Bentley
Advancing Infrastructure

Project Summary

Organization:
WSP/McGee

Solution:
Structural Engineering

Location:
London, United Kingdom

Project Objectives:

- To overcome complex situational, structural, and geotechnical engineering challenges while converting London's Admiralty Arch into a five-star hotel.
- To optimize design to maximize space while minimizing the structural work zone and implementing innovative construction methodologies.

Project Playbook:
PLAXIS®, RAM®

Fast Facts

- WSP helped design and construct a new basement to house hotel amenities for this iconic project, which presented complex site constraints and requirements.
- PLAXIS helped perform a ground assessment to better understand the impact of the clay soil on the project's structural integrity.
- Integrating RAM for structural design facilitated iterative modeling and a top-down construction methodology.

ROI

- RAM saved 25% in structural design time to complete the design phase one month ahead of schedule.
- PLAXIS facilitated finite element analysis, enabling the team to understand the tunnel movement and prevent tunnel deformation.
- Bentley's interoperable digital solution streamlined workflow processes to deliver the most cost-effective design within the tight deadlines.

WSP and McGee Optimize Complex Basement Design on Waldorf Astoria Hotel in London

Leveraging RAM and PLAXIS Provides Innovative Structural Solutions to Save 25% in Design Time

Redeveloping Historic Infrastructure

One of London's most iconic buildings, completed circa 1911, the Admiralty Arch was designed to reflect a sense of stature and grandeur as the former house of the Royal Navy. Incorporating three archways that are the gateway to Buckingham Palace and Trafalgar Square, the structure includes six levels above ground and two sublevels. As part of a redevelopment initiative to convert this historic landmark into a Waldorf Astoria Hotel, residences, and private-members' club global engineering firm WSP was contracted to provide structural and geotechnical engineering services for two new basements located directly below the existing roadway on either side of the arch. The 12-meter-deep Trafalgar Square basement contains two sublevel housing amenities for the new luxury hotel, including a spa, swimming pool, and ballroom.

As a listed structure of historic relevance, the building transformation presented very demanding requirements and significant design challenges. With two London Underground tunnels potentially limiting the basement excavation depth and clay soil causing heave at the site, the project required precise structural and geotechnical solutions. In addition, building the basement under one of the most famous roads in London necessitated careful construction planning. The team needed to keep constant traffic flow and ensure that there were no signs of construction on site in the event that any royal ceremonial procession needed to pass through the arches. To optimize design and streamline delivery and construction processes, WSP relied on Bentley's interoperable digital modeling and analysis applications.

Overcoming Site Constraints

With the location of the basement planned above two tunnels, the team implemented a box-in-box design approach to provide acoustic isolation for the rooms. The challenge was how to structurally support the basement amid the site constraints. WSP first evaluated how the existing structure and new sublevels would interact with the soil, as well as how the earthworks and construction would impact the two existing underground tunnels beneath the site.

Because the soil is clay, WSP had to address the heave—the movement or displacement of the earth when weight is removed from above it. While the team would usually allow the heave to occur, in this case, the integrity of the tunnels could be compromised. The upward movement could deform and permanently damage the tunnels, affecting the tracks and the trains.

The team used Bentley's geotechnical analysis software, PLAXIS, to develop a detailed ground movement assessment to fully understand the soil composition, its interaction with the arch structure, and the movement of the tunnel at every stage of construction. In standard construction, a basement supports a superstructure above it with all forces going down. However, with no superstructure above the basement, the basement piles need to be located at either side of the six-meter exclusion zones of the tunnels to hold the basement down as the clay expands. The piles are creating tension to hold the substructure in the ground while keeping the tunnels in place.

Using Bentley's geotechnical application, WSP analyzed and predicted movements and forces at a cross-section level of the 3D model to determine how to control the movement of the basement and effectively provide the required tension piles and balance loads. The team conducted 2D and 3D finite element analysis to look at the longitudinal effects along the entire chain of tunnels and determined an optimal solution to limit the movement of the tunnel within acceptable levels.

RAM Optimizes Structural Design

WSP also used Bentley's RAM structural analysis software to prepare an analysis and design the model to match the results of the ground movement assessment, varying the spring stiffness of the different piles. RAM helped determine the most efficient solution for basement slabs and raft foundations. While WSP preferred thicker rafts and slabs, the architect and contractor wanted them as thin as possible and with minimal excavation. The challenge was to minimize the thickness of the structural elements to create the most space and deliver the highest basement, while having enough weight to control the tunnel movement and reduce the amount of tension in the piles.

"RAM Concept provides a successful platform for analysis, design, and delivery that exceeds all our expectations. We are committed to using RAM software in our concrete buildings."

– Diego Padilla Phillipps, Associate Director of Structures, WSP

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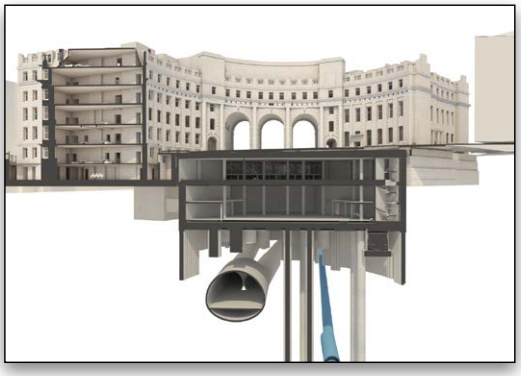

WSP used integrated geotechnical and structural digital applications to determine an optimal design solution.

The interoperability of RAM with third-party software allowed WSP to create geometry for several iterations with the architect. Using Bentley's structural design and analysis application, the team performed iterative modeling and analysis to find the right balance between slab thickness, reinforcement requirements, and self-weight that was most beneficial against the uplift of the basement. WSP modeled 16 different stages for each slab to ensure that every construction stage, loading case, and all the different spring conditions for the piles were addressed. "That's what we used RAM Concept for – beautiful iteration trying to find the right amount of structure," stated Diego Padilla Phillipps, associate director of structures at WSP. RAM accelerated iterative modeling, saving 25% in structural design time, and enabled WSP to determine a cost-effective structural solution, resulting in delivery of an innovative and economical design.

Interoperability Facilitates Top-down Construction Methodology

Using Bentley's integrated geotechnical and structural digital applications, WSP determined an optimal design solution. However, the bigger challenge was building it on such a unique site amid requirements that the area remain open to traffic. McGee implemented a phased, top-down construction process. The methodology required building the piles first, then the ground-floor slab. Once those assets were built, the road was re-opened and the excavation began.

The 3D models streamlined workflows among the various disciplines and helped obtain proper statutory approvals. Leveraging Bentley's interoperable applications throughout initial scheme design, and final construction shortened the design phase by one month and optimized the complicated construction sequence.

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