White Paper A

DISCUSSION OF CONVENTIONAL CHALLENGE COURSE DESIGN

By ACCT Standards Development Committee
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Most conventional wood pole challenge courses are very similar from an engineering standpoint. This appendix presents additional information and a few of the basic design assumptions helpful in understanding most wood pole challenge courses in existence using ANSI/ACCT 03-2016 Standards, Chapter 1.

WOOD SUPPORT POLES

Standard D.3.3. states: "Wood poles used as critical element support structures shall comply with prevailing editions of the American National Standard for Wood Products – Specifications and Dimensions (ANSI 05.1) or Structural Glue Laminated Timbers for Utility Structures (ANSI 05.2)."

The most common wood support poles on high challenge course elements are (ANSI 05.1) Class 2 in size. Class 2 poles have a 3,700 lbf. (16.5 kN) rated breaking strength when horizontally loaded 2 feet (610 mm) from the top, when fixed at ground level. This is enough reserve strength to withstand failure of the guy system with a typical 3/8–inch (9.5 mm) 7x19 GAC lifeline opposite the guy. Generally speaking, guys in this situation are not considered critical because the consequence of failure is not likely to lead to serious injury or death to any person, as the poles are not likely to break. Certain elements, such as zip lines and high swing elements are more sensitive to lifeline tension, and the guys may need to be considered critical. Beyond this basic loading concept, tower structures and platforms in poles, plus wind, ice and snow loads, etc. add complexity to the designer's choice of pole and guy configuration and size. Such complexities warrant design consultation with a professional engineer.

Wood poles are commonly installed in the ground to a minimum depth of 4 feet (1,220 mm) or 10% of pole length plus 2 feet (610 mm), whichever is greater. Media such as sand or rock, or high ground water environments may require increased embedment depths or alternative installation techniques and materials. Again, such complexities may warrant consultation with a professional engineer.

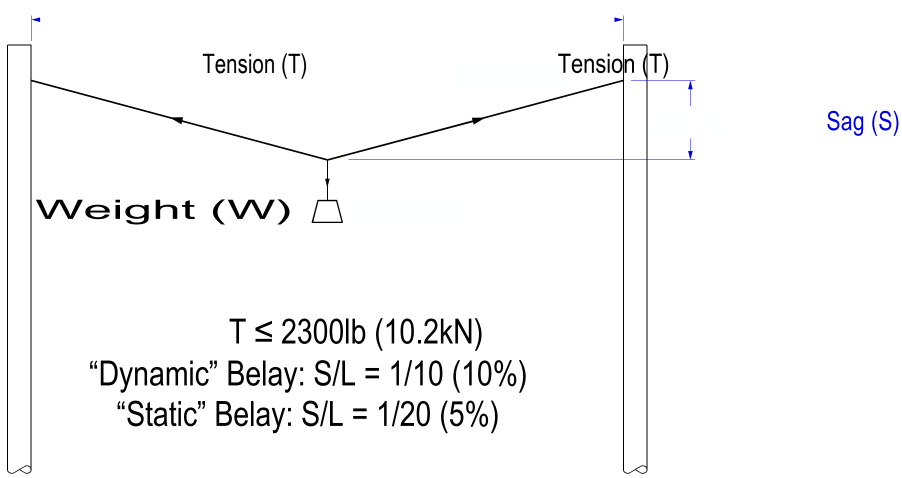
Standard E.2.3. states: "Horizontal lifeline systems including terminations, anchorage(s), anchorage connectors, and backups shall be designed to a minimum rated breaking strength of five times the expected load (safety factor of 5:1) as determined by a qualified person."

On a conventionally designed horizontal lifeline using 3/8-inch (9.5 mm) 7 x 19 GAC and wire rope clip terminations (80% efficiency), the minimum cable system breaking strength is 11,500 lbf (51.2 kN), or 80% of the wire rope's published breaking strength of 14,400 lbf (64 kN). After applying the 5:1 safety factor, the working load limit of the system is one fifth of this breaking strength, or 2,300 lbf (10.2 kN). To assure that the working load remains within this 2,300 lbf (10.2 kN) limit, the lifeline must have a particular amount of sag under load (see Diagram AA1 below). Lifeline sag under load is greater for top rope belay systems than for self-belayed lanyard systems because the vertical load transmitted to the horizontal lifeline in a top rope belay system is approximately double that of a self-belayed lanyard system.

On a conventional top rope belay element of relatively short span (where the weight of the lifeline material is insignificant), a single person may generate a vertical load up to 1,000 lbf (4.4 kN) under normal operating conditions. This live load generated by the participant is transmitted through the lifeline. In order for the lifeline tension to remain below the working load limit of 2,300 lbf (10.2 kN) for a 3/8-inch (9.5 mm) 7 x 19 GAC lifeline system, a minimum sag/span ratio of approximately 1:10 (or 10% sag) is required. For example, a loaded lifeline with 3 feet (910 mm) of sag in a 30-foot (9.1 m) span has a sag/span ratio of 1:10, or 10% sag. In other words, a loaded horizontal lifeline with 10% sag is sufficient to support a 1,000 lbf (4.4 kN) peak vertical load.

On a conventional traversing element of relatively short span and exclusively operated using a self- belayed lanyard system (and NEVER used with a top rope belay system), a single person may generate a vertical load up to 500 lbf (2.2 kN) under normal operating conditions. This live load generated by the participant is transmitted through the lifeline. In order for the lifeline tension to remain below the working load Limit of 2,300 lbf (10.2 kN) for a 3/8-inch (9.5 mm) 7 x 19 GAC lifeline system, a minimum sag/span ratio of approximately 1:20 (or 5% sag) is required. For example, a loaded lifeline with 1.5 feet (460 mm) of sag in a 30-foot (9.1 m) span has a sag/span ratio of 1:20, or 5% sag. In other words, a loaded horizontal lifeline with 5% sag is sufficient to support a 500 lbf (2.2 kN) peak vertical load.

Diagram AA1



Although accurate, it is impractical to apply a 1,000 lbf (4.4 kN) load for an exact sag measurement on a top rope belayed element when in the field. On relatively rigid support structures such as a guyed pole course, a reasonably accurate sag measurement may be obtained by simply suspending a person on a top rope belay system, and the resultant sag measured. Ideally, a tension meter (a shunt-type strand dynamometer) is used to directly measure the tension in any wire rope when it is loaded. By simulating the operating conditions on a challenge course element as accurately as possible (applying the expected load) and using a tension meter to measure the tension, one may determine if any wire rope in the system is functioning within its working load limit.

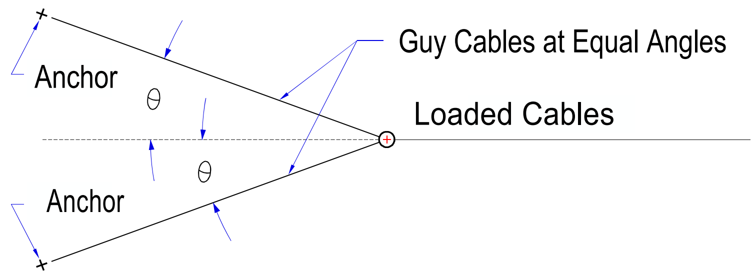
The zip line element falls into the latter category, as it employs a self-belayed lanyard. However, as the length of a zip line increases, so does the contribution to the overall tension from the weight of the wire rope (dead load). Therefore, the above assumptions are not accurate in longer zip lines. Again, such complexities warrant design consultation with a professional engineer.

GUY SYSTEMS

DPI Standard D.4.1. (Strength) states: "Guy cables (excluding ground anchors or footings) shall have the same safety factor as the lifeline(s) that they support and be based on the expected load in the guy cable." DPI Standard D.4.2. (Design Considerations) states: "Guy systems shall be designed by a qualified person. The designer shall consider the relative support provided by structure, guys, and the interaction between them."

Guy cables should be positioned to counter-balance the horizontal component of the load generated by the lifelines, activity support lines, or other structures. Guys transmit this horizontal bending load to the ground anchor to assure that the whole system is functioning within its working load limit. As mentioned in the discussion of wood support poles, the designer determines whether the guy is critical in nature, ensures that the geometry of the guys properly oppose the applied load, and that the required shock-absorbing characteristics of the system are achieved. In tree courses, guys are specified at the designer's discretion based on the size and type of tree, the nature of the soil, and the load-bearing requirements of the element.

Diagram AA2



TYPICAL DESIGN WHEN DOUBLE GUYS ARE USED

The designer determines a guy's required strength as a function of the relative strength of the pole or structure it is supporting, its relative importance to the overall structure (whether or not it is critical), and the need to limit bending or maintain structural stability to allow for proper operation of the element – they are a component of the overall design of the structure. For example, if wood support poles are ANSI (05.1) Class 1, the structural support needed from a guy is much less than if those poles were Class 4 in size. With Class 4 support poles, the guy(s) may be considered critical and require greater strength to sufficiently support the increased expected load. However, guy(s) may still be specified on Class 1 poles to limit bending to ensure proper element operation. For example, if a zip line support pole flexes much at all, the zip line cable height and tension is compromised, rendering the zip line operationally unacceptable.

Guy systems are integral to the overall structural design of challenge courses. The expected load to the cables discussed above usually differ on either side of a guy-supported column or structure because the pole "absorbs" some portion of the horizontal load from the opposite side, unless the pole is hinged at the ground and cannot stand on its own or the cable tensions are balanced from one side to the other (and the pole is in pure compression with no induced bending load). Designs where guys are not needed or desired are possible when a designer considers support structure strength, stiffness, stability, and geometry.

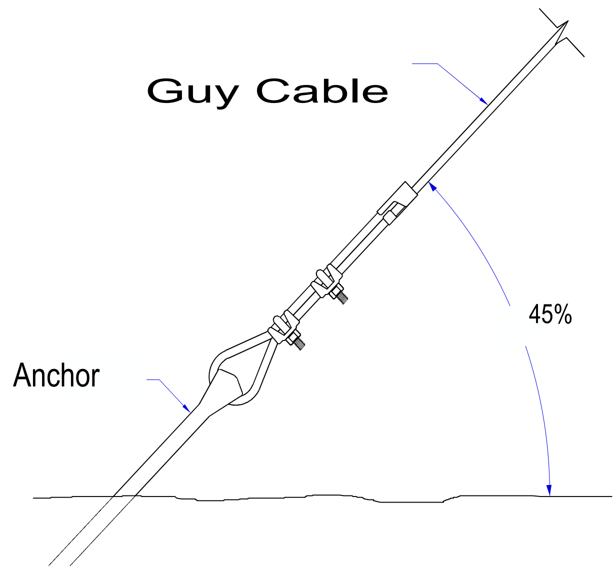
GUY TERMINATION AND ANCHOR PLACEMENT

Guy termination anchorage on poles should be appropriately placed, so working load limits are not exceeded. As a general design practice, guys are located to not induce bending in the pole. On typical utility pole challenge courses, guy anchorages are ideally installed close to opposing lifeline or other anchorages to minimize this bending force in the pole.

GUY SYSTEM GROUND ANCHORS

The most common challenge course ground anchors employ standard utility line hardware, although trees are also used for the same purpose. Ground anchors are typically installed equidistant from the pole at ground level as the top anchorage is above ground level, thereby creating a 45° angle between the guy cable and level ground. Angles greater than 45° are acceptable provided that the guy system strength requirements (D.3.1.) are met.

Diagram AA3



ANCHORAGES AND OTHER FASTENERS

When specifying anchorage components and other fasteners, it is important to consider the application for which they were originally designed and how they may be adapted for challenge course use. For example, caution should be exercised when specifying threaded eyes (eye nuts) or, more specifically, threaded rod (all-thread) in applications where angled or cyclical bending loads are induced in the fastener's threaded area. Cyclical bending may result in premature fatigue failure in the threaded area of the bolt. Therefore appropriately sizing threaded rod and eyes warrant design consultation with a professional engineer.

Many forged eyebolts used on challenge courses have not undergone proof testing by the manufacturer. In order to comply with standard E.1.2. (System Integrity), a common practice to assure integrity of untested bolts in life safety or other critical systems is to implement redundant cable loops (backups).

In determining appropriate washers for fasteners, the material and the application should be considered. For example, in softer materials such as wood, washers should be used on both ends of fasteners to allow for proper tightening. In media with expansion/contraction cycles, lock washers or alternative locking methods may be required to ensure the fastener remains properly secured over time.