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### Xero Flor XF300 and XF301 Green Roof System Wind Uplift Resistance Certification

The Xero Flor Precultivated Mat Green Roof System was evaluated for resistance to wind uplift displacement while in a fully assembled, green roof system installation. This analysis was performed by an independent, certified testing laboratory familiar with green roof system technologies – WSG Engineering, Aachen, Germany. The WSG analytical report entitled “Assessment of positional security against wind uplift for a roof planting system that is permeable to wind” was issued in November, 1999.

#### ANALYTICAL STUDY COMPONENTS

XF301 system security against wind uplift was evaluated for each of the following flat roof variables: roof area to building height ratio, roof central areas, roof perimeter areas, roof corner areas, and roof surface unevenness caused by structural seams. It is noted that the stated certification against wind uplift applies to air permeable green roof layers, specifically the assembled components of the Xero Flor XF301 green roof system and are invalid if any Xero Flor components are substituted by other materials. The original WSG Engineering report is available upon request.

#### RESULTS & CONCLUSIONS

German wind tunnel testing of the XF301 vegetation blanket showed that its permeable nature allowed for pressure equalization between the upper surface and the underside, resulting in a moderating factor in the order of 0.01, which is to say that only 1% of the wind pressure is experienced by the blanket after pressure equalization. Note that WSG Engineering increased this factor to R = 0.04 for a more conservative assessment.

Wind pressure on the roof is a function of the geographical location, the terrain, the building geometry, the location on the roof (field, edge, corner), etc. We multiply factors onto the wind design pressure to reflect the actual wind pressure on the roof:

$$(G/A)_{\text{erf}} = V_{\text{ges}} R C_{\text{pex}} q \quad (6)$$

where  $(G/A)_{\text{erf}}$  = resulting wind pressure

$V_{\text{ges}}$  = design safety factor (1.44 as in page 2 of XF report)

R = moderating factor (0.04)

$C_{\text{pex}}$  = coefficient reflecting geometry and location on the roof

q = design wind pressure

For the most severe case considered in the XF test report (p 5):

Corner of a small roof of a tall building ( $h/a > 0.4$ ) at  $h = 20 - 100$  m (66 – 330 ft):  $C_{\text{pex}} = 3$

At  $q_G = 10$  psf ( $q_H = 4.2$  psf):  $(G/A)_{\text{erf}} = 1.44 \times 0.04 \times 3 \times 4.2 = 0.7$  psf

At  $q_G = 30$  psf ( $q_H = 12.6$  psf):  $(G/A)_{\text{erf}} = 1.44 \times 0.04 \times 3 \times 12.6 = 2.2$  psf

Therefore, the resulting *wind uplift pressure* acting on the mat that is created by a design wind gust pressure of 10 – 30 psf is **0.72 – 2.18 psf**.

The *wind uplift resistance* of the XF301 mat is its dry weight, which is  $(G/A)_{\text{dry}} = 5.5$  psf

Since wind uplift resistance  $(G/A)_{\text{dry}}$  is 5.5 psf, which is greater than the wind uplift pressure  $(G/A)_{\text{erf}}$  at 2.2 psf, XF301 mat is secured on the roof.



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## Assumptions and Limitations

Wind is dynamic and wind speed is often reported in different averaging time. In Canada and Germany, roof design is based on mean hourly wind pressure and mean hourly wind speed, though in the US, design is based on the three-second peak gust speed. Therefore, we converted the US design values into mean hourly speed before using the equations in the XF wind testing report.

Converting wind speed from one averaging time to another, e.g. gust peak ( $V_G$ ) to mean hourly ( $V_H$ ), is not always straightforward. A major limitation in the calculation is the conversion factor from three-second peak gust to mean hourly wind speed. Although several wind engineering references use the factor 1.54, wind speed is dynamic and random in nature and the conversion factor varies with randomness of the wind speed distribution. The designer should consult wind engineers for advice on appropriate correction factors for their geographic region.

Another factor is the wind coefficient ( $C_{pex}$ ). Although it is generally agreed that wind speed increases in height and that it is highest at corners than edges than in the field, the factors can be different for different jurisdictions. Local building code should be consulted for analysis.

## SUMMARY

It is understood that the Xero Flor system is stable against displacement to the degree that the wind-affected roof system load exceeds the wind uplift pressure. The WSG assessment utilized a safety factor = 1.44 in calculation of wind uplift pressure to compensate for experimental wind load determination and normal variability in green roof system dry weight.

The conclusion of the WSG analysis was that the assembled XF301 System is secure against wind uplift displacement at building heights of up to 328 ft (100m).

For building heights or geometries with potential to exceed the wind displacement resistance of the Xero Flor green roof system, we offer a ballasted design utilizing an overlay of washed river stone. River stone is spread directly over the prevegetated mat at time of installation to provide sufficient loading weight – recommended not to exceed 5 lb/sf - to overcome any potential or calculated wind uplift pressures. The pre-established plant community overgrows the stone ballast layer within the first growing season, obscuring the stone from view and securing it against removal. Note that local building code must be consulted to determine the appropriate size stone to be used as root ballast overburden.

## References

A Guide for the Wind Design of Mechanically Attached Flexible Membrane Roofs. A. Baskaran & T.L.Smith, National Research Council of Canada, 2005, p.89.

DIN 1055 - Part 4. Design Loads for Structures. Wind effect standards.

ENV 1991-2-4. European wind loading standard for structures.

The effect of wind on roofing systems. Gerhardt, H.J. (1999). Shaker Verlag Publishing (Aachen, Germany).