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Original Paper

Tall Buildings in Dubai—Converting Architecture into Reality

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Abstract

In just over two decades, Dubai has transformed from a desert served by a single port to a flourishing metropolis. Dubai alone is the home to 20% of the world's tallest 50 buildings. This transformation brings new challenges to the city during construction and post completion. The surrounding areas will be affected by these skyscrapers from transportation, traffic constraints, parking, power and water consumption and other factors.

The cost of building a skyscraper remains the major obstacle with the need to source out new materials other than steel and concrete. Also, moving people around efficiently in super tall buildings is another challenge for engineers keeping in mind the unique designs that architects are looking after. Once all design aspects are concluded and approved by different stakeholders, it will move on to the next phase which is construction, that is called: Reality.

Construction realization is the focus of this paper. It will discuss the actual facts and surprises which will be encountered during the transformation of the design into shop drawings and tangible concrete. A physical case study from a busy district in the city of Dubai is the main focus of this study along with the core challenges and obstacles faced the team during the execution phase. Also, this review will debate couple of design elements that were considered as a design feature then developed to be a real construction challenge.

Originality/value: the paper will focus on a case study of a high-end skyscrapers designed and built in the city of Dubai in a dense area and the challenges faced by the team during construction. These challenges are beneficial to understand since they will help architects and designers to take into consideration during their studies.

Keywords

architectural elements, construction challenges, design considerations, Dubai municipality, mixed-use skyscrapers, tall buildings

1. Introduction

Dubai is located on the Eastern coast of the Arabian Peninsula, in the south west corner of the Arabian Gulf. Before the oil discovery in Dubai in 1966, the city was fully dependent on trading and its main industry was pearling. The discovery of oil changed everything though, Dubai's reserves were insignificant compared with other emirates, the ruler of Dubai, was determined to turn the city into a trading hub. The first major "free zone" was launched in 1985, and this was a key boost in the economy since foreign companies could operate with almost no taxes or customs. With the accelerated wealth in the city after the year 1998, the government put into effect a plan to turn the city into the world's top tourist destination. The city became well known for its rich culture, diversity, and popularity. With thriving business community, luxurious hotels, sophisticated infrastructure, Dubai managed to be a very attractive city to tourists and businessmen receiving millions of leisure and business visitors each year (Dubai tourism authority). Today its economy is diversified to trade, manufacturing, leisure and entertainment. By introducing free trade policies this has distinguished it from the other emirates within the UAE, making it a special economic area similar to Singapore and Hong Kong (Importing urban giants: Re-imaging shanghai and Dubai with skyscrapers, 2013). Today the city of Dubai is considered a wealthy city and most modern anywhere, boasting the highest skyline in the Middle East including the tallest tower in the world (Burj Khalifa) and two of the tallest hotels in the world. It attracts a booming tourist business, drawn in part by major sporting events including horse races, boat races, tennis matches, and air shows. It is also considered as a major shopping destination and an international city. Dubai has emphasized on the creation of a world class city comprising skyscrapers, shopping malls, hotels, leisure and entertainment which will evolve around the city's vision to be an attraction and a tourist destination. The city has expanded within a decade to an enormous scale in order to cope up with the real-estate boom which took place between 2002 and 2009, however, due to this growth and expansion, many fundamental infrastructure networks were running behind, especially the transportation system. Many large developments were left out without basic transportation network only depending on private cars and taxis. The government of Dubai has realized this issue and started addressing it by creating several projects such as Dubai metro, Dubai Tram and other roads and bridges around those developments (Jacobs, 2018).

2. Background

The term "skyscraper" was first used in 1885 to describe the 55-meter high Home Insurance Building in Chicago (Binder, n.d.). The history of skyscrapers and tall buildings in Dubai began with the construction of Dubai World Trade Centre in 1979 comprising of 39 floors and 149m tall, which was considered as the first high-rise building in the city. At the time of its completion, it also stood as the tallest building in the Middle East until the completion of the Burj Al Arab 20 years later (Binder, n.d.). Dubai World Trade Center Tower, is a symbol of prosperity (Figure 1) and it represents the start of a new era in the past decades and was a turning point for Dubai, a city that, back then, did not have any

significant high-rise buildings. The Dubai world center means a point of no return in the way of the small fishing settlement that dreamed of being a macro-metropolis (Xixerone, Asia, Dubai, Middle East, 2015) (Figure 2).

Figure 1. Dubai in 1973

Figure 2. Dubai in 1992

20 years later, another flagship tower was constructed which is Burj Al Arab (Figure 3) a luxury hotel stands at 391m high.

Figure 3. Burj Al Arab Luxury Hotel

Following the year 1999, and the construction of Burj Al Arab, the city realized its strength, fortune and ability to accept the challenge of constructing towers and skyscrapers all over the city. As of 2015, the skyline of Dubai is ranked sixth in the world with 48 buildings rising at least 100m in height and ranked the 4th globally in terms of skyscrapers with 95 towers reaching 200m or greater in height by the 2017 (Binder, n.d.).

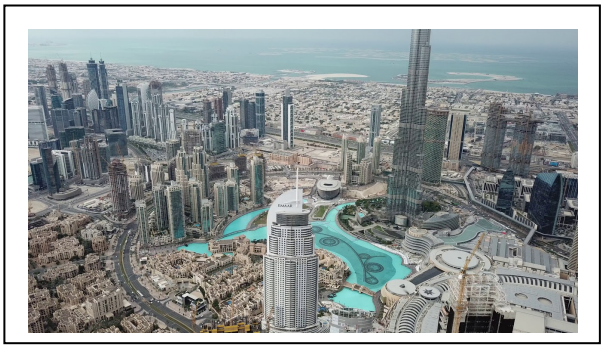


Figure 4. Dubai Skyline of Burj Khalifa Downtown

3. Analysis

The study focuses on the analysis of an existing area in the city of Dubai which is populated with towers and Highrise buildings. From year 2005 onwards, Dubai has been the land of tall buildings boom. The city is now the home to the world's tallest building-Burj Khalifa (Figure 4). As of 2019, approximately 49 new skyscrapers are being built in the city (Binder, n.d.).

Table 1 reflects the latest statistics covering tall buildings for 150m+.

Table 1. Tall Buildings Facts (Binder, n.d.)

150m+ Buildings	190 Completed-51 Underconstrciton
300m+ Buildings	22 Completed-13 Under Constrciton
Most Common Function	Residnetial (52%)
Most Common Material	Concrete (94%)

Also, Table-2 shows the top highest building built in the city of Dubai

Table 2. Tall Buildings Facts (Binder, n.d.)

Building	Completion Date	Height in meter
Burj Khalifa	2010	828
Marina 101	2017	425
Princess Tower	2012	413
23 Marina	2012	392
Elite Residence	2012	380
The Address Boulivard	2017	370
Almas Tower	2008	360
Gevora Hotel	2017	356

These buildings and skyscrapers are distributed along the city of Dubai, however, majority of them are located in three areas namely Dubai Marina, Jumeirah Lake Towers (JLT) and Jumeirah Beach Residence (JBR) where the construction took place between the year 2004 and 2017. More than 100 buildings were constructed in that area which is considered a construction phenomenon by itself. The construction methodology and techniques which were used to complete these buildings are considered top-notch and a civil engineering achievement. Majority of the towers are between 250-300m with few between 300m-400m.

3.1 Dubai Marina

Dubai Marina (Figure 5) is built along a 3 km stretch of an artificial canal; it has a population of 45,395. The ultimate plan for this development is to accommodate more than 120,000 people in residential towers and villas. Dubai Marina was inspired by the Concord Pacific Place development along False Creek in Vancouver, BC, Canada (CIB World Building Congress, 2007).

Figure 5. Dubai Marina

3.2 Jumeirah Lake Towers

Figure 6. Jumeirah Lake Towers

The other major development with multiple towers is Jumeirah Lakes Towers (JLT) (Figure 6) consists of 80 towers being constructed along the edges of three artificial lakes. The total area covered by the lakes, waterways and landscaping is approx.730,000 m2. The towers range between 35 floors to 45, except for the centerpiece which is 66 floors (Xixerone, Asia, Dubai, Middle East, 2015).

3.3 Jumeirah Beach Residence

Another great development in the same area is the Jumeirah Beach Residence known as (JBR) (Figure 7). A tourist destination for visitors and tourists who are visiting Dubai. This development is considered the largest single-phase residential development in the world and contains 40 towers. JBR was launched in 2002 and completed in 2007. The walk at the JBR is a 1.7km strip of multiple restaurants and shopping.

Figure 7. Jumeirah Beach Residence

Figure 8. Jumeirah Beach Residence

The above three examples of a magnificent developments where the developers have challenged the nature of sand dunes and the heat of the gulf. Nevertheless, such developments have overloaded the infrastructure with massive requirements of power, water and other facilities. Also, the number of people living in such developments will definitely have an impact on the public realm of the streets in addition to the need to provide sufficient car parking and enough roads and bridges to encounter the peak hours (CIB World Building Congress, 2007).

4. Municipalities, Authorities and Design Guidelines

Dubai municipality is officially the main authority that is supposed to govern all urban development related aspects of the city. However, many authorities, such as JAFZA (Jebel Ali Free Zone Authority), DTMFZA (Dubai Technology and Media Free Zone Authority), TECOM (Dubai Technology, Electronic Commerce and Media) and others, that are mainly the regulatory authorities of free zones, are also major references within the regulatory framework.

Free Zones in Dubai are economic zones that have special legal and regulatory frameworks. They often offer tax-free conditions and other benefits for expatriate investors. Each zone is operated and managed

by a free zone authority that has a set of prerogatives, such as offering business licenses, and setting the regulations at different scales. In Dubai each Free Zone specializes in one or more business industry, related to industry, business, media (Oula, n.d.).

These free zones set the design and master plan guidelines for each area governed by that free zone. They were found during the construction boom in order to facilitate and support developers with the design revisions and approvals. They have their own regulations, authorities and administrative bodies that escape administrative control. Projects inside free zones follow the planning regulations specific to that zone, and do not have to seek approval from the municipality or other institutional authorities. In other words, most of the massive developments constructed after the year 2000 were not part of Dubai municipality review or urban planning umbrella. Having said that, this has helped the city to grow rapidly in less than 20 years by providing lean regulations and immediate approvals to developers. On the other hand, the downside of this vast construction, is the need for the municipality to develop proper and sufficient road network and public transportation to connect with the city infrastructure since each development functions as a unique stand-alone city which requires to be connected with the city infrastructure (https://en.wikipedia.org/wiki/Dubai_Marina).

5. The Case Study

Figure 9. One JBR Project

Figure 10. One JBR Project

The case study (Figures 9 and 10) in this paper focuses on one of the skyscrapers built in Jumeirah Beach residence (JBR) district in the city of Dubai. The tower is located in a very busy area between two Hotel buildings accessed by one-way road (Figure 11).

Development Highlights:

Table 3. Developments Highlights

Type	Luxury and exclusive residential development
Location	One of the last few waterfront locations with attractive views on JBR
Units & Mix	164 units; mix of 2, 3, 4 and 5 bedroom apartments
Main Target Market	Who are looking for a primary or secondary residence
Facilities	Swimming pools (some units have private pools), function rooms, kids play area, driver's room, semi private lifts

Site location:

Figure 11. Project Location

Figure 12. Project Positioning

The location of the project site is a challenge by itself yet unique and distinguished. The plot area is 16,828 m2 with full sea view and private beach access (Figure 12). The project comprises of 49 floors with 1 basement and a total built up area of 74,413m2.

5.1 Project Description and Design Discussion

The project has been designed in an exclusive technique in order to maximize the sea views. The core is facing the street allowing enough elevators to provide exclusivity to residence and guests. A huge steel structure has been added to the street façade to cover the core and to give the project a unique design. The rear façade facing the sea is a full curtain wall of aluminum cladding and wide glazing with 3m cantilevered balconies capitalizing on the fabulous sea view. Penthouses have been introduced at the higher levels with exclusive lifts and dedicated car parking. The building has been elevated above the ground to provide a drop off area with a large glass atrium covered with a 12m cantilever of steel structure which is part of the façade design. From a discussion point of view, and to support the originality of this paper, the design did not consider many construction aspects which might be

challenging from constructability aspect and this will encounter additional cost and time to the development.

5.2 Project Challenges

During the design stage, architects focus on geometry, function and other design aspects leaving the construction challenges to the site team. In other words, some design elements may look appealing on drawings but yet very challenging and costly to build. Furthermore, designers should take in to account the project location and surrounding restrictions in their design criteria which may have major impact during construction phase.

Below is a list of major challenges faced by the team during the construction phase which were not considered during design phase:

5.2.1 Site Analysis

The first step into such development is understanding the site location (Figure 13) and context, entrances and egresses, day light orientation and views. The site is located in a very busy area with high volume of cars since it is tourist attraction. Also, on both sides of the plot falls 2 hotels served by one-way road (Figure 14). This has made the delivery of construction material very difficult due to restricted vehicle size allowance as well as the availability of laydown and storage area. On the other hand, working hours were limited as well to avoid disturbance of hotels on both sides.

Figure 13. Location

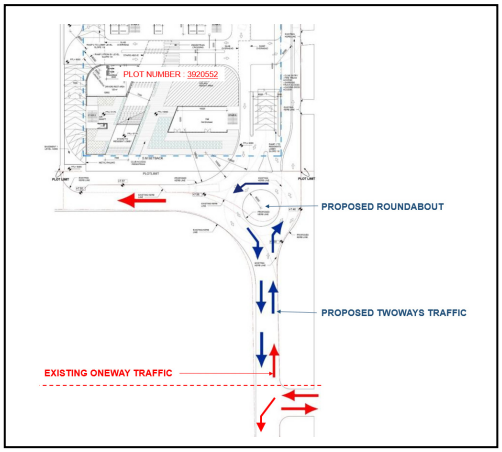


Figure 14. Project Entry

5.2.2 Infrastructure and Utility Requirements

The second challenge encountered was the availability of infrastructure services demands. This plot is considered the last undeveloped plot in the area with an original classification of Ground floor +1 allocated for a club house.

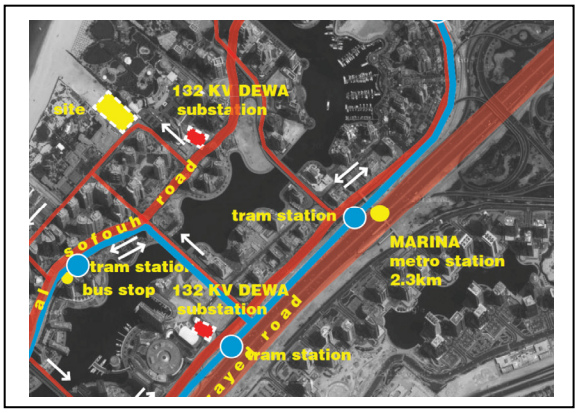


Figure 15. Surrounding Roads

So, this means that the services tapped to the plot limit will not cover the full demand required for a skyscraper. Several design workshops took place with authorities and service providers in order to secure services demands (Figure 15). This required additional investment in building new electrical substation and larger chilled water pipes to secure the required demands.

5.2.3 Vertical Transportation

The project is designed as B+G+P+47+R with 164 high-end apartments. The developer requirements were to provide exclusivity and luxury in the project. A comprehensive vertical transportation study was carried out to fulfill the design brief requirements. The recommendation was to provide 11 lifts as follows: 8 lifts, 1 service lift and 2 express and exclusive lifts all the way to the penthouses at level 46.

The production program was a crucial element in the project where it was essential to operate the first 2 lifts within one year of the construction to be used for labor and material movement. Any delay in this delivery will have major impact on the finishes schedule due to delay in shifting of materials. The challenge here was to conclude all design requirements of the elevator to allow early order of the lifts. Several design workshops were carried out at the early stage of the project in order to finalize the lift details including the cabin designs and finishes, lift buttons, final internal dimension and of course the commercial proposal. As clearly shown in Figure 16, the core and elevators consumed the majority of the core.

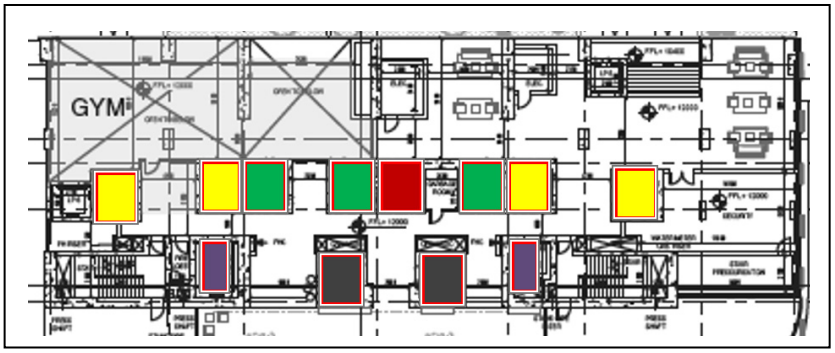


Figure 16. Lift Cores

5.2.4 Fire and Life Safety

This is one of the most vital fundamentals in designing any skyscraper. With the involvement of specialized fire, life and safety specialists, the project was studied carefully from all aspect covering the curtain wall detailing, fire stoppers on each floor, special details between the apartments, fire escape route, fire pumps were installed at the basement and at the service floors (level 13 and 31) to cover the complete building. The design had to run multiple simulations to be compliant with the civil defense authority requirements. This is a big challenge for designers where buildings have to be fully compliant with the international codes. Also, the execution of such detailing has to be fully inspected at site by attested engineers.

5.2.5 Views and Lifestyle

Another challenge for the architect in such projects is to fully maximize the views especially in such iconic location yet feasible. The plot has a full sea view where the design was based on a single loaded corridor, all the services and main core was viewing the street and the apartments have full sea view. The challenge here was structural complexity. Figure 17 highlights the main views overlooking the sea.

Figure 17. Views Analysis

5.2.6 Site Mobilization and Storage Areas

This is the first challenge faced by the contractor when taking over the site. As shown in Figure 18, the plot was so limited where the basement is built on the full land this means the plot is completely occupied. On the other hand, the plot has one access on the road and surrounded from both sides with developments. The solution was to divide the project into zones where the contractor can utilize the first part as a storage area and laydown area. Figures 18 and 19 highlights zones 3 and 4 c which were kept on hold to be used as project access. Such challenge usually is not considered during the design and is captured at site.

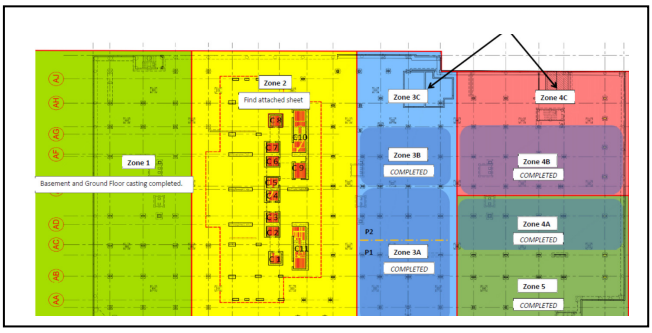


Figure 18. Logistics Plan

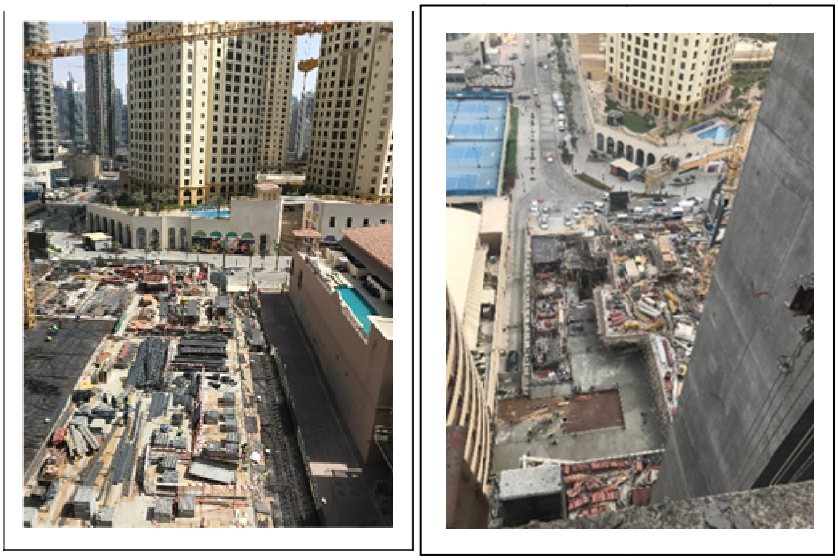
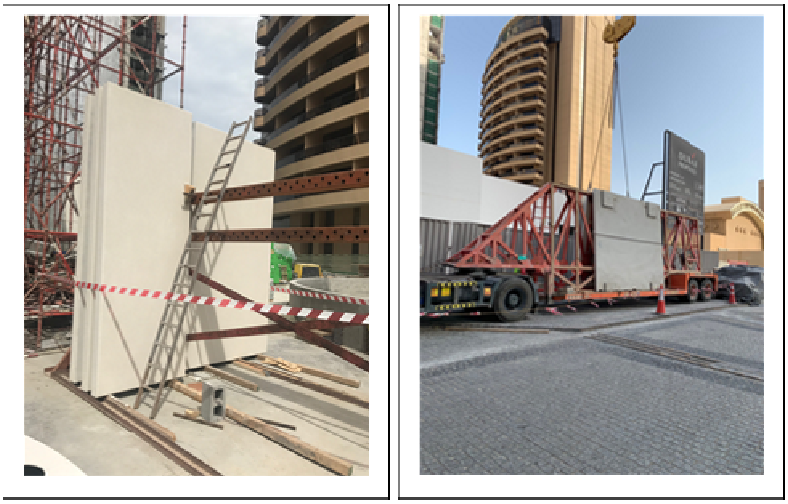


Figure 19. Logistics Plan

5.2.7 Façade Cladding

The front façade which is street facing was cladded with pre-cast panels as shown in Figure 20. The challenge started from the loading and off-loading the huge panels where the truck has a limited time to double park at the road in front of the plot as shown in Figure 21, then the pre-cast panels were stored temporarily at the podium until the panels are fixed within 12 hours to avoid overloading the podium slab. The decision to clad the building with such heavy material was to avoid future maintenance cost since the pre-cast panel requires minimum maintenance. On the other hand, the heavy wind load which will affect the tower at higher levels, i.e., more than 100m high will require steady material such as aluminum cladding or pre-cast panels.



Figures 20 & 21. Precast Panels

5.2.8 Steel Fins at the Main Façade

The building has an impressive steel fins covering the street façade. The structure has been introduced as an architectural feature also to cover the concrete solid walls behind which served as the core of the building. During the execution phase, the builder had to study and revise the method statement several times to be able to install the metal fins on the façade. Figures 22 and 23 shows the complexity of integrating the steel fins with the pre-cast façade cladding and the huge operations required for this installation.

Figure 22. Scaffolding to Support the Canopy

Figure 23. FinsSteel Structure

5.2.9 Entrance Main Canopy

Another complication was the installation of the main entrance canopy which was interconnected with the fins installed earlier on the façade as Figures 24 and 25. The canopy formed the ceiling of the entrance lobby. This connection has created a construction complication at site since the full steel structure has to be completed at the same time before removing the scaffolding supporting the canopy and starting the entrance lobby works. In the opinion of the author, this could have been designed in a less complication form by introducing a free-standing canopy on columns and not a cantilever type.

Figure 24. Canopy installation

Figure 25. Canopy steel structure

5.2.10 Staggered Balconies Design

At the back side of the building, an astonishing view towards the sea is facing the skyscraper which the design has successfully managed to fully capitalize on this view by opening the building from the rear façade and introducing a full curtain wall with generous 3m cantilever balconies. The balconies were staggered and not aligned in the same vertical direction as shown in Figure 25. The design intent was to have a vibrant façade and to avoid a boring office look and feel. This un-unity in the balcony locations have introduced a major challenge during construction where the builder was unable to unitize the construction method through mast climbers or normal cradles to execute the works. The solution was to erect scaffolding and formworks for each set of balconies all the way to the last balcony in the building as reflected in Figure 27. This had time impact throughout the construction duration and has caused unnecessary construction challenge.

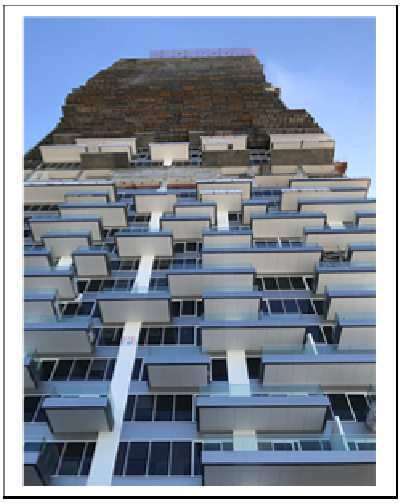


Figure 26. Balcony Design

Figure 27. Scaffolding for the Balconies

From the author's point of view, the designer could have introduced a simpler design solution which can represent the design intent in several areas that could have had negative cost and time impact. Finally, much more challenges and difficulties were encountered during the execution of this project which were thought of by the team to make sure the project is moving on time and budget. Multiple discussions and workshops took place in order to come up with the most possible solutions. The project started to take shape as the construction is progressing as shown in Figures 28 and 29, yet, many issues to be resolved until the completion and handover.

6. Conclusion

The literate review discussed in details some examples of factual challenges were faced during transforming the design drawings into shop drawings then to reality. Contractors and builders need to wear the designer hat in order to understand certain details. Also, the architect needs to visit the site regularly to make sure his details are well understood and executed.

7. Recommendation

Skyscrapers design is a challenging task to the architect from all aspects. The designer must integrate all engineering disciplines into the design to confirm the outcome is a livable, functional, feasible and on top of that great architecture. Utilities demand, location and access are major factors that should be taken into account during the design process. Once the project moves to execution phase, different type of challenges will be encountered by the team. The surrounding of a skyscraper plays a main role in defining the challenges and risks. Designers need to understand the location and site during the design stage. Also, it is recommended to conduct several discussions with contractors to integrate their comments in the design. Some design and architectural elements introduced in the design may have great cost or time impact during execution. Such elements may require extensive detailing or even redesign to come across unnecessary complication.

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