Analysis of Billboards Signs Collapse Due to Intensive Wind of Hurricane Maria

CE- 6905 Master of Engineering in Civil Engineering
Ernesto J. Santiago Caraballo, B.S.C.E., P.E.
Gustavo E. Pacheco-Crosetti, Ph.D., P.E.
Polytechnic University of Puerto Rico

♦ Abstract

Billboards signs are commonly used by the outdoor media companies to deliver a message to the public and society. High-intensity winds could cause severe damage to the sign structure causing sudden collapse. After hurricane Maria, during field inspections, a local buckling and plastic yielding type of failure was noted at the lower ends of poles supporting the sign's structure. In this project we selected a case study at the Municipality of Bayamon, and developed a refined Finite Element Model to perform advanced analysis that may capture the billboard collapse mechanism, allowing us to backward compute the wind speed that may have produce such failure.

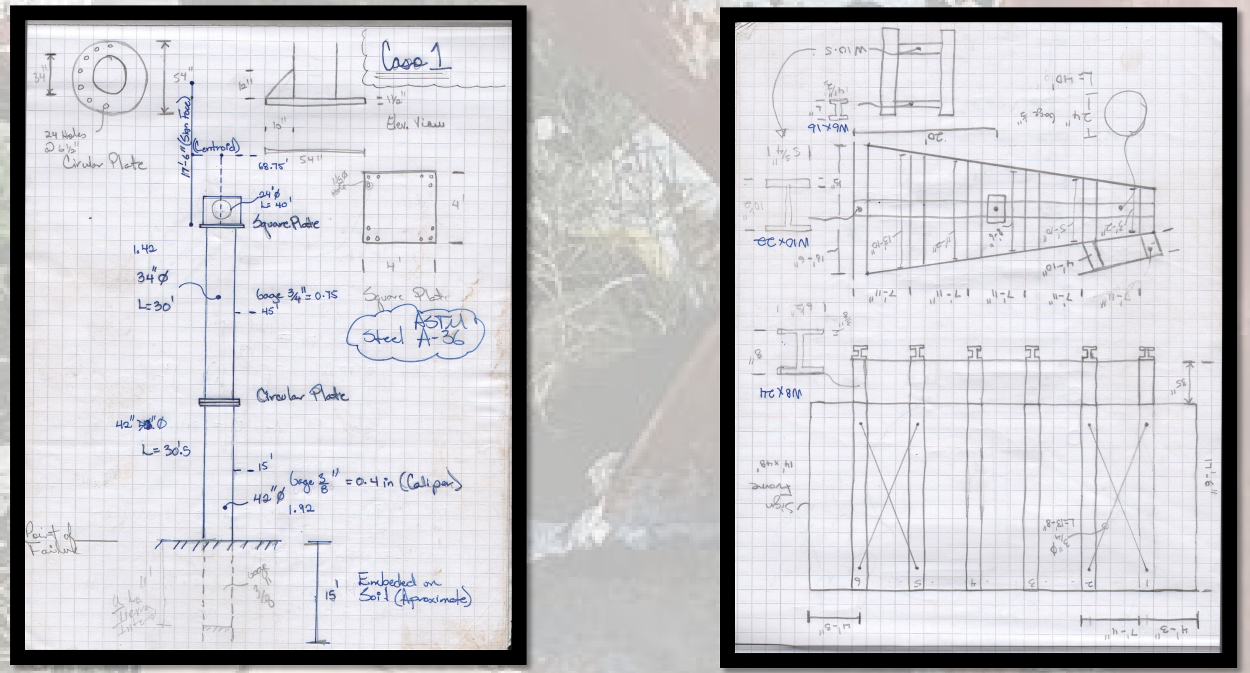
♦ Introduction

- The high winds produced by hurricanes, tornadoes and other severe storms can cause widespread destruction.
- On September 20, 2017, the island was hit by strong Category IV hurricane called "Maria" [1].
- Wind speeds of 155 mph were recorded by weather agencies in different places of Puerto Rico.
- As shown in the next figures wind force acting on existing signs face was excessive enough to produce local buckling and plastic yielding failures at the base of the free standing structure.

Different Types of Billboard Collapse in San Juan Metropolitan Area

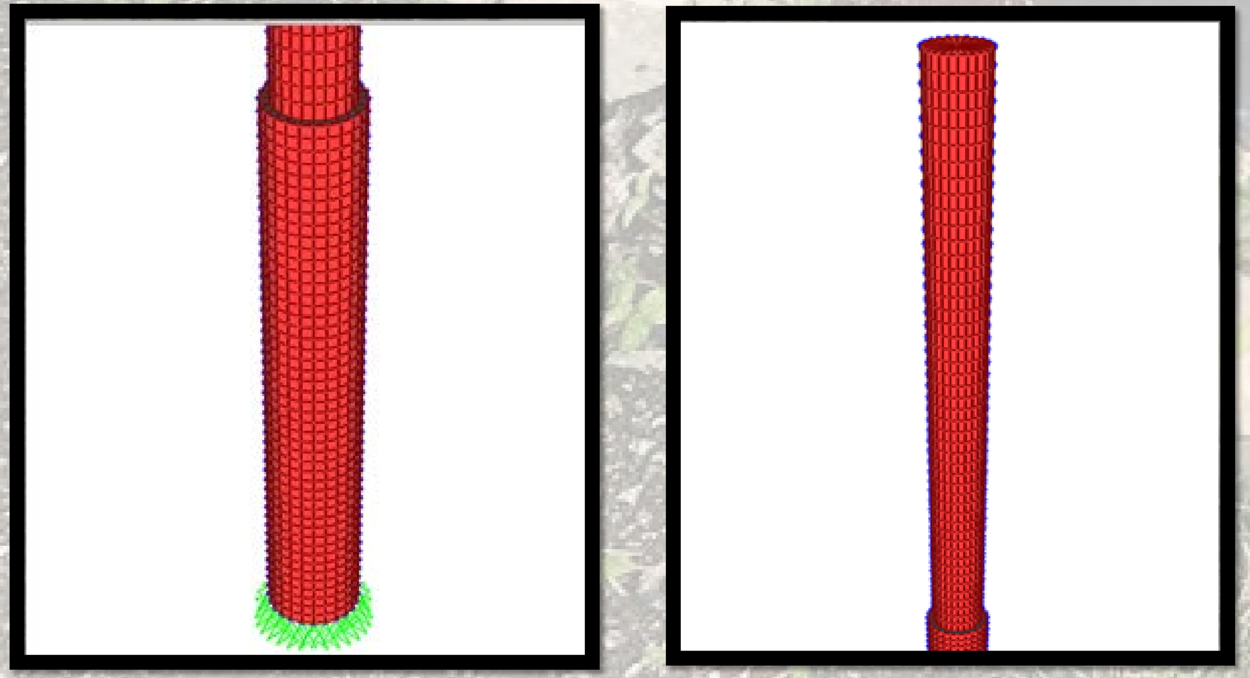
♦ Methodology

- Different cases of billboard failures were identified.
- Field visits were developed to perform a visual inspection, take measurements, and perform a general assessment of the failure, and identified main damages as caused by local buckling and yielding of the post.
- 14' x 48' Billboard Sign located at Christian Church parking at the Municipality of Bayamon was selected.
- Dimensions of the structure were obtained from the site visit.
- Linear Elastic Buckling Analysis was performed to find the critical load factor and the bucking modal shape, and determine which velocity of wind produced the critical condition that may produce caused the buckling failure.
- Full Static Nonlinear Analysis (Pushover Analysis) considering material nonlinearity and geometric P-Delta effects was performed with the same purpose.



Field Data Sketch Up

♦ Analytical Model



FEA software Analytical Model

- A discretization of shell element pin connected at the base with 48 division on Z direction and 24 on the angular direction.
- A rigid diaphragm plate was inserted between both poles to connect one each other.
- Additional diaphragm plate was located on top of the upper pole.

♦ Analysis & Results

Load Considered:

Trials	Dead Load[2]	Wind Load[1]	Mz (K*ft)
1	14.345 kip	10 kip	0
2	14.345 kip	10 kip	96

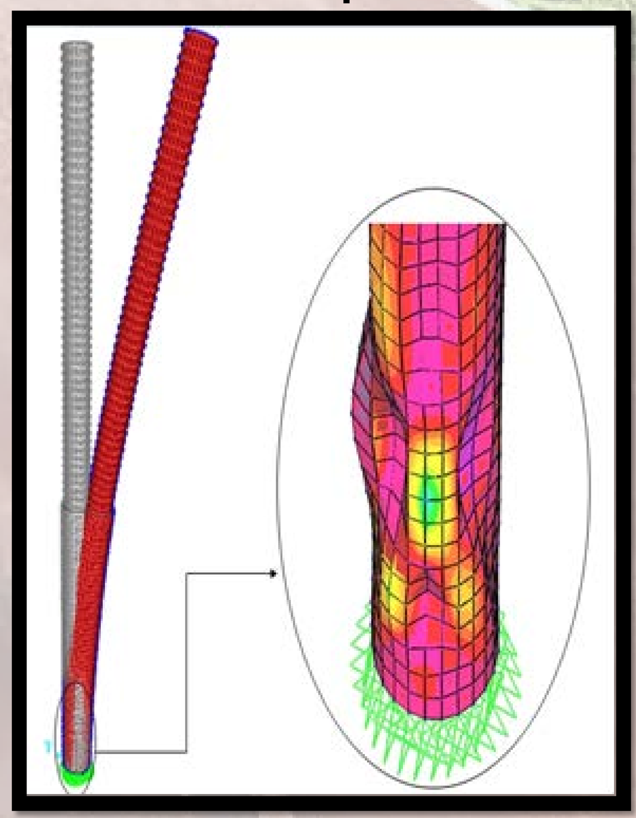
1. Pressures effect due to wind was applied on both poles

Buckling Analysis

Trials	Fy (ksi)	Dead Load	Wind Load	Load Factor	Mz (K*ft.)
1	36,000	14.345 kip	10 kip	4	0
2	46,000	14.345 kip	10 kip	5	0

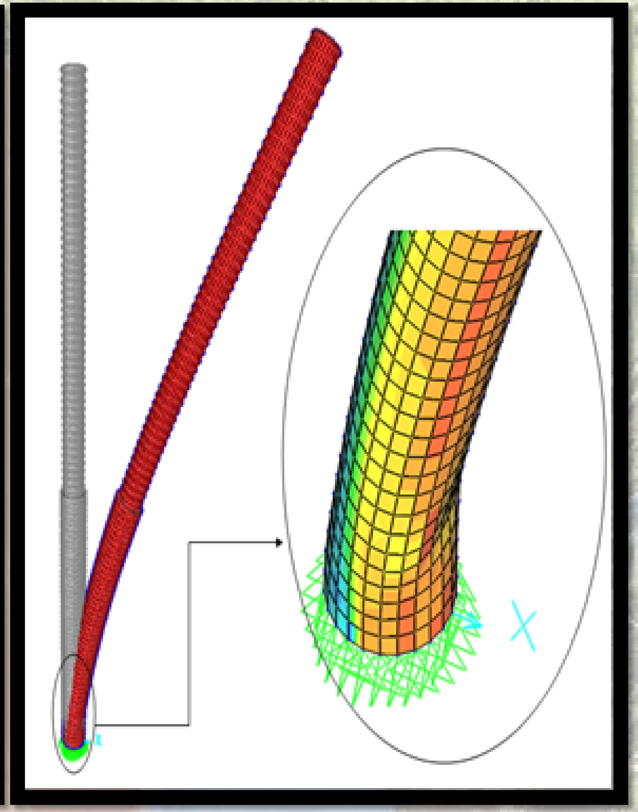
Pushover Analysis

Deformed Shapes:



Buckling Analysis

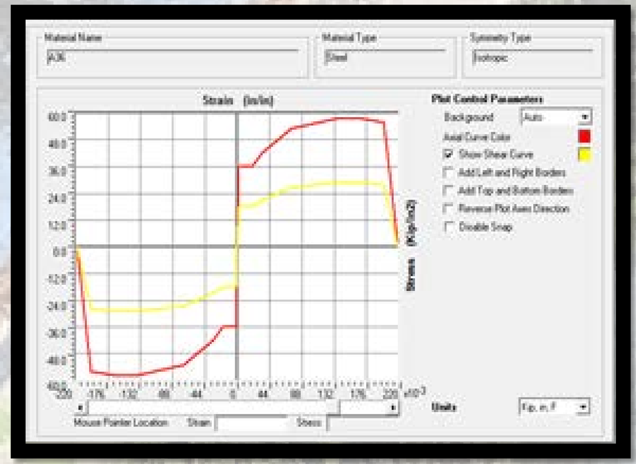
Trials	Analysis Type	Critical Load Factor	Wind Speed (MPH)
1	Linear	31.15	310
2	**Linear**	**14.24**	**209**



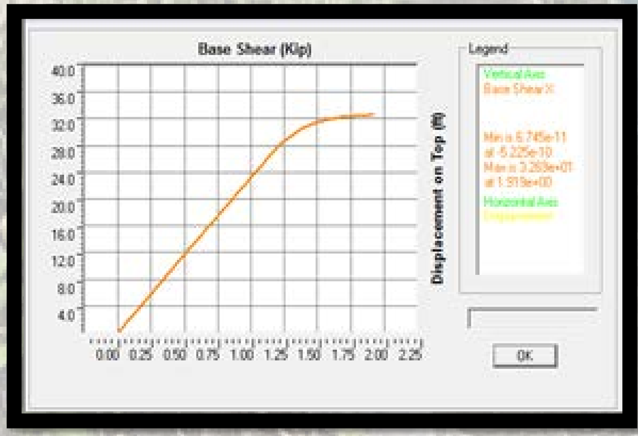
Pushover Analysis

Trials	Fy (Ksi)	Wind Speed (MPH)
1	36,000	**111**
2	46,000	**136**

Stress vs. Strain Diagram



Base Shear vs. Displacement Curve



♦ Conclusion

- After linear buckling analysis modeling was performed, the most reasonable model was the linear buckling analysis in Trial 2. That trial resulted in the lower critical load factor, meaning that this condition was the governing one. And the buckling mode showed a strong resemblance to the field observation.
- An estimated velocity of 209 mph was calculated using the analytical procedure established by ASCE Code 7-05 [2].
- From the static nonlinear analysis (Pushover) an estimated velocity of 111 mph was calculated for A-36 steel material.
- From this results lower loads were obtained, it clearly shows that the failure condition was not initiated by elastic buckling and that perhaps it was due to plasticization accompanied subsequently of local buckling or yielding accompanied by an inelastic local buckling.
- It is recommended to obtain more information about the properties of the material, the original design specifications and perform laboratory tests, in order to be able to do additional analysis of "pushover" and determine the wind speed more assertively.
- There is no doubt that Hurricane Maria established an unprecedented event for the signs industry in Puerto Rico since we must learn. The future of sign design parameters was directly changed after the mentioned above-declared disaster. It is reasonable to believe that the current code must be changed to a higher amount of wind speed.

♦ References

[1] A.B. Penny, R. Berg and R. Parch, "Tropical Cyclone Report- Hurricane Maria," AL-152017. Miami., FL, USA, 2018.

[2] American Society of Civil Engineer ASCE 7-05, "Minimum Design Loads for Building and Other Structures", Structural Engineering Institute, Reston VA. ASCE 2005.

[3] B. Jones, "Engineering Sign Structures An Introduction To Analysis and Design", First Edition, Cincinnati, OH: ST Media Group International Inc., 2006.

♦ Acknowledgements

I would to thanks my advisor, Dr. Gustavo Pacheco Crosetti, for his supportive recommendation during the development of this project.

I would like to give special recognition to my family and friends who helped me achieve my goal of obtaining a master degree.

All those mentioned above, in their own particular way, were a substantial inspiration for the development of this project. Their contribution helped me become a knowledgeable person and a complete professional. To them I will eternally grateful.