windflow velocities at the external drainage positions than would be encountered under static pressure test conditions. Accompanying these higher velocities, it is suggested that water-carry over and therefore potential leakage would be increased.

Another issue regarding test standards that is a potential problem includes the selection of test pressures at which air infiltration rates are normally measured and test pressures at which water penetration is tested. It is suggested there that further data correlating the variables within wind driven rain and concerning overall performance of human comfort air conditing systems under buildings having some air leakage through facades.

All of these variables must come together in a single or related set of testing facilities. An early facility was developed by Brown & Ballantyne [1] of CSIRO's Division of Building Research. The main timber test frame from their work is installed on this site. Their method is termed SIROWET, indicating CSIRO's wall Evaluation Technique. This form of testing is now routinely carried out only by my company under a co-operative research agreement with CSIRO - DBR. The two main characteristics of the Sirowet Method are that the pressure and suction forces are applied to the outside face of the facade sample and that the air pressure is fluctuated for the water tightness testing. These dynamic external forces are normally applied sinusoidally with a time period of two to four seconds. Evidence of, or international acceptance of, this sort of testing is now being found.

Under these test conditions the sample is held on a series of large frames. These are designed on a stiffness criterion so that relative displacement measurements can be made back to the facade sample. By its nature the main frame is static and the incorporation of dynamic sway or earthquake loading systems complicates the facade fixing systems enormously. The overall forces involved are fairly large, for example, on the original Sirowet sized rig the total box force of 12 tons for a 4 kP test is easily retained by the small beam system. However, the new test facility located at the Victorian Technology Centre with a larger frame system and 6 kP test capability is subjected to loadings of 35 tons. Naturally the restraining systems are significantly larger. Water supply and air systems are also designed with this pressure in mind.

Racking (sway) forces associated with small samples are found to be less than 1 ton for a typical sample, while for a larger sample recently tested the racking force was estimated to be up to 9 tons. It is possible to combine racking and pressurisation or racking, shrinkage and pressurisation in the large external rig at the Victorian Technology Centre. The addition of thermal performance testing using solar simulation lights precludes the use of the external pressure box. Thermal tests in combination with testing inplane can be easily accommodated, while the perpendicular loading of glazing systems is not so simple. In these cases point load systems have been devised to apply the same static force, element bending moments and element edge deflections as would be expected for uniformly loaded elements. These mechanically applied simulated wind loads are not varied dynamically.

The instrumentation and controls for these testing programs are relatively simple with calibrated measurement of air and water pressures, air and water flows, and structural displacements. For structural displacement systems a 20 channel data logging system is currently being used in conjunction with DBR to log displacements and calculate span deflection ratios.

Results of typical tests include water penetration observations, span deflection ratios of glazing panel and framing members, differential presurisation measurements within intermediate volumes and other observation of physical performance notably of gaskets and opening sash members. Of particular interest have been tests on transom extrusions where non symmetrical extrusion sections have led to a complex displacement under load of the element and when combined with glazing forces applied through resilient gaskets becomes mathematically undeterminable. In these cases physical full-scale acceptance tests are conducted. In-plane differential movements under pressurisation and sway conditions have also been measured, as is glazing gasket performance, under load, cold and hot.

From the growing experience with the design and manufacture of facade systems, it is reasonable to expect that most acceptance testing carried out will be uneventful. Design changes have been noted however for the smaller elements within facade systems including the sizing and location of drainage channels and ports, the sizing of glazing gaskets, and the sizing and location of internal flashing or intermediate water stops.

It will be interesting to note whether the increasing use of elastomeric sealants, either alone or in combination with mechanical fixings, will lead to more development information coming from facade performance testing. This may well be the case since full scale facade performance testing is becoming normal practice for occupied buildings over approximately 20 storeys, and for buildings where the occupiers are seeking long term economical performance. Similarly the extension of the simple static type tests to include other dynamic and thermal variables we believe is sure to come. All of these will increase the confidence of the supplier and of the client as to the performance of the facade in question.

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