Special Issue: Robotics in Tall Building Construction

Research Report: The Future of Robotic Construction
An Innovative Construction Elevator Ecosystem
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Intelligent 3-D Elevator Shaft Mapping
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“The degree to which the COVID-19 pandemic directly affected the construction schedule of a tall building in 2020 was highly variable in relation to local regulations and the ability of the contractor to keep a sufficient number of workers on-site.”

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Global News

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Americas

Chicago’s Cascade, a 130-meter residential tower, has officially topped out. Part of the larger Lakeshore East development, the multifamily building will hold 503 units and offer access to the new Cascade Park. Nearby in the Midwest region, the 155-meter Couture residential project received its final financing approval in Milwaukee, setting the stage for it to begin construction in early 2021. On the East Coast, in New York City, 22 Chapel Street, a 74-meter reinforced concrete residential tower, has topped out in Brooklyn. Of the building’s 180 units, 25 will be designated affordable housing.

From the Southeast to the Southwest, the lower region of the United States has seen a flurry of activity. Amid a general proliferation of high-rises in Charlotte, another uptown tower has progressed. FNB Tower, a residential and office building, has topped out at 29 stories. Nearby, the 17-story Two Legacy Union has also topped out, and the 23-story Honeywell Tower and 40-story Duke Energy buildings are progressing. To the west in Tennessee, a 30-story skyscraper has been proposed for Memphis’ Pinch District at 369-371 North Main Street. The project’s programming would potentially include retail, hotel, and residential uses.

One West Palm, a twin-tower complex in West Palm Beach, has resumed construction after a pause earlier in 2020, with a planned completion date sometime in the summer of 2022. Further south in Florida, the luxury Miami high-rise Missoni Baia has reached the halfway point on its ascent to a planned 198 meters. The residential tower will feature 249 one-to-five-bedroom units, with interiors designed by the legendary luxury Italian brand, Missoni. Public spaces and amenity areas within the development will also be designed by the fashion house. Also in Miami, Downtown 5th, a multifamily twin-tower complex, has made strides toward completion, with the topping off of both its east and west towers at 52 stories.

High-rise activity continues to be robust in Texas. In Dallas, One Newpark is the phase-one anchor of Newpark Dallas, a new “smart district” coming to the southern end of the city’s downtown. The mixed-use building will rise 38 stories, featuring a dramatic void in its center. In total, Newpark Dallas will deliver more than 92,903 square meters of Class-A office space, 18,580 square meters of urban retail space, thousands of residential units, and a proposed educational campus comprising up to 92,903 square meters. Elsewhere in the city, Dallas’ first JW Marriott has broken ground, and is planned to deliver 283 luxury hotel rooms by 2022.

Over on the West Coast, the iconic Transamerica Pyramid Center in San Francisco has been sold, cementing what is being called the largest commercial real-estate transaction to take place since the COVID-19 pandemic began. The 260-meter pyramidal building rising prominently in the city’s financial district was sold for US$650 million, to a joint real-estate and finance venture.
Approaches to Robotic Technologies in the Building Industry

Robotization of Traditional Construction Procedures

Two main tendencies regarding the approach to robotics in construction were explored, through different stages of development and adoption by the sector, following diverse rationales. There is a more “classical” interpretation of “robotization” of conventional construction procedures, whose principle is to execute traditional construction operations with robotic mechanisms (see Figure 1). These devices perform the same tasks as human workers, either replacing or complementing them in the performance of dull and physically demanding activities. Within this framework, the trend for the first line of development has shifted from a first stage, in which the objective was merely the repetition of construction-related tasks, to the current trend of pursuing the manufacturing of devices with an ever-increasing level of self-sufficiency. These devices are able to collect and process data in order to increase their adaptability to the context within which they operate, and are thus able to operate uninterrupted. For collaborative robots, intended to work alongside human workers, the required degree of sophistication is related not so much to self-sufficiency as to safety and...
Introduction

Elevator shafts are key structures in buildings. They essentially form one room, from the basement of a building up to the top. Elevators must be constructed in close conjunction with overall building erection. In spite of the large size and long construction time of the elevator shafts, they need to be within close geometric tolerances to allow for proper elevator installation.

First, elevator shafts need to be straight, in order to guarantee good elevator ride quality. Any kinks or curves in the elevator rails due to out-of-plumb shafts can lead to oscillations of the elevator car as it travels at high speed along the rails. Required tolerances in shaft straightness also include the positioning of the elevator shaft door openings, which must be all in line with each other.

Second, cross-sections of the elevator shaft must be made over its entire length to the admissible tolerances in order to assure the elevator fits. This is especially crucial, as today’s elevator systems maximize space utilization in elevator shafts, leaving only a small amount of room for adaptation to geometric irregularities.

Detecting tolerance issues in the elevator shaft during elevator installation leads to corrective actions on the construction site, namely the ordering of new shaft material or partial removal of concrete (see Figure 1). Advance knowledge of whether and where corrective actions must be scheduled is essential, in order to prevent potentially costly delays and disturbances on construction sites.

Special attention has to be paid at handover of the elevator shaft from the builder to the elevator company. Common practice today entails elevator companies making a rough manual measurement with plumb lines in the shaft and measuring the wall and door distances on each floor with respect to the plumb lines. This is an error-prone and time-consuming task that only allows spot checks in the shaft, and not a comprehensive measurement. This paper presents the latest research on how to obtain accurate 3-D models of the entire built elevator shaft, and how to digitally install the elevator model prior to physical installation, in order to detect any geometric tolerance issues.

Abstract

Laser and camera scanning, as well as mapping solutions, are increasingly used to create accurate 3-D models of the built environment. This paper presents a prototype of an intelligent camera system for automated elevator shaft scanning and mapping. It aims at assessing whether elevator shafts are built within admissible tolerances. The system works in four steps. First, time-synchronized cameras with a 360-degree view are lifted within the shaft by a small rope winch or a drone. In the second step, a precise digital 3-D model of the built elevator shaft is derived from the camera images. In the third step, the positions of the shaft door openings are identified in the 3-D model, by using computer analysis. In the fourth step, the digital elevator CAD model is placed into the real shaft 3-D model, based on the positions of the door openings. Using this system the elevator can be digitally installed, prior to the start of physical installation.

Keywords: Construction, Digital Twin, Imaging
Value Engineering of Barrette Foundations For Tall Buildings in the Middle East

Abstract

Large-diameter piles and barrettes are the two most common foundation types for tall buildings in the Middle East region, where ground conditions are challenging due to the presence of weak carbonate rocks. Barrettes are a better alternative when heavy foundation loads need to be transferred through limited base areas, as they offer greater contact area, generating increased friction for the same volume of concrete thus, giving significant savings. The advent of Osterberg Cell (O-Cell) testing made it possible to fully test high-capacity barrettes. In this paper, the design of barrette foundations are compared to piles, with settlement predictions using geophysics data compared to O-Cell observations. Based on foundation design and value engineering using O-Cell test results of a tall building project in Business Bay where a saving of 11 percent barrette length resulted in reducing carbon emissions by about 4770 MT, foundation designs of several tall buildings in Dubai are reviewed, and recommendations are provided for optimized design and realistic settlement predictions for future tall buildings, which will help save construction-related resources and reduce carbon footprint.

Keywords: Barrettes, Geotechnical Engineering, O-Cell Tests, Piles

Introduction

Rapid urbanization in recent decades resulted in a tremendous increase in the rate at which supertall towers (with a height of 300 meters or greater) are being constructed around the world (CTBUH 2020). Globally, the embodied carbon of a building accounts for about 11 percent of emissions. There is also an ever-increasing need for resource optimization, ensuring minimum carbon footprint with environmentally friendly and sustainable design and construction methods, which challenges civil engineers to go beyond the traditional and typical conservative design and testing methods, pushing them to evolve and adopt more innovative and optimized design solutions.

Value engineering and design optimization of tall and supertall tower foundations in weak rock formations and recommendations for future designs are discussed in this paper. Dubai ranks number 4 in the world as of 2020 in terms of the number of buildings of more than 150 meters’ height (CTBUH 2020); therefore, a discussion focusing on the United Arab Emirates’ (UAE’s) geology is considered relevant. Figure 1 presents La Maison, a 320-meter residential building under construction in Dubai, the subject property in this research.

The supertall towers constructed in the Middle East region are typically supported by deep piles or barrettes, socketed in to weak and weathered carbonate rocks, whose strength and stiffness do not necessarily improve with depth (Poulos 2009, 2010, 2017; Poulos and Badelow 2015; Katzenbach, Leppla & Choudhury 2016). In this paper, foundation design for a tower using barrette foundations is compared with equivalent-diameter piles, to demonstrate that barrettes are an efficient alternative to bored cast-in-situ deep foundations, which efficiently transfer the heavy foundation loads of supertall towers to the ground. Value engineering using Osterberg cell (O-Cell) test results on barrettes and settlement prediction derived from cross-hole seismic tests are discussed.
Tall Buildings in 2020: COVID-19 Contributes To Dip in Year-On-Year Completions

Abstract
In 2020, the tall building industry constructed 106 buildings of 200 meters’ height or greater, a 20 percent decline from 2019, when 133 such buildings were completed.* The decline can be partly attributed to work stoppages and other impacts of the COVID-19 pandemic. This report provides analysis and commentary on global and regional trends underway during an eventful year.

Note: Please refer to Tall Buildings in Numbers—The Global Tall Building Picture: Impact of 2020 in conjunction with this paper, pages 48–49.

*The study sets a minimum threshold of 200 meters’ height because of the completeness of data available on buildings of that height.

Keywords: Construction, COVID-19, Development, Height, Hotel, Megatall, Mixed-Use, Office, Residential, Supertall

Introduction
For many people, 2020 will be remembered as the year that nothing went to plan. The same can be said for the tall building industry. As a global pandemic took hold in the first quarter, numerous projects around the world, at various stages, ground to a halt as restrictions on assembly came into force. It is therefore not surprising that 2020 yielded 106 completions of buildings 200 meters and taller, a 20 percent decline from 133 in 2019, when 105 such buildings were constructed (see Figure 1).

This is the second year in a row in which the completion figure declined. In 2019, the reasons for this were varied, though the change in the tall building climate in China, with public policy statements against needless production of exceedingly tall buildings, constituted a strong factor that has persisted into 2020.

The tallest building to complete in 2020 was Central Park Tower in New York City, at 472 meters. This is the first time in five years in which the tallest completed building was not in China, and the first time since 2014, when One World Trade Center (New York City) completed, that the tallest building of the year was in the United States.

This is also the first year since 2014 in which there has not been at least one building taller than 500 meters completed.

Effects of COVID-19
As with most other enterprises, the degree to which the COVID-19 pandemic directly affected the construction schedule of a tall building in 2020 was highly variable in relation to local regulations and the ability of the contractor to keep a sufficient number of workers on-site. CTBUH is anecdotally aware of nine projects across Malaysia, India and Brazil whose completion schedules were pushed into 2021 as a direct consequence of COVID-19. There were mandated work stoppages in cities such as New York and San Francisco, though these could not be traced to any specific delays. As tall buildings are often lagging economic indicators, any chilling effect that economic conditions or work interruptions may have had on new project starts, or projects that were under construction in 2020 and were scheduled to be completed in 2021 or later, remains to be seen. It must be remembered, the economic crisis of 2008 was not reflected...
About the Council

The Council on Tall Buildings and Urban Habitat (CTBUH) is the world’s leading non-profit organization for all those interested in the future of cities. It explores how increased urban density and vertical growth can support more sustainable and healthy cities, especially in the face of mass urbanization and the increasing effects of climate change worldwide.

Founded in the USA in 1969, the CTBUH member network embraces more than a million professionals working in all building industry sectors in almost all countries of the world. With offices in Chicago, Shanghai, and Venice, the Council runs hundreds of multidisciplinary programs across the world each year, through its regional chapters and expert committees; its annual conferences and global awards program; through funded research projects and academic collaborations; and via its extensive online resources and physical outputs. The Council is perhaps best-known to the public as the arbiter of tall building height and the global authority that bestows titles such as “The World’s Tallest Building”.

Operating on a global scale, the CTBUH serves as a platform for both cutting-edge information-share and business networking for all companies and professionals focused on the inception, design, construction, and operation of cities, and the buildings they comprise.

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