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I. Sprynchak
O. Stoliarenko

Revolution in construction. Skyscrapers. Burj Dubai.

Vinnytsia National Technical University

Анотація
Ця стаття розповідає про досягнення інженерів в технологіях будівництва. Оповідається історія проривів у створенні хмарочосів, які дозволили інженерам побудувати 828-метровий хмарочос "Бурдж-Халіфа» в Дубаї. Обговорюються також наступні будівлі: Equitable Life Building, Флетайрон-білдінг, Штаб-квартира Організації Об'єднаних Націй, оригінальні башти Всесвітнього торгового центру, Ві́лліс Та́уер та Тайбей 101.
Ключові слова: *хмарочос, будівля, винахід, технологічні інновації.*

Abstract
This article tells about the achievements of engineers in construction technologies. Tells at the history of skyscraper breakthroughs, culminating in the construction of the 828-metre tall Burj Dubai. The following buildings are also discussed are the Equitable Life Building, the Flatiron Building, the United Nations Headquarters, the original World Trade Center towers, the Sears Tower and Taipei 101.
Keywords: *a skyscraper, a building, an invention, technological innovations.*

This is the tallest man-made structure on earth. A city in the sky nearly half a kilometer tall the Burj Dubai is the pinnacle of skyscraper engineering. It owes its success to seven key inventions. We have lined up seven landmark buildings historic Giants of the skyscraper world. At the heart of each one lies a major technological innovation that allowed engineers to reach ever taller into the sky. One by one traveling up the scale will reveal the incredible stories behind these structures and the inventions that have driven them higher. Seven ingenious leaps forward that have enabled skyscrapers to evolve from big to bigger into the world's biggest.

Dubai is the fastest-growing city in the world. An army of cranes and labourers work around the clock to turn the city into a place that the whole world will look up to. The centerpiece in the grand plan is the Burj Dubai the tallest skyscraper in the world. It is the ultimate lead in a series of historic engineering breakthroughs. To understand how the Burj Dubai can be this tool we need to go back in time and look at how skyscrapers begin the first breakthrough happens in the 19th century with a building that's only 43 meters tall. The builders of the equitable Life Building in New York realize that before buildings can reach taller. They must find a way to make people climb higher [1, 2].

The first big obstacle to skyscrapers is the stair. People weren't willing to walk lots of flights of stairs. Stairs and old office buildings for long they were very dark and people weren't ready to climb stairs more than to the second floor the third floor and if you were a lawyer and you were looking for clients and you were on the fifth floor you're undoubtedly going to lose clients because they didn't want to come up to your office. By the time you reach to the sixth floor seventh floor you're incredibly windy. There's an obvious solution to the problem the elevator. But early elevators have one deadly fault nothing stops them from falling if the Rope breaks. But then a mechanic from Vermont invents a device that can stop a falling elevator almost instantly in 1854 Elijah graves otis demonstrates his invention at the World's Fair in New York. He stands on a platform high up in the air apparently held only by a rope. Then otis tells his gasping audience that the rope is about to be cut.

Is the world's first fully automated safety elevator. It's a simple yet very clever invention. The critical element the elevator rope is secured with a powerful wagon spring mounted on top of the cab. This spring connects to a set of metal prongs on each side of the elevator. The prongs run along guide rails fitted with a row of teeth.

When the Rope breaks it triggers a chain of events. The spring relaxes and forces the metal prongs into the teeth locking the cab in place. This is a true engineering breakthrough a fact lost on Elisha Otis. The elevator completely transforms the urban landscape. And it all starts on a busy street corner in downtown New York. The building standing here today is the new equitable life headquarters. It has replaced the old equitable life building which is not a skyscraper as we note. Until the equitable life the lower floors for building are the most desirable but the elevator completely reverses the economics of real estate. The Burj

Dubai takes the idea of the elevator to the extreme. Equitable life had seven and a half stories the Burj Dubai has over 160 a height that stretches elevated technology to its absolute limit.

The Burj Dubai will be able to accommodate 35,000 people. Getting a population the size of a small town in and out of the building is the ultimate challenge for the elevators. To cope with the numbers the Burj Dubai has 53 different elevators. Some reach over 35 kilometres an hour and climb a hundred and 20 floors in under 50 seconds. The biggest lifts carry up to 46 passengers. Stopping such a speeding juggernaut in an emergency is a Titanic challenge. As soon as an elevator on the Burj Dubai exceeds its speed limit emergency brakes spring into action. Metal brake shoes bite down on the guide rails and generate enough braking power to stop the elevator within a few meters [8].

The safety elevator allows the skyscraper to break through the five-story barrier. Suddenly tall buildings a big business. But as they approach 80 meters traditional building materials are no longer strong enough. To make the leap to the 87 meter fuller Flatiron Building in New York. The skyscraper must be reinvented. This is the Monadnock building in Chicago a living fossil in the skyscraper world. When it opens in 1893 it's the world's largest office block. But it's 16 stories stretch stone to the limit. The walls at the bottom must be a whopping 2 meters thick to bear the weight of the Monadnock. The structure is so extremely heavy that it begins to sink into the soft Chicago soil. Eventually half a meter of bricks and mortar disappear underground. Obviously stone is not skyscraper material. So when the architect of the Monadnock Daniel Burnham plans the fuller building in New York he's in a bit of a pickle. The extremely narrow plot dictates that his 22 story skyscraper has to be triangular. Birnam knows that there is no room for stone walls. They would have to be so thick that they would be hardly any space left on the ground floor and wasting valuable space is a cardinal sin for a skyscraper architect. Stone is out of the question. But if you look at the fuller flatiron today. It looks like it's built from stone so how did Burnham do it. It's all just a facade.

Under the skin of the full lies one of the most important building technologies ever invented. Burnham makes the building out of steel columns and steel beams locks together into a steel skeleton. Steel is much stronger than stone so this skeleton can be thin and light yet. It can support the weight of the whole structure to keep the weather out Burnham can simply hang thin masonry walls of the steel frame like curtains. The building is an immediate success. The Flatiron even affects the weather. Steel construction truly moves the skyscraper on. This is a new breed of building. The skeleton of the Burj Dubai by combines the best of steel and stone. It uses over 30,000 tonnes of steel but in a very clever way the steel is embedded in artificial stone concrete. This reinforced concrete backbone will be clad in a high-tech curtain wall of glass and steel. The wall latches onto the Burj Dubai in units of up to two stories tall. The panels themselves are rigid but the joints between them are flexible. If an occupant moves a heavy piece of furniture towards the edge of the skyscraper. The floor will Bend and force down the exterior wall. But the flexible joint in between the wall panels absorbs the movement so the wall as a whole is not damaged. The joints also allow each wall section to expand and contract as the Desert Sun passes around the skyscraper heating it up. But the most potent force it must withstand is the desert wind. The curtain wall of the borscht buy will cost a hundred million dollars so before it's bolted on the engineers take prototype sections for a test drive [3].

Today the engineers apply the ultimate test an aircraft engine simulates a Desert Storm. The propeller spits wind and rain backwards at the curtainwall section mounted behind it. It reaches speeds of 75 kilometers an hour a real challenge for the curtain wall will the prototype withstand pressures. But today the prototype passes the test with flying colors. The Burj Dubai takes one step further to completion. Now the challenge for the engineers is to stop the baking Desert Sun from turning their beautiful glass tower into a giant oven. Steel catapults skyscrapers to unseen heights as walls now no longer have to bear all the weight architects can make them out of completely new materials. Glass promises to flood buildings with light. But also with heat to beat this new enemy skyscrapers would need to get cooler.

When the United Nations designed their new headquarters in New York they face a dilemma. They want to cover the building with glass to make the interior as bright as possible. What they don't want is a 39 storey greenhouse. A glass wall would allow a lot of light into the building but also solar radiation. This would be absorbed by the objects inside. These in turn would radiate heat into the surrounding air and warm it up. As the sealed glass windows can't let the hot air escape things would get uncomfortable very quickly. An American engineer called Willis carrier cracks the cooling problem. He invents a machine that can cool and dry hot moist air by making it wet. First it injects a fine mist of cold water into a chamber. Next it sucks hot soggy air into this cold mist seen up close something remarkable happens. As the hot air hits the surface of the cold water the air cools down releases its moisture onto the droplets. So the air is cooled and dried in a single step [4].

Air conditioning allows skyscrapers like the Burj Dubai to rise up in even the hottest climates and there is hardly a place on earth where air conditioning matters more than Dubai. Temperatures easily reach 40 degrees Celsius in the shade the average humidity is 90% a truly extreme environment for a skyscraper. The key to shielding the Burj Dubai from the rutile Desert Sun is built into its glass skin. The outside pain is coated with a thin layer of metal like sunscreen the metal coating deflects ultraviolet radiation that would otherwise heat up the building. But the sunscreen is useless against the infrared that radiates from the hot desert sand. So the inner pane is coated with a thin layer of silver that keeps the heat rays out over 30,000 glass panels enough to cover 17 football fields will protect the Burj Dubai from the scorching heat [8].

To work more comfortably inside skyscrapers and taller skyscrapers housing more workers often greater profits. The only problem is that bigger skyscrapers take much longer to built. To reach the dizzying 417 meters of the World Trade Center engineers have to invent a new much faster way of building skyscrapers.

Long before the twin towers in New York become the tallest buildings in the world. Their developers face a mammoth problem. The minute they start construction the clock starts ticking. Every day their building is unfinished costs them deal. So they have to work out how to reduce the construction time to the absolute minimum. The solution they come up with is to prefabricate sections of the towers and assemble them like a giant jigsaw puzzle. They build the sections off sites and ship them to the towers construction site precisely when they're needed. The only problem is how to lift the super-heavy 50 tons sections into place quickly enough. The traditional tool to build skyscrapers like the Empire State Building is the derrick crane. But to get Derrick's from one floor to the next they have to be disassembled carried up and reassembled a process that can take two days.

Such a crane is not going to be fast enough for the World Trade Center. The team find a revolutionary crane in Australia. It can lift 50 tons and four of them can reach into every corner of a Twin Towers. And once they have assembled three floors an amazing thing happens. The bottom of the crane releases collides up three storeys and locks back into place. And then the whole crane jumps itself up to the next level. That's why it's called the kangaroo crane. With the help of the prefabricated sections and the jumping kangaroo cranes the Twin Towers take shape rapidly. The builders managed to finish up to two floors every week. In 1970 world trade tower one becomes the tallest building in the world and while even more floors appear at the top tenants move in at the bottom. Time is money [5].

On the Burj Dubai the kangaroo crane is still the crane of choice. Here the builders have taken prefabrication to a new level. The key to speed is a new technology called jump forming the process starts the bottom of the building. Steel workers assembled steel cages that will become the backbone for the floors and wall to the Burj Dubai. The kangaroo cranes hoist the steel cages up and slop them into specialmolds called jump forms in goes the concrete and 12 hours later when the concrete hardens the form gets ready for the jump. Hydraulic Pistons push the form up leaving the concrete block behind. It takes only two hours for the form to move up to the next level where the process starts all over again. This way the Burj Dubai is cast in place layer by layer like a giant wedding cake. But delivering concrete to the top of the tower gets more difficult with every floor. It's five o'clock and the man on the day-shift go home. But on the top of the Burj Dubai the casting crew are waiting for the concrete to arrive. Below workers prepare the pumps. They can really only pour concrete at night because in the searing daytime temperatures that concrete would overheat. They need 630 horsepower pumps to cope with the 25 tons of concrete contained in each pipe. And they're about to pump this concrete higher than anyone has ever done before. An amazing challenge for the pumping system. It takes 40 minutes for the concrete to travel up the pipes from the bottom to the hundred and 55th floor. It's a combined effort of raw machine power and subtle chemistry. If the concrete is too thin and set slowly it causes delays. If it's too thick it may set too soon and block the pipes. That night it takes until 4:00 a.m. before the job is finished. Now the concrete and steel skeleton of the Burj Dubai is nearly complete on a mammoth project that will cost about 1 billion dollars to build every day is precious.

But the system has worked to perfection. The tower is nearly 600 metres tall and a new floor goes on every three days. Prefabrication technology allows giant skyscrapers to grow even faster which makes them even more profitable and desirable. But as skyscrapers soar even higher into the clouds they become exposed to a new enemy. One that exploits every weakness [8].

The wind to build the 440 2 meter Sears Tower in Chicago the proverbial Windy City engineers must turn the skyscraper inside out. In 1970 the architects building the new headquarters for Sears & Roebuck in Chicago faced a problem. Their skyscraper the Sears Tower will be over a hundred floors tall a height that exposes it to huge wind forces. Building this skyscraper using a traditional steel skeleton would cause massive problems. The torah' steel skeleton gets the more susceptible it is to bending in high winds. Gusts off Lake Michigan can buffered a skyscraper add up to 80 kilometers an hour. This causes the upper floors to sway affecting the workers inside. The architects of the Sears Tower invent a technology that can beat the wind. They shift the steel framework from the inside of a building to the outside. This so-called exoskeleton makes it very hard for wind to bend the building. In the Sears Tower nine such Jews locked together to make the building rock salt. The exoskeleton is the best way of resisting wind ever invented to prefer. Even at wind speeds of over 90 km/h the top floor of the Sears Tower only moves 15 centimeters. The Burj Dubai is expected to be nearly twice as tall as the Sears Tower. At this extreme height fighting the wind with a rigid exoskeleton is not good enough. To stop the high-caliber residents from getting seasick. The architects turned to highly advanced aerodynamics. At high speeds wind can be extremely dangerous for a skyscraper. Air rushes around the building performs mini tornadoes called vortices. These areas of low pressure suck the building sideways and the toll of the building the more dangerous the vortices become. So on the Burj Dubai rather than fight the wind bill and the design team decide to deceive. It they don't like the tower flat and rectangular but give the Burj Dubai a more unpredictable shape. Each section of the tower is designed to deflect the wind in a different way. This disrupts the power of the vortices and breaks the hold of the wind and the building. With mobility gravity heat and wind conquered the skyscraper faces its next big challenge. In Asia where booming economies want to show off their wealth super tall skyscrapers become the objects of desire [6, 8].

Binet Jie is rife with the Nemesis of tall buildings earthquakes. To build the 509 meter Taipei 101 skyscrapers take another leap forwards. In 1999 the architects of the world's tallest skyscraper the Taipei 101 in Taiwan faced a problem. Taipei sits near the Pacific Ring of Fire the most seismically active area on earth. An earthquake hits the city roughly twice a year. It's not a question of if but when the earth will shake the Taipei 101. Adam Crew will test a model building on an earthquake simulator to make it realistic this model is built with spaghetti. With the top floor glued in place the model is ready to face the tremors. Adam crude tests a second model that has elastic bands added to the spaghetti. To survive in fast and violent quakes the Taipei 101 needs a dash of elasticity. So the designers make their building rigid where it has to be but flexible where it can afford to be. At the heart of the Taipei 101 they put 36 rigid steel tubes filled with concrete and give the building strength. While the columns stand firm during a quake the rest of the structure is elastic it can flex and roll the punches. Halfway during the construction mother nature tests this design to the limit. On the 31st of March 2002 an earthquake hits the taipei 101 the quake has shattered smaller buildings but the Taipei 101 is still standing. The engineers of the Taipei 101 claim that during the quake their building is the safest place in town. The Burj Dubai can withstand earthquakes of up to 6 on the Richter scale because it has a massive reinforced concrete skeleton. But here the engineers face a different problem. Making a super tall building stand up in the desert sand requires special measures. Drilling into the rock in Dubai may be hard but it's when you pull your drill out that the real trouble starts. The rock under the Burj Dubai is fragile and saturated with groundwater any big hole will cave in immediately. To stop this from happening the engineers fill the bore holes with a viscous polymer slurry. Which pushes the groundwater and rock fragments to the edge of the ball and keeps it open. The syrupy polymer is denser than water but lighter than concrete. The concrete displaces the slurry and eventually hardens to form a foundation pile. 200 of these piles work together to stop half a million tons of real estate from sinking into the ground. In just over a hundred and thirty years the skyscraper conquers all the forces of nature using the power of human ingenuity. But as buildings saw higher and higher into the sky. They become more vulnerable. Now the fear of terrorism threatens their existence. Today a final technological leap forward keeps the occupants of the world's biggest skyscraper safe.

A chilling day in September 2001 seems to spell the end of the skyscraper. After the attacks of 9/11 many believe that no super tall building will ever be built again. Evacuating a skyscraper is a phenomenal challenge the taller you build the more people have to walk ever further to get to safety on 9/11 the difficulties become tangible. The bulged by has built-in fire protection as its concrete backbone is naturally fire resistant. But it's expected to be nearly twice as tall as the twin towns. So how did people get out in an emergency the answer is they don't.

The Burj Dubai contains 9 very special rooms refuge rooms built from layers of reinforced concrete and fireproof sheeting the walls of these rooms withstand the heat of a fire for two hours. Each room has a special supply of air pumped through fire resistant pipes. Sealed fireproof doors stop smoke from leaking in. In the refuge room residents can seek shelter from a fire until emergency services bring it under control. There is one of these rooms about every 30 floors which should allow residents to reach them without too much effort. Refuge rooms are a radical idea but even the safest place in the world is no good if the access route is blocked by smoke. But there is technology that takes smoke out of the equation. The Burj Dubai has an early warning system that guards it round the clock. If fire activates a smoke detector a heat sensor or water sprinkler a network of high-powered fans kick in. The fans force clean cool air through fire resistant ducts into the building. The fresh air pushes the smoke out of the stairwell and keeps the evacuation routes clear. it's fire safety fit for a 21st century skyscraper.

When the Burj Dubai is complete it will be the tallest structure that mankind has ever built on the face of the planet. Standing on the shoulders of historic engineering marvels the Burj Dubai really is the ultimate skyscraper. Until someone builds an even bigger one.

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Спринчак Ілона Ігорівна - студентка групи Б-16, факультет будівництва теплоенергетики та газопостачання, Вінницький національний технічний університет, Вінниця, e-mail: 1b16b.sprynchak@gmail.com

Столяренко Оксана Василівна - доцент кафедри іноземних мов, Вінницький національний технічний університет

Науковий керівник: ***Столяренко Оксана Василівна*** - доцент кафедри іноземних мов, Вінницький національний технічний університет, м. Вінниця

Sprynchak Ilona I. - Department of Civil and Industrial Construction, Vinnytsia National Technical University, Vinnytsia, email: 1b16b.sprynchak@gmail.com

Stoliarenko Oksana V. - associate professor at foreign languages department, Vinnytsia National Technical University, Vinnytsia

Supervisor: ***Stoliarenko Oksana V.*** - Associate Professor at Foreign Languages Department, Vinnytsia National Technical University, Vinnytsia