Waste Isolation Pilot Plant

Advantic Leads Design and Delivery of Emergency Response Composite Structure

Challenge

On February 14, 2014 a 55-gallon drum of contaminated material burst at the U.S. Department of Energy's Waste Isolation Pilot Plant (WIPP), releasing a small cloud of radioactive material. The event occurred deep within a stack of waste containers in the confined space of a disposal room carved into a geologic salt deposit nearly 2,100 feet underground. Following the incident and appropriate safety responses, a full accident investigation commenced.

Solution

Given the remote location of the disposal room, and the delicate nature of the contents, WIPP required a means to insert a 90-ft cantilevered boom capable of deploying a 15-lb sensor package within an operating window of only 30 vertical inches above the waste stack. To add to the complexity, the boom was required to provide self-driven motion in both lateral directions so as to permit survey of the entire chamber, and had to be operable by workers in full-body protective suits with allowable time at the contaminated site of less than an hour. Further, the entire system had to be transported to the deployment location in sections less than 10 feet in length, and no individual component could weigh more than 100-pounds. *As shown in Figure 1*

Item	Requirement
Beam cantilever length	90 feet
Maximum beam deflection over 90 feet	30 inches
Sensor payload with power drive weight	15 pounds
Beam motion requirement	Bi-lateral, self-driven
Maximum weight of system component	100 pounds
Assembly and operational constraints	Personnel in full-body protective suits
Time available for design, raw material procurement, fabrication, system assembly, testing, performance validation, and delivery	7 weeks

Table 1 | Design Requirements

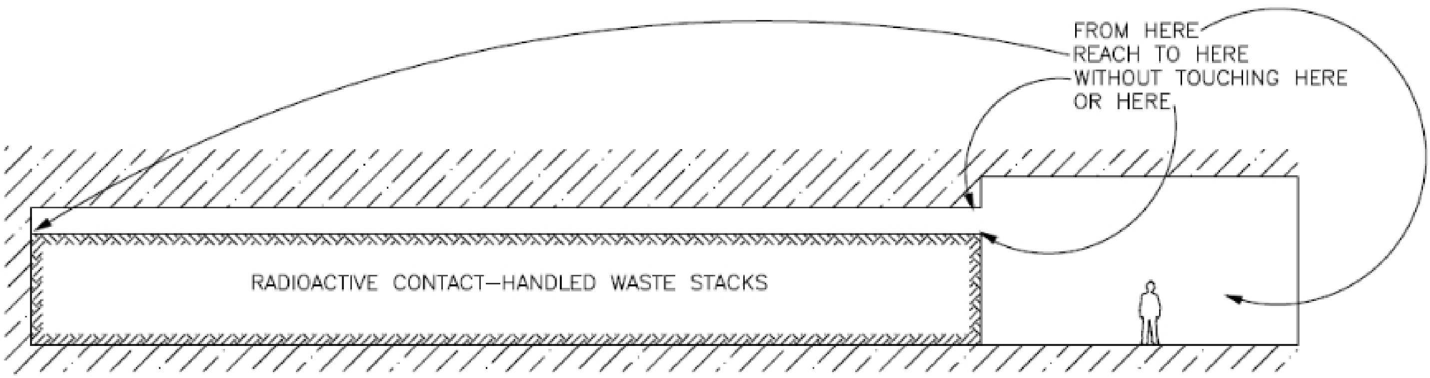

Figure 1 | Scale Profile of Operational Window

Challenge Accepted: Advantic Solution

WIPP approached the combined team of Advantic, NONA Composites (NONA -www.nonacomposites.com), and Cornerstone Research Group (CRG -www.crgrp.com) for a solution after several unsuccessful attempts in working with conventional materials concepts.Advantic co-led the project, leveraging in-house expertise in composites structural engineering, multi-material interface design, rapid composite structure fabrication, and electrical and mechanical system integration. The carbon-fiber beam was fabricated using NONA's proprietary high performance no-oven, no autoclave thermoset resin and infusion experience. CRG, parent company to both Advantic and NONA, provided a multi-disciplinary team of engineers to design and build mechanical,actuation and power, and remote sensing systems

Figure 2| Completed Project REACH Structure and Team

Several large mechanical structures were designed and built for this effort:

- 104-foot carbon-epoxy built-up box beam
- Pultruded polyester-glass beam support cradle and deployment structural frame
- Self-driven rail and trolley for lateral motion

Given the timeline required for delivery, all system components were fabricated in parallel. From raw material through finished assembly, a stringent independently-led quality control program affirmed compliance with rigorous design specifications and assured a high-quality finished product. All structural and mechanical systems were represented on approved technical drawings prior to initiation of fabrication. These drawings, along with process control travelers, followed each component throughout the assembly.

The carbon-epoxy beam was fabricated from 72 composite articles, totaling over 1,500 square feet of infused custom laminate produced in less than three weeks. Further finish trim, adhesive surface preparation, adhesive bonding, riveting, and painting were completed in a subsequent three weeks.

The pultruded structure was fabricated from standard structural cross sections assembled in five rigid frames connected via precision-cut stability members. Advantic's in-house team of engineers and technicians accomplished the fabrication of this structure in under two weeks, including assembly of the high-tolerance steel rail system and requisite joining details to the substructure rail and trolley.

The entire system was assembled as component fabrication completed, which allowed the project team to compress the manufacturing schedule

Figure 3 | Assembled Carbon-Epoxy Box Beam

Figure 4 | Disassembled Box Beam

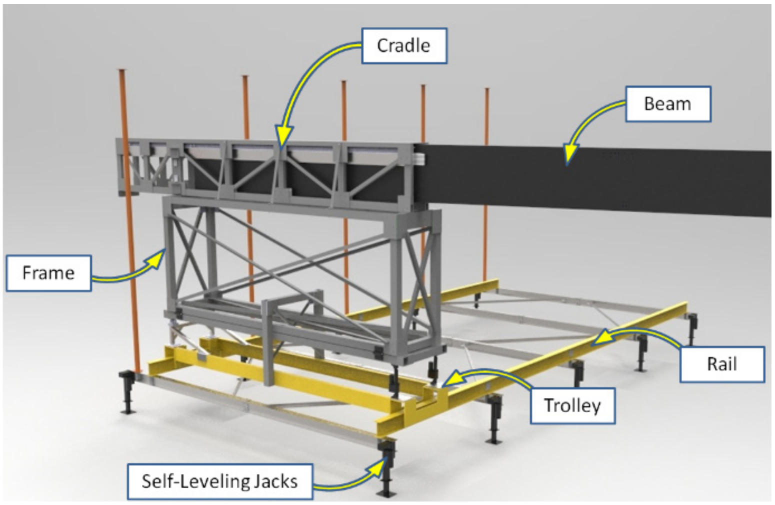

Figure 5 | System Schematic

Figure 6 | Assembled Structure

Successful Installation

Upon completion of the entire system assembly, system validation and acceptance testing was performed under WIPP supervision. The structural, mechanical, and electrical systems performed as designed, and the device was accepted by the customer without hesitation. Immediately, the system was dismantled and shipped to New Mexico for re-assembly in its permanent home far beneath the city of Carlsbad.

For WIPP, the project has been a complete success. From September through December 2014, the WIPP Recovery Team trained with the structure in an above-ground facility to carefully orchestrate their future underground movements in the contaminated environment and ensure the ability to recover the requisite data needed for the investigation. Then, in January 2015, the Reach structure was installed at the contaminated site, deployed, and operated to successfully accomplish the program objectives.

Value

Advantic, with partners NONA and CRG, delivered a structural solution where other conventional material solutions could not meet project objectives, and on a timeline that few other companies in the US were prepared to achieve.

- Technical and program-level leadership of an emergency response project, including quick feasibility studies and design alternatives.
- Rapid teaming and design/build workforce scale-up.
- Highly parallel fabrication of a custom structural solution that exceeds challenging performance requirements while utilizing readily available inventory of raw materials.
- Design for constructability overcoming limiting installation constraints on time and worker.
- Detailed, audited quality program.

Further Reading

- www.wipp.energy.gov/WIPPRecovery
- http://www.compositesworld.com/articles/cfrp-camera-boom-enables-safe-spill-inspection
- http://www.bizjournals.com/dayton/print-edition/2014/10/17/beavercreek-firm-contributes-big-to-nuclear-waste.html

Technical Nuts & Bolts

Given the deflection requirement the design of the entire structure was driven by stiffness. Accordingly, all material selection, joint detailing, and dissimilar material interfaces were closely scrutinized and designed for tight tolerance. In addition to the deflection constraints, the incredibly tight time frame for delivery required design for manufacturability to drive many decisions. One of the first activities of design was to evaluate the domestic inventory of carbon fiber, resin, tooling materials, adhesives, and structural pultrusions available for immediate delivery to Advantic's facilities in Dayton, Ohio.Design activities proceeded one step ahead of manufacturing, with regular controlled revisions to design accomplished via a formal revision process in response to manufacturing queries and requests for modification The standard modulus carbon-epoxy box beam tapered from 30" in depth at the root to 8" in depth at the tip, and maintained a consistent 6" width. In the interest of ease of fabrication, the beam was designed as a series of 12 connected nine-foot length sections, each constructed by connecting two C-channels to two sidewall plates via structural adhesives and rivets. The tall sidewalls were internally stiffened where buckling was a concern. The

composite laminate layup for each of the sections was determined via numerical optimization of the design space of available fabric types for system-scale performance as characterized by finite element models of the structure. Coupon-scale testing of several available adhesives, including combined rivet-adhesive joints, were performed to determine the optimal solution as a trade off between manufacturing efficiency and structural performance. Given the weight restrictions for an individual component, but recognizing that speed of site assembly was critical given the limited work time available at the contaminated site, the cradle and frame for the beam was designed utilizing pultruded composites. Lightweight but stiff assemblies were prefabricated in each of the primary planes of the frame, utilizing gusseted glued-and-screwed connections with each truss substructure for rigid behavior. A high-tolerance steel rail and roller installation completed the mechanism by which beam deployment occurs. The entire beam and frame assembly was required to traverse laterally across a 30-foot width, and a light steel crane rail system was purpose-built for the application, including the trolley drive system. The rails were mounted to a self-leveling jack system to accommodate the uneven salt mine floor, and the trolley interface to the pultruded frame was fitted with a coupled actuation mechanism to permit the front of the frame to raise and lower by as much as 6 inches relative to the rear hinge.