Vulnerability of low-rise commercial-residential buildings in the Florida Public Hurricane Loss Model

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ABSTRACT

As a follow-up of the initial success of the Florida Public Hurricane Loss Model (FPHLM), authorities from the state of Florida decided to expand the model to include commercial-residential buildings that encompass low-rise buildings (1-3 stories) and mid-high rise buildings (4+ stories). The model is devised to provide the state of Florida with a flexible tool to assist in the projection of insured losses, hurricane disaster prevention and mitigation related efforts. This paper presents an approach to estimate the vulnerability of commercial residential low-rise buildings. It addresses the current state of the model and the work in progress including a description of exterior and interior damage estimation techniques. It also reports selected results of a Florida commercial-residential building stock survey. Mid-high rise buildings differ from the low rise buildings in dimensions, materials and behavior, and therefore they demand a different treatment. Although not the main objective of this paper, a short description of the process to estimate the exterior and interior damage in mid-high rise buildings is provided to contrast both approaches.

INTRODUCTION

There has been in the last years a rising interest in the use of catastrophe (CAT) models in the public and private sector to increase public safety, to project losses, mitigate buildings damage and regulate insurance premiums [1]. The Florida Public Hurricane Loss Model (FPHLM) commissioned by the State of Florida, is the first public model for predicting hurricane related insurance losses. In its first stage, the FPHLM assessed the insured losses to single-family residential buildings only [2-7]. As such, the model has been certified by the Florida Commission on Hurricane Loss Projection Methodology. It has recently been expanded to include commercial-residential buildings as well, which are divided into low-rise (LR) (1-3 stories) and mid-high rise (MR) (4+ stories) buildings.

The model is developed by researchers from different fields of expertise such as atmospheric science, civil engineering, actuarial and computer science. The researchers are mainly from Florida International University (FIU), Florida Institute of Technology (FIT), the University of Florida (UF), Florida State University (FSU) and the National Oceanographic and Atmospheric Administration (NOAA). The model remains open to the scientific community scrutiny and it has the potential to be expanded outside the state of Florida to other hurricane prone regions.

For buildings subjected to hurricanes, the exterior damage is primarily caused by wind, while interior damage is mainly produced by water penetration. In the FPHLM, exterior damage to the different building types is computed by carrying out Monte Carlo simulations that estimate the damage to the building envelope subjected to 3-sec peak gust wind speeds and debris missile impacts. Interior damage is assessed with the help of damage relationships that associate exterior and interior damage. These relationships are developed by integrating the information from exterior damage, the amount of wind-driven rainfall that enters the buildings and engineering judgment. Exterior and interior damages are combined and weighted to define the vulnerabilities of the different building types as a function of wind speed. This paper presents selected results of the exposure study, the description of the modules to assess exterior as well as interior damage of LR buildings and a brief account of damage estimation for MR buildings.

LOW RISE BUILDINGS SURVEY

The single-family residential building features statistics outlined in previous surveys [8,9] cannot be directly extrapolated to LR buildings which constitute a more heterogeneous group. Instead, LR buildings were surveyed throughout the state of Florida with the aid of property appraisers' databases. Based on the results of a detailed exposure study of Florida's commercial-residential building stock, which includes the prevalence of different types of exterior and interior wall materials, roof structures and covers, year built, buildings dollar exposure, number of apartments per floor, apartment areas, the predominant building types were identified.

The survey was intended to be as complete as possible in describing the features of the Florida's commercial-residential building stock. To this purpose the thirty most populated counties plus Monroe County because of its exposure, which actually account for around 90% of the population, were contacted. Twenty three out of the thirty one county property appraisers provided their commercial-residential databases in response to the data call, but it was not possible to get useful information from every available county. For instance at the date of the survey Miami-Dade and Broward did not record useful information from an engineering point of view, to characterize the LR buildings although they are planning to do so in the short term. Around 19 counties had partially useful information and only 13 had complete information on the building features investigated in the survey. Therefore caution needs to be exercised when making state-wide extrapolations from the results. Although more detailed results have been shown elsewhere [10], selected results will be shown here for illustration purposes.

EXTERIOR WALL MATERIALS

For the exterior envelope, the more prevalent materials for exterior walls are concrete block and timber as seen in Table 1. Roughly, the state average proportions are 60% concrete block and 40% timber. Yet these proportions are not uniform throughout the state. Concrete block walls prevail largely in the south. The proportion changes gradually towards the north where timber walls predominate in the Panhandle.

Table 1: LR buildings exterior walls proportions

County	Timber	Concrete Block	Other
Palm Beach	25%	71%	4%
Orange	35%	60%	5%
Pinellas	28%	72%	-
Duval	51%	49%	-
Brevard	35%	64%	-
Lee	16%	84%	-
Volusia	56%	41%	3%
Pasco	16%	84%	-
Marion	27%	73%	-
Lake	44%	55%	1%
Leon	56%	40%	4%
Alachua	30%	52%	18%
Saint Lucie	23%	75%	1%
Osceola	51%	49%	-
Bay	48%	36%	16%
Saint Johns	78%	22%	-

ROOF TYPES

The prevailing roof type for the surveyed counties is gable with 70%, while hip accounts for around 23% (Table 2). As expected, gable roofs prevail because they are easier and cheaper to build but their resistance to wind damage is not, on the average, as good as that of hip roofs.
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Table 2: LR buildings roof type proportions

County	Gable	Hip	Flat
Volusia	73%	21%	6%
Marion	69%	26%	1%
St. Lucie	67%	21%	-

YEAR BUILT

The year built is an important indicator of buildings' resistance. To choose meaningful cut-off dates, improvements in construction practices and building codes in Florida were traced. The first milestone occurred during the 1970's construction boom (see Figure 1) when the state of Florida required all counties to adopt and enforce some of the state approved model codes [11]. In 1982, the Standard Building Code (SBC) adopted the Main Wind Force Resisting Sytem (MWFRS) and Component & Claddings (C&C) approach used today [12]. In addition, as reported by Artiles [12], by mid 1980's, the use of clips became relatively standard state-wide. For the survey the cut-off date of 1983/1984 was selected. After Hurricane Andrew struck in 1992 the use of rated shingles, resistant garage doors as well as other improvements became common all over the state [12]. Thus 1992/1993 is taken as another cut off date. Finally in 2001, Florida adopted the unified Florida Building Code (FBC) similar to the International Building Code, and incorporating the South Florida Building Code in the so-called High Wind Velocity Zone . The FBC became effective on March 2002, so the final cut-off date is 2002/2003.

The survey shows that most of the actual LR building stock in the surveyed counties dates from the 70's and the 80's and then the proportion decreases (Figure 1). See Table 3 for the details county by county.

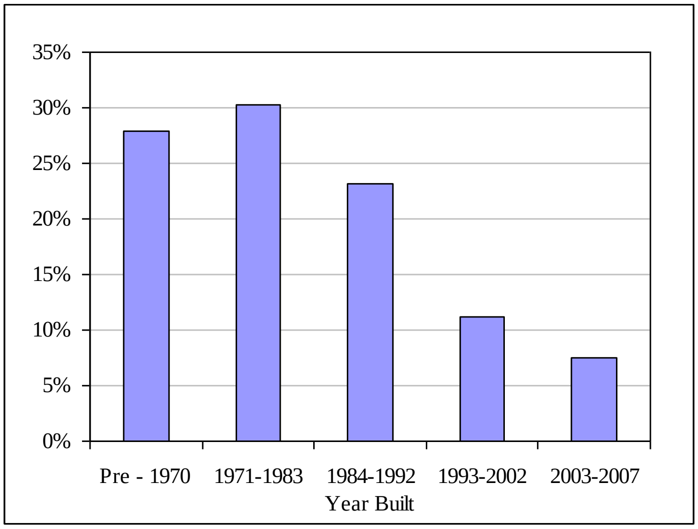

Figure 1: LR buildings average year built for surveyed counties

Table 3: LR buildings year built detail

County	Pre - 1970	1971-1983	1984-1992	1993-2002	2003-2007
Palm Beach	31%	35%	24%	7%	3%
Hillsborough	27%	36%	22%	10%	5%
Orange	20%	29%	38%	10%	3%
Pinellas	58%	29%	9%	2%	2%
Duval	85%	8%	7%	0%	0%
Brevard	25%	27%	35%	10%	3%
Polk	33%	43%	18%	3%	3%
Lee	12%	30%	19%	14%	25%
Volusia	19%	31%	34%	8%	8%
Pasco	24%	56%	12%	1%	7%
Seminole	13%	35%	32%	18%	2%
Collier	14%	9%	21%	49%	7%
Marion	4%	33%	41%	13%	9%
Alachua	17%	48%	18%	13%	4%
Saint Lucie	46%	30%	11%	9%	4%
Osceola	12%	24%	38%	18%	8%
Bay	15%	37%	27%	15%	6%
Saint Johns	13%	11%	24%	9%	43%
Monroe	61%	24%	8%	5%	2%

DOLLAR EXPOSURE

The number of buildings versus their dollar exposure is a valuable parameter to evaluate the relative importance of different building types in the building stock. Figure 2 shows that while 1-story low rise buildings prevail in absolute numbers, 2-stories have a higher dollar value. Also, 1-story buildings have a comparable dollar value with 3-stories buildings. Hence it is important that all three cases are appropriately considered in the simulations.

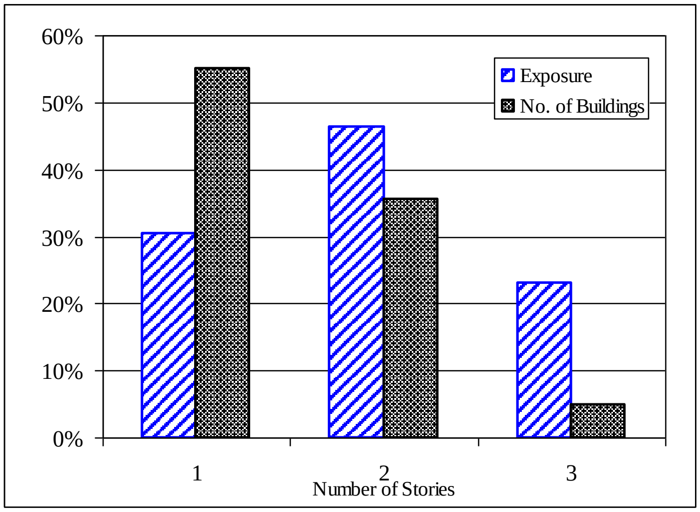

Figure 2: LR buildings' exposure value compared to the number of buildings in 4 counties (Brevard, Lee, Palm Beach and Pinellas)

BUILDING TYPES DEFINITION

The main objective of the building survey is to identify the building types that represent most of the LR building stock and to quantify the contribution of the different constructive features so that engineering models can be built and tested to assess damage. A classification that includes wall type, roof cover and roof type, type of opening protection, number of stories, and year built is shown in Table 4. The combination of the different features in Table 4 accounts for the total number of options to be modeled.

The engineering team of the FPHLM assigned to each building type 3 different strength levels: strong, medium, or weak. The strength definition is based on a combination of features such as roof to wall connections, roof sheathing nailing, roof cover, and opening protection. These features are related to year built and corresponding building code enforcement [12].

Table 4: LR most prevalent buildings types

Category	Wall type	Roof Cover	Roof Type
Main Building types	CB	Shingles	Gable
	CB	Shingles	Hip
	Wood	Shingles	Gable
	Wood	Shingles	Hip
Windows	Shuttered / Impact-resisting / Not impact-resisting		
No. of Stories	1 / 2 / 3		
Building strength	Strong, Medium, Weak		
Alternative Roof Cover	Metal or Tiles		

The building types in Table 4 include most of the existing types, but certainly not all of them. An insurance portfolio could include buildings types that do not match any of the main building types. For instance, shed and flat roof types, membrane and gravel roof covers are not very frequent for commercial residential LR buildings. Generic vulnerability curves of the cases not specifically considered as main building types are currently being approximated by combining the known building types' vulnerabilities weighted by the respective proportions in which they participate in the building stock. See Equation 1.

$$V_O = aV_1 + bV_2 + cV_3 + \ldots + nV_n \qquad (1)$$

where *a*, *b*, *c*, *n* and V_1, V_2, …, V_n are the percentages of participation in the building stock and the vulnerability curves of building types 1, 2, 3, …n respectively.

LOW-RISE BUILDINGS VULNERABILITY

Single-family residential and LR buildings have similar roof types, roof covers, wall types etc. Furthermore, the proportions of the different roof types, exterior wall materials, interior walls, flooring and ceiling are sometimes similar for LR buildings and single-family buildings [8, 10]. Consequently, the engineering team of the FPHLM, which already has experience modeling single-family buildings [2-5,13,14], concluded that an approach similar to the one used for single-family homes is applicable to the case of the LR buildings, with some modifications.

Building vulnerability correlates building damage and hurricane wind speed. In the LR model, the vulnerability is expressed by a matrix whose columns sorted for increasing wind speeds, represent the joint-probability density function $P(D_i|V_j)$ of building damage D_i, defined as replacement cost ratio, for given wind speed V_j. The rows of the matrix correspond to increasing damage. Damage ratios damage D_i, increase in 2% increments up to 20%, and then in 4% increments up to 100%, on the other hand the wind speed ranges from 50 to 250 mph in 5 mph increments. The information inside the vulnerability matrix is consolidated into a vulnerability curve by computing the mean damage at each wind speed interval as:

$$\overline{D}(V_j) = \sum_i D_i P\left(D_i \middle| V_j\right) \quad \text{with} \quad j = 50,55,\ldots250;\ i = 2\%,\ 4\%,\ \ldots,100\% \qquad (2)$$

where $\overline{D}(V_j)$ is the vulnerability curve whose elements are mean damages as a function of the increasing wind speed intervals. See Figure 3.

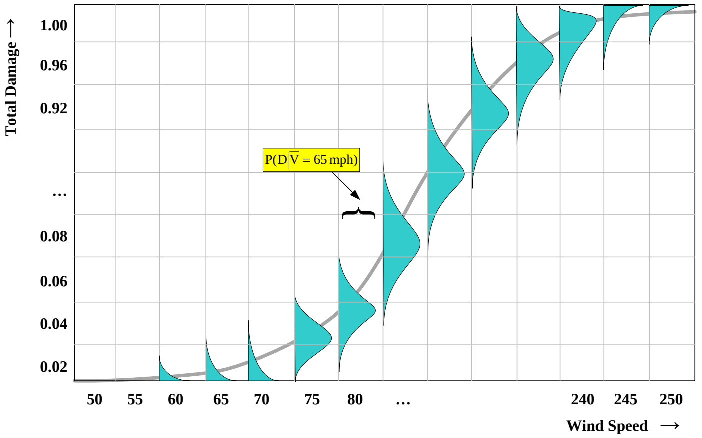

Figure 3: Vulnerability matrix layout

The definition of building vulnerability in terms of damage ratios involves steps such as exterior damage assessment through Monte Carlo simulations, cost analysis, interior and utilities damage estimates from exterior damage and the final aggregation of the damage for all components. The damage is defined as the ratio of the aggregated damage repair cost, including handling and removal costs, over the cost of the entire building.

The process to estimate the vulnerability for a particular building type is illustrated in Figure 4. Given a particular building type, a previously calculated damage array that expresses the exterior damage in the envelope (including roof) is loaded. This array is the result of thousands of Monte Carlo simulations. The damage array has the exterior damage information organized for each wind speed and wind direction. For a particular wind speed and wind direction, each component's physical damage is normalized to a percentage value. For instance, the number of damaged doors, windows, and sliders is divided by the total number of the corresponding opening; collapsed trusses are divided over the total number of trusses and so forth. The cost of the damage is then assessed.

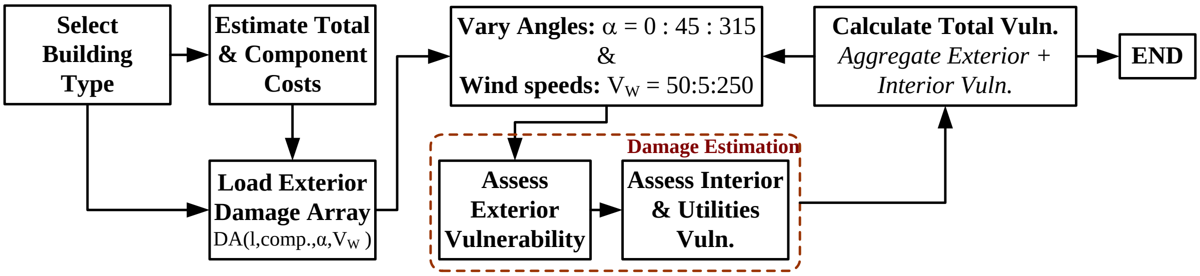

Figure 4: Vulnerability estimation process. (In the damage array, "l"= simulation run number; comp.= component type, e.g. window; α= angles, i.e. wind direction; V_W= wind speeds)

To assess interior damage, a set of curves that express interior damage as a function of exterior damage is currently under development. They are computed by estimating the amount of water that enters into the building through the breaches in the envelope. This set of empirical relationships, to be discussed in some more detail in the next section, is applied to derive interior damage and utilities damage as a function of exterior damage, for each of the thousands of simulations. As in the case of exterior damage, a cost is assigned accordingly to damaged interior components and utilities. The damage ratio (DR) as a function of wind speed for the components, interior and utilities is calculated by adding the corresponding costs of damaged components plus damaged interior plus damaged utilities divided over the overall building cost that is contingent upon the type and size of the building. See Equation 3.

$$DR(V_w, \alpha) = \frac{1}{TC}\left[\sum_k D_k^C\left(C_k^C\right) + D^I I^C + D^U U^C\right] \qquad (3)$$

where $DR(V_W, \alpha)$ is the damage ratio as a function of the wind speed V_W and the wind angle α, TC is the total cost, D_k^C, D^I, D^U denote physical damage to exterior component "k", interior and utilities, and C_k^C,I^C, U^C are the k-th exterior component, interior and utilities repair costs. All the costs include material, labor, and disposal of damaged elements, as needed.

Derivation of the probability distribution functions of damage at each wind speed interval is the final step of the process. At this point, for each wind speed interval, the cells of the vulnerability matrices are computed as the summation of specific damage ratios for all wind directions divided by the total number of simulations at that particular wind speed interval. See an example of vulnerability curve in Figure 5.

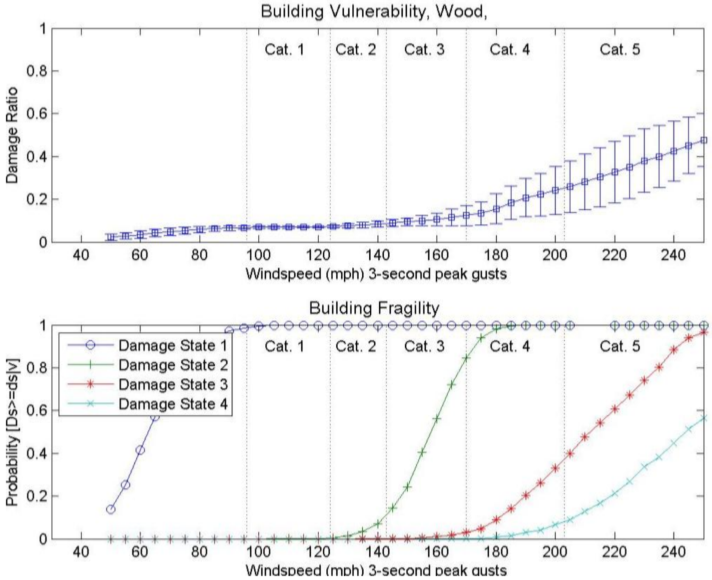

Figure 5: Sample vulnerability and fragility curves for a gable, timber, 1-story strong resistance building with shingles.

EXTERIOR DAMAGE ASSESSMENT

A short account of the exterior damage assessment is provided here. For a thorough explanation of the approach see [15]. Buildings' exterior damage to each type is assessed through Monte Carlo simulations. Each building model is subjected to 3-sec gust wind speeds that increase from 50 to 250 mph with 5 mph increments. The wind source is oriented around the perimeter of the building model from 0 degree to 315 in 45 degrees increments. The model is thus tested thousands of times for all possible angles at every wind speed. In each case, the strength of each building types' components are randomly assigned by means of proper probability density functions which are calibrated from tests carried out by FPHLM experts at the University of Florida and from manufacturers' information, or any other valid source of information. The approach is based on a cascade effect concept i.e. if on a particular run of the simulation a given component fails; the algorithm redistributes all internal and external pressures. When the redistribution is complete, the algorithm records the damage magnitude in each component and a new run is triggered. The model does not record the accumulation of damage from one simulation to the next. The process repeats itself until the predetermined number of runs, wind speeds and wind directions are fulfilled. The information is recorded in a damage array of 4 dimensions as shown in equation 4.

$$DA = DA(\mathrm{Runs}, \mathrm{Components}, \mathrm{Winds}, \mathrm{Angles}) \in (x \cdot 10^{3}, 32, 41, 8) \qquad (4)$$

The components listed in each of the 32 columns correspond to: roof cover, roof sheathing, overhang, roof-to-wall connections, gable end trusses, gable end wall cover, gable end sheathing, wall cover, wall sheathing, windows failed from wind pressure, windows failed from debris impact and more components times the corresponding number of stories. A damage array is produced for each building type in Table 4, from which the building vulnerability is derived as described previously.

Cost Analysis

The cost information to compute damage ratios is based on a detailed cost analysis which includes the costs of material, labor, and contractor's overhead and profit (O&P) for each building component. Since material qualities and labor efficiency vary, the costs of representative components' are averaged. On the other hand, the total costs of entire buildings are computed by analyzing the square foot price of the typical buildings for different base areas, so that for all given building types there are cost functions that depend on the area of the building. Thus the LR model has a cost-estimation structure suitable to most building types and sizes.

The fluctuations in costs, inflation, and building depreciation do not compel quarterly or yearly adjustments because the ratio between components and total building cost is expected to remain stable. Nonetheless this assumption is evaluated on a periodic basis to make corrections if necessary.

The Florida Building Code (FBC) prescribes that when the damage to certain components exceeds given thresholds then the entire component needs to be replaced and brought up to code. For instance, inside the wind borne debris region or the high velocity wind zone, if the roof has more than 25% damage, the whole roof must be brought up to code; also if 50% of the windows has been damaged then all windows needs to be replaced with new windows that meet the current code. Other thresholds apply outside the aforementioned regions. The model incorporates these provisions so that if any of the thresholds is exceeded, then the cost to replace the whole component is computed.

WORK IN PROGRESS

INTERIOR-EXTERIOR RELATIONSHIPS

As mentioned before, it is not possible to estimate the interior damage along with exterior damage at the same time because they both have different causes; exterior damage is caused by wind pressure and debris impacts and is estimated through the corresponding Monte Carlo simulations, while interior damage is mainly caused by water intrusion. The estimation of interior damage is performed through a set of relationships which correlate the percent damage in the *i*-th exterior component with the resulting interior damage due to water ingress. In the residential single-family building model of the FPHLM the interior-exterior relationships are currently based mainly on engineering judgment. A new approach that considers explicitly the effect of water intrusion on interior damage, the vertical water propagation, and the information provided in the exterior damage matrices is desired. Because there is a great deal of uncertainty in the way that water ingresses inside a building, a Monte Carlo approach to reproduce the physics of the phenomenon seems convenient. The rationale for the new approach is as follows.

First, estimates of vertical rainfall rate and rain duration in hurricanes can be obtained from probability distribution functions. Second, a simplified method is currently under development to estimate the relationship between the wind speed, rainfall rate and the amount of rain that hits the building envelope, i.e. the impinging rain. **Error! Reference source not found.** shows a qualitative sample of a simplified method for converting vertical rainfall rate to horizontal rainfall rate. This simplified approach does not take into consideration the curved trajectory that a particle undergoes under wind speed and uses raindrop size distributions and vertical rainfall rates I, [16,17] to calculate the raindrop distribution for different rainfall rates and the rain admittance factors [18,19]. Thus the rainfall rate impinging on a building face is estimated with curves similar to **Error! Reference source not found.** for each wind speed and vertical rainfall rate.

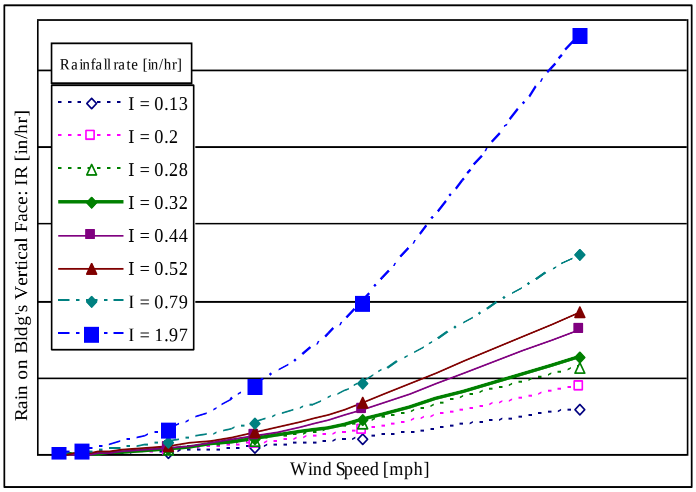

Figure 6: Wind-driven horizontal rain. I is the rainfall rate in inches/hour

Third, for each given wind speed and wind direction there is thousands of simulations of the extent of damage to all external components. Then, after converting vertical rainfall rate to horizontal rainfall rate the amount of water that passes through the breach size of each external envelope component is computed by multiplying breach area times horizontal rainfall times rain duration. The total amount of water that enters the building is estimated by adding up the water that enters through all breaches of the building envelope corresponding to the following components: roof cover, roof sheathing, truss toppling, gable cover, gable sheathing, overhang, wall cover, wall sheathing, windows, entry doors and sliding doors.

Fourth, a relationship is necessary to transform water penetration, and water propagation into interior damage. To derive such a relationship the authors are studying the records of damage to certain buildings in Melbourne, Florida, from hurricanes Charley, Frances and Wilma. It is expected that additional data will be available for analysis in the near future.

The relationships ponder damage at low and high wind speeds. Hurricane wind speed determines the path through which water will find its way into the building. At low wind speeds, water enters through wall cracks, wall penetrations, ventilations, unsealed windows, door thresholds, soffits, etc. At high wind speeds water enters through the breaches in the envelope due to wind effects and missile impact. The relationships are built by simulating the interaction between the envelope damage, the wind speed, rainfall rate and duration, and existing buildings defects, combined with statistical relationships between water contents and interior damage and calibrated with engineering judgment and actual or experimental damage data. A set of interior vulnerability curves can be produced for each building type.

LR BUILDINGS WEIGHTING SCHEME FOR MISSING INFORMATION

Insurance portfolio files do not have all the information necessary to select the right vulnerability curve for a particular building type. For example, usually, insurance portfolios do not specify roof type or opening protection type (shutters, impact resisting, not impact resisting). If this is the case, neither of the vulnerability curves prepared for these specific building characteristics can be selected. Therefore in addition to the vulnerability curves (Figure 5) of the main building types as listed in Table 4, weighted vulnerability curves that consolidate roof types and window cases are also needed in order to account for an average vulnerability for given wall type, number of stories and building strength.

The proposed weighting scheme consolidates desired building type vulnerabilities into a weighted vulnerability by combining each of them according to their respective percentage of participation into the building population. The percentage of participation is retrieved from the survey statistics for each building type and is expressed with a matrix of the form

$$W_S(\#\ \text{Stories},\ \text{Wall type}) = \begin{bmatrix} P(\text{Shutter}\,|\,\text{Gable}) & P(\text{no Shutter}\,|\,\text{Gable}) \\ P(\text{Shutter}\,|\,\text{Hip}) & P(\text{no Shutter}\,|\,\text{Hip}) \\ P(\text{Shutter}\,|\,\text{Other}) & P(\text{no Shutter}\,|\,\text{Other}) \end{bmatrix}$$

where W_S is the weighting factor matrix for given number of stories and wall type, and P(Protection | Roof type) stands for the conditional probability of each case. The weighted vulnerability curve for a given wall type and number of stories is given in Equation 5

$$V^W = \sum_i V_{\text{Type } i} W_S^{\text{Type } i} \tag{5}$$

where V^W is the weighted vulnerability, $V_{\text{Type } i}$ is the vulnerability curve of type “i” and $W_S^{\text{Type } i}$ is the percentage of participation of type “i”. Thus with this procedure all possible occurrences that are not grasped with the most predominant building types can assessed with the weighted vulnerability curves.

MID/HIGH-RISES TREATMENT IN THE LOSS MODEL

A short description of the vulnerability approach for commercial-residential mid-high (MR) rise buildings is presented here. For a detailed account see [15, 20]. The LR and MR approaches to estimate the buildings’ vulnerability inside the commercial-residential module of the Florida Public Hurricane Model are different. There are many reasons that justify this separate treatment. The mid and high rise building are usually engineered structures, suffering few structural failures during a wind storm but subject to cladding and opening failures and the resultant water ingress. These buildings may remain structurally intact, but rendered uninhabitable by water penetration damage. These buildings come in many different types, shapes, height, geometry, etc. They consist of steel, reinforced concrete, timber, masonry, or a mix of these different materials. Unlike single family residential and low-rise commercial residential, it is not realistic to establish a single ‘base’ structure, as that will necessarily leave out a majority of existing mid and high rise structures. It is also difficult to come up with a reasonable mix of multiple generic ‘base’ models that will represent the vast majority of these structures. For example, just considering steel frame structures in isolation leaves open a wide variety of building shapes, many of which are ‘unique’ with the specific intent of the builder/architect. These different shapes of course lead to very different wind loading scenarios, and therefore different vulnerabilities.
Consequently the Florida Public Model has adopted a modular approach to model mid and high-rise buildings. Rather than consider a structure as a whole, the base modules are typical apartment units, with different façade treatments, divided into corner and non-corner units. The vertical location of the unit accounts for different debris hazard potential. Thus, buildings with any number of stories, and any number of units per floor can be modeled by aggregating the corresponding module vulnerability and accounting for correlation of damage among units (e.g., failure of an opening in a 5th floor unit creates problems for lower units with no failures).

The building survey showed that there is no predominant dimensional pattern or base layout for mid-high rises. As matter of fact there is a significant variability on the dimensions on base plans, number of stories, apartments per story, and apartment area. The general configuration of the building adds another source of variability. The apartments in a building can be accessed from outside (open building) and from inside (closed building). Thus in a closed building the corner apartments have two exposed walls while middle apartments have only one. In an open building the corner units have three exposed walls while middle apartments have two (Figure 7). The vulnerabilities of open and closed buildings differ.

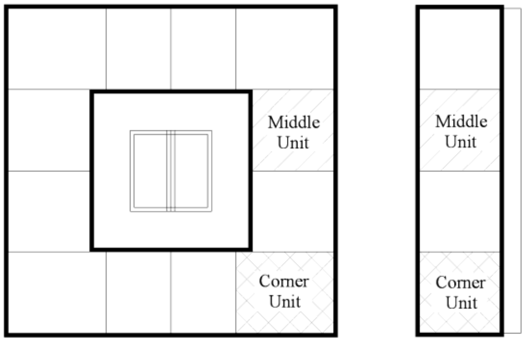

Figure 7: Closed and open building plan views with middle and corner apartment types.

Exterior damage in the apartments is assessed with Monte Carlo simulations for varying wind speeds and wind angles and an exterior damage array is produced for every apartment type. The overall building's exterior damage is computed by picking the vulnerability corresponding to all apartment types and aggregating them. On the other hand, interior damage is estimated by computing the water amount that ingress the apartments as a result of impinging rain (**Error! Reference source not found.**) and breaches in the envelope. Interior damage is aggregated for all apartments. Total damage is computed by aggregating exterior and interior damages according to the intricacies of actuarial policies.

This approach is versatile enough to grasp different buildings regardless of their configuration that includes open or closed building, number of apartments per story apartment area, number of stories and so forth.

CONCLUSIONS

This paper describes the development of vulnerabilities for commercial-residential low rise building. An overall description of the approach with an account of its main modules is presented. In addition a selection of results from a Florida's low-rise buildings survey is presented. There are many similarities, and comparable challenges between the singles family homes and low rise condo or apartment buildings, in terms of building types, and subsequent vulnerabilities.

A novel approach is being implemented to relate damage to the envelope of the building with damage to its interior and contents. The new approach is based on an estimate of water intrusion, and water propagation. Sensitive points include the estimate of vertical rain fall, rain duration, conversion of vertical rainfall into horizontal rainfall and correlation of water intrusion with interior and contents damage. Access to meteorological data, and damage and claim data are important for the validation and calibration of these interior damage vs. exterior damage relationships. This approach is more rational than the approach currently adopted in many cat models, including the single family home version of the FPHLM, and its implementation will depend should lead to more accurate loss predictions.

A short account of the approach for mid-high rise buildings was also presented to emphasize the fact that the same approach to predict losses to both, low rise and mid-high rise buildings is impractical because of the differences between both building types.

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