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Wind-Induced Door Operability – The Case for Establishing Design Criteria

Sarah Stenabaugh [1], Albert Brooks [2], Jon Galsworthy [3]

[1] *Cermak Peterka Petersen Wind Engineering Consultants, Mississauga, Canada, sstenabaugh@cppwind.com*
[2] *Cermak Peterka Petersen Wind Engineering Consultants, Mississauga, Canada, abrooks@cppwind.com*
[3] *Cermak Peterka Petersen Wind Engineering Consultants, Mississauga, Canada, jgalsworthy@cppwind.com*

SUMMARY: (10 pt)
In adverse conditions, wind forces on exterior doors can cause operability issues. Excessive opening wind forces can make doors challenging to close and even hover open. Alternatively, excessive closing forces can cause doors to slam shut and be difficult to open when exiting the building. The lack of an established criterion makes it difficult to assess the expected performance of exterior doors.

Keywords: wind-induced forces, door operability, accessibility, urban environment

1. INTRODUCTION

In adverse conditions, wind forces on exterior doors can cause operability issues. Wind tunnel pressure coefficients can be combined with a wind climate model and door parameters to evaluate opening and closing forces for a range or mean recurrence intervals or probabilities of exceedance. Excessive opening wind forces can make doors challenging to close and even hover open. Alternatively, excessive closing forces can cause doors to slam shut and be difficult to open when exiting the building. The intended use of the door and desired reliability need to be considered in the analysis as expectations may differ, for instance primary entrance/egress doors should be evaluated differently from maintenance doors to an area inaccessible to tenants. Mitigation measures need to be evaluated before implementation as some options designed to improve the closing performance may in turn increase the opening forces and thus mitigation options must be balanced. Most guidelines on door operability or performance focus on accessibility and fire protection. The lack of an established criterion makes it difficult to assess the expected performance of exterior doors and plan for mitigation measures where applicable.

2. CRITERION FROM LITERATURE

The majority of door operability literature is focused on accessibility or fire protection and may not be directly applicable to considering the effect of wind on exterior door operability. The Americans with Disabilities Act (ADA, 1990) states that interior doors should require no more than 5 lbf to open, while an opening force for exterior doors is not specified. Due to the lack of established standards, this is sometimes referenced and proposed as a standard. However, this is not likely applicable to wind as the 5 lbf criterion should be considered static as there is no wind force on an interior door. This criterion is in place to ensure that interior doors can be set in motion by a small force. Alternatively, exterior doors form part of the building envelope and should require more force to open. In the absence of a specified pressure, tabulated strength values for various age ranges can be considered (see table 1). The minimum strength values for older adults could be considered as a criterion where complaints may begin. In emergency situations, 21 lbf is sometimes used as the point at which traffic is slowed to a significant degree.

For a traditional swing door, a probability of roughly two hours per year (0.022%) may be recommended for a main entrance where reliable function is typically important, though the exact probability is debatable. This is in line with safety exceedance calculations in pedestrian wind studies (Lawson, 1990). For secondary doors, those that are not as commonly used or access space that is used during amenable weather conditions, probabilities of one hour per week are proposed.

Table 1. Functional strength values for door operability (Lbf). One hand opening without jerking motion (forces would be greater for jerking motion). Adapted from Klote and Milke, (2002).

Age Group (Years)	Function (Direction)	Functional Strength – Male | Female in Lbf		
		Mean	Max	Min
5-6	Push	20 | 16	35 | 28	7 | 10
	Pull	27 | 19	41 | 32	18 | 11
60-75	Push	53 | 36	121 | 69	21 | 19
	Pull	69 | 45	177 | 91	23 | 22

2. MECHANISMS

For a side-swinging door, assuming force is applied at a knob or handle close to the jamb, and neglecting hinge friction, an estimate of opening force may be obtained by multiplying the pressure by the door area divided by two and adding the door closer force if there is a closing mechanism. For example, a wind-induced pressure of 1 psf on a door with an area of 18 ft^2 gives a momentary opening force of 9 pound-force solely due to the wind.

The total pressure across a door is a combination of the external wind pressure (that can act toward or away from the exterior surface) and the internal pressure within the building (that can act toward or away from the interior surface). The interior pressure is influenced by the wind pressure at façade openings, by the HVAC system, and stack effect when there is potential infiltration due to air leakage. In assessing door operability, the internal pressure of a lobby or volume behind an exterior door was calculated considering solely infiltration due to air leakage considering a range of fluctuation from -0.05 inches to +0.05 inches of water, common for building pressurization (ASHRAE, 2015). No matter the swinging direction, people will have to help close the door by pushing or pulling on it when the exterior wind and internal pressurization overcome the door closer force, otherwise the door will remain open until the wind dies down.

Figure 1 shows the sign convention for the forces on a door. The total force at the handle (F_{applied}) results from the combination of the external wind force (F_{wind}), the internal room pressurization force (F_{interior}) and the door closer force ($F_{\text{door closer}}$). The door closer force is induced by a closing mechanism and may vary.

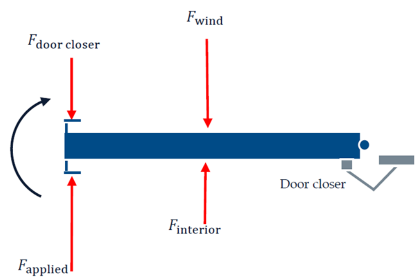

Figure 1. Example of figure

The closing mechanism can effectively be shifted or 'tuned' for each door by adjusting the door closer force. If, for example, an outward swinging door is acceptable for a positive wind force, but when negative wind forces are too high, the door closer force can be turned up to assure the door closes by itself or stays closed a larger percent of the time. Where applicable, a door closing force of more than 7 lbf is recommended to mitigate wind-induced door operability issues. Conversely, if the positive wind forces are problematic but the negative forces are quite mild, then the door closer force may be turned, typically within the range of 4 lbf to 14 lbf. A high closing force up to 14 lbf implies that the door will be more difficult to open all the time. The probability of exceedance (i.e., likelihood of door operability issues) will vary depending on the frequency and necessity of intended use.

3. ANALYSIS

External pressure coefficients measured in the wind tunnel can be combined with Weibull models of local wind climate and door design parameters can be used to evaluate the door opening and closing forces. The figures below show the door forces vs probability of exceeding the designed maximum door closing and opening force for a given internal pressure setting.

- The **black line** is the probability distribution of door closing forces, F_{close}.
- The **highlighted black line** behind the **black line** represent the variation in the curves based on the allowed range of the internal pressure setting (± 0.5"w.g. from neutral).
- The **blue line** is the probability distribution of door opening forces, F_{open}.
- The **highlighted blue line** behind the **blue line** represent the variation in the curves based on the allowed range of the internal pressure setting (± 0.5"w.g. neutral).
- The two vertical **red solid lines** indicate the designed maximum door opening and closing pressures
- Posted values indicate the probability that either F_{close} exceeds design maximum closing force or F_{open} exceeds the maximum opening force. The three values correspond to the minimum, maximum and stated internal pressure.
- The **red dotted line** indicates the exceedance threshold. If the **red solid lines** intersection with probability distribution lines lies below the exceedance threshold, then this implies that the probability of exceeding a particular door opening/closing criterion is within the suggested range.

On the left, the door does not meet the desired performance for a primary entrance as the closing forces exceed the threshold on a much more frequent basis. On the right, a vestibule with a pivot door was investigated as a mitigation strategy. The forces were reduced through the addition of a moment arm of the pivot door and implementing the vestibule reducing the wind forces. This also reduces the associated risk of exceedance. It is expected that by implementing pivot doors in a vestibule configuration will achieve the desired performance. Other mitigation options including tuning the door closers, sliding doors and revolving doors. Evaluating door operability prior to construction can identify potential issues and make mitigation easier to implement.

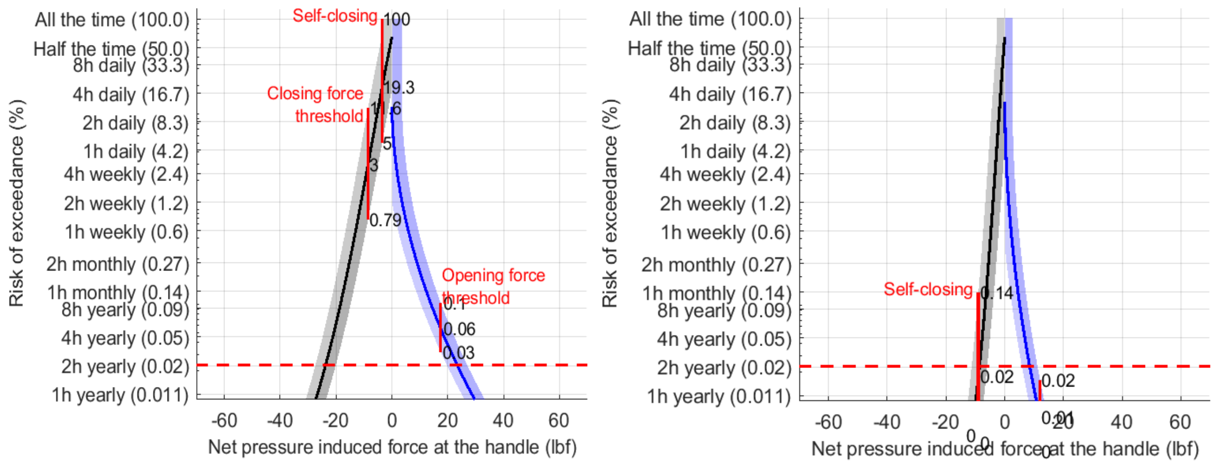

Figure 2. Example of figure.

7. CONCLUSIONS AND NEXT STEPS

Wind pressures can cause challenges that hinder door operability, either by making doors difficult to open (and then slamming these doors shut) or preventing the doors from fully closing or staying closed without a latch. Without an established force criteria or performance standards, it is difficult to assess the performance of exterior doors under wind forces. Forces and associated risk of exceedances are presented for discussion. Further development of door operability considerations are recommended.

ACKNOWLEDGEMENTS

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