

ENTRY FORM



DVASE 2010 Excellence in Structural Engineering Awards Program

PROJECT CATEGORY (check one):

New Building under \$30M		Other Structures Under \$10M	X
New Building over \$100M		Other Structures Over \$10M	
New Building \$30M - \$100M		Free Style	

Approximate construction cost of facility submitted:	\$2.3 M
Entry Fee:	FREE
Name of Project:	Tree Walk Adventure
Location of Project:	The Morris Arboretum of the University of Pennsylvania, Chestnut Hill, Philadelphia, PA
Date construction was completed (M/Y):	June 2009
Structural Design Firm:	CVM Engineers, Inc.
Affiliation:	All entries must be submitted by DVASE member firms or members.
Architect:	Metcalfe Architecture & Design
General Contractor:	CVM Construction Managers, Inc.

Company Logo (insert .jpg in box below)



Provide a concise project description in the following box (one page maximum). Include the significant aspects of the project and their relationship to the judging criteria.

The Tree Walk Adventure provides visitors with a one-of-a-kind opportunity to get up-close and personal with the tree canopy at the Morris Arboretum. Conceptually designed by Metcalfe Architecture & Design, the Tree Walk became a reality with the unique structural solutions provided by CVM Engineers. The 500 ft. long handicap accessible walkway is situated on a steep ridge of the Wissahickon Gorge and is 50 ft. above ground at its highest point. The structure consists of micro-pile foundations, galvanized structural steel framing with wood decking, a steel- and wood-framed "Pavilion" tree house, a glulam bridge leading to the "Birds Nest" exhibit and a cargo net area for climbing. The project is marked by the challenges presented for its construction.

Significant care had to be taken to maintain the existing tree and plant life, and the design was carried out with this in mind. The first unique problem was the trees' root systems, which are very dense in the upper 5' of soil, preventing the use of spread footings. This necessitated the use of micro-pile foundations. Each steel column bears on a 2' diameter x 3' deep concrete pier which encapsulates the micro-piles at the surface. Three 5" diameter battered piles, consisting of a grouted #8 grade 75 all-thread epoxy coated bar, extend 20' into the subsurface. The upper 10' is encased in a steel casing (unbonded), while the lower 10' is uncased (bonded). This foundation system minimized impact on the tree roots while providing the necessary resistance to the calculated gravity and lateral loads.

The superstructure is comprised of hot-dip galvanized structural steel. Towers consisting of three 8" diameter steel pipes are laced together with a seemingly random pattern of steel angles, which provide the required column bracing for axial and flexure. Steel wide-flange beams span between the towers and are braced at the top flange by a zig-zag pattern of HSS braces which cantilever past the wide-flange beams to support the HSS railing posts. The decking of the first half of the walkway consists of locally harvested Black Locust, while the second half is steel grating with a slip-resistant treatment. Since the structure's classification falls somewhere between a building and a bridge, both IBC/ASCE-7 and AASHTO pedestrian bridge criteria were used to develop live, wind, and earthquake loads, as well as investigate vibration. The main challenge in the design of the walkway was to balance the code provisions for vibration while accommodating the Arboretum's desire for an "exciting" experience for its visitors. The lack of any significant dead load on the walkway (i.e. no concrete slabs) and spans between the towers of over 40' necessitated deeper, heavier WF sections than what was needed for flexure, shear and deflection. The walkway meets the 5% of gravity acceleration tolerance for outdoor footbridges per AISC Design Guide 11: Floor Vibrations Due to Human Activity. The AISC guidelines were found to converge with the criteria set forth in AASHTO's Guide Specifications for Design of Pedestrian Bridges, which was used to calculate the fundamental frequency and second harmonic of each span based on its dead load deflection. A finite element model was built to analyze the structure as a whole and a modal analysis confirmed the findings of the AISC and AASHTO criteria. Two expansion joints consisting of Teflon slide-bearings allow for thermal movements. The design of the superstructure was such that each tower and each span of walkway was able to be pre-assembled in the shop, minimizing the number of lifts required through the dense trees and reducing field erection time.

The central feature of the project is the "Pavilion" tree house, designed as a steel frame of pipe columns and WF beams with cedar posts sprouting from the pipes to support the roof, which is framed with cherry beams and trusses. From the "Pavilion", visitors can cross the 35' long "Bridge" consisting of Alaskan Yellow Cedar glue-laminated wood beams with steel pipe railings. The "Bridge" leads to the "Bird's Nest", which is framed with steel HSS sections, then "weaved" with wood branches to give it the appearance of a nest. The main support spine of the Bird's Nest is hung from a single point from two 45' long propped-cantilevered "monopoles" which are fabricated from 1/2" thick steel plate formed into a 16-sided tube. The poles taper from 18" diameter at the base to 12" at the top. The design of the monopoles demonstrated a creative application of available materials as this type of steel pole is typically used in the transportation industry for highway signage and lighting structures. The bridge is supported on a crossbar between the monopoles using a custom slide bearing connection that allows for translation and rotation of the monopoles relative to the bridge due to varying pedestrian loads on the bridge and in the birds nest. Finite element modeling was used to determine the deflection of the cantilevered monopoles given the weight of the birds nest and bridge. This aided in determining the required length for the Bridge components and the initial Birds Nest floor elevation in order for the final elevation to match that of the Pavilion after dead load deflections. The clevis and turnbuckle design of the hanging support allowed for final field adjustability of the Birds Nest elevation.

The final unique component of the Tree Walk is the "Squirrel Scramble" area, featuring two large cargo nets for visitors to climb across or simply relax in while suspended 50' above the ground. The complex problem of resolving the catenary forces from the netting was solved by using finite element modeling to determine the initial curvature of the netting. This pre-displacement of the netting ensured that the occupant loading would result in end reactions that could be resisted by the wide-flange walkway beams. The net is continually lashed to a continuous 1" diameter steel bar. Two custom hinged steel brackets form the perimeter around each tree and were fabricated to match the necessary pre-displacements of the netting. The netting itself is 1/2" diameter Dyneema/Spectra Ultra High Molecular Weight Polyethylene in 4" grids.

The structural design of the Tree Walk Adventure was no doubt an "adventure" in solving unique challenges presented by the architectural concepts and the project site constraints. CVM Engineers' creativity and innovation along with constant collaboration with Metcalfe Architecture & Design, CVM Construction Managers, and the Morris Arboretum staff, resulted in a fantastic idea becoming a reality. This breathtaking permanent installation at the Morris Arboretum is proof that architecture, structural engineering and construction can peacefully co-exist with nature. The project has received rave reviews from the Morris Arboretum, the University of Pennsylvania, and multiple media outlets, as well as multiple awards and honors. Thank you for your consideration!

Please attach your photos as previously described in the call for entries document and insert captions for the photos in the following boxes.





Photo 3: Glulam "Bridge" & steel "Birds Nest" with steel monopoles & micropile foundations



Photo 4: Steel towers supporting framing around trees and cargo netting



Photo 5: Cargo netting around trees at steel grating "Squirrel Scramble" area

By signing, signatory agrees to the following and represents that he or she is authorized to sign for the structural design firm of record:

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