White Paper

Wind Loading On Base Station Antennas

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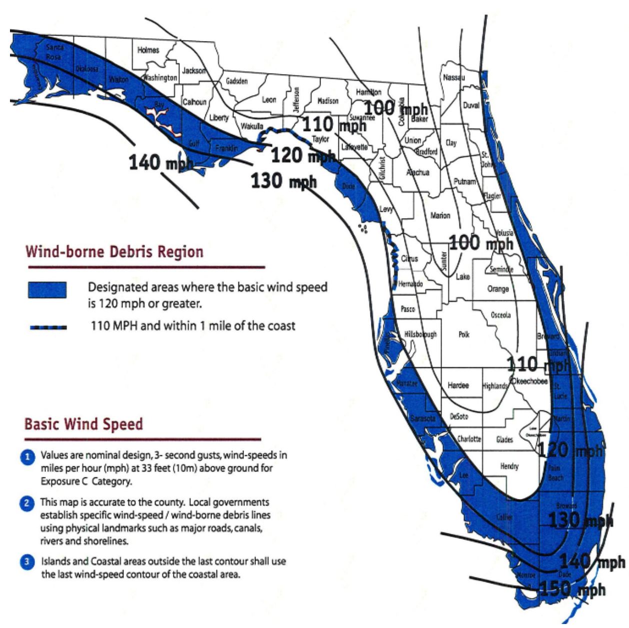
Introduction

As wireless telecommunication services continue to expand, wireless providers are deploying more and more base station antennas in order to meet the growing demand. As a result, antenna towers and support structures are being pushed to the limits of their load capacity. It is therefore important for wireless service providers and tower owners to understand the impact that each base station antenna has on the overall tower load.

Base station antennas not only add load to the towers due to their mass, but also in the form of additional dynamic loading caused by the wind. Depending on the aerodynamic efficiency of the antenna, the increased wind load can be significant. Its effects figure prominently in the design of every Andrew base station antenna. This paper focuses on how Andrew Solutions determines wind load values and Effective Drag Areas published in its catalogs and technical specifications.

In determining wind load values, Andrew uses stand-alone antennas subjected to 150 kilometers per hour (93 miles per hour) winds directed from both front and side. The resulting wind load values can then be used to compare aerodynamic efficiencies between various antenna profiles. These should be used as a starting point for loads used in the tower design and not as absolute maximum wind load values.

Figure 1. Basic Wind Speed Design Factors.



Additionally, there are other location-specific factors to consider when calculating antenna wind load. These include but are not limited to: geographic location, tower height, tower or building structure, surrounding terrain, and shielding effects from other mounted antennas. For example, some regions have maximum wind speeds of 140km/h while others may be as high as 240km/h (Figure 1). Using Andrew calculated values at 150km/h may cause the tower to be over-designed or even worse, greatly under-designed. Industry standards such as TIA-222-G "Structural Standards for Antenna Supporting Structures" take into account these additional factors.

Wind Load Calculation

Wind load is calculated using the following equation:

$$F_w = \tfrac{1}{2} \cdot \rho \cdot (C_{dp} \cdot \lambda) \cdot V^2 \cdot A$$

Where:

- F_w = Force due to wind (lbf, N)
- ρ = Air Density (.075lb/ft^3, 1.22 kg/m^3)
- C_{dp} = Profile Drag Coefficient (from text or experimental data)
- λ = Length/Width Aspect Ratio Correction Factor
- V = Wind Velocity (ft/s, m/s)
- A = Cross Sectional Area Normal to wind direction (length*width) (ft^2,m^2)

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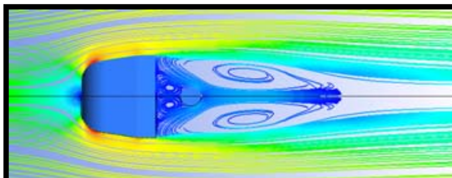
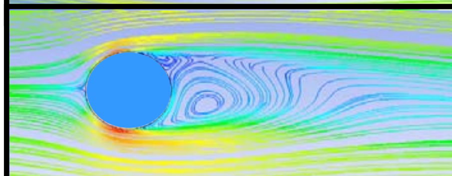
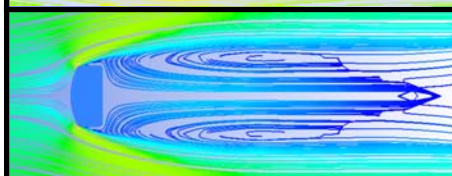
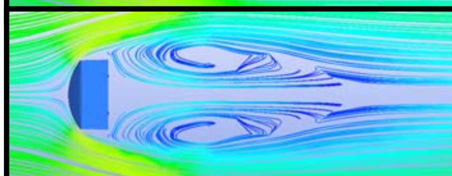
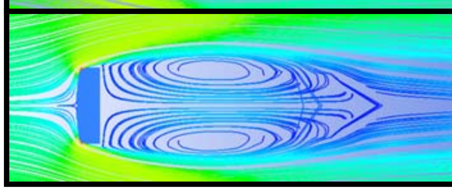
Table 1. Drag Coefficients For Various Antenna Profiles.

	Profile Drag Coefficient*
	1.0
	1.2
	1.6
	1.7
	1.9

*Profile Drag Coefficients (C_{dp}) listed are based on Reynolds Numbers between 10^4 and 10^5 and do not include Aspect Ratio Correction Factor.

Drag Coefficient

The drag coefficient is a key component in calculating wind load on an antenna. Its value varies for each antenna shape and must be determined experimentally or with the aid of Computational Fluid Dynamic (CFD) analysis. If the drag force on an antenna is known, the antenna's drag coefficient can be calculated using the following equation.

$$C_{da} = \frac{F_w}{\frac{1}{2} \cdot \rho \cdot V^2 \cdot A}$$

The area used in this equation is the cross sectional area perpendicular to the wind direction. A variety of resources list experimental drag coefficients of basic shapes and profiles. This data provides a good estimation of simple antenna profiles and is often used by Andrew as a starting point during testing and design. The experimental data is then confirmed with both wind tunnel testing and CFD analysis. Table 1 lists drag coefficients of various antenna profiles.

It is important to note that the drag coefficient of antennas with round and cylindrical profiles are more dependant on the Reynolds number than profiles with abrupt corners. For this reason, values listed are based on Reynolds numbers between 10^4 and 10^5. Once the correct drag coefficient has been determined for a given profile, antennas can be scaled up or down and new wind loads calculated.

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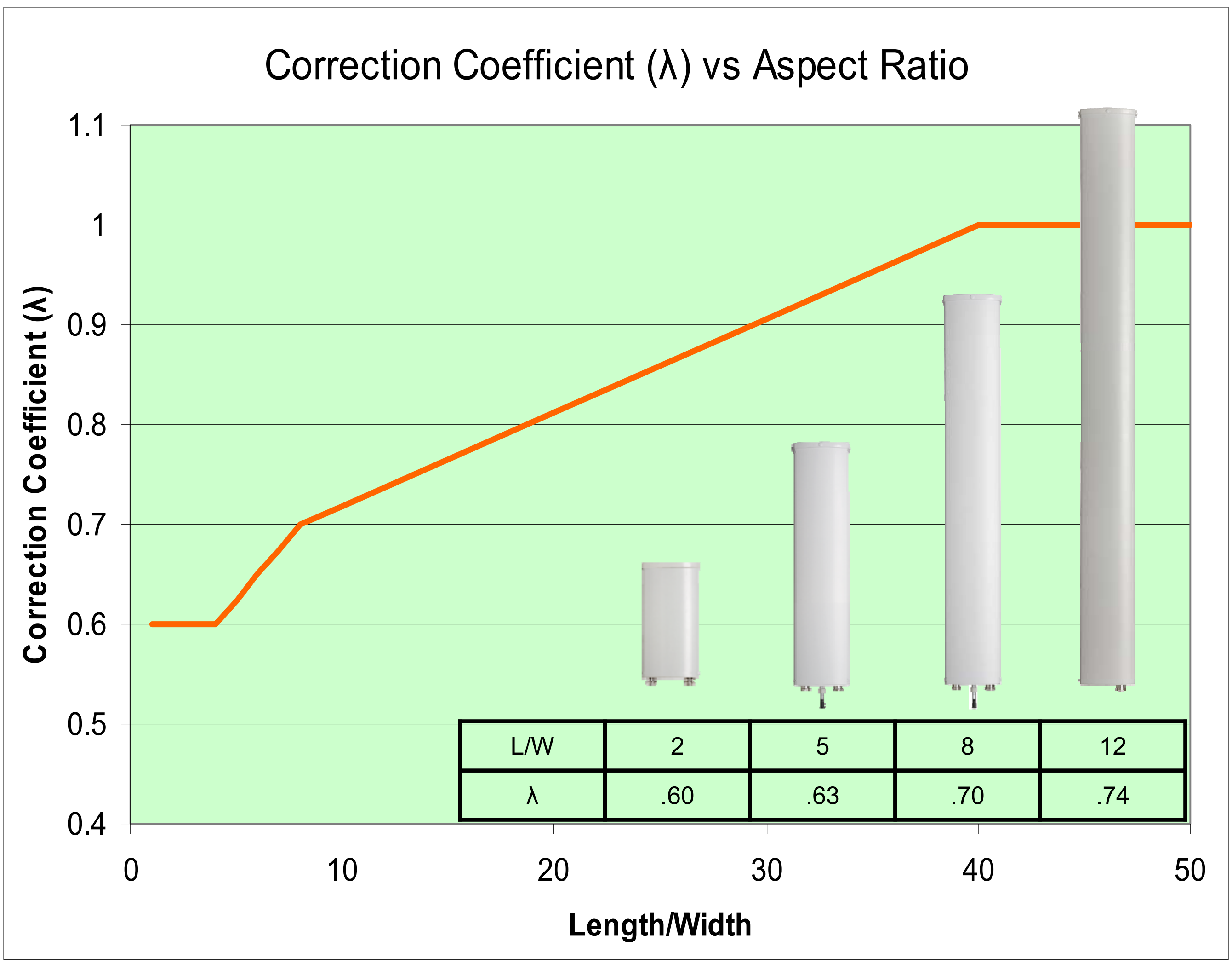
Aspect Ratio Correction Factor

An object with infinite length exhibits the same air flow pattern around every cross section. A reduction of drag due to the existence of ends is a function of the length to width aspect ratio. Many antennas feature radomes with similar cross sectional profiles but varying lengths. The aspect ratio correction factor is used to take into account this variation in antenna length (Figure 2). The antenna drag coefficient (C_{da}) for a given length is equal to the profile drag coefficient (C_{dp}) multiplied by the aspect ratio (λ).

$$C_{da} = C_{dp} \cdot \lambda \qquad F_w = \tfrac{1}{2} \cdot \rho \cdot (C_{dp} \cdot \lambda) \cdot V^2 \cdot A$$

Figure 2. Correction Coefficient Versus Aspect Ratio.

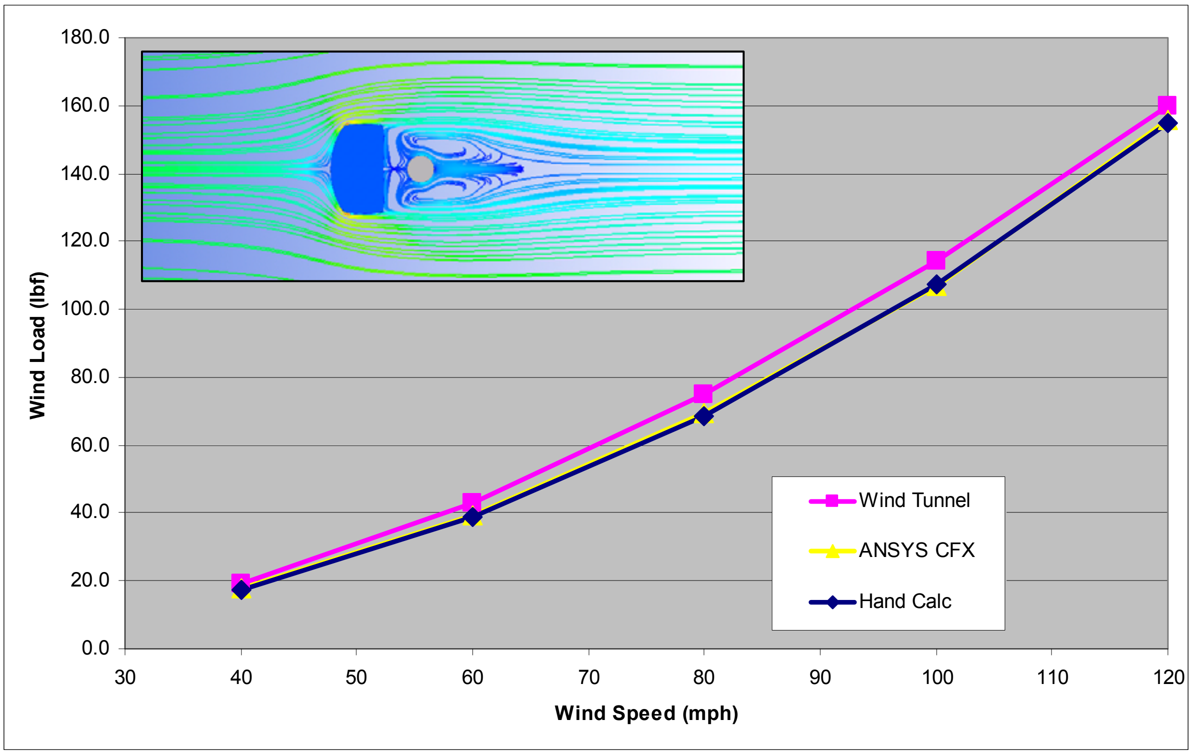


L/W	2	5	8	12
λ	.60	.63	.70	.74

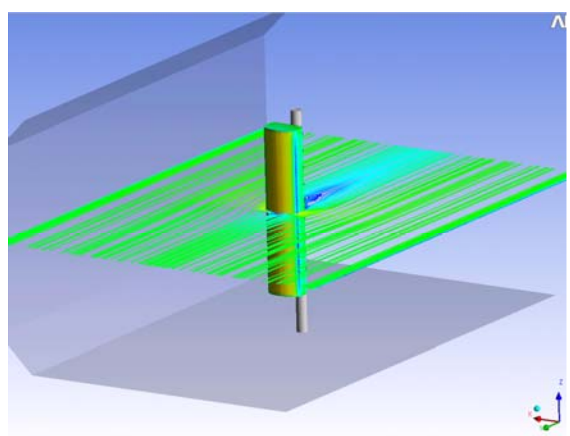
Wind Load Comparisons

As stated earlier, Andrew's wind load calculations are verified by CFD analysis as well as full scale wind tunnel testing. In general, calculated wind load values are within 5% of load data gathered in full scale model wind tunnel testing. The following graph shows wind load values determined by each method for the LNX-6513DS antenna (Figure 3). Additional antenna profile wind load comparisons are included in Appendix A of this report.

Figure 3. Wind Load Comparison Of LNX-6513DS.



Wind Tunnel Testing Of LNX-6513DS



ANSYS/CFX Wind Load Simulation Of LNX-6513DS

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Equivalent Flat Plate and Effective Projected Drag Areas

In the automotive and aviation industries, the equivalent flat plate area (EFA) is used to compare aerodynamic efficiencies from one car or plane to another. In telecommunications the EFA can be used in much the same way for comparing antenna shape profiles. In addition, tower designers may use the EFA to describe the load capacity of a particular tower. The EFA for an antenna is the area of a hypothetical flat surface perpendicular to the fluid flow that produces the same drag as the antenna being analyzed. The equivalent flat plate area is calculated as follows:

Setting the antenna wind load at a given wind speed equal to the flat plate wind load

$$.5 \cdot \rho \cdot V^2 \cdot A_a \cdot C_{da} = .5 \cdot \rho \cdot V^2 \cdot A_{fp} \cdot C_{dfp}$$

Solving for A_{fp}

$$A_{fp} = \frac{A_a \cdot C_{da}}{C_{dfp}}$$

Where:
A_{fp} = equivalent flat plate
A_a = Antenna projected area
C_{da} = Drag Coefficient of Antenna
C_{dfp} = Drag Coefficient of flat plate

It is critical to understand not only the reference area of the antenna being analyzed, but the flat plate reference area as well. Is it circular, square, rectangular, or infinitely long? The shape of the reference flat plate can make a significant difference in the area calculated as shown in Table 2.

Table 2. Equivalent Flat Plate Areas Versus Reference Shape.

	Antenna	Circle	Square	Aspect Ratio	Infinite
C_d	1.11	1.17	1.18	1.54	2.20
EFA (m²)	0.23	0.22	0.22	0.17	0.12

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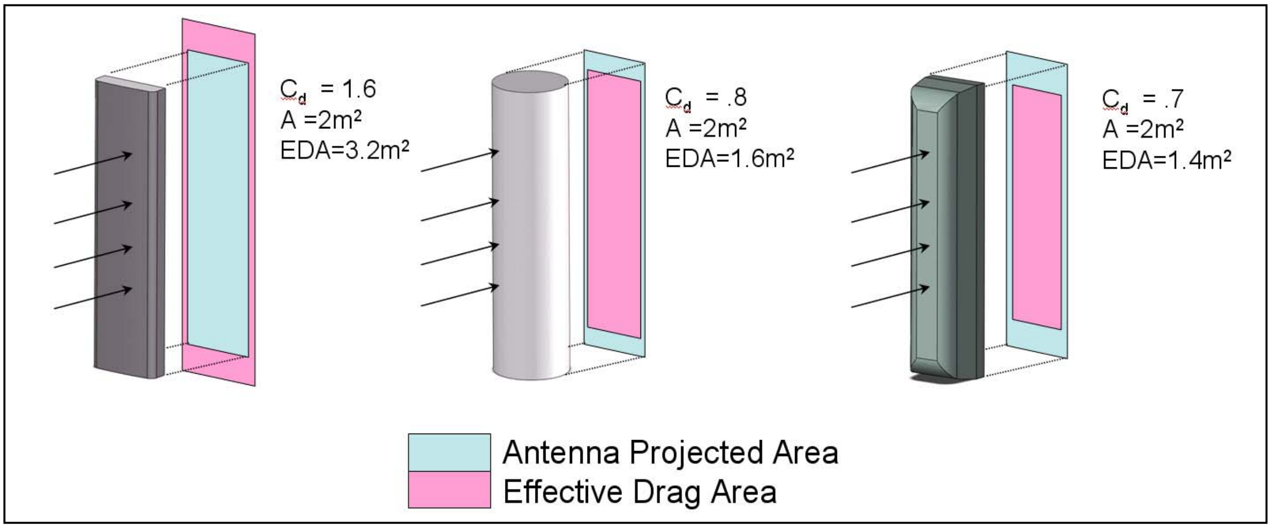
A more accepted practice is to assume that the flat plate reference area has a drag coefficient of 1.0, meaning the equivalent flat plate area is equal the antenna's drag coefficient multiplied by the antenna's projected area perpendicular to the wind direction. This is referred to by Andrew Solutions as the Effective Drag Area (EDA). In order to stay consistent with the latest revision of TIA-222, Andrew has adopted the following calculation for EDA.

$$EDA = C_{da} \cdot A$$

Where:
EDA = Effective Drag Area (ft^2, m^2)
C_{da} = Antenna Drag Coefficient
A = Projected Area of the Antenna (ft^2, m^2)

The more aerodynamic the antenna profile, the smaller the Effective Drag Area, as seen in Figure 4.

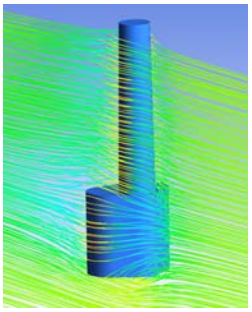
Figure 4. Projected Area And Drag Area.



Wind Load on External Actuators

According to TIA-222-G (Table 2–8, note 2), if the projected area of the irregularity (in this case the external actuator) is less than 10% of the projected area of the antenna, then the area of the irregularity can be ignored. Therefore, Andrew does not include the wind loading of external actuators in their calculations of the antenna wind load. The streamlined design of the Andrew ATM200 actuator allows it to be considered as part of the cable run when calculating tower loads (Figure 5).

Figure 5. Airflow Around ATM200 External Actuator.



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Wind Survivability Testing

All Andrew antenna designs are engineered and tested to survive wind speeds of up to 150mph. These tests are performed using static loads and/or full model wind tunnel testing (Figure 6). Static loads used are calculated per TIA-222-C using the following equation:

$$F = .004 \cdot V^2 \cdot A$$ Flat Profile

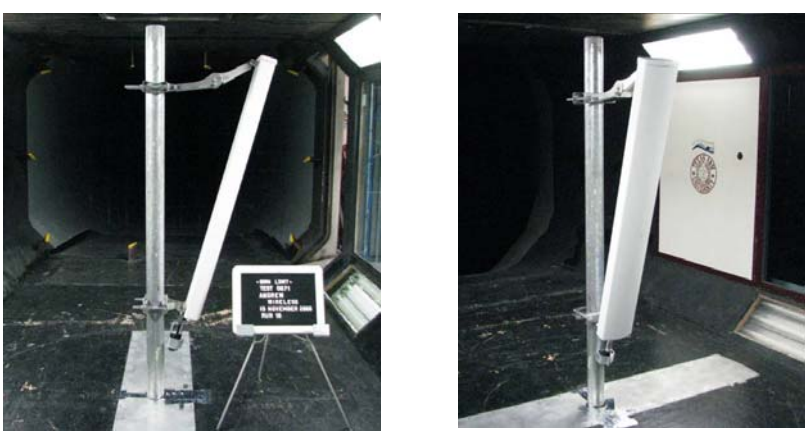
$$F = .003 \cdot V^2 \cdot A$$ Cylindrical Profile

Where:
- F=Static Load (lbf)
- V=Velocity (mph)
- A=Projected Area (ft^2)

This method assumes a flat plate cross section (no force reduction for curved surfaces) and includes a 30% margin to account for the added effects of wind gusts and ice.

Figure 6. Wind Load And Tunnel Testing.

Static Wind Load Testing



Wind Tunnel Testing

Visit our Web site at www.commscope/andrew.com or contact your local Andrew Solutions representative for more information.

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Conclusion

In many cases, the cost of leasing tower space is largely based on how much loading a base station antenna adds to the tower structure. Wireless operators often use wind load data presented by base station antenna manufacturers when deciding on which antennas to deploy. Therefore, it is important for operators and tower owners to fully understand how wind load data is calculated so that fair comparisons can be made between various antenna designs. This paper presents the methods in which Andrew Solutions determines frontal and lateral wind load values, as well as the effective drag area. These methods are backed up by full scale wind tunnel testing, as well as computational fluid dynamic simulation. Wind load data provided by Andrew Solutions is accurate and reliable, giving wireless service providers the tools to make the best antenna purchase decision.

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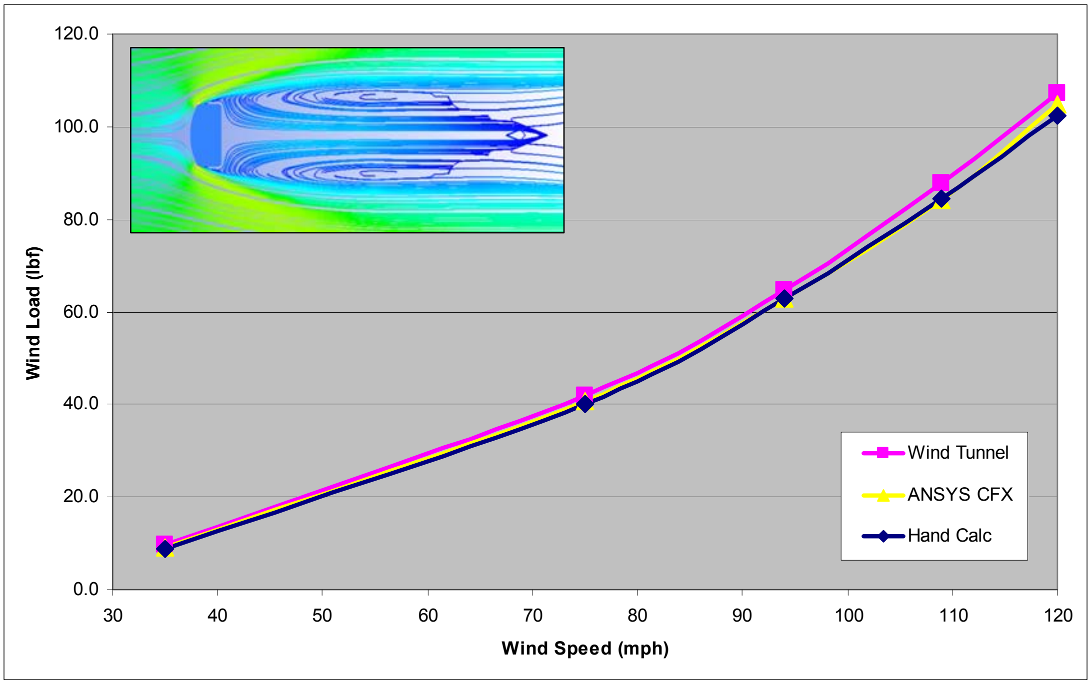
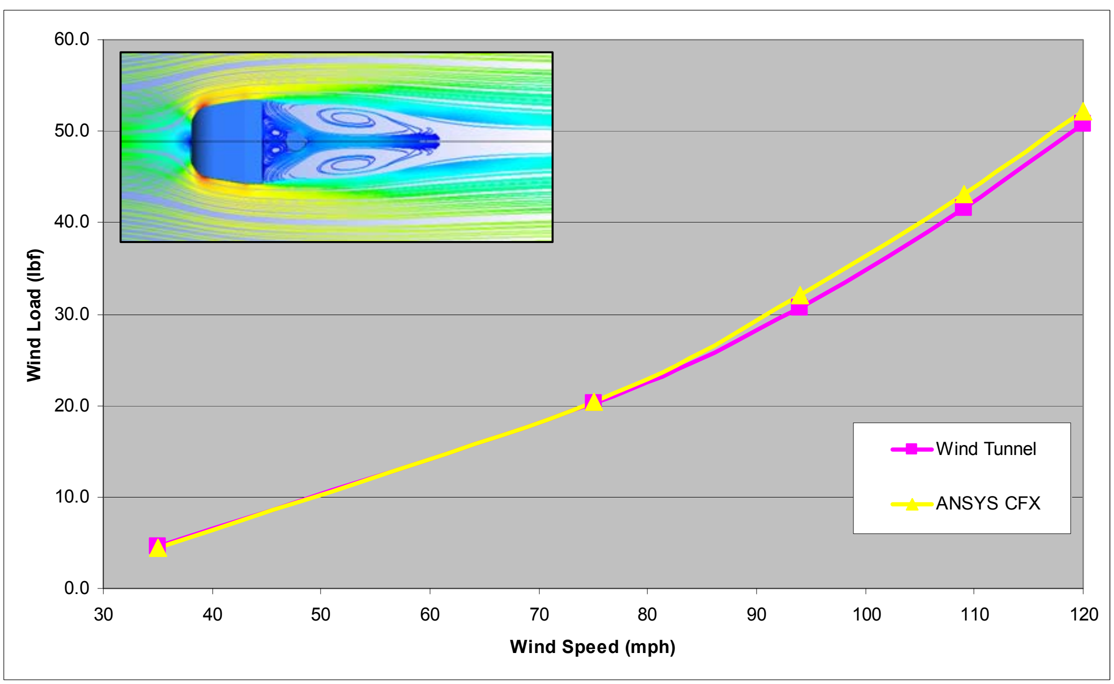
Appendix A

Comparison of wind tunnel testing to CFD simulations and Andrew wind load calculator.



HBX-6516DS-VTM Wind Load



DB844G65A-XY Wind Load

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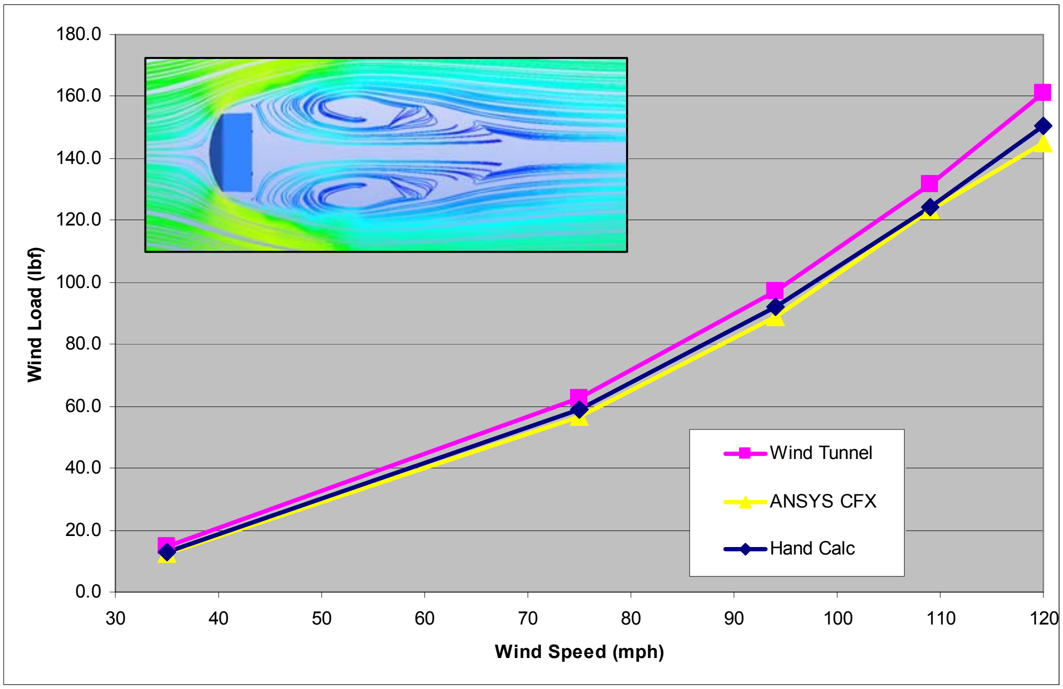
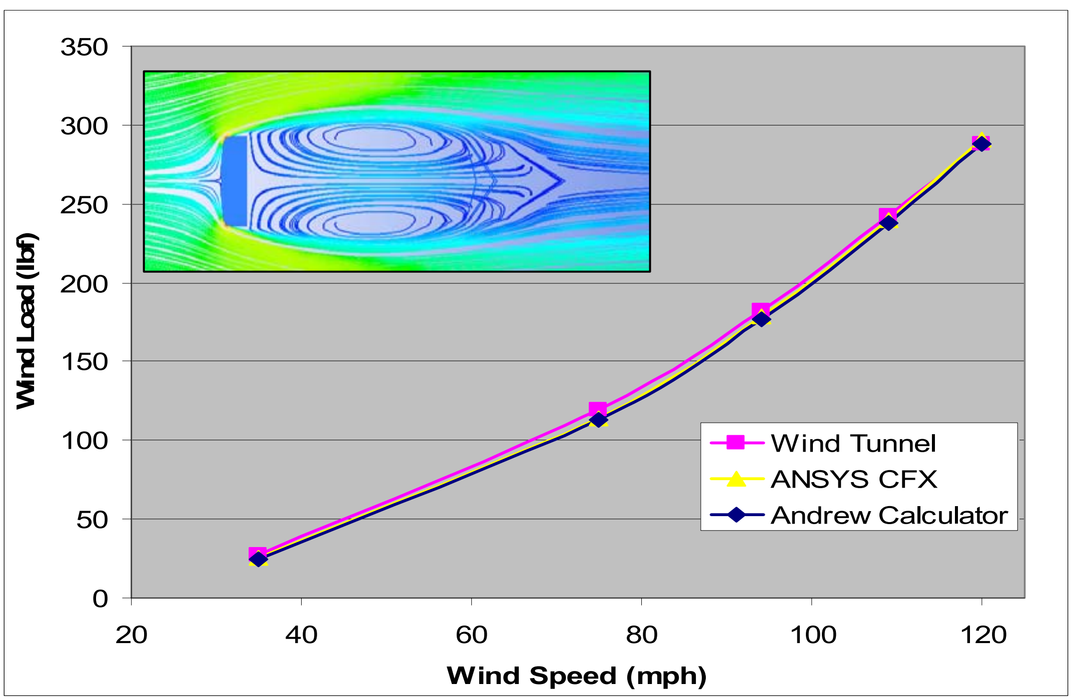


DB854DG90ESX Wind Load



ADFD1820-6565C-XDM Wind Load

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