An Evaluation of the Fire and Wind Safety of the Burj Dubai

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Executive Summary

Dubai, UAE, is set to erect the most colossal structure the world has ever seen, the Burj Dubai. Upon its completion in September 2009, the skyscraper will stand over 800 m tall, comfortably winning distinction as the world's tallest, free-standing man-made structure. With unprecedented heights, the Burj Dubai is truly impressive; however the questions become: Can a building that tall actually stand? What are the most difficult logistical problems facing the tower? Can these problems be resolved? Exhaustive study into the fire and wind safety of the Burj Dubai needs to take place in order to confirm the safety of future occupants and tourists.

The Burj Dubai features some of the most creative and innovative architecture and accommodations ever seen. Some of these are designed to improve safety, particularly fire safety. With a building that tall, firehouses will not be able to reach maybe 10 - 15% of the floors. Necessities of fire safety include the ability for public servants to reach any height of the building quickly, for occupants to evacuate efficiently and safely, to control the spread of the fire and, more importantly, smoke. The Burj Dubai uses an intricate system of elevators to aid with fire safety. Some faster, larger service elevators can override local elevators and work to transport crowds. Other "lifeboat" elevators can actually be manually operated on emergency power using a camera and a joystick. The Burj Dubai also is equipped with areas of refuge approximately every 25 floors. These are designed for safety, including LCD monitors for instruction, fire resistant construction, and connection to multiple staircases. The building's ventilation is also revolutionary, and helps immensely with the issue of smoke and other toxins.

Wind stability is the other great concern with a structure of this magnitude. The design is expected to maintain a comfortable factor of safety at all times, even under large wind loads, to avoid catastrophic failure. The entire Burj Dubai design bodes well for wind safety. The structure features a Y-shaped, rigid cross-section which is easy to construct. The skyscraper also is "tapered," meaning the wings recess as the floors increase. This confuses the wind and counteracts the formation of vortices, greatly reducing wind load. Finally, the concrete mixtures are custom, and are impressive not only in their strength but in their constructability at high heights. The steel reinforcement is the last, and possibly most important, piece that contributes to the tower's structural integrity. It is found that the building is remarkably sturdy, both in torsion and under lateral stressing. This is supported by wind tunnel testing.

The combination of these mitigation techniques for both fire and wind in the record-holding skyscraper make the building very safe. I have found that the building is fully equipped and ready to handle most crisis situations, provided that staff and crisis management personnel are prepared to follow the plans. The building allows for open communication in crisis situations, along with a series of stairwells, emergency elevators, and refuge areas to avoid trapping any occupants. The equipped features of the tower also allow for great control over the fire and the smoke toxins it produces.

In addition, the building is remarkably stable. The chosen design never allows the wind to congregate and as such never experiences a whole lot of force from fluid sources. Concrete reinforcement and a very strong foundation further increase structural integrity. Finally, the building gets exponentially lighter as it ascends its 162 floors; this makes the weight at the top much lighter than the weight at the bottom. Despite this positive recommendation, the only concerns addressed in this report are fire and wind safety. There is no perfect way of predicting what the building will undergo in its lifespan. However, in this preliminary analysis the Burj Dubai appears prepared to take the crown as the tallest building in the world, and should hold as an icon of human achievement for many years.

1.0 Introduction

For those who do not know, Dubai is one of the seven emirates of the United Arab Emirates (UAE); it is the second largest emirate by area and the most populated. Dubai is currently ruled by Mohammed bin Rashid Al Maktoum, and has been controlled by the Al Maktoum dynasty since 1833. Population has increased ten-fold since the 1970's, and its economy, initially built on the oil industry, has diversified to include real estate, trade, financial services, and tourism. A mix of low labor cost and powerhouse budget makes for a city that has seen some of the most extravagant architecture.

Over the years, the Dubai emirate has attracted great attention through its real estate projects, standing as a symbol of human ambition and a playground for architectural engineers. The territory seems to have an insatiable thirst for innovative design and the newest, biggest project. The region has erected some of mankind's most conceptual structures, including a man-made island shaped like a palm tree, the world's largest fountain (costing a mere $800 million), and the world's largest hotel. And the development doesn't stop there. The ever-unsatisfied province has recently assembled one of the most astonishing and intimidating edifices the world has ever seen: the Burj Dubai.

The Burj Dubai (Tower of Dubai) will soon achieve the status of the tallest man-made, free-standing structure in the world. Upon its completion in September of 2009, the colossal building will dominate all of the Council on Tall Buildings and Urban Habitat's (CTBUH) height categories. In December of 2008, the designers revealed, after a long period of confidentiality, the building was originally designed for be 808 m tall. There is some speculation on the final height considering late-coming design changes. Needless to say, the world can be sure it will comfortably surpass the current record holder, the 509 m (1670 ft) tall Taipei 101.

The building will in-turn act as a city within a city, contracting hotels, a mall, restaurants, offices, and residential housing to fill its 162 floors. The building's architect, Adrian Smith, worked closely with Chicago's Skidmore, Owings and Merrill (SOM), a design team famous for the Sears Tower. Along with Samsung Engineering & Construction, the primary builders, the building joins a 2 km^2 development project called "Downtown Burj Dubai." The building, though impressive, will also have cost approximately $4 billion when completed, which pales in comparison to the $20 billion dollar budget for the entire new "Downtown Burj Dubai." (Arnold, 2008)

At this point, it is difficult to accurately say how many people will end up occupying the building, although one can make a logical guess of thousands each day. Regardless of the specifics, the sheer magnitude of the structure will make movement through the building complicated. The future occupants expect to be able to get to their destination floors and locations with as little holdup, and as little effort, as possible. At the same time, those same occupants expect to be safe when they are in the building, and want to be assured that they will never be trapped inside. This is where the design team's job gets complicated and inventive. This paper examines these techniques and evaluates the safety of the Burj Dubai, specifically as it pertains to fires and high winds. In this report I will address the various architectural features that preemptively handle dangerous situations, as well as evacuation and crisis management plans in the event of a dire circumstance.

2.0 Design Concepts

The goal of the Burj Dubai design team was to develop a model that would not only be stable and self-sustaining at record breaking heights, but also easy to construct and maintain. They also wished for the utmost satisfaction to the future occupants. First and foremost, they need the occupants to feel safe while enjoying all of the services of the unsurpassed edifice.

2.1 Shape

The architect, Adrian Smith (2008), illustrates his design as follows:

> In developing the initial concept for Burj Dubai, I searched for elements within the existing context and culture of the area to reflect on and draw inspiration from. Within the Middle East and in Dubai, there are strong influences of onion domes and pointed arches, and there are patterns that are indigenous to the region, some of which are flower like with three elements, some with six and so on. Other influences range from spiral imagery and philosophy embedded in Middle Eastern iconographic architecture and motifs. These motifs have their origin in organic growth structures and plant materials… The overall composition is a vertical object reduced and transformed by spiral reduction of branch lengths until it reaches its central shaft at which point the shaft peels away to reveal a triptych configuration that erodes in a spiral manner until there is a single spire. (p. 2)

The final cross-section is a sort of inverted triangle. The three wings of the building stretch out from a central core. This makes for a very rigid structure under torsion , as well as ensuring maximum visibility along the wings. The building is "tapered," meaning that the wings recess as they approach the top. This creates an exponential shape that not only emphasizes height, but has a collection of other benefits described later. Figure 1 depicts the profile and section views of the building. The buttress core is six-sided, and acts as the "spire" of the skyscraper. Concrete used for the core is super reinforced, and ranges between 500 mm to 1300 mm thick. They core walls are supported through a series of 800mm to 1100mm deep reinforced concrete. (Abdelrazaq, S.E., et al., 2008, p. 3) Due to the fortitude, the core houses the majority of important amenities, including the water and plumbing systems, electrical grids, and elevators.

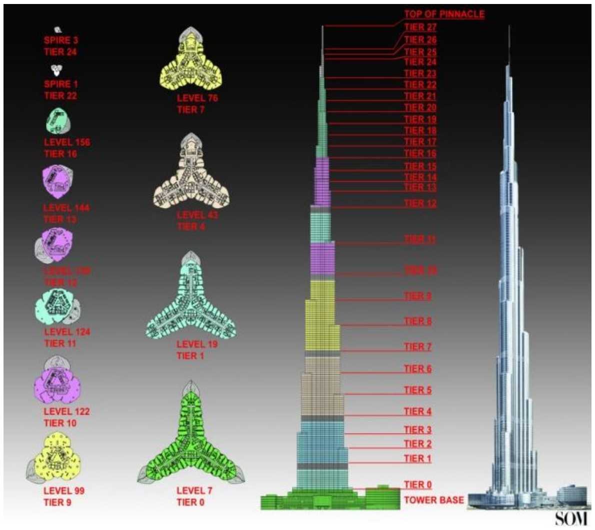

Figure 1 – Burj Dubai cross-section and profile (http://www.worldarchitecturenews.com/news_images/1000%20Burj%20cross%20section.jpg)

2.2 Elevator Systems

The Tower of Dubai plans to yet again impress the world with its maneuverability. An intricate system of elevators is the primary mode of vertical transportation. The main consideration with this is the mixed-use of the building. Also, according to Weismantle (2007), "[the Burj Dubai] is so tall that current elevator technology would not permit a single elevator to travel the entire height of the building" (p. 340). This means the Burj Dubai design team needed to design an efficient transfer system, using local and shuttle elevators. This is analogous to commuter trains used in many big cities around the world. The most effective way to do this is by stacking local passenger and service elevators so they only service pertinent floors; tall, fast shuttle elevators are used to navigate between sections. Current elevator design requires "buffer zones" to house mechanical components of the elevator systems. The Burj Dubai handles this by placing mechanical and electrical service floors in between sections accessed only by stairs, as shown in figure 2. (Weismantle, Smith, & Sherriff, 2007, pp. 340-345)

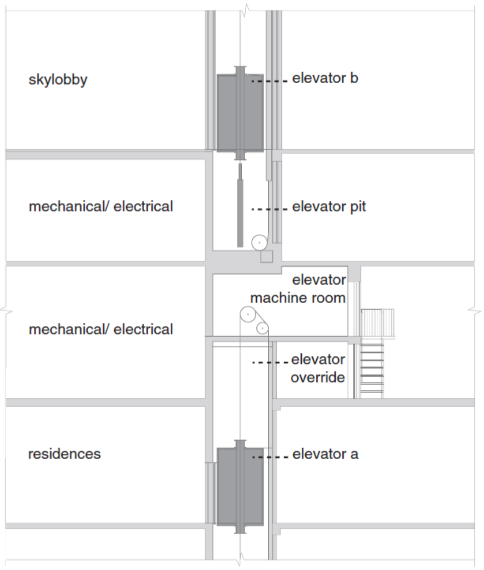

Figure 2 – Elevator Stacking (Weismantle, 2007, p. 341)

3.0 Safety Considerations and Risks

The natural questions become: Is it safe to house so many people in one building? Is it logical to build so high, considering the potential for fire on any given floor? Can something that imposing remain freestanding without cable supports, especially with the effects of wind? These questions cannot be accurately answered by intuition alone. Analysis of design fail-safes and overall structural integrity must be conducted, along with research into the safety plans arranged for the future occupants.

3.1 Worst Case Scenario

The risks involved with this building are somewhat apparent. The amount of money invested in the Burj Dubai Project is in the billions, and as such cannot be taken lightly. Perhaps most importantly, people's lives are at risk. With the building reaching unprecedented heights, we are unable to know from past experience what will happen with this building. In the event of a catastrophic failure, the damages to the surrounding area and the loss of life would be unspeakable. The ambition of this report is to better understand the limitations of this new record holder, and hopefully help avoid the aforementioned circumstance.

4.0 Fire Safety

The first area of concern, and perhaps most evident, is the fire safety of the Burj Dubai. I chose to address this area of concern because it probably the most likely dilemma the building will face. There are many considerations with this. Firstly, public servants need to be able to quickly access any level of the skyscraper. At the same time, occupants need to be informed of the situation, understand what to do, and be able to evacuate safely and in a timely manner if needed. Finally, the design has to be able to handle smoke, not only ventilating it quickly, but by not letting it spread to the rest of the structure.

4.1 Controlling the Fire

As with most buildings, the Burj Dubai is outfitted with an automatic sprinkler system; its main task is to control the spread of the fire. Assisting in fire safety is the fire resistant construction. The skyscraper's composition protects surrounding floors, rest zones, mechanical areas, and hazardous areas from the other areas around it. Occupants can be confident that fire will not spread significantly far inside of the Burj Dubai. The fire itself is mainly a threat to the occupants in the immediate vicinity; however a larger threat is the smoke and toxic gases that have the potential to spread to even remote areas of the building. (Evenson & Vanney, 2008, p. 3)

4.1.1 Ventilation

The Burj Dubai is equipped with many smoke resistant features. Firstly, the building uses pressurized exit stairs. There are also exhaust systems in place, along with overall smoke resistant construction. All of these features act together and are designed to operate automatically when a fire alarm is tripped either manually or from the fire detection system. Each floor is outfitted with a smoke compartment that traps and contains smoke. Finally, a smoke control panel will be provided to emergency personnel. This will allow firefighters and paramedics to manually adjust the smoke control systems at their discretions. (Evenson, 2008, p. 3)

4.1.2 Mitigating the Stack Effect

There is another fluids related phenomenon that needs to be addressed, called the stack effect. Sometimes called the "chimney" effect, the stack effect is pressure driven, and occurs because of the difference in air densities of the cool inside air of the tower to the hot outside Dubai air. This will tend to push the inside air down the interior of the tower, which sufficed to say can be dangerous with smoke. (Wilson & Tamura, 1968) The Burj Dubai architects have counteracted this effect in numerous ways. Just a few of the many techniques are listed below: (Weismantle, 2007, pp. 351-352)

- Stairwells are not in a continuous shaft
- Extra sets of doors were placed between resident towers, elevator shafts, and lobby areas
- Residential doors have adjustable door bottom seals
- Major air systems in the tower have various speeds; this allows them to react in a range of pressure conditions

- Outside air intake and exhaust systems have monitoring systems for added control
- The smoke exhaust system doubles as pressure relief to avoid over-pressurization

4.1.3 Firefighter Accessibility

It is important for emergency personnel (e.g. firefighters, paramedics, police) to be able to access a building quickly in the event of an emergency. Being a record holder does not exclude the Burj Dubai from this rule. In addition, these personnel cannot be expected to scale all 162 floors through stairwells. This need gets back to the elevator systems. The tower has service elevators that run higher than local passenger elevators. In fact, one of these service elevators runs over 500 m, and is the tallest elevator shaft in the world. (Weismantle, 2007, p. 342) These are very fast, and are configured to override the local elevators to allow for the quickest and easiest transfers. The elevators themselves are fire/smoke resistant. With these, it makes accessing the building a relatively painless process. However, what about the converse, evacuation?

4.2 Occupant Evacuation

Occupant evacuation is the concern of any building; however, it poses a special challenge given the height of the Burj Dubai. With the tremendous climb, residents will need information on the situation, mechanical assistance to speed the process, and stairwells and safe zones in the event of mechanical failures. It is important to note that most crises the building will experience will not require full building evacuation. However, when lives are at stake, it is still important to be sure that it is possible.

4.2.1 Areas of Refuge

The tower design includes strategically placed areas of refuge which allow for better controlled evacuation. Represented in figure 3, the typical area of refuge will have fire rated exit stairs closed off by doors to counter the spread of smoke. Building employees will be trained to direct and instruct evacuees. Also, the areas of refuge are designed to connect to various stairwells. This means that occupants can be directed down the safest path, and will almost never be trapped. As usual, the areas of refuge are encased in fire resistant concrete, are well ventilated, and can be lit by emergency lights.

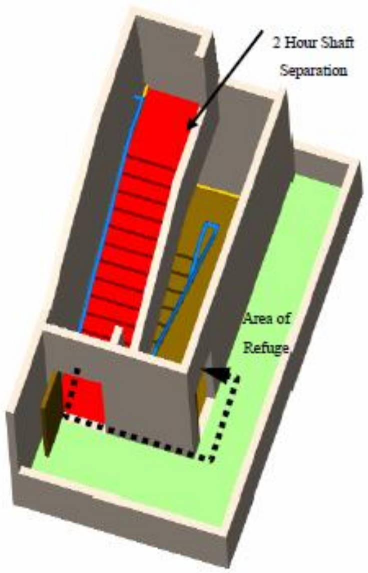

Figure 3 – Typical Design for Area of Refuge
(Evenson, 2008, p. 4)

4.2.2 Elevator-Assistance

Similar to the public servants scaling the building, the evacuees cannot be expected to descend the building given its awesome height. For this, mechanical assistance is in place. In the core of the building, the tower has large "lifeboat" elevators. These lifts are completely operable on emergency back-up power, and can accommodate crowds of people. The lifeboat elevators are especially important, because they encase the occupants in a fire-safe elevator. Perhaps the most interesting feature of these elevators is the manual override. Indeed, these elevators can actually be controlled through cameras and a joystick by the Dubai Civil Defense. The cameras are also outfitted with LED lights to allow security teams to illuminate and inspect hoist equipment and elevator components. Engineers of multiple sources have estimated the time reduction of stairs-only to stairs with lifeboat assistance to be about 46%. Finally, these special elevators, designed by Rolf Jensen & Associates, Inc., can be reached through a remote audio system. This, in addition to more methods described below, allow crisis management teams to assist and instruct extremely effectively. (Weismantle, 2007, pp. 343-345, and Evenson, 2008, p. 4)

4.2.3 Communication

The Burj Dubai is outfitted with an emergency P.A. system and fire alarms. The system is designed for selective notification to specific zones, but can reach the entire structure. Exit signage and emergency lighting make evacuation easier, along with multiple staircases designed to not isolate any single one. The advanced building communication system is also equipped with public address systems and LCD units install in residence halls, hotel rooms, and areas of refuge. The areas of refuge described earlier are meant to be used for continuous instruction as well. All of these enhance life safety through communication, and effectively increase speed and effectiveness of the Burj Dubai Crisis Management System. (Evenson, 2008, p. 5)

5.0 Wind Safety

With any tall building, wind is of great concern; it acts as a fatigue loading and accounts for the majority of torsion and transverse stresses that the building experiences. As such, considering the aerodynamics of the structure's shape is extremely important early in the design process. These considerations depend on many factors, including wind speed and surface area. However, all structures need to meet the basic requirements for stability, strength, and serviceability. "One of the critical phenomena that affects tall slender towers is vortex excitation, which causes strong fluctuation forces in the crosswind direction. This is probably "the main behavior that distinguishes tall towers from mid-rise buildings." (Irwin, Kilpatrick, et al., 2008, p. 916) The main goal of the Burj Dubai design team was to reduce these vortices by "confusing" the wind. Also, they constructed the building with advanced material reinforcement, so the building can remain stable under loading, even under its immense weight.

5.1 Mitigation

There have been various ways that tower designers have dealt with the issue of high winds. Some use supplementary dampening systems, such as the TMD of Taipei 101. Others choose to utilize the wind to improve sustainability. The Commerzbank building in Frankfurt, Germany uses the wind as natural ventilation. (Irwin, 2008, pp. 925-927) However the Burj Dubai is different. The building's design is almost entirely designed around combating the wind forces.

5.1.1 Rigid Design

One of the ways that the Burj Dubai is able to remain free standing is because of its "Y-shape" as described earlier. Triangles are very strong shapes; from any angle they are supported by all edges (wings in the case of the Burj Dubai). Using this idea, the architect Adrian Smith was able to design the skyscraper to foster constructability, as well as make the building extremely rigid under torsion. Combined with the six-sided core and the rest of the design described in sections 2.0-2.2, the Burj Dubai is resistive to almost any applied forces.

5.1.2 Confusing the Wind

Another key design feature of the tremendous tower is its recessive, tapering cross section. There are mathematical models that describe "vortex shedding." Vortex shedding happens when a fluid (in this case air) flows past blunt objects and essentially creates low-pressure vortices downstream of the object. When this happens, the object will tend to move toward the low-pressure zone. In addition, vortex shedding is oscillatory, and as such has frequency. If the oscillatory frequency of the vortices matches the resonance frequency of the building, the structures movement can become erratic and potentially dangerous. (Cermak, 1976) Needless to say, this is an important problem to address.

Adrian Smith realized that the frequency of vortex shedding varies with width. With a constantly changing width, vortices are constantly trying to shed at different frequencies. This causes interference, which causes "confusion," which causes cancellation. This is the fundamental idea behind the tapering of the Burj Dubai. As the building ascends and the jet streams get stronger, the Burj Dubai easily cuts through the breeze. In assurance to the mitigated wind effects, floors get lighter and smaller as they get higher in the sky. The wider, more supported foundation could support a swaying top with relative ease. This, from a distributed load standpoint, allows the edifice to completely stand alone with no cable supports. All of this in turn makes for a structure that is ingenious in its handling of transverse and torque loadings, and theoretically very safe. (Irwin, 2008, p. 917) Later in the report, we will see that these theories are supported in practice. But no matter how strong the design is, proper material selections need to be made to ensure stability and safety.

5.2 Concrete

Perhaps the most important consideration for the structural integrity of the Burj Dubai is the concrete used. With over 330,000 m^3 of concrete distributed throughout the 162 floors of the building, advanced modes of concrete design needed to be implemented. (Burj Dubai, 2007) The concrete mixtures have to be able to not only be strong enough to handle the stresses of the enormous skyscraper, but also be able to be pumped up to world record heights without losing any of its properties. This was perhaps the most difficult concrete design task, namely because of immense height and the high summer temperatures of Dubai.

Four separate concrete mixes have been developed and used in the skyscraper. They contain varying levels of Portland concrete and fly ash. This is to account for the varying pumping pressures as the building ascends. The Putzmeister pumps used in the construction were the two largest in the world. They are able to withstand pumping pressures of up to a 350 bars (metric unit of pressure, 1 bar = 100 kPa) through high pressure 150 mm pipelines. (Baker, Korista, et al., 2007, p. 10) The mixtures, under such immense pressure, needed to be cooled with ice, and took approximately a half an hour to reach the top. The pumps have set a world record at 601 meters. (Putzmeister, 2007) However stand-alone concrete is not extremely reliable; it is the inventive reinforcement that makes for the greatest contribution to structural integrity.

5.2.1 Reinforcement Design

The arrangement of steel reinforcement beams is another area of design that had to be taken very seriously by the engineers of Skidmore, Owings, and Merrill. With record-breaking heights comes record-breaking stress, notably due to the weight of the building and the wind forces it is exposed to. Ethically, there can be no question about the integrity of the structure walls.

The demands of the steel link beams largely depend on the positioning of the beam in the structure. Due to the tapering of the tower, the beams most demanding load comes from gravity, increasing with the distance from the core. Also, the largest loads are generated in beams closest to setbacks. In general, the beams used in the Burj Dubai are stocky. Their cross-sections are generally 650 mm wide (2.13 ft) and 825 mm tall (2.7 ft). (Lee, Kuchma, et al., 2008) However, most often the arrangement of the beams is more important than the beam strength itself.

As far as design is concerned, the linked beams of the Burj Dubai high-rise followed two conventions. Firstly, they use a conventional deep beam design method from ACI (American Concrete Institute) documentation. This is mainly for vertical members and foundation, and has axial beams for good handling in tension and compression. The second beam type integrated a strut-and-tie method. (Lee, 2008)

I was unable to find an exact representation of the Burj Dubai design. However, Dr. C. C. Fu of the University of Maryland defines a strut-and-tie model as “a conceptual framework where the stress distribution in a structure is idealized as a system of struts (compressive members), ties (tensile members), and nodes (connections).” (Fu, 2001, slide 14) He also stated that good models are ones that do not require large deformation before the tie can yield, because brittle concrete has a limited capacity for plastic deformation. From my research, my best assumption for the Burj Dubai design is depicted in figure 4, based on the fact that the strut-and-tie of the Burj Dubai increased strength to three times the expected yield and the presented model is regarded as “good”

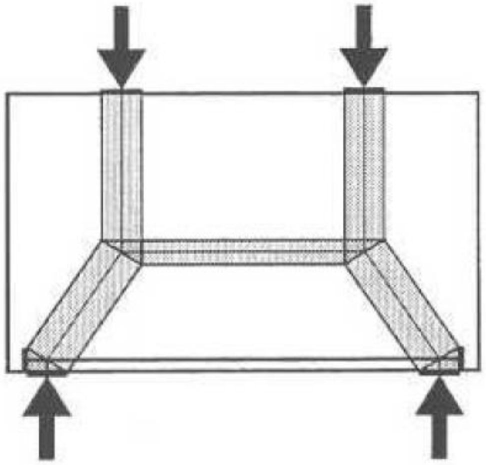

Figure 4 – “Good” Strut-and-Tie model (Fu, 2001, slide 46)

by Dr. Fu.

5.3 Exterior Walls

With all the commotion of constructing the skyscraper, SOM needed their exterior wall system to be as pain-free as possible. They are designed for simplicity, ease of transport, prefabrication, and repetition. The final design strategy was a “curtain wall” that was both easy to construct and maintain.

Each panel was prefabricated, and designed to interlock with surrounding panels. Joints are weather-tight, and designed to permit movement when subject to temperature differences, wind, seismic events, and other deformations the structure may undergo. The typical panel is constructed out of extruded aluminum, polished steel fins, high-performance insulated glass, and occasional patterned stainless steel backup panels. They all work together to permit over 20% of visible light into the building while allowing less than 16% of the ambient temperature. (Weismantle, 2007, p. 354)

5.4 Wind Tunnel Testing

Wind tunnel testing is a tool used by engineers to examine the nature of wind forces acting on complex structures. The process involves placing a completed model (usually wood or plastic) on a turntable inside a wind tunnel. The model is then subject to air blown at various angles. From this, engineers can determine how the building will react under various wind speeds through mathematical models and computer software. They can contrast their findings to the weather patterns and expected wind speeds of the building’s region, and use it all to design the safest structure possible.

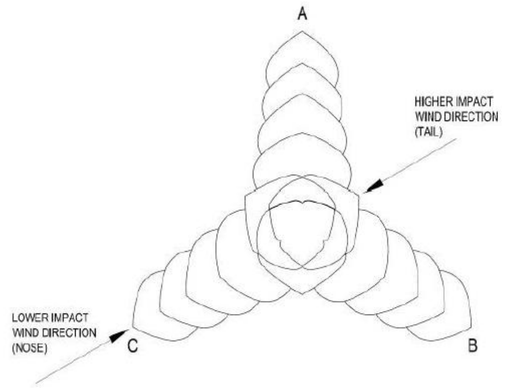

Figure 5 – Representative top view of tower (Baker, 2007, p. 7)

In the case of the Burj Dubai, the wind tunnel testing included rigid-model balance tests, aeroelastic model study, measurement of localized pressures, and pedestrian wind environment tests. (Weismantle, 2007, p. 347) There are essentially six important wind directions to consider with the Burj Dubai. Three of the principle directions are “nose-winds,” where the wind blows directly on the point of a wing of the building (Nose A, Nose B, and Nose C). The remaining three principle directions are called “tail-winds,” which focus on areas in between “noses.” Figure 5 represents this.

During the wind tunnel testing process, the architects and designers made structural and design changes to the model. These changes were optimized to bring wind forces to a minimum by altering the width and shape of floors. (Nasvik, 2008) This process resulted in a great reduction in wind forces by “confusing” the wind, as described earlier. After numerous wind tunnel tests and adjustments, aeroelastic model tests were initiated. It is important to note an aeroelastic model is a model that has properly scaled stiffness, mass, and dampening. These models are able to demonstrate higher level structural responses. (Baker, 2007, p. 7)

The testing concluded that the Burj Dubai is very structurally stable under vibrations and wind. According to a case study by Weismantle, Smith, & Sheriff in 2007, the largest negative wind load on their model was -5.5 kPa; the largest was +3.5 kPa (p. 348). Also, the aeroelastic models predicted that the building motions stay under standard maximums and require no auxiliary dampening.

6.0 Report Disclaimer

It is important to note that the conclusions made in this paper are only pertinent to fire and wind safety. There is little ability to accurately tell what natural agitation the building will undergo. Dubai does not have a strong history of tsunamis or earthquakes; the UAE is far enough from fault lines and tends to only experience minor quakes. (“Far enough,” 2008) However, such events should not be discounted, and are being left for assessment by another report.

7.0 Conclusions

Through examination of the Burj Dubai, I have been able to construct a large knowledge base. From various case studies and credited writings by a range of engineers and Adrian Smith himself, I have scrutinized the design features of the record-setting skyscraper.

The Burj Dubai performs remarkably well under wind forces. The building’s ingenious setback spire design resists vortex shedding and as such does not allow for the wind to coordinate on the walls of the tower. Also, its rigid triangular shape and buttress core allow the building to stand freely. The in theory and in wind testing, the Burj Dubai has performed admirably. The concrete of the building is supported well by thick steel beams; testing shows it can comfortably handle even the highest stresses the building will experience. Combined with an extremely strong foundation, the edifice is remarkably strong in torsion and under lateral stressing. I believe, along with numerous other engineers, that the structure will be more than capable of standing strong even under in strong wind situations.

The designers of the Tower of Dubai have taken the safety of future occupants into great consideration. I was able to find a lot of material pertaining to the safety features, all of which ensure the floors of the building are indeed protected from fire. Through the use of elevators and staircases, crisis management personnel can easily access any level of the building. In contrast, the innovative maneuverability also allows for quick evacuation, all the while keeping communication open and the spread of smoke down.

In summation, the Burj Dubai is a very safe building in regards to fire and wind. Future occupants can be confident that the building is stable and will handle well in crisis situations. The various systems in place have made it so that any occupant can be reached in almost every circumstance, as well as escape quickly to either an area of refuge or all the way out of the building. From my inspections, I expect the Burj Dubai to stand as a symbol of human ambition and intelligence for a very long time. Although the height of the building is remarkable, the architectural stability and safety is close, if not, just as impressive.

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