

Report of Recommended Statewide Public Hurricane Shelter Criteria

Hurricane Shelter Criteria Committee, State Civil Defense

PURPOSE OF THIS REPORT

The Hawaii State Legislature-enacted Disaster Emergency Preparedness Act of 2005 states:

The department of defense shall develop Hawaii public shelter and residential safe room design criteria by January 1, 2006, and shall facilitate impact resistance testing and certification of safe room design; provided that safe room prototype models are developed with public or private sector grants or investments. These criteria shall include Hawaii performance-based standards for enhanced hurricane protection areas and essential government facilities capable of withstanding a five hundred-year hurricane event and providing continuity of government or sheltering operations thereafter.

The Disaster Emergency Preparedness Act of 2005 is included as Exhibit I to this report. State Civil Defense, acting through its State Hazard Mitigation Forum, organized a Hawaii Shelter Criteria Committee to assist in developing the new criteria by January 1, 2006. This 2005 report provides recommended criteria and reference standards for the enhanced hurricane protection areas and for essential government facilities needed for continuity of government and continuity of operations. State Civil Defense plans further development of these criteria and guidelines in 2006. Residential safe room design criteria are not presented in this report.

COMPOSITION OF THE COMMITTEE

The Hurricane Shelter Criteria Committee is comprised of representatives of each county, the State Civil Defense Hazard Mitigation Officer, the State Comptroller, the American Red Cross Director of Disaster Services, a committee chair appointed by the State Hazard Mitigation Forum, and representatives of the Hawaii State Hurricane Advisory Committee, the Hawaii State Earthquake Advisory Committee, and the Structural Engineers Association of Hawaii. The members of the committee are listed in Exhibit II.

PUBLIC SHELTER STATUS

In Hawaii, residents and visitors cannot move away from a storm's landfall, as they do on the U.S. mainland, to reduce the life-threatening effects of a hurricane. They must remain in-place and have immediately available hurricane resistant homes, hotels, and public shelters. in which to seek refuge. (See Exhibit III for a tabulation of existing shelter spaces by County.) In that regard, government in Hawaii has a more crucial and difficult responsibility to provide for the health, safety and welfare of its citizens. Hawaii has a severe shortage of public shelter, with a hurricane refuge space shortfall of at least 175,000 based on studies done in 2003, even if only 35% of the resident population seeks protection in public shelters. Since current facilities used as shelters vary in shape, size, location and construction, it is presently uncommon to find universal all-hazards shelters. For example, a building of sufficient strength to withstand hurricane force winds may be located in a flood plain and, therefore, be unsuitable as a hurricane shelter. Conversely, other buildings of a lesser construction standard, while not suitable for hurricane wind effects, may still be acceptable for tsunami or flooding events. Shelters rated for earthquakes may have insufficient window protection. Very few buildings statewide were originally designed for shelter use.

HURRICANE HAZARD: WINDSPEED VERSUS RETURN PERIOD

Due to the rarity of tropical cyclone occurrence at a specific location, the prediction of design windspeeds must frequently be obtained by statistical means, such as a Monte Carlo simulation. Windspeed hazard curves have recently been derived by two independent research investigations (Cermak Peterka Petersen, Inc. 2002 sponsored by NASA and Applied Research Associates, 2001, sponsored by the Hawaii Hurricane Relief Fund). Both utilized long-term simulations of storm tracking. (These analyses did not include any potential effects of global climate change.)

Table 1. Estimates of <i>Single Site Hazard</i> Return Interval	Estimated Peak Gust (mph) in 10 m Open Terrain Exposure			
	Kauai	Oahu	Maui	Hawaii
150 to 300-years	108			
500-year (CPP, 2002)	128	135	Subject to further study	
500-year(ARA, 2001)	120	128		120
1000-year (CPP, 2002)	150		Subject to further study	
1000-year (ARA, 2001)	133	140		133

Table 2. Hurricane Categories and Reference Windspeeds					
Saffir Simpson Category	1	2	3	4	5
Central Pressure (mb)	>979	965-979	945-964	920-944	<920
1 minute sustained speed	74 - 95	96 - 110	111 - 130	131 - 155	>155
3-sec. Peak Gust	82 - 108	109 - 130	131 - 156	157 - 191	>191

Table 3. Hurricane Annual Odds of Occurrence <i>Anywhere in Hawaii</i> by Saffir Simpson Category Based on NASA and HHRF Sponsored Research			
Hurricane Category	1 Minute Sustained Windspeed	3-Second Peak Gust	Approximate Annual Odds of Occurrence
Any Hurricane	Greater than 74 mph	Greater than 82 mph	1 in 15
1	74 to 95 mph	82 to 108 mph	1 in 25
2	96 to 110 mph	109 to 130 mph	1 in 50
3 or 4	111 to 155 mph	131 to 191 mph	1 in 75

The information on hurricane hazard shown above was used as a reference in order to define the windspeed consistent with a 500-year return period probability, and generally corresponds to a low Category 3 hurricane. A windspeed strength target of 156 mph representing the upper end of Category 3 was used for the strength basis of the Enhanced Hurricane Protection Areas. This is somewhat greater than a 500-year wind, but it will result in shelters with better clarity of occupant safety for operational and emergency planning purposes. By performing better than at minimum life safety, EHPA shelters would provide better assurance of continued shelter or congregate care operations after the event. This 1,000-year, 156 mph windspeed strength is greater than what was provided in past building code minimum standards adopted in Hawaii. Should State Civil Defense desire criteria that minimally meets the estimated 500-year windspeed, which are representative of a high Category 2 to low Category 3 storm, the committee can re-adjust the structural criteria for windspeed.

RECOMMENDATIONS

This report provides the recommended criteria and reference standards in accordance with public safety considerations. A recommended hierarchy of hurricane shelter criteria is proposed, taking into account new and existing construction within four main classifications:

1. New Essential Facility for Continuity of Government and Continuity of Operations (EFCOOP) offering near absolute protection in Category 4 hurricanes,
2. New or Existing Enhanced Hurricane Protection Areas (EHPA) complying with the Disaster Preparedness Act of 2005,
3. Existing Hurricane Shelter Type A offering significant hurricane wind protection although not up to level of EHPA, and
4. Existing Hurricane Shelter Type B, offering hurricane wind protection with added risk.

A number of nonstructural and functional features are now included in the shelter selection criteria as well as strength of the structural system. Criteria for the appropriate siting of new shelters to account for other natural hazards are also included. (An additional list of other preferred, but not required, features is given in Exhibit IX.) The itemized criteria for the four shelter classifications are presented in tabular form in the following section, including:

- Hurricane Intensity
- Performance Objectives
- Occupancy Period
- Floor area and Space Requirements
- Tsunami, Surge, and Flood Site Selection and Seismic Considerations
- Wind Exposure and Windspeed
- Debris Impact Resistance
- Rooftop Equipment Anchorage
- Shelter Survey and Evaluation Requirements
- Periodic Inspections of Physical Conditions
- Instances when Compliance Re-evaluation are required

New State government facilities of certain Assembly, Civic Administrative, Educational and Institutional Occupancies, or those occupancies designated by State Civil Defense and the owner State agencies, should be designed and constructed to include Enhanced Hurricane Protection Areas-with the capability and capacity to provide shelter refuge to the actual number of occupants for whom each building is designed. This may be addressed by designated selective buildings within an overall complex so long as the occupant capacity is achieved for the complex. EHPAs may be a single large room or a combination of rooms, located on one or more stories, and possibly in more than one building. The process and additional details of the implementation of this recommendation require further discussion and coordination. The EHPA should be provided in new usable floor area, determined by subtracting from the gross square feet the floor area of excluded spaces, partitions and walls, columns, fixed or movable objects, furniture, equipment or other features that under probable conditions cannot be removed or stored during use as a storm shelter.

Larger capacity private shelters (such as certain Waikiki hotels) should also utilize these recommended criteria to reestablish their operational qualification with State or County Civil Defense. Since these four new classifications utilize more refined criteria, an individual shelter may not be rated by the shelter classifications used in the past. Previous public shelter guidelines used by State Civil Defense and county civil defense agencies date from 1997. (Exhibit IV)

These four classifications of incrementally increasing protection can be roughly interpreted as follows:

Shelter Classification	Expected Performance Objective	Hurricane Category
Type B Hurricane Shelter	Life Safety, with significant structural and nonstructural damage permitted	Category 1 Hurricane
Type A Hurricane Shelter	Life Safety, with significant non-structural damage and low to moderate structural damage permitted	Category 2 Hurricane
Enhanced Hurricane Protection Area	Operational during and after a 500 to 1,000-year event	Category 3 Hurricane
Essential Facility for Continuity of Operations	Near-Absolute Protection and Continuity of Operations during and after a hurricane of maximum considered intensity	Category 4 Hurricane

This concept is graphically illustrated in the figure below that also provides comparisons with the peak gust windspeed strength capacities.

Shelter Type B provides structural capacity for 108 mph (upper Category 1 hurricanes)	Shelter Type A provides structural capacity for 130 mph(upper Category 2 hurricanes)	Enhanced Hurricane Protection Area Shelter provides capacity for 155 mph (upper Category 3 hurricanes)	Essential Facilities necessary for COG and COOP provides capacity for 190 mph (upper Category 4 hurricanes)
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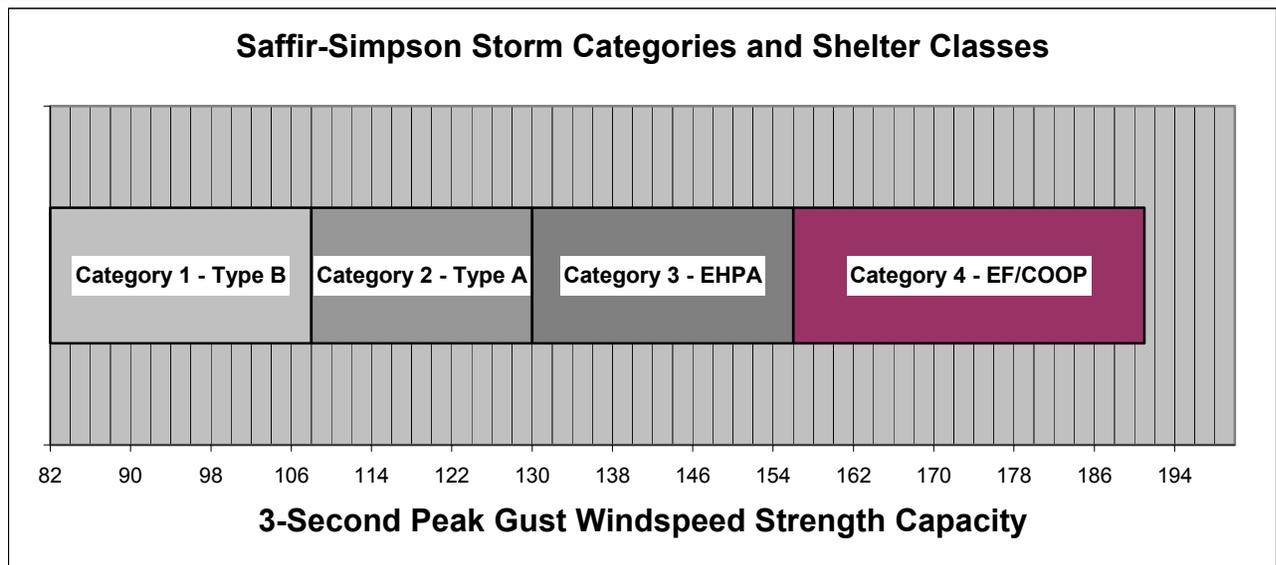


Figure 1. The Strength Capacities of the Shelters by Storm Categories and Gust Windspeeds

Note: A descriptive table of Storm Categories is given in Exhibit X.

Table 5. Summary of Recommended Criteria and Guidelines for Hurricane Shelter Classifications

Criteria	Guidelines for Existing Buildings not originally designed for sheltering Type B	Guidelines for Existing Buildings not originally designed for sheltering Type A	Criteria for Enhanced Hurricane Protection Areas Disaster Preparedness Act of 2005 Type EHPA	Criteria for Near-Absolute Protection Essential Facilities needed for COG/COOP (<i>italics</i> note differences from ICC Storm Shelter Draft Standard) Type EFCOOP
Designation	Type B High Wind Shelter	Type A Hurricane Shelter	Enhanced Hurricane Protection Area	Essential Facility for Continuity of Operations
Hurricane Intensity	Saffir-Simpson Category 1	Saffir-Simpson Category 2	Saffir-Simpson Category 3	Saffir-Simpson Category 4
Building Performance Objective	Life Safety, with significant structural and nonstructural damage permitted during a Category 1 Hurricane.	Life Safety, with significant non-structural damage and low to moderate structural damage permitted during a Category 2 Hurricane.	Enhanced Hurricane Protection Areas to be operational during and after a Category 3 Hurricane. Also, per ASCE 7-02: Sustain local damage with the structural system as a whole remaining stable and not damaged.	Near-Absolute Protection and Continuity of Operations in <i>Category 4</i> Hurricanes
Occupancy Period Assumption	1 day	1 day or more	1 day or more	Many days to weeks without interruption of operations
Shelter Floor Area	Usable floor area must be calculated; gross area not permitted to be used. The usable shelter floor area shall be determined by subtracting from the gross square feet the floor area of excluded spaces, partitions and walls, columns, fixed or movable objects, furniture, equipment or other features that under probable conditions cannot be removed or stored during use as a storm shelter.			
Space During Event Conditions	15 sf per person for minimum compliance with ARC 4496 (2002) No areas near glass windows to be utilized unless protected			<i>15 sf per person for minimum compliance with ARC 4496 (2002)</i>
Tsunami	Locate outside of Tsunami Evacuation zones unless justified by site specific evaluation or vertical evacuation policies as determined by the county civil defense agency		<i>Locate outside of Tsunami Evacuation zones</i>	
Seismic	Comply with code requirements			<i>Designed for IBC 2003 Seismic Importance Factor of 1.5</i>

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Surge / Flood	Floor slab on grade or the bottom of lowest structural framing of an elevated first floor space to be above the Base Flood Elevation		Floor slab on grade or the bottom of lowest structural framing of an elevated first floor space to be above Base Flood Elevation + 1.5 ft., , or at higher elevation as determined by a modeling methodology that predicts the maximum envelope and depth of inundation including the combined effects of storm surge and wave actions with respect to a Category 3 hurricane	<i>Floor slab on grade or the bottom of lowest structural framing of an elevated first floor space to be above Base Flood Elevation + 3 ft., , or at higher elevation as determined by a modeling methodology that predicts the maximum envelope and depth of inundation including the combined effects of storm surge and wave actions with respect to a Category 4 hurricane</i>
Windspeed Strength Design Capacity Objectives	Shelter to be evaluated by a Structural Engineer per the IBC 2003 and ASCE 7-02 Rated for 80 mph minimum peak gust design speed with a load factor of 1.6 Topographic and directionality factors depending on the site Importance Factor of 1.15 ● Strength Capacity for ≥108 mph peak gust	Shelter to be evaluated by a Structural Engineer per the IBC 2003 and ASCE 7-02 Rated for 95 mph minimum peak gust design speed with a load factor of 1.6 Topographic and directionality factors depending on the site Importance Factor of 1.15 ● Strength Capacity for ≥130 mph peak gust	IBC 2003 and ASCE 7-02 115 mph peak gust design Speed with a load factor of 1.6 Topographic and directionality factors depending on the site Importance Factor of 1.15 ● Strength Capacity for 156 mph peak gust	IBC 2003 and ASCE 7-02 <i>140 mph peak gust design speed with a Load Factor of 1.6</i> <i>Topographic factors depending on the site</i> <i>Directionality Factor = 1.0</i> <i>Importance Factor of 1.15</i> ● Strength Capacity for 190 mph peak gust
Wind Exposure Categories	B or C			

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Debris Impact Resistance Objectives	Buildings without opening protection, provided only interior rooms are used , or minimum conformance to ASTM E1996-05 Level A 2g steel balls at 130 fps (90 mph)	Minimum conformance to ASTM E1996-05 Level C 4.5 lb. 2 X 4 @ 50 fps (34 mph) Design for interior pressure based on largest door or window openings on each facade	Walls and Glazing must resist ASTM E1996 -05 Level D 9 lb. 2 X 4 @ 50 fps (34 mph) Design for interior pressure based on largest door or window openings on each facade	<i>Walls and Glazing must resist ASTM E1996-05 Level E 9 lb. 2 X 4 @ 80 fps (55 mph)</i> Design for interior pressure based on largest door or window openings on each facade
Rooftop Equipment Anchorage	No requirement unless rolling or falling hazard through roof	Recommended Anchored Rooftop Equipment if needed for operations	Rooftop equipment and anchorage designed or retrofitted for wind criteria	Rooftop equipment and anchorage designed for wind criteria

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<p>Outline of Shelter Survey & Evaluation – More Specific Procedures to be developed for use by Building Owners and Civil Defense Agencies</p>	<ul style="list-style-type: none"> ● Screening evaluation surveys of existing shelters including ARC 4496 and ARC 6564 Facility Survey Forms and ranking of 15 least risk criteria for each facility ● Initial Wind Code and Benchmark documentation review and building inspection including floor plan documentation indicating all shelter portions of the facility ● Structural check of any attached/host buildings ● Evaluation report by Structural Engineer with statement of opinion of compliance of wind code benchmark and debris impact opening protection requirements and identification of 	<ul style="list-style-type: none"> ● Screening evaluation surveys of existing shelters including ARC 4496 and ARC 6564 Facility Survey Forms and ranking of 15 least risk criteria for each facility ● Initial Wind Code and Benchmark documentation review and building inspection including floor plan documentation indicating all shelter portions of the facility ● Structural check of any attached/host buildings ● Evaluation report by Structural Engineer with statement of opinion of compliance of wind code benchmark and 	<ul style="list-style-type: none"> ● Construction Documents shall include General Notes to include Basis of Design criteria and Project Specifications shall include opening protection devices and a construction Quality Assurance program ● Floor plans shall indicate all EHPA portions of the facility and exiting routes ● EHPA design and construction documents shall be peer-reviewed by an independent SE engaged by State Civil Defense ● Report by Structural Engineer to include statement of opinion of compliance with wind design and debris impact opening protection requirements 	<ul style="list-style-type: none"> ● Construction Documents shall include General Notes to include Basis of Design criteria and Project Specifications shall include opening protection devices and a construction Quality Assurance program ● Floor plans shall indicate all EFCOOP portions of the facility and exiting routes ● <i>EFCOOP design and construction documents shall be peer-reviewed by an independent SE engaged by State Civil Defense</i> ● Report by Structural Engineer to include statement of opinion of compliance with wind design and debris impact opening protection requirements

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Outline of Shelter Survey & Certification—More Specific Procedures to be developed for use by Building Owners and Civil Defense Agencies	any retrofits necessary for life safety <ul style="list-style-type: none"> ● Doors attached at 6 points including latches ● Windows and louvers with at least ASTM E1996 Level A-rated protection ● GIS geocoding coordinates 	debris impact opening protection requirements and identification of any retrofits necessary for life safety <ul style="list-style-type: none"> ● Doors attached at 6 points including latches ● Windows and louvers with at least ASTM-E1996 Level C-rated protection ● GIS geocoding coordinates 	<ul style="list-style-type: none"> ● Structural check of any attached/host buildings shall be performed ● GIS geocoding coordinates 	<ul style="list-style-type: none"> ● Structural check of any attached/host buildings shall be performed ● <i>GIS geocoding coordinates</i>
Periodic Inspections	Facility to be inspected every three years by the owner to determine whether any changes have occurred pertinent to the original basis for classification; report to be submitted to State Civil Defense, unless more immediate repairs are identified by the shelter evaluation. Exposed building appurtenances necessary for operations, such as antenna and equipment, may need more frequent inspections.			
Compliance Re-evaluation	Compliance re-evaluation only if significantly altered or damaged, or retrofitted		Compliance re-evaluation only if significantly altered or damaged	

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Essential Nonstructural Features and Accessories of the Facility	<p>Concrete or CMU exterior walls Long span roof areas such as gyms and auditoriums with light-framing should be evaluated by a Structural Engineer Identifying sign to be posted during operations, both tactile and visible</p> <p>At least two doors Emergency vehicle access 1 Toilet per 50 occupants located on site</p> <p>1 sink per 100 occupants Fire Extinguisher Mechanical ventilation as required per Code</p>	<p>ARC 4496 “Preferred” compliance</p> <p>Identifying sign to be posted during operations, both tactile and visible At least two doors Emergency vehicle access 1 Toilet per 50 occupants located in the building area, including at least one ADA-accessible toilet at a ground floor location 1 sink per 100 occupants Fire Extinguisher Mechanical ventilation as required per Code Natural ventilation of 12 sq. in. per occupant required Emergency Power of 2 hour duration with coupling for portable generator for use of:</p> <ul style="list-style-type: none"> Communications Emergency Lighting Emergency HVAC All Operational and Life Safety Equipment 	<p>ARC 4496 “Preferred” compliance</p> <p>Identifying sign to be posted during operations, both tactile and visible At least two doors Emergency vehicle access 1 Toilet per 50 occupants located in the building area, including at least one ADA-accessible toilet at a ground floor location 1 sink per 100 occupants Fire Extinguisher Mechanical ventilation as required per Code Natural ventilation of 12 sq. in. per occupant required Emergency Power with coupling for portable generator for use of:</p> <ul style="list-style-type: none"> Communications Emergency Lighting Emergency HVAC All Operational and Life Safety Equipment 	<p>ARC 4496 “Preferred” compliance</p> <p>Identifying sign to be posted during operations, both tactile and visible At least two doors Emergency vehicle access 1 Toilet per 50 occupants located in the building area, including at least one ADA-accessible toilet at a ground floor location 1 sink per 100 occupants Fire Extinguisher Mechanical ventilation as required per Code Natural ventilation of 12 sq. in. per occupant required Emergency Power with coupling for portable generator for use of:</p> <ul style="list-style-type: none"> Communications Emergency Lighting Emergency HVAC All Operational and Life Safety Equipment

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	Parking		Parking	Parking Manager's Office Communication system Capability to provide 1 gal potable water per person per 8 hours 1 shower per 40 occupants Food Preparation area
Accomodations for Special Needs Persons	First Story or ADA-accessible route to a shelter area at each site with a minimum of 1 wheelchair space for every 200 shelter occupants where shelter accommodates more than 50 persons 40 sf space/person only if bedridden			ADA accessible

IMPLEMENTATION

Currently, the State of Hawaii does not have any specific laws or regulations governing the incorporation of hurricane-resistant shelter criteria in public funded buildings and associated infrastructure. Each county adopts its own building codes as well as rules for inspection and enforcement. The Department of Education and Department of Accounting and General Services typically just comply with each county's building code minimum standards in which the school facility is being constructed. Therefore, implementation should take the following steps:

1. In order to have State buildings capable of serving as shelters in the future, it is recommended that State buildings be designed with Enhanced Hurricane Protection Areas of sufficient size to provide sheltering refuge for at least its actual occupancy load. This may be addressed by designated selective buildings within an overall complex so long as the occupant capacity is achieved for the complex. EHPA's may be a single large room or a combination of rooms, located on one or more stories, and possibly in more than one building. The process and additional details of the implementation of this recommendation require further discussion and coordination between State Civil Defense and new State building owner agencies.
2. Implementation of the recommended shelter criteria is expected to require updating of the design policies of several State agencies that are responsible for the design, construction, and maintenance of State buildings. As an example, the DAGS DPW Design Consultant Criteria Manual, including its Design Criteria, Technical Guides and Design Checklists would need to reflect any Executive Order relating to EHPA-complying State buildings. As another example, maintenance policies may wish to consider retrofitting of windows and doors of critical public facilities whenever replacing these enclosure elements. This technical implementation effort should be placed under a coordinating executive department. The State agencies mostly affected would be:
 - a. The Department of Accounting and General Services (Public Works and Central Services Divisions),
 - b. Department of Education (Facilities Development and Facilities Maintenance Branches), and
 - c. The University of Hawaii System (Facilities Management).
3. It is recommended that State Public Shelter EHPA Design Criteria Specifications and Essential Facility for Continuity of Operations EFCOOP Design Criteria Specifications and guidance commentaries be written to incorporate the recommended criteria of this report, so that they can be adopted by administrative rules. Alternatively, if a Uniform Statewide Building Code is established (as recommended by a separate Task Force convened under Senate Concurrent Resolution 17) the shelter criteria could be incorporated as statewide code amendments. In order to have more buildings built capable of serving as hurricane shelters, a consistent Statewide building code would be preferable.
 - a. The International Code Council's Consensus Committee on Storm Shelters is currently developing a Standard for the Design and Construction of Storm Shelters. The objective of this Standard is to provide technical design and performance criteria that will facilitate and promote the design, construction, and installation of safe, reliable, and economical storm shelters to protect the public. However, this standard is for a much rarer and more severe 10,000-year storm, rather than the 500-year storm that the State Legislature stipulated in Hawaii's Disaster Emergency Preparedness Act of 2005. The recommended criteria for the EFCOOP Class of essential facilities with continuity of operations during and after a hurricane of maximum considered intensity are predominately based on a draft version of this newly developing standard. Such critical

- function essential facilities have building performance objectives of near-absolute protection that are similar to the type of shelter criteria being developed by ICC. The Hawaii Hurricane Shelter Criteria committee intends to offer its comments to the ICC group and monitor the completion of the final standard, at which time additional adaptations may be incorporated in a future version of this report.
- b. The drafting of these specifications will also need the funded involvement of private sector or State professional structural engineers and architects working under the supervision of a State executive department that has a responsibility or vested interest in building performance and/or the public safety of buildings.
 - c. Subsequently, funding support for the technical training relating to these updated requirements will be necessary at the affected State departments.
4. Supplemental design and construction funding will need to be budgeted during the planning stages for the buildings selected to be subject to the proposed new EHPA requirement.
 5. The current inventory of existing and potential shelter facilities should be surveyed statewide and evaluated in accordance with the updated criteria and Benchmark Code Edition Year Guidelines. Many existing shelters may need further retrofits to achieve the level of safety assurance called for in the Disaster Emergency Preparedness Act of 2005.
 - a. This evaluation will require professional structural engineering expertise in assistance to American Red Cross, County and State civil defense agency representatives. The due diligence should include review of original construction drawings, physical inspections, and evaluation of the facility's compliance with structural and nonstructural criteria. As a given facility is surveyed, deficiencies should be identified, which, if corrected, will improve the shelter's capacity and its relative safety classification.
 - b. It is recommended that the building data questionnaire forms, survey procedures and risk-based documentation forms be standardized and used together with electronic database linked to GIS mapping to enable a unified means of facility data acquisition, vulnerability assessment for multiple hazards, ranking, and facility status management. These surveys ultimately provide a means to identify cost-effective retrofit projects that, as funded, will have a positive impact upon the State's deficit of hurricane shelter space.
 - c. Subsequent periodic inspections of the physical condition of public shelters by the owners should include those features and elements essential to its performance, as defined in the recommended shelter facility criteria.
 6. Those private facilities allowed to operate as shelters will need to become re-qualified in compliance with one of the updated Shelter Classifications. Specific procedures should be developed for use by private building owners, so that adequate documentation of shelter criteria compliance can be reviewed by the approving State or county agency.
 - a. There is legislation that enables private facilities to house the public with relief for negligence liability. Hawaii Revised Statutes (HRS) 128-19 provides relief for negligence liability to private sector owners who volunteer the use of their facilities as an emergency shelter. The immunity protection that may be provided applies when an owner or controller of the facility meets the following criteria: (1) Their actions relating to the sheltering of people are voluntary; (2) They receive no compensation for the use of the property as a shelter; (3) They grant a license or privilege, or permit the property to be used to shelter people; (4) The Director of Civil Defense, or delegated agency or person, has designated the whole or any part of the property to be used as a shelter; (5) The property is used to shelter persons; and (6) The use occurs during an actual impending, mock, or practice disaster or attack.

GUIDANCE ON DESIGN VINTAGE BENCHMARK YEARS TO AID IN THE SELECTION AND PRIORITIZING OF PUBLIC SHELTERS

Hawaii design “projected area” wind pressures have changed over the years as indicated below:

Table 6. Evolution of Design Wind Pressures by Code Vintage	
Code Years	Design Wind Pressure at 10m height, Open Exposure, Flat Land
2000 to 2006 IBC	26.5 psf
1991 to 1997 UBC	26.7 psf
1982 to 1988 UBC	28.7 psf
1958 to 1979 UBC	20 psf

Historical Background on the Vulnerability of the General Building Stock Designed to Code Minimum Forces

The critical benchmark year identifying legacy structures previously designed to a low wind pressure would be the years of each county’s adoption of the 1982 or later UBC editions, indicated below.

Table 7. Wind Code Benchmark Years for Engineered Structures after which date the design pressures are roughly comparable to modern standards			
Kauai	Honolulu	Maui	Hawaii
1984	1984	1989	1985

The 1982 to 1997 UBC values were predicated on an 80 mph basic fastest-mile windspeed, approximately equivalent to a 95 mph 3-second peak gust, and provided structural capacity for Category 1 hurricanes. The 3-second peak gust is the wind parameter now used in the *International Building Code 2003* (IBC). The IBC 3-second gust windspeed standard now established for Hawaii is 105 mph statewide, which is effectively 10 mph greater than the equivalent UBC windspeed when converted to a common peak gust averaging time. Although not yet adopted by any county in Hawaii, the adoption of the IBC would provide improved structural capacity for about a 133 mph peak gust, Category 2 hurricane (maintaining life safety with structural and nonstructural damage).

For Enhanced Hurricane Protection Areas complying with the Disaster Preparedness Act of 2005, a higher standard of performance is necessary, since the facility must remain operational during and after the hurricane event of 500-year return period, in addition to providing life safety. Since the code-minimum wind resistive design requirements were not intended to provide this higher Performance Objective, other factors must be considered in evaluating the suitability of legacy buildings for hurricane shelter use.

A historical comparison of wind and seismic design requirements indicated that many existing modern buildings may have seismic design requirements that may result in higher levels of lateral strength that can be utilized for hurricane resistance, at least for the main wind resisting system, if not components, windows and cladding of the building enclosure. For low-rise structures utilizing concrete or masonry wall construction and concrete floor and roof construction, seismic design forces typically are greater than the wind design forces. In many engineered structures in the

Counties of Honolulu, Maui, and Hawaii, seismic design requirements will increase the structural system's capacity for low to mid-rise concrete buildings (but not their cladding and components). **Certain concrete buildings constructed under DAGS 1982-1998 legacy standards for "minimum" seismic zone 3 forces were required to be designed for higher seismic forces and thus may have a higher reserve of lateral strength available for hurricane resistance. This represents a significant pool of existing State buildings that have greater potential to be made to comply with the EHPA criteria.** However, note that the first Uniform Building Code with Seismic Requirements that was adopted by all Counties was the 1973 UBC. Therefore, building designed to earlier codes cannot be deemed a priori to have any seismic resistance available for hurricane wind forces. All counties in Hawaii did not adopt the 1973 UBC (or better) until 1982.

Guidance on design vintage benchmark years is given to aid in the selection of public shelters from existing facilities; these vary by County code adoption history and local wind exposure. These benchmarks are preliminary, and the windspeed may be impacted by topographic wind accelerations that should be considered in a final evaluation of the proposed shelter by a structural engineer and a representative of State or County Civil Defense.

Table 8. Building Design Code Edition Benchmark Year Guidelines to Identify Buildings with Better Potential to Comply as Hurricane Shelters

Building Structural System Description (Height up to 60 ft. unless otherwise noted)	Type A or B shelters in Exposure B Oahu and Kauai	Type A or B shelters in Exposure C or EHPA Exposure B Oahu & Kauai	Type A or B shelters in Exposure B Maui & Hawaii	Type A or B shelters in Exposure C or EHPA in Exposure C Maui & Hawaii
Wood Frame and Wood Shearwall	Not Permitted	Not Permitted	Not Permitted	Not Permitted
Steel Moment-Resisting Frame	1994	1994	1994	1994
Steel Braced Frame	1988	1988	1988	1988
Light Metal Frame	Not Permitted	Not Permitted	Not Permitted	Not Permitted
Steel Frame w/ Concrete Shear Walls	1988	1988 Oahu 1988 up to 45 ft. (Kauai)	1976	1976
Reinforced Concrete Moment Frame	1988	1988	1976	1976
Reinforced Concrete Shear Wall	1976 Oahu 1988 Kauai	1988 Oahu 1988 up to 45 ft. (Kauai)	1973	1973
Steel or Concrete Frame with CMU exterior walls	1988	1988 Oahu 1988 up to 45 ft. (Kauai)	1976	1976
Steel or Concrete Tilt-up Warehouse with wood or metal roof	Not Permitted	Not Permitted	Not Permitted	Not Permitted
Reinforced Fully Grouted Masonry	1976 Oahu 1988 Kauai	1988	1973	1973

Notes:

- 1. Government buildings with concrete or masonry exterior walls and concrete roofs complying with DAGS DPW Directive for Seismic Zone 3 Structural Design, Calendar Years of Design 1982 – 1998, are likely to structurally comply with the EHPA Wind Loading Criteria on the Main Wind Resisting System.**
2. The benchmark code edition years must be converted to calendar design/permitted years based on the code adoption history of each county.
3. Topographic effects must be considered in the evaluation of shelter wind resistance, where such information is available.
4. All buildings must be evaluated for compliance with the windspeed capacity requirements, debris impact, essential features, and nonstructural requirements. Individual buildings not meeting a benchmark design year may still be used as a shelter based on an evaluation by a structural engineer for ultimate windspeed capacity, and evaluated for other shelter requirements by ARC and State or County Civil Defense.

CONVERTING FROM CODE EDITION YEAR TO CALENDER YEAR OF DESIGN AND CONSTRUCTION

Throughout the state's history, the counties have adopted model building codes on independent schedules, and counties have on occasion skipped several consecutive 3-year updates of the codes. Accordingly, the County-specific code adoption year of each model Uniform Building Code must be compared against the design and construction year of existing shelters to determine the actual design standard used.

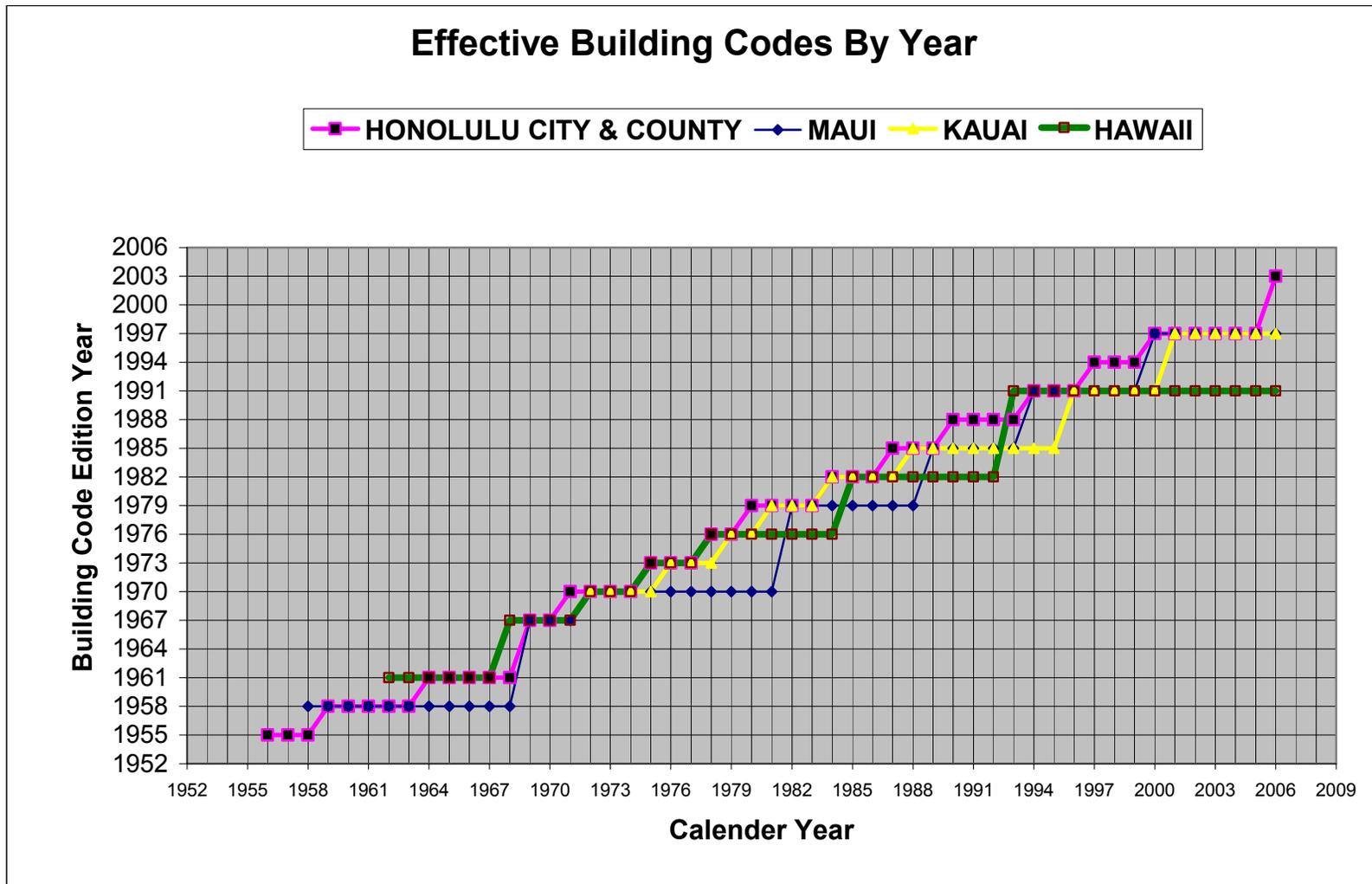


Figure 2. Conversion from Code Edition Year to Calendar Year of Design

Background References on Existing Criteria and Guidelines:

There have been several efforts over the years to establish hurricane shelter criteria based on various criteria of risk.

- State Civil Defense currently has a 1997 guideline (Exhibit IV) that references the prior ASCE 7-98 structural wind provisions; this does not comply with the performance criteria enacted by the 2005 State Legislature.
- Florida established Public Shelter Design Criteria in Section 423.25 of the Florida Building Code (Exhibit VII); this standard recognizes several different risk-based levels of hurricane resistance for rating both existing and newly constructed Enhanced Hurricane Protection Areas and shelters. It also uses a recommended 1,000-year windspeed.
- The American Red Cross has published its recommendations in ARC 4496 Standards for Hurricane Evacuation Shelter Selection (2002). (Exhibit VI)
- The International Code Council's Consensus Committee on Storm Shelters is currently developing a Standard for the Design and Construction of Storm Shelters. The objective of this Standard is to provide technical design and performance criteria that will facilitate and promote the design, construction, and installation of safe and reliable storm shelters to protect the public. However, this standard is for a much rarer and more severe 10,000-year storm, rather than the 500-year storm that the State Legislature stipulated in Hawaii's Disaster Emergency Preparedness Act of 2005 and buildings built to that standard will be more costly. The EFCOOP Class of essential facilities required for continuity of operations during and after a hurricane with maximum considered intensity are predominately based on a draft version of this newly developing standard. Such critical function essential facilities have building performance objectives of near-absolute protection that are commensurate with the shelter criteria being developed by ICC.

COMPARISON WITH FLORIDA

Prior to Hurricane Andrew (1992), Florida shelters were selected by local officials and ARC volunteers. Selection was based on mass care operational features, not necessarily hurricane hazard and engineering criteria. After Hurricane Andrew in 1992, the Florida Legislature enacted a law establishing comprehensive measures to reduce a large statewide deficit of shelter space. These measures included a hurricane shelter survey and retrofit program and new requirements for the design and construction of school facilities to include Enhanced Hurricane Protection Areas. There were related efforts to reduce shelter demand by significantly upgrading building and residential code standards as well as public education.

The Hawaii criteria recommended by this committee have several similarities with the Florida shelter standards:

1. Florida's Wind Storm Design Criteria is multi-leveled, with several performance categories defined by the return period of the wind hazard, including two levels of EHPA ratings.
2. The Florida and Hawaii criteria are based on ASCE 7 wind loads (not the legacy Uniform Building Code).
3. The Florida and Hawaii criteria utilize a load and resistance factor based design method per ASCE-7.
4. ARC 4496(2002) compliance is a minimum requirement.
5. Windborne debris impact criteria is calibrated to the design windspeed of the facility.
6. Florida requires that a certain portion (50%) of the floor area of new educational facilities be EHPA-compliant. The recommendation for Hawaii is capacity for the actual occupancy number.
7. Usable and not gross floor area is the basis for determining the shelter occupant capacity.

8. Evaluation and documentation require the involvement of professional structural engineers.
9. Periodic inspections of the condition of existing shelters are required.

SUMMARY

The Hurricane Shelter Criteria Committee convened by the State Hazard Mitigation Forum offers its recommendations that updated criteria for four classifications of shelters be established, requests that the recommendations be reported to the 2006 Hawaii State Legislature by the Department of Defense as called for in the Disaster Emergency Preparedness Act of 2005, and the Committee furthermore requests additional support for the additional work towards its implementation in criteria for State-owned building design and construction as identified in this report.

EXHIBITS

Exhibit Description	Exhibit No.
Disaster Emergency Preparedness Act of 2005, State Legislature SB960 CD1	I
Committee Member Listing	II
Hawaii Public Shelters as of 2004	III
1997 Hurricane Resistant Shelter Criteria	IV
ASTM E1996 (2005) Standard	V
ARC 4496 (2002) Standards for Hurricane Evacuation Shelter Selection	VI
Florida Building Code §423.25 Public Shelter Design Criteria	VII
Least Risk Decision Making Criteria (Blank Form)	VIII
Other Preferred Features and Operational Considerations	IX
Saffir-Simpson Hurricane Scale Range (with additional Hawaii Damage Indicators)	X

OTHER REFERENCES

American Society of Civil Engineers, Minimum Design Loads for Buildings and Other Structures ASCE 7-02, Reston, VA, USA, 2002.

ARA, Inc., Hazard Mitigation Study for the Hawaii Hurricane Relief Fund, ARA Report 0476, Raleigh, NC, USA, 2001.

Chock, G. and Cochran, L., Modeling of Topographic Wind Effects in Hawaii, Journal of Wind Engineering and Industrial Aerodynamics, August, 2005.

International Code Council, Inc., 2003 International Building Code, 2002.

Peterka, Jon A. and Banks, David, Wind Speed Mapping of Hawaii and Pacific Insular States by Monte Carlo Simulation – CCP, Inc. Final Report 99-1773, NASA Contract NASW-99046, Ft. Collins, CO, USA, 2002.

Exhibit I

Description:

Appropriates funds for tsunami and hurricane preparedness efforts including updating maps, installing and maintaining alarm sirens, constructing additional shelter space, retrofitting public shelters, developing residential safe room design standards, mitigation, shared mitigation grants, providing around-the-clock alert staff, and expanding public education campaigns. Appropriates funds from the Hawaii hurricane relief fund and improves the loss mitigation grant program. (CD1)

THE SENATE

TWENTY-THIRD LEGISLATURE, 2005

STATE OF HAWAII

S.B. NO. 960
H.D. 1

C.D. 1

A BILL FOR AN ACT

RELATING TO CIVIL DEFENSE.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF HAWAII:

PART I

SECTION 1. This Act may be cited as the Disaster Emergency Preparedness Act of 2005.

SECTION 2. The legislature finds that the State's growing population and a general lack of awareness on the part of the public with respect to natural disaster preparedness, dictates appropriate government action. This Act addresses the need for disaster preparedness by appropriating funds for natural disaster preparedness, including tsunami and hurricane preparedness efforts, appropriating funds from the hurricane reserve trust fund to retrofit and protect public buildings against hurricanes, developing standards for residential safe rooms, and improving the loss mitigation grant program by permitting the construction of safe rooms.

The legislature finds that, although the funding for this Act is financed through the principal in the hurricane reserve trust fund, the expended funds will stimulate the economy and replace any "lost" interest income from the fund without jeopardizing the State's ability to reissue hurricane insurance, if necessary.

The original purpose of establishing the Hawaii hurricane relief fund was to provide a means of financing hurricane insurance coverage for the hurricane after the next one, provided that insurers withdraw from the Hawaii hurricane insurance market. This Act will provide protections against the next natural disaster.

PART II

SECTION 3. Due to Hawaii's experience with tsunamis and hurricanes, a disaster alert system is in place providing early warning to residents. Even with this comprehensive, state-of-the-art-monitoring system in place, Hawaii's disaster warning efforts have not kept pace. Antiquated siren systems, outdated evacuation maps in telephone books, insufficient shelter space, limited public education projects, and a lack of around-the-clock alert staff mean Hawaii residents may lose critical seconds in evacuation time or, worse, be unable to access emergency care and shelter in the event a disaster strikes.

The purpose of this part is to appropriate funds for natural disaster preparedness efforts, including installing and maintaining new siren systems, updating evacuation maps in phone books, constructing additional shelter space and retrofitting existing public buildings that could serve as emergency shelters, developing statewide residential safe room design standards by January 1, 2006, providing around-the-clock alert staff for the civil defense division, and expanding public education campaigns that emphasize the need for natural disaster, including tsunami and hurricane preparedness.

SECTION 4. There is appropriated out of the hurricane reserve trust fund the sum of \$2,000,000 or so much thereof as may be necessary for fiscal year 2005-2006, and the sum of \$2,000,000 or so much thereof as may be necessary for fiscal year 2006-2007 for tsunami and hurricane preparedness efforts, including installing and maintaining new siren systems, updating evacuation maps in telephone books, constructing additional shelter space and retrofitting existing public buildings that could serve as emergency shelters, developing statewide residential safe room design standards by January 1, 2006, providing around-the-clock alert staff for the civil defense division of the department of defense, and expanding public education campaigns emphasizing the need for tsunami and hurricane preparedness.

The sum appropriated in this part shall be expended by the department of defense for the purposes of this part.

SECTION 5. The department of defense shall develop Hawaii public shelter and residential safe room design criteria by January 1, 2006, and shall facilitate impact resistance testing and certification of safe room design; provided that safe room prototype models are developed with public or private sector grants or investments. These criteria shall include Hawaii performance-based standards for enhanced hurricane protection areas and essential government facilities capable of withstanding a five hundred-year hurricane event and providing continuity of government or sheltering operations thereafter.

SECTION 6. The department of defense shall coordinate all work performed pursuant to this part with the state or county agencies having responsibility for the repair, maintenance, and upkeep of any public building to be retrofitted.

SECTION 7. Any portion of the appropriations may be used for the purpose of matching federal hazard mitigation funds if these funds become available for use in retrofitting public buildings with hurricane protective measures.

PART III

SECTION 8. The loss mitigation grant program was established to assist residents with installing wind resistive devices to protect their property against hurricanes. The addition of providing grants for safe rooms will also allow residents who may not be able to afford reinforcement of their entire home, protection against natural disasters.

SECTION 9. Section 431:22-101, Hawaii Revised Statutes, is amended by amending the definition of "wind resistive devices" to read as follows:

"Wind resistive devices" means devices and techniques, as identified and determined in accordance with section 431:22-104(b), that increase a building's or structure's resistance to damage from wind forces. The term shall also include safe rooms that are defined and built pursuant to design standards of the department of defense's civil defense division that are adopted pursuant to chapter 91."

SECTION 10. Section 431:22-104, Hawaii Revised Statutes, is amended by amending subsection (a) to read as follows:

"(a) Subject to the availability of funds and the standards in this article, grants for wind resistive devices shall be awarded by the commissioner:

(1) That reimburse [~~fifty~~] thirty-five per cent of costs incurred for the wind resistive devices and their installation [~~and inspection~~], up to a maximum total reimbursement of \$2,100 per dwelling;

(2) On a first-come, first-served basis, as determined by the commissioner; and

(3) For a wind resistive device or devices installed only in a single or multi-family residential dwelling."

SECTION 11. Section 431:22-104, Hawaii Revised Statutes, is amended by amending subsection (c) to read as follows:

"(c) In addition, a grant may be made to an applicant only if the applicant:

(1) Has met the descriptions, specifications, guidelines, and requirements established by the commissioner for the grant program;

(2) Has filed a completed application form, as determined solely by the commissioner, together with all supporting documentation required by the commissioner;

(3) Has, in the case of a building with multiple dwellings, filed together completed grant applications for all dwellings in the building~~[+]~~, for installation of wind resistive devices indicated in section 431:22-104(b) (1), (2), and (4); provided that this requirement does not apply [+]to~~[+]~~ section 431:22-104(b) (3);

(4) Has installed a wind resistive device or devices including residential safe room designs that meet the standards established by the state department of defense and that have been designated and approved by the commissioner;

(5) Has fully paid, prior to applying for the grant, the cost of the wind resistive device

or devices, as well as the installation [~~and inspection~~] costs for which the grant is sought. The grant shall be used to reimburse only these costs or a portion thereof;

(6) Has hired an inspector, determined by the commissioner to be qualified in accordance with the requirements of the commissioner, who has verified in writing that the installation of the wind resistive device or devices is complete and is in compliance with the grant program specifications, guidelines, and requirements, as determined by the commissioner;

(7) Has installed the wind resistive device or devices after July 1, 2002;

(8) Has provided any other information deemed necessary by the commissioner; and

(9) Has met all additional requirements needed to implement the grant program as determined by the commissioner."

SECTION 12. There is appropriated out of the hurricane reserve trust fund of the State of Hawaii the sum of \$2,000,000, or so much thereof as may be necessary for fiscal year 2005-2006, and the sum of \$2,000,000, or so much thereof as may be necessary for fiscal year 2006-2007, for the deposit into the loss mitigation grant fund.

SECTION 13. There is appropriated out of the loss mitigation grant fund of the State of Hawaii the sum of \$2,000,000, or so much thereof as may be necessary for fiscal year 2005-2006, and the sum of \$2,000,000, or so much thereof as may be necessary for fiscal year 2006-2007, for the loss mitigation grant program established under chapter 431, article 22, Hawaii Revised Statutes.

The sum appropriated in this part shall be expended by the department of commerce and consumer affairs for the purposes of this part.

PART IV

SECTION 14. Statutory material to be repealed is bracketed and stricken. New statutory material is underscored.

SECTION 15. This Act shall take effect on July 1, 2005.

Exhibit II

Hawaii Hurricane Shelter Criteria Committee Members

	<u>Member</u>	<u>Contact</u>
	State Department of Defense	Faye Chambers
	State Civil Defense	State Hazard Mitigation Officer
	Department of Accounting and General Services	Russ Saito
		State Comptroller
	State Hazard Mitigation Forum	Gary Chock
	Martin & Chock, Inc.	Committee Chair
	Hawaii Hurricane Advisory Committee	Arthur Chiu
	Dept. of Civil & Environmental Engineering, UH Manoa	
	Maui Civil Defense Agency (MCDA)	Robert Collum
		Civil Defense Staff Specialist
	Oahu Civil Defense Agency	Kenneth Gilbert
		Disaster Response and Recovery Officer
	Hawaii Civil Defense Agency	Neil Gyotoku
	Kauai Department of Public Works	Doug Haigh
		Chief of the Building Division
	Structural Engineers Association of Hawaii	Howard Lau
	Shigemura Lau Sakanashi Higuchi & Associates	
	American Red Cross Hawaii State Chapter	Maria Lutz
		Director of Disaster Services
	Hawaii State Earthquake Advisory Committee	Ian Robertson
	Dept. of Civil & Environmental Engineering, UH Manoa	Chair of the HSEAC

Hawaii Public Hurricane Shelter Status

Jurisdiction	Usable Spaces in Public Hurricane Shelters
City and County of Honolulu	252769
County of Kauai	15847
County of Maui	35149
County of Hawaii	31891
State of Hawaii	335656

Note: The analysis of space available is based on a space allotment of 10 square feet per person per current State Civil Defense planning criteria.

July 29, 1997

HURRICANE RESISTANT SHELTER CRITERIA

The following guidelines have been developed by State Civil Defense to assist in selecting and designating hurricane shelters. The items listed below are intended as broad, general guidelines and describe the *ideal* design and construction standards that should be incorporated in an emergency shelter. It should be noted that structures not meeting the guidelines may, in some cases, be used for sheltering. If such an alternative is chosen, emergency managers must assume various additional degrees of risk.

1. *Structural Considerations.* The shelter should be constructed of reinforced concrete and/or reinforced masonry materials. Alternately, the structure could incorporate wood/steel framing and other types of siding/roofing providing there is a complete load path which securely attaches the roof to the walls and the walls to the foundation. The building *must* have the capability to resist a minimum Uniform Building Code (UBC) wind speed of 80 mph. Additionally, the shelter should be an "engineered structure" (i.e., designed and constructed under the supervision of a licensed structural engineer).
2. *Architectural Considerations.* The structure should be designed with minimal windows. Windows are vulnerable to penetration from wind-borne missiles and projectiles. If windows are to be included in the building envelope, they should have protection devices (rated steel/aluminum shutter systems, hurricane panels, heavy plywood, etc.) or have impact-resistant glazing. If the glazing-only option is chosen, glazing should be capable of withstanding a minimum Uniform Building Code (UBC) wind speed of 80 mph, be a rated glass window assembly, and meet the impact standard of the Southern Building Code Congress International (SBCCI) Test Standard for Determining Impact Resistance from Windborne Debris, SSTD 12-94.
3. *Doors and Door Frame Considerations.* All doors and door frames should be rated assemblies capable of resisting a minimum UBC wind speed of 80 mph winds.
4. *Considerations for Objects on Roof.* Vents, fans, ducting, air conditioning equipment and other objects located on the roof should be securely fastened to the building structure, and be able to withstand a minimum sustained UBC wind speed of 80 mph.

5. NFIP Considerations. The structure should not be located within a National Flood Insurance Program flooding zone, an inundation zone recognized by an approved Federal Emergency Management Agency or US Army Corps of Engineers study, or a flooding/inundation zone identified by local emergency management personnel. (Note: Use of sheltering facilities on floors above anticipated flooding inundation levels are satisfactory.)
6. ADA Considerations. Accessibility to shelter areas in accordance with the requirements of the Americans with Disability Act.
7. Sheltering Requirements. For short term sheltering, it is desirable but not essential that the emergency shelter have:
- An independent emergency electrical power source (e.g., an emergency generator with an ample supply of fuel to operate during and after the disaster occurs).
 - Rest rooms and potable water available for shelter occupants.
 - As many vehicle parking spaces as possible.
 - A communications system (i.e., radio, telephone, etc.) available for shelter management.
 - Kitchen facilitates for long-term care only (i.e., congregate care in the aftermath of an emergency or disaster).

Emergency Shelter Categories

State Civil Defense provides the following descriptions of the various categories for emergency public shelter spaces. Facilities in categories 1, 2, and 2A are adequate for sheltering during a hurricane. Those facilities listed in categories 3 and 4 are inadequate for hurricane sheltering but may be used for other purposes.

CATEGORY I - SHELTERS USABLE WITH RISK.

The current shelter survey assumes that a building is usable for sheltering with risk if it is not in an identified flooding or inundation surge zone if it enhances (but not guarantees) the safety of evacuees, and if it has, upon visual inspection:

- a. A load path that appears to tie the roof and walls to a solid foundation.
- b. A structure able to resist wind uplift forces.
- c. A roof overhang that generally does not exceed three feet or is braced or anchored to minimize wind uplift.
- d. Properly attached roof cladding; i.e., vents air-conditioning ducts/units securely fasted to the building structure.
- e. Exterior walls of concrete block or reinforced concrete. (Selected buildings with exterior wooden walls that appeared to have complete load paths and were shielded by other buildings were found to be acceptable providing the structure met all other shelter criteria.).
- f. Load-bearing interior walls or interior walls that are generally protected from tropical cyclone effects.
- g. Door frames that are securely attached to the structure and are properly braced. Door is secured to structure at six points.
- h. Windows that have wooden or PVC louvers and sturdy security/debris screens to protect against flying debris.
- i. Topographical features that minimize exposure to the effects of wind.

CATEGORY 2- USABLE WITH ADDED RISK- NEEDS SECURITY SCREENS

The listed building or room has wooden or PVC louvers but no security/debris screens. The building meets other Category 1 standards and can be used for evacuee sheltering in its present configuration. Priority should be given to installing sturdy aluminum/steel security/debris screens on all wood PVC-louvered windows.

CATEGORY 2A - USABLE WITH INCREASED RISK

The listed building or room meets Category 2 criteria but requires minimal mitigation measures such as additional bracing or minor hardware installation. The activation of this shelter category will be dictated by the need for public shelter space as determined by Civil Defense officials.

CATEGORY 3 - NOT PRESENTLY USABLE - MINOR UPGRADING REQUIRED

The listed building or room is not yet ready for evacuee occupancy. Some rooms require the replacement of glass louvers with wood/PVC louvers, the installation of debris impact resistant covers over some glass windows/panels, doors require additional hardware or bracing, etc. The upgrading costs are not considered significant for shelter space gained.

CATEGORY 4- NOT USABLE - MAJOR UPGRADING REQUIRED

The building/room is not ready for evacuee use. Modifications to roofs, roof and auxiliary elements (air vents, skylights), foundations, walls, glass windows/panels, doors, etc. are essential. The recommended modifications would probably be very expensive and, in some cases, fail a cost-benefit analysis.



Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricanes¹

This standard is issued under the fixed designation E 1996; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers exterior windows, glazed curtain walls, doors and impact protective systems used in buildings located in geographic regions that are prone to hurricanes.

1.2 This specification provides the information required to conduct Test Method E 1886.

1.3 Qualification under this specification provides a basis for judgment of the ability of applicable elements of the building envelope to remain unbreached during a hurricane; thereby minimizing the damaging effects of hurricanes on the building interior and reducing the magnitude of internal pressurization. While this standard was developed for hurricanes, it may be used for other types of similar windstorms capable of generating windborne debris.

1.4 This specification provides a uniform set of guidelines based upon currently available information and research.² As new information and research becomes available it will be considered.

1.5 All values are stated in SI units and are to be regarded as standard. Values given in parentheses are for information only. Where certain values contained in reference documents cited and quoted herein are stated in inch-pound units they must be converted by the user.

1.6 The following precautionary statement pertains only to the test method portion, Section 5, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

¹ This specification is under the jurisdiction of ASTM Committee E06 on Performance of Building Constructions and is the direct responsibility of Subcommittee E06.51 on Performance of Windows, Doors, Skylights, and Curtain Walls.

Current edition approved May 1, 2005. Published May 2005. Originally approved in 1999. Last previous edition approved in 2004 as E 1996 – 04.

² See the Significance and Use Section of Test Method E 1886.

2. Referenced Documents

2.1 ASTM Standards:³

E 631 Terminology of Building Constructions

E 1886 Test Method for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials

2.2 ASCE Standard:⁴

ASCE 7 American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures

3. Terminology

3.1 Definitions:

3.1.1 General terms used in this specification are defined in Terminology E 631.

3.1.2 Terms common to this specification and Test Method E 1886 are defined in Test Method E 1886, unless defined herein.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *assembly elevation*—vertical dimension above adjacent mean ground level at which fenestration or impact protective system assembly is to be installed, measured to the lowest point of the assembly.

3.2.2 *basic wind speed*—three-second gust speeds as defined in the latest edition of ASCE 7.

3.2.3 *impact protective system*—construction applied, attached, or locked over an exterior glazed opening system to protect that system from windborne debris during high wind events.

3.2.3.1 *Discussion*—Impact protective systems include types that are fixed, operable, or removable.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

⁴ Available from The American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191.

3.2.4 *infill*—glazing in a fenestration assembly or curtain wall.

3.2.5 *integral mullion*—a horizontal or vertical member which is bounded at both ends by crossing frame members.

3.2.6 *maximum deflection*—Greatest deformation of an element or component under the application of an applied force.

3.2.7 *maximum dynamic deflection*—greatest deformation of an element or component during the missile impact.

3.2.8 *porous impact protective system*—an assembly whose aggregate open area exceeds ten percent of its projected surface area.

3.2.9 *valley*—a pivoting axis of an impact protective system designed to rotate adjacent slats or panels outward.

4. Test Specimens

4.1 Number of Test Specimens:

4.1.1 Fenestration Assemblies:

4.1.1.1 Three test specimens shall be submitted for the large missile test.

4.1.1.2 Three test specimens shall be submitted for the small missile test.

4.1.1.3 One additional test specimen may be submitted for each of the tests should no more than one of the original three specimens fail any portion of the testing.

4.1.2 Impact Protective Systems:

4.1.2.1 A minimum of three test specimens shall be submitted for the large missile test for the largest span to be qualified.

4.1.2.2 A minimum of three test specimens shall be submitted for the small missile test.

4.1.2.3 One additional test specimen may be submitted for each of the tests should no more than one of the original specimens fail any portion of the testing.

4.1.2.4 For systems with more than two track or mounting conditions, one test specimen shall be submitted for each additional combination of track or mounting condition if tested in accordance with 5.3.3.8.

4.2 Test specimens shall be prepared as specified in Test Method E 1886.

4.3 The size of the test specimen shall be determined by the specifying authority. All components of each test specimen shall be full size.

4.4 Where it is impractical to test the entire fenestration assembly such as curtain wall and heavy commercial assemblies, test the largest size of each type of panel as required by the specifying authority to qualify the entire assembly.

4.5 Fenestration assemblies and impact protective systems intended to be mulled together shall be tested separately or tested by combining three specimens into one mounting frame separated only by the mullions.

5. Test Methods

5.1 Test specimens shall be tested according to Test Method E 1886.

5.2 Determine the missile based upon building classification, wind speed and assembly elevation according to Section 6.

5.3 Location of Impact:

5.3.1 Large Missile Test—Impact each impact protective system specimen and each fenestration assembly infill type

once as shown in Fig. 1, except for additional impacts specified in 5.3.2 and in 5.3.3.8.

5.3.1.1 Impact one specimen with the center of the missile within a 65-mm (2 1/2-in.) radius circle and with the center of the circle located at the center of each type of infill.

5.3.1.2 Impact a different specimen with the center of the missile within a 65-mm (2 1/2-in.) radius circle and with the center of the circle located 150 mm (6 in.) from supporting members at a corner.

5.3.1.3 Impact the remaining specimen with the center of the missile within a 65-mm (2 1/2-in.) radius circle and with the center of the circle located 150 mm (6 in.) from supporting members at a diagonally opposite corner.

5.3.2 Additional Impact Locations in Wind Zone 4 (see Fig. 1):

5.3.2.1 Impact the same specimen specified in 5.3.1.1 a second time with the center of the second missile within a 65-mm (2 1/2-in.) radius circle and with the center of the circle located 150 mm (6 in.) from supporting member at a corner.

5.3.2.2 Impact the same specimen specified in 5.3.1.2 a second time with the center of the second missile within a 65-mm (2 1/2-in.) radius circle and with the center of the circle located at the center of each type of infill.

5.3.2.3 Impact the same specimen specified in 5.3.1.3 a second time with the center of the second missile within a 65-mm (2 1/2-in.) radius circle and with the center of the circle located at the center of each type of infill except as specified in 5.3.3.6.

5.3.2.4 For test specimens with bracing at the specified impact location(s), the impact location(s) shall be relocated to the nearest area with no bracing.

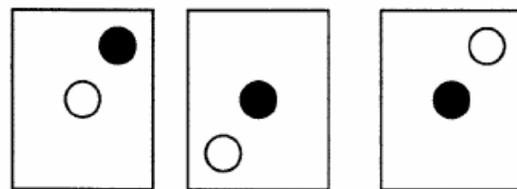
5.3.3 Special Considerations:

5.3.3.1 For test specimens containing multiple panels, impact the exterior glazing surface innermost from the exterior plane of the fenestration assembly or impact protective system panel innermost from the exterior.

5.3.3.2 For test specimens containing fixed and operable panels of the same type of infill, impact the operable portion.

5.3.3.3 For operable test specimens, a corner impact location shall be nearest a locking device and the other corner impact location shall be at a corner diagonally opposite.

5.3.3.4 For test specimens with bracing at the specified impact location(s), the impact location(s) shall be relocated to the nearest area with no bracing.



● Only applicable in Wind Zone 4, FIG. 1 Impact Location for Large Missile Test (Each Type of Infill)

5.3.3.5 The impacts on accordion impact protective systems shall be at the valleys located closest to the impact locations shown in Fig. 1.

5.3.3.6 In Wind Zone 4, impact the integral mullion mid-span in lieu of the impact specified in 5.3.2.3 if applicable.

5.3.3.7 In Wind Zone 4, for each type of mullion impact one mullion with the longest span at mid span in addition to impacts specified in 5.3.

5.3.3.8 For impact protective systems that are testing specimens to qualify more than two track or mounting conditions in accordance with 4.1.2.4, each such specimen shall be impacted three times at the locations shown in Fig. 2.

5.3.4 *Small Missile Test*—Impact each impact protective system specimen and each fenestration assembly infill type three times with ten steel balls each as shown in Fig. 3.

5.3.4.1 Each impact location shall receive distributed impacts simultaneously from ten steel balls. The impact shall be described in the test report.

5.3.4.2 The corner impact locations shall be entirely within a 250-mm (10-in.) radius circle having its center located at 275 mm (11 in.) from the edges.

5.3.4.3 The edge impact locations shall be entirely within a 250-mm (10-in.) radius circle at the centerline between two corners having its center located at 275 mm (11 in.) from the edge.

5.3.4.4 The center impact location shall be entirely within a 250-mm radius (10-in.) circle having its center located at the horizontal and vertical centerline of the infill.

NOTE 1—Impact locations for small missile test may overlap depending on the size of the specimen.

5.4 *Air Pressure Cycling*

5.4.1 *Air Pressure Differential:*

5.4.1.1 The air pressure portion of the test shall use the test loading program in Table 1. Select P_{pos} and P_{neg} for the maximum inward (positive) and maximum outward (negative) air pressure differential for which qualification is sought.

5.4.1.2 The air pressure differential to be used for porous impact protective systems shall be F (the design wind force for other structures as specified in ASCE 7) divided by the horizontally projected area of the entire assembly.

5.4.2 Except in Wind Zone 4, porous impact protective systems whose aggregate open area exceeds 50 % of their projected surface area that pass the small missile test and that are not subject to the large missile test need not be tested for the air pressure portion of the test described in this section.

5.5 For porous impact protective system specimens that are tested independently of the fenestration assemblies they are

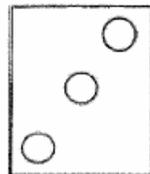
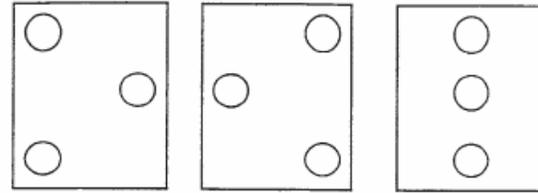


FIG. 2 Impact Locations for Testing Specimens for Two Track or Mounting Conditions



Specimen 1 Specimen 2 Specimen 3
FIG. 3 Impact Locations for Small Missile Test (Each Type of Infill)

TABLE 1 Cyclic Static Air Pressure Loading

Loading Sequence	Loading Direction	Air Pressure Cycles	Number of Air Pressure Cycles
1	Positive	0.2 to 0.5 P_{pos}	3500
2	Positive	0.0 to 0.6 P_{pos}	300
3	Positive	0.5 to 0.8 P_{pos}	600
4	Positive	0.3 to 1.0 P_{pos}	100
5	Negative	0.3 to 1.0 P_{neg}	50
6	Negative	0.5 to 0.8 P_{neg}	1050
7	Negative	0.0 to 0.6 P_{neg}	50
8	Negative	0.2 to 0.5 P_{neg}	3350

intended to protect, measure and record both the maximum dynamic deflection and the residual deflection following the impact test and measure and record the maximum deflection in combination with the residual deflection during the air pressure cycling test. Measure all deflections to the nearest 2 mm (0.1 in.).

6. Missiles

6.1 The specifying authority shall select an applicable missile by defining a level of protection, a wind zone, and an assembly elevation above the ground.

6.2 The applicable missile from Table 2 shall be chosen using Table 3 or Table 4, unless otherwise specified.

6.2.1 Unless otherwise specified, select the appropriate level of building protection from 6.2.1.1-6.2.1.3 and enter Table 3 or Table 4 at the appropriate column.

6.2.1.1 *Enhanced Protection (Essential Facilities)*—Buildings and other structures designated as essential facilities, including, but not limited to, hospitals; other health care

TABLE 2 Applicable Missiles

Missile Level	Missile	Impact Speed (m/s)
A	2 g = 5 % steel ball	39.62 (130 f/s)
B	910 g = 100 g (2.0 lb. = 0.25 lb.) 2×4 in. 52.5 cm = 100 mm (1 ft - 9 in. = 4 in.) lumber	15.25 (50 f/s)
C	2050 g = 100 g (4.5 lb. = 0.25 lb.) 2×4 in. 1.2 m = 100 mm (4 ft = 4 in.) lumber	12.19 (40 f/s)
D	4100 g = 100 g (9.0 lb. = 0.25 lb.) 2×4 in. 2.4 m = 100 mm (8 ft = 4 in.) lumber	15.25 (50 f/s)
E	4100 g = 100 g (9.0 lb. = 0.25 lb.) 2×4 in. 2.4 m = 100 mm (8 ft = 4 in.) lumber	24.38 (80 f/s)

TABLE 3 Description Levels

NOTE—For Missiles B, C, D, and E also use Missile A for porous impact protective systems (see 8.4).

Level of Protection	Enhanced Protection (Essential Facilities)		Basic Protection		Unprotected	
	≤ (30 ft) 9.1 m	> (30 ft) 9.1 m	≤ (30 ft) 9.1 m	> (30 ft) 9.1 m	≤ (30 ft) 9.1 m	> (30 ft) 9.1 m
Assembly elevation						
Wind Zone 1	D	D	C	A	None	None
Wind Zone 2	D	D	C	A	None	None
Wind Zone 3	E	D	D	A	None	None
Wind Zone 4	E	D	D	A	None	None

TABLE 4 Description of Levels for Rooftop Skylights in One- and Two-Family Dwellings

NOTE 1—The term “One- and Two-Family Dwellings” includes all buildings included under the scope of the International Residential Code 2000 published by the International Code Council.

Level of Protection	Basic Protection	
	≤ (30 ft) 9.1 m	> (30 ft) 9.1 m
Assembly elevation		
Wind Zone 1	A	A
Wind Zone 2	B	A
Wind Zone 3	C	A
Wind Zone 4	D	A

facilities having emergency treatment facilities; jails and detention facilities; fire, rescue and police stations, and emergency vehicle garages; designated emergency shelters; communications centers and other facilities required for emergency response; power generating stations; other public utility facilities required in an emergency; and buildings and other structures having critical national defense functions.

6.2.1.2 *Basic Protection*—All buildings and structures except those listed in 6.2.1.1 and 6.2.1.3.

6.2.1.3 *Unprotected*—Buildings and other structures that represent a low hazard to human life in a windstorm including, but not limited to: agricultural facilities, production greenhouses, certain temporary facilities, and storage facilities.

6.2.2 Unless otherwise specified, select the wind zone based on the basic wind speed as follows:

6.2.2.1 *Wind Zone 1*—110 mph (49 m/s) ≤ basic wind speed < 120 mph (54 m/s), and Hawaii.

6.2.2.2 *Wind Zone 2*—120 mph (54 m/s) ≤ basic wind speed < 130 mph (58 m/s) at greater than 1.6 km (one mile) from the coastline. The coastline shall be measured from the mean high water mark.

6.2.2.3 *Wind Zone 3*—130 mph (58 m/s) ≤ basic wind speed ≤ 140 mph (63 m/s), or 120 mph (54 m/s) ≤ basic wind speed ≤ 140 mph (63 m/s) and within 1.6 km (one mile) of the coastline. The coastline shall be measured from the mean high water mark.

6.2.2.4 *Wind Zone 4*—basic wind speed > 140 mph (63 m/s).

7. Pass/Fail Criteria

7.1 In Wind Zones 1, 2, and 3, the specifying authority shall select an applicable pass/fail criterion based on 7.1.1, 7.1.2, and 7.1.3.

7.1.1 Fenestration Assemblies and Non-Porous Impact Protective Systems:

7.1.1.1 The test specimen shall resist the large or small missile impacts, or both, with no tear formed longer than 130 mm (5 in.) and wider than 1 mm (1/16 in.) through which air can pass or no opening formed through which a 76 mm (3 in.) diameter solid sphere can freely pass when evaluated upon completion of missile impacts and test loading program.

7.1.1.2 All test specimens meeting the enhanced protection impact levels shall resist the large or small missile impacts, or both, without penetration of the inner plane of the infill or impact protective system, and resist the cyclic pressure loading specified in Table 1 with no tear formed longer than 130 mm (5 in.) and wider than 1 mm (1/16 in.) through which air can pass.

7.1.2 Porous Impact Protective Systems Tested Independently of the Fenestration Assemblies They are Protecting:

7.1.2.1 There shall be no penetration of the innermost plane of the test specimen by the applicable missile(s) during the impact test(s).

7.1.2.2 Upon completion of the missile impact(s) and test loading program, there shall be no horizontally projected opening formed through which a 76 mm (3 in.) diameter solid sphere can pass.

7.1.3 Doors that are a part of the means of egress and emergency escape and rescue openings, as both terms are defined and used in the International Building Code⁵ published by the International Code Council, shall be openable without the use of tools upon completion of missile impact and test loading program.

7.2 In Wind Zone 4, the specifying authority shall select an applicable pass/fail criterion based on 7.2.1 and 7.2.2.

7.2.1 All test specimens shall resist the large or small missile impacts, or both, without penetration of the inner plane of the infill or impact protective system, and resist the cyclic pressure loading specified in Table 1 with no tear formed longer than 130 mm (5 in.) and wider than 1 mm (1/16 in.) through which air can pass.

7.2.2 The overlap seams of an impact protective system shall not have a separation greater than 1/180 of the span or 13 mm (1/2 in), whichever is less, after impact. The length of the separation shall not be greater than 900 mm (36 in.) or 40 % of the span whichever is less.

8. Product Qualification

8.1 When all test specimens submitted have met the requirements of this specification based on the pass/fail criteria described in Section 7, except in the case of 8.2, the set of test specimens shall be accepted according to the designated building classification, wind speed and assembly elevation.

8.2 If any test specimen fails to meet the requirements of this specification based on the pass/fail criteria described in Section 7, it shall be rejected and one additional identical test shall be performed on the additional specimen specified in

⁵ Available from International Code Council (ICC), 5203 Leesburg Pike, Suite 600, Falls Church, VA 22041.

4.1.1.3 or 4.1.2.3. Any additional failures shall constitute failure of the entire set of test specimens and it shall be rejected.

8.3 Porous impact protective systems and all impact protective systems in Wind Zone 4 and in essential facilities in all Wind Zones that are tested independently of the fenestration assembly shall be accepted for installations in which they are offset from the fenestration assemblies by the greater of the following:

8.3.1 The maximum dynamic deflection, as measured in 5.5 plus 25 %, or,

8.3.2 The sum of the maximum deflection and the residual deflection, as measured in 5.5 plus 25 %.

8.4 Any test specimen that has passed the large missile impact test is not required to pass the small missile test, except for impact protective systems that contain openings greater than 5 mm ($\frac{3}{16}$ in.), projected horizontally.

8.5 Substitutions shall be according to the following criteria:

8.5.1 Successful tests of a fenestration assembly shall qualify other assemblies of the same glass type and treatment with thicker or equal monolithic glass and laminated glazing with equal thickness glass and a thicker or equal interlayer, provided the glazing detail is unchanged.

8.5.2 Successful tests of a fenestration assembly shall qualify other assemblies of the same type that contain smaller sashes, panels, or lites at equal or lower design pressures provided the same methods of fabrication are used and the anchorage of the lites is unchanged. Smaller assemblies shall not exceed dimensions of the tested width or height.

8.5.3 Successful tests of a fenestration assembly shall qualify other assemblies with the same glazing type and treatment that are tinted, heat absorbing, reflective, or otherwise aesthetically modified, provided the requirements of 8.5.1 and 8.5.2 are satisfied.

8.5.4 Successful tests of a fenestration assembly that contains construction to improve thermal efficiency of frame or sash, shall qualify other assemblies that do not contain construction to improve thermal efficiency provided the same extrusions are used and the requirements of 8.5.1 and 8.5.2 are satisfied.

8.5.5 Successful test of a fenestration assembly shall qualify other assemblies containing a frame or sash having a greater section modulus provided the construction details and reinforcement remain unchanged and the requirements of 8.5.1 and 8.5.2 are met.

8.5.6 Successful tests of an impact protective system shall qualify other assemblies of the same or less area, and the same or greater section modulus, provided the construction details and reinforcement are unchanged.

8.6 Manufactured assemblies successfully tested shall not be combined unless the structural supports and connections between assemblies have been designed for the wind loads.

8.7 Qualification at any load level automatically includes qualification for all lower load levels.

9. Compliance Statement

9.1 Report the following information:

9.1.1 Detailed description of test specimen(s) and test results in accordance with the Report section of Test Method E 1886.

9.1.2 Missile type and cyclic loading pressure(s) for which the test specimen qualified.

9.2 Attach a copy of the test report from Test Method E 1886, to Compliance Statement for this specification.

10. Keywords

10.1 building envelope; curtain walls; cyclic pressure loading; doors; fenestration; hurricanes; impact protective systems; missile impact; windborne debris; windows; windstorms

APPENDIXES

(Nonmandatory Information)

X1. BREACHING OF THE BUILDING ENVELOPE

X1.1 *Damage and Internal Pressurization*—Windows, doors, and curtain walls are building envelope components (defined as “components and cladding,” in ASCE 7) often subject to damage in windstorms. Windborne debris impact can not only cause failure of these building envelope components but can also expose a building’s contents to the damaging effects of continued wind and rain. From a structural perspective, a potentially more serious result can be internal pressurization of the building. When the windward wall of a building is breached, the internal pressure in the building increases resulting in larger outward acting pressure on the other walls and roof. Similarly, when a breached wall is subject to leeward wall pressures, the internal pressure in the building decreases possible resulting in larger inward acting pressures on the other

walls and roof. Depending on the size of the breached envelope components, the building may be classified as a “partially enclosed building” as defined in ASCE 7. For this classification of building, the internal pressure coefficient increased to +0.55 (from +0.18 for an enclosed building) and to –0.55 (from –0.18 for an enclosed building) this represents more than a three fold increase in internal pressure and, if not accounted for in design, can significantly increase the net pressure (both positive and negative) for which the envelope components were designed.

X1.1.1 ASCE 7 specifies that buildings in “wind borne debris regions” having glazing in the bottom 60 feet that is not designed or protected from missile impact, have such glazing be treated as openings for the purpose of classifying a building

as “enclosed” or “partially enclosed.” This may require these buildings to be designed for larger internal pressures if classified as a “partially enclosed building.” It is the intent of this ASTM specification to quantify the requirements for windborne debris impact.

NOTE X1.1—Dade⁶ (1) and Broward (2) counties, SBCCI Standard SSTD 12 (3), and The Texas Department of Insurance Building Code for Windstorm Resistant Construction (4) do not limit missile impact protection to the bottom 18.2 m (60 ft).

X1.2 Design Pressure and Product Qualification Under This Specification:

X1.2.1 The air pressure cycling portion of Test Method E 1886 applies pressures that are a function of P , where P denotes the maximum inward (P_{pos}) and outward (P_{neg}) air pressure differentials, which are either specified or are equal to the design pressure. “Design pressure” is defined in Test Method E 1886 as follows:

^a—the uniform static air pressure difference, inward or outward, for which the test specimen would be designed under service load conditions using conventional structural engineering specification and concept. This pressure is determined by either analytical or wind tunnel procedures (such as specified in ANSI/ASCE 7).⁶

X1.2.2 ASCE 7 defines the fenestration as “components and cladding.” The procedure for determining the design pressure

⁶ The boldface numbers given in parentheses refer to a list of references at the end of the standard.

for components and cladding is different for low-rise buildings (buildings having a mean roof height less than or equal to 18.2 m (60 ft) than for other buildings not classified as low-rise buildings. In either case, the design pressure is a function of several parameters including Importance Factor (I), Exposure Category (A, B, C, or D), topography and Topographic Factor (K_{zt}), Mean Roof Height (h), height of the fenestration assembly above the ground, location (zone) of the fenestration assembly on the building elevation, and the Effective Wind Area (A) of the fenestration assembly. Only the latter parameter, Effective Wind Area (A), is under the control of the building designer and fenestration manufacturer.

X1.2.3 All of these parameters should be considered when selecting P_{pos} and P_{neg} . When defining substitution criteria the specification addresses only one of these, area of assembly, in 8.5.2 (“Successful tests of a fenestration assembly shall qualify others of the same type that contain smaller sashes, panels or lites assemblies at equal or lower design pressures...”). Section 5.4.1.1 of this specification states that the selection of P_{pos} and P_{neg} should be made “...for which qualification is sought.” A conservative approach would base P_{pos} and P_{neg} on the highest factor for each parameter (that is, open exposure, tallest building, highest importance factor, edge location, and smallest area). An alternate approach should explicitly state what assumptions were made for each parameter in the selection of P_{pos} and P_{neg} .

X2. IMPACT RISK ANALYSIS

X2.1 Summary of Risk Parameters in Ref (5)—The report discusses the following parameters that affect the risk of building damage from windborne debris:

- X2.1.1 Wind velocity,
- X2.1.2 Type and quantity of missiles in the wind-field generated from ground sources,
- X2.1.3 Type and quantity of missiles in the wind-field generated from building sources, as function of the quality of construction,
- X2.1.4 Density of buildings,
- X2.1.5 Shape and height of buildings, and
- X2.1.6 Percentage of glazed openings.

X2.2 The report combines a hurricane wind field model, a missile generation model, a missile trajectory model and an impact model to produce a risk analysis. The output is expressed in terms of curves of specified impact energy resistance or impact momentum resistance levels plotted on a graph with reliability (R) (from 0.75 to 1.00) on the vertical axis and wind velocity (from 110 to 170 mph peak gusts) on the horizontal axis. Plots have been generated for single story detached residential buildings, for two different values for the quality of construction and density of buildings, and three different values for percentage of glazed openings.

X2.3 The Performance Objective of This Specification

X2.3.1 This specification establishes missile impact criteria for all building types and occupancies. The antecedents for this effort are the criteria established in Australian National Standards (6) the Florida counties of Dade (1) and Broward (2), in SBCCI Standard SSTD 12 (3), and in the Texas Department of Insurance Building Code for Windstorm Resistant Construction (4). All of these are based on analysis and judgement of experts after many years of windstorm study. The Twisdale et al. study represents new inputs into this body of analysis and experience. Since it so far has covered only a very limited range of buildings out of the total scope of this specification, its application to the development of this specification has also required a degree of judgement.

X2.3.2 The energy and momentum curves included in the Twisdale et al. (5) report are referenced to a zero energy or momentum curve, that can be interpreted as the reliability achieved at various wind speeds when no impact resistance is provided. Other curves describe reliability versus wind speed at increasing amounts of impact resistance, for example 10, 20, 50, 100, 200, and 300 lb of momentum. All the curves illustrated by Twisdale et al. (5) including the zero resistance

curve, demonstrate reliability above 0.85 at 110 mph wind speed. Reliability diminishes rapidly, with varying slopes, at higher wind speeds.

X2.3.3 Two approaches can be taken to using these curves to inform the specification process:

the absolute reliability approach, and the relative improvement approach.

X2.3.4 *The absolute reliability approach* establishes the objective of achieving a specified level of reliability, say 0.90, by specifying the appropriate impact resistance for different wind speeds, and, possibly, building types. This approach is attractive because it enables the definition of reliability to be consistent with the reliability objective of traditional structural design. However, it has two disadvantages in this case:

X2.3.4.1 The curves plotted are actually average values and should be thought of as broad fuzzy bands with large confidence bounds due to the many uncertainties embedded in the analytical models that produce them. Therefore, establishing a specified reliability level may be misleading without extensive qualifying statements.

X2.3.4.2 The curves diminish so fast at higher wind speeds that the levels of resistance required to achieve high values of reliability at these wind speeds would require impact energies and momenta far in excess of anything considered heretofore, and possibly in excess of the capabilities of the apparatus specified in Test Method E 1886.

X2.3.5 *The relative improvement approach* takes its cue from the zero protection curves, and establishes the objective of achieving a specified proportional improvement in reliability. A 50 % improvement, .50 to .75, 0.60 to 0.80, 0.70 to 0.85, 0.80 to 0.90, and so forth, could be the objective. The curves illustrated by Twisdale et al., for the limited range of parameters analyzed, suggest that a 50 % or better improvement can be achieved by providing impact protection from a 4100 g (9 lb) 2 by 4 travelling at 15.24 m/s (50 f/s). This is of the same order of magnitude included in the Australian, SBCCI, Florida, and Texas standards.

X2.3.6 Thus, the proposed specification can be justified on the basis of the relative improvement approach and its relation to previous research and antecedents. It can be further refined as more analytical information is developed.

X3. ASSEMBLY ELEVATION ABOVE THE GROUND

X3.1 Section 6.1 of this specification establishes assembly elevation above the ground as one of three parameters to be used in the selection of an applicable missile. Unless otherwise specified, Table 3 is to be used. Table 3 uses two elevation categories: ≤ 9.1 and >9.1 m (30 and 30 ft). Various 2 by 4 in. lumber (large) missiles representative of ground-level debris

and structural debris are specified in the former (≤ 9.1 m (30 ft)). 2 g steel balls (small missiles) representative of roof gravel are specified in the latter (>9.1 m (30 ft)). The assembly elevation subject to large missiles may be increased by the specifying authority where it determines that the assembly is exposed to structural debris from adjacent structures.

REFERENCES

- (1) "Section 2315 Impact Tests for Windborne Debris," South Florida Building Code – Dade County Edition, Metro Dade County, Miami, FL, 1994, pp. 23-33 – 23-38.
- (2) "Section 2315 Impact Tests for Windborne Debris and Section 2316 Impact Test Procedures," South Florida Building Code – Broward County Edition, Broward County Board of Rules and Appeals, Ft. Lauderdale, FL, 1994, pp. 23-24 – 23-21.
- (3) *SBCCI Test Standard for Determining Impact Resistance from Windborne Debris*, Southern Building Code Congress International, Inc., 900 Montclair Road, Birmingham, AL 35213-1206, 1994.
- (4) *Building Code for Windstorm Resistant Construction*, Texas Department of Insurance, 33 Guadalupe Street, Austin, TX 78714-9104, 1997.
- (5) Twisdale, L.A., Vickery, P.J., and Steckley, A.C., *Analysis of Hurricane Windborne Debris Impact Risk for Residential Structures*, Applied Research Associates, Inc., Raleigh, NC, March 1996.
- (6) Standard Australia, *Australian Standard SAA Loading Code, Part 2: Wind Loads*, North Sydney, New South Wales, Australia 2060.

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Least-Risk Decision Making

Safety is the primary consideration for the American Red Cross in selecting hurricane evacuation shelters. When anticipated demands for hurricane evacuation shelter spaces exceed existing capacity as defined by the preceding standards, there may be a need to utilize less preferred facilities. It is critical that shelter selection decisions be made carefully and in consultation with local emergency management and public safety officials. This process should include the following considerations:

- No hurricane evacuation shelter should be located in an evacuation zone for obvious safety reasons. All hurricane evacuation shelters should be located outside of Category 4 storm surge inundation zones. Certain exceptions may be necessary, but only if there is a high degree of confidence that the level of wind, rain, and surge activities will not surpass established shelter safety margins.
- When a potential hurricane evacuation shelter is located in a flood zone, it is important to consider its viability. By comparing elevations of sites with FIRMs, one can determine if the shelter and a major means of egress are in any danger of flooding. Zone AH (within the 100-year flood plain and puddling of 1-3 feet expected) necessitates a closer look at the use of a particular facility as a sheltering location. Zones B, C, and D may allow some flexibility. It is essential that elevations be carefully checked to avoid unnecessary problems.
- In the absence of certification or review by a structural engineer, any building selected for use as a hurricane evacuation shelter must be in compliance with all local building and fire codes. Certain exceptions may be necessary, but only after evaluation of each facility, using the aforementioned building safety criteria.
- The Red Cross uses the planning guideline of 40-square feet of space per shelter resident. During hurricane conditions, on a short-term basis, shelter space requirements may be reduced. Ideally, this requirement should be determined using no less than 15 square feet per person. Adequate space must be set aside for registration, health services, and safety and fire considerations. Disaster Health Services areas should still be planned using a 40-square feet per person calculation. On a long-term recovery basis, shelter space requirements should follow guidelines established in ARC 3041, *Mass Care: Preparedness and Operations*.

Hurricane Evacuation Shelter Selection Process

General procedures for investigating the suitability of a building or facility for use as a hurricane evacuation shelter are as follows:

- Identify viable sites. Evacuation and transportation route models must be considered.
- Complete a risk assessment on each viable site. Gather all pertinent data from SLOSH and/or SPLASH (storm surge), FIRM (flood hazard) models; determine the facility base elevation; and obtain hazardous materials information and previous studies concerning each building's suitability.
- Have a structural engineer evaluate the facility and rate its ability to withstand wind loads according to ASCE 7-98 or ANSI A58 (1982) structural design criteria.
- Inspect the facility and complete a *Red Cross Facility Survey* (ARC Form 6564) and a *Self-Inspection Work Sheet/Off Premises Liability Checklist*, in accordance with ARC 3041. Note all potential liabilities and the type of construction. Consider the facility as a whole. One weak section may seriously jeopardize the integrity of the building.

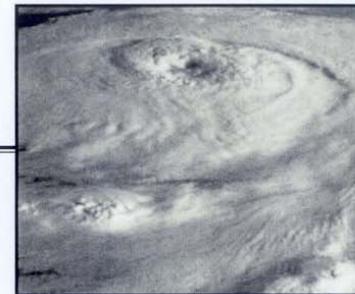
Increasing Shelter Inventory

An annual review of all approved hurricane evacuation shelters is required. Facility improvements, additions, or deterioration may change the suitability of a selected facility as a hurricane evacuation shelter. Facility enhancements may also enable previously unacceptable facilities to be used as hurricane evacuation shelters.

Work with officials, facility managers, and school districts on mitigation opportunities. Continue to advocate that the building program for new public buildings, such as schools, should include provisions to make them more resilient to possible wind damage. Suggest minor modifications of municipal, community, or school buildings, such as the addition of hurricane shutters, while buildings are being planned. Such modifications will make them useful as hurricane evacuation shelters.

Finally, add any new shelters to chapter shelter system and disaster response plans. Share shelter information with local emergency planning partners and the state lead chapter for Disaster Services for inclusion in state disaster response plans.

ARC 4496
Rev. January 2002



Standards for Hurricane Evacuation Shelter Selection

 **American
Red Cross**
Together, we can save a life

An interagency group comprised of the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, the Environmental Protection Agency and Clemson University, has developed hurricane evacuation shelter selection standards. These standards reflect the application of technical data compiled in hurricane evacuation studies, other hazard information, and research findings related to wind loads and structural problems. These standards are supplemental to information contained in ARC 3041, *Mass Care: Preparedness and Operations* concerning shelter selection.

Planning considerations for hurricane evacuation shelters involve a number of factors and require close coordination with local officials responsible for public safety. Technical information contained in Hurricane Evacuation Studies, storm surge and flood mapping, and other data can now be used to make informed decisions about the suitability of shelters.

In the experience of the American Red Cross, the majority of people evacuating because of a hurricane threat generally provide for themselves or stay with friends and relatives. However, for those who do seek public shelter, safety from the hazards associated with hurricanes must be assured. These hazards include—

- Surge inundation.
- Rainfall flooding.
- High winds.
- Hazardous materials.

The following standards address the risks associated with each of these hurricane-associated hazards.

Surge Inundation

In general, hurricane evacuation shelters should not be located in areas vulnerable to hurricane surge inundation. The National Weather Service has developed mathematical models, such as Sea, Lake, and Overland Surges from Hurricanes (SLOSH) and Special Program to List Amplitudes of Surges from Hurricanes (SPLASH), that are critical in determining the potential level of surge inundation in a given area.

- Carefully review inundation maps in order to locate all hurricane evacuation shelters outside of Category 4 storm surge inundation zones.
- Avoid buildings subject to isolation by surge inundation in favor of equally suitable buildings not subject to isolation. Confirm that ground elevations for all potential shelter facilities and access routes obtained from topographic maps are accurate.
- Do not locate hurricane evacuation shelters on barrier islands.

Rainfall Flooding

Rainfall flooding must be considered in the hurricane evacuation shelter selection process. Riverine inundation areas shown on Flood Insurance Rate Maps (FIRMs), as prepared by the National Flood Insurance Program, should be reviewed. FIRMs should also be reviewed in locating shelters in inland counties.

- Locate hurricane evacuation shelters outside the 100-year floodplain.
- Avoid selecting hurricane evacuation shelters located within the 500-year floodplain.
- Avoid selecting hurricane evacuation shelters in areas likely to be isolated due to riverine inundation of roadways.
- Make sure a hurricane evacuation shelter's first floor elevation is on an equal or higher elevation than that of the base flood elevation level for the FIRM area.
- Consider the proximity of shelters to any dams and reservoirs to assess flow upon failure of containment following hurricane-related flooding.

High Winds

Consideration of any facility for use as a hurricane evacuation shelter must take into account wind hazards. Both design and construction problems may preclude a facility from being used as a shelter. Local building codes are frequently inadequate for higher wind speeds.

- If possible, select buildings that a structural engineer has certified as being capable of withstanding wind loads according to ASCE (American Society of Engineers) 7-98 or ANSI (American National Standards Institute) A58 (1982) structural design criteria. Buildings must be in compliance with all local building and fire codes.
- Failing a certification (see above), request a structural engineer to rank the proposed hurricane evacuation shelters based on his or her knowledge and the criteria contained in these guidelines.
- Avoid uncertified buildings of the following types:
 - Buildings with long or open roof spans longer than 40 feet.
 - Unreinforced masonry buildings.
 - Pre-engineered (steel pre-fabricated) buildings built before the mid-1980s.
 - Buildings that will be exposed to the full force of hurricane winds.
 - Buildings with flat roofs or built with lightweight materials.
- Give preference to the following:
 - Buildings with 10°-30° pitched, hipped roofs; or with heavy concrete roofs.
 - Buildings no more than 60 feet high.
 - Buildings in sheltered areas (protected from strong winds).
 - Buildings whose access routes are not tree-lined.

Hazardous Materials

The possible impact from a spill or release of hazardous materials should be taken into account when considering any potential hurricane evacuation shelter.

All facilities manufacturing, using, or storing hazardous materials (in reportable quantities) are required to submit *Material Safety Data Sheets* (emergency and hazardous chemical inventory forms) to the Local Emergency Planning Committee (LEPC) and the local fire department. These sources can help you determine the suitability of a potential hurricane evacuation shelter or determine precautionary zones (safe distances) for facilities near potential shelters that manufacture, use or store hazardous materials.

- Facilities that store certain reportable types or quantities of hazardous materials may be inappropriate for use as hurricane evacuation shelters.
- Hurricane evacuation shelters should not be located within the ten-mile emergency planning zone (EPZ) of a nuclear power plant.
- Chapters must work with local emergency management officials to determine if hazardous materials present a concern for potential hurricane evacuation shelters.

Interior Building Safety Criteria During Hurricane Conditions

Based on storm data (e.g., arrival of gale-force winds), determine a notification procedure with local emergency managers regarding when to move the shelter population to pre-determined safer areas within the facility. Consider the following:

- Do not use rooms attached to, or immediately adjacent to, unreinforced masonry walls or buildings.
- Do not use gymnasiums, auditoriums, or other large open areas with long roof spans (longer than 40 feet) during hurricane conditions.
- Avoid areas near glass unless an adequate shutter protects the glass surface. Assume that windows and the roof will be damaged and plan accordingly.
- Use interior corridors or rooms.
- In multi-story buildings, use only the lower floors (no higher than 60 feet) and avoid corner rooms.
- Avoid any wall section that has portable or modular classrooms in close proximity, if these are used in your community.
- Avoid basements if there is any chance of flooding.

Exhibit VII Florida Building Code

423.25 Public shelter design criteria.

423.25.1 New facilities.

New educational facilities for school boards and community college boards, unless specifically exempted by the board with the written concurrence of the applicable local emergency management agency or the Department of Community Affairs (DCA), shall have appropriate core facility areas designed as enhanced hurricane protection areas (EHPAs) in compliance with this section.

Exception : Facilities located, or proposed to be located, in a Category 1, 2, or 3 evacuation zone shall not be subject to these requirements.

423.25.1.1 Enhanced hurricane protection areas (EHPA).

The EHPA areas shall provide emergency shelter and protection for people for a period of up to 8 hours during a hurricane.

423.25.1.1.1 The EHPA criteria apply only to the specific portions of (K-12) and community college educational facilities that are designated as EHPAs.

423.25.1.2 The EHPAs and related spaces shall serve the primary educational or auxiliary use during non-shelter occupancy.

423.25.2 Site.

Factors such as low evacuation demand, size, location, accessibility and storm surge may be considered by the board, with written concurrence of the local emergency management agency or the DCA, in exempting a particular facility.

423.25.2.1 Emergency access.

EHPAs shall have at least one route for emergency vehicle access. The emergency route shall be above the 100-year floodplain. This requirement may be waived by the board, with concurrence of the local emergency management agency or the DCA.

423.25.2.2 Landscaping.

Landscaping around the EHPAs shall be designed to preserve safety and emergency access. Trees shall not conflict with the functioning of overhead or underground utility lines, or cause laydown or impact hazard to the building envelope.

423.25.2.3 Parking.

During an emergency condition, vehicle parking shall be prohibited within 50 feet (15 240 mm) of an EHPA. Designated EHPA parking areas may be unpaved.

423.25.2.4 Signage.

Floor plans of the facility, indicating EHPAs, shall be mounted in the emergency manager's office/area.

423.25.3 Design.

EHPAs may be above or below ground and may have more than one story, provided the design satisfies the wind load and missile impact criteria. Modular and open-plan buildings may serve as EHPAs provided the design satisfies the wind load and missile impact criteria.

423.25.3.1 Excluded spaces.

Spaces such as mechanical and electrical rooms, storage rooms, open corridors, kitchens, science rooms and labs, vocational shop areas and labs, computer rooms, attic and crawl spaces, shall not be used as EHPAs.

423.25.3.2 Capacity.

Fifty percent of the net square feet of a designated educational facility shall be constructed as EHPAs. The net square feet shall be determined by subtracting from the gross square feet those spaces, such as mechanical and electrical rooms, storage rooms, open corridors, kitchens, science rooms and labs, vocational shop areas and labs, computer rooms, attic and crawl spaces that shall not be used as EHPAs. The board, with concurrence of the applicable local emergency management agency or DCA, may adjust this requirement if it is determined to be in its best interest. The capacity of an EHPA shall be calculated at 20 square feet (2 m²) per occupant (adults and children five years or older).

423.25.3.3 Toilets.

Toilet and hand washing facilities should be located within the EHPAs and provided at one toilet and one sink per 40 occupants. These required toilet and hand-washing facilities are not in addition to those required for normal school occupancy and shall be included in the overall facility fixture count.

423.25.3.3.1 Support systems for the toilets, e.g., bladders, portable toilets, water storage tanks, etc., shall be capable of supplying water and containing waste, for the designed capacity of the EHPAs.

423.25.3.3.2 Plumbing and valve systems of "normal" toilets within the EHPAs may be designed for conversion to emergency operation to meet the required demand.

423.25.3.4 Food service.

Where feasible, include counter tops for food distribution functions in the EHPAs.

423.25.3.5 Manager's office.

An administration office normally used by a school administrator shall be identified as the EHPA manager's office and shall be located within the EHPA. The office shall have provisions for standby power, lighting, communications, main fire alarm control panel and storage for the manager's equipment.

423.25.4 Structural standard for wind loads.

At a minimum, EHPAs shall be designed for wind loads in accordance with ASCE 7, Minimum Design Loads for Buildings and Other Structures, Category III (Essential Buildings) . Openings shall withstand the impact of wind-borne debris missiles in accordance with the impact and cyclic loading criteria per SBC/SSTD 12. Based on a research document, Emergency Shelter Design Criteria for Educational Facilities , by the University of Florida for the DOE, it is highly recommended by the department that the shelter be designed using the map wind speed plus 40 mph, with an importance factor of 1.0.

423.25.4.1 Missile impact criteria.

The building enclosure, including walls, roofs, glazed openings, louvers and doors, shall not be perforated or penetrated by a flying object. For walls and roofs, the missile criteria is as provided in SBC/SSTD 12.

423.25.4.1.1 Materials used for walls, roofs, windows, louvers, and doors shall be certified for resistance to missile impact criteria.

423.25.4.1.2 The glazed openings or permanent protective systems over glazed openings shall be designed for cyclic loading.

423.25.4.2 Roofs.

Roof decks shall be cast-in-place 4-inch (102 mm) or more, normal weight concrete. Concrete decks shall be waterproof. Systems other than cast-in-place concrete shall have adequate bearing, anchorage against wind uplift, diaphragm action, and resistance to rain that are equivalent to a cast-in-place system.

Exception : Structural precast concrete roofs, composite metal decks with normal weight concrete roofs, or other systems and materials that meet the wind load and missile impact criteria may be used.

423.25.4.2.1 Light weight concrete or insulating concrete may be used on roof decks of EHPAs provided the roof decks are at least 4-inch (102 mm) cast-in-place normal weight concrete or other structural systems of equivalent strength.

423.25.4.2.2 Roof openings (e.g., HVAC fans, ducts, skylights) shall be designed to meet the wind load and missile impact criteria.

423.25.4.2.3 Roof coverings shall be specified and designed according to the latest ASTM and Factory Mutual Standards for materials and wind uplift forces. Roofs shall be inspected by a licensed engineer/architect and a representative of the roofing manufacturer.

423.25.4.2.4 Roofs shall have adequate slope and drains sized for normal use and shall have emergency overflow scuppers which will accommodate a 2-inch -per-hour (51 mm) rain for 6 hours.

423.25.4.2.5 Parapets shall satisfy the wind load and missile impact criteria; roof overhangs shall resist uplift forces.

423.25.4.3 Windows.

All unprotected window assemblies and their anchoring systems shall be designed and installed to meet the wind load and missile impact criteria.

423.25.4.3.1 Windows may be provided with permanent protective systems, provided the protective system is designed and installed to meet the wind load and missile impact criteria and completely covers the window assembly and anchoring system.

423.25.4.3.2 EHPAs without windows shall have mechanical ventilation systems.

423.25.4.4 Doors.

All exterior and interior doors subject to possible wind exposure and/or missile impact shall have doors, frames, anchoring devices, and vision panels designed and installed to resist the wind load and missile impact criteria or such doors, frames, anchoring devices, and vision panels shall be covered with permanent protective systems designed and installed to resist the wind load and missile impact criteria.

423.25.4.5 Exterior envelope.

The exterior envelope, louvers over air intakes and vents, and gooseneck type intakes and vents of EHPAs shall be designed and installed to meet the wind load and missile impact criteria.

423.25.4.5.1 HVAC equipment mounted on roofs and anchoring systems shall be designed and installed to meet the wind load criteria.

423.25.4.5.2 Roof mounted HVAC equipment shall have a 12-inch-high (305 mm) curb around the roof opening and be designed to prevent the entry of rain water.

423.25.4.6 Foundations and floor slabs.

Foundations shall be designed to resist all appropriate loads and load combinations, including overturning moments due to wind. The floor elevation and necessary life safety and other emergency support systems of EHPAs shall be elevated above the maximum storm surge inundation elevation associated with a Category 4 hurricane event. Storm surge elevations shall be identified by the most current edition of the regional Sea Lake and Overland Surges from Hurricanes (SLOSH) studies and atlases.

423.25.5 Electrical and standby emergency power system.

The EHPA shall be provided with a standby emergency electrical power system, per Chapter [27](#), NFPA 70 Articles 700 and 701, which shall have the capability of being connected to a backup generator or other optional power source. Where economically feasible, an equivalent photovoltaic system may be provided. The EHPA's emergency systems includes, but are not limited to: (1) an emergency lighting system, (2) illuminated exit signs, (3) fire protection system(s), alarm (campus wide) and sprinkler, and (4) minimum ventilation for health/safety purposes. The fire alarm panel shall be located in the EHPA manager's office. A remote annunciator panel shall be located in or adjacent to the school administrator's office. When generators are installed, the facility housing the generator, permanent or portable, shall be an enclosed area designed to protect the generators from wind and missile impact. Air intakes and exhausts shall be designed and installed to meet the wind load and missile impact criteria. Generators hardened by the manufacturer to withstand the area's design wind and missile impact criteria shall be exempt from the enclosed area criteria requirement.

423.25.5.1 EHPA lighting.

Emergency lighting shall be provided within the EHPA area, EHPA manager's office, toilet rooms, main electrical room and generator spaces and shall be at least 10 footcandles (100 lux) of general illumination, which can be reduced to 1/2 footcandle (5 lux) in the sleeping areas during the night.

423.25.5.2 Optional standby circuits.

Additional nonlife safety systems, as defined by Chapter [27](#), NFPA 70 Article 702 (optional standby circuits), may be supplied power, if available, by the Standby Emergency Power System. These systems shall be connected to the Standby Emergency Power System via an electrical subpanel to the Standby Electrical Power System's main electrical panel. This will allow selective or total load shedding of power if required. The fire alarm, emergency lighting and illuminated exit signs throughout the entire campus shall receive first priority to power provided by the Standby Emergency Power System per Chapter [27](#), NFPA 70 Article 700. The systems listed are not all encompassing but are in order of priority. Local officials may request additional non-life safety systems they deem necessary for health, welfare and safety of the public during occupancy:

1. Remainder of the school's campus security lighting (building and site).
2. Additional ventilation systems within the EHPA, including heat.
3. Intercom system.
4. Food storage equipment.
5. Additional electric receptacles, other than those required by Section [423.25.5.3](#).

423.25.5.3 Receptacle outlets.

A minimum of four electrical outlets, served with power from the standby circuits, shall be provided in the EHPA manager's office.

423.25.6 Inspections.

EHPAs shall be considered "threshold buildings" in accordance with Section 553.71(7), Florida Statutes, and shall comply with Sections 553.79(5), 553.79(7), and 553.79(8), Florida Statutes.

423.25.6.1 Construction of EHPAs shall be inspected during the construction process by certified building code inspectors or the design architect/engineer(s) certified pursuant to Part XII Chapter 468, Florida Statutes and threshold inspectors for compliance with applicable rules and laws.

423.25.6.2 The emergency electrical systems shall be inspected during the construction process by certified electrical inspector or Florida-registered professional engineers certified pursuant to Part XII Chapter 468, Florida Statutes, skilled in electrical design.

423.25.6.3 EHPAs shall be inspected and recertified for compliance with the structural requirements of this section every five years by a Florida-registered professional engineer skilled in structural design. If any structural system, as specified in this section, is damaged or replaced, the recertification shall be obtained prior to the beginning of the next hurricane season.

423.25.6.4 All shutter systems, roofs, overflow scuppers, and structural systems of EHPAs shall be inspected and maintained annually prior to hurricane season and after a major event. All emergency generators shall be inspected under load conditions including activation of the fire alarms, emergency lights as per applicable equipment codes and NFPA standards, and including mechanical systems and receptacles connected to the emergency power.

Exhibit VIII

Least-Risk Decision Making: ARC 4496 Guideline Summary			
Survey Date: _____		County: _____	
Facility Name: _____		Address: _____	
City: _____ State: _____		Zip Code: _____	
Coordinates: Latitude _____		Longitude _____	
CRITERIA	PREFERRED	MARGINAL	NEEDS FURTHER INVESTIGATION OR MITIGATION
1. Storm Surge Inundation/SLOSH			
2. Rainfall Flooding/ Dam Consideration/ FIRM Zone			
3. Hazmat Considerations			
4. Lay-down Hazard Exposure			
5. Wind and Debris Exposure			

6. Wind Design Verification			
7. Construction Type/ Load-path Verification			
8. Building Condition			
9. Exterior Wall Construction			
10. Fenestration/ Window Protection			

11. Roof Construction/ Roof Slope			
12. Roof Open Span			
13. Roof Drainage/ Ponding			
14. Interior Safe Space			
15. Life Safety/ Emergency Power Generator			

Exhibit IX OTHER PREFERRED FEATURES AND OPERATIONAL CONSIDERATIONS

The committee has chosen to include a listing of other preferred features and operational responsibilities as a clarification of how the required shelter facility criteria is coordinated with other considerations.

Preferred (optional) features	Existing Shelters Type B	Existing Shelters Type A	Enhanced Hurricane Protection Areas Type EHPA	Essential Facilities needed for COG/COOP Type EFCOOP
Prototypical Building and Design Code	<i>Preferred systems per DAGS DPW Directive for Seismic Zone 3 Structural Design, Calendar Years of Design 1982 – 1998 or UBC Benchmark Years</i>		<i>Preferred IBC 2003 concrete, masonry, or structural steel framing</i>	
Preferred Features	<i>Buildings with 10 ° to 30 ° pitch hip anchored truss roofs or with concrete roofs</i> <i>Buildings not higher than 60 feet</i> <i>Buildings in topographically sheltered areas</i> <i>Restrooms in the shelter</i> <i>Emergency generators available</i>		<i>Enabled use as an EOC Backup Facility</i>	
Other Preferred Hazard Mitigation Considerations	<i>Use of Interior rooms in lower floors less than 60 feet high</i>		<i>Design for All-Hazards</i>	
Adjacent Hazard Mitigation	<i>No hazardous material facilities located nearby</i> <i>No unanchored light-framed portable ancillary structures nearby</i>		<i>No hazardous material facilities located nearby.</i> <i>No unanchored light-framed portable ancillary structures nearby unless shelter is designed for rollover debris impact hazards</i>	
Operational Responsibilities of the ARC	<i>24/7 Red Cross management per ARC 3041 and as indicated in the State and County Emergency Operations Plans</i> <i>Communications to ARC and EOC</i> <i>First Aid Kits / Flashlights AM/FM Radio</i> <i>Management of the operational transition from a short-term hurricane refuge to congregate care shelter</i>			
Essential Items that the Occupants should bring to the shelter	<i>1 gal potable water per person per day (except for EFCOOP which has provisions for water supply)</i> <i>Personal items carry-on bag with:</i> <i>Family needs, such as 2-week supply of daily prescription medications, a 3-day supply of non-perishable food and any special dietary foods, can opener, infant formula and diapers,</i> <i>Prescription eyewear, and personal hygiene items such as waterless cleaner, toothbrush/toothpaste, toilet paper roll,</i> <i>List of any required Medications/special medical information/Medical Care Directives/health insurance card, Personal ID's and other important documents</i> <i>First Aid Kit</i> <i>Flashlights, batteries, and spare bulbs, portable radio with spare batteries,</i> <i>Change of clothes, towel</i> <i>Pillows, blankets, and folding mattresses / air mattresses</i>			

Exhibit X

Saffir/Simpson Hurricane Scale Ranges with Additional Hawaii Damage Indications

Hurricane Category	Central Pressure	Sustained Winds	Peak Gust (over land) mph	Approximate Storm Surge Height (ft.)	Damage Potential Indications
	Mm of mercury at 32 degrees F				
Tropical Storm	979-1007	40-73 mph		2-3 ft	Some. Minor damage to buildings of light material. Moderate damage to banana trees, papaya trees, and most fleshy crops. Large dead limbs, ripe coconuts, many dead palm fronds, some green leaves, and small branches blown from trees.
1	980-992	74-95 mph	82-108	4-5 ft	Significant. Corrugated metal and plywood stripped from poorly constructed or termite-infested structures and may become airborne. Some damage to wood roofs. Major damage to banana trees, papaya trees, and fleshy crops. Some palm fronds torn from the crowns of most types of palm trees, many ripe coconuts blown from coconut palms. Some damage to poorly constructed signs. Wooden power poles tilt, some rotten power poles break, termite-weakened poles begin to snap. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings.
2	965-979	96-110 mph	108-130	6-8 ft	Moderate. Considerable damage to structures made of light materials. Moderate damage to houses. Exposed banana trees and papaya trees totally destroyed, 10%-20% defoliation of trees and shrubbery. Many palm fronds crimped and bent through the crown of coconut palms and several green fronds ripped from palm trees; some trees blown down. Weakened power poles snap. Considerable damage to piers; marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation from some shoreline residences and low-lying areas required.
3	945-964	111-131 mph	130-156	9-12 ft	Extensive. Extensive damage to houses and small buildings; weakly constructed and termite-weakened house heavily damaged or destroyed; buildings made of light materials destroyed; extensive damage to wooden structures. Major damage to shrubbery and trees; up to 50% of palm fronds bent or blown off; numerous ripe and many green coconuts blown off coconut palms; crowns blown off of palm trees; up to 10% of coconut palms blown down; 30%-50% defoliation of many trees and shrubs. Large trees blown down. Many wooden power poles broken or blown down; many secondary power lines downed. Air is full of light projectiles and debris; poorly constructed signs blown down. Serious coastal flooding; larger structures near coast damaged by battering waves and floating debris.
4	920-944	131-155 mph	156-191	13-18 ft	Extreme. Extreme structural damage; even well-built structures heavily damaged or destroyed; extensive damage to non-concrete failure of many roof structures, window frames and doors, especially unprotected, non-reinforced ones; well-built wooden and metal structures severely damaged or destroyed. Shrubs and trees 50%-90% defoliated; up to 75% of palm fronds bent, twisted, or blown off. Many crowns stripped from palm trees; numerous green and virtually all ripe coconuts blown from trees; severe damage to sugar cane; large trees blown down; bark stripped from trees; most standing trees are void of all but the largest branches (severely pruned), with remaining branches stubby in appearance; trunks and branches are sandblasted. Most wood poles downed/snapped; secondary and primary power lines downed. Air is full of large projectiles and debris. All signs blown down. Major damage to lower floors of structures due to flooding and battering by waves and floating debris. Major erosion of beaches.
5	< 920	> 155 mph	> 191	> 18 ft	Catastrophic. Building failures; extensive or total destruction to non-concrete residences and industrial buildings; devastating damage to roofs of buildings; total failure of non-concrete reinforced roofs. Severe damage to virtually all wooden poles; all secondary power lines and most primary power lines downed. Small buildings overturned or blown away.