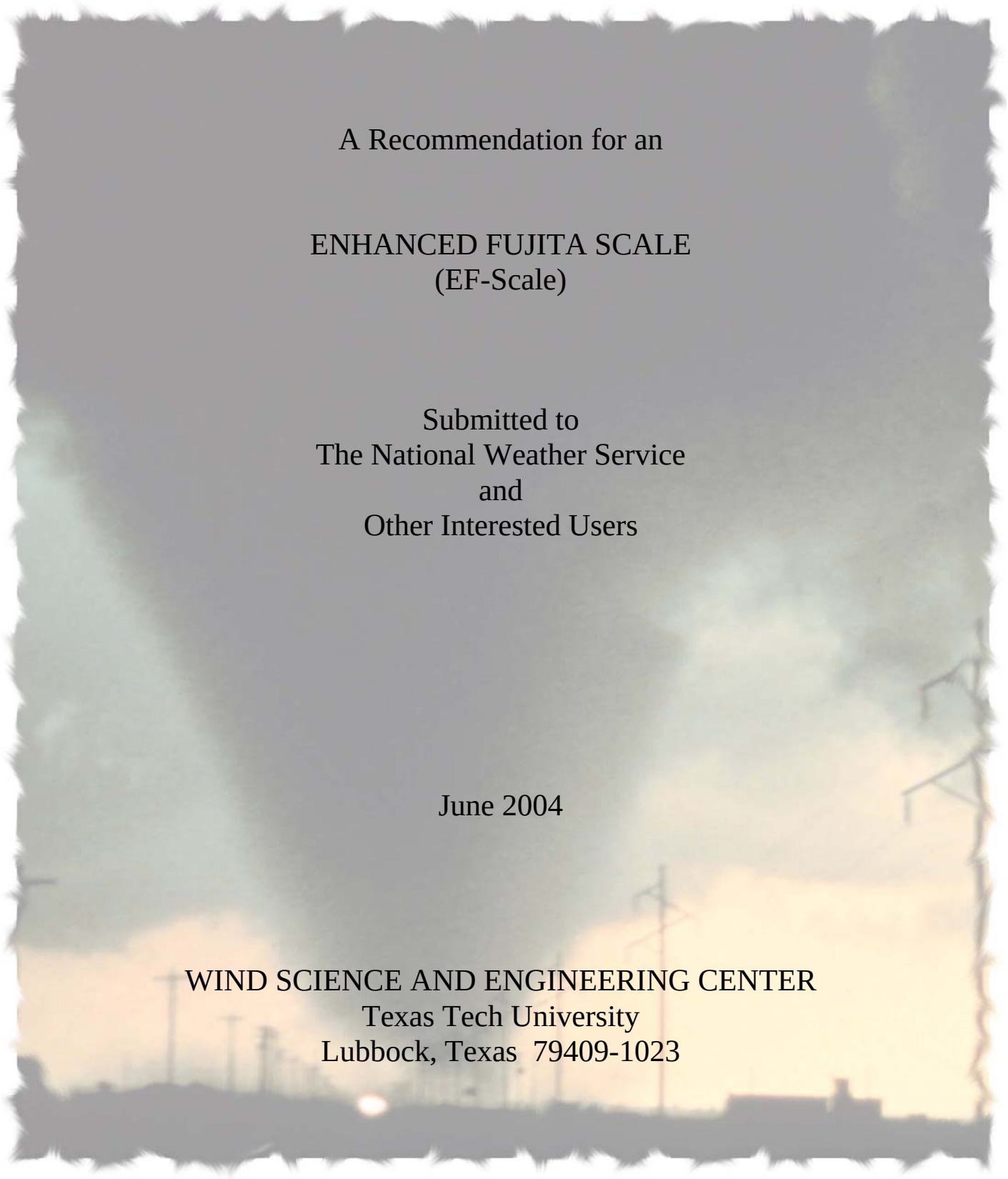

A Recommendation for an

ENHANCED FUJITA SCALE
(EF-Scale)

Submitted to
The National Weather Service
and
Other Interested Users

June 2004

WIND SCIENCE AND ENGINEERING CENTER
Texas Tech University
Lubbock, Texas 79409-1023

FOREWORD

This project is conducted under the auspices of the Wind Science and Engineering Center at Texas Tech University. Drs. James R. McDonald and Kishor C. Mehta are Co-PIs on the project. This investigation was performed under the Department of Commerce NIST/TTU Cooperative Agreement Award 70NANB8H0059. Dr. Jim St. Pierre is the project administrator, and Dr. Emil Simiu has technical oversight responsibility.

As many as forty professionals from the engineering and meteorological communities participated in the Forum in expert elicitations. These individuals willingly gave their time to enhance the Fujita scale. Their time and efforts are acknowledged by the Wind Science and Engineering Center, Texas Tech University.

For the proposed EF Scale to replace the original Fujita Scale, it must be acceptable for use by the National Weather Service and many other users. Personnel from the National Weather Service have provided valuable input to the project. Every effort is being made to gain a wide spread consensus from both the engineering and meteorological communities.

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INTRODUCTION

Dr. Ted Fujita (1971) developed the Fujita Scale to provide a method to rate the intensity of tornadoes. The intent of the scale was to distinguish between weak tornadoes and strong tornadoes. There was a need to be able to rate tornadoes in the historical database as well as future tornadoes as they occur. The meteorological and engineering communities almost immediately accepted the Fujita Scale.

The National Weather Service (NWS) applies the Fujita Scale in rating tornadoes as they occur. Dr. Fujita's group at the University of Chicago and personnel at the National Severe Storms Forecast Center (NSSFC) independently assigned Fujita Scale ratings to tornadoes in the historical records based on written descriptions of the damage. The University of Chicago database has not been kept up to date in recent years. The Storm Prediction Center (SPC) maintained the NSSFC database through 1995. Tornado records since that time are kept at the National Climatic Center in Asheville, NC.

Although the Fujita Scale has been in use for 33 years, the limitations of the scale are well known to the users. The primary limitations are a lack of damage indicators, no account of construction quality and variability, and no definitive correlation between damage and wind speed. These limitations have led to inconsistent rating of tornadoes and, in some cases, an overestimate of tornado wind speeds. Thus, there is a need to revisit the concept of the Fujita Scale and to improve and eliminate some of the limitations. The Enhanced Fujita Scale proposed in this document is referred to as the EF Scale to distinguish it from the original Fujita Scale.

BACKGROUND

NWS personnel who are responsible for rating tornadoes have expressed frustrations in applying the Fujita Scale in a consistent and accurate manner. Weak links in a structural system or a slow-moving storm sometimes lead to an overrating of a tornado event. Several technical articles suggest that wind speeds associated with some descriptions of damage are too high. For example, a 260 mph wind speed is not required to completely destroy a well constructed house and blow away the debris. The damage occurs at significantly lower wind speeds. Minor et al. (1977) and Phan and Simiu (2003) confirm that F4 and F5 ratings of housing damage overestimate the wind speeds required to produce the damage. In the Fujita Scale, there is a lack of clearly defined and easily identifiable damage indicators. A larger catalog of damage

indicators is needed along with estimates of the wind speed required to cause a certain type of damage.

Recognizing the need to address these limitations, Texas Tech University (TTU) Wind Science and Engineering (WISE) Center personnel proposed a project to examine the limitations, revise or enhance the Fujita Scale, and attempt to gain a consensus from the meteorological and engineering communities. A steering committee was first organized to initiate the project. Members of the Steering Committee are listed in Table 1. The next step was to organize a forum of users to identify the issues and develop strategies to improve or replace the Fujita Scale. The steering committee established the following objectives for the forum:

- Bring together a representative group of Fujita Scale users
- Identify key issues
- Make recommendations for a new or modified Fujita Scale
- Develop strategies for reaching a consensus from a broad cross section of users

Of the 26 users of the Fujita Scale invited, twenty attended the Fujita-Scale Forum, which was held in Grapevine, Texas, March 7-8, 2001. Forum participants are listed in Table 2. The group met for a day and a half and developed the following strategies for an Enhanced Fujita Scale:

- Identify additional damage indicators
- Correlate appearance of damage and wind speed
- Preserve the historical database
- Seek input from users

DAMAGE INDICATORS AND DEGREES OF DAMAGE

NWS personnel at the forum expressed the need for additional damage indicators that could be used in rating the intensity of tornadoes. Based on their vast tornado damage investigation experience, the TTU project team proposed 28 damage indicators consisting of buildings, structures, and trees. For each damage indicator (DI), several degrees of damage (DODs) are identified. The DODs are sequenced so each one requires a higher expected wind speed than the previous one. Damage ranges from the initiation of visible damage to complete destruction of the particular DI. A benefit of this approach is that, in the future, additional DIs can be added to the current list as new information becomes available.

Table 1

Steering Committee Members

Member	Title	Organization
Jim McDonald	Professor	Texas Tech University
Kishor Mehta	Director	Wind Science & Engineering Center
Don Burgess	Assistant Director	National Severe Storms Lab
Joe Schaefer	Director	Storm Prediction Center
Michael Riley	Engineer	National Institute of Standards and Technology
Brian Smith	Meteorologist	National Weather Service

Table 2

Fujita Scale Forum Participants

Forum Participant	Organization
Chuck Doswell	University of Oklahoma
Gregory Forbes	The Weather Channel
Joe Golden	Forecast Systems Laboratory
Tom Grazulis	Tornado Project
Rose Grant	State Farm Insurance
Quazi Hossain	Lawrence Livermore National Lab
Jeffery Kimball	U.S. Department of Energy
Tim Marshall	Haag Engineering
Daniel McCarthy	Storm Prediction Center
Brian Peters	National Weather Service
Erik Rasmussen	CIMMS, Boulder, CO
Tim Reinhold	Clemson University
Thomas Schmidlin	Kent State University
Lawrence Twisdale	Applied Research Associates
Larry Vennozzi	National Weather Service
Roger Wakimoto	UCLA
Josh Wurman	University of Oklahoma

The strategy of damage indicators requires that an expected, upper, and lower bound wind speed be defined for each DOD. The range of wind speed defined by the upper and lower bound wind speeds accounts for circumstances that cause the actual wind speed associated with the damage to deviate from the expected value. The expected value of wind speed to cause a given DOD is based on a set of "normal" conditions: no glaring weak links, traditional construction quality, appropriate building materials, compliance with local building code, and continuous maintenance. A weak link is a discontinuity in the load path, which runs from the building surface through the structural system to the foundation. Inadequate nailing of wood roof decking, marginal anchoring of roof structure to top of wall, discontinuity in the connection between first and second floor, and use of cut nails instead of anchor bolts to attach sill plate to foundation are examples of load path discontinuities. Traditional construction quality means construction practices are considered acceptable in a majority of similar DIs in an area. Appropriate building materials are suitable for their specific use and for the environment of the area. Normal maintenance implies that the facility has not run down or deteriorated over time.

To obtain wind speeds associated with each DOD is a challenge. A deterministic approach involves structural analysis to determine component and structure resistance. Wind speeds to produce loads that overcome structural resistance are calculated. Monte Carlo simulation of tornado winds to produce damage to components or structure is another approach. Both of these approaches are time-consuming and expensive. The TTU project did not have sufficient resources available to carry out a full-blown study using either the deterministic or simulation approach.

An alternative approach has been successfully used to estimate seismic parameters that cannot be measured directly. The concept involves expert elicitation. In this case, a group of experts makes their best estimate of the expected, upper, and lower wind speeds to cause each DOD. Since all experts will not predict the same wind speeds, the mean and standard deviation of the expected, upper, and lower bound wind speeds are calculated. The means of the experts' estimates are the expected wind speed and the range of values for a particular DOD. The group follows a well-defined protocol to arrive at the final estimates of wind speed.

EXPERT ELICITATION PROCESS

The elicitation protocol was established by the Senior Seismic Hazard Assessment Committee (SSHAC, 1997). A very specific procedure must be followed in order to achieve confidence in the results of the elicitation. The following steps constitute the process:

- Identify and describe the DIs in detail
- Identify and engage a panel of experts
- Discuss and refine the issues with the experts; provide all available data
- Train experts in the elicitation process
- Conduct individual elicitations and group interactions
- Analyze and aggregate elicitations and resolve issues
- Refine the wind speed estimates with several iterations
- Document and communicate the process and final results
- Obtain additional peer review of the process and results.

Six well-recognized experts were selected according to the SSHAC protocol. The expert's background included two meteorologists, two engineers, one architect, and one individual with both a meteorological and engineering background. The engineers both have extensive wind damage investigation experience. One meteorologist worked with Dr. Fujita for a number of years; the other has extensive experience with damage investigations and Doppler radar research. The architect is a roofing expert with extensive roof damage documentation experience. The last expert uses his expertise in meteorology and engineering to assist insurance companies in understanding their wind damage losses. The experts are:

Greg Forbes – Meteorologist, the Weather Channel

Don Burgess – Meteorologist, National Severe Storms Laboratory

Doug Smith – Engineer, Wind Science and Engineering Center, TTU

Tim Reinhold – Engineer, Clemson University

Tom Smith – Architect, private consulting practice

Tim Marshall – Meteorologist/Engineer, Haag Engineers

The experts met for a day and a half to initiate the elicitation process. The DIs and DODs were defined. The experts were trained in the process and given all available data. They completed their first elicitation, which was their best estimate of the expected, upper, and lower

bound wind speed, for each DOD, by the end of the first day. The results of Elicitation Round #1 were tabulated and presented to the experts the next morning. The results were discussed. They clarified the wording of some DODs. The meeting ended with instructions to the experts to refine their wind speed estimates based on discussions and comments on the first round elicitation. Again the results were tabulated by calculating mean and standard deviation of the estimated wind speeds. The DODs were arranged in order of increasing expected value of wind speed to cause the described damage. Results were distributed to experts again with instructions to make additional changes or adjustments to their values if needed. Very few changes were noted in the third round.

PROPOSED DAMAGE INDICATORS AND DEGREES OF DAMAGE

For each DI the following information is provided:

- Name of DI
- Description of typical construction
- A series of DODs and the expected, lower, and upper bound wind speed from the expert elicitation for each DI
- A plot of expected, lower, and upper bound wind speeds for each DOD
- Photo of a typical DI (except for the most obvious ones)
- Photo illustrating specific DODs (when available)

The DIs are listed in Table 5. The DODs for a particular DI range from initiation of damage to total destruction of the building or structure. Each DI has several DODs, which describe damage in the range between initiation of damage and total destruction. A description of construction, a table of DODs and estimated wind speeds, and a plot of DOD versus wind speed are provided on one page for each DI. These pages are contained in the Appendix A. As an example, Table 6 reproduces the data sheet for One- and Two-Family Residences.

To understand how the process works, damage to a typical two-story residence is described here to illustrate how the degrees of damage are defined. The first DOD is initiation of damage. Visible damage generally initiates at the roof with loss of a small percentage (<20%) of roofing material. Windows and door glass begins to break from flying debris. This action is followed by removal of additional roofing material and uplift of part or all of the roof deck. Garage doors collapse inward or outward, depending on wind direction. Internal pressure develops as a result

of the broken windows or failed doors. Part of or all of the roof structure lifts up and is carried away by the winds. With removal of all or part of the roof structure, walls are no longer supported at the top. Exterior walls of the top floor collapse first, followed by the interior walls. As damage progresses, the second-floor floor structure is lifted up and removed. This leaves the first-floor walls unsupported. Again the exterior walls collapse first, followed by destruction of most first floor interior walls except possibly at small rooms, hallways or closets. The last degree of damage represents total devastation of the two-story residence. In a very intense tornado, this sequence of events takes place very rapidly. The roof and walls breakup creating flying debris that adds to the destruction.

Table 3.

Damage Indicators for EF Scale

DI No.	Damage indicator (DI)
1	Small Barns or Farm Outbuildings (SBO)
2	One- or Two-Family Residences (FR12)
3	Manufactured Home – Single Wide (MHSW)
4	Manufactured Home – Double Wide (MHDW)
5	Apartments, Condos, Townhouses [3 stories or less] (ACT)
6	Motel (M)
7	Masonry Apartment or Motel Building (MAM)
8	Small Retail Building [Fast Food Restaurants] (SRB)
9	Small Professional Building [Doctor's Office, Branch Banks] (SPB)
10	Strip Mall (SM)
11	Large Shopping Mall (LSM)
12	Large, Isolated Retail Building [K-Mart, Wal-Mart] (LIRB)
13	Automobile Showroom (ASR)
14	Automobile Service Building (ASB)
15	Elementary School [Single Story; Interior or Exterior Hallways] (ES)
16	Junior or Senior High School (JHSH)
17	Low-Rise Building [1-4 Stories] (LRB)
18	Mid-Rise Building [5-20 Stories] (MRB)
19	High-Rise Building [More than 20 Stories] (HRB)
20	Institutional Building [Hospital, Government or University Building] (IB)
21	Metal Building System (MBS)
22	Service Station Canopy (SSC)
23	Warehouse Building [Tilt-up Walls or Heavy-Timber Construction](WHB)
24	Transmission Line Towers (TLT)
25	Free-Standing Towers (FST)
26	Free-Standing Light Poles, Luminary Poles, Flag Poles (FSP)
27	Trees: Hardwood (TH)
28	Trees: Softwood (TS)

Table 4.

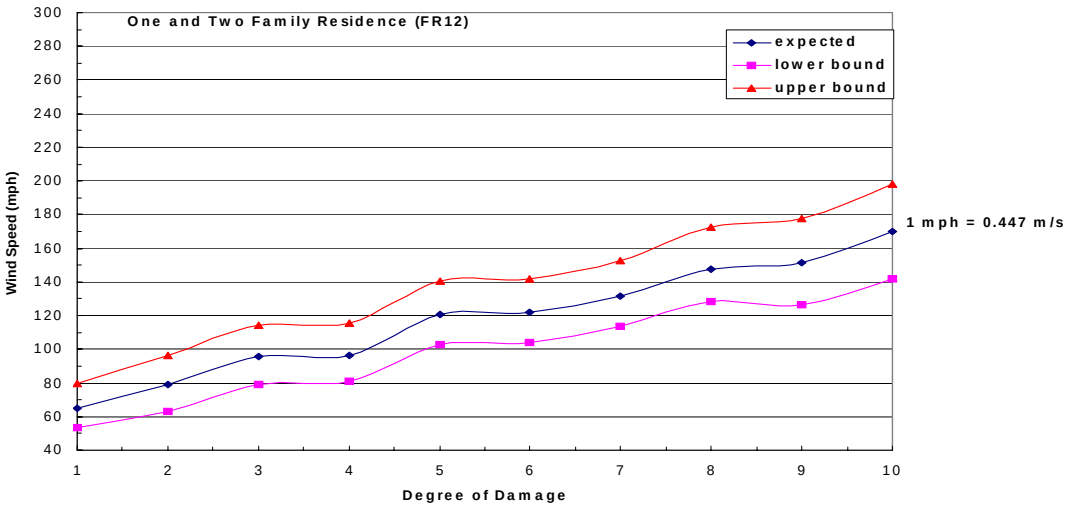
One- and Two-Family Residences (FR12)

Typical Construction

- Asphalt shingles, tile, slate or metal roof covering
- Flat, gable, hip, mansard or mono-sloped roof or combinations thereof
- Plywood/OSB or wood plank roof deck
- Prefabricated wood trusses or wood joist and rafter construction
- Brick veneer, wood panels, stucco, EIFS, vinyl or metal siding
- Wood or metal stud walls, concrete blocks or insulating-concrete panels
- Attached single or double garage

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	65	53	80
2	Loss of roof covering material (<20%), gutters and/or awning; loss of vinyl or metal siding	79	63	97
3	Broken glass in doors and windows	96	79	114
4	Uplift of roof deck and loss of significant roof covering material (>20%); collapse of chimney; garage doors collapse inward or outward; failure of porch or carport	97	81	116
5	Entire house shifts off foundation	121	103	141
6	Large sections of roof structure removed; most walls remain standing	122	104	142
7	Top floor exterior walls collapsed	132	113	153
8	Most interior walls of top story collapsed	148	128	173
9	Most walls collapsed in bottom floor, except small interior rooms	152	127	178
10	Total destruction of entire building	170	142	198

* DOD is degree of damage



Note that DOD No. 5 is not part of the sequence described above. Occasionally an entire house will shift off its foundation when not securely anchored to the foundation. The house is simply sitting on the foundation with no attachments. After shifting off the foundation, additional damage may occur.

The DODs for each DI are arranged in a sequence of increasing degrees of damage. Thus, if only the roof structure of the two-story residence is uplifted by a storm and the exterior walls remain in place (DOD 6), the expected wind speed of the storm at that location is estimated to be 122 mph. The reported value could vary from 104 to 142 mph depending on circumstances. Large overhangs (greater than 2 ft), improper toe nailing (two nails instead of three), or rotted wood at roof-to-wall connection would suggest a wind speed less than 122 mph but not less than 104 mph.. Use of hurricane clips or other positive anchorage devices suggest a wind speed higher than 122 mph but not greater than 142 mph.. The EF-Scale rating would be the category containing the estimated wind speed for this degree of damage.

CORRELATION OF FUJITA SCALE AND EF SCALE

Members of the Fujita-Scale Forum insisted that the historical tornado database be preserved. Thus, there is a need to derive a relationship between the Fujita Scale and the EF Scale. The first step in the process is to obtain a correlation based on wind speed. In order to obtain a correlation between Fujita-Scale and EF-Scale wind speeds, the help of a second set of experts was needed. They used the original Fujita Scale criteria to assign Fujita-Scale categories(i.e. F0, F1, etc) to the DODs of the new EF Scale. A regression analysis was performed to obtain a relationship between the Fujita-Scale and EF-Scale wind speeds. The steps of the process are described in this section.

The second expert group was selected for their experiences with damage investigation and application of the Fujita Scale. The following experts participated:

Bill Bunting – NWSFO – Fort Worth, Texas

Brian Peters – NWSFO – Calera, Alabama

John Ogren – NWSFO – Indianapolis, Indiana

Dennis Hull – NWSFO – Pendleton, Oregon

Tom Matheson – NWSFO – Wilmington, North Carolina

Brian Smith – NWSFO – Valley, Nebraska

The exercise was conducted by mail without a formal meeting of the group. The purpose and procedure of the exercise were described in an accompanying letter. Since we were interested in knowing how these experts would rate the DIs and DODs based on the original Fujita Scale, only one iteration was solicited. They were simply asked to apply a Fujita-Scale rating to the damage description of each DOD for all 28 DIs. The Fujita-Scale ratings were then expressed in terms of the median value of each Fujita-Scale wind speed range. The Fujita-Scale wind speeds were then converted to a 3-second gust frame of reference. The average, estimated Fujita-Scale wind speed of the six experts was then compared with the expected value wind speed from the expert elicitation process for each DOD. A regression analysis was then performed to obtain a correlation between the mean Fujita-Scale wind speed and the EF-Scale expected wind speed for each DOD. Figure 1 is a plot of the points used in the regression analysis. A linear regression function fit the data very well.

$$y = 0.6246x + 36.393, \quad (1)$$

where y is the EF-Scale wind speed and x is the Fujita-Scale wind speed (both are 3-second gust in mph).

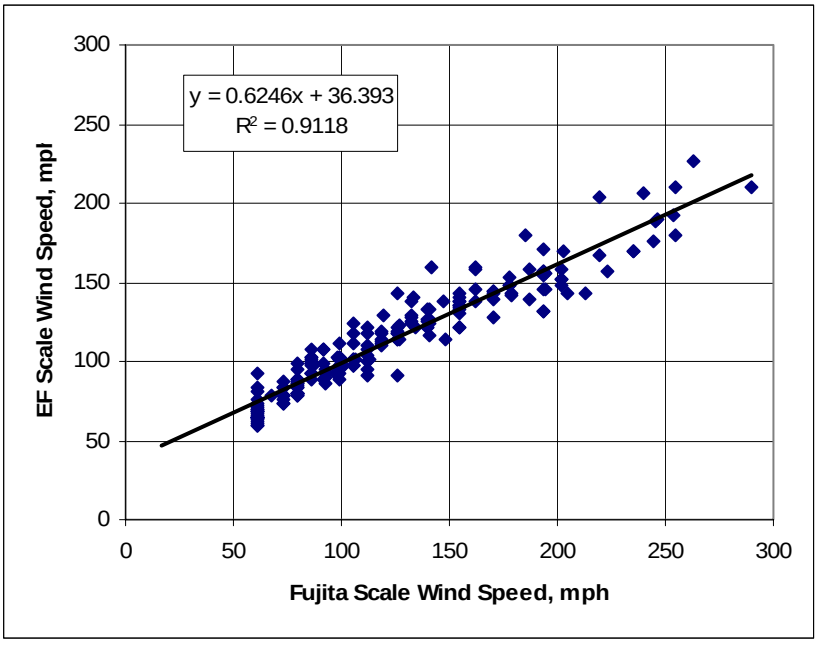


Figure 1. Correlation of Fujita-Scale and EF-Scale Wind Speeds

The correlation coefficient is

$$R^2 = 0.91, \quad (2)$$

which represents a very good fit of the data.

PROPOSED EF SCALE

The basic wind speed ranges of the proposed EF-Scale are derived from the original Fujita Scale ranges by using Equation 1. The original Fujita-Scale wind speeds are first converted from fastest one-quarter mile to 3-second gust speeds using the Durst curve (Durst, 1960). They are then substituted into Equation 1 to obtain the wind speed ranges of the EF Scale. Table 5 shows the results of these calculations. The recommended EF-Scale wind speeds are shown in Table 6. Values have been rounded to avoid implying more accuracy than justified.

Table 5

EF-Scale Wind Speed Ranges Derived from Fujita-Scale Wind Speed Ranges

Fujita Scale			EF Scale	
Fujita Scale	Fastest 1/4/-mile Wind Speeds, mph	3-Second Gust Speed, mph	EF Scale	3-Second Gust Speed, mph
F0	40 - 72	45 78	EF0	65 - 85
F1	73 - 112	79 - 117	EF1	86 - 109
F2	113 - 157	118 - 161	EF2	110 - 137
F3	158 - 207	162 - 209	EF3	138 - 167
F4	208 - 260	210 - 261	EF4	168 - 199
F5	261 - 318	262 - 317	EF5	200 - 234

Table 6

Recommended EF-Scale Wind Speed Ranges

Derived EF Scale		**Recommended EF Scale**
EF Classes	3-Second Gust Speed, mph	**3-Second Gust Speed, mph**
EF0	65 - 85	**65 - 85**
EF1	86 - 109	**86 - 110**
EF2	110 - 137	**111 - 135**
EF3	138 - 167	**136 - 165**
EF4	168 - 199	**166 - 200**
EF5	200 - 234	**>200**

By correlating the Fujita-Scale wind speeds with the EF-Scale wind speeds, a tornado rated according to the Fujita Scale will have the same "F-Number" in the EF Scale, e.g. F3 translates into EF3, although the wind speed ranges are different (see Table 5).

The recommended EF5 category has no stated upper bound. An absolute upper bound on tornado wind speed has not been defined to date. Having no stated upper bound for EF5 will prevent the news media from always assuming the worst case scenario.

EF-SCALE PROTOCOL

The EF-Scale is intended for application to an individual building, structure, or other damage indicator. It is also designed to obtain a rating for a tornado event. Members of the Forum were very specific in their opinion that a single building, structure, or other DI should not be used to rate a tornado event. Several DIs should be considered in assigning an EF-Scale rating to a tornado event.

RATING AN INDIVIDUAL BUILDING, STRUCTURE OR OTHER DAMAGE INDICATOR

An EF-Scale rating is obtained for an individual building, structure, or other damage indicator by the following a sequence of actions. A DI is identified from one of the 28 DIs in the Table 3. The construction or description should match the DI being considered and the observed damaged should match one of the DODs.

Under normal circumstances, the expected value is representative of the observed damage; however, there are factors or conditions that can cause a deviation (either lower or higher) from the expected wind speed for a DOD. The evaluator makes a judgment within the range of upper and lower bound wind speeds as to whether the wind speed to cause the damage is higher or lower than the stated expected value for the particular DOD. The EF-Scale rating is the one with a range of wind speed that contains the estimated wind speed to produce the DOD. The EF-Scale rating as described above applies only to that particular indicator. Additional DIs should be considered in assigning an EF-Scale rating to a tornado event.

RATING A TORNADO EVENT

The rating of a tornado event should represent an estimate of the highest wind speed that occurred during the life cycle of the tornado. It is well known that intensity (wind speed) varies

both along the length and across the width of a tornado damage path. A true upper bound tornado wind speed may not be possible to estimate if the actual wind speed is greater than the upper bound wind speed of the DI being considered. For example, the upper bound wind speed for total destruction of a one and two-family residence is 198 mph. The actual wind speed in the tornado could have been higher since there is not another DOD to indicate a higher wind speed.

Ideally the recommended approach for assigning an EF-Scale rating to a tornado event involves the following steps:

- Conduct an aerial survey of damage path to identify applicable damage indicators and define the extent of the damage path
- Identify several DIs that tend to indicate the highest wind speed within the damage path
- Locate those DIs within the damage path
- Conduct a ground survey and carefully examine the DIs of interest
- Follow the steps outlined for assigning EF-Scale rating to individual DIs and document the results
- Consider the ratings of several DIs, if available, and arrive at an integrated EF-Scale rating for the tornado event
- Record the basis for assigning an EF-Scale rating to the tornado event
- Record other pertinent data relating to the tornado event.

CONCLUSION

An Enhanced Fujita Scale (EF Scale) is proposed in this document. The enhanced scale addresses the major limitations of the original Fujita Scale that was first published in 1971. Additional damage indicators (DIs) are proposed along with degrees of damage (DODs). Through an expert elicitation process, wind speeds corresponding to the described damage for each DOD are estimated. The estimated wind speed then determines the EF-Scale category appropriate for the observed damage. The categories range from EF0 to EF5. The wind speed ranges in each category are related to Fujita Scale ranges by a correlation function (Equation 1). This correlation between Fujita-Scale and EF-Scale wind speeds provides a link between the two scales and thus makes it possible to express a Fujita-Scale rating in terms of an EF-Scale rating.

The only difference is the wind speed ranges in each scale. Thus, the historical tornado database is preserved and can be easily converted to the criteria of the EF Scale.

The problem of no DIs in open country remains. Research is currently underway to identify additional damage indicators and to obtain estimates of the wind speeds to cause defined damage. Of particular interest are damage to various crops, farm equipment, silos, grain storage facilities, and irrigation equipment. These indicators can be incorporated as DIs in the EF Scale as reliable data become available. The technology of portable Doppler radar should also be a part of the EF Scale process, either as a direct measurement, when available, or as a means of validating the wind speeds estimated by the experts.

The authors recommend that the EF Scale be given serious consideration for ultimately replacing the Fujita Scale as a means of rating the intensity of tornadoes. Additional refinements will be possible as experience is gained from use of the EF Scale.

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APPENDIXES

A. Twenty-eight Damage Indicators with Photos

B. Expert Elicitation of Damage versus Wind Speed

C. Fujita Scale Ratings of DODs by NWS Panel

Appendix A

TWENTY-EIGHT DAMAGE INDICATORS WITH PHOTOS

NO.	DAMAGE INDICATORS (DI)
1	Small Barns or Farm Outbuildings (SBO)
2	One- or Two-Family Residences (FR12)
3	Manufactured Home – Single Wide (MHSW)
4	Manufactured Home – Double Wide (MHDW)
5	Apartments, Condos, Townhouses (ACT)
6	Motel (M)
7	Masonry Apartment or Motel (MAM)
8	Small Retail Building (SRB)
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10	Strip Mall (SM)
11	Large Shopping Mall (LSM)
12	Large, Isolated Retail Building (LIRB)
13	Automobile Showroom (ASR)
14	Automobile Service Building (ASB)
15	Elementary School (ES)
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17	Low-Rise Building [1-4 Stories] (LRB)
18	Mid-Rise Building [5-20 Stories] (MRB)
19	High-Rise Building [More than 20 Stories] (HRB)
20	Institutional Building (IB)
21	Metal Building System (MBS)
22	Service Station Canopy (SSC)
23	Warehouse Building (WHB)
24	Electrical Transmission Lines (ETL)
25	Free-Standing Towers (FST)
26	Free-Standing Light Poles, Luminary Poles, Flag Poles (FSP)
27	Trees: Hardwood (TH)
28	Trees: Softwood (TS)

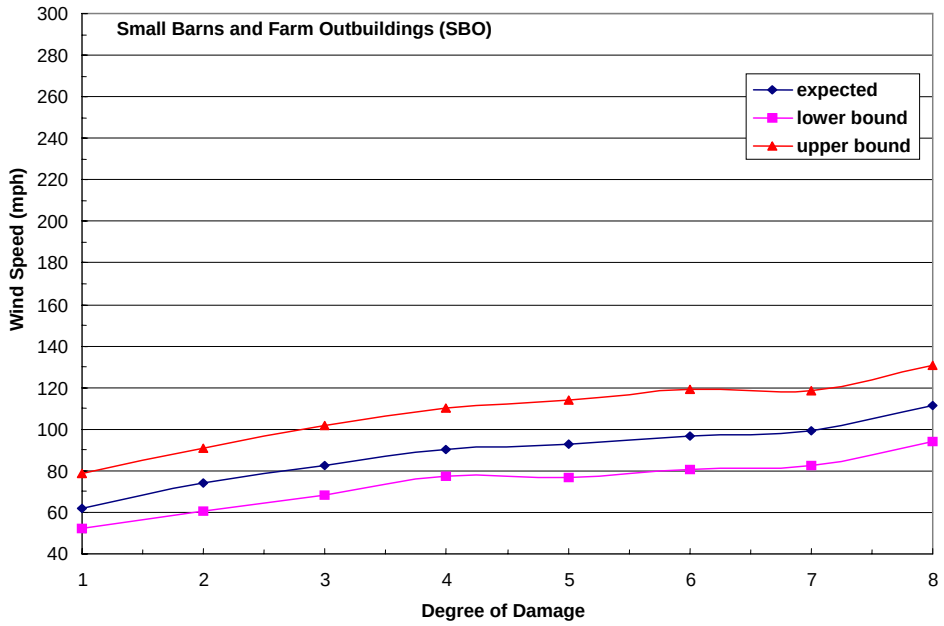
1. SMALL BARNS AND FARM OUTBUILDINGS (SBO)

Typical Construction

- Less than 2500 sq ft
- Wood or metal post and beam construction
- Wood or metal roof trusses
- Wood or metal panel siding
- Metal or wood roof
- Large doors

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	62	53	78
2	Loss of wood or metal roof panels	74	61	91
3	Collapse of doors	83	68	102
4	Major loss of roof panels	90	78	110
5	Uplift or collapse of roof structure	93	77	114
6	Collapse of walls	97	81	119
7	Overturning or sliding of entire structure	99	83	118
8	Total destruction of building	112	94	131

* Degree of Damage



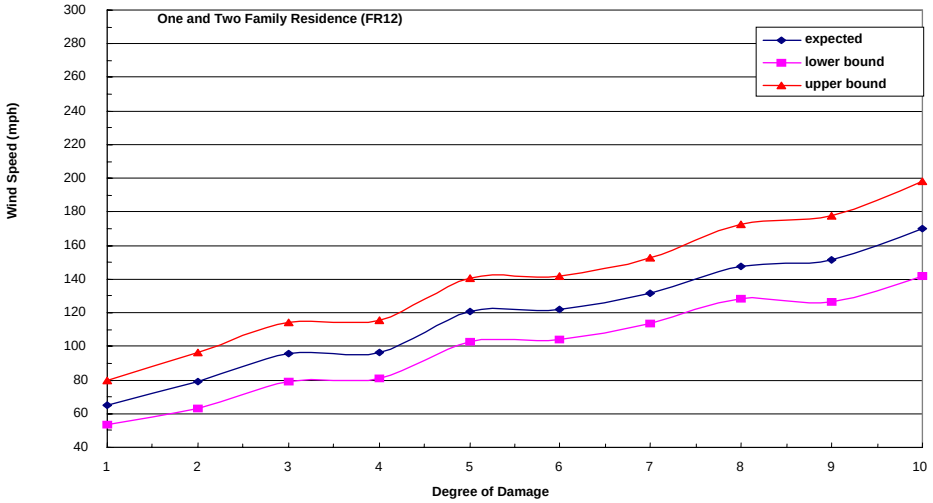
2. ONE-AND TWO-FAMILY RESIDENCES (FR12)
(1000 – 5000 sq. ft.)

Typical Construction

- Asphalt shingles, tile, slate, or metal roof covering
- Flat, gable, hip, mansard, or mono-sloped roof or combinations thereof
- Plywood/OSB or wood plank roof deck
- Prefabricated wood trusses or wood joist and rafter construction
- Brick veneer, wood panels, stucco, EIFS, vinyl, or metal siding
- Wood or metal stud walls, concrete blocks or insulating-concrete panels
- Attached single or double garage

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	65	53	80
2	Loss of roof covering material (<20%), gutters and/or awning; loss of vinyl or metal siding	79	63	97
3	Broken lass in doors and windows	96	79	114
4	Uplift of roof deck and loss of significant roof covering material (>20%); collapse of chimney; garage doors collapse inward; failure of porch or carport	97	81	116
5	Entire house shifts off foundation	121	103	141
6	Large sections of roof structure removed; most walls remain standing	122	104	142
7	Top floor exterior walls collapsed	132	113	153
8	Most interior walls of top story collapsed	148	128	173
9	Most walls collapsed in bottom floor, except small interior rooms	152	127	178
10	Total destruction of entire building	170	142	198

* Degree of Damage



2. ONE-AND TWO-FAMILY RESIDENCE (FR12)

FR12: DOD 2: Loss of roof covering (<20%)

FR12: DOD 4: Uplift of roof deck and loss of roof covering (>20%); garage door collapses outward

FR12: DOD 6: Large sections of roof removed; most walls remain standing

FR12: DOD 7: Top floor (First floor in this case) exterior walls collapsed

FR12: DOD 10: Total destruction of entire building

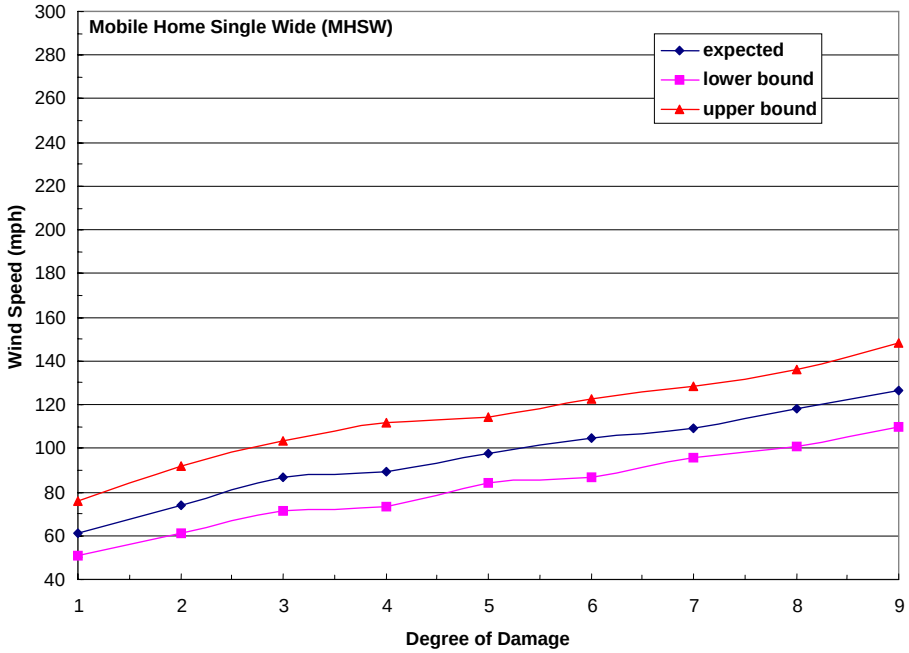
3. MANUFACTURED HOMES – SINGLE WIDE (MHSW)

Typical Construction

- Steel undercarriage supported on concrete block piers
- Metal straps and ground anchors (Frame and/or over-the-top strap anchors)
- Asphalt shingles or one-piece metal roof covering
- Wood roof joists
- Metal, vinyl, or wood siding
- Wood roof joists
- Wood stud walls and partitions
- Better construction in post 1974 models in coastal areas

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	61	51	76
2	Loss of shingles or partial uplift of one-piece metal roof covering	74	61	92
3	Unit slides off block piers but remains upright	87	72	103
4	Complete uplift of roof; most walls remain standing	89	73	112
5	Unit rolls on its side or upside down; remains essentially intact	98	84	114
6	Destruction of roof and walls leaving floor and undercarriage in place	105	87	123
7	Unit rolls or vaults; roof and walls separate from floor and undercarriage	109	96	128
8	Undercarriage separates from unit; rolls, tumbles and is badly bent	118	101	136
9	Complete destruction of unit; debris blown away	127	110	148

* Degree of Damage



3. MANUFACTURED HOMES – SINGLE WIDE (MHSW)

MHSW: DOD 3: Unit slides off block piers but remains upright

MHSW: DOD 4: Complete uplift of roof; most walls remain standing

MHSW: DOD 6: Destruction of roof and walls leaving floor and undercarriage in place

MHSW: DOD 9: Complete destruction of unit; debris blown away

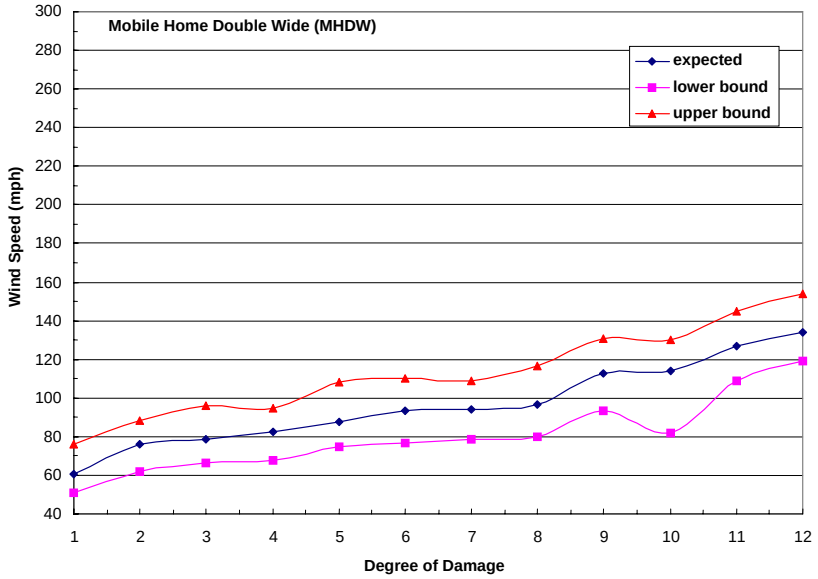
4. MANUFACTURED HOME – DOUBLE WIDE (MHDW)

Typical Construction

- Steel undercarriage supported on concrete block piers
- Multi-unit connection at roof, floor, and end walls
- Frame straps and ground anchors spaced at 10 – 12 ft apart
- Flat, gable, or hip roof shape
- Asphalt shingles or metal roof panels
- Plywood/OSB roof decking
- Wood rafter or shallow joist construction
- Metal, vinyl, or wood siding

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	61	51	76
2	Loss of shingles or other roof covering (<20%)	76	62	88
3	Damaged porches or carports	78	67	96
4	Broken windows	83	68	95
5	Uplift of roof deck and loss of significant roof covering material (>20%)	88	75	108
6	Complete uplift of roof; most walls remain standing	93	77	110
7	Unit slides off CMU block piers	94	78	109
8	Removal of entire roof structure leaving most walls standing	97	80	117
9	Complete destruction of roof and walls leaving undercarriage in place	113	93	131
10	Unit rolls, displaces or vaults	114	82	130
11	Undercarriage separates from floor, rolls and tumbles, badly bent	127	109	145
12	Complete destruction of unit; debris blows away	134	119	154

* Degree of Damage



4. MANUFACTURED HOME – DOUBLE WIDE (MHDW)

MHDW: DOD 5: Uplift of roof deck and loss of significant roof covering material (>20%)

MHDW: DOD 11: Undercarriage separates from floor; rolls and tumbles, badly bent

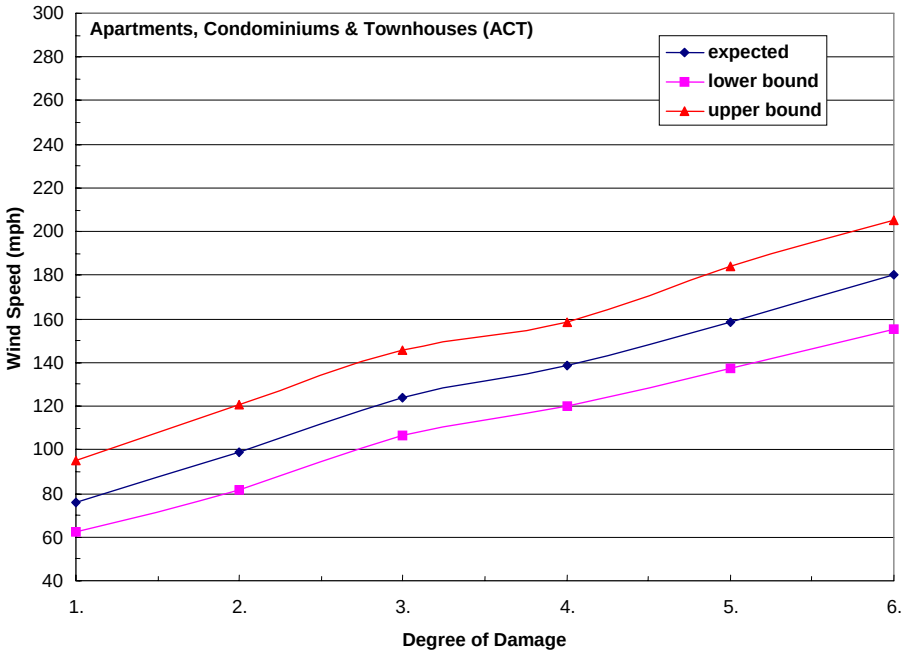
5. APARTMENTS, CONDOMINIUMS AND TOWNHOUSES (ACT)
(Three stories or less)

Typical Construction

- Flat, gable, hip, or mansard roof
- Asphalt shingles, tile, metal, or BUR roof covering
- Plywood/OSB roof decking
- Light-framed wood or metal roof trusses
- Wood, metal, or vinyl panels, stucco brick veneer or EIFS wall covering; combinations of wall coverings
- Wood or metal stud walls
- Wood floor diaphragms
- Sliding patio doors; balconies

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	76	63	95
2	Loss of roof covering (<20%)	99	82	121
3	Uplift of roof decking; significant loss of roof covering (>20%)	124	107	146
4	Uplift or collapse of roof structure leaving most walls standing	138	120	158
5	Most top story walls collapsed	158	138	184
6	Almost total destruction of top two stories	180	155	205
7	Total destruction of entire building			

* Degree of Damage



5. APARTMENTS, CONDOMENIUMS, AND TOWNHOUSES (ACT)

ACT: Gable roof, asphalt shingles, wood decking, light-framed wood construction, brick veneer, wood stud walls, balconies

ACT: DOD 2: Loss of roof covering (<20%)

ACT: DOD 4: Uplift or collapse of roof structure leaving most walls standing

ACT: DOD 5: Most top story walls collapsed

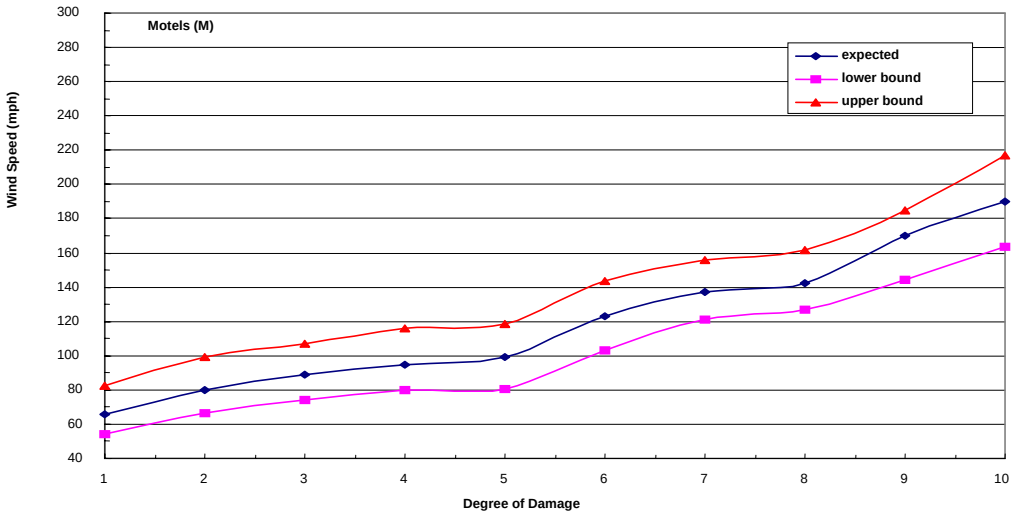
6. MOTELS (M)

Typical Construction

- Less than or equal to four stories
- Facility made up of one or more multi-story, rectangular buildings
- Flat, gable, hip, or mansard roof
- Asphalt shingles, tile, slate, or BUR roof covering
- Plywood/OSB roof decking
- Wood or metal prefabricated roof trusses
- Wood floor diaphragms
- Wood or metal stud walls
- Stucco, EIFS, wood, metal, or brick veneer wall cladding
- Canopy over driveway at entrance
- Exterior walkways or balconies

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	66	54	83
2	Loss of roof covering (<20%)	80	67	99
3	Broken windows or patio doors	89	74	107
4	Uplift of roof decking; significant loss of roof covering (>20%);loss of EIFS wall cladding	95	80	116
5	Uplift or collapse of canopy over driveway	99	81	118
6	Uplift or collapse of roof structure leaving most walls standing	123	103	143
7	Collapse of top story exterior walls	138	121	156
8	Collapse of most top story walls	143	127	162
9	Collapse of top two floors of three or more stories	170	144	185
10	Total destruction of entire building	190	163	217

* Degree of Damage



6. MOTELS

M: Less than five stories; one or more rectangular modules; flat, gable, hip, or mansard roof; asphalt shingles, tile, slate, or BUR covering; plywood or metal roof decking; stud walls with EIFS, stucco, or wood siding or brick veneer; canopy over driveway at entrance; exterior walkways or balconies

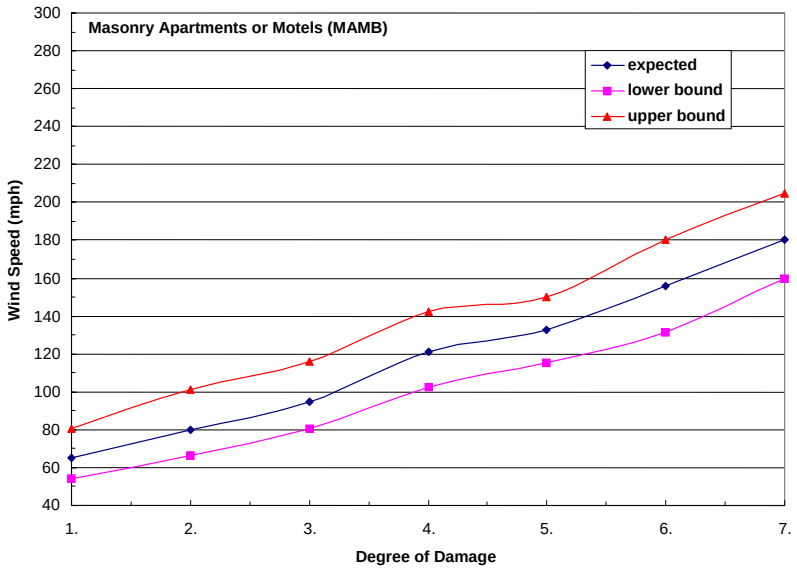
7. MASONRY APARTMENTS OR MOTELS (MAM)

Typical Construction

- Less than or equal to four stories
- Facility made up or one or more multi-story, rectangular buildings
- Flat, gable, hip, or mansard roof
- Asphalt shingles, tile, slate, or BUR roof
- Light steel roof framing with metal deck and lightweight insulation
- Pre-cast hollow-core concrete roof and floor system
- Cast-in-place concrete roof and floor system
- CMU non-bearing walls
- CMU load-bearing walls
- Stucco, EIFS, or brick veneer wall cladding
- Exterior walkways or balconies

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	65	54	81
2	Loss of roof covering (<20%)	80	67	101
3	Uplift of lightweight metal roof decking	95	81	116
4	Uplift of pre-cast or cast-in-place concrete roof decking	121	103	143
5	Collapse of top story walls	133	115	150
6	Collapse of top two floors of three or more stories	156	132	180
7	Total destruction of a large section of building	180	160	205

* Degree of Damage



7. MASONRY APARTMENTS OR MOTEL (MAM)

MAM: Four stories, rectangular plan, mansard roof, pre-cast, hollow-core roof & floor system, CMU load-bearing walls, EIFS exterior walls

MAM: DOD 4: Uuplift fo pre-cast roof decking

MAM: DOD 5: Collapse of top story walls

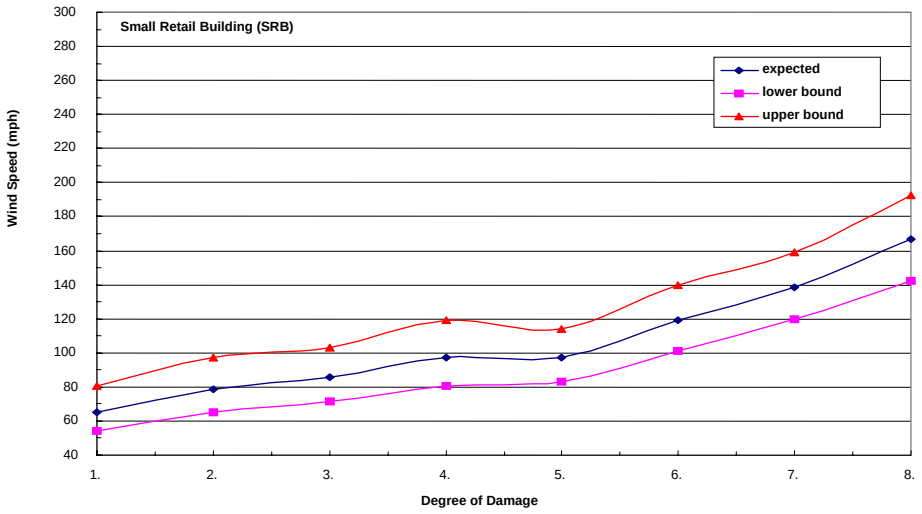
8. SMALL RETAIL BUILDING (SRB)

Typical Construction

- Best example is fast-food restaurant
- Flat, hip, gable, mansard, or monoslope roof
- Asphalt shingles, metal panels, slate, tile, single-ply, or BUR roof covering
- Plywood/OSB roof decking
- Wood or metal roof structure consisting of trusses or rafters and joists
- Wood or metal stud walls
- Typically have large areas of window glass and double entry doors
- Canopies, covered walkways, or porches
- Wood, brick veneer, metal or vinyl siding, concrete blocks, EIFS, or stucco wall cladding

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	65	54	81
2	Loss of roof covering (<20%)	78	65	98
3	Broken glass in windows and doors	86	72	103
4	Uplift of roof decking; significant loss of roof covering (>20%)	98	81	119
5	Canopies or covered walkways destroyed	98	83	114
6	Uplift or collapse of entire roof structure	119	101	140
7	Collapse of exterior walls; closely spaced interior walls remain standing	138	120	159
8	Total destruction of entire building	167	143	193

* Degree of Damage



8. SMALL RETAIL BUILDING (SRB)

SRP: Hip roof, metal panel roof, wood trusses and stud walls, metal or vinyl siding

SRP: DOD 3: Broken glass in windows and doors

SRB: DOD 5: Canopies and covered walkways destroyed

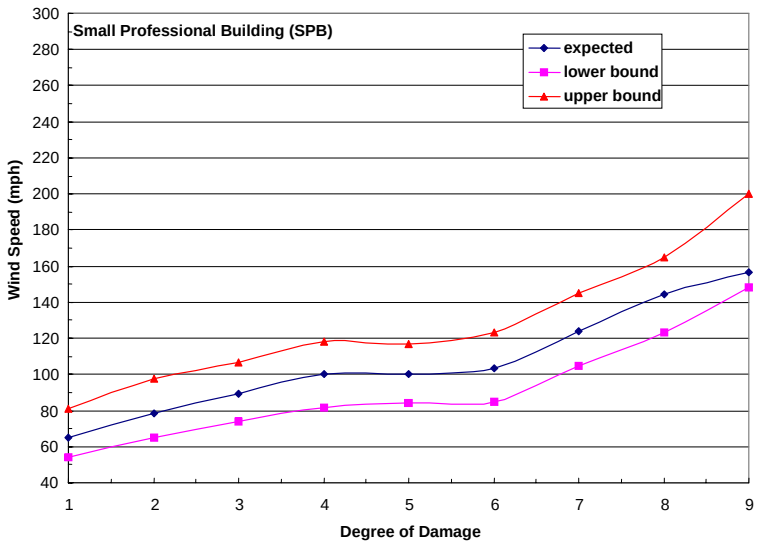
9. SMALL PROFESSIONAL BUILDING (SPB)
(Single story, less than 5000 ft^2)

Typical Construction

- Flat, gable, hip, mansard, or mono-slope roofs with or without parapet walls
- Asphalt shingles, tile, slate, metal panels, single-ply, or built-up roof covering
- Light-frame steel construction, steel joists and formed metal decking
- Load-bearing masonry construction with steel or wood roof structure
- Timber post and beam construction
- Wood or metal stud walls, non-bearing masonry walls
- Metal or vinyl panels, stucco or EIFS cladding
- Skylights and/or clearstories

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	65	54	81
2	Loss of roof covering (<20%)	78	65	98
3	Broken windows, including clear story windows or skylights	89	74	107
4	Exterior doors fail	100	82	118
5	Uplift of roof decking; significant loss of roof covering (>20%); loss of rooftop HVAC equipment	100	84	117
6	Collapsed façade or parapet walls	103	85	123
7	Uplift or collapse of entire roof structure	124	105	145
8	Collapse of exterior walls; closely spaced interior walls remain standing	144	123	165
9	Total destruction of entire building	157	148	200

* Degree of Damage



9. SMALL PROFESSIONAL BUILDING (SPB)

SPB: Hip roof, metal panel roofing, light-frame steel construction, metal stud walls, brick veneer

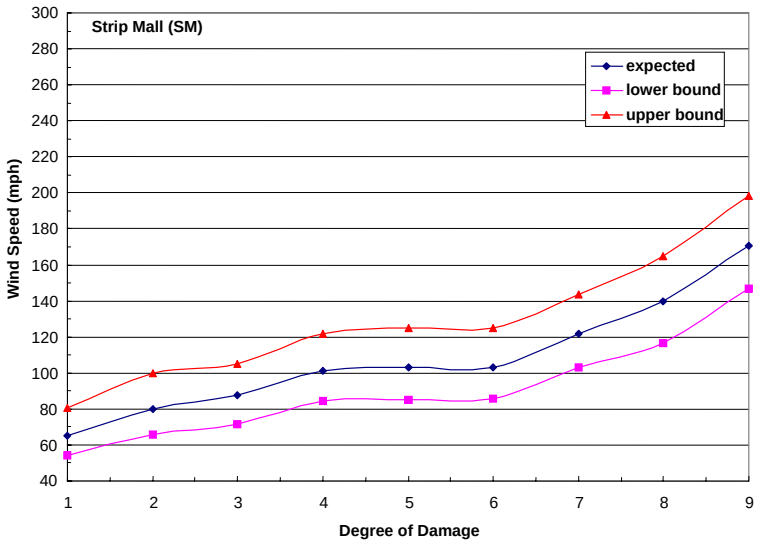
10. STRIP MALL (SM)

Typical Construction

- Large, rectangular single-story building with large surrounding parking lots
- Flat roof with parapet wall
- Built-up roofing or single-ply roof membrane with rigid insulation
- Wood or metal deck, wood-fiber cement panels
- Light-frame steel roof support with steel joists or joist girders
- Brick or concrete block wall construction
- Large window glass and glass entry doors
- Covered walkway attached to building

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	65	54	81
2	Uplift of roof covering at eaves and roof corners	80	66	100
3	Broken windows or glass doors	88	72	105
4	Uplift of roof decking	101	84	122
5	Collapsed façade or parapet walls	103	85	125
6	Covered walkways uplifted or collapsed	103	86	125
7	Uplift or collapse of entire roof structure	122	103	143
8	Collapse of exterior walls; closely spaced interior walls remain standing	140	117	165
9	Complete destruction of all or a large section of building	171	147	198

* Degree of Damage



10. STRIP MALL (SM)

SM: Long, rectangular, single-story building; flat roof with parapet; BUR or single-ply membrane roof system with rigid insulation; wood, metal, or wood-fiber cement roof panels; concrete block walls or stud walls with brick veneer; large glass windows and glass entry doors; canopy or covered walkway attached to building

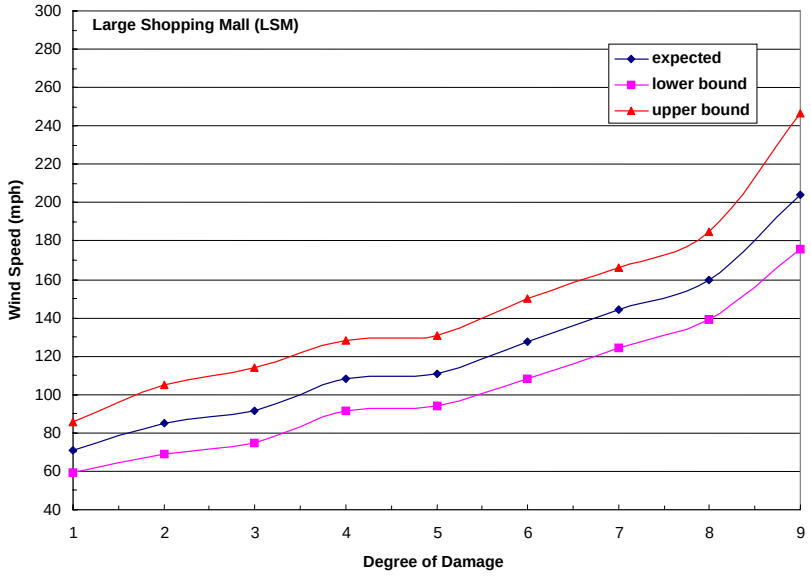
11. LARGE SHOPPING MALL (LSM)

Typical Construction

- Typically one or two stories
- Flat roof; some areas with relatively large spans
- Skylights and clear stories
- Single-ply or BUR with or without roof gravel
- Metal stud walls with brick veneer, stucco, or EIFS cladding
- Light steel structural framing with open web joists, light metal framing or 3-D space framing
- Glass at entries

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	71	59	86
2	Loss of roof covering (<20%)	85	69	105
3	Broken skylights, clearstory windows and atrium walls broken	92	75	114
4	Uplift of some roof decking; significant loss of roofing material (>20%); loss of rooftop HVAC	108	92	128
5	Wall cladding stripped starting at corners and progressing to other areas	111	94	131
6	Roof structure uplifted or collapsed	128	108	150
7	Exterior walls in top story collapsed	144	124	166
8	Interior walls of top story collapse	160	139	185
9	Complete destruction of all or a large section of the building	204	176	247

* Degree of Damage



11. LARGE SHOPPING MALL

LSM: One or two stories, flat roof with some large spans, skylights, built-up roof with gravel, metal stud walls with brick veneer, light steel structural framing, glass entries

LSM: DOD 4: Uplift of some roof decking; significant loss of roofing material (>20%); loss of rooftop HVAC

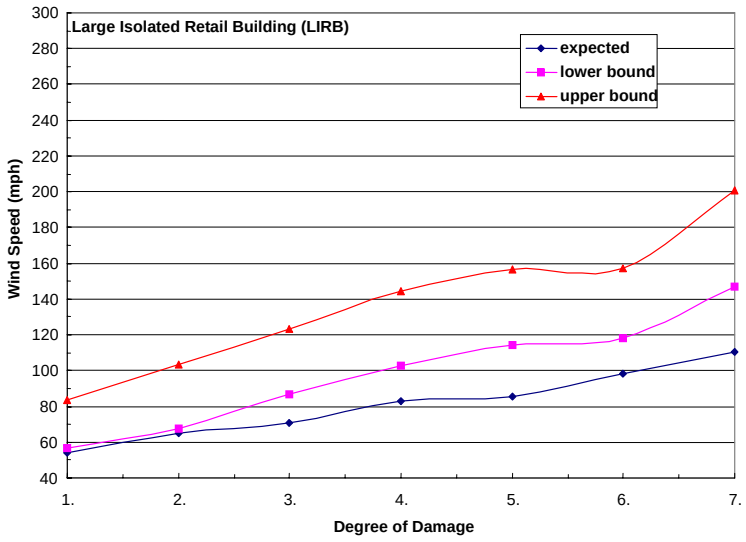
12. LARGE ISOLATED RETAIL BUILDING (LIRB)

Typical Construction

- Flat roof with BUR and gravel or single-ply membrane roof; generally has a 2-3 ft parapet
- Open web joists and steel girders or joist girders supported by tall pipe columns
- Metal deck with rigid insulation or lightweight concrete fill slab
- Large windows on front side of building
- CMU walls, tilt-up concrete panels, metal stud walls covered with EIFS, or combinations of these

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	54	57	83
2	Loss of roof covering (<20%)	65	68	103
3	Uplift of some roof decking; significant loss of roofing material (>20%); loss of rooftop HVAC	71	87	123
4	Long roof spans collapsed downward	83	103	144
5	Uplift and removal of roof structure	85	114	157
6	Inward or outward collapse of exterior walls	98	118	158
7	Complete destruction of all or a large section of the building	110	147	201

* Degree of Damage



12. LARGE ISOLATED RETAIL BUILDING

LIRB: Flat roof with built-up tar and gravel roofing; 2-3 ft parapet; metal roof deck with rigid insulation; light steel roof structure; tilt-up concrete panel walls; glass store front

LIRB: DOD 3: Significant loss of roofing material; loss of rooftop HVAC

LIRB: DOD 4: Long span roof structure collapses downward

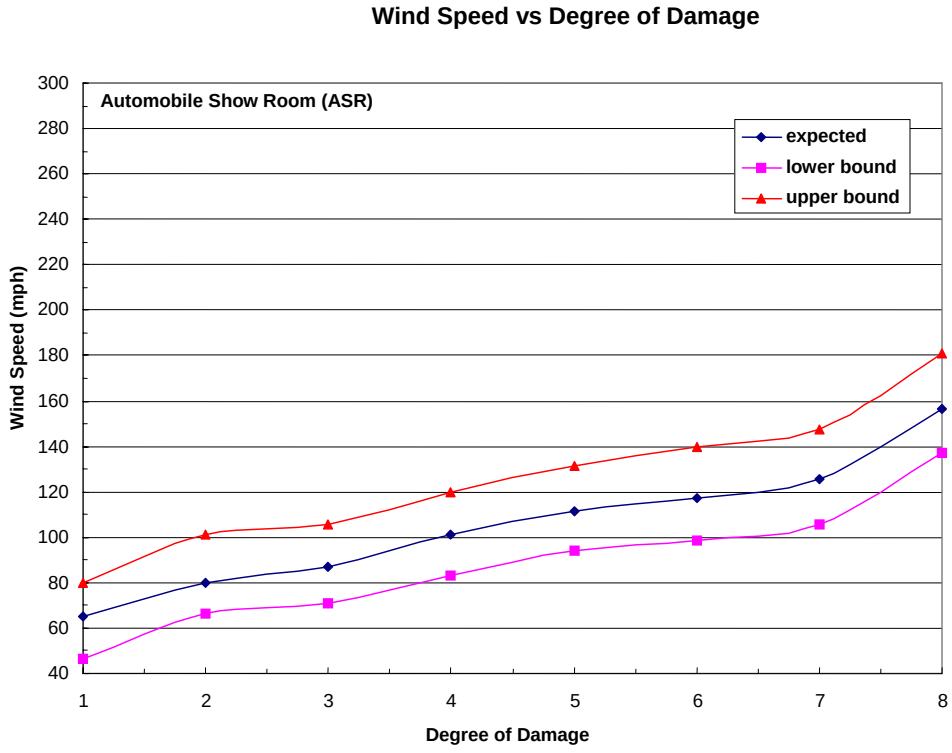
13. AUTOMOBILE SHOWROOM (ASR)

Typical Construction

- Most showrooms are single-story buildings with flat roof
- Roof system is BUR or single-ply membrane
- Metal roof deck or plywood panels
- Steel structural framing with open web steel joists
- Metal stud walls with EIFS, stucco, or tilt-up panels
- Exterior walls on 2 or 3 sides have large glass windows

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	65	47	80
2	Loss of roof covering (<20%)	80	67	101
3	Broken glass in windows or doors	87	71	106
4	Uplift of some roof decking; significant loss of roofing material (>20%); loss of rooftop HVAC	101	83	120
5	Cladding stripped off walls	112	94	132
6	Uplift or collapse of roof structure	118	98	140
7	Exterior walls collapsed	126	106	148
8	Complete destruction of all or a large section of the building	157	138	181

* Degree of Damage



13. AUTOMOBILE SHOWROOM (ASR)

ASR: Single story with flat roof; BUR or single-ply membrane; metal or plywood roof deck; stud walls with EIFS, stucco or tilt-up panels

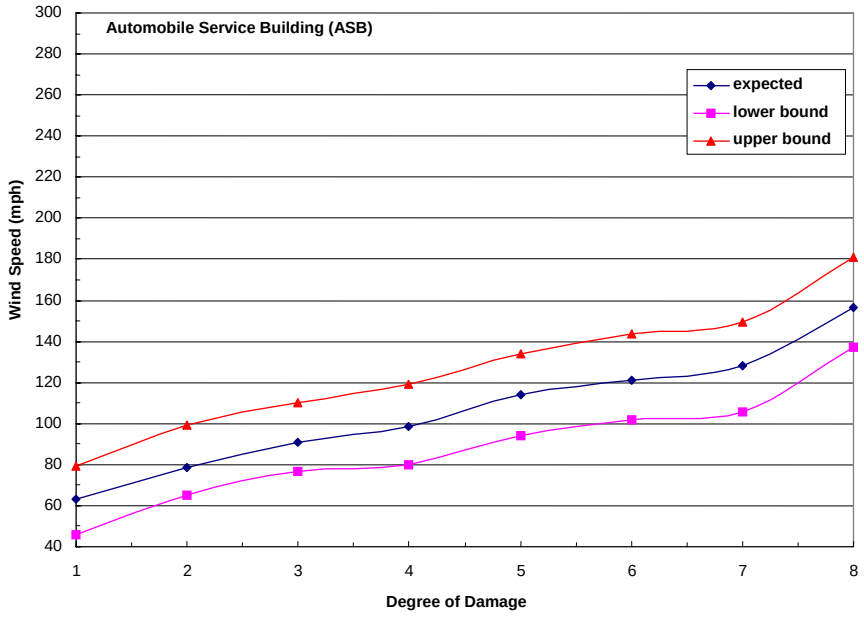
14. AUTOMOBILE SERVICE BUILDING (ASB)

General Description

- Single story building with flat roof and relatively tall walls with parapet
- Roof coverings are typically BUR with gravel or single-ply membrane
- Roof structure is light steel framing or open web steel joists and metal roof deck
- Exterior walls are concrete masonry or precast tilt-up panels
- Numerous large metal overhead doors

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	63	46	79
2	Loss of roof covering (<20%)	78	65	99
3	Failure of large overhead doors	91	77	110
4	Uplift of some roof decking; significant loss of roofing material (>20%); loss of rooftop HVAC	98	80	119
5	Collapse of non-bearing masonry or tilt-up walls	114	94	134
6	Uplift or collapse of roof structure	121	102	143
7	Collapse of load-bearing walls	128	106	149
8	Complete destruction of all or a large section of the building	157	138	181

* Degree of Damage



14. AUTOMOBILE SERVICE BUILDING (ASB)

ASB: Single story, flat roof, tall walls and parapet; BUR or single-ply roof covering; CMU or pre-cast tilt-up panels; numerous overhead doors

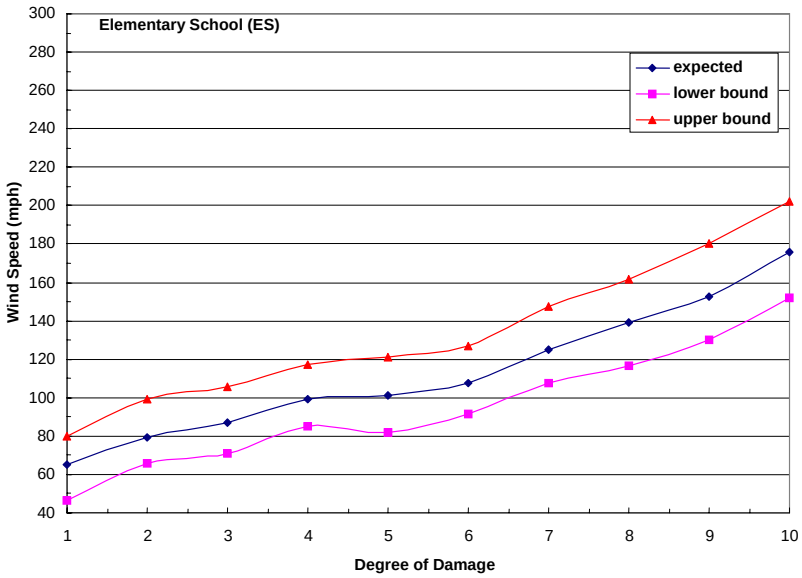
15. ELEMENTARY SCHOOL (ES)

General Description

- These buildings are typically single story with flat roofs
- Building may contain a small gym or cafeteria with moderately long spans between supports
- Buildings have long interior hallways with bearing or non-bearing walls
- BUR, single-ply membrane, or metal standing seam roof panels
- Metal or plywood roof decking supporting a light-weight poured gypsum deck
- Roof structure consists of open web steel joists bearing on exterior walls and steel interior girders
- Exterior non-bearing walls constructed with CMUs, glass curtain walls or metal studs with brick veneer, stucco, or EIFS cladding
- CMU bearing walls with brick veneer, stucco, or EIFS cladding
- Walls can have a large percentage of window glass

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	65	47	80
2	Loss of roof covering (<20%)	79	66	99
3	Broken windows	87	71	106
4	Exterior door failures	99	85	118
5	Uplift of some roof decking; significant loss of roofing material (>20%); loss of rooftop HVAC	101	82	121
6	Damage to or loss of wall cladding	108	92	127
7	Uplift or collapse of roof structure	125	108	148
8	Collapse of non-bearing walls	139	117	162
9	Collapse of load-bearing walls	153	130	180
10	Total destruction of a large section of building or entire building	176	152	203

* Degree of Damage



15. ELEMENTARY SCHOOL (ES)

ES: Single story with flat roof; built-up roofing with gravel; brick veneer; large percentage of window glass; long interior hallways; load-bearing walls

ES: DOD 5: Significant loss of roofing material (>20%); uplift of roof decking

ES: DOD 5: Significant loss of roofing material (>20%); uplift of roof decking

ES: DOD 7: Uplift of entire roof structure

ES: DOD 9: Collapse of load-bearing walls

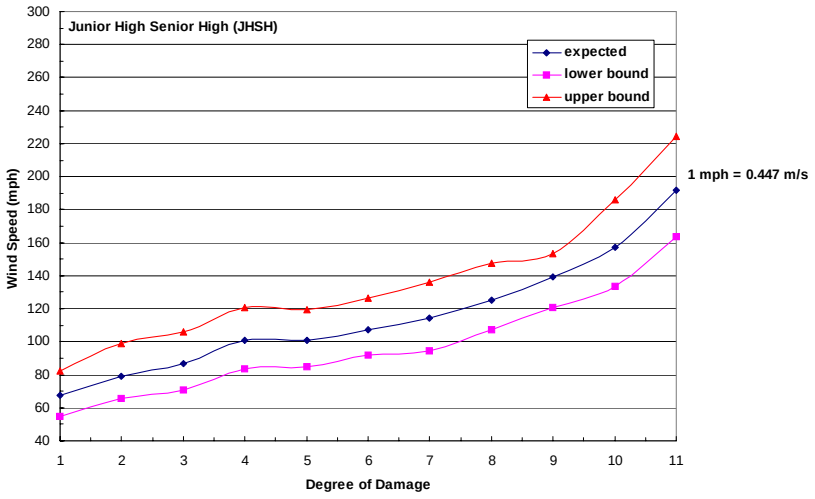
16. JUNIOR OR SENIOR HIGH SCHOOL (JHSH)

General Description

- Generally large one or two-story buildings with flat roofs
- May contain gymnasiums, cafeteria, and auditorium with large structural spans; may have a basement
- Classroom wings have interior hallways with bearing or non-bearing interior walls
- BUR or single-ply membrane roof covering with or without gravel
- Structural system may consist of an all steel structure or an all reinforced concrete structure or a combination of both
- Roof structure may be light steel construction with open web joists supported on steel beams; corrugated metal roof deck with rigid insulation or poured gypsum deck
- Exterior walls constructed of concrete or clay blocks with brick veneer, stucco, or EIFS; metal and glass curtain walls; walls may have more than 30% windows

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	68	55	83
2	Loss of roof covering (<20%)	79	66	99
3	Broken windows	87	71	106
4	Exterior door failures	101	83	121
5	Uplift of metal roof decking; significant loss of roofing material (>20%); loss of rooftop HVAC	101	85	119
6	Damage to or loss of wall cladding	108	92	127
7	Collapse of tall masonry walls at gym, cafeteria or auditorium	114	94	136
8	Uplift or collapse of light steel roof structure	125	108	148
9	Collapse of exterior walls in top floor	139	121	153
10	Most interior walls of top floor collapsed	158	133	186
11	Total destruction of a large section of building envelope	192	163	224
12	Significant damage to steel or concrete structural system			

* Degree of Damage



16. JUNIOR OR SENIOR HIGH SCHOOL (JHSH)

JHSH: Generally one or two story with flat roof; BUR or single-ply membrane roof with gravel; block walls with brick veneer, stucco, or EIFS, metal or glass curtain walls; large percent window glass

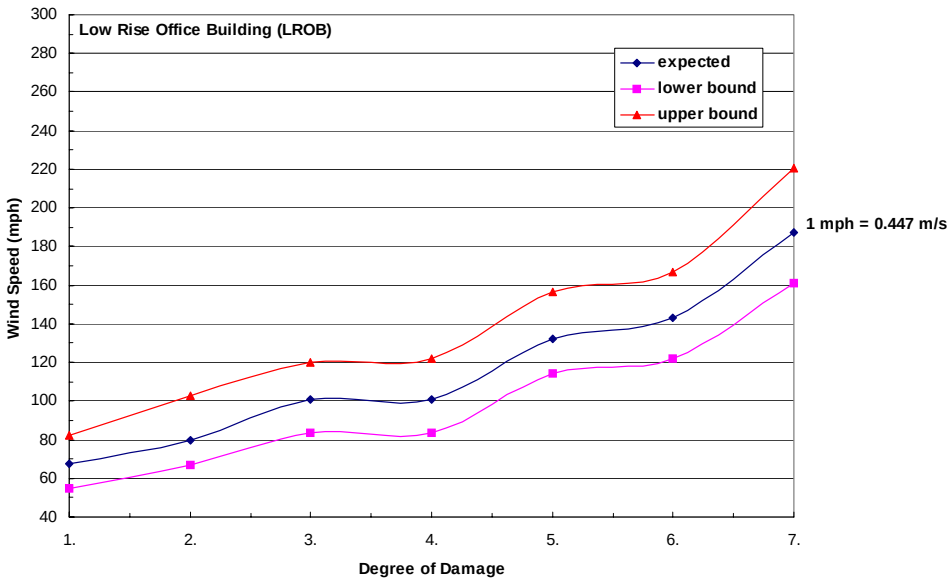
17. LOW-RISE BUILDING: 1–4 STORIES (LRB)

General Description

- Generally consist of rectangular modules but can be “odd shaped” in plan
- Most will have flat roofs but can have gable, hip, or mansard shapes
- Roofing materials include BUR, single-ply membrane, metal panels, or standing seam
- Roof deck is wood or metal deck, poured gypsum deck, or concrete slab
- Steel or reinforced concrete structural frame
- Glass and metal curtain walls, metal studs with EIFS, non-bearing masonry walls with stucco, or brick veneer
- Examples are office buildings, medical facilities, and bank buildings.

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	68	55	83
2	Loss of roof covering (<20%)	80	67	103
3	Uplift of metal roof decking at eaves and roof corners: significant loss of roofing material (>20%)	101	83	120
4	Broken glass in windows, entryways or atriums	101	83	122
5	Uplift of lightweight roof structure	133	114	157
6	Significant damage to exterior walls and some interior walls	143	122	167
7	Complete destruction of all or a large section of building	188	161	221

* Degree of Damage



17. LOW-RISE BUILDING 1-4 STORIES (LRB)

LRB: Rectangular modules but can be “odd shaped”; flat, gable, hip, or mansard roof shapes; BUR, single-ply membrane or metal panel roof system; wood, metal, poured gypsum, or concrete roof deck; glass or metal curtain walls, metal studs with EIFS, stucco, or brick veneer, masonry bearing walls

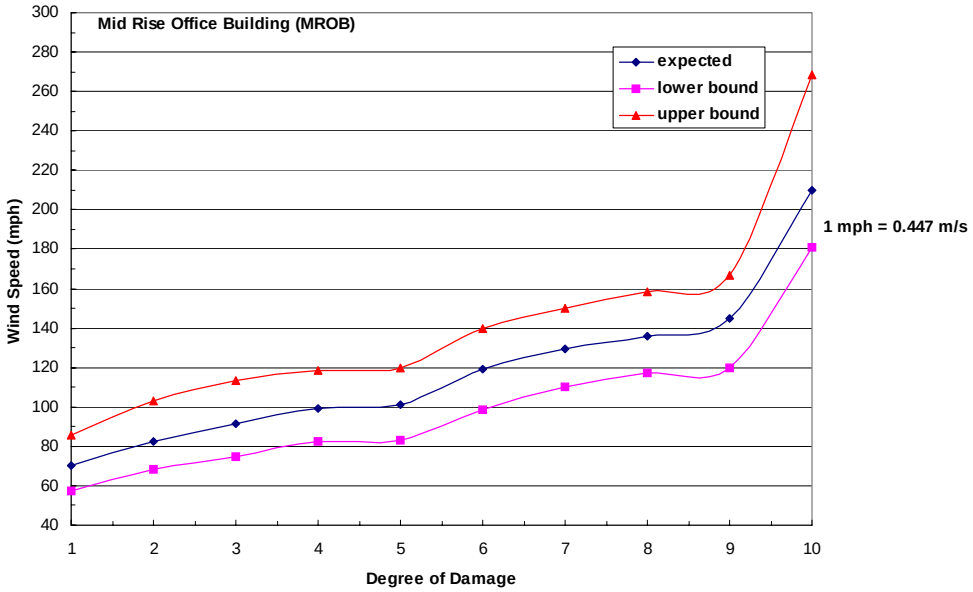
18. MID-RISE BUILDING: 5–20 STORIES (MROB)

General Description

- Generally consist of rectangular shapes but can have curved or triangular footprints
- Roofs are generally flat; may have an elevator/mechanical penthouse; parapet walls
- Structural frame is steel or reinforced concrete
- Roofing materials are BUR or single-ply membrane with or without gravel
- Penthouse is steel framing with metal panels, or metal studs with stucco or EIFS
- Exterior cladding is glass or metal curtain walls; pre-cast concrete window wall panels or a combination of the two
- Roof structure consists of metal deck, poured gypsum deck or concrete slab
- Examples are office buildings, medical facilities, and residential buildings

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	70	58	86
2	Loss of roof covering (<20%)	83	68	103
3	Damage to penthouse roof and walls; loss of rooftop HVAC equipment	92	75	113
4	Damage to parapet walls or coping	99	83	118
5	Broken glass in curtain walls; glass in entryways; significant damage to building interior	101	83	120
6	Uplift of lightweight roof decking; significant loss of roofing material (>20%)	119	98	140
7	Broken curtain wall panel anchors	129	110	150
8	Uplift or collapse of roof structure	136	118	158
9	Significant damage to curtain walls and some interior walls	145	120	167
10	Permanent structural deformation	210	181	268

* Degree of Damage



18. MID-RISE BUILDING 5-20 STORIES (MRB)

MRB: Generally rectangular shapes; flat roof with parapet and penthouse; BUR or single-ply membrane with or without gravel; metal deck, poured gypsum, or concrete deck; glass or metal curtain walls, marble panels or pre-cast concrete wall panels

MRB: DOD 6: Broken glass in curtain walls; damage to building interior

MRB: DOD 9: Failure of exterior walls

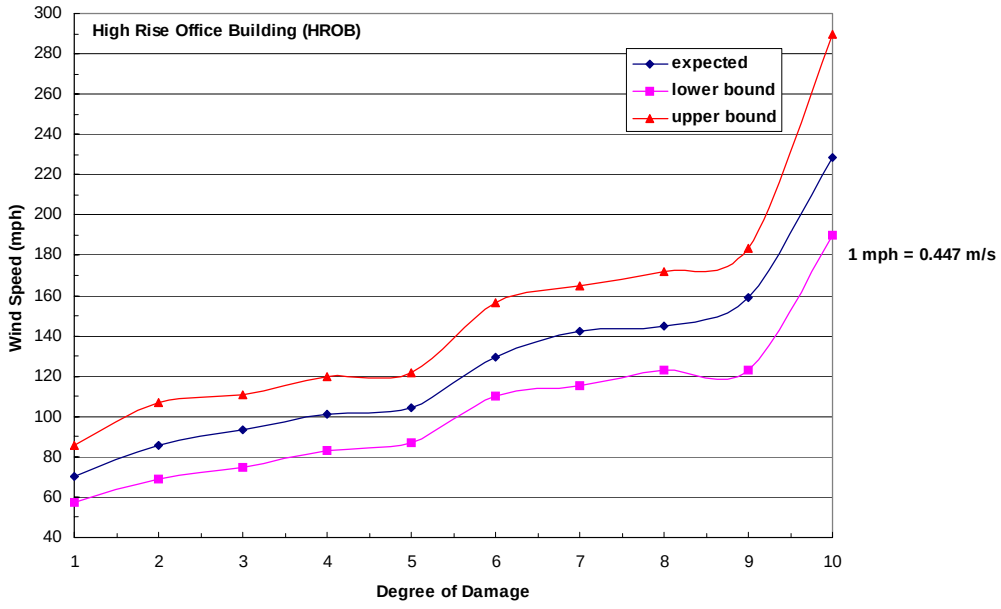
19. HIGH-RISE BUILDING: GREATER THAN 20 STORIES (HROB)

General Description

- Generally consist of rectangular shapes but can have curved or triangle footprints
- Roofs are generally flat but may have a more complex roof shape as part of esthetic statement
- Roofing material single-ply membrane fully adhered, polyurethane foam roof, metal, or copper clad roof covering
- Penthouse is steel framing with metal panels
- Exterior cladding is glass or metal curtain walls or pre-cast concrete window panels
- First floor often has very large glass areas that are susceptible to debris impact
- Atriums with overhead glazing or tall window walls
- Examples are hotels, office buildings, and condominiums

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	70	58	86
2	Loss of roof covering (<20%)	86	69	107
3	Damage to penthouse roof and walls; loss of rooftop HVAC equipment	93	75	111
4	Broken glass in exterior walls at 1st and 2nd floors; broken glass in entryways	101	83	120
5	Damage to parapet walls or coping	104	87	122
6	Broken curtain wall panel anchors	129	110	157
7	Significant loss of roofing material (>20%)	143	115	165
8	Significant damage to curtain walls and interior walls	145	123	172
9	Uplift or collapse of roof structure	159	123	183
10	Significant structural deformation	228	190	290

* Degree of Damage



19. HIGH-RISE BUILDING – GREATER THAN 20 STORIES (HRB)

HRB: Rectangular or complex shape; flat or complex roof shape;
Single-ply membrane, polyurethane foam, metal, or copper roof system;
penthouse; glass or metal curtain wall, masonry,
or pre-cast concrete wall panels

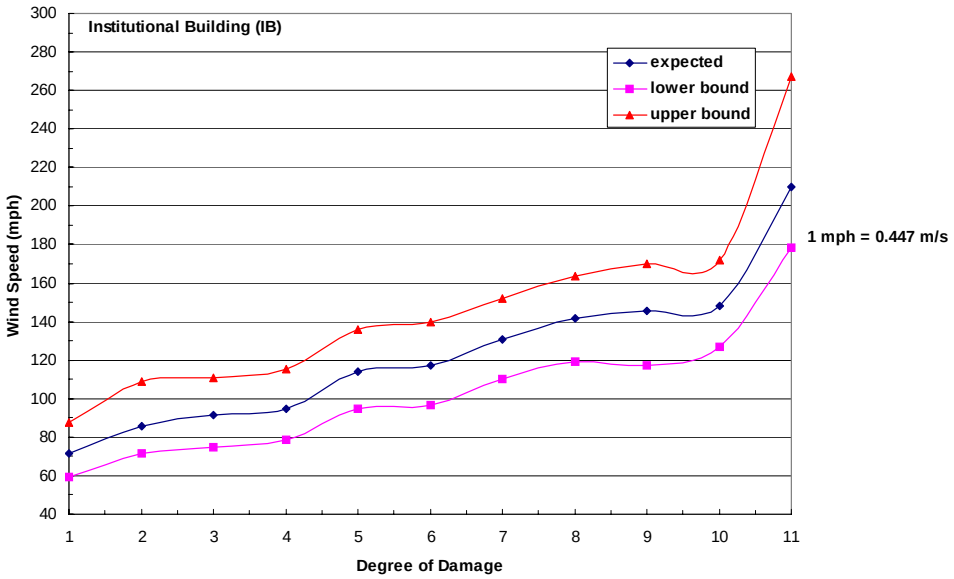
HRB: DOD 5: Broken glass in curtain wall; significant damage to building interior

20. INSTITUTIONAL BUILDING (IB)

General Description

- Examples are hospitals, courthouses, university buildings, state and federal buildings, jails
- Range in height from 1 – 10 stories
- Roofing materials include fully adhered and mechanically fastened single-ply membranes, polyurethane foam, copper clad domes
- Structure is normally reinforced concrete
- Walls are masonry with cut stone or precast panels – very ornate
- Balcones, porches, and porticos with heavy façade
- Relatively small windows

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	72	59	88
2	Loss of roof covering (<20%)	86	72	109
3	Damage to penthouse roof and walls; loss of rooftop HVAC equipment	92	75	111
4	Broken glass in windows or doors	95	78	115
5	Uplift of lightweight roof deck and insulation; significant loss of roofing material (>20%)	114	95	136
6	Façade components torn from structure	118	97	140
7	Damage curtain walls or other wall cladding	131	110	152
8	Uplift of pre-cast concrete roof slabs	142	119	163
9	Uplift of metal deck with concrete fill slab	146	118	170
10	Collapse of some top story exterior walls	148	127	172
11	Significant damage to building envelope	210	178	268



20. INSTITUTIONAL BUILDING (IB)

IB: Height from 1 to 10 stories; single-ply membrane, polyurethane foam, or metal roof systems; masonry, cut-stone or pre-cast wall panels; balconies, porches, or porticos; heavy façade; relatively small windows

IB: DOD 6: Uplift of light-weight roof deck and insulation; significant loss of roofing material (>20%)

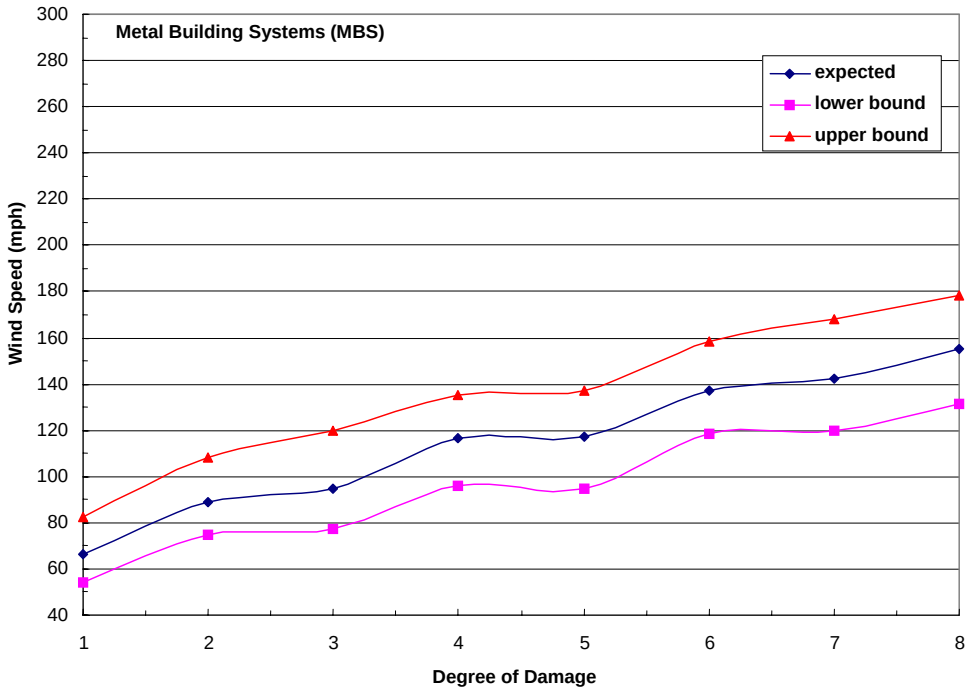
21. METAL BUILDING SYSTEMS (MBS)

General Description

- Examples are warehouses, industrial facilities, small arenas
- Metal panel walls and standing seam roof
- Nearly always have a gable roof and relatively tall walls
- Large overhead doors
- Large-span single bay rigid frames
- Z or C-shaped purlins and girts span between rigid frames
- Lateral loads resisted by x-bracing in direction parallel to ridge
- Relatively weak end-wall frame

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	67	54	83
2	Inward or outward collapsed of overhead doors	89	75	108
3	Metal roof or wall panels pulled from the building	95	78	120
4	Column anchorage failed	117	96	135
5	Buckling of roof purlins	118	95	138
6	Failure of X-braces in the lateral load resisting system	138	118	158
7	Progressive collapse of rigid frames	143	120	168
8	Total destruction of building	155	132	178

* Degree of Damage



21. METAL BUILDING SYSTEM (MBS)

MBS: Metal roof and wall panels; gable roof shape; Z or C-shaped purlins and girts; single-bay rigid frames; x-bracing parallel to ridge

MBS: DOD 7: Collapse of rigid frames

MBS: DOD 8: Total destruction of building

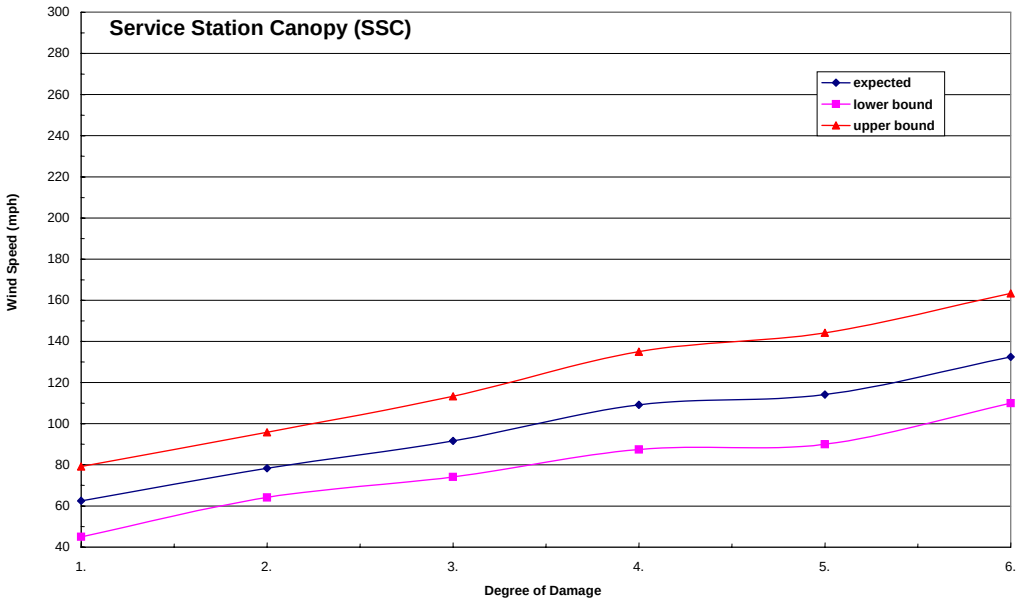
22. SERVICE STATION CANOPY (SSC)

Typical Construction

- Modern service stations consist of a very large canopy covering the entire pump area and small building that houses cashier and retail space
- Canopy structure constructed of steel beam framework supported on 4 or more tall columns
- Metal panels cover bottom side of the canopy
- Light weight fascia materials, either metal or plastic, cover the perimeter of canopy

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	63	45	79
2	Fascia material blown from canopy	78	64	96
3	Metal roof panels stripped from canopy	92	74	113
4	Columns bend or buckle under wind load	109	88	135
5	Canopy collapsed due to column foundation failure	114	90	144
6	Complete destruction of canopy	133	110	163

*Degree of Damage



22. SERVICE STATION CANOPY (SSC)

SSC: Large rectangular free-standing canopy supported on columns; metal panels cover bottom side of canopy; metal or plastic fascia materials cover perimeter of canopy

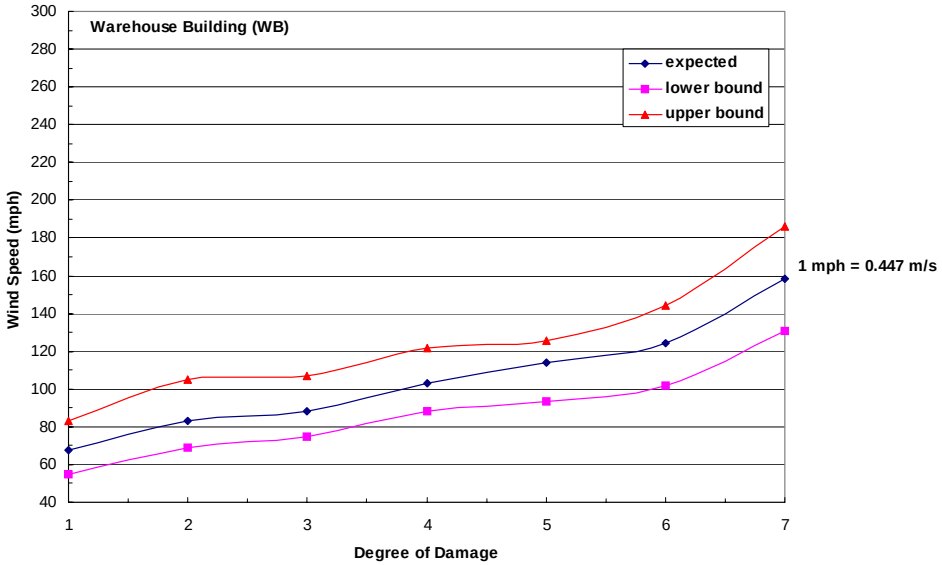
23. WAREHOUSE BUILDING (WHB)

General Description

- This category includes all building systems except Metal Building Systems
- Examples include warehouse, storage, and industrial buildings
- Buildings are generally rectangular in plan with flat, gable or hip roofs
- Built-up roofs with gravel, single-ply membrane ballasted, mechanically attached or fully adhered
- Light-frame steel construction with masonry bearing walls
- Large overhead doors
- Pre-cast concrete columns, beams, and double tees with tilt-up wall panels
- Heavy timber construction with stud walls and wood panels

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	68	55	83
2	Loss of roofing material (<20%)	83	69	105
3	Inward or outward collapse of overhead doors	88	75	107
4	Uplift of roof deck; significant loss of roofing material (>20%); loss of rooftop HVAC equipment	103	88	122
5	Collapse of other non-bearing exterior walls	114	93	126
6	Collapse of pre-cast concrete tilt-up panels	124	102	144
7	Total destruction of a large section of building or entire building	158	131	186

* Degree of Damage



22. WAREHOUSE BUILDING (WHB)

WHB: Rectangular in plan with flat roof; BUR or single-ply membrane roofing system with or without gravel; masonry bearing walls, tilt-up precast concrete wall panels or stud walls with wood panels; large overhead doors

WHB: DOD 6: Collapse of non-bearing exterior wall

WHB: DOD 7: Total destruction of a large section of building

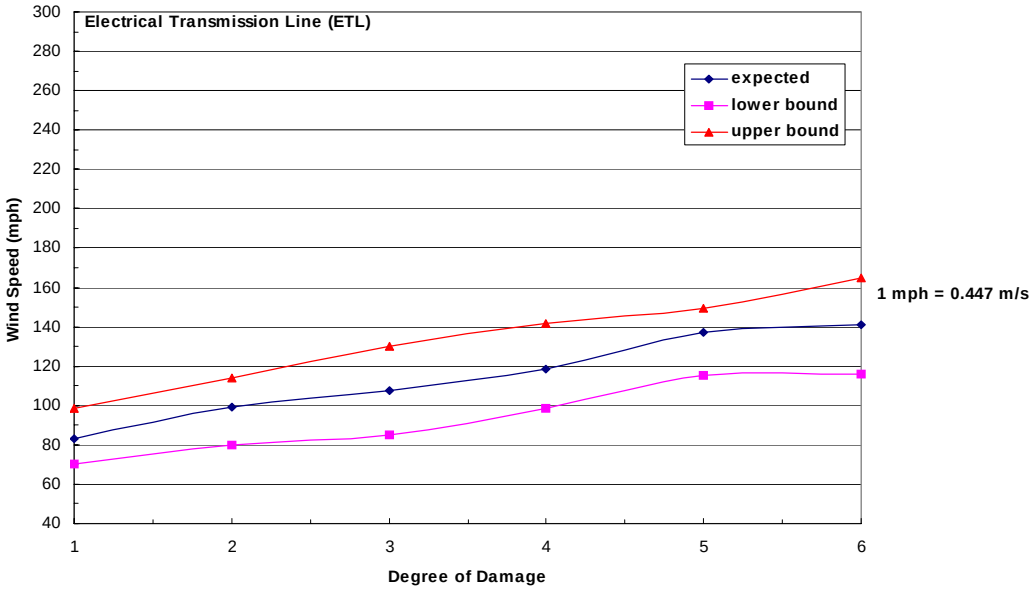
24. ELECTRICAL TRANSMISSION LINE (ETL)

Typical Construction

- Single wood poles with wood cross arms
- Single steel or concrete poles with metal cross arms
- Metal trussed towers

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	83	70	98
2	Broken wood cross member	99	80	114
3	Wood poles leaning	108	85	130
4	Broken wood poles	118	98	142
5	Broken or bent steel or concrete poles	138	115	149
6	Collapsed metal truss towers	141	116	165

* Degree of Damage



24. ELECTRICAL TRANSMISSION LINE (ETL)

ETL: Single Wood Pole

ETL: Single Steel Pole

ETL: Metal Truss Tower

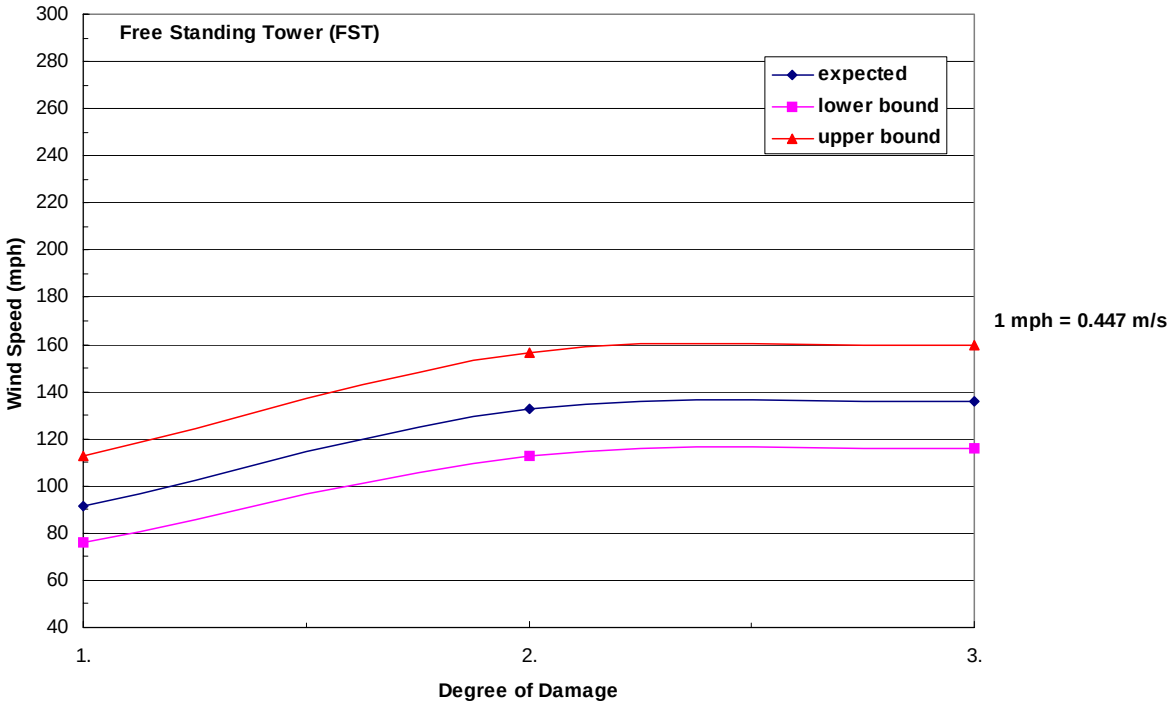
25. FREE-STANDING TOWERS (FST)

Typical Construction

- Single metal poles (Cell phone tower)
- Trussed tower (Microwave tower)

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	92	76	113
2	Collapsed cell-phone tower	133	113	157
3	Collapsed micro-wave tower	136	116	160

* Degree of Damage



24. FREE-STANDING TOWERS (FST)

FST: Free-standing Truss Tower

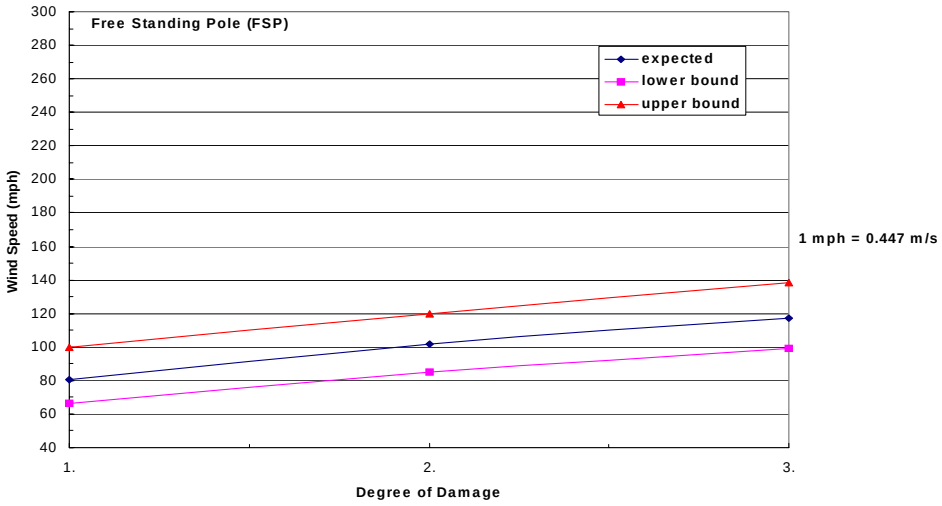
26. FREE-STANDING LIGHT POLES, LUMINARY POLES, FLAG POLES (FSP)

Typical Construction

- Cantilevered metal pole

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	81	67	100
2	Bent pole	102	85	120
3	Collapsed pole	118	99	138

* Degree of Damage



26. FREE-STANDING LIGHT POLES, LUMINARY POLES, FLAG POLES (FSP)

FSP: Light Poles

FSP: Luminary Poles

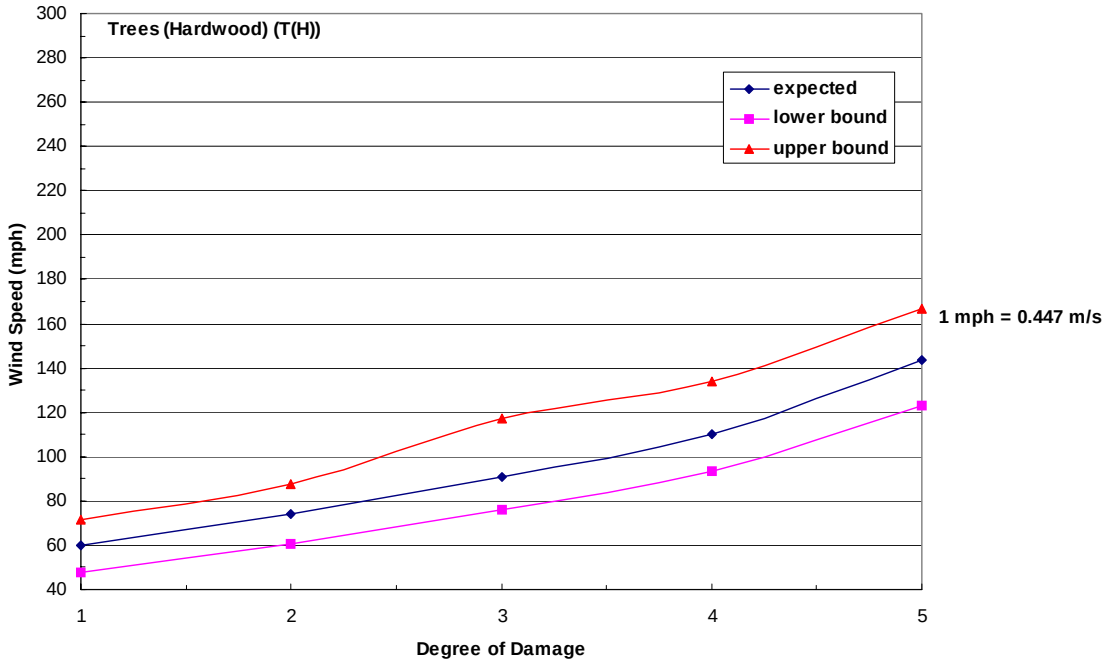
27. TREES: HARDWOOD

Typical Construction

- Hardwood: Oak, Maple, Birch, Ash

DOD*	Damage description	EXP	LB	UB
1	Small limbs broken (up to 1" diameter)	60	48	72
2	Large branches broken (1"-3" diameter)	74	61	88
3	Trees uprooted	91	76	118
4	Trunks snapped	110	93	134
5	Trees debarked with only stubs of largest branches remaining	143	123	167

* Degree of Damage



27. TREES HARDWOOD (TH)

TH: Oak, Maple, Birch, Ash

TH: DOD 4: Tree uprooted

TH: DOD 5: Tree debarked with only stubs of largest branches remaining

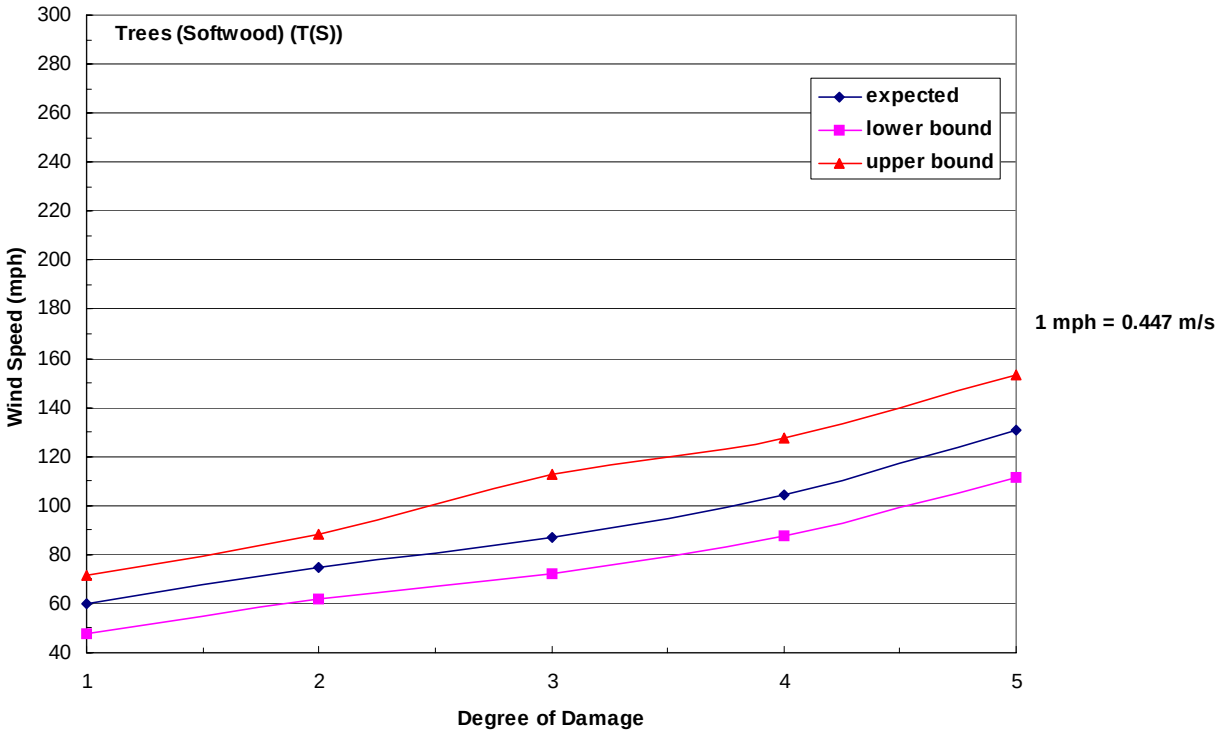
28. TREES (SOFTWOOD)

Typical Construction

- Softwood: Pine, Spruce, Fir, Hemlock, Cedar, Redwood, Cypress

DOD	Damage description	EXP	LB	UB
1	Small limbs broken (up to 1" diameter)	60	48	72
2	Large branches broken (1" – 3" diameter)	75	62	88
3	Trees uprooted	87	73	113
4	Trunks snapped	104	88	128
5	Trees debarked with only stubs of largest branches remaining	131	112	153

* Degree of Damage



Appendix B

EXPERT ELICITATION OF DAMAGE VERSUS WIND SPEED

Small Barns or Farm Buildings

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
SBO	1.0	50	70	70	55	65	60	61.67	1.18
	2.0	65	80	85	65	70	80	74.17	4.12
	3.0	80	90	85	75	85	80	82.50	1.77
	4.0	70	110	90	75	95	100	90.00	7.07
	5.0	80	100	100	85	90	100	92.50	5.30
	6.0	80	110	95	95	100	100	96.67	2.36
	7.0	80	120	110	85	100	100	99.17	0.59
	8.0	100	130	115	115	110	100	111.67	8.25

One and Two-Family Residences

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
FR12	1	60	80	70	60	60	60	65.00	8.37
	2	70	90	85	70	80	80	79.17	8.01
	3	75	130	85	80	105	100	95.83	20.35
	4	85	110	100	85	100	100	96.67	9.83
	5	120	130	110	120	120	125	120.83	6.65
	6	85	140	120	140	120	125	121.67	20.17
	7	125	120	115	150	125	155	131.67	16.63
	8	125	160	130	165	135	170	147.50	19.69
	9	130	160	150	165	150	155	151.67	12.11
	10	130	170	160	200	170	190	170.00	24.49

Manufactured Home Single Wide

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
MHSW	1	50	70	65	60	60	60	60.83	6.65
	2	65	80	70	70	80	80	74.17	6.65
	3	70	100	90	90	90	80	86.67	10.33
	4	75	100	90	90	90	90	89.17	8.01
	5	90	110	100	95	100	90	97.50	7.58
	6	100	120	100	100	110	100	105.00	8.37
	7	100	120	110	115	110	100	109.17	8.01
	8	120	120	110	120	125	115	118.33	5.16
	9	120	130	120	130	135	125	126.67	6.06

EXPERT ELICITATION OF DAMAGE VERSUS WIND SPEED

Manufactured Home Double Wide

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
MHDW	1	50	70	65	60	60	60	60.83	6.65
	2	65	80	80	70	80	80	75.83	6.65
	3	75	80	70	80	85	80	78.33	5.16
	4	75	100	80	80	80	80	82.50	8.80
	5	75	100	85	80	85	100	87.50	10.37
	6	80	110	100	90	90	90	93.33	10.33
	7	80	110	110	90	95	80	94.17	13.57
	8	80	110	95	100	95	100	96.67	9.83
	9	100	120	110	120	115	110	112.50	7.58
	10	110	130	120	120	105	100	114.17	11.14
	11	120	130	125	135	130	120	126.67	6.06
	12	120	140	130	150	135	130	134.17	10.21

Apartments, Townhouses, Condos

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
ACT	1	65	90	70	70	80	80	75.83	9.17
	2	80	110	120	85	100	100	99.17	14.97
	3	120	130	130	120	120	125	124.17	4.92
	4	130	140	140	150	130	140	138.33	7.53
	5	140	150	150	190	165	155	158.33	17.51
	6	160	180	160	220	170	190	180.00	22.80

Motels

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
M	1	65	80	70	60	60	60	65.83	8.01
	2	75	90	85	70	80	80	80.00	7.07
	3	75	110	90	80	80	100	89.17	13.57
	4	85	110	90	85	100	100	95.00	10.00
	5	80	110	90	110	105	100	99.17	12.01
	6	120	130	125	120	120	125	123.33	4.08
	7	130	130	130	150	130	155	137.50	11.73
	8	130	140	135	165	130	155	142.50	14.40
	9	160	160	160	200	150	190	170.00	20.00
	10	160	180	170	230	170	230	190.00	31.62

EXPERT ELICITATION OF DAMAGE VERSUS WIND SPEED

Masonry Apartment or Motel

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
MAMB	1.	65	80	65	60	60	60	65.00	7.75
	2.	75	90	85	70	80	80	80.00	7.07
	3.	100	100	95	85	100	90	95.00	6.32
	4.	120	120	105	130	150	100	120.83	18.00
	5.	130	120	115	165	140	125	132.50	18.10
	6.	160	140	130	190	160	155	155.83	20.60
	7.	180	160	150	220	180	190	180.00	24.49

Small Retail Building

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
SRB	1	65	80	65	60	60	60	65.00	7.75
	2	65	90	85	70	80	80	78.33	9.31
	3	65	100	100	90	80	80	85.83	13.57
	4	80	110	110	85	100	100	97.50	12.55
	5	70	100	90	120	105	100	97.50	16.66
	6	100	120	130	120	120	125	119.17	10.21
	7	120	140	140	160	130	140	138.33	13.29
	8	140	160	150	230	165	155	166.67	32.20

Small Professional Building

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
SPB	1	65	80	65	60	60	60	65.00	7.75
	2	65	90	85	70	80	80	78.33	9.31
	3	65	100	100	90	80	100	89.17	14.29
	4	65	130	95	90	120	100	100.00	23.02
	5	80	110	110	100	100	100	100.00	10.95
	6	80	110	120	100	110	100	103.33	13.66
	7	120	130	130	120	120	125	124.17	4.92
	8	130	140	140	160	140	155	144.17	11.14
	9	140	160	150	130	170	190	156.67	21.60

EXPERT ELICITATION OF DAMAGE VERSUS WIND SPEED

Strip Mall

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
SM	1	65	80	65	60	60	60	65.00	7.75
	2	70	90	90	70	80	80	80.00	8.94
	3	65	100	110	90	80	80	87.50	16.05
	4	100	110	110	85	100	100	100.83	9.17
	5	80	110	120	100	110	100	103.33	13.66
	6	100	100	95	120	105	100	103.33	8.76
	7	120	120	130	120	120	120	121.67	4.08
	8	140	130	140	160	140	130	140.00	10.95
	9	160	150	150	230	180	155	170.83	31.05

Large Shopping Mall

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
LSM	1	65	90	65	75	60	70	70.83	10.68
	2	65	110	90	85	80	80	85.00	14.83
	3	75	100	100	95	80	100	91.67	11.25
	4	100	130	110	110	100	100	108.33	11.69
	5	100	110	110	110	110	125	110.83	8.01
	6	110	140	120	130	125	140	127.50	11.73
	7	120	150	140	160	140	155	144.17	14.29
	8	130	160	150	170	160	190	160.00	20.00
	9	200	180	160	260	195	230	204.17	35.84

Large Isolated Retail Building

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
LIRB	1	65	80	65	70	60	70	68.33	1.87
	2	65	90	90	80	80	80	80.83	6.83
	3	100	110	110	100	100	100	103.33	9.17
	4	120	120	130	120	115	125	121.67	5.16
	5	120	140	140	130	120	155	134.17	5.16
	6	120	120	140	140	130	170	136.67	13.57
	7	160	140	150	230	170	190	173.33	18.62

EXPERT ELICITATION OF DAMAGE VERSUS WIND SPEED

Automobile Showroom

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
ASR	1	50	80	70	70	60	60	65.00	10.49
	2	65	90	85	80	80	80	80.00	8.37
	3	65	100	105	90	80	80	86.67	14.72
	4	85	110	110	100	100	100	100.83	9.17
	5	85	100	120	130	110	125	111.67	16.93
	6	100	110	130	120	120	125	117.50	10.84
	7	100	110	140	140	130	135	125.83	16.86
	8	120	120	150	230	165	155	156.67	40.46

Automobile Service Building

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
ASB	1	50	80	70	60	60	60	63.33	10.33
	2	65	90	85	70	80	80	78.33	9.31
	3	70	100	95	90	90	100	90.83	11.14
	4	85	110	110	85	100	100	98.33	11.25
	5	100	110	120	130	125	100	114.17	12.81
	6	100	120	130	130	120	125	120.83	11.14
	7	110	120	130	150	135	125	128.33	13.66
	8	120	130	150	220	165	155	156.67	35.17

Elementary School

Bldg	Damage Indicator	Expected Values						Mean	Std Dev
		1	2	3	4	5	6		
ES	1	50	80	70	70	60	60	65.00	10.49
	2	65	90	85	75	80	80	79.17	8.61
	3	65	100	105	90	80	80	86.67	14.72
	4	65	120	100	90	120	100	99.17	20.60
	5	85	110	110	100	100	100	100.83	9.17
	6	75	120	120	120	110	100	107.50	17.82
	7	120	120	130	130	125	125	125.00	4.47
	8	140	120	130	150	140	155	139.17	12.81
	9	100	140	140	175	170	190	152.50	32.52
	10	160	140	150	230	185	190	175.83	32.93

Appendix C

FUJITA-SCALE RATINGS OF DODs BY NWS PERSONNEL

Small Barns and Farm Outbuildings (SBO)		Expert F-Scale						Median 3-sec Gust Speed						Expert	Elicitation
DOD*	Damage description	1	2	3	4	5	6	1	2	3	4	5	6	Mean	Mean
1	No visible damage	0	0	0	0	0	0	61.25	61.25	61.25	61.25	61.25	61.25	61	62
2	Loss of wood or metal roof panels	0	0	0	0	0	0	61.25	61.25	61.25	61.25	61.25	61.25	61	74
7	Overturning or sliding of entire structure	0	0	1	1	1	1	61.25	61.25	98.20	98.20	98.20	98.20	86	99
5	Uplift or collapse of roof structure	0	0	1	1	1	1	61.25	61.25	98.20	98.20	98.20	98.20	86	93
3	Collapse of doors	0	0	0	1	0	1	61.25	61.25	61.25	98.20	61.25	98.20	74	83
6	Collapse of walls	0	0	1	1	0	2	61.25	61.25	98.20	98.20	61.25	139.60	87	97
4	Major loss of roof panels	0	1	1	1	0	2	61.25	98.20	98.20	98.20	61.25	139.60	93	90
8	Total destruction of building	1	1	2	2	1	2	98.20	98.20	139.60	139.60	98.20	139.60	119	112
One and Two Family Residences (FR12)															
DOD	Damage description	1	2	3	4	5	6								
1	Threshold of visible damage	0	0	0	0	0	0	61.25	61.25	61.25	61.25	61.25	61.25	61	65
2	Loss of roofing material (< 20%), gutters and/or awning; loss of vinyl or metal siding	0	1	0	1	0	0	61.25	98.20	61.25	98.20	61.25	61.25	74	79
10	Total destruction of entire building	4	4	4	4	4	4	235.60	235.60	235.60	235.60	235.60	235.60	236	170
3	Broken glass in doors or windows	2	1	0	2	0	1	139.60	98.20	61.25	139.60	61.25	98.20	100	96
5	Entire house shifts off foundation	3	2	2	3	2	2	185.25	139.60	139.60	185.25	139.60	139.60	155	121
4	Uplift of roof deck and loss of significant roof covering material (>20%);collapse of chimney; garage doors collapse inward or outward; damage to porch or carport	1	1	1	2	1	1	98.20	98.20	98.20	139.60	98.20	98.20	105	97
6	Large sections of roof structure removed; most walls remain standing	2	2	2	2	2	2	139.60	139.60	139.60	139.60	139.60	139.60	140	122
9	Most walls collapsed in bottom floor, except at small interior rooms	3	3	4	3	3	4	185.25	185.25	235.60	185.25	185.25	235.60	202	152
7	Top floor exterior walls collapsed	3	3	4	3	3	3	185.25	185.25	235.60	185.25	185.25	185.25	194	132
10	Most interior walls of top story collapsed	2	3	3	3	3	3	139.60	185.25	185.25	185.25	185.25	185.25	178	148
*Numbers correspond to DODs in Appendix A															
Manufactured Homes Single Wide (MHSW)															
DOD	Damage description	1	2	3	4	5	6								
1	No visible damage	0	0	0	0	0	0	61.25	61.25	61.25	61.25	61.25	61.25	61	61
2	Loss of shingles or partial uplift of one-piece metal roof covering	0	0	1	0	0	0	61.25	61.25	98.20	61.25	61.25	61.25	67	74
5	Unit rolls on its side or upside down; essentially intac	1	0	1	1	0	1	98.20	61.25	98.20	98.20	61.25	98.20	86	98
3	Unit slides off masonry block piers but remains upright	1	0	1	1	0	0	98.20	61.25	98.20	98.20	61.25	61.25	80	87
6	Destruction of roof and walls leaving floor and undercarriage in place	2	1	1	2	0	1	139.60	98.20	98.20	139.60	61.25	98.20	106	105
4	Complete uplift of roof, most walls remain upright	1	0	1	1	0	1	98.20	61.25	98.20	98.20	61.25	98.20	86	89
7	Unit rolls, displaces or vaults; roof and walls separate from floor and undercarriage	1	1	2	2	1	1	98.20	98.20	139.60	139.60	98.20	98.20	112	109
8	Undercarriage separated from unit; rolls, tumbles and is badly ben	1	1	2	2	1	2	98.20	98.20	139.60	139.60	98.20	139.60	119	118
9	Complete destruction of unit; debris blown away	2	2	2	2	2	2	139.60	139.60	139.60	139.60	139.60	139.60	140	127
Manufactured Homes Double Wide (MHDW)															
DOD	Damage description	1	2	3	4	5	6								
1	No visible damage	0	0	0	0	0	0	61.25	61.25	61.25	61.25	61.25	61.25	61	61
2	Loss of shingles or other roofing material (<20%)	0	1	1	0	0	0	61.25	98.20	98.20	61.25	61.25	61.25	74	76
4	Broken windows	1	0	1	1	0	0	98.20	61.25	98.20	98.20	61.25	61.25	80	83
6	Complete uplift of roof; most walls remain standing	1	1	1	1	0	0	98.20	98.20	98.20	98.20	61.25	61.25	86	93
3	Damaged porch or carport	0	0	1	1	0	0	61.25	61.25	98.20	98.20	61.25	61.25	74	78
5	Uplift of roof deck and loss of significant roof covering material (>20%)	1	1	2	1	0	1	98.20	98.20	139.60	98.20	61.25	98.20	99	88
9	Complete destruction of roof and walls leaving floor and undercarriage in place	2	2	2	1	1	1	139.60	139.60	139.60	98.20	98.20	98.20	119	113
7	Unit slides off CMU block piers	1	1	1	1	1	1	98.20	98.20	98.20	98.20	98.20	98.20	98	94
8	Removal of entire roof structure leaving most walls standing	1	1	2	1	1	1	98.20	98.20	139.60	98.20	98.20	98.20	105	97
10	Unit rolls, displaces or vaults	2	2	2	2	1	1	139.60	139.60	139.60	139.60	98.20	98.20	126	114
11	Undercarriage separates from floor; rolls and tumbles, badly bent	2	3	2	2	1	2	139.60	185.25	139.60	139.60	98.20	139.60	140	127
12	Complete destruction of unit; debris blown away	3	3	2	2	2	2	185.25	185.25	139.60	139.60	139.60	139.60	155	134
Apartments, Condominiums & Townhouses (ACT)															
DOD	Damage description	1	2	3	4	5	6								
1	No visible damage	0	0	0	0	0	0	61.25	61.25	61.25	61.25	61.25	61.25	61	76
2	Loss of roof covering (<20%)	0	1	1	1	0	0	61.25	98.20	98.20	98.20	61.25	61.25	80	99
3	Uplift of roof decking; significant loss of roof covering (>20%)	1	2	2	1	0	1	98.20	139.60	139.60	98.20	61.25	98.20	106	124
4	Uplift or collapse of roof structure leaving most walls standing	2	2	2	2	1	2	139.60	139.60	139.60	139.60	98.20	139.60	133	138
5	Most top floor walls collapsed	3	2	3	3	2	2	185.25	139.60	185.25	185.25	139.60	139.60	162	158
6	Almost total destruction of top two floors	3	3	3	3	3	3	185.25	185.25	185.25	185.25	185.25	185.25	185	180
7	Total destruction of entire building	4	4	4.5	4	4	4	235.60	235.60	262.72	235.60	235.60	235.60	240	206
Motels (M)															
DOD	Damage description	1	2	3	4	5	6								
1	No visible damage	0	0	0	0	0	0	61.25	61.25	61.25	61.25	61.25	61.25	61	66