Wind Load Test Facility

Mission Statement

The mission of the Wind Load Test Facility is to create and evaluate an array of cost effective, simple, practical measures, which can be employed in existing or new construction to substantially reduce the risks of injury, damage and losses in severe windstorms.

To accomplish this mission, the Wind Load Test Facility:

- Conducts applied and fundamental research needed to develop cost effective physical mitigation measures for improving the performance of low-rise buildings in severe windstorms.
- Educates students, professionals and the public about wind hazards and the kinds of measures that can be taken to reduce risks of injury and damage in severe windstorms.
- Investigates the strengths and weaknesses of historical, current, and remedial construction measures as they relate to the performance of buildings in windstorms, evaluates the relative costs and benefits of remedial construction measures and provides objective information on the costs and potential benefits of the measures.
- Conducts scientific and engineering research needed to reduce or remove practical, technical, building code and regulatory impediments to the use of wind resistant construction methods.

Projects and Accomplishments

Roof Coverings:

The wind resistance of a secondary water penetration barrier using self-adhesive roll flashing was studied. Tests showed that 4- or 6-inch wide strips resisted uplift pressures as high as 250 psf when applied over a ½-inch gap between sheathing. The rolls of self-adhesive flashing are commercially available from a number of manufacturers and usually cost less than $20 for a 100-foot roll. (Included in retrofit guide listed below.)

Roof Sheathing Attachment:

The performance of automatic feed screws for roof sheathing attachment in high wind areas was studied. Screws provide about 4 times the capacity of nails in withdrawal and offer the potential for significant increases in uplift resistance of sheathing connections. Resistance to code adoption based on the brittle failures of screws in shear led to detailed studies of uplift and shear resistance of roof sheathing attached with nails and screws. This study included the first ever, combined shear and uplift tests of roof sheathing, despite the fact that this is their normal load condition in wind events. This study, completed in October 2000 should form the basis for new building code provisions. However, the study also demonstrated that there are a number of areas where we still need to improve our understanding of roof sheathing attachment and performance. There are clear indications that a mechanics based model of roof sheathing performance is possible, provided the fundamental capacities of the components and potential redistributions of loads are well understood.

Retrofit guidelines for strengthening the connection of roof sheathing when someone re-roofs their house. (Pamphlet and Video)

The use of adhesives in a retrofit application was investigated as one method for improving the attachment of roof sheathing for people who are not ready to re-roof. Significant increases in uplift capacity were discovered for simple applications using AFG-01 approved construction adhesives. (Pamphlet and Video)

A variety of displays and hands on demonstrations have been developed to help communicate these problems and solutions.

The study of wind loads on roofs continues to be an area of active research both in terms of field studies and wind tunnel investigations. The challenge for the development of cost effective but structurally sound mitigation measures is a balancing of realistic loads with realistic expectations of uplift resistance. Field studies seek to provide information concerning wind loads on roofs of buildings in real-world locations. Much of the existing data has been obtained from wind tunnel model tests of isolated buildings or from a limited number of field studies on isolated buildings. None of the field data has been collected in hurricane wind conditions. There is also little data about the gust structure of winds in hurricanes that provides the kind of detail needed for adequate evaluation of the wind tunnel simulations. These on-going studies include:

- Mobile, trailer mounted, anemometer towers that are used for the collection of wind data in hurricanes. Four of these units have been built and are being operated in co-operation with the University of Florida. Data has been collected in several weak storms over the past two hurricane seasons.
- The instrumentation of houses in the South Florida area has been undertaken for the Florida Department of Community Affairs. This work has also been conducted in conjunction with the University of Florida. Ten houses have been pre-wired in the South Florida area at 12-mile intervals between Homestead and Jupiter. These are owner occupied houses in real subdivisions. If a storm strikes the area, these houses will provide the first ever, actual measurements of hurricane induced wind loads on homes.
- Wind loads on porches, overhangs and gable roof overhangs are being studies in our wind tunnel facilities by two Masters of Science students. This load information is needed to improve the design of connections for roof overhangs. Code loads have increased substantially for roof overhang areas in recent years. Yet, there is little hard data to back up these provisions.

Measurements of the actual wind resistance of real homes in the as-built condition are needed to support cost benefit studies for remedial measures as well as to help define how much remedial work is needed in a typical situation. Changes in moisture content of lumber over the years can affect the capacities of connections and the resistance of fasteners. One critical area is the determination of the withdrawal resistance of nails used to attach roof sheathing. We have developed a mobile testing machine for measuring the withdrawal capacity of nails and have used it in one instance on a house that was slated for demolition in Greenville. The withdrawal resistances were substantially lower than anticipated by typical design equations. One nail withdrew under a load of only eight pounds.

Structural Connections:

Poorly attached roof structures have failed completely in severe windstorms. The typical toe nailed connections used in older homes and still used in homes located away from the coast exhibit very low capacities. Hurricane straps can provide substantial increases in capacity if they are properly sized and installed. We have developed a portable test apparatus that allows us to conduct demonstrations of the capacities of various construction techniques at hurricane expositions. We participated in four of these expositions in 2000 and were able to have builders homeowners and building officials mock up their connections at the expos and get instant feedback on the capacities. More work needs to be done, to provide backup information on design loads, so that people can relate the capacities to their particular situation.

One of our students has developed a retrofit connection that can be mounted over the interior wall finishes without requiring a lot of messy remodeling work or tearing out of finishes.

Another student is working on retrofit ideas for garage door openings, where there is little room for shear walls. His work suggests that the capacity can be tripled with little effort and a couple hundred dollars worth of materials.

Work on safe areas that can be built in existing houses at costs ranging between $600 and $1000, has been completed for the SC EPD and FEMA Region 4. Review of this work by FEMA Headquarters suggests that it will likely be included in the next revision of the FEMA shelter guide. That work has also helped to focus studies on connections between walls and floors and between walls and roof structures. The debris impact studies for the wall options investigated in that study have provided basic impact resistance information for a number of common sheathing and construction materials. This is providing a basis for comparing the resistance of existing houses with those outfitted with strong areas.

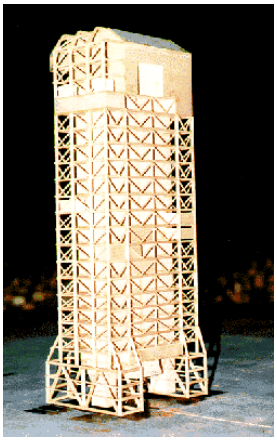
Window Protection:

Protection of glazed openings has turned into a hot topic in building code committees and a contentious issue between builders and insurers. Clemson University has built an air canon and can conduct the routine testing of protective systems. However, we have concentrated on trying to understand the impact forces of various materials including the standard 2x4 missile, clay tiles, roof covering materials and other types of potential debris. In order to do this, we have developed impact plates that allow measurement of the impulse forces exerted by the various missiles. We have looked at forces applied by angular impacts. This information should be combined with probabilistic models of flying debris to provide better estimates of actual risks for debris impact and penetration of different types of protective systems.

We have also been working on novel ideas for lightweight fabric based window protection systems. A key obstacle to these devices is the attachment of the protective system to the framing around the opening. We are looking at interior systems that would allow installation without going outside the house.

Opportunities and Challenges

1. Horry County is preparing to buy out about 29 site built homes and a number of manufactured housing units that have been damaged by flooding from Hurricane Floyd. The homes provide a unique opportunity to study in-situ resistance of homes in a coastal area that cut across age, size and price. It is clear that the wind resistance of houses can decrease with time depending on fluctuations in environmental conditions and maintenance of the home. In an age when cost benefit evaluation is the watchword of government and the National Association of Home Builders fights anything that will increase costs, it is imperative that property owners are provided with objective information on both costs and benefits of potential remedial measures aimed at improving wind resistance. This starts with understanding the typical strengths and weaknesses of existing homes. We have been offered access to these homes for testing purposes before they are demolished and removed from their current sites. There are a number of studies that would be extremely valuable for establishing baseline capacities, for assessing the costs and performance of mitigation measures, and for demonstration value. Some preliminary ideas include:
    a. Capacity of roof sheathing attachment in resisting uplift loads
    b. Gable end wall strength at the wall to truss connection with and without bracing
    c. Resistance of gable end roof overhang to uplift forces
    d. Resistance of windows, doors and sliding glass doors to wind pressure and debris impact from roof covering materials
    e. Capacity of conventional and retrofitted garage doors to wind pressure
    f. Capacity of roof to wall and wall to foundation connections with and without retrofits
    g. Capacities of wall connections and remedial measures to improve the connections between wall segments at corners
    h. Costs and difficulties associated with installing safe areas within some of the homes
    i. Load deformation characteristics of the manufactured home anchoring systems under system loads
    j. Methods for improving the anchorage of the manufactured homes
    k. Methods for strengthening a portion of the manufactured home to create a hardened area
2. Participation in Hurricane Mitigation Expos in the coastal areas and conducting training sessions for shelter construction and evaluation of shelter options in areas prone to tornados. We have developed a number of displays and hands-on activities to help educate homeowners and builders about possible mitigation measures. Support is needed for travel and student labor plus printing of brochures and handouts. We also need support to develop additional handouts to cover window protection issues, garage door retrofit options, and structural retrofit options.
3. The NAHB has recently completed its own guide for the design of houses. In it, they have taken every opportunity possible to suggest methods that will reduce loads and provide minimal strength requirements. It is full of "design this way unless you have to meet ASCE 7, in which case you will have to do this." As far as we have been able to determine, there have been no attempts to look at the incremental improvements in capacity that you buy with modest changes in material costs or the addition of larger metal connectors. We believe that there is a need to conduct analyses of the costs and potential benefits of the NAHB design guide, ASCE 7 loads and what we would call code plus, where a judicious selection of connectors provides additional capacity that may add significant protection from strong hurricanes or moderate to strong tornados. We believe that it will be in the public's interest to provide objective information on the costs and increased capacity so that someone who is having a house built could choose between various options for building strength and security in severe wind events.



We are also interested in expanding our network of instrumented houses to cover the coast of South Carolina. We have developed the technology under grants from SC Sea Grant and the Florida Department of Community Affairs. It is unobtrusive and once the house is pre-wired, we can set up the instruments in about two hours as the storm is approaching. We would like to involve local coastal universities in this monitoring activity and to extent the number of instrumented trailers so that we can provide better coverage of the coast and begin to gain more information on the changes in winds as the storm progress.