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CONSTRUCTION OF A LIGHTWEIGHT CANOPY WALKWAY IN A CHOCÓ CLOUD FOREST, ECUADOR

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ABSTRACT. A canopy walkway was built at a remote cloud forest site using lightweight polyester webbing. Selecting easy-to-work-with materials, a small construction team designed and fabricated the walkway on location in 1996. Standard bridge design equations were used in the field to adapt the basic construction plan to the site. This field approach is well suited to a small team working in a remote area with a limited budget. Walkway design, materials, and construction methods are described.

Key words: canopy walkway, cloud forest, Chocó, Ecuador

INTRODUCTION

Epiphytes form a major component of the rich biodiversity found in Neotropical forests. Epiphyte species richness is greatest in the wettest tropical forests, such as the extensive cloud forests of the Northern Andes. Studies of the diversity and ecology of tropical epiphytes can be challenging because of difficult access to the rain forest canopy at remote sites, often in areas with little infrastructure. Canopy walkways, which can serve research and ecotourism, have been in use since the early 1970s. Since that time, various construction methods have been used at a number of sites throughout the world (Muul 1999).

To minimize the logistical constraints of canopy access, straightforward walkway construction methods are preferred, especially if a small team can build the walkways quickly and inexpensively. The Drake Walkway introduced by Mitchell (1982) was designed with this intent; it is a lightweight canopy walkway made from polyester tape (seatbelt webbing) that can be moved from site to site.

The walkway described in this article was constructed using the same basic materials and methods as the Drake Walkway but with modifications designed to keep the cost low and the construction methods simple. This was achieved mainly by avoiding the use of pre-fabricated components. Another positive aspect of this approach was the use of standard bridge design equations, which allowed all fabrication to be performed on location and eliminated the need for an advance survey of the construction site. Because the study site was located six hours from the nearest road by foot or mule back, walkway materials had to be relatively lightweight and easy to transport; and construction could not involve many heavy tools.

One member of the team did most of the construction with intermittent help from several others, beginning in November 1995 and completing the walkway in April 1996. Two people working steadily could construct such a walkway in four to six weeks.

The walkway was installed at the Los Cedros Biological Reserve, a 6000-ha private cloud forest reserve in northwest Ecuador (0°18′30″N, 78°46′45″W). The reserve is situated on the southern border of the Cotacachi-Cayapas National Reserve in an area characterized by rugged topography and high rainfall (>5 m/year). This area is located within the Chocó biogeographic region, which extends along the west coast of Colombia and northwestern Ecuador.

Unique geographic and climatic features contribute to making the rain forests of the Chocó among the most biodiverse of any forests in the world (Dodson & Gentry 1991). The mid-elevation forests of the Northern Andes, including the Chocó cloud forests, may harbor the world's greatest diversity of vascular epiphytes. In particular, the diversification of epiphytic orchids in the Northern Andes has been termed explosive (Gentry & Dodson 1987a, 1987b). At the Los Cedros Reserve, approximately 150 species of epiphytic orchids are known (S. Dalström unpubl. data). Some of these are new species recently described by Luer (1996).

During the past 50 years, widespread forest clearing in western Ecuador has resulted in massive biological extinction, and remnant forests remain mostly at high elevations in areas that can be difficult to reach (Dodson & Gentry 1991). Conservation of these areas is crucial to protect the rich biodiversity they harbor, and canopy studies are a key component of such efforts.

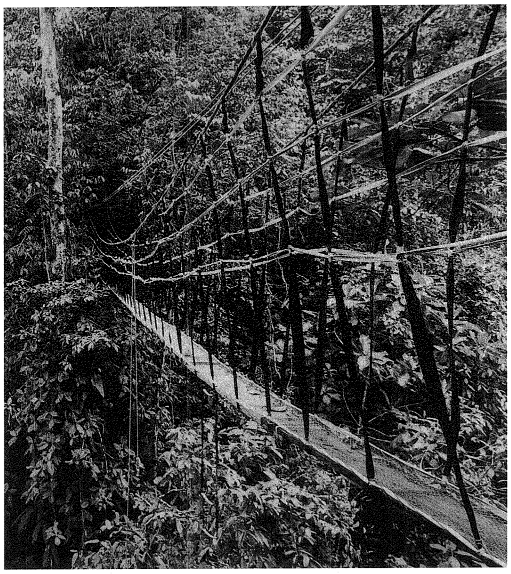
MATERIALS AND METHODS

The canopy walkway is situated in a steep ravine in primary forest at 1350 m elevation. The 21-m long walkway begins on a hillside and ends in an emergent strangler fig tree (*Ficus* species), 23 m above ground. The walkway passes through a number of smaller trees and provides convenient access to the epiphyte-rich canopy of the strangler fig. Initial access into the fig tree was made using single-rope technique (Dial & Tobin 1994, Moffett & Lowman 1995). A thin nylon line was set from the fig tree to the hillside using a throwing weight, and a larger diameter line was then drawn across; this line was later used to pull the walkway main cables across the span.

Walkway Design

The finished walkway resembles a suspension bridge, having parabolic main support cables and a level walking surface (FIGURE 1). Boards cut locally and provided by staff of the Los Cedros Reserve were used to construct the walkway deck. The two anchor trees were selected for their large bole diameters and stable root systems. The main-cable anchor points were placed at equal heights in the anchor trees to obtain a symmetric and level walkway. Polyester webbing (5 cm) was used to make the main cables and the support stirrups. Although comparable to rope in strength, polyester webbing is more malleable, runs more smoothly over surfaces, and can be wound into relatively compact rolls.

The main cables were composed of two redundant continuous lengths of webbing. The first length originated from the south side of the hillside tree, crossed over to the fig tree, and was wrapped three times around each of two large limbs before being returned to the north side of the hillside tree. The second cable originated from the north side of the hillside tree and was wrapped in the fig tree at the same spots on top of the first cable before being returned to the south side of the hillside tree. The walkway was tensioned into final position, and the ends of the webbing were wrapped four times around the hillside tree and tied off. Wraps were used to anchor the cables, because knots significantly reduce the strength of rope and webbing (Padgett & Smith 1987). To avoid constricting conductive tissues of the anchor trees, the team raised the



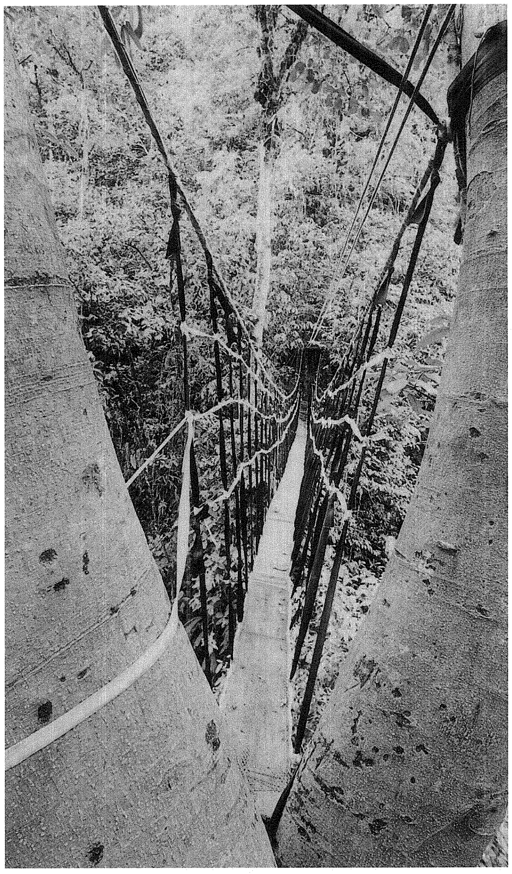


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FIGURE 1. Two views of the completed walkway looking east from the strangler fig tree toward the hillside entrance.

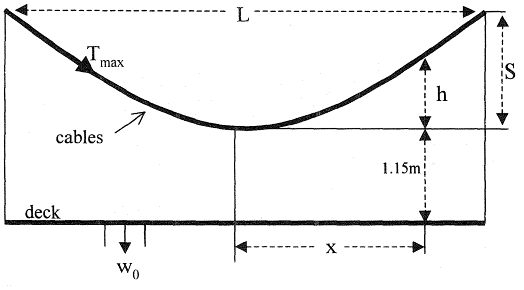

FIGURE 2. Standard bridge construction dimensions used in the calculations. Note: L = total length, S = parabolic sag, x = distance of stirrup attachment point from the walkway midpoint, h = height of cable rise at x, w_0 = weight per meter, and T_{max} = maximum tension in cables using equation 1.

wraps off the surface of the trees using a series of wooden dowels (5–8 cm diam.).

The tensile strength of the polyester webbing was 2000 kg, and with two lengths employed, the breaking strength of the main cables was approximately 4000 kg. This walkway could accommodate two 80-kg users with a safety margin of 11× including the approximately 200-kg weight of the walkway. A 10–15× safety margin is recommended, because of the potentially large forces generated by dynamic loading (Padgett & Smith 1987).

Calculations for Walkway Dimensions

The distance between the anchor trees determined the span length; the height of the cables above the walkway deck at mid-span was set, for convenience, at about waist height; and the walkway deck was placed at ground level on the hillside for easy access. With these three parameters defined, standard bridge design equations, calculated on a portable computer, were used in selecting the appropriate points for attaching the main cables to the anchor trees.

The tension generated in the parabolic main cables at the anchor points (T_{max}) was evaluated for various parabola depths using equation 1 (Hibbeler 1983).

$$T_{max} = w_0\frac{L}{2}\sqrt{1 + (L/4S)^2}$$

For a span length (L) and weight per unit length (w_0), T_{max} decreases exponentially as the sag (S) is increased. The sag needs to be as large as practical to minimize T_{max} and allow the anchor trees to sway as normally as possible. For this design, with L = 21 m, S = 1.5 m, and w_0 = 10 kg/m, the T_{max} was 190 kg per side, or 380 Kg on the anchor (FIGURE 2). Increasing S somewhat more could have been advantageous (FIGURE 3); but it would have been significantly more difficult to arrange the anchor spots higher in the anchor trees at this site.

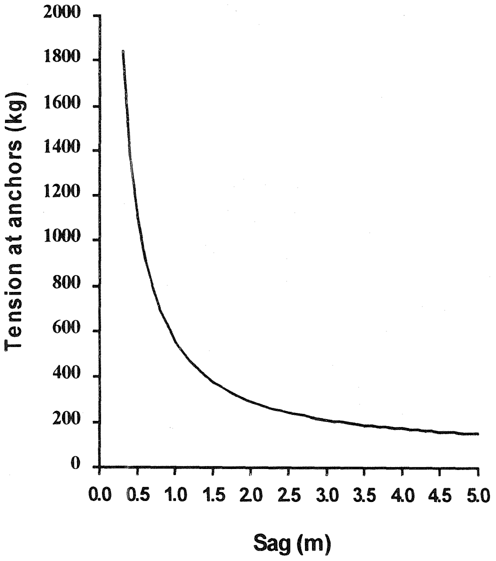

FIGURE 3. Maximum tension (T_{max}) in cables vs. parabolic sag (S).

Support Stirrups

A series of U-shaped support stirrups cradle the walkway deck at 50-cm intervals along the entire span. To determine the correct length for each support stirrup, the height between the main cables and the level walkway deck was calculated at each stirrup attachment point, using the parabola equation (equation 2).

$$h = x^2S/(0.5L)^2$$

The height (h) of the parabola at each stirrup attachment point (x), as measured from the midpoint of the span, is determined for a span length L, with sag S (see FIGURE 2). To calculate the height between the cables and the walkway deck at each stirrup attachment point, the cable height at mid-span (1.15 m) was added to h.

The stirrup sides were not vertical because the distance between the main cables was wider than the walkway deck width (w); therefore, the actual length of each stirrup side was calculated using the Pythagorean theorem. The total length for each stirrup was calculated by multiplying the side length by two and by adding the deck width and extra length for tying two end loops. The stirrups were cut to length from a roll of polyester webbing; the end loops were tied with water knots; and each stirrup was then numbered and slid over the walkway cables in order.

Walkway Deck

The walkway deck was made from locally cut boards (28 × 210 × 2 cm) provided by staff of the Los Cedros Biological Reserve. To increase longevity, the boards were treated with Borax as a biocide. To construct the deck, the team overlapped the boards by 30 cm and lashed them together with polypropylene twine. The boards also were lashed to each walkway support stirrup. As each new board was added, the construction team pulled the emerging deck across the span. After final positioning, the stirrup end loops were secured to the main cables with twine. Thin-gauge wire fencing material then was rolled across the walkway deck and secured to each support stirrup to provide a non-slip walking surface. After completing the walkway, the team built a platform (3 × 4 m) in the strangler fig tree.

Final Positioning

Proper tension for final positioning of the walkway was developed in the main cables using a 2-ton hand winch attached to a secondary anchor tree located just uphill from the primary anchor tree. A bridle system, composed of 11 mm rope with Prusik loops attached to each end, was connected to the hand winch. The Prusik loops (7-mm nylon cord) were tied around the walkway cables with Prusik knots and then attached to each end of the 11-mm bridle rope with carabiners. The bridle rope, at its midpoint, was passed through a heavy-duty steel pulley hooked to the hand winch. The walkway deck was leveled from side to side by the action of the pulley sliding along the bridle rope as the winch was tightened. Tension was applied until the walkway deck was level and flat across the span. After the cables were moved into final position, the main-cable ends were wrapped around the hillside anchor tree and tied together.

Safety

A loosely strung ¼″ steel cable was installed above the walkway for use as a safety line. A walkway user wearing a climbing harness thus could clip to the safety line using a short leash equipped with a steel safety clip.

Three tiers of side rails made of thin 2-cm wide polyester webbing also were installed. These side rails, spaced 25 cm apart vertically beginning just below waist height, were attached to each support stirrup with clove hitches.

A heavy-duty arborist harness was used for the initial tree work, but a lightweight harness was preferred during the walkway construction. A 100-m roll of 2.5-cm tubular nylon webbing was useful in constructing the temporary anchors and miscellaneous utility and safety lines needed during construction.

Longevity

The main cables were wrapped with strips of ultraviolet resistant plastic to guard against ultraviolet (UV) degradation. A revisit to the site two years later found the covered main cables unfaded, but the non-covered support stirrups had faded somewhat. Plant and fungal growth was noted on non-covered polyester in the most shaded portions of the walkway. Although the biological growth did not penetrate the tight polyester webbing, some fraying of surface fibers was evident under magnification. The protective dowels used under the cable wraps on the anchor trees had to be replaced because of decay, along with some of the boards in the most shaded portion of the walkway deck.

DISCUSSION

The disadvantages of polyester webbing compared to metal components include greater susceptibility to abrasion, UV degradation, and potential impacts from biological growth. Designs utilizing stainless steel main cables (Lowman & Bouricius 1995, Inoue et al. 1995) may be preferable where practical, especially for long-term use. The design described here, generally following that developed by Mitchell, is suitable, however, for low-cost projects with limited personnel, where ease of construction is a major factor.

The advantages of this design are related mainly to the uncomplicated tools and construction methods involved. The walkway was built for a total cost of $1500, including the price of an inexpensive portable computer. (A 40-m walkway could have been built with these materials, but a suitable 40-m span was not found at the site). The use of locally cut boards for the walkway deck helped keep the cost down. By employing basic bridge design equations in the field, a safe and rugged walkway was designed and manufactured on-site without advance inspection or pre-construction of components. The walkway, in relatively good shape after two years, was left in place after minor maintenance.

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