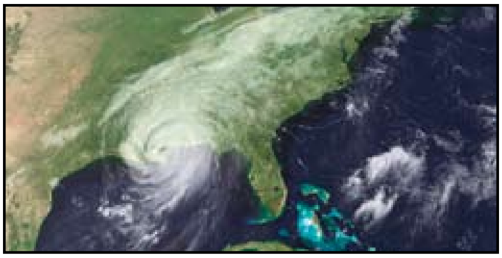
Severe Hurricanes – Facing the Challenge

PART 1 – Dual Concept of Strength and Safety

By Joe Kallaby, P.E., S.E.



Hurricane Katrina exploded into a Category 5 storm on August 28, 2005. It was one of the most powerful storms on record for the Atlantic Basin. Courtesy of GOES Project Science Office, NASA, Visible Earth.

In the wake of recent disasters, like Hurricane Katrina in 2005, the need to have a viable concept and procedure that can be used by practicing engineers to address severe hurricanes has become evident. In Part 1 of this series on Facing the Challenge, the author presents the Dual concept of Strength and Safety. A brief look at the significant elements of hurricanes is followed by description of how these elements impact structural design.

Part 2 will list several structural design scenarios impacted by hurricanes followed by a step-by-step procedure applying the dual concept.

In the March 2007 issue of STRUCTURE®, the article *Severe Events, Facing the Challenge* proposed that Reserve Capacity (RC) of structures be tailored to provide survivability thresholds to be set by standards or codes. It listed hurricanes and earthquakes as examples of recurring severe events that impact the life and safety of the public.

The author suggests that, at or near coastlines, new structures be designed, and existing ones be rated or upgraded, based on which hurricane category (CAT) they can survive, under impact of surge (and/or wave) and wind. Survival is measured by the RC of the structure prior to collapse. Literature search indicates a lack of a comprehensive procedure to address this need. This article presents such a procedure for wind and surge; waves are beyond this scope.

The Need

Hurricanes are here to stay, global warming aside. Their power to devastate or obliterate whatever is in their path hardly needs to be noted. New Orleans simply stands out among many previous catastrophes on the gulf and Florida coasts. Hundreds of miles of shoreline from Texas to Florida, and up through the Atlantic seaboard, are dotted with homes, buildings and assorted structures, inhabited by some 90 million people, that may be in the path of such severe hurricanes. The need for safer structures is self evident.

The Quest & Challenge

Designing structures for hurricanes has focused on their wind component, with 3 second gusts up to 150 mph (ASCE 7-05) along the Gulf and Atlantic seaboards. Including the much more powerful surge component is rare, if considered at all. Designing for the more powerful hurricanes (CAT 4 or 5) to include wind and surge using common practice (elastic design) is cost prohibitive, but more importantly, unjustified and unwarranted.

Can we design structures that can better protect their occupants?

It is understandable to assume that hardly anything can stand in the path of a severe hurricane. It was also understandable that in the early 1900s, designing a building almost half a mile in height would be unthinkable. The same can be said of producing oil and gas in waters almost two miles deep. The hurricane challenge is no different. This article presents a logical and viable concept and procedure to meet this challenge. Developed by the author, it was used on a gulf coast Command Center Building, with gratifying success.

The Dual Concept of Strength and Safety

The Dual Concept states that structures are to be:

a) Designed using standard (elastic) practice, referred to as the Design Strength Level (DSL) for hurricane intensity two levels less than the most intense hurricane expected in the area.

b) Investigated for their reserve strength capacity, referred to as the Reserve Strength Level (RSL), to satisfy the demands of the most intense hurricane expected in the area. RSL analysis is carried out using the Pushover procedure.

In lieu of the above, statutory requirements, as they are developed, would apply. The intent of RSL is to ensure that the structure will not collapse under either approach.

Table 1: Typical Surge Data

Category 3				Category 4				Catagory 5			
Direction	Speed	Tide	Surge	Direction	Speed	Tide	Surge	Direction	Speed	Tide	Surge
NW	15	12	12.4	NNW	05	12	19.7	NW	15	12	22.9
N	15	12	11.9	N	05	12	19.5	WNW	15	12	22.5
NNW	15	10	11.9	NE	05	12	19.5	NW	05	12	22.4
NW	10	12	11.9	NNE	05	12	19.4	NW	10	12	22.4
NW	15	10	11.9	NW	05	12	19.3	NNW	05	12	22.3
WNW	15	12	11.9	NNW	05	10	18.5	N	05	12	22.2

Note that:

1) Surge heights, in feet, should recognize the impact of topography and the presence of major structures, such as levees, in the path of the surge.
2) The first column is the direction to which the hurricane is heading.
3) The second column is the speed of the eye of the hurricane. It is either 5, 10 or 15 knots.
4) Third column is the tide level. 10 represents normal tide. 12 represents high tide.
5) Fourth column is the actual height of surge above Mean Sea Level (MSL), including tide.

The dual concept and the pushover procedure are discussed in detail in the March 2007 article mentioned above.

Partial Collapse of the Wendell Hanger, Lakefront Airport, New Orleans, LA ., Courtesy of Ed Huston, Smith & Huston, Inc., All Rights Reserved.

A Close Look At Hurricanes

Before we address hurricane effects on structures, it is important to understand what hurricanes are and how they are measured.

Hurricanes are violent tropical cyclones (counter-clockwise), with fast (=>74 mph) moving winds, massive waves and torrential rains. Upon reaching shore, the waves become unstable and break up into small ones, but they usually generate a surge, which is a large "wall" of water, 100 miles across or more, moving at high speed. Hurricane strength is commonly measured by the Saffir-Simpson scale, as five categories. It was developed in 1969 by Herbert Saffir, a civil engineer, and by Bob Simpson, director of the US National Hurricane Center at the time.

The U.S. National Hurricane Center classifies hurricanes of Category 3 and above as *major hurricanes*. The definition of sustained winds recommended by the World Meteorological Organization (WMO) and used by most weather agencies is that of a 10-minute average at a height of 10 meters (33 feet). The U.S. weather service defines sustained winds based on 1-minute average speed, also measured 10 meters (33 feet) above the surface. Central pressure values are approximate. Intensity of example hurricanes is from both the time of landfall and the maximum intensity.

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Partial Collapse of the building at 109 Tchoupitoulas, New Orleans, LA ., Courtesy of Ed Huston, Smith & Huston, Inc., All Rights Reserved.

What Hurricanes Can Do To Structures

Damage to near shore and shoreline structures may be caused by each of the following, or a combination thereof, as may apply:

Wind: It may act on the full height, or just the upper part of structures, depending on the presence of wave or surge. The forces with which it attacks the structure can generally be well evaluated.

Wave: A wave may travel far enough to impale shoreline structures. The resulting forces on structures are more complex. Wave height is usually controlled by hurricane intensity and seafloor topography, which, for mild shore gradients, results in a breaking wave.

Partial Collapse of the Million Air Hanger, Lakefront Airport, New Orleans, LA ., Courtesy of Ed Huston, Smith & Huston, Inc., All Rights Reserved.

Surge: Sea level rises as a storm intensifies. Reaching land, it rushes at high velocity impacting everything in its path.The forces it generates are akin to wind, in that they depend on contact area, velocity, and approach angle. Katrina delivered surge heights as much as 30 feet for miles inland.

Surge is rarely used in the design of structures on land. It has little significance offshore. Design data needed for surge include elevation above MSL or height, speed and direction. A typical set of data for CATs 3, 4 and 5 for a given site, defined by its latitude and longitude, is shown in *Table 1* (*see page 28*).

Inundation: Many areas may be subject to inundation (flooding) after the surge has passed, causing uplift of structures, hydrostatic pressure on their exterior walls (radial compression), and loss of foundation support, among other ills, such as subsidence.▪

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Watch for Part 2 of this series in an upcoming issue of STRUCTURE® magazine.

Hurricane Categories

Category					
Category 1	Sustained Winds	33 – 42 m/s	74 – 95 mph	64 – 82 kt	119 – 153 km/h
	Storm Surge	4 – 5 ft		1.2 – 1.5 m	
	Central Pressure	28.94 in (Hg)		980 mbar	
	Potential Damage	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal flooding and minor pier damage.			
	Example Storms	Bess (1974); Jerry (1989); Ismael (1995); Danny (1997); Gaston (2004)			
Category 2	Sustained Winds	43 – 49 m/s	96 – 110 mph	83 – 95 kt	154 – 177 km/h
	Storm Surge	6 – 8 ft		1.8 – 2.4 m	
	Central Pressure	28.50 – 28.91 in (Hg)		965 – 979 mbar	
	Potential Damage	Some roofing material, door, and window damage. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected anchorages may break their moorings.			
	Example Storms	Carol (1954); Diana (1990); Erin (1995); Marty (2003); Juan (2003)			
Category 3	Sustained Winds	50 – 58 m/s	111 – 130 mph	96 – 113 kt	178 – 209 km/h
	Storm Surge	9 – 12 ft		2.7 – 3.7 m	
	Central Pressure	27.91 – 28.47 in (Hg)		945 – 964 mbar	
	Potential Damage	Some structural damage to small residences and utility buildings, with a minor amount of curtain wall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain may be flooded well inland.			
	Example Storms	Alma (1966); Alicia (1983); Roxanne (1995); Fran (1996); Isidore (2002)			
Category 4	Sustained Winds	59 – 69 m/s	131 – 155 mph	114 – 135 kt	210 – 249 km/h
	Storm Surge	13 – 18 ft		4.0 – 5.5 m	
	Central Pressure	27.17 – 27.88 in (Hg)		920 – 944 mbar	
	Potential Damage	More extensive curtain wall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland.			
	Example Storms	"Galveston" (1900); Hazel (1954); Iniki (1992); Iris (2001); Charley (2004)			
Category 5	Sustained Winds	≥ 70 m/s	≥ 156 mph	≥ 136 kt	≥ 250 km/h
	Storm Surge	≥ 19 ft		≥ 5.5 m	
	Central Pressure	< 27.17 in (Hg)		< 920 mbar	
	Potential Damage	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required.			
	Example Storms	"Labor Day" (1935); "Mexico" (1959); Camille (1969); Gilbert (1988); Andrew (1992)			