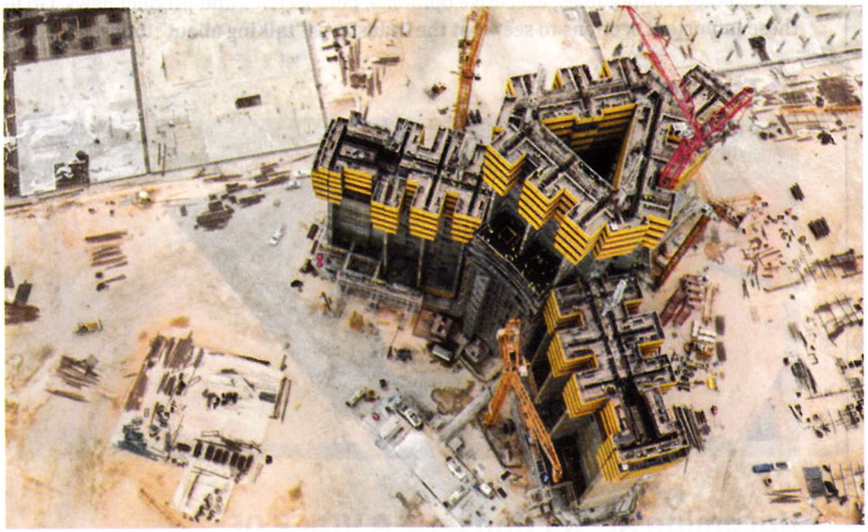
TALL BUILDINGS

Jeddah Tower's 'Climb' to One Kilometer Picks Up Speed



THREE WINGS The concrete superstructure consists of a shear-wall core and walls, connected by link beams, within the three wings of the Y-in-plan building. There are no columns in the megatower.

Having recently reached a height of 113 meters, the contender for the title of the world's tallest building is slowly growing up in Jeddah, Saudi Arabia. Only time will tell whether the Jeddah Tower, formerly known as the Kingdom Tower, will reach its design height of more than 1 kilometer. If it does, it will be at least 172 m taller than the current record-holder, the 828-m Burj Khalifa in Dubai.

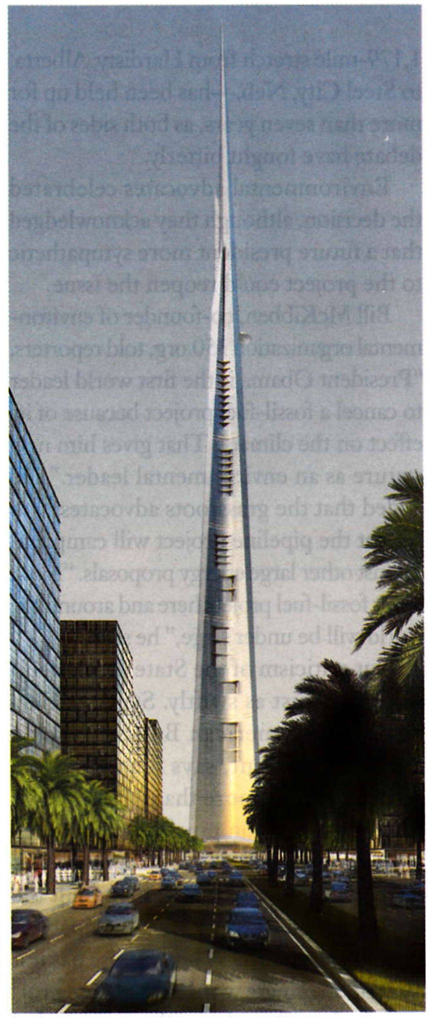
Completion is expected in 2019. "Nothing is in the way of reaching our goal," said Mounib Hammoud, CEO of the developer, the Jeddah Economic Co. (JEC), at the Council on Tall Buildings and Urban Habitat 2015 international conference, held on Oct. 26-28 in New York City. "We are overcoming all the challenges and difficulties," he added at the CTBUH event, which drew 1,200 attendees from 45 nations.

The first 26 stories contain more than 25% of the megatower's 500,000 cu m of concrete. From below grade up, everything about the project is either unprecedented, problematic, unexpected or all of the above, said team members.

"It's never easy," added Hisham A. Jomah, JEC's chief development officer. "Every day is a challenge," said Hammoud, "but we have an organized army to address" the problems.

Adrian Smith + Gordon Gill Architecture designed the 465,000-sq-m, tapered megatower with three wings that slope in at slightly different angles, forming a taper. The building, with a shear-wall concrete core, has no columns. Instead, throughout each floor plate, there is a series of 85-MPa reinforced-concrete walls, interconnected by link beams, according to the structure's designer, Thornton Tomasetti.

The taper minimizes vortex shedding, said Jon Galsworthy, a principal of wind engineer Rowan Williams Davies & Irwin Inc. For RWDI, the challenge was the downwash conditions created by the concave surfaces of the wings, which gather air and push it down. This configuration creates local pressures on the cladding and affected mullion design. "The pressures are highest at the bottom of the building," said Galsworthy. Canopies will deflect wind away from pedestrians, he adds.



TAPER The tower's form minimizes vortex shedding, but concave surfaces create downwash.

A damper, which is in final design, will minimize sway of the steel spire and improve occupancy comfort at the upper levels. The highest residential floor will be 496 m above grade.

Plans call for the world's highest observation deck—a 500-sq-m outdoor terrace, 638 m above grade. The terrace will cantilever 30 m from the tower.

Visitors will access the terrace by an express elevator, located in the middle of the core, which is the only place for a continuous run, said Jeff Montgomery, head of major projects for Kone Areeco Ltd. Kone is supplying the lift, called UltraRope, which is light enough for the 638-m single run, thanks to carbon-fiber-based belts instead of steel ropes.

By far the most challenging aspect of the job—working at extreme and potentially dangerous heights—is yet to come, said Peter Savoy, construction director for the project manager, Mace International Ltd.

Logistics of circulating some 9,000 workers and associated materials through such a tall tower have never before been worked out. Tower cranes will reach 618 m, for example. "There is a lot of work to do to come up with alternative solutions to the norm," said Mace.

The terrace is a case in point. The intention is to prefabricate the 25-m-dia, dish-shaped steel structure—with its cladding—on the ground and lift large sections using strand jacks. The goal is to reduce lifting by some 90%, minimize work at heights and enhance the schedule.

Mace currently is forecasting 20% to 35% weather-related downtime for special lifts and for "climbing" the crane—eventually to a record height of 618 m. "We will have to be lifting through light winds," said Savoy. "We are currently forecasting wind at 100-meter intervals up the height of the tower, which allows us to predict future weather conditions as near as is practical."

The foundation consists of 270 reinforced-concrete friction piles, ranging in diameter from 1.5 m to 1.8 m, to accommodate a gravity load of 860,000 tonnes. The piles range in length from 45 m at the wing tips to 105 m under the core, where the loads are the greatest.

However, the deepest piles are not because of capacity; they are there to reduce settlement by about 75 millimeters, said Alan Poeppel, senior principal for the tower's geotechnical engineer, Langan International.

The waterfront site consists of silty sand at grade, up to 2 m thick. Beneath that is a 45-m- to 50-m-thick layer of porous limestone, full of imprints of shells. Underlying that is a 2-m- to 10-m-thick layer of mudstone and gravel.

The rock is at least an order of magnitude softer than Manhattan bedrock, said Poeppel. "The foundation design was challenging because of the size and weight of the tower and the rock, which is weak to very weak compared to other types of rock," he added.

For the piles, the first big hiccup came during test borings. "As soon as we broke ground, all hell broke loose," said Jomah.

During one test pile operation, "10 cubic yards of concrete leaked into the gravel zone," explained Poeppel. "We weren't expecting that, but, at the end of the day, it was good because we were filling voids with concrete."

The general contractor, Saudi Binladin Group (SBG), began pile work in November 2012. It took one year. "We had no real surprises," said Savoy.

But construction of the 4.5-m- to 5-m-thick reinforced-concrete mat, a Y in plan, required overcoming extreme hurdles, added Savoy. For starters, rebar could not be prefabricated into cages because of the undulating shape of the mat. Crews installed the 18 tons of rebar by hand, which was time-consuming.

Savoy calls the installation of the mat's shear studs "perhaps" the most difficult part of the mat. The studs, as originally designed, would have been tough to install due to some 36 layers of rebar.

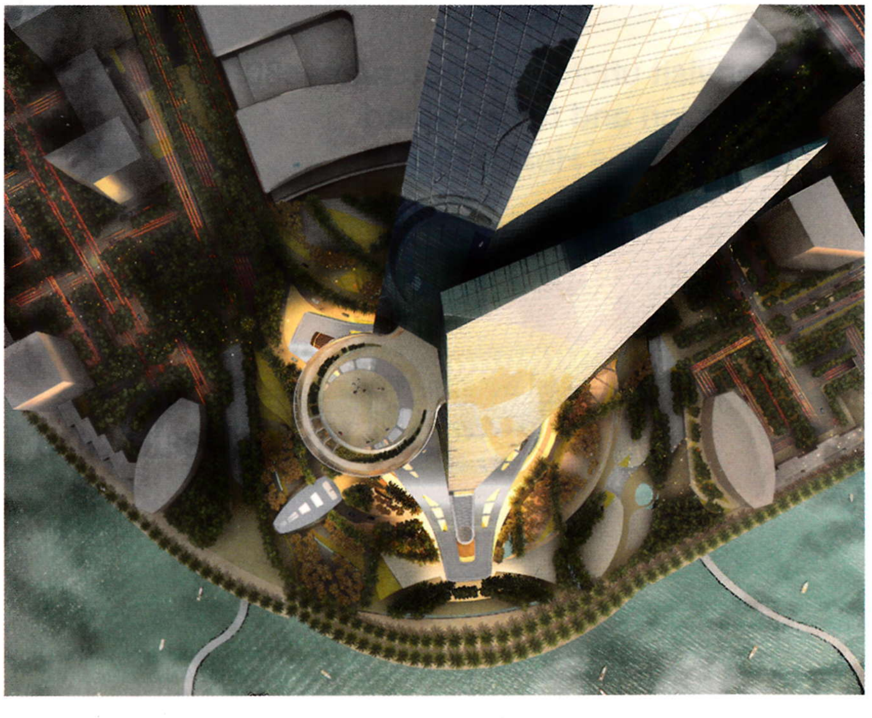
SBG redesigned the shear studs so that the crank at the upper end of each stud was omitted and a foot plate was installed in its place. "We believe this solution saved up to six weeks" on the overall mat schedule, said Savoy.

The next mat challenge was concrete quality control. To get a handle on it, crews cast a 15-m-sq test block of 85 MPa concrete. It was monitored for performance and thermal gain during placement and for 56 days afterward.

The superstructure's first floor was, as predicted, complex because it included setting the jump form, said Savoy. The first floor took about 35 days, as expected. Since then, workers have averaged a 14-day floor cycle. The slow start is primarily due to the technical challenges within the first 25 floors of the building, said Savoy. For example, crews had to place steel link beams ranging from 12 to 32 tonnes.

To improve the cycle, "watchers" recorded every element of the work over a three-floor zone. Then, changes were made. The efficiency gain was between 15% and 30%. The target for the simpler upper floors is a four- or five-day cycle. ■

By Nadine M. Post



CIRCULAR TERRACE Plans call for the world's highest observation deck, a dish-shaped terrace with an area of 500 sq meters designed to cantilever 30 m from the megatower at an elevation of 638 m.

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TALL BUILDINGS

Ropeless Elevators On the Horizon

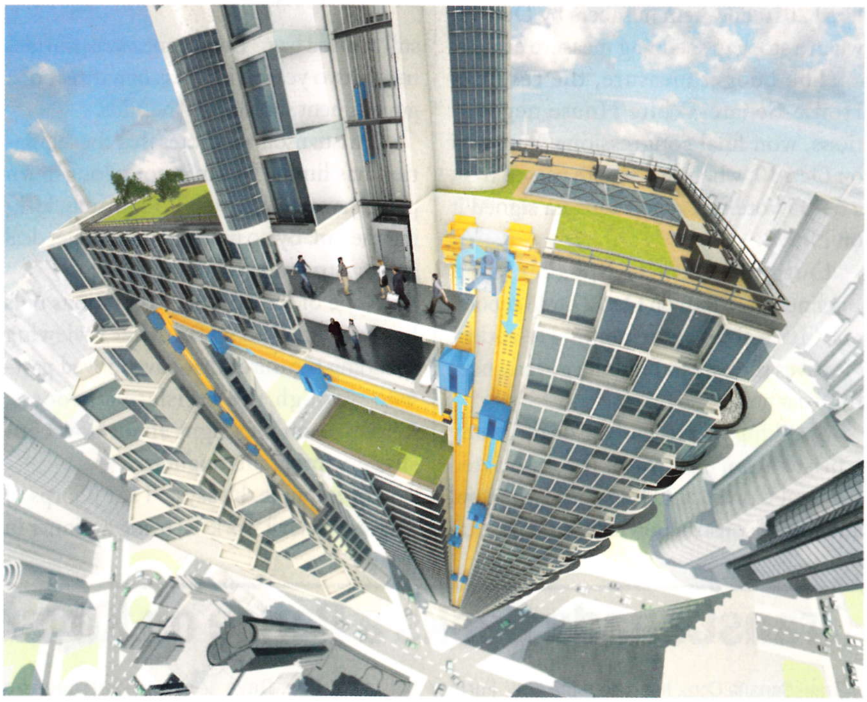
High-rise system, designed to allow vertical, horizontal and inclined travel, likely in four years

The first ropeless, tall-building elevator—a compact, lightweight system that mimics a subway line on end—is set to enter the testing and certification stage in early 2017. If all goes as planned, ThyssenKrupp Elevator AG expects to have its linear-drive system, designed to travel vertically, horizontally or on an incline, ready for the market in four years.

"Elevators have been a limiting factor in the past" in the development and design of tall buildings, said Markus Jetter, head of development for ThyssenKrupp (TK), at the Council on Tall Buildings and Urban Habitat's 2015 conference, held from Oct. 26-28 in New York City. "This opens a completely new dimension for buildings in height and shape," added Jetter at the CTBUH event, which drew 1,200 registrants from 45 nations.

Critical to the schedule is completion—expected at the end of next year—of what will become, for a time, the world's tallest elevator test tower and the first to double as an observation tower. In 2017, the 246-meter tower in Rottweil, Germany, equipped with 12 elevator shafts in its 21-m-dia reinforced-concrete core, will begin testing TK's ropeless high-rise transportation system, called Multi.

"Multi generates more handling capacity and shorter waiting times independent of travel height," said Jetter. TK, among the world's four biggest elevator companies, will not reveal its three-year research-and-development investment in Multi, other than to say the company spent a total of $771.4 million on R&D in the September 2013-14 fiscal year, the last year for which figures are available.



SUBWAY ON END The system under development uses magnetic levitation, rather than ropes; allows more than one cab per shaft, much like a subway line; and reduces the footprint of the shaft.

IMAGES COURTESY OF THYSSENKRUPP

Test Towers Grow Up

The race among elevator makers for the world's tallest test tower is heating up. The Rottweil tower may lose its title as the tallest test tower to Canny Elevator Co. Ltd., which is building a 288-m-long test facility with a 268-m tower, in Wujiang China. KONE Inc. expects to complete a test tower approximately 226 m tall in Kunshan, China, this year; it will then hold the height record until the TK or the Canny project is done. There may be taller test towers rising, but only the $44-million Rottweil tower will have an observation deck open to the public.

Multi, already prototyped, operates on the basic premise of a circular system. A single loop—or guideway—can contain several cabs.

"It's similar to a subway, with multiple trains using the same rail and riding in the same direction on one track," said Jetter.

TEST TOWER Rottweil tower, at 246 meters in height, will test and certify the ropeless elevator system starting in 2017, after completion of tower constuction next year. Rope lifts also will be tested.

In the vertical mode, each cab will cantilever from its side rail and be equipped with a linear motor drive, adapted from TK's Transrapid magnetic-levitation train. Applied to vertical transportation, this technology maximizes shaft efficiency in mid- to high-rise buildings because each shaft accommodates more than one cab, says TK. Shaft transport capacities will increase by 50%, and elevator footprints will be reduced by up to 50%, according to TK.

DUAL PURPOSE Tower will be the only elevator test tower to double as an observation tower.

The system will be best suited for buildings taller than 300 m. TK is aiming for a cab speed of 5 m per second, which will enable access to an elevator cab every 15 to 30 seconds, with a transfer stop every 50 m. Though there are faster elevators, the total time to destination is shorter because of shorter waiting and loading times, said Jetter.

"There will still be sky lobbies for supertall buildings, and one Multi can serve several sky lobbies," he added. Multi also can be used with conventional elevators.

The system allows for 6-sq-m shafts—about a third smaller than others—because there are no ropes, there is a multilevel brake system, and there are inductive power transfers from the shaft to the cab. Cabs will weigh 50% less than traditional cabs, thanks to lightweight composite construction.

Multi will have a higher first cost than rope systems but will free up floor space. The smaller shaft space also would give the developer the option to reduce the overall footprint of the building, which would mean lower first costs of other systems, said Jetter.

Safety

Propulsion and braking systems in the cabs, combined with a control system that prevents cabs from getting too close to each other, ensure safety, says TK.

A newly developed linear drive—a magnet—enables a single motor to perform horizontal and vertical movements. An exchanger turns the cab's drive to move the cab horizontally—on a turned guiding system, from one vertical shaft to another—keeping the cab itself vertical at all times, said Jetter.

Three of the shafts in the Rottweil tower are reserved for Multi testing and certification. In the other shafts, TK will test systems with travel speeds of up to 64.8 kilometer per hour.

Ed. Züblin AG began work on the 10,000-sq-m tower, which includes a slipformed core, last March. Designed by architect Helmut Jahn and architect-structural engineer Werner Sobek, the tower will be wrapped in 17,000 sq m of a lightweight polytetrafluoroethylene-coated fiberglass fabric.

The observation level is 232 m above grade. Access will be up a dedicated glass-enclosed elevator on the outside surface.

All heat generated by devices such as motors and computers is stored in an air cell above a half-height shaft. Heat exchangers will transmit heat to the tower's rooms, including a conference center. Traction elevators will generate electricity when in use.

A tuned mass damper, meant to reduce cross-wind-induced vibrations from a sway of +/- 800 millimeters to +/- 150 mm, will have an effective mass of 240 tonnes and is adjustable for a range of 0.165 to 0.21 Hz, said Christian Meinhardt, a director with GERB Schwingungsisolierrungen GmbH & Co. GERB designed the single pendulum, steel-framed TMD, with prefabricated concrete slabs for the counteracting mass. Installation is set for next month.

The TMD's mass is attached to linear drives, similar to those of Multi, said Meinhardt. The drives will excite artificial vibrations in the tower to test the lifts under sway conditions, he added.

The tower will rank as Germany's second tallest, after the 368-m Berlin TV Tower. But the Rottweil tower's observation deck, at 232 m, will allow the public to rise 29 m higher than the Berlin tower's 203-m-high deck. ■

By Nadine M. Post