5 Building Envelope Performance

Good structural system performance is critical to avoiding injury and minimizing damage to a building and its contents. It does not, however, ensure occupant or building protection. Good performance of the building envelope is also necessary. The envelope includes exterior doors, non-load bearing walls and wall coverings, roof coverings, windows, shutters, and skylights. Historically, poor building envelope performance is the leading cause of damage to buildings and their contents during hurricanes.

5.1 Doors

The BPAT observed a limited number of catastrophic door failures. However, in many cases where the doors were weak, the entire wall failed before the door assembly itself failed. Wind-driven water infiltration between the door and frame was a common problem. Most door assemblies observed did not have weatherstripping, and when it was present it provided limited resistance to rain driven by high winds.

Exterior door failure has two important effects. First, failure can cause a sudden increase in internal air pressure, which may lead to exterior wall, roof, interior partition, ceiling, or structural damage. Second, wind can drive water through the opening, causing damage to interior contents and finishes. Essentials to good door performance include: product testing to ensure that sufficient factored strength to resist design wind loads exists; suitable anchoring of the door frame to the building; and for glazed door openings, the use of laminated glass or shutters to protect against windborne missile damage as discussed in Section 5.4. Missiles are both natural and man-made. Natural missiles include tree limbs, and man-made missiles include items such as building debris, fence debris, refuse containers, and lawn furniture

5.1.1 Glass Doors

A variety of problems with glass doors were observed, including blow-out/blow-in of the door frame and glazing (Figure 5-1), door breakage and loss of glazing from its frame (Figure 5-2), and disengagement of sliding doors from their tracks. These problems were caused by over-pressurization or missile impact.

FIGURE 5-1 This sliding glass door and window assembly in a hotel room was 7' 2" high and 14' long. The head of the frame was attached with four pairs of #12 or #14 screws in plastic sleeves. The sleeves pulled out and the entire length of the frame was pushed inward, resulting in substantial glass breakage. This building was located on Isla Verde in San Juan.

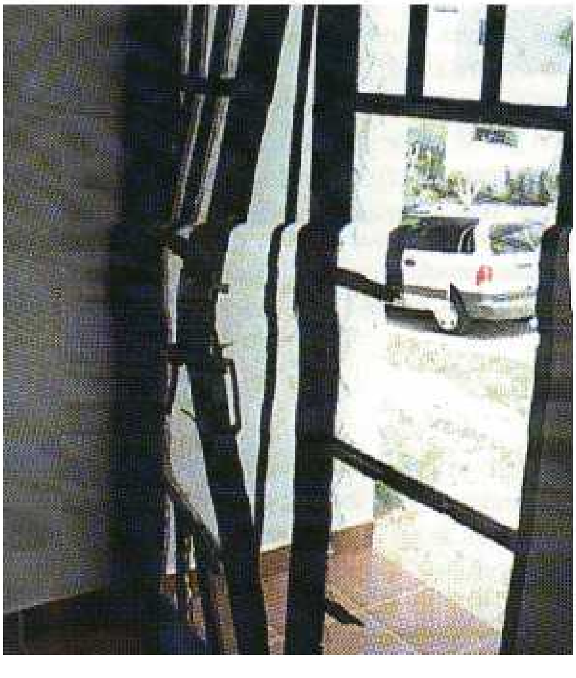

FIGURE 5-2 Missiles broke this wood/glass door and several adjacent window panes.

5.1.2 Personnel Doors

The BPAT observed few instances of door or door frame failure. However, Figure 5-3 illustrates a metal door that was blown out when the frame anchors pulled out. The door was blown out after the louvered window on the building failed, allowing an increase in internal air pressure.

FIGURE 5-3 A missile traveling right to left struck the window louver. The door frame was attached by fasteners into wooden plugs that had been set into holes drilled into concrete. Once the louver failed, the door frame failed.

5.1.3 Security Grilles, Rolling (Overhead) and Garage Doors

Rolling doors and garage doors frequently perform poorly during high winds. In several instances observed in Puerto Rico, large openings were protected with security grilles, rather than rolling or garage doors (Figure 5-4). Very little load is applied to security grilles during high winds because of the large amount of net free open area. As a result, security grilles performed very well. Depending on the grilles, security grilles may stop large airborne missiles. It is important to note that areas with security grilles must be designed as open structures (without a building envelope). This will normally increase wind pressures acting on the structural frame of the building, as well as components and cladding.

FIGURE 5-4 The security grille on this fire station offers greater wind performance reliability than a solid door because very little air pressure is applied to it during high winds. This fire station is located on the island of Culebra.

5.2 Non-Load Bearing Walls, Wall Coverings, and Soffits

Non-load bearing walls and wall coverings generally performed well during Hurricane Georges. The BPAT did observe several types of problems however.

Non-load bearing walls (or door or window assemblies) that fail can cause extensive interior damage because of the development of high internal air pressure and/or wind-driven water infiltration. Figure 5-5 shows the damage that occurred when a portion of the exterior envelope failed. Composite wall panels and their connections, exterior insulation finish system (EIFS), and other types of exterior wall coverings should be tested to ensure the components have suitable strength.

FIGURE 5-5 The gypsum wallboard was blown off this interior partition after the exterior non-load bearing wall was blown away, allowing an uncontrolled, rapid increase in internal air pressure.

5.2.1 Non-Load Bearing Walls and Soffits

The BPAT observed three types of non-load bearing walls: metal panels over light-gauge steel framing, EIFS, and composite wall panels. Problems resulting in water infiltration were observed with each type and are discussed below.

Metal panels over light-gauge steel framing were the most common non-load bearing walls observed. The BPAT noted the loss of metal panels due to an insufficient number of panel fasteners. In one instance, metal panels at the gable end of a building were damaged when a rooftop water tank blew off and struck the side of the building (Figure 5-6).

FIGURE 5-6 Rain entered this hospital on Culebra after a water tank struck the metal wall panels.

A problem with EIFS at an ocean front high-rise was also observed. It appeared that the exterior wall stud tracks were insufficiently attached (Figure 5-7). Failure of the wall system resulted in substantial interior damage.

Buildings clad in EIFS often provide a false sense of security since they appear to be clad in concrete, but may or may not be backed by concrete or masonry. When EIFS is used as a covering over concrete, as shown in Figure 5-11, this is not an issue. However, when EIFS is not applied over concrete, as shown in Figure 5-7, the building could be mistakenly construed as offering a safe area of refuge from high winds. EIFS applied on a steel or wood-frame building as the exterior wall is not an as reliable building envelope as a concrete wall in resisting high winds and missiles. An EIFS not backed by concrete or masonry may be identified by a hollow sound when a person bangs on the panel or by a deflection when a person pushes the panel.

The BPAT observed two buildings with composite wall panels composed of thin metal sheets bonded to a cardboard honeycomb core. The panels were attached with screws from the metal framing into the interior metal skin. On one building, the panels were also used as the soffit. In both buildings, the panels blew off because of insufficient strength of the connections between the composite panels and the structural frame of the building (Figure 5-8).

FIGURE 5-7 This EIFS wall system was composed of synthetic stucco over 1-in thick expanded polystyrene insulation (EPS) over a layer of exterior gypsum board over 6-in deep steel studs, with a layer of gypsum board on the interior side of the studs. Fiberglass batt insulation was installed within the stud cavity. There were several different planes of failure. Insufficiently attached stud tracks appeared to have been the initial failure point. This building was located on Isla Verde.

FIGURE 5-8 Several composite panels blew off from the fascia and soffit of this building at the airport on Isla Grande. Although several screws were installed, the metal into which they were driven was too thin to develop sufficient blow-off resistance to withstand the wind loads.

5.2.2 Wall Coverings

The BPAT observed four types of wall covering problems:

- Loss of stucco applied over cast-in-place concrete.
- Problems with EIFS coverings.
- Ceramic tiles that were blown off.
- Problems caused by wind scour.

None of these problems resulted in water infiltration; however, with the exception of wind scour, failure of the wall covering resulted in additional debris being added into the wind field.

The loss of stucco applied over cast-in-place concrete was the most common problem observed with wall coverings (Figure 5-9). Rather than cast concrete with a relatively flat and smooth surface, traditional practice in Puerto Rico has been to cast the concrete rough, as shown in Figure 5-10, and apply a stucco finish.

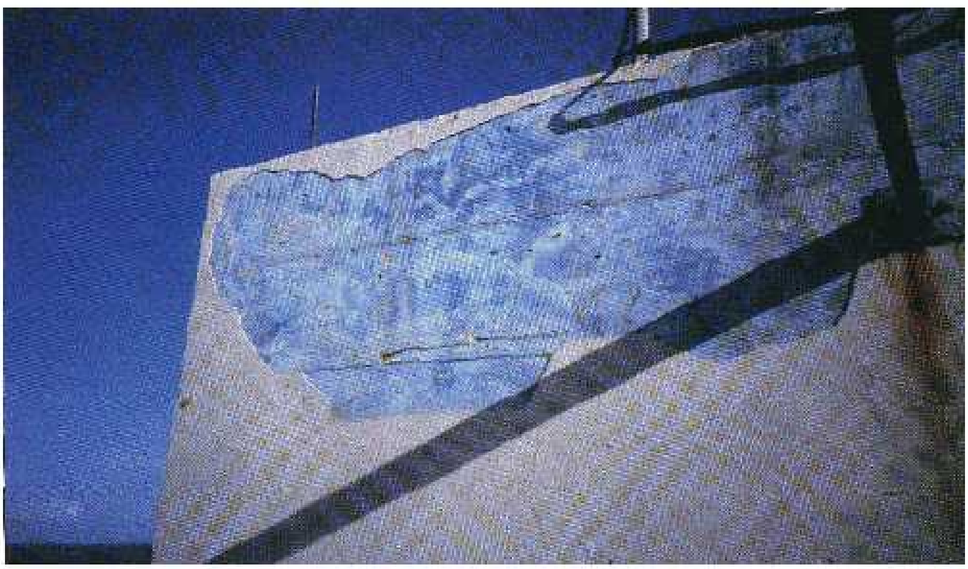

FIGURE 5-9 The stucco was blown off the corner area of this wall, where the suction pressures were high. Note the rough texture of the concrete.