WIND RESISTANCE (TORNADOS AND HURRICANES)

In most areas of the United States using IBC 2003, the earthquake loading will be more critical than wind. But wind loads should be checked, and more emphasis today is being put on designing structures to withstand tornado and hurricane impacts, certainly in coastal areas where they are being addressed through supplemental codes and other local requirements.

Precast concrete structural systems and architectural panels provide significant benefits in meeting wind-resistance needs. A calculation for determining proper windloads for precast concrete structures can be found in MNL-120-04: *PCI Design Handbook, Sixth Edition*.

Tornados

Single-family homes provide the greatest danger of destruction during a tornado. In regions of the country where tornados can wreak havoc on single-family homes, precast concrete designs can provide a durable, wind-resistant structure. Several key elements are desired in designing a home to resist tornado damage. These include:

Eight-four unit assisted-living facility built to withstand an F-4 tornado. Photo: Dukane Precast Inc.

- Connections that securely tie the house together from roof to foundation, providing protection for winds up to 130 mph.
- Impact-resistant roof materials that better withstand high winds and fire.
- Windows and doors with higher wind- and water-design pressure ratings and a garage door capable of withstanding impact from large objects.
- Construction materials and siting work that eliminate the threat of flood or wildfire.

A number of designers and precasters have worked together to create precast concrete housing designs across the country. These designs not only protect homes from wind damage but also cut energy costs, are constructed quickly and provide a range of aesthetic designs that can blend with any neighborhood.

A variety of precast concrete components are used to create tornado-resistant housing. These include foundation walls, loadbearing precast concrete wall panels with an architectural finish, and hollow-core plank for floors and roofing. Precast concrete's inorganic and noncombustible composition ensure the housing will not generate mold or mildew following torrential rains, nor will they catch on fire should sparks ignite flammables.

Hollow-core plank is a key component in housing. Typically, one thickness is used as the lower level's ceiling and the upper level's floor. It is also used as the roofing substructure, again serving as the ceiling of the lower level at the same time. The long spans available with hollow-core planks are particularly useful for opening up interiors while providing a safe room for protection from high winds.

Precast concrete panels offer several different uses in housing designed to withstand tornados, including façades and foundation walls. Insulated panels, typically 10 by 16 ft in size, are used as foundation walls, with an insulating board on their back (interior) side. The walls offer more than twice the strength of concrete-block walls (5000 psi compared to 2000-2400 psi) and minimize seams through which moisture can penetrate.

Precast concrete homes provide significantly more protection from wind-borne debris than other building materials, according to tests conducted by the Portland Cement Association. The group tested various walls with the impact of a 2x4 wood stud traveling at 100 mph, the equivalent of wind-borne debris during a tornado with 250-mph winds. About 90% of tornados have wind speeds of less 150 mph, the group says. Of all materials tested, only the concrete design stopped the debris from penetrating the wall. All others suffered penetration.

The actual cannon used. Spectators even got to touch the 2 x 4 to confirm the authenticity. In the distance are the panels ready to be tested with the safety wall behind. Photos: Susan Leader.

In test one, the 2 x 4 went through this vinyl sided, wood-frame wall panel like a hot knife through butter. Notice the entry, and the exit holes. Not only are they clean holes, but it didn't even slow the projectile down.

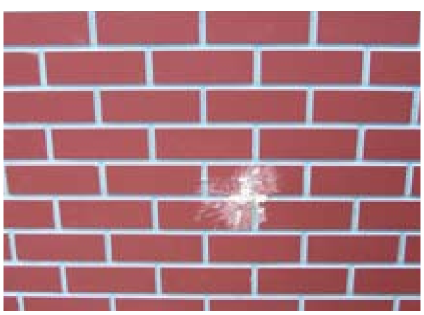
Note as well the significant hole in the safety wall behind the panel in the photo to the right.



Test two shot the 2 x 4 through a brick wall with wood frame. Surprisingly, it's not all that much safer then siding. What you don't see are the pieces of brick that went flying through the back side of the panel. This wall introduced even more projectiles into the house.



Test three smashed a 2 x 4 through a brick home with steel framing. This damage is still rather significant, but in this test the projectile did not travel through the wall. Looking at the back side shows it would take only slightly more force to push all the way through.





Now for the real test: hurl a 2 x 4 at a precast wall panel at 112 mph. The result: no damage visible, not even a chip.

Wall Type:	Test Wall Description:	Speed of Debris:	Results:
Wood frame:	5/8-in. gypsum board interior finish, 2x4 wood studs at 16 in. o.c., 3 1/2-in. batt insulation, 3/4-in. plywood sheathing, vinyl-sided exterior finish	109 mph	The debris missile perforated completely through the wall assembly. Little damage to missile.
	5/8-in. gypsum board interior finish, 2x4 wood studs at 16 inches o.c., 3 1/2-in. batt insulation, 3/4-in. plywood sheathing, 4-in. brick veneer with 1-in. air space	69.4 mph	The debris missile perforated completely through the brick veneer and the interior finish. Minor damage to missile.
Steel frame:	5/8-in. gypsum board interior finish, steel studs at 16 in. o.c., 3 1/2 in. batt insulation, 3/4-in. plywood sheathing, vinyl-sided exterior finish	103.5 mph	The debris missile perforated completely through the wall assembly. Little damage to missile.
	5/8-in. gypsum board interior finish, 2x4 wood studs at 16 in. o.c., 3 1/2-in. batt insulation, 5/8-in. gypsum board sheathing, synthetic stucco exterior finish	50.9 mph	The debris missile perforated completely through the wall assembly. No damage to missile.
Concrete:	6-in.-thick reinforced concrete wall, #4 vertical reinforcing bars, 12 in. o.c, no finishes	109 mph	No cracking, front-face scabbing, or back-face spalling of concrete seen.
	6-in.-thick reinforced concrete wall, #4 vertical reinforcing bars, 24 in. o.c, no finishes	102.4 mph	No cracking, front-face scabbing, or back-face spalling of concrete seen.
ICF:	Block ICF foam forms, 6-in.-thick flat concrete wall, #4 vertical reinforcing bars, 12 in. o.c., vinyl siding (tested twice with similar results)	103.8 mph	Debris penetrated vinyl siding and foam form. No cracking, front-face scabbing, or back-face spalling of concrete wall seen.
	Block ICF foam forms, 6-in.-thick flat concrete wall, #4 vertical reinforcing bars, 24 in. o.c., 3-in. brick veneer with ties spaced 1 in. each way	99 mph	Debris penetrated and cracked brick veneer. Foam form dented. No cracking, front-face scabbing, or back-face spalling of concrete wall seen.
	Panel ICF foam forms, 4-in.-thick flat concrete wall, #4 vertical reinforcing bars, 24 in. o.c., vinyl siding	96.7 mph	Debris penetrated vinyl siding and foam form. No cracking, front-face scabbing, or back-face spalling of concrete wall seen.
	Block ICF foam forms, variable thickness “waffle” concrete wall, 6 in. maximum thickness, and 2 in. minimum thickness, #4 vertical reinforcing bars in each 6-in. vertical core at 24 in. o.c, synthetic stucco finish (tested twice with similar results)	100.2 mph	Debris penetrated synthetic stucco finish and foam form. Impact of wall at 2-in.- thick section. No cracking, front-face scabbing, or back-face spalling of concrete wall seen.

Note: All concrete tested had 3000-psi compressive strength with a maximum aggregate size of 3/4 in. with a 6-in. slump.
Source: Portland Cement Association

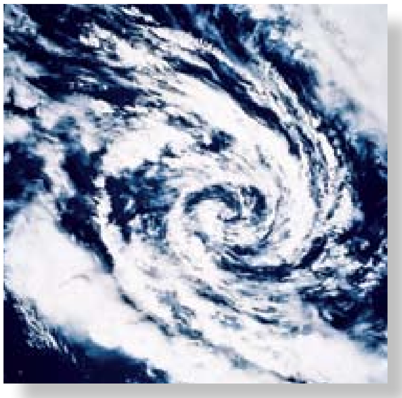


Photo: ©PhotoDisc.

Hurricanes

The devastating impact of recent hurricanes, notably Katrina and Rita, have put a spotlight on designing to withstand the highest levels of these forces, which are more complex than those associated with tornados. Hurricanes produce not only high winds but also forces associated with the impact from high waves and immense amounts of water overwhelming a structure.

Precast concrete components can help to withstand these forces if designers take into account all of the actions involved and how the components must react to them. The factors that designers must consider include:

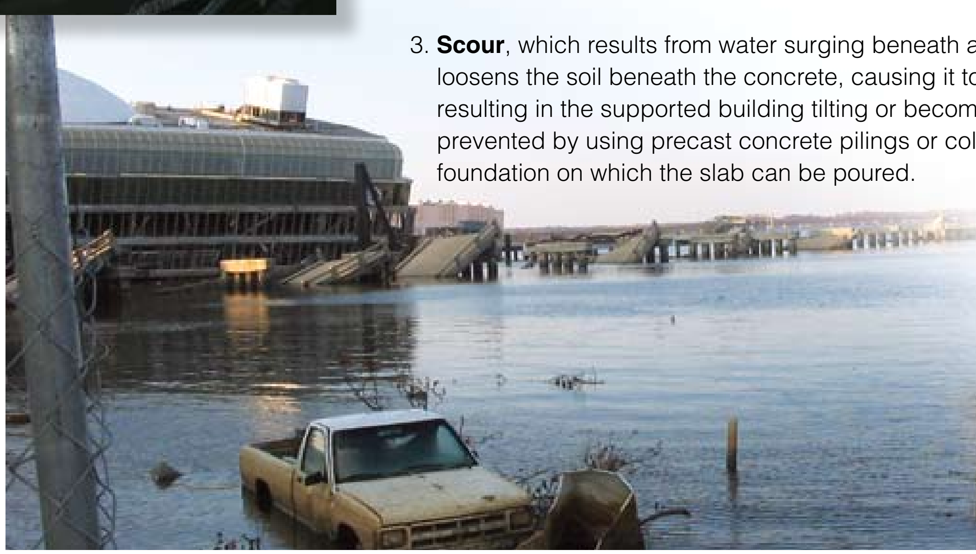
1. **High winds**, which can be dealt with similarly to those in tornados and do not pose a substantial risk for buildings built of precast concrete. Examination of projects exposed to the high winds of Hurricane Katrina indicated that wind loads for precast concrete buildings were well accounted for. Wind-borne debris creates the largest problem and results in only chipping or cracking in some instances at the high end of the wind speeds.

   To be certain of withstanding wind loads in these high-risk areas, designers should overcompensate for potential problems. Designing for a 200-mph wind and using reinforcement to meet that level of force should protect the structure under any situation. Modifying designs to reduce surface area will also help to ensure that wind loads do not create a problem.

2. **Surge**, in which large amounts of water rush over the land and up to buildings. Often, this water carries with it loose debris that can be substantial in nature and can act as a battering ram against a building. In some cases, if the surge is high enough, the debris can impact the building at a height that was not designed to withstand such force. This can cause damage to the stems on double tees, particularly on parking structures. Creating a precast concrete soffit or other protective shield that prevents large debris from surging through the structure at such a height can mitigate this concern.

3. **Scour**, which results from water surging beneath a slab on grade. This action loosens the soil beneath the concrete, causing it to deteriorate or break up, resulting in the supported building tilting or becoming unstable. This can be prevented by using precast concrete pilings or columns to create a stable soil foundation on which the slab can be poured.

Much of the damage done to precast concrete parking structures along the Gulf Coast by Hurricane Katrina was caused by the high storm surge, which flooded the structures and caused double tees to be puched off their supports. Otherwise, the material performed well. (Three photos below).



4. **Buoyancy**, in which the water levels rise above the first floor of a structure, such as a parking structure, where the levels are supported by double tees. Designs typically do not account for tees being lifted from their position. Connections must account for this possibility in the areas of the highest concern.

5. **Structure orientation**, which should provide the smallest exposure to the likely direction of a hurricane in areas most likely to be hit. Interiors also should take the concept of surging water into account. For instance, in parking structures, ramps should be faced away from the ocean to allow water to flow through the structure rather than be blocked by it. Creating fewer obstacles for the likely path that water will follow during a hurricane will minimize damage.

Salt-water damage, in the form of corrosion or deterioration of the components after water recedes, should not create a long-term problem. In many instances, precast concrete components produced for these marine environments already include additives that hinder the potential for corrosion.

Home Designs

Designing homes for wind loads can follow the same concepts as expressed for tornado designs, and these concepts are available throughout the country from precasters. Meeting the needs for protecting against surging water requires additional consideration.

With surges in New Orleans, La., of 12 ft or more, one design option is to use precast concrete piles or columns to create a first-level garage on top of which the living space can be created, using precast concrete panels to create the shell.

The home still can have wood and drywall interior framing, although if the surge or other water damage reaches the interior, all these materials may have to be completely removed to remediate mold. Even then, the shell and structural integrity remain intact, eliminating the need to start from scratch (see Reference 2).

Concrete is not damaged by water. In fact, concrete that does not dry out continues to gain strength in the presence of moisture. Concrete submerged in water absorbs small amounts of water over long periods of time, and the water does not damage the concrete. In flood-damaged areas, concrete buildings are often salvageable.

Concrete will only contribute to moisture problems in buildings if it is enclosed in a system that does not let it breathe or dry out, and moisture is trapped between the concrete and other building materials. For instance, vinyl wallcoverings in hot and humid climates will act as a vapor retarder, allowing moisture to become trapped between the concrete and wall covering. For this reason, impermeable wallcoverings (vinyl wallpaper) should not be used (see Reference 3).