RStandard Pole Design Guide

General Methodologies and Procedures for Structure Design using
RStandard® Modular Composite Poles and
PLS-Pole®

<table>
<thead>
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<th>Description</th>
<th>Date</th>
<th>Compiled By</th>
<th>Engineering Approval</th>
</tr>
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<tr>
<td>A</td>
<td>Issue for External Customer Release</td>
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<td>F. Volk 2010/07/06</td>
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1 Introduction

This Design Guide is a supplement to the RStandard Structural Design Guide which details the performance and behaviour of RStandard poles in utility and communication structures. The following recommended design formulas and procedures are derived from a number of composite and utility/communications structure design references. In the event of a disagreement between the recommendations stated in this guide and the relevant regional or national design code, the code shall be taken as the ruling document.

In addition to this Design Guide, RS Technologies (RS) has partnered with Power Line Systems (PLS) to offer a FRP component for PLS-Pole and PLS-CADD. Both are industry leading software tools for the design and global analysis of utility poles and lines, as well as communications structures. PLS-Pole is the only software recommended by RS for structural analysis of RStandard poles.

It is assumed that the engineer utilizing this guide has a background in structural design and the associated fundamental methodologies. In addition to this, general working knowledge of PLS-Pole is recommended as this guide focuses on the use of PLS-Pole for RStandard pole structure analysis. General knowledge of the RStandard product line is also an asset.

If you have any questions, comments, or to request a copy of the RStandard Pole Technical Binder, please feel free to contact RS toll free at (877) 219-8002, or email at info@grouprsi.com.

For more information on PLS software visit www.powline.com.
2 General Design Methodologies

This guide covers both “Global” and “Local” design methodologies for RStandard poles.

“Global” design and analysis are effective for evaluation of general overall structural integrity of a structure but may not account for specific structure characteristics with could have an impact on structural integrity only in a specific region of the structure. “Local” design and analysis typically takes information from a global analysis and applies it to a specific region of a structure to account for unique characteristics of that region.

An example of global analysis is using PLS-Pole to determine the deformed shape of a pole or structure under an applied load. The analysis results will show the calculated stresses, component utilizations, deformed geometry and deflections of the structure. Two characteristics that are not considered in PLS-Pole analysis are holes in the components (continuous cross-sections are assumed), and the physical connection hardware between components (rigid connections are assumed).

Local analysis is required to evaluate what a global analysis does not consider. Using the above example, large holes or regions containing a large number of holes need special consideration. PLS-Pole will analyze a cross-arm and the pole it is mounted on but not the strength of the connection between them (i.e. the bolts, mounting bracket, etc.).

2.1 RStandard Pole Product Line

The RStandard product line consists of ten standard thin-walled FRP tapered hollow tubes or modules which can be used to create pole combinations of varying size and strength up to overall pole lengths of 175 ft. [53.3m]. The modules are designed with a friction fit slip-joint that allows them to be stacked up to eight modules high. Modules 1-5 are designed for a ‘net 15 ft.’ [4.6m] while the modules 56, 67, 89, and 1011 are designed for a ‘net 30 ft.’ [9.1m] contribution to overall pole length (‘net’ refers to overall length minus overlap length for each module).

2.1.1 Special Module Combination Considerations

The RStandard modules are stacked in order by module number with the following considerations:

1. Module 56 and 1011 are always base modules; for example, the M56 cannot be stacked on top of the M67.
2. M5 and M56 cannot be used in the same pole but the M5 can be stacked on top of the M67.
3. M1 and M1L (an extended version of the M1 with ‘net 20 ft.’ [6.1m]) are interchangeable but cannot be used simultaneously.

2.1.1.1 M1L Restrictions

M1L is intended for general use in light duty self-supporting monopole structures. For guyed or multi-pole structures the M1L should only be used in poles up to 65 ft. [15.2m] in length. This restriction is due to the high slenderness ratio (or Length to Diameter ratio) and flexibility of the module.
2.2 Composite Material Information

RStandard poles are constructed from a filament wound fibre-reinforced polymer (FRP) material system.

FRP materials in general are non-isotropic in nature meaning that their mechanical properties vary based on the direction and orientation of the fibre in relation to the applied loads. This introduces complexity to structural analysis if the non-isotropic nature of the material is to be considered. However, simplifications can be made provided the inherent impact of these simplifications is recognized and accounted for.

One such simplification can be made through the use of “bulk” material properties. Bulk material properties represent the overall response of the structure to a defined loading condition. These are determined through a compilation of physical test data and theoretical calculations to determine a quasi-isotropic (“bulk”) material property for a specific structure and mode of loading. For example: the elastic modulus (E) of an anisotropic composite material is different in multiple directions (E_{xy}) but if the load vs. deflection response for a composite structure is reasonably linear, a single value for flexural modulus can be determined. This single value can then be used as the “bulk” modulus for calculating the deflection of the structure under similar loading as used to determine the bulk property. As such, care must be taken when using “bulk” properties to ensure they are appropriate for the defined geometry, material composition, and mode of loading. (i.e. A flexural strength property should only be used in cases where flexural loading is the sole or majority mode of loading present. Conversely, it would NOT be good practice to use flexural strength to determine allowable loads for bolt bearing.)

This Design Guide consists of a detailed set of design considerations, bulk material properties, guidelines and recommendations for design of structures using RStandard poles. It is the responsibility of the engineer to assure that this information is applied appropriately.
### 2.3 Global RStandard Module Properties

RStandard pole properties for global structural performance are defined based on each module due to differences in geometry and material composition. Table 1 contains the basic geometrical properties of all RStandard modules, these are the properties used in the PLS FRP pole library files for RStandard poles.

#### Table 1 – RStandard Module Geometry (Imperial and SI Units)

<table>
<thead>
<tr>
<th>Module Label</th>
<th>Length (ft)</th>
<th>Thickness (in)</th>
<th>Lap Length (ft)</th>
<th>Tip Diameter (in)</th>
<th>Base Diameter (in)</th>
<th>Tube Taper (in/ft)</th>
<th>Weight (lbs.)</th>
<th>Weight Density (lbs/ft^3)</th>
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<tbody>
<tr>
<td>Imperial Units</td>
<td></td>
<td></td>
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<td></td>
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<td>0.465</td>
<td>1.694</td>
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<td>9.768</td>
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<td>2.264</td>
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<td>115.49</td>
</tr>
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<td>11.087</td>
<td>15.315</td>
<td>0.243</td>
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<td>4</td>
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<td>1197.1</td>
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<tr>
<td>10/11</td>
<td>36.877</td>
<td>0.459</td>
<td>3.924</td>
<td>16.591</td>
<td>21.284</td>
<td>0.247</td>
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<td>19.88</td>
<td>680</td>
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</tbody>
</table>

* All properties at 0°C (32°F) unless otherwise specified.

Bulk flexural material properties have been developed for all RStandard modules through correlation of full scale pole bend tests (modified ASTM D1036 – Standard Test Methods of Static Tests of Wood Poles), theoretical calculations, and material level tests. The following bulk RStandard module properties, in Table 2, are valid for use in global structural analysis where a pole is subjected primarily to flexural and vertical loading. These properties are used in the PLS FRP pole library files for RStandard poles.
The behavior of complex structures (i.e. guyed structures, H-frames, etc.) may be analyzed using these properties. However, certain scenarios involving more complex loading may warrant further investigation and special consideration. These scenarios are addressed in the following sections of this guide.

Table 2 – RStandard Bulk Module Properties (Imperial and SI Units)

<table>
<thead>
<tr>
<th>Module Label</th>
<th>Modulus Of Elasticity (psi)</th>
<th>Failure Stress (psi)</th>
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<tbody>
<tr>
<td>Imperial Units</td>
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<tr>
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<td>3.096.E+06</td>
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</table>

* All properties at 0°C (32°F) unless otherwise specified.

In general, a Poisson’s ratio of 0.3 and coefficient of thermal expansion (CTE) of 2.24 x 10^-5 m/m/°C may be used for all RStandard modules.
2.4 Global Structure Analysis Methodologies

Using the properties in section 2.2, an RStandard pole can be evaluated for global performance characteristics such as strength, pole deflection, etc. Although global performance is one component in design using RStandard poles, global analysis should not be the sole basis for selecting a specific RStandard pole configuration. Additional considerations are covered in the following sections of this guide.

In general, the bulk flexural pole material properties in section 2.2 are provided in accordance with American and Canadian utility and communications codes and standards for engineered materials (i.e. steel). Most North American utility codes directly address the use of FRP poles and define the appropriate factors to apply. In instances where a code or standard does not specifically address the use of FRP, RS recommends that unless otherwise specified by the code, the RStandard pole may be treated in a similar fashion to a steel pole. The engineer must determine if this practice is appropriate to maintain the validity of the specific code in question.

Utility and Communications Structure Codes which specifically address FRP materials:

- **CSA C22.3 No.1 (Canadian Standards Association)** (CSA, Latest Edition)

To determine whether a particular RStandard pole is acceptable for a specific case, based on global performance, a pole utilization approach can be taken. Strength utilization is defined as the amount of applied stress as a percentage of the maximum allowable stress (or failure stress) where any value greater than 100.00% indicates failure. RS recommends that four major components of stress be considered in determining pole utilization, these components are axial, flexural, torsion, and shear stresses. Most utility and communications codes dictate how these stress components are to be combined for the purposes of a strength check and determining a utilization value. Unless otherwise specified by a particular code, RS recommends the following general equation be used for determining pole utilization.

\[
U = \frac{\sqrt{\left(\frac{F_A + F_B}{\sigma_F \times SF}\right)^2 + 3\left(\frac{F_v + F_T}{\sigma_F \times SF}\right)^2}}{\sigma_F \times SF} \times 100\%
\]

Where:
- \(U\) = Pole Utilization [%]
- \(F_A\) = Normal Stress Due to Axial Loading
- \(F_B\) = Normal Stress Due to Bending Moments
- \(F_V\) = Shear Stress Due to Shear Force
- \(F_T\) = Shear Stress Due to Torsion
- \(\sigma_F\) = Module Failure Stress
- \(SF\) = Strength Factor (\(\leq 1.00\))

Note: This strength check equation is included in PLS-Pole as the “ASCE/SEI 48-05” strength check.
RStandard poles are comprised of stacked thin-walled FRP tapered hollow tubes (modules) that include at least one slip-joint region. RS recommends the conservative practice of calculating the pole utilization based on the utilization of the inner module with no consideration for the contribution from the outer module in the slip-joint region.

Determining the deformed geometry for a structure under load is an essential part of structure design. The modulus of elasticity (modulus) values provided in section 2.2 should be used with non-linear analysis algorithms to calculate the deformed geometry of the pole. RS recommends that the modulus properties are used as stated without any reduction factors. Use of reduction factors on modulus properties may result in excessively conservative deflections and un-realistic increases in pole utilization due to moments caused by excessively offset vertical loads (P-delta effects).

RS strongly recommends that non-linear analysis be used for RStandard pole design as this will consider the increase in applied moment due to the offset of vertical loads in the poles utilization. Most utility design codes and standards require non-linear analysis of composite materials. In any RStandard structural analysis, care should be taken to limit conditions of instability such as S-bending and high vertical loading wherever possible. These and other special conditions are addressed in the following sections of this guide.

2.4.1 Finite Element Analysis (FEA) Software

RS in collaboration with PLS have developed the FRP framework and library files for RStandard pole analysis using PLS-Pole and PLS-CADD. RS uses PLS-Pole and PLS-CADD internally and recommends this software to our customers for global structural analysis of RStandard poles. PLS-Pole, PLS-CADD and the FRP framework have been developed to conform to the general conditions and recommendations outlined in section 2.4 and are the only FEA software programs recommended by RS for design and evaluation of RStandard structures.

For more information on PLS products, visit www.powline.com.

Note: The engineer should be familiar with the methodologies and standard practices, as well as have a general understanding of the fundamentals and restrictions of FEA and PLS software. Due to variance in FEA methodologies and parameters, results from one program to another may vary. The engineer must determine the validity of any FEA generated result in each specific case.

2.4.2 Special Global Structural Considerations for RStandard Poles

2.4.2.1 “S-bending” and “Bowing”

“S-bending” and “Bowing” occur when a structure’s deformed geometry emulates the shape of an “S” or “C” between physical restraints. Both conditions increase the potential for buckling of the structure. S-bending is of additional concern because of the multiple inflection points.

In the case of S-bending or bowing, RS recommends that the centerline of the undeformed (unloaded) pole geometry not fall outside the deformed (loaded) geometry between any physical restraints, in the general direction in which the restraint applies. This can be analyzed by determining the resultant horizontal deflection of the pole at a specific location; this deflection should not exceed half the outer-diameter.
(outer-radius) of the section in question. This practice ensures that the centre of any vertical load on the pole is maintained within the pole geometry between restraints which will allow the vertical load to be distributed over the pole’s whole cross-section. Therefore, the resisting moments of the pole wall will always have a longer moment arm than the applied vertical load. The assumption in this practice is that the failure stress in section 2.2 is applicable because the compressive load is similar to the typical mode of failure in full scale testing of RStandard poles, which is compressive side failure of the pole wall.

Note: Pole deformations outside of the undeformed pole centerline in any region of the pole with a “free” end are not conditions of S-bending or bowing, so the corresponding recommendations need not be considered in that case.

Using the PLS-Pole analysis output report, the horizontal deflection of any point along the pole is provided in the “Detailed FRP Pole Usage” table by load case. Horizontal components of deflection are shown in Figure 1 under the headings; “Trans. Defl.” and “Long. Defl.” Pythagorean theory may be used if displacement occurs in both the transverse and longitudinal direction to obtain the resultant horizontal deflection at any point along the pole.

Once the horizontal deflection is known, this can be compared to the outer diameter of the same point found in the “FRP Pole Properties” table of the PLS-Pole analysis report.
Figure 2 – “FRP Pole Properties” Table of RStandard Structure
(Note: Using the procedure described in this guide, although PLS indicates pole usage is <100%, the S-bending is significant enough to raise concern.)

When there is sufficient S-bending or bowing to raise concern with the structure design, increasing the module combination, modifying the restraint configurations, and/or modifying the loading/framing of the structure can help reduce the S-bending to meet the recommendations in this section.

### 2.4.2.2 High Vertical Compressive Loads

High vertical loads require further investigation to ensure the physical capacities of the slip-joint interfaces are not exceeded or that the pole is not susceptible to buckling.

With regards to the slip-joint interface, the maximum compressive load on any slip-joint shall not exceed 150 kips. [667 kN]. For compressive loads higher than 100 kips. [445 kN] additional restraints/fasteners may be required in the slip-joint to restrict excessive slip-joint settling. When designing additional fastener configurations for slip-joints the fasteners should be equally spaced and the fastener configuration must be designed to the higher of the maximum compressive or tensile loads on the slip-joint from all load cases. Consult section 3.2 for further information on designing slip-joint fastener configurations.

The “axial force” on any slip-joint is provided in the PLS-Pole analysis report’s “Detailed FRP Pole Usage” table by load case (positive ‘+’ values indicate tension).
### Figure 3 - “Detailed FRP Pole Usage” Table of RStandard Structure (with High Vertical Compressive and Tensile Loads)

<table>
<thead>
<tr>
<th>Element</th>
<th>Grid Label</th>
<th>Position</th>
<th>Slip-joint Region</th>
<th>High Tension Load in Slip-joint.</th>
<th>Uplift Load on Pole</th>
<th>Vertical Load for Base Plate or Foundation Selection.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL FRP</td>
<td>End</td>
<td>0.40</td>
<td>12.93</td>
<td>0.63</td>
<td>0.23</td>
<td>0.08</td>
</tr>
<tr>
<td>FL Pole</td>
<td>Start</td>
<td>0.00</td>
<td>15.21</td>
<td>0.43</td>
<td>0.15</td>
<td>0.00</td>
</tr>
<tr>
<td>FL Pole</td>
<td>End</td>
<td>0.40</td>
<td>15.21</td>
<td>0.43</td>
<td>0.15</td>
<td>-0.41</td>
</tr>
<tr>
<td>FL Pole</td>
<td>Start</td>
<td>0.00</td>
<td>15.21</td>
<td>0.43</td>
<td>0.15</td>
<td>-0.41</td>
</tr>
</tbody>
</table>

**Figure 3** - Table showing detailed FRP pole usage for load cases with high vertical and tensile loads, highlighting critical points such as slip-joint regions and load classifications for base plate or foundation selection.
(Note on Figure 3: This example shows compressive “axial” loads in slip-joint or “splice” regions are acceptable; however, tensile “axial” loads exceed the capacity of the slip-joint without additional fasteners. In this case, additional lag screw fasteners were added to the affected slip-joint regions to support the maximum compressive load, as this was greater than the maximum tensile load.)

2.4.2.3 Slip-Joint Tension Loads

RS recommends that the maximum axial tensile load condition not exceed 20 kips. [89 kN] in any slip-joint. This value considers the recommended assembly force and the additional resistance of the standard joint hardware for RStandard poles. If the maximum axial tension condition exceeds RS’ recommendation, additional restraints or hardware may be added to the joint to ensure modules do not separate. When designing additional fastener configurations for slip-joints, the fasteners should be equally spaced and the fastener configuration must be designed to the higher of the maximum compressive and tensile loads on the slip-joint from all load cases. Consult section 3.2 for further information on designing slip-joint fastener configurations.

3 Local Design Methodologies

3.1 General Hole Recommendations

The use of holes in utility and communication poles is a necessary design consideration with thin-walled structures such as RStandard poles for three reasons; stress concentration due to discontinuity of reinforcement fibres and hole geometry, reduction in section properties, and reduction in the pole’s load capacity due to an increase in the potential for localized buckling.

A reduction in section properties results in a reduction in the pole’s load capacity in the same region simply due to the removal of material. The remaining material is required to carry the entire load, subsequently increasing the overall stress at that section.

Holes also introduce stress concentrations by creating a discontinuity in both the wall material and the fibres that pass through the same location. In general, a stress concentration due to a hole in an RStandard pole is assumed to radiate outward from the hole evenly, dissipating with increased distance from the hole. Appropriate stress concentration factors are determined predominantly by considering hole size, proximity to other features (overall geometry) and mode of loading.

The solid circular cross-section of an RStandard pole is ideal for resisting localized buckling because of its geometry. The stability of the pole wall is reduced when holes are present because it creates a discontinuity in the solid circular cross-section; this reduces the pole’s ability to resist localized buckling.

The following sections will address the recommended methodologies and best practices to select appropriate hole sizes, locations and to ensure strong, durable hardware connections.
3.2 Holes and Hardware Connections

The RStandard Hardware Guidelines should be referred to for appropriate hole sizing and spacing, as well as determining appropriate hardware for use with RStandard poles.

Ensuring appropriate hole size and spacing is important in achieving a strong, durable connection to the pole wall. The following are guidelines for hole size and spacing which should be maintained:

1. Minimum Hole Spacing: Center-to-center distance of any two holes should be a minimum of 6D (six times), where D is the diameter of larger of the two holes.
2. Minimum Edge Distance: A minimum distance of 6D (six times), where D is the hole diameter, should be maintained from the edge of the module to the center of the hole.
3. Maximum Hole Size: Hole diameters larger than 1.25 in. [32 mm] in diameter are not recommended.

![Figure 4 – Hole spacing guidelines.](image)

High level assessments of large holes and ports (i.e. >1.25” [32 mm]) are addressed in section 3.3.

RStandard poles have “No Drill” zones around the base of the slip-joint region that are not permitted to contain holes of any kind. These zones (illustrated in Figure 5) start at the base of the outer module of each slip-joint and extend 5 in. [127 mm] up and 3 in. [76 mm] down from the module edge. The “No Drill” zones ensure the structural integrity of the slip-joint is maintained when the pole is under load.
In cases where violations of the hole size, spacing or conflicts with “No Drill” zones are unavoidable, RS may be contacted to resolve any holes that do not meet these guidelines or for additional guidance for evaluation of high hole density regions of a pole.

In addition to these guidelines, section 3.2.1 should be used to determine the appropriate maximum connection loads for a specific piece of hardware or in the design of custom hardware for a specific application.

### 3.2.1 Methodologies for Designing Hardware Connections

RS Standard poles have undergone in-house and third-party testing to verify appropriate pole wall connection properties for hardware connections. The properties provided in this section are bulk properties of the FRP material and should only be used for design and evaluation of hardware connections.

RS recommends the following maximum allowable stress conditions be used for the design and evaluation of hardware connections to RS Standard poles. These values reflect the ability of the composite pole wall to withstand connection loads applied through the hardware. In the design of any off-the-shelf and/or custom designed hardware to be used with RS Standard poles, a minimum safety factor of 1.0 may be applied in all cases.

Due to the nature of the RS Standard composite material, when load is applied at 0° or 90° to the pole wall a state of “pure” loading exists whereby maximum stress condition is governed by a single load scenario. Alternatively, when load is applied to the pole wall at an eccentric angle (i.e. 45°) a state of “combined” loading exists. Due to this combined load state, the maximum stress condition for analyzing an individual (component) load scenario differ from those for a pure load state.
Figure 6 – Illustration of Hardware Loading States

Table 3 – Hardware Design Strengths for Pure Load States

<table>
<thead>
<tr>
<th>Loading Scenario</th>
<th>Pure Design Strength*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Hole Bearing</td>
<td>173.9 MPa [25.2 ksi.]</td>
</tr>
<tr>
<td>Transverse Hole Bearing</td>
<td>120.9 MPa [17.5 ksi.]</td>
</tr>
<tr>
<td>Pull-out Wall Bearing</td>
<td>3.54 MPa [0.51 ksi.]</td>
</tr>
<tr>
<td>Push-through Wall Bearing</td>
<td>3.16 MPa [0.46 ksi.]</td>
</tr>
</tbody>
</table>

*Pole wall strengths are ≤ 5% LEL strength for the applicable load cases.

Table 4 – Hardware Design Strengths for Combined Load States

<table>
<thead>
<tr>
<th>Loading Scenario</th>
<th>Combined Design Strength*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Hole Bearing</td>
<td>109.7 MPa [15.9 ksi.]</td>
</tr>
<tr>
<td>Transverse Hole Bearing</td>
<td>82.1 MPa [11.9 ksi.]</td>
</tr>
<tr>
<td>Pull-out Wall Bearing</td>
<td>1.76 MPa [0.26 ksi.]</td>
</tr>
<tr>
<td>Push-through Wall Bearing</td>
<td>2.23 MPa [0.32 ksi.]</td>
</tr>
</tbody>
</table>

*Pole wall strengths are ≤ 5% LEL strength for the applicable load cases.

Load Scenario Definitions:

Vertical Hole Bearing – vertical loads applied to a bolted connection where the bolt shank transfers the load to the pole wall through the surface of a hole.

Transverse Hole Bearing – horizontal loads applied to a bolted connection where the bolt shank transfers load to the pole wall through the surface of a hole.
Pull-out Wall Bearing – horizontal loads and/or moments applied to either bolted or banded connections which transfer load the pole wall surface, “pull-out” refers to an applied load that acts in the direction away from the pole.

Push-through Wall Bearing – horizontal loads and/or moments applied to either bolted or banded connections which transfer load the pole wall surface, “push-through” refers to an applied load that acts in the direction towards the pole.

In addition to the design strengths in Tables 3 and 4, some fastener types have specific load capacities for specific loading conditions. Table 5 gives the maximum allowable attachment loads for blind-nuts, lag screws, and self-drilling screws under the specified load conditions.

Table 5 – Fastener Maximum Allowable Attachment Loads

<table>
<thead>
<tr>
<th>Fastener</th>
<th>Load Conditions</th>
<th>Max Allowable Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾” Bolt/Blind-Nut</td>
<td>Vertical shear load only.</td>
<td>35.6 kN [8.0 kips.]</td>
</tr>
<tr>
<td></td>
<td>Load with pull-out component.</td>
<td>27.5 kN [6.2 kips.]*</td>
</tr>
<tr>
<td>½” Lag Screw</td>
<td>Vertical shear, hardware to pole wall.</td>
<td>21.8 kN [4.9 kips.]**</td>
</tr>
<tr>
<td></td>
<td>Vertical shear, slip-joint restraint.</td>
<td>11.1 kN [2.5 kips.]</td>
</tr>
<tr>
<td>¼” Self-drilling Screw</td>
<td>Vertical shear, hardware to pole wall.</td>
<td>7.69 kN [1.7 kips.]**</td>
</tr>
</tbody>
</table>

* Resultant load in any direction.
** Fasteners fail in shear, no damage occurs to the pole wall.
All loads are ≤ 5% LEL load supported by the pole wall.

To determine the suitability of a hardware connection, the strengths and loads given in this section may be used in standard Hooke’s Law and force/moment balance equations for determining the applied stress on a hardware connection. RS recommends the following guidelines when performing these calculations:

1. All bearing or contact surface areas should be considered as their effective projected area (EPA), rather than the total contact area. The EPA is a conservative estimate that accounts for the non-uniform distribution of load on curved surfaces in most hardware connection applications. The EPA is a reasonable approximation for the contact area of steel hardware on an FRP pole.

   a. Additionally, for bolt bearing calculations the contact EPA of only the loaded side should be considered. For example, if a through bolt is supporting a vertical load on only one side of the pole. Only one hole contact should be considered however, if there is vertical load applied on both sides of the bolted connection, two (2) contacts may be used. In both cases, the EPA of one bolt hole contact can be calculated as the bolt diameter times the module wall thickness.
2. Unless otherwise defined by the applicable code or standard, the applied load to be considered should be the total factored working load applied to the hardware connection in question. The loads applied to any hardware connection point can be obtained directly from the appropriate table of the PLS analysis report. In some cases, the resultant loads are determined by the difference between the ‘origin’ and ‘end’ values at the node which attaches to the pole; this is the case for cross-arms for example. Other hardware such as clamps, braces, and insulators, the reported loads from the PLS analysis report can be applied directly.

3. RS has reported the hardware connection strengths and loads in this section as ≤ 5% LEL strengths and loads; as such RS minimum recommended safety factor is 1.0 when evaluating hardware connections using the information provided in this section. It is the engineer’s responsibility to ensure the safety factor used is appropriate for the specific application.

![Figure 7 – “Summary Brace Forces and Usage” Table of RStandard Structure](image)

(Note: These axial brace loads are applied to hardware analysis at the angle between the pole centreline and the brace centreline.)

![Figure 8 – “Detailed Post-Insulator Usage” Table of RStandard Structure](image)

(Note: The “forces” and moments calculated based on post geometry are applied to hardware analysis at the attachment point to the pole.)
3.3 Special Hole Circumstances (including Large holes and Ports)

Although not ideal for optimum RStandard pole performance, large holes and/or ports may, in some cases, be accommodated in RStandard poles through additional analysis. Additional reinforcement may be required at these locations to mitigate the effects of the induced stress concentration. RS must be consulted on any hole or port analysis on RStandard poles, where the hole/port exceed the specified hole size limits in this guide.
4 Embedment/Foundation Evaluation

RS recommends the use of ANSI/ASAE Standard EP 486.1 Shallow Post Foundation Design (ASAE, Latest Edition) to perform embedment or foundation evaluation for RStandard poles. This standard provides a simple approach to determine if the embedment depth is adequate for a specific type of soil, to resist the overturning moment and shear force, and vice versa. Additionally, the evaluation of embedment or foundation for uplift forces is covered by the standard. To evaluate foundation deflection, RS recommends the use of RUS Bulletin 1724E-205 (US DOA, Latest Edition).

For vertical foundation resistance, RS recommends a simple normal stress calculation compared to the allowable vertical soil bearing capacity.

4.1 Obtaining Loads on the Foundation

The loads used for embedment or foundation evaluation are found in the “Summary of Joint Support Reactions” table in the PLS-Pole summary output report. It is a typical assumption that the pole is fixed at ground line however; if fixity is defined at some depth below ground-line, the loads at the fixity point should be used.

Two approaches exist for selecting the loads to use for foundation analysis; the first uses the maximum loads from all load cases and the calculation is only completed once, alternatively the maximum loads from each load case are evaluated separately. It is the Engineer’s responsibility and judgment to select the appropriate approach for the specific application.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact, NSSC Heavy (OLF)</td>
<td>PL: g</td>
<td>-0.04</td>
<td>-3.26</td>
<td>-6.16</td>
<td>3.26</td>
<td>63.22</td>
<td>-0.94</td>
<td>-0.00</td>
<td>63.22</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Intact, NSSC Heavy (OLF)</td>
<td>PR: g</td>
<td>-0.03</td>
<td>-3.16</td>
<td>21.68</td>
<td>3.16</td>
<td>63.39</td>
<td>-0.90</td>
<td>-0.00</td>
<td>63.39</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Intact, High Wind</td>
<td>PL: g</td>
<td>-0.01</td>
<td>-4.65</td>
<td>-35.19</td>
<td>-35.19</td>
<td>63.39</td>
<td>-0.90</td>
<td>-0.00</td>
<td>63.39</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Intact, High Wind</td>
<td>PR: g</td>
<td>-0.01</td>
<td>-4.47</td>
<td>-38.73</td>
<td>-38.73</td>
<td>63.39</td>
<td>-0.90</td>
<td>-0.00</td>
<td>63.39</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Intact, Wind &amp; Ice</td>
<td>PL: g</td>
<td>-0.01</td>
<td>-2.93</td>
<td>-6.62</td>
<td>2.93</td>
<td>58.69</td>
<td>-0.38</td>
<td>-0.00</td>
<td>58.69</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Intact, Wind &amp; Ice</td>
<td>PR: g</td>
<td>-0.01</td>
<td>-2.85</td>
<td>-2.85</td>
<td>2.85</td>
<td>58.69</td>
<td>-0.38</td>
<td>-0.00</td>
<td>58.69</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Intact, Heavy Ice</td>
<td>PL: g</td>
<td>-0.01</td>
<td>-0.04</td>
<td>10.25</td>
<td>0.04</td>
<td>58.69</td>
<td>-0.38</td>
<td>-0.00</td>
<td>58.69</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Intact, Heavy Ice</td>
<td>PR: g</td>
<td>-0.01</td>
<td>-0.04</td>
<td>10.25</td>
<td>0.04</td>
<td>58.69</td>
<td>-0.38</td>
<td>-0.00</td>
<td>58.69</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Unbalanced Ice</td>
<td>PL: g</td>
<td>-2.47</td>
<td>-3.33</td>
<td>33.30</td>
<td>-294.68</td>
<td>-8.68</td>
<td>-3.33</td>
<td>33.30</td>
<td>-294.68</td>
<td>8.68</td>
<td>0.00</td>
</tr>
<tr>
<td>Unbalanced Ice</td>
<td>PR: g</td>
<td>11.97</td>
<td>-2.01</td>
<td>31.26</td>
<td>-283.07</td>
<td>7.55</td>
<td>-2.01</td>
<td>31.26</td>
<td>-283.07</td>
<td>7.55</td>
<td>0.00</td>
</tr>
<tr>
<td>Deflection 0</td>
<td>PL: g</td>
<td>2.72</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>-0.00</td>
<td>0.39</td>
<td>0.02</td>
<td>-0.00</td>
<td>0.39</td>
<td>0.00</td>
</tr>
<tr>
<td>Deflection 0</td>
<td>PR: g</td>
<td>-0.01</td>
<td>-0.02</td>
<td>2.78</td>
<td>0.02</td>
<td>-0.00</td>
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<td>-0.00</td>
<td>0.39</td>
<td>0.00</td>
</tr>
<tr>
<td>Deflection 60</td>
<td>PL: g</td>
<td>-0.01</td>
<td>-0.17</td>
<td>2.11</td>
<td>0.17</td>
<td>-0.00</td>
<td>0.39</td>
<td>0.02</td>
<td>-0.00</td>
<td>0.39</td>
<td>0.00</td>
</tr>
<tr>
<td>Deflection 60</td>
<td>PR: g</td>
<td>-0.01</td>
<td>-0.19</td>
<td>3.39</td>
<td>0.19</td>
<td>-0.00</td>
<td>0.39</td>
<td>0.02</td>
<td>-0.00</td>
<td>0.39</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 10 – “Summary of Joint Support Reactions” Table of RStandard Structure
(Note: When the fixity point is not defined at the ground line in PLS, the “Joint Label” will be “f” in place of “g”.)
4.2 Foundation Types

ANSI/ASAE Standard EP 486.1OCT00 Shallow Post Foundation Design provides design cases and calculations for the following types of foundations:

1. Non-constrained for post without collar.
2. Non-constrained for post with collar.
3. Constrained where the post is restrained at ground line without collar.
4. Constrained where the post is restrained at ground line with collar.
5. Constrained where the post is restrained above ground surface without collar.
6. Constrained where the post is restrained above ground surface with collar.

Foundation Definitions:

- Footing – a pad, plate or other device primarily used for supporting vertical load at the base of the pole.
- Collar – a device near the pole base used to increase the lateral bearing capacity of a foundation.
- Restraint – a device at or above ground line which restricts pole movement in a horizontal direction.

For the purposes of this design guide, only foundation type #1 – “Non-constrained for post without collar” or “direct embedment” will be covered in full.

4.3 Lateral Strength Calculation

The following equation is used for lateral strength evaluation of foundation type #1:

\[
d = \sqrt{\left(6V_a + \frac{8Ma}{d}\right)} \div S_b
\]

Where:
- \(d\) = Pole Embedment Depth
- \(b\) = Effective Width of the Pole (Pole Diameter at Ground Line)
- \(Ma\) = Bending Moment
- \(S\) = Allowable Lateral Soil Bearing Capacity
- \(V_a\) = Shear Force

This equation may be used in two ways;

- If the allowable lateral soil bearing capacity is known, the equation may be used to evaluate the minimum pole embedment depth.
- If the allowable lateral soil bearing capacity is unknown, an embedment depth may be assumed and the equation solved to determine the minimum allowable lateral soil bearing capacity.

4.4 Deflection Calculation

RUS Bulletin 1724E-205 defined equations for the deflection of the foundation at the ground line/fixity point for two different soil types. For foundations which use restraints at or above ground line, the deflection of the pole’s foundation may be assumed to be zero in relation to the restraint. Design of restraints is not covered in this guide.
1. For clay soil:

\[ Y_g = \frac{2.15PD_r}{D_e} \left( \frac{1.87D_r}{D_e} - 1 \right) \frac{K}{D_e} + 0.683 \]

\[ \frac{D_r}{D_e} = \frac{1.87M}{PD_e} + 1 \]

2. For granular soil:

\[ Y_g = \frac{3PD_r}{n_hD_e^2} \left( \frac{1.5D_r}{D_e} - 1 \right) \]

\[ \frac{D_r}{D_e} = \frac{1.5M}{PD_e} + 0.75 \]

Where:

- \( Y_g \) = Deflection at Ground Line
- \( M \) = Bending Moment
- \( P \) = Shear Force
- \( K \) = Horizontal Modulus of Subgrade Reaction (\( = n_hD \))
- \( D \) = Embedment Depth
- \( n_h \) = Constant of Horizontal Modulus of Subgrade Reaction
- \( D_e \) = Embedment Depth
- \( D_r \) = Depth from Ground Line/Fixity Point to Point of Rotation for a Rigid Pile

### 4.5 Vertical Bearing Strength Calculation

The following equation is used for vertical bearing strength evaluation of RStandard poles directly embedded without a footing.

\[ B = \frac{P_v}{A_B} \]

Where:

- \( B \) = Minimum Allowable Vertical Bearing Capacity of the Soil
- \( P_v \) = Vertical Force
- \( A_B \) = Area of the Pole Base Plate (\( \approx \) Area of a Circle, of the OD at the Pole Base)

In cases where the required minimum allowable vertical bearing capacity cannot be achieved, off-the-shelf or custom bearing plates or footing capable of supporting the vertical load will be required.

### 4.6 Uplift Resistance Calculation
ANSI/ASAE Standard EP 486.1OCT00 Shallow Post Foundation Design uses the following equation to calculate the uplift resistance of a foundation with a circular concrete collar.

\[ U = \alpha G \left[ 0.33 \pi \left[ \frac{d - t}{\tan \theta} + \frac{0.5W}{\tan \theta} \right]^3 (\tan \theta)^2 - 0.125 \frac{W^2}{\tan \theta} \right] - A_p (d - t) + 0.25 C \pi W^2 t G \]

(Note: The definition of each term below indicates the assumptions used to determine the equation to be used for direct embedment foundations without a collar.)

Where:
\( U \) = Soil and Foundation Uplift Resistance
\( \alpha \) = Soil Density
\( C \) = Concrete Density (= 0 for direct embedment without collar)
\( G \) = Gravity
\( d \) = Embedment Depth
\( t \) = Collar Thickness (= 0 for direct embedment without collar)
\( W \) = Collar Width (= OD of RStandard Pole Base)
\( \theta \) = Soil Friction Angle
\( A_p \) = Cross-sectional Area (= Area of a Circle, of the OD of the Pole at Ground Line/Fixity)

Based on the assumptions for direct embedment of an RStandard pole without a collar, the following equation may be used to calculate the maximum uplift capacity.

\[ U = \alpha G \left[ 0.33 \pi \left[ \frac{d + 0.5W}{\tan \theta} \right]^3 (\tan \theta)^2 - 0.125 \frac{W^2}{\tan \theta} \right] - A_p d \]

If additional uplift capacity is required, a number of options are available including uplift anchors, off-the-shelf pole bearing plates, or a custom collar may be used. It is the engineer’s responsibility to ensure that the device(s) chosen are appropriate for the specific application.

5 General Factor of Safety Guidelines

RS has developed general factors of safety for various loading scenarios to prevent “first failure” of a module or pole. First failure is defined as the first visible, non-reversible damage inflicted on the pole wall. RS’ chosen definition of a safety factor is the ratio of the ultimate (first failure) stress to the allowable stress.

Safety Factor (S.F.) = Ultimate Stress (U.S.)/ Allowable Stress (A.S.)
Therefore, A.S. = U.S./S.F.

Safety factors compensate for:
- Allowable tolerances of the part
- Uncertainty of the anticipated loading (magnitude, type or placement)
- Assumptions in methods of analysis

Page 23 of 24
• Fabrication tolerances (squareness of cuts, normal tolerances, etc.)

RS’ recommended minimum safety factors used for design are shown in Table 6. These safety factors should be applied in addition to applicable factors of the appropriate design code. For any analysis types not specifically addressed in Table 6, RS recommends a minimum safety factor of 2.0 for all static load conditions, based on the factored working load as defined by the applicable code or standard, if any.

Table 6 – Minimum Recommended Safety Factors by Analysis Type

<table>
<thead>
<tr>
<th>Analysis Type</th>
<th>RS Recommended Minimum Safety Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Structural Pole Analysis; axial, moment, shear, and torsion loads.</td>
<td>1.0 *</td>
</tr>
<tr>
<td>Pole Foundation Analysis</td>
<td>1.0 **</td>
</tr>
<tr>
<td>Bolted Hardware Connections</td>
<td>1.0 *</td>
</tr>
<tr>
<td>Banded, Straped, Clamped Hardware Connections</td>
<td>1.0 *</td>
</tr>
<tr>
<td>Slip-Joint Analysis</td>
<td>1.0 *</td>
</tr>
<tr>
<td>Modulus and/or Deflection Calculations</td>
<td>1.0 *</td>
</tr>
</tbody>
</table>

* based on factored working load as defined by the applicable code or standard, including strength factors.

** based on factored allowable soil properties.

The safety factors given are for static load conditions only. Safety factors for impact loads and dynamic loads are typically a minimum of two times the static load safety factor. Long term service loads which result in creep deformations and/or fatigue may require even higher safety factors to ensure satisfactory performance.

The RS recommended minimum safety factors are not the only safety factors that may be used in design. The engineer may choose to adjust the safety factors based on a particular applications and considerations including margin of safety, costs, confidence of loads or materials, etc. at their risk and discretion.

6 Works Cited

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