Review of
A Proposed Methodology for Estimating Wind Damage to Residential Slab-Only Claims Resulting from a Hurricane Impacting the Texas Coastline

Prepared by
Lance Manuel, PhD, PE

March 2, 2016

An Expert Panel provided a report summarizing their proposed methodology for estimating wind damage to residential slab-only claims resulting from a hurricane impacting the Texas coastline. This report was reviewed and a summary of comments is offered below. This peer review includes analysis of criteria, methodology, findings, and recommendations made by the Expert Panel. No raw data of any kind that were used by the Expert Panel in developing the recommended methodology were analyzed in this peer review; only the proposed use of such data was evaluated.

Scope: The Expert Panel's proposed methodology and recommendations are confined to losses to insurable property that are incurred as a result of (i) wind, (ii) waves, (iii) tidal surges, or (iv) rising waters not caused by waves or surges (which refers to general flooding).

Definitions: While these are not standard usage, the following damage state definitions are stated in the report. The terms "slab" or "slab-only" claims refer to claims following destruction of a superstructure due to forces caused by the tropical cyclone. Other "non-slab" claims refers to cases where partial buildings remain; in this case, an adjuster or engineer visits the site to determine the building damage.

The proposed methodology is presented in detail outlining the modules that deal with the hazards (wind, surge, and wave); damage estimation (including detailed presentations with examples that address demand and capacity side variables and their uncertainties for different structural component and system performance functions); and validation studies of the damage estimation methodology against post-storm field investigation and claims data. Estimation of economic losses (structure and content losses) is mentioned only very briefly in Section 8. It is the Expert Panel's recommendation that economic losses be estimated by TWIA (Texas Windstorm Insurance Association) using adjusters when necessary to determine costs associated with repair and replacement. The Expert Panel recommends that the model developed should not be used to estimate contents losses. A report generation module is presented in Section 9 which includes a very effective enumeration of the information (site-specific storm information, hazards, building vulnerability, damage) that should be archived.

On the basis of the hazard and damage estimation modules, information on time-dependent wind speeds and storm surge/wave hazards is first gathered; then, the probability of failure of various building components and systems is assessed during the storm in question. Affected areas are used to weight the failure probabilities and thus provide damage rates. Financial losses and insurance policy payouts can follow, given the percent damage estimates; report generation formalizes the documentation of the data, models, hazard and damage computation, and loss estimation.

In Section 11, the Expert Panel provides a set of detailed recommendations for TWIA. These include Pre-Storm Actions, Post-Storm Actions, and Continuing Model Validation.

Overall, the methodology and framework presented are founded on sound principles that are reflected in all of the modules individually and how they are integrated into the recommended methodology.

There is one issue that may be raised and that has to do with the computation of probabilities of failure and discussed in Section 6 and in Section 13. In an early part of the report (Section 5.4), it is stated that probability of slabbing must be estimated both by waves/surge and by wind. Then, on pg. 6-1, it is stated that, "*1. For cases where the maximum probability of collapse due to surge and waves is exceeded by the maximum probability of collapse due to wind, the structure shall be considered to have collapsed due to wind. 2. Otherwise, wind damage for computing losses shall be taken at that time when surge slabbing probabilities reach their maximum.*"

The determination of which hazard—between waves/surge and wind—is considered to have caused the failure depends heavily on computations of probability. Because this determination will undoubtedly affect how claims are dealt with, it is suggested in this peer review that the probability computations developed later in Section 6 and illustrated with examples in Section 13 ought not to rely on unjustified assumptions and simplifications, especially if resulting probability estimates are likely to be inaccurate.

If distributions of underlying variables are known, if they can be established from the literature, or if their knowledge can be elicited from experts, there is no reason why the computation of probabilities needs to be based on the FOSM-MV (First-Order Second-Moment – Mean Value) approach, which relies on a Taylor series expansion of the performance function (limit state function) about the mean values of all variables and retains only first-order terms. This method effectively linearizes the performance function and then assumes that the linearized function has a normal distribution whose mean and standard deviation are easily derived using only information about the function (at the mean values of all variables) and its gradients (also at the mean). Even more troubling is that two mechanically equivalent performance functions, $g1(X,Y) = X/Y - 1$ and $g2(X,Y) = X - Y$ (where X and Y are two random variables that can be thought of as generalized capacity and demand variables) will, in general, provide different estimates of failure probability (i.e., the FOSM-MV method is mathematically a non-invariant method for such computations). In the illustration, although both $g1(X,Y) < 0$ and $g2(X,Y) < 0$ could define "failure" when $X < Y$, the FOSM-MV approach will not yield the same failure probabilities.

Consider the "roof covering performance function" example starting on pg. 13-4.

There are seven random variables involved: C_1, C_2, R_{rc}, K_z, V, GC_p, and GC_{pi}.

Discussion on pg. 6-49 suggests that C_1 is assumed normal. This is implied by the derivation of the coefficient of variation.

While not stated explicitly in the report, both the component reduction factor, C_2, due to age and the roof covering resistance, R_{rc}, may be assumed normal.

Of the demand-side variables, one could well imagine that V follows an extreme value distribution with the same mean and COV as are used (in the example, mean = 105.22 mph and COV = 0.18). For instance, Ellingwood and Tekie (1999), a study cited in the Expert Panel report, use a Type I distribution for the 50-year maximum fastest mile wind. This is an important variable in the performance function and should be represented as accurately as possible.

The main point is that even if all the seven random variables are normal, it is not advisable to use the FOSM-MV approach to compute probabilities of failure. The algebraic combination of these variables as products, powers of 2, differences, etc. as they appear in the performance function guarantees that it will not be normal. Indeed, if one is to compute the probability of failure for any limit state, it is far more accurate and most definitely feasible computationally to use Monte Carlo simulation. In Mathcad or some similar office-friendly computational tool, the calculations are straightforward. And, as mentioned, the FOSM-MV method is a non-invariant method; different answers can arise merely from how the performance function is expressed.

It is interesting to compare the performance function statistics by the FOSM-MV approach with Monte Carlo sampling. On a notebook computer, in Mathcad, it took less than 3 seconds to carry out 100,000 Monte Carlo simulations for the "roof covering performance function" example. More importantly, in this performance function, selected only because it was the first one in Section 13-4, the correct mean value of this performance function is 1.180, not 2.999 as seen on pg. 13-5. The standard deviation of the performance function was also different—30.63 versus 30.31 on pg. 13-5. The probability of failure estimates were only slightly different for this case—0.470 versus 0.461 on pg. 13-5—but given that such estimates have a direct bearing on assessing whether a structure failed due to wind loading or not, estimates of probability should be computed without introducing further approximations than are warranted.

Note that the comparisons presented here are with all the variables assumed normal; if any variable is non-normal, differences between FOSM-MV estimates and Monte Carlo could well be greater. Also note that exhaustive checks for all the performance functions comparing Monte Carlo versus FOSM-MV were not undertaken; it is possible that larger differences in computed probability might result than was the case with the roof-covering performance function.

Indeed, the Expert Panel notes correctly in Section 6.7 in their listed limitations (Items 2 and 3) that the FOSM-MV approach results are sensitive to the specific formulation of the limit state function and that when non-normal random variables are involved, the Gaussian assumption in computing failure probabilities may be invalid.

Note that the Monte Carlo approach is not only easy to code, it is invariant, it can allow for any form of the limit state function (even a look-up table), it doesn't require gradient computations, and it can easily accommodate non-Gaussian random variables. Finally, repeating a point made before, if the ultimate determination of cause of failure hinges on relative probability of failure estimates from different hazards (wind versus waves/surge), it is suggested that the FOSM-MV approach not be the preferred one and that Monte Carlo sampling should be used instead.

In Section 11.1.2, the Expert Panel notes that candidate methods such as Monte Carlo simulation or the Rackwitz-Fiessler method may be computationally less efficient than the FOSM-MV approach. It is suggested in this peer review, however, that at least the Monte Carlo approach is definitely worth employing in calculations for reasons already stated above. The Rackwitz-Fiessler method is an improvement over FOSM-MV on two counts—from the standpoint of accuracy and because the method is invariant—but it relies on an optimization procedure and can be more difficult to program; also, like the FOSM-MV method, it relies on gradients of the performance function. Its chief advantage over FOSM-MV is that it permits the use of any distributions for the random variables involved and while it uses a first-order (linearized) version of the performance function, the linearization is about a critical point in the random variable space where failures are most likely as opposed to linearizing about the mean values of all the variables. This critical "design" point is not known a priori, it needs to be found by optimization. All things considered, the Rackwitz-Fiessler method offers some advantages in accuracy over FOSM-MV but the effort involved does not justify its use. Monte Carlo simulations, on the other hand, are trivial to program and are recommended.

Finally, a few editorial issues are noted:
Pg. 4-1, 3rd paragraph, 2nd line: Section 4 is referred to for the surge and wave hazard component. The correct reference should be to Section 5. A line later, reference is made to Section 5 for the Damage Estimation Module; the correct reference should be to Section 6.
Pg. 6-6, Eq. 5.6 should be Eq. 6.6
Pg. 6-7, Eq. 5.7 should be Eq. 6.7
Pg. 6-8: What is Equation 7 in Table 6-1? Perhaps this was meant to be Eq. 6.7? (See note above: Eq. 6.7 is likely mislabeled as Eq. 5.7)

Overall Conclusions:
1. The methodology presented is founded on sound principles that are reflected in the individual modules and in their integration into the overall framework.
2. Because probability computations are important in ascribing cause for failures to specific hazards, it is recommended that Monte Carlo simulations be employed rather the FOSM-MV approach to ensure greater accuracy, without significant additional burden or expense.