Comparative Analysis of the Wind Speeds and Wind Loads Requirements for Puerto Rico on the Last Three Decades

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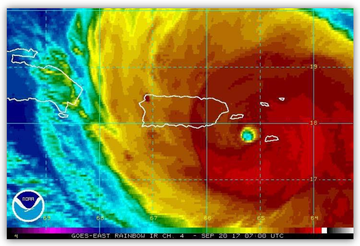
Abstract

This project presents an analysis of the changes and differences of the wind load provisions between the Building Regulation No. 7 of Puerto Rico (amended in 1987) and the ASCE 7-88 through ASCE 7-16 and how they compare to the current code of Puerto Rico. The comparison focuses on wind speeds, external pressures, and resulting external pressures considering factored actions (ultimate state design). As result of the analysis, it was observed a general tendency to increase the basic wind speed with the years, but since the load factor for wind loads in the 2010 and 2016 edition was reduced to 1.0 (wind loads are considered ultimate loads), the resulting factored pressures have been reduced as compared to the current code that follows the 2005 edition of the ASCE 7. Considering the damages and structural failures observed just after the passing of Hurricane Maria in Puerto Rico, and the ones produced by Hurricane San Felipe in 1928, and due to the possibility of adopting new building codes such as the ASCE 7-16, we suggest that a code revision regarding the basic wind speed for Puerto Rico is strongly necessary.

Introduction

In the aftermath of Hurricane Maria, Puerto Rico suffered a lot of catastrophic damages to structures, residential homes and infrastructural components. Maria by far is the strongest hurricane, with registered sustained winds greater than 150 mph, to make landfall in Puerto Rico since Category 5 hurricane known as San Felipe the Second in 1928. The wind effects on building structures are important because they give us a motive to investigate the reason behind these failures and to be able to improve the design and construction in Puerto Rico.



Background

The Building Regulation No. 7 of Puerto Rico and the American Society of Civil Engineers Standard 7 (Minimum Design Loads for Buildings and Other Structures) provide the minimum requirements for general structural design to safeguard the public health and safety the occupants of new and existing buildings and structures. These standards were used in this research to assess the changes in wind loads provisions.

Problem

Since the highest wind speed of Hurricane Maria was greater than the 3-sec gust wind speed under the current Puerto Rico Building Code in which refers to the ASCE 7-05, a brief research was conducted to compare the wind load factors, the wind speeds and ultimate external wind pressure between the Building Regulation No. 7 of Puerto Rico and the ASCE 7-88 through the ASCE 7-16 to assess if the changes implied an increase in safety or not.

Methodology

- Identify the specifications for the wind provisions contained in the Building Regulation No. 7 of Puerto Rico and in the different versions of the ASCE 7 since 1988.
- Develop a computer program in VBA+Excel to compute the dynamic wind pressure at 33 ft of height, and the external windward wall pressure according to the different standards.
- Compare the basic wind speeds, the resulting external pressures, the corresponding factored pressures (ultimate state design), and the equivalent ultimate wind speed using the following information:
  - Risk Category II building
  - At 33 feet of height
  - For Exposure C and D classification

Results and Discussion

- The following table presents the ultimate external wind pressures for Exposure C.
- Ultimate external wind pressures from the ASCE 7-98 to ASCE 7-05 are larger wind pressures than the ones in the ASCE 7-10 and ASCE 7-16 despite having higher wind speeds.

Code	Wind Speed (mph)	External Pressure (psf)	Ultimate External Pressure (psf)
1987	110	26.40	34.32
1988	95	28.47	37.01
1995	125	27.20	35.36
1998	145	31.11	49.78
2002	145	31.11	49.78
2005	145	31.11	49.78
2010	150	33.29	33.29
	160	37.88	37.88
	170	42.76	42.76
2016	150	33.29	33.29
	160	37.88	37.88
	170	42.76	42.76

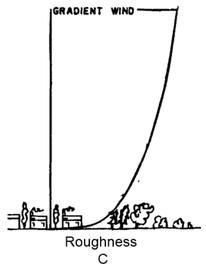
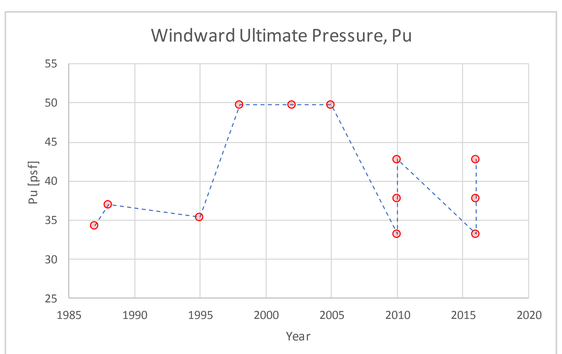


Table of result for Ultimate Wind Pressures at 33 ft of height for Exposure C for windward walls and an Image of the variation of wind speed with height z for a Surface Roughness C



Line graph for Ultimate Wind Pressures for Exposure C specified in the ASCE 7 and the Building Regulation Code for windward walls

- The following table shows the ultimate external wind pressures for an Exposure D.
- The ultimate external wind pressures from the ASCE 7-98 to ASCE 7-05 in hurricane prone areas, correspond to an Exposure C as per the standard.
- Still, the ultimate wind pressures from the ASCE 7-98 to ASCE 7-05 are larger than the ASCE 7-10 and ASCE 7-16 except for ultimate wind pressures for 170 mph.

Code	Wind Speed (mph)	External Pressure (psf)	Ultimate External Pressure (psf)
1987	110	26.40	34.32
1988	95	35.61	46.30
1995	125	32.10	41.72
1998	**145**	**31.11**	**49.78**
2002	**145**	**31.11**	**49.78**
2005	**145**	**31.11**	**49.78**
2010	150	39.29	39.29
	160	44.70	44.70
	170	50.46	50.46
2016	150	39.29	39.29
	160	44.70	44.70
	170	50.46	50.46

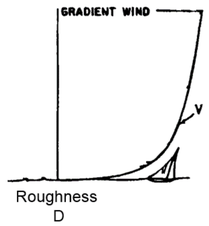
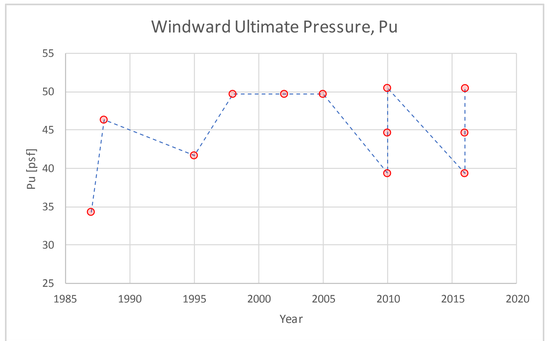
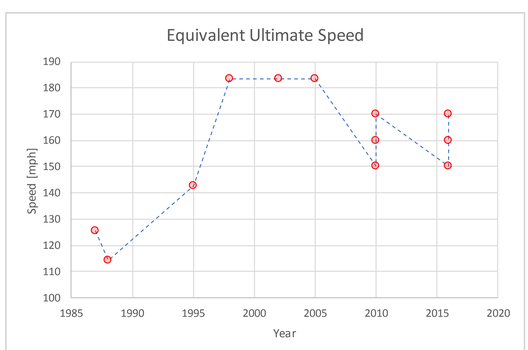


Table of result for Ultimate Wind Pressures at 33 ft of height for Exposure D for windward walls and an Image of the variation of wind speed with height z for a Surface Roughness D



Line graph for Ultimate Wind Pressures for Exposure D specified in the ASCE 7 and the Building Regulation Code for windward walls

- The line graph shows the equivalent ultimate wind speeds at its highest between 1998 and 2005 with 183 mph for Risk Category II.



Equivalent Ultimate Speed for Puerto Rico

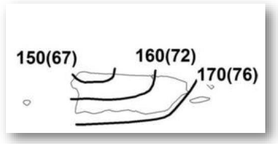
Conclusions

- Despite the apparent increase in basic wind speeds in the ASCE 7-16 as compared to ASCE 7-05

ASCE 7-05

Location	V mph	(m/s)
Hawaii	105	(47)
Puerto Rico	145	(65)
Guam	170	(76)
Virgin Islands	145	(65)
American Samoa	125	(56)

ASCE 7-16



  - It was observed that the changes have resulted in a reduction in factored (ultimate) external wind pressures.
  - ASCE 7-05 is generally more conservative.

- The following table summarizes the wind speeds that should be adopted in ASCE 7-16 in order to obtain similar factored pressures than ASCE 7-05

Category	Equivalent Wind Speed ASCE 7-05	ASCE 7-16		
		West	Center	East
I	160.94	140	150	160
II	183.41	150	160	170
III	196.69	160	170	180
IV	196.69	160	170	190

- We expect this work will contribute to the amendments that would be proposed to the new PR Building Code.

Future Work

- Conduct the same analysis for Components and Cladding design method.
- Verify the changes in the general anchor requirements for the Components and Cladding elements.

Acknowledgements

I wish to express my sincere gratitude to Dr. Gustavo E. Pacheco-Crosetti for his guidance and encouragement in providing me the opportunity to do this project on this important topic.

References

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