17th Australasian Wind Engineering Society Workshop
Wellington, New Zealand
12-13 February 2015

Testing of Garage Doors and Large Access Doors

S.J. Ingham[1] and G. Stark[1]

[1]Cyclone Testing Station, College of Science, Technology and Engineering
James Cook University, Townville 4811, Australia

Abstract

The aim of this paper is to demonstrate the importance of understanding testing regimes and limitations for testing garage doors and large access doors for use in external walls of buildings. Updated standards have been introduced giving a more defined testing method. Users should have a clear understanding of the importance of ensuring that doors can resist pressure acting in both directions. Actions transmitted from the door to the supporting structure or building should also be understood when designing for garage doors and large access doors.

Introduction

Damage investigations following Tropical Cyclone Yasi showed that a large number of garage doors had been compromised, leading to increased internal pressures and, in some cases, catastrophic failures within the building envelope (Boughton et al., 2011). The generally poor performance of these types of doors has been highlighted in previous reports on wind damage in cyclonic and other high wind events. As a result, the Australian Standard for garage doors and large access doors (AS/NZS 4505) was revised. This welcomed revision to the standard introduced simulated wind load strength testing regimes for both non-cyclonic and cyclonic regions and gives a guide to typical wind pressure ratings derived from Australian Standard AS 4055-2006. This standard also includes provisions to evaluate actions transferred from the door to the supporting structure or building that should be considered by engineers when designing the buildings to contain these doors.

The most commonly tested garage doors and large access doors have been categorised into the following types:

- Continuous/rolling curtain doors
- Roller Shutters
- Sectional or Panel Doors

Each type of door responds slightly differently when subjected to wind loads, however the principles that govern the ability of all doors to resist wind loading remain the same. The doors may experience either nett inward or nett outward pressures in a severe wind event. If the door is on a windward wall, it may experience positive external pressure combined with negative internal pressure, resulting in a combined (or nett) pressure pushing the door inward. If the door is on a leeward or side wall, it may experience negative external pressure and positive internal pressure, resulting in a nett pressure sucking the door outward. Typically the maximum forces on the door are similar in magnitude in both directions and so it is important that doors are designed to resist these forces in both directions. One of the most common failure modes observed has been disengagement of the door from its tracks (Boughton et al., 2011).

As the span of the door increases, the forces that can be generated in the door, its connections and the surrounding structure also increase, so it is particularly important that the performance of wider doors is well understood. In addition, retro-fitting of doors onto existing structures can generate additional stress that may not have been accounted for in the original design, thereby leading to potential vulnerability of the structure.

In many instances the design of doors has been largely ignored or considered independently of the design of the surrounding structure. In reality, acceptable performance of a garage door or other large access door has a direct bearing on the vulnerability of the entire structure. Failure of a door can create a dominant opening and result in a significant change in internal pressure, with the potential to increase the net pressure on various parts of the structure and cladding, with the potential for catastrophic failure. An understanding of a door's ability to resist wind pressures in both directions, as well as an understanding of the forces transferred to the supporting structure should therefore be seen as a critically important part of the design of a building.

Simulated Wind Load Strength Testing in the Laboratory

General Requirements

Simulated wind load strength testing of garage doors and large access doors is conducted on either full scale specimens or on components or sub-assemblies. The full scale test specimens generally consist of a full width segment of the system to be tested, including the door material with any associated locking mechanism and the guides, with appropriate fixing arrangement to the supporting structure. This paper will focus mainly on the testing of rolling curtain doors and roller shutters in the positive pressure airbox test rig.

Full scale test specimens are tested in a horizontal orientation, whereas the real life installation will be in a vertical orientation. To compensate for this, the test pressures are adjusted to account for the self-weight of the test specimen. A full scale test specimen can be tested in either a "blow-in" or "blow-out" configuration, where the positive pressure is applied to either the inside or outside face of the door, to simulate the pressures acting on the door.

Test Pressures

When testing a door, the maximum test pressure that is achieved must be higher than the ultimate wind pressure rating for the door. A sampling factor is used to account for factors associated with variability of the material and the test procedure. If a target ultimate wind pressure rating is known prior to testing, the test pressure is the product of target wind pressure and the appropriate sampling factor (which will depend on the number of repeat tests, apart from other factors). Where there is no specific target for the ultimate wind pressure rating, the test pressure will be the highest applied pressure during testing, which is held for one minute, without the door failing. The ultimate wind pressure rating will then be the test pressure achieved, factored down by the relevant sampling factor.

Non-Cyclonic Region Testing

For non-cyclonic regions, each specimen is tested by subjecting it to an increasing uniform pressure that is applied to either the inside or outside face of the door. The pressure is raised and held at appropriate increments until failure of the door system occurs. The maximum pressure that can be sustained is recorded as the test pressure.

Cyclonic Region Testing

AS/NZS 4505 includes the following loading sequence for the testing of doors to be used in cyclonic regions.

Fatigue Loading Sequence	
Range	**Number of cycles**
0 to 0.4 P_t	800
0 to 0.5 P_t	200
0 to 0.65 P_t	20
0 to 1.0 P_t	1

Where P_t is the test pressure

Table 1. Fatigue loading sequence specified in Australian Standard AS/NZS 4505:2012 for doors to be used in cyclonic regions.

It is known that doors will not experience the same loading sequence as other building elements in cyclonic conditions. The numbers and range of load cycles included in AS/NZS 4505 are based on the previous standard and are only around 10% of the cycles proposed for other building components. While considered reasonable, it should be noted that this sequence has not been derived from a Rainflow (load cycle) analysis of appropriately spaced pressure tap data.

Acceptance Criteria for Tested Specimens

Clause 7.3.3 of Australian Standard AS/NZS 4505:2012 considers doors to have passed if, after testing, all of the following criteria have been satisfied:

- There is no dislodgement of door components.
- There is no damage to any of the connections between the frame and the supporting structure, or no damage between the door and the guide that would allow the door to become unlocked or open.
- There is no damage to any component, locking device or fastener that would allow the door to become unlocked or open.

The test specimen can show signs of distortion and permanent deformation and be non-serviceable and still be considered a successful outcome.

Forces Transferred to Support Structure and Transmission Angle

In order to resist pressures commonly experienced in cyclonic regions, the door design will usually require some form of locking mechanism to hold the curtain material within the guides when the door curtain flexes during exposure to wind pressures. Even in non-cyclonic areas, such a mechanism may be needed to achieve adequate door performance. The forces exerted onto the supporting structure when the door curtain flexes are represented in Figure 1.

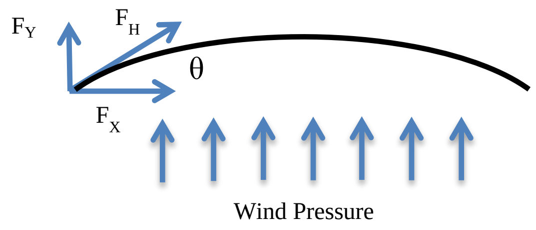

Figure 1. Sketch in plan view of the deformed door and the force exerted on the structural frame by the door (F_H). F_X is the in-plane component of F_H, F_Y is the out-of-plane component of F_H and θ is the transmission angle.

The shape of the door when it is flexed causes the locking mechanism to be in tension and because the transmission angle θ is usually small, the forces involved are often much larger than the forces acting parallel to the wind direction. There have been examples where doors have been designed with a locking mechanism; however the large in-plane forces have been too great for the design of the supporting structure, causing the door to disengage from the supporting structure at the connection of the guide, as shown in Figure 2.

Figure 2. Failure of a garage door with wind locks installed and still engaged in the guides, but has become detached from the support structure (Boughton et al., 2011).

The amount of flex that a door system can tolerate is an important consideration in the design of the door and associated components, as well as affecting the forces that must be resisted by the surrounding structure. The amount of flex is largely a function of the float between the door curtain and the guides. If the door has the ability to flex more, then the transmitted forces (particularly those in the plane of the surrounding wall) can be reduced dramatically. However, increasing the ability for the door to flex results in a higher transmission angle between the curtain and the guide and this can result in the locking mechanism disengaging from the guide. A sequence of increasing transmission angles causing a roller shutter slat to disengage from the guide is shown in Figure 3.

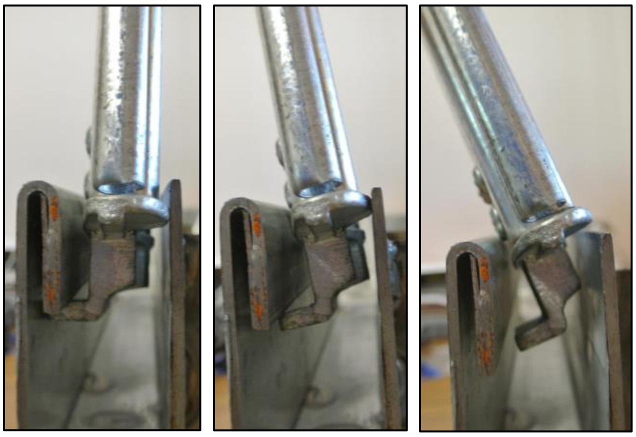

Figure 3. Sequence showing how increasing the transmission angle between a roller shutter slat and the guide can result in the slat disengaging from the guide.

The door designer must keep the transmission angle low enough so that the locking mechanism remains engaged within the guide, while allowing some flex in the door system so that the forces transferred to the supporting structure and the building due to both inward and outward pressures are as low as possible.

Limitations to Laboratory Testing

As stated earlier, with the increasing spans of doors the associated forces on the door system and the surrounding structure are increased. In order to test doors with spans above 5m, the Cyclone Testing Station had to design and fabricate robust ends that can be used in the airbox test rig. These ends are significantly thicker than previously utilised equipment and have an increased number of tie-down locations as a means of shedding the load exerted from the doors during testing. A sketch of the new airbox ends is shown in Figure 4.

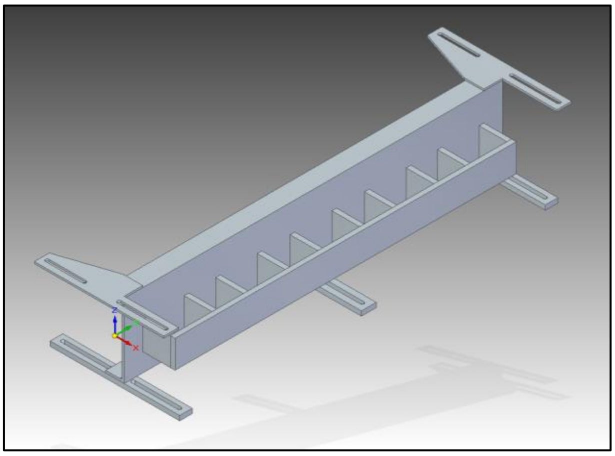

Figure 4. Sketch of the airbox test rig ends that has been developed specifically for the testing of garage doors to account for large in-plane loads as increasing spans are tested.

The airbox approach is currently believed to be the most reliable method of evaluating door performance. The Cyclone Testing Station has considered the requirements for a dedicated test rig for full scale door specimens of varying widths, to determine if fabricating such a test rig is feasible. This would be largely dependent upon the needs of the door manufacturing industry.

The current test method allows for the use of a full width but not full height section of a door system. In reality, a door system may include a drum at the top and some form of stiffener and weather seal at the bottom. It is assumed that these design elements will not have a significant influence on door performance. Their influence could be further investigated if there was industry interest in a test rig for complete door systems.

During testing, a uniform pressure is applied to the entire face of the door, whereas in a real wind event there may be localised pressure zones acting on the face of the door, especially for wider doors. It could be argued that this makes the proposed approach to testing slightly conservative, but it is considered reasonable as it simplifies the test method. It is also possible that if more localised pressures were applied to the door, any unequal loading could adversely affect capacity or engagement.

Windborne Debris Impact Testing in the Laboratory

General Requirements

For a door to claim a windborne debris impact rating it must resist a standard projectile in accordance with the Australian Standard AS/NZS 1170.2. This rating is only required for specific building types and locations. As part of the test, the door system must resist the projectile at a minimum of three locations on a full scale test specimen, including the centre of the door, the centre of a supported edge within 300mm of the edge and in a corner of the door.

Acceptance Criteria for Tested Specimens

AS/NZS 4505:2012 stipulates that the door shall have passed if there is no penetration of the door or no detachment of the door is observed. These criteria seem straightforward but may warrant further clarification, or a review of whether other acceptance criteria may be adequate in specific circumstances. The term “detachment” could be as conservative as “no single locking mechanism (or part thereof) can become detached from the door or guide” or as relaxed as “the whole door does not become detached from the guides” (suggesting that a locking mechanism or part thereof can be disengaged from the guide and the door still has passed).

The intent of a windborne debris test in AS/NZS 4505:2012 is to support life safety and to reduce the potential for projectiles to enter the building. On that basis, it could be argued that the door in Figure 5 could be considered to have done its job and should be considered a pass, even though there is some local disengagement of the locking mechanism/s. Figure 6, on the other hand, has resulted in a significant opening which, while it may have arrested the projectile, could lead to other projectiles of the same nature passing through and might therefore be classified as a failure.

It is proposed that further discussion may be needed around wind borne debris acceptance criteria, which may also be dependant upon the building application. For example, cyclone shelters may warrant a more stringent set of acceptance criteria than houses or sheds.

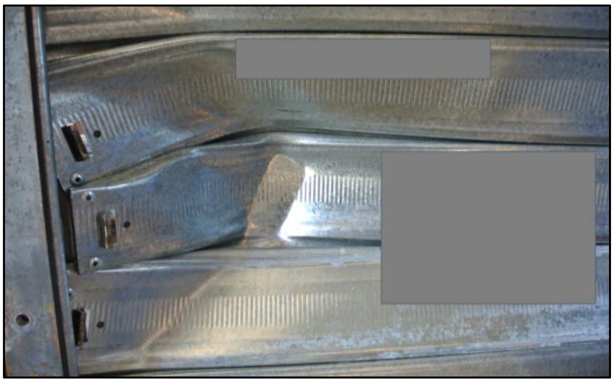

Figure 5. Example of impact location targeted adjacent to supported edge on roller shutter with locking mechanisms at each slat.

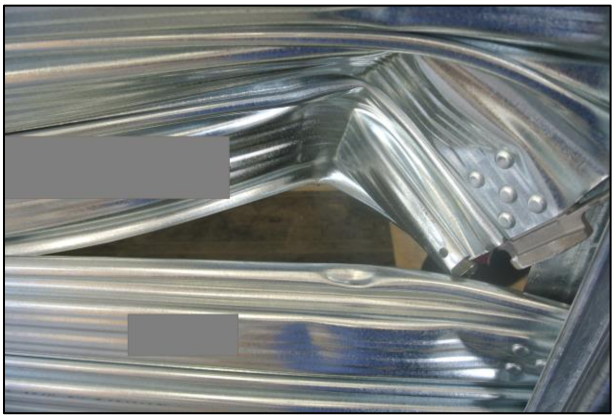

Figure 6. Example of impact location targeted adjacent to supported edge on roller shutter with locking mechanisms at every second slat where slats have split away from adjacent slat creating a large opening.

Discussion

It is well known that there have been many cases where inadequate consideration has been given to the interaction of garage doors and the surrounding structure in the design of houses and other similar scale buildings, such as sheds. Damage investigations have consistently shown unacceptable levels of door failure in both cyclonic and non-cyclonic areas. In many cases this has also led to more extensive damage to other parts of the structure or cladding.

The introduction of AS/NZS 4505:2012 and its adoption into building regulations has helped to address this issue in cyclonic areas, by making it mandatory that door performance is properly evaluated. Unfortunately the design provisions of AS/NZS 4505:2012 have not been adopted into regulation for non-cyclonic areas, even though there is a greater potential for catastrophic damage from poor door performance there. Failure of a door can lead to internal pressures that exceed those normally considered in design, as the building is normally assumed to remain intact. To avoid the potential for catastrophic failure, it is recommended that designers ensure that doors intended for buildings in non-cyclonic areas also adopt the practices in AS/NZS 4505:2012, as is the case in cyclonic areas.

Recommendations

It is recommended that where a building includes a garage door or other large access door in the building envelope:

- That the door is designed in accordance with AS/NZS 4505:2012, for any location in Australia.
- That the forces that might be transmitted from the door into the structure in a wind event are adequately considered in the design of the surrounding structure and in the connection of the door system to the surrounding structure.
- That adequate detailing is available of the connection between the door and the surrounding structure.

It is also recommended that further consideration is given to acceptance criteria for wind-borne debris testing of garage doors and other large access doors.

Conclusion

This paper has outlined the importance of proper evaluation of the performance of garage doors and other large access doors. It is essential that door performance is assessed as an integral part of the performance of the entire building structure, as any door failure has implications for other parts of the structure. Damage investigations have consistently shown unacceptable door performance.

The publication of AS/NZS 4505:2012 and its adoption into regulation has now largely addressed this issue for cyclonic areas but there is still the potential for catastrophic failure due to over-stressing of the structure or cladding in non-cyclonic areas, where AS/NZS 4505:2012 has not been adopted into regulation.

It has been shown that the proper evaluation of doors to resist wind loads involves the assessment of performance in both the inward and outward directions, as the magnitude of forces in both directions can be similar.

Acknowledgments

The authors acknowledge the support of David Henderson in the preparation of this paper.

References

Australian/New Zealand Standards 4505:2012 Garage doors and other large access doors.

Boughton G, Henderson D, Ginger J, Holmes J, Walker G, Leitch C, Somerville L, Frye U, Jayasinghe N, Kim P (2011) Technical Report No. 57 Tropical Cyclone Yasi Structural damage to buildings.