



American Association  
for Wind Engineering

# THE WIND ENGINEER

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Wind effects on Portable Toilets  
(see cover story)



Hurricane Katrina destroys cladding on  
buildings (see cover story)

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## Performance of Glass/ Cladding of High-Rise Buildings in Hurricane Katrina

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### Introduction

On August 29, 2005, Hurricane Katrina made landfall on the coast of Louisiana reported as a Category 4 hurricane. The center of the storm passed approximately 30 miles to the east of New Orleans, Louisiana around 9 AM CDT. In an effort to understand and improve the performance of glass and cladding on tall buildings in urban areas to extreme winds associated with hurricanes, the NatHaz Modeling Laboratory at the University of Notre Dame conducted a field reconnaissance study to assess the damage to the glass and cladding of a number of tall buildings in the Central Business District of New Orleans and surrounding areas. An additional focus of this study was to investigate the effectiveness of vertical evacua-

tion – allowing citizens to escape the flood waters of hurricanes by seeking shelter at higher elevations in engineered structures.

### Research Team and Objectives

The Research Team from the NatHaz Modeling Laboratory at the University of Notre Dame included Dr. Ahsan Kareem and Rachel Bashor. Dr. Elizabeth English from Louisiana State University joined the team during its visits to New Orleans to conduct field surveys and interviews of building owners, managers and maintenance personnel as well as residents and visitors who remained in New Orleans during the hurricane. The objectives of the study included: correlating wind induced damage to observed winds; examining the performance of glass and cladding on tall buildings; determining the causes of poor performance; assessing the performance of the buildings for vertical evacuation and the effectiveness of this mode of evacuation in urban areas struck by hurricanes.

### Description of Hurricane Winds

Determining the actual wind speed in New Orleans during the storm passage is

*(Continued on page 2)*

## Stability of Portable Toilets During Wind

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### 1. INTRODUCTION

Single cubicle portable toilets are a feature of many recreational events such as sporting fixtures and outdoor concerts. They are, however, susceptible to being blown over during strong wind events causing distress, danger and fouling to occupants and some bystanders (although many bystanders do gain a deal of amusement). Figure 1 illustrates an overturned cubicle.

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somewhat challenging due to the lack of available data. The Florida Coastal Monitoring Program (FCMP) at the University of Florida collected wind data at several locations during the passage of the hurricane through the use of deployable monitoring systems. They estimated the maximum 3-second wind speed for the region south of New Orleans to be 102 mph (46 m/s). Measurements by Texas Tech University for this region estimated the maximum 3-second wind speed to be 82 mph (36 m/s). These measurements, however, were taken north of Lake Pontchartrain and, therefore, do not necessarily represent the wind conditions in the Central Business District of New Orleans. In addition to these sources, information derived from the NOAA Hurricane Research Division of the Atlantic Oceanographic and Meteorological Laboratory places the maximum 3-second wind speed in the New Orleans area about 90 mph (40 m/s). All of the estimates are well below the ANSI A58-1 (1982) design wind of 118 mph and the ASCE 7-05 (2005) design wind of 130 mph for New Orleans, both measured in 3-second gust.

These sources also indicated that the wind was from the northeast for the first part of the storm and then shifted to the west/northwest. These wind directions match the wind field generated by a storm following the path of Katrina. Accordingly, the damage to the buildings was expected to be concentrated on the north face and the northeast and northwest edges of the buildings. Field observations confirmed that damage to buildings occurred mostly on the north and west faces, as expected given the prevailing wind direction of the storm.

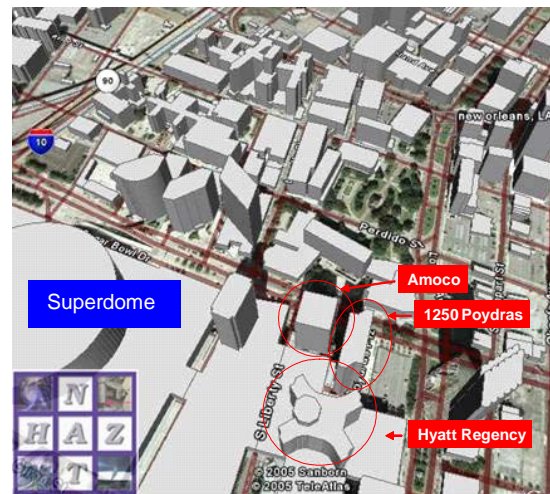
### Observation of Building Damage

The damage to the glass and cladding of tall buildings varied significantly throughout the Central Business District. Many buildings only suffered minor damage - perhaps a few broken windows - whereas several buildings suffered heavy damage to the glass and cladding, especially to the north and west faces. This damage pattern correlated with the prevailing wind directions as the hurricane passed by the city. In New Orleans, the research team documented the condition of the exterior faces of twenty high-rise buildings in the area and toured the damaged areas and rooftops of several buildings including the Hyatt Regency Hotel, the Amoco Building, and the 1250 Poydras Building. These buildings, located near the Superdome (See Figures 1 and 2), sustained significant glass and cladding damage as well as damage to their roofs and rooftop structures and appurtenances.

Buildings in which no apparent damage was observed included: One Shell Square, New Orleans Marriott, One Canal Place, and National American Bank. Buildings in which some damage was observed included: Bank One Center, Crescent City Residences, Energy Center, LL&E

Tower, Sheraton New Orleans, 1010 Common, World Trade Center New Orleans, 225 Baronne Street, Entergy Tower, Hibernia Bank Building, Hilton New Orleans Riverside, Loews Hotel, and 1515 Poydras. Buildings that sustained heavy damage included: Texaco Center, Dominion Tower, Hyatt Regency New Orleans, 1250 Poydras Plaza, and Amoco Building. A summary of damage to a selected suite of buildings, identified in Figure 1, is now provided.

**Figure 1** Location of select buildings investigated by the research team



**Figure 2** Damage to Hyatt Regency Hotel and Amoco Building as seen from the roof of City Hall



### Hyatt Regency Hotel

The Hyatt Regency Hotel, located near the Superdome, suffered significant glass and cladding damage, especially on the north face of the hotel (See Figure 3). Nearly every window on the north face of the hotel was broken as it experienced not only high winds during the storm,

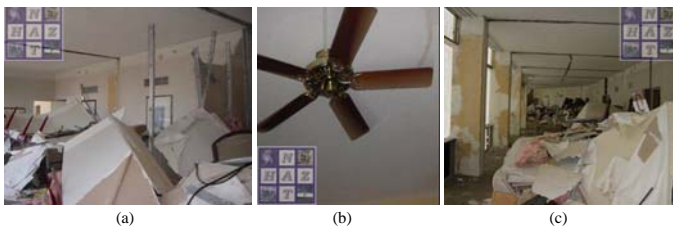
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but also wind with debris accelerating through the canyon formed by the upwind buildings. Some of the falling glass during its downwards trajectory damaged glass at lower levels, initiating a domino effect causing more damage to windows below. Along with the glass damage, the building roof was also significantly damaged. Large portions of the roofing material were torn up and missing. There was evidence of abrasions on certain faces of the various roof structures, including the round center tower, and evidence of façade elements ripped off at several corners. The debris found on the property included gravel, fasteners, and large pieces of glass likely from upwind buildings. In addition, the inside of the hotel was heavily damaged with walls torn down and room contents scattered everywhere (See Figure 4).

**Figure 3** East and north faces of Hyatt Regency Hotel.



**Figure 4** Inside view of the top, north floor of the Hyatt Hotel: (a) East, (b) Ceiling fan pushed



**Amoco Building**

The Amoco Building sustained a large amount of glass and cladding damage as well as damage to the rooftop penthouse (See Figures 2 and 5). A large percentage of the windows were broken and boarded up with plywood. Of the windows that were not covered, many of them showed pitting where a missile had impacted the window. The roof of the Amoco Building originally had a layer of loose pea gravel several inches thick that covered the built-up roof surface completely. The wind blew off much of the gravel, piling some up along the south parapet and exposing sections of tar. The penthouse

structures on the roof suffered considerable damage, as their large beams had been blown off supports and their connections torn out of the cinder block wall. The four columns that supported the penthouse had all been pushed away from the supports - one was missing from the rooftop. It appeared that the bolts that held the steel columns to the concrete bases had been sheared off. Most of the penthouse cladding had been blown off; some large components were found on an adjoining low-rise building south of the Amoco Building.

**Figure 5** Rooftop penthouse on Amoco Building was nearly destroyed



**1250 Poydras**

The building known as 1250 Poydras also suffered damage to the glass and cladding, especially on the north face (See Figure 6). The old gravel roof of this building had been replaced two years ago; however, the roofing membrane had bubbled up in the northeast corner. Additionally, a roof drain had been pulled up. The penthouse was in good condition with exception of the loss of one

**Figure 6** West face of 1250 Poydras.



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large door. Overall the roof of 1250 Poydras performed satisfactorily. However, some debris from different sources was found.

### **Possible Scenarios**

The gathered evidence suggests that the majority of the damage was likely caused by wind-borne debris. The wind-borne debris included pea gravel, rooftop appurtenances, siding, and penthouse structures which became airborne and caused significant damage to the glass and cladding of the surrounding buildings. The finding of gravel, glass shards, pitted glass and other debris on or inside buildings supports this scenario. The breakage patterns to the spandrel glass supports the missile impact theory due to the appearance of impact-induced pitting with cracks that spread from the impact point (See Figure 7 and 8). Given the orientation of the buildings in relation to the damaged areas and the availability of wind-borne debris from upwind buildings, it is conjectured that the main debris source was the gravel roofs and appurtenances of upwind buildings.

**Figure 7** Broken window on north face of Hyatt Regency Hotel, likely caused by missile impact.



**Figure 8** Missile impact pitting on Amoco Building.



Another cause of damage can be contributed to poor connections and lack of redundancy. This applies mostly to roof top structures. Nearly all of the damaged penthouses had missing siding at the corners associated with high levels of suction. For example, the round tower on the roof of the Hyatt was missing siding on the north face. Also, miscellaneous fasteners were found on the roof of the Hyatt among the debris. Another example of inadequate connections and bracings was the penthouse on the Amoco Building.

### **Vertical Evacuation**

The team assessed the feasibility of vertical evacuation during a hurricane with building managers and occupants. During the passage of the storm, about 3,000 people were in the Hyatt Regency Hotel. The majority of which were local residents with the rest being tourists and employees. Despite the considerable damage that the building experienced, the hotel was able to feed, provide water, and generally keep order in the ballrooms. The staff also maintained communications with the guests, which was important in providing a sense of security and awareness of the building's condition. The biggest problem was the loss of air conditioning.

In another area of town, about 1,000 guests stayed in the Sheraton Hotel, which suffered minimal glass damage. Most of the guests were tourists who were not able to get out prior to the storm. As in the Hyatt Hotel, everyone stayed in the ballrooms throughout the storm. Prior to the visits, an interview was conducted by the research team with a faculty member from Notre Dame who was stranded at the Sheraton Hotel during the hurricane. Concerning refuge in a high-rise building, the faculty member felt safe under the supervision of the management at the hotel. The key factors that ensured a sense of security included the management informing the guests how to prepare and maintaining communication with the guests during and after the hurricane. Overall the hotels that provided shelter were able to keep occupants safe, although the degree of comfort varied.

In urban zones, interior regions of high-rise buildings can serve as a storm refuge to escape from storm surge and wind effects. Therefore, cities with limited escape routes and lack of transportation may consider vertically evacuating some residents provided selection of buildings, their availability, and the integrity of their structural systems and cladding have been pre-evaluated.

### **Concluding Remarks**

In an effort to understand and improve the performance of glass and cladding on tall buildings subjected to extreme winds associated with hurricanes, the research team conducted a field reconnaissance study to assess the damage to the glass and cladding of a number of tall buildings in New Orleans in the wake of Hurricane Katrina. The

team found considerable evidence that wind-borne debris from rooftops attributed to the glass and cladding damage of buildings. In several cases, vertical evacuation was effective in providing a safe refuge from hurricane flood waters despite the significant glass and cladding damage sustained. A detailed report is forthcoming.

Commonly, in extreme wind events, an overall lack of wind resistant provisions is responsible for most structural damage, including glass and cladding, rather than simply the severity of the storm. This conclusion was previously noted during Hurricane Celia in Corpus Christi, Texas, Hurricane Alicia in Houston, Texas, Hurricane Andrew in South Florida, and Typhoon York in Hong Kong. Cladding damage as experienced during Hurricane Katrina is not only costly but also threatens lives, exposes building interiors to costly damage, and puts buildings out of service for extended periods of time thus seriously impacting the community's day-to-day infrastructure and economy. As long as the availability of wind-borne debris exists in urban areas, it will continue to threaten the integrity of fragile building envelopes even in storms that experience winds under design level. Current levels of cladding damage and associated losses are unacceptable. In order to alleviate this situation, effort must be made to limit the roof top gravel, secure appurtenances and appendages, and ensure the integrity of penthouses and railings.

### ***Acknowledgements***

The support of the National Science Foundation through grant CMS 05-53060 is gratefully acknowledged. The authors sincerely thank Dr. Elizabeth English for her support, ranging from arranging travel and lodging logistics to making contacts in local buildings to providing hard hats. The team would like to acknowledge interaction with Tom Smith during the course of the study. Professors Kurt Gurley from the Florida Coastal Monitoring Program and John Schroeder of Texas Tech University are thanked for making wind data available to the authors. The views and findings presented herein are those of the authors and do not necessarily reflect those of the sponsors. The research team must also thank the building owners, management, and occupants - especially Randy Dawes - for their cooperation.

(Continued from page 1)



Figure 1: Overturned portable toilet

**2. PORTABLE TOILET SPECIFICATIONS**

The potential for a portable toilet to blow over is dependent on a number of factors including its dimensions, shape and total mass. The total mass is a combination of the empty mass of the toilet, the fullness of the tank, and the mass of any occupant. Typical dimensions, masses and capacities of portable toilets in several countries are given in Table 1.

Table 1: Portable toilet specifications

Country	Cubicle height (meters)	Cubicle breadth (meters)	Cubicle depth (meters)	Empty cubicle mass (kg)	Tank capacity (liters)
Australia / NZ	2.10	1.2	1.2	80	250
Hong Kong	2.36	1.12	1.12	70	300
UK	2.30	1.12-1.20	1.12-1.20	110	151
USA	2.26	1.12	1.12	77	246

Table 1 illustrates that the dimensions, if not the masses and capacities, of portable toilets are broadly similar worldwide. One architectural feature that does change significantly between manufacturers (e.g. Portaloo, Porta-john, Portalet etc.) is the roof shape, and this might be expected to have some influence on the wind loads and stability.

**3. WIND TUNNEL TESTS TO DETERMINE MOMENT COEFFICIENTS FOR TYPICAL PORTABLE TOILET DESIGNS**

A six-degree of freedom base balance was used for the 1:25 scale model testing of a typical portable toilet: 1.8 m high by 1 m square at the base. The model was tested with various roofs as shown in Figure 2. Along-wind base overturning moments were normalised according to Equation 1 and presented in Figure 3 for the various roof configurations.

$$C_M = \frac{M}{\frac{1}{2} \rho \bar{V}^2 b h^2}$$

Where M is the measured moment, b is the width normal to the wind direction, and h is the eaves height.

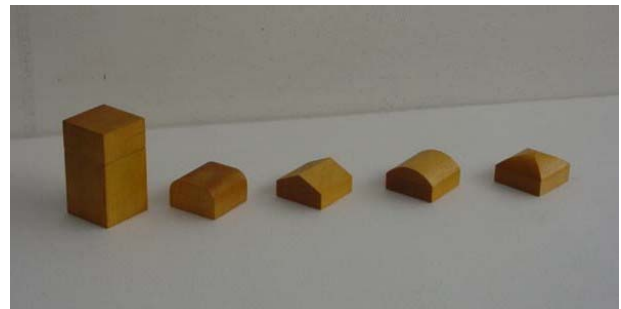


Figure 2: Model portable toilet with various roofs

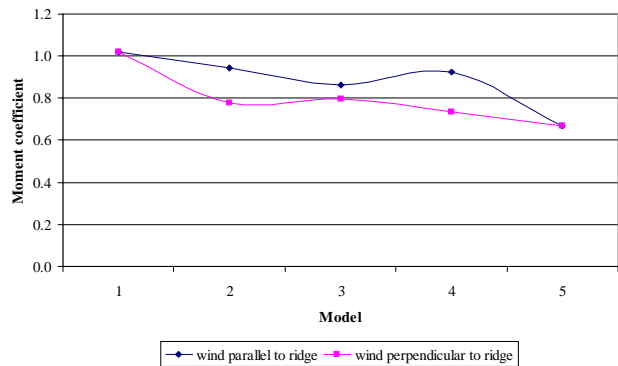


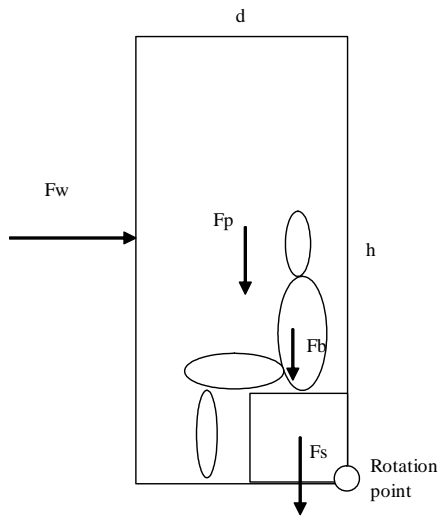
Figure 3: Moment coefficient for isolated portable toilet

It is unsurprising that as the degree of rounding increases the moment coefficient decreases.

**4. EXTRAPOLATION OF WIND TUNNEL RESULTS TO FULL-SCALE**

Combining the wind tunnel information with the free body diagram, Figure 3, and assuming quasi-steady conditions the gust wind speed required to destabilise the portaloo for an average person with an empty or full tank is given in Table 2.

(Continued from page 6)



**Fig 3:** Free body diagram of occupied portable toilet

**Table 2:** Wind speeds to cause overturning

Country	Occupant mass (kg)	Wind speed causing overturning ( $\text{ms}^{-1}$ )	
		Tank empty	Tank full
Australia / New Zealand	80	16.1	23.4
Hong Kong	70	13.9	22.0
UK	80	16.2	20.2
USA	95	15.9	22.7

It is evident that the wind speeds in Table 2 are well below serviceability wind speeds. They are, however, consistent with the authors' observations and some full-scale experimentation.

**5. OTHER FACTORS AFFECTING STABILITY**

The experiments and discussion above have assumed that the toilets are not secured to the ground. In fact, most manufacturers recommend some form of tethering or staking the toilets to the ground. In practice, the manufacturers spoken to recognise that this often does not happen. One manufacturer reported a previous attempt to increase the mass of the toilets to compensate for this, but this was rejected by operators as making the toilets more difficult to handle and manoeuvre. Changes in base dimension are not particularly practical because of the im-

plications for transportation, although extended bases are sometime bodged together on exposed sites.

Toilets are often used in groups as shown in Figure 4, and optimum spacing of the toilets may help significantly in increasing their wind performance. This is the subject of further wind tunnel testing.



**Figure 4:** Typical group of four portable toilets

**6. CONCLUDING REMARKS**

Wind tunnel tests have shown that portable toilets may be dangerous during even moderate wind. The importance of securing the toilet before use can not be overstated. Further work is being done to develop guidelines for safe toilet use. These will, however, not prevent deliberate misuse of toilets for purposes for which they were not intended (see Figure 5).



**Figure 5:** Intentionally overturned portable toilets

# Iawe International Association for Wind Engineering

Prot: Iawe\_86/06\_GS

Genoa, September 26, 2006

To the Presidents of Iawe Member Organisations

To Iawe Supporting Members

**Re: Iawe Awards 2007—Call for Candidatures**

Ladies and Gentlemen,

Following previous communications, the discussion occurred with the Member Organisations and the final resolution of the Iawe Executive Board during its last meeting in Yokohama at the venue of CWE 2006, it is my great pleasure and honour to inform you of the formal institution of **Iawe Awards** to be awarded every four years at the International Conferences on Wind Engineering, since the 12th ICWE, Cairns, 2007. The awards are devoted to Senior and Junior researches (up to four awards for each category) in the broad field of Wind Engineering, in accordance with attached rules.

Nominations may be made by Member Organizations or Individual members or Supporting Members of Iawe. Nominations should consist of no more than three A4 pages, including a summary *vitae* for the nominee.

**Nominations shall be sent to the Iawe Secretary General no later than January 31, 2007.**

I ask all you to spread this Call for Candidatures through your Organisations and their Individual Members, giving maximum diffusion to this initiative. In particular, considering the importance of this letter, I ask the Presidents or the Secretaries of the Member Organisations to acknowledge the receipt of this letter and to confirm that suitable actions will be carried out to guarantee its maximum diffusion.

Full information is also available on the home page of the Iawe web site: [www.iawe.org](http://www.iawe.org).

Looking forward to hearing from you, with best regards, I remain.

Giovanni Solari  
Iawe President

CC: Iawe Executive Board  
Secretariats of Iawe Member Organisations

# IAWE International Association for Wind Engineering

## RULES FOR IAWE AWARDS

### Document approved by the IAWE Executive Board on July 18, 2006

1. Up to four Senior Awards and four Junior Awards may be awarded at each International Conference on Wind Engineering (ICWE).
2. Nominations shall be called for by the Executive Board, at least six months before, and received at least three months before, each ICWE.
3. Nominations may be made by Member Organisations or Individual members or Supporting Members of the IAWE. Nominations should consist of no more than three A\$ pages including a summary *vitae* for the nominee.
4. No more than two Senior Awards and two Junior Awards to nominees from any one Region, may be made at each ICWE.
5. The recipients of the Awards shall be recommended to the Executive Board by an Awards Committee composed of five members appointed by the Executive Board. No more than two members of the Awards Committee (including the President) shall be members of the Executive Board. No more than two members of the Awards Committee shall belong to a same region. No member of the Awards Committee shall themselves be a nominee for an Award. If a member of the Awards Committee is nominated for an award, that member shall decline the nomination or shall be suitably replaced by the Executive Board.
6. The criteria for the Awards are as follows:
  - a) Senior Award. A record of outstanding achievement, normally within the previous ten-year period, in at least two out of: I) significant and original contribution to wind engineering research; ii) applications to wind engineering practice; iii) educational contributions in the field of wind engineering; iv) international community involvement.
  - b) Junior Award. A record of outstanding achievement, within the previous five-year period, in at least one of: I) significant and original contribution to wind engineering research; ii) applications to wind engineering practice; iii) educational contributions in the field of wind engineering. Nominees should be under the age of forty years at the start of the ICWE during which the Award is made.
7. Awards (but not nominations) may be made posthumously.
8. The nature and value of the Awards shall be determined on each occasion by the current Executive Board. The Executive Board shall be responsible for organizing the conferment of the Awards at the ICWE.

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- The advancement of science and practice of wind engineering.
- The solution of national wind engineering problems through transfer of new knowledge into practice.

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