Title: **How to Resolve the Challenges of Tall Building Foundations?**

Author: Ahmad Rahimian, Chief Executive, WSP | Parsons Brinckerhoff

Subject: Geotechnic/Foundation

Publication Date: 2017

Original Publication: CTBUH Journal 2017 Issue II

Paper Type:
1. Book chapter/Part chapter
2. **Journal paper**
3. Conference proceeding
4. Unpublished conference paper
5. Magazine article
6. Unpublished

Ask a CTBUH Expert: Ahmad Rahimian

How to Resolve the Emerging Challenges Of Tall Building Foundations?

Dr. Ahmad Rahimian, *WSP*

As the world urbanizes, the number of tall buildings will increase, particularly in coastal regions with soft soil conditions, placing strain on foundation design and affecting sub-surface infrastructure already in place. Several high-profile cases of tall buildings sinking or settling have made the news recently. We asked, "How to Resolve the Emerging Challengesof Tall Building Foundations?"

About the Author

Ahmad Rahimian is Director of Building Structures at WSP. Dr. Rahimian is the recipient of the 2007 AISC Special Achievement Award and the 2005 ASCE-CERF Charles Pankow Innovation Award for innovation. He is a Distinguished Alumnus at NYU School of Engineering and holds two US patents for seismic protective design.

Foundation Engineering Challenges

In a field that greatly depends on past experience and empirical methods, foundation engineering is challenged to establish design and performance parameters for tall buildings. Design needs include: evaluation of bearing capacity and stability; impacts of the cyclic nature of wind on building response; load distribution among support elements; and building-to-building interactions in closely spaced developments, as well as constructability.

In cities such as New York, accessible sound bedrock in many locations can make the foundation choice relatively simple, such as spread footings with capacities of up to 1,172 metric tons per square meter, or caissons to bedrock in locations with complex underground infrastructure. These systems do not influence the structure's stiffness, frequency, or performance under wind or seismic loads. However, they may require rock anchors for countering net uplift forces from wind and gravity loads or overturning from seismic events. In areas with soft and poor soil conditions, mat, raft, deep foundations, or a combination of these are needed for adequate support (e.g., Torre Mayor in Mexico City with piles, MesseTurm Trade Tower in Frankfurt and the Shard in London with raft and pile foundations). These foundation systems may influence the tower's lateral stiffness and frequencies, thus affecting the structure's performance under wind, static, and dynamic effects.

Path to Resiliency

In addition to safety and economic demands, foundation design must incorporate current needs for resiliency and sustainability, which raise practical and philosophical questions requiring cross-disciplinary interaction between planners, architects, owners, and the affected public. Codes provide risk-based (ASCE/SEI 7-16) and performance-based design (PBD) criteria (CTBUH 2008) for superstructures, while foundations are expected to remain elastic.

Measured settlements of 101 to 127 millimeters have shown no major impact on the functionality of tall buildings, provided that strict tilt criteria were met. Established case histories refer to tolerable settlements of 101 millimeters and angular distortions of 1/500 to 1/1000 radians for supertall buildings.

Let's Communicate

Some foundation challenges could be resolved early in the design process by means of effective communication between structural and geotechnical engineers, including:

- Clarifying governing code and design basis criteria.
- Determining differential and total settlements and lateral deformations, for all loading demands.
- Setting parameters, testing, and incorporating soil-structure interaction (SSI) and strain dependency in the structural model.
- Agreeing whether the assumed building "base" is at the ground surface or basement bottom.
- Identifying drainage issues or corrosive soils that may affect concrete mix and materials (e.g., steel pile wall thickness).
- Identifying potential interaction with existing adjacent structures, substructure infrastructure, and critical utilities.

Future: Reaching Higher by Digging Deeper

The creation of a PBD framework for foundations of tall buildings should consider a holistic approach to the soil-foundation-structure system and in certain cases, incorporation of fail-safe or self-re-centering systems to allow fast return to service after hazardous events.

Engineers make decisions based on a combination of numerical tools, real-time instrumentation, and 3D visualization software, allowing model calibration and adjustments as the project develops. Quality construction, with proper foundation testing and short- and long-term monitoring, is essential. A global database of performance observations and load tests of foundations for tall buildings could be helpful.

Ultimately, foundation engineers have to view computer modeling only as a tool to evaluate various parameters and help them to confirm or reject engineering options, based on a blending of fundamentals and their own sense of proportion. ■