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THE LACK OF FIRE SAFETY KNOWLEDGE AND IMPLEMENTATION THE CASE OF HIGH-RISE BUILDINGS

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Abstract

High-rise buildings are growing rapidly in number around the world. They are becoming important landmarks that mark out certain geographical areas. The fires of high-rise building have many characters not found in traditional low-rise buildings, like the variety of blazing factors, ways of fire spreading, and difficulty of evacuation. Hence, the protection features of conventional fire methods are not sufficient in designing towers. The paper, at first, summarizes the characteristics of high-rise buildings and fires, the unique features of Tall Buildings and the special life safety requirements for the high-rise buildings. Consequently, the topic of fire and life safety codes implementation during the design and construction phases should be brought to the forefront into the building design process, in order to improve the skills of architectural engineers concerning the integration of safety and fire protection methods.

Then, case studies have been selected from PETRONAS tower Malaysia, MARINA tower Beirut, and BURJ KHALIFA ,UAE; which are designed by various legislations. This shows that there is a direct link between design outcomes and the legislation of buildings.

Keywords

Architecture, high-rise building, Design Process, Life safety, fire saftey

1. INTRODUCTION

In regard to the National Fire Protection Association (NFPA 2012), towers are specified as "buildings greater than 75 feet (approximately 23 m) in height where the building height is measured from the lowest level of fire department vehicle access to the floor of the highest occupiable story". The long vertical distance makes it particularly hard for occupants to arrive at the ground level safely in shorty time. A large number of pedestrians meet at some intersections which may lead to congestion, and hold-up the egress progress. On the other hand, extended exposure to heat and smoke cause disablement or death. Hence, the topic of fire and life safety codes implementation during the design and construction phases should be considered. The architect considers several factors throughout the design process of a building. The most important ones are: the design layout, the functional requirements or purpose, the position of building elements and components, and the specification of building materials. All are essential measures needed to reduce the risk of incidences of fire, whether the reason goes back to negligence, accidents or deliberate actions. The architect also needs to ensure that the spread of fire is reduced by providing sufficient routs of escape in the incidence of fire, and the protection of buildings' structural elements. The architect is desired to join all relevant information by standards and codes of practice and regulations relevant to buildings' fire safety. Architects sometimes consider that it is better to resolve building code issues at the end of their design process, once all architectural ideas are completely formed. However, early understanding and integration of code-compliant design provisions during a project diminishes the need for costly and time-consuming rework in project documentation, or throughout construction. An understanding of how code officials view buildings is essential for taking proper code decisions at early stages of the project. Therefore, this paper aims to raise awareness about the role of architects in the fire protection during the design of buildings through the integration of life safety into the design process.

2. HIGH-RISE BUILDING

A *high-rise building* is defined in Chapter 2 of the IBC (international building code) as a "building with an occupied floor located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access." The height shall be determined from the level that can be reach by the fire vehicle and the top occupied level (figure 1). High-rise buildings impose more life safety challenges in comparison to traditional low-rise buildings in terms of: extended egression of time and distance, conductivity of fire department, evacuation strategies and direction of smoke and fire control. A tall building consists of multiple floors leads to a greater number of people to go on stairs longer vertical distances for achieving building evacuation. Fire safety in tall buildi public, and local, regional and federal governn and build communities (Website 1).

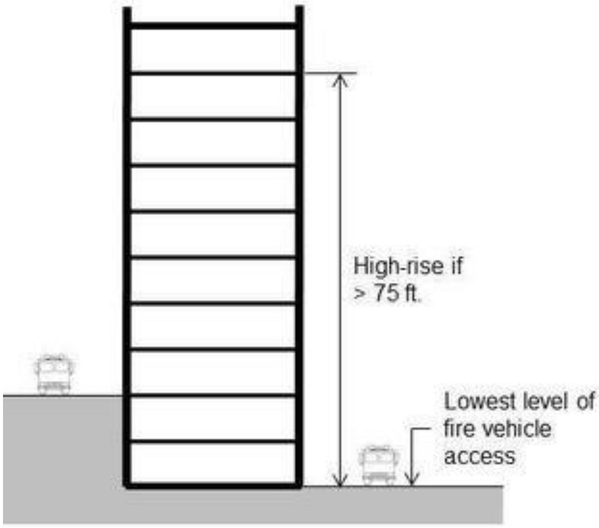

Fig.1: High-rise building definition
Source: www.specsandcodes.com

3. TALL BUILDINGS IN NUMBERS WORLD'S HIGHEST OBSERVATION DECKS

Tall buildings are famous for their observation decks. It is often considered a substantial source of revenue for their structures as shown in figure 2. People enjoy the charming views of the cities from the observation decks, and it can even affect the international reputation of the cities. Others choose to include all forms of amusements, such as roller coasters, glass floors, and bungee jumps (Website 2).

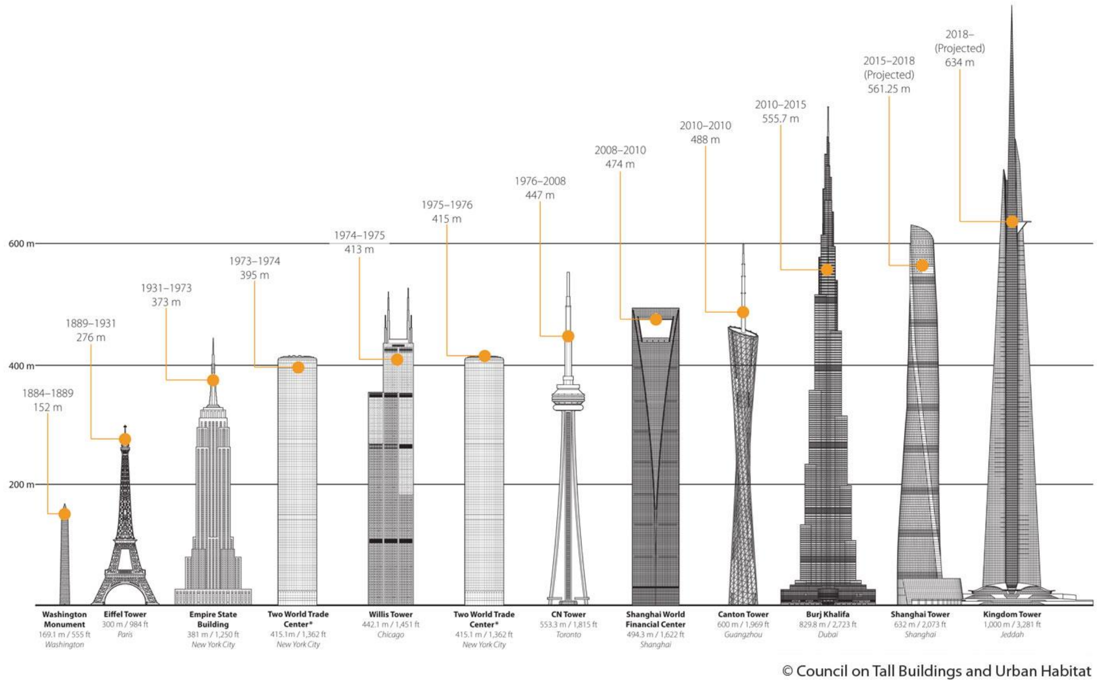

Fig.2: Tallest Buildings Around the World
Source: www.ctbuh.org

4. CHARACTERISTICS OF HIGH-RISE BUILDINGS

Tall buildings have three characteristics (Liu, X., Zhang, H., & Zhu, Q. 2012): Construction structure is sophisticated considering its high height, podium, and the number of floors. The density of the population is elevated and the functions are complex, including residential building, hotel, office building, store, etc... Combustibles are multiple and fire load is huge, including combustible decorative material, such as wall cloth of plastic, curtains, ceilings, wallpapers, etc. Characteristics illustration from above are as follows:

4.1. Fire Spreads Quickly

Tall buildings consist of several staircases, air passages, cable shafts, pipe shafts, elevator shafts, and other vertical shafts. Fire departure must be arranged rationally, or else they will become routs to disperse fire, particularly in libraries, hotels, office buildings, and other tall buildings. Due to the found inflammable material, combustion will reach high intensity and expand quickly, the moment it catches fire. As a result of air convection, the horizontal velocity of smoke diffusion is 0.3 m/s within the premier stage of fire, while it can reach up to 3-4 m/s in extreme cases. Smoke will diffuse to the highest floor by the vertical shafts in 30 seconds, where its velocity is 10 times more than that in the horizontal direction, for a building of 100m in heights, as soon as it catches fire. UAE where there are many tall buildings has suffered a spate of fires in its high-rises in recent years including the latest fire on The side of the 48-floor Abbco Tower in Sharjah, which neighbors Dubai, saw flames shoot up them.

4.2. It is Difficult to Evacuate

High-rise buildings have several floors with long vertical dimensions, and hence will take much more time to evacuate, taking into Consideration that the density of the population is condensed. Furthermore, the moment it grasps fire, air flow is reopened and fires and smoke will expand rapidly, making it hard to evacuate. Certain developed cities buy some lift-up fire engines. Yet, the major cities with tall buildings don’t have them, because their height does not meet the demands of safe evacuation. In general, common elevators can't maintain power fails nor fires. Thus, the stairs are used to evacuate in the majority of tall buildings. Where this is a challenging task especially when the staircases are filled with smoke.

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4.3. It is Hard to put out the Fire.

High-rise buildings' height can range from tens to hundreds of meters which makes it harder to put out the fire. Thus, we should rely on self-save meaning that we should expel fires through indoor fire systems. Because of the economic and technological limitations, the indoor fire systems of high-rise buildings are not ideal, especially for the second class of high-rise buildings. Several factors make it harder to expel high-rise buildings' fires such as the lack of firewater, strong thermal radiation, and the speed of fire spreading.

5. UNIQUE FEATURES OF HIGH-RISE BUILDINGS

The following features of Tall buildings might adversely impact the fire safety of a building(Quiter 2012):

5.1. Height Beyond Available Resources of Fire Department Ladders

Standard fire department aerial ladders can possess an efficient reach that recognizes a setback distance from a building.

5.2. Extended Evacuation Time

Completing building evacuation increases in time as the height of the building increases.

5.3. Pronounced Stack Effect

The stack effect occurs in tall buildings. A pressure difference in their height is noticed, as a result of temperature changes between the temperature of the air outside the building, and that inside the building.

5.4. Water Supply Limitations

The needs of water supply in high rise buildings might exceed the capability of water supply of fire department pumpers and public mains.

5.5. Greater Challenges of Mixed Occupancies

Several high-rise buildings have diverse occupancies, including retail, residential, automobile parking, business, public assembly (e.g., restaurant), transportation facilities, educational, health care, and correctional and storage. The fire protection systems offered by those occupancies are more challenging when they are settled in tall buildings.

5.6. Iconic Nature

Though a building doesn't need to be tall to be iconic, high rise buildings are considered iconic in general, because they are extraordinary in height, design or other features.

6. THE PURPOSE OF LIFE SAFETY CODE

NFPA 101, 2012 edition *International Fire Code 101.3 stated that the aim of the code was to establish the minimal requirements consistent with good practice for providing protection from the hazards of fire, and a reasonable level of life safety, explosion or dangerous conditions in buildings and premises, and to ensure safety to fire fighters through emergency operations. The implementation of Fire safety codes leads to avoiding loss of life when fire happens in a structure. The global fire protection association has invested wide effort to advance building fire safety. Fire codes around the world have begun to go hand in hand with the local construction codes in an effort to reflect and make use of this new knowledge the fire codes selection is dependent on the region and country where different countries have their own codes. The fire and life safety codes and guidelines are used in some countries around the world while most countries especially Africa and Asia lack proper safety and fire prevention codes which meet international standards. NFPA can play a significant role to protect lives and property and in this paper we emphasize on its implementation (Website 3). Explicitly NFPA have invested huge effort during the last 20 years to strengthen codes and standard for first responder safety, the built environment, emergency preparedness, and more (NFPA Journal®, September/October 2011).

7. BASIC FACTS ABOUT CODES

There are basic facts about codes that establish minimum standards (Rowland J. Mitchell). Based on our professional judgment, it is our duty to surpass minimum code requirements, when applicable. Similar to the registered design professionals, authorities having jurisdiction are designed to safeguard the public health, welfare and safety. For a project to be occupational under the same edition of the code, it should be reviewed constantly, authorized, investigated, and legalized. Don't choose nor let the reviewing agency to select the best provisions from other code editions. Some jurisdictions consider two codes. For instance, the building department can use the International Building Code whereas the fire department can use the International Fire Code. In similar cases, more restricted provisions are to be applied. These regulations are purposed mainly to reduce the risk of insured loss. However, those codes foremost exist for people protection.

8. BALANCED FIRE PROTECTION IN BUILDINGS

Nowadays it is common for architects and designers to be involved in global projects (Alfredo Ramirez 2014). Their projects include materials such as steel building component members, gypsum walls, glass curtains, wall finishes, etc... Architects and designers provide balanced fire protection in buildings through the use of a mixture passive and active construction methods and systems in collaboration of a high performance MEP systems for high-rise building. The (ctbuh,2017) provides additional guidance on this topic. The goal of balanced fire protection within high-rise structures is to provide life safety solutions for the building's inhabitants and property protection. These are top of mind necessities for building owners, occupants and investors.

9. DESIGN USING FIRE SAFETY REGULATIONS

When starting a project, design and authenticate all agencies that have jurisdiction with all their acquired codes. When an updated edition of a code is out, verify with the convenient agency the timesheet for its acquisition, because it should be active when the project requests for the building's permit. Since projects are round-the-clock, there is an extended period of time for code transition. There is no specified time to drive a code search; when the design is developed and refined, several parts of the search must be managed at different stages (Mitchell and Bruckner Coles 2004):

9.1. Schematic Design

Set up factors that influence the facility's design, including types of the occupancy, construction type, limitations of height and area, requirements of egress, fire protection systems, and accessibility.

9.2. Design Development

Verify factors developed in schematic design and affirm further code factors that impact buildings' systems, including fire separations and stoppage, roof coverings, and accessibility.

9.3. Construction Documents

Assure compliance with particular factors such as UL design of assemblies related to fire, opening protective, interior finishing classifications, etc...

After finishing the schematic design or during its development, form a code compliance plan and meet with the convenient agencies. This will allow feedback from the code official, which helps avoiding big surprises at building permit time, and encouraging them to be part of the design process. In all scenarios, don't forget to document. Your documentation might not stop the agency from making updates, but it will certainly reassure to the owner that you are doing the job well. This will ensure procurement of additional fees for code changes, a much easier task according to the standard owner-architect agreement. Variations providing life safety are often taken into consideration, although the final decision goes to the code official. Try to always comprehend the code being conveyed by the letter of code. Additionally, ask the code official to cite the article and paragraph of the code, if you think they requested something that is not a particular code item. The need for fire and life safety recommends a fire safety education for architects and engineers under different modules. Fire safety education delivers architects with a good understanding of fire safety codes leading to help them integrate their intentions into early stages of the project and turn them into opportunities for creativity (EBENEHI, 2016).

10. DESIGN CRITERIA OF FIRE SAFETY IN THE HIGH-RISE BUILDING

The high-rise building requires special fire safety requirements that highly change from the low rise building.to ensure a safe and healthy living. Several unique challenges selected the design criteria of tall buildings as indicated in table 1 below. Each case study should adopt their local applicable fire safety codes requirements. Each codes have precise sets of requirements regarding tall buildings. Ensuring the fire safety of buildings is a complex issue which are intended to protect against loss of life and limit fire. For example, in the case studies considered in this paper there are several commonalities between life safety codes adopted as summarized in table 1 (Website 4).

Table 1: Design Criteria
Source: The author

Type of Construction-fire Resistance (Construction type, allowable height, and area)	Compartmentation (Exposures/separation requirements)	Refuge Area (Exits ,exits remoteness, & area of refuge)	Occupant Evacuation		Firefighting Operation	
			Smoke protected exit stairs	evacuation elevators	Firefighting accessibility	Fire command center

In this section we will analyses the fire safety in 3 case studies including Burj Khalifa in Dubai, Petronas Tower in Malaysia and Marina Tower in Lebanon. These case studies were selected because first Petronas was the tallest building in the world in 1998 where the fire safety standard was carefully followed but it was less developed compared to the case to Burj Khalifa, which became the tallest building in 2004 and it followed a strict fire safety standard, that was well developed. Finally, the case of marina tower is selected as the tallest building in Lebanon and to show the case of not following and implementing a strict fire safety standard.

10.1. Burj Khalifa

The Tower of Dubai known as Burj Dubai, acquired the reputation of the longest man-made, freestanding structure worldwide. The building holds hotels, restaurants, offices, a mall, and residential housing that fills its 162 floors. Thousands of people are estimated to be occupying the building each day. Disregarding the specifics, the sheer magnitude of the structure is likely to complicate the motion in the building. The future residents look forward to be able to reach their destination floors and locations safely with minimal delay.

10.1.1. Design Concept

The design team of Burj Dubai aimed to construct and maintain a structure that would be steady and self-sustaining at record-breaking heights. They also strived for ultimate occupants' satisfaction, and making them feel safe while enjoying unlimited services of the edifice. Adrian Smith, the architect (2008), elaborates his concept by mentioning that in the development of Burj Dubai's design, he looked up for elements within the existing culture of Middle East and Dubai to reflect on and take inspiration within it. He says that there is strong impact of pointed arches and onion domes, and that there are patterns that are indigenous to the area, some of which are flower-like elements. Furthermore, he mentions that other impacts extend from spiral imagery and philosophy established in the iconographic architecture of the Middle East, further elaborating that these motifs are based in organic growth structures and plant materials, and that the overall composition is a vertical object diminished and with spiral reduction modification of branch lengths until it reaches its central shaft. At this point the shaft peels away to reveal an arrangement that wears away in a spiral manner reaching a single spire.

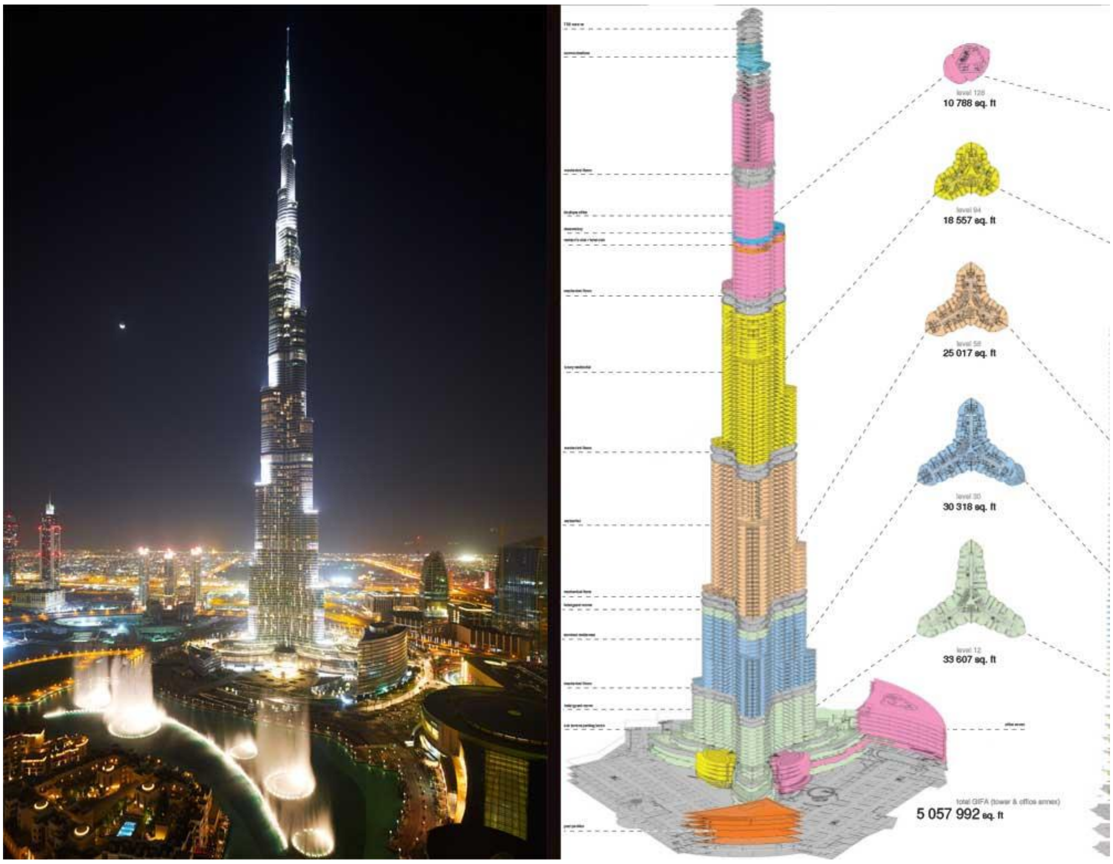

Fig.3: Burj Dubai Profile
Source: www.old.skyscraper.org/

10.1.2. Evaluation of the Fire Safety of the Burj Dubai

Burj Khalifa, shown in figure 3, was designed to be the centerpiece of a large-scale, mixed-use development to include 30,000 homes[citation needed], nine hotels (including The Address Downtown Dubai), 3 hectares (7.4 acres) of parkland, at least 19 residential skyscrapers, the Dubai Mall, and the 12-hectare (30-acre) artificial Burj Khalifa Lake. The Burj Khalifa is being designed according to the IBC (international building code) with an incorporation of the British standard to provide a safe environment to the occupants (John Evenson 2008). The safety of future occupants was greatly taken into consideration by the designers of the tower. There were many materials related to the safety features, to make sure the building's floors are highly safeguarded from fire. Personnel of crisis department can easily access all building levels through the use of elevators and staircases. On the contrary, the innovative maneuverability supplies quick evacuation, while making sure communication is open, and that the spread of smoke is confined.

10.1.3. Safety Considerations

a. Type of Construction

The most important aspect of the structural integrity of Burj Dubai is the advanced modes of concrete design applied. With more than 330,000 m3 of concrete spread through the 162 building (Burj Dubai, 2007). The concrete mixtures have to be powerful enough to handle the compressions of the massive skyscraper, and able to reach world record heights without losing any of its properties. This concrete design task was the most complicated, because of the hot temperatures of Dubai, and enormous height of Burj Dubai.

b. Compartmentation

Burj Dubai is supplied with several smoke-resistant features. For instance, the building is supplied with pressurized exit stairs. It act simultaneously, and is designed to operate instantly when a fire alarm drops out, either manually, or from the fire detection system. Every floor is outfitted with a smoke chamber that withholds smoke. Lastly, a smoke control panel will be given to paramedics and firefighters. This ensures that emergency employees can manually adjust the smoke control systems.

c. Areas of Refuge

The design of the tall buildings includes strategically located areas of refuge that ensures evacuation is controlled. As shown in figures 4 and 5, the typical area of refuge will be able to resist smoke from spreading, due to having fire related exit stairs enclosed by doors.

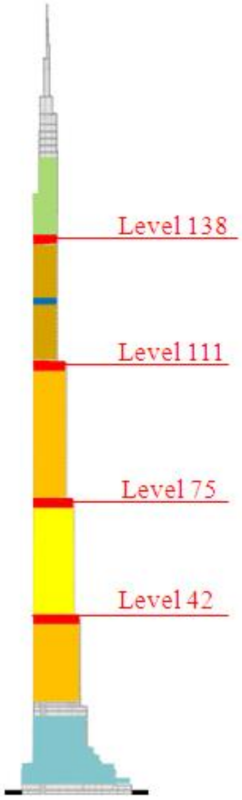

Fig.4: Refuge Floor
Source: Rolf Jensen & Associates, Inc.

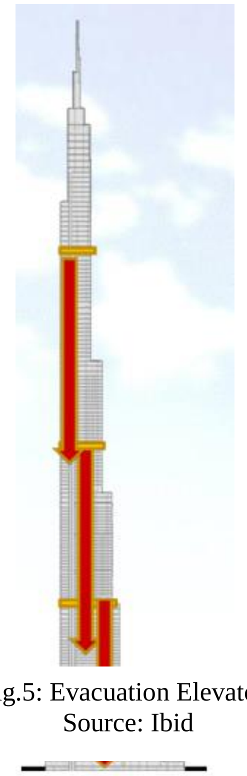

Fig.5: Evacuation Elevators
Source: Ibid

Building personnel are to be trained to direct evacuees. Additionally, the areas of refuge are designed to link to several stairwells. Meaning that occupants will not likely to be trapped, because they can be directed down to the lowest risk passage. where the places of shelter are lit by emergency lights, well ventilated, and masked by fire resistant concrete.

d. Occupant Evacuation

Occupant evacuation is a challenging concern given the height of Burj Dubai. Hence, residents will need information on the situation, mechanical assistance to speed the process, and stairwells and safe zones in the event of mechanical failures, due to the massive climb. Although full building evacuation might not be required in case of fire, it is essential for it to be applicable in tall buildings.

e. Fire-fighting Operation

Burj Dubai is supplied with several smoke resistant features, that are programmed to run automatically and act jointly when a fire alarm is triggered by the fire detection system, or manually.

10.2. Petronas Towers

The Petronas Towers located in the commercial district of the city known as the 'Golden Triangle' were designed to be the centerpiece of a wider complex called the Kuala Lumpur City Centre (KLCC), a mixed-use development with a site area of 14.15 acres, that includes the Petronas Towers, two office towers, service facilities and underground parking, multimedia conference Centre, Petroleum Discovery Centre, an art gallery, and a concert hall. A multi-story shopping and entertainment galleria links the twin towers at their lower part to integrate with the whole complex. Rising 452 meters, these twin towers were recognized as the tallest worldwide from 1998 to 2004, being 88 stories high of 218,000 square meters of floor space each. The towers are linked by a sky bridge at the 41 and 42 floors, to smoothen inter-tower traffic.

10.2.1. Design Concept

Designed by Cesar Pelli, it was set as an architectural and cultural symbol in Kuala Lumpur, evoking the richness of the country by reflecting the dominant Malaysian Islamic culture. Pelli's conceptual efforts in integrating Islamic motifs and symbols into the towers design impacted the building details, and made it not only recognized for their height. An essential symbol found in the Islamic cultures called the Rub el Hizb, that is recognized by two overlapping squares, one of which is rotated 45 degrees, with a circle inscribed in the center, was used by pelli, as a mean to develop the building plan ending in two extruded 8 points shape. The designer "scalloped" the pinpoints to develop an elegant ornamental found in many Islamic motifs, rather than just leaving it as an extrusion of a preexisting symbol.

10.2.2. Evaluation of the Fire Safety of the Petronas tower

Kuala Lumpur City Centre has built a mixed-use development including shopping mall, a five-star hotel, and an 864-seat concert hall for the Malaysian Philharmonic Orchestra and an enormous mosque hand decorated by Uzbekistan craftsmen. The PETRONAS Twin Towers were constructed to meet the requirements of BS 5588 part 5: Fire Precautions in the Design, Construction and Use of Buildings -- Access and facilities for firefighting (1991). Seeking conformity with the Malaysian codes, was the conceptual approach for the fire protection and life safety plan, specifically the building by-laws for the federal factory territory of Kuala-Lumpur. Where it became essential for the design to deviate from the code requirements, by using alternative reference codes to achieve a corresponding level of life safety qualifications.

10.2.3. Safety Considerations

a. Type of Construction

The most considerable foundation in the world of depth 120 meters (approx. 400 ft.) holds the Petronas Towers. The two towers are constructed with strengthened reinforced concrete to decrease vibrations and structural strains from overflow winds. Each tower is supported by a ring of 16 cylindrical columns of high-strength reinforced concrete, being placed on the inner corners of the star-shaped plan, with columns connected by arched ring beams, that are manufactured of structural concrete as well. However, to magnify the building's svelte appearance, at the base of the building, the columns that measure about 2.4 meter in diameter, become narrower as they ascent between the floors, along with inclining towards the center of the towers.

b. Compartmentation

The building control system (BCS) provides central management and monitoring for air-conditioning control, lighting control, with electrical and chilled water monitoring, and energy management services. The BCS is linked to the life-safety system, which is created to override the BCS at the time an emergency occurs. In case a fire surges on a floor, the BCS permits a pressure differential between that and the adjacent floors, allowing the fire to be embraced throughout the evacuation procedure.

c. Areas of Refuge

Refuge areas joined with elevators and sky lobbies, could be safely used from sky lobbies as shown in figures 6 and 7 down below. The sky bridge became an essential feature as the project progressed, where it was not considered a prerequisite in the brief. It was comprehended that its mid-height location allows access between the twin towers as another possible exit path, which avoids adding two more fire stairs.

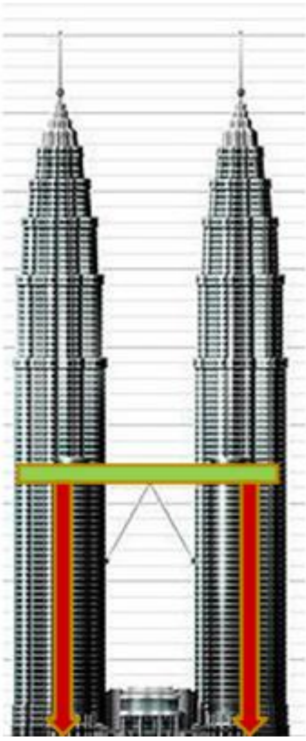

Fig.6: Refuge Floor
Source: Rolf Jensen & Associates, Inc.

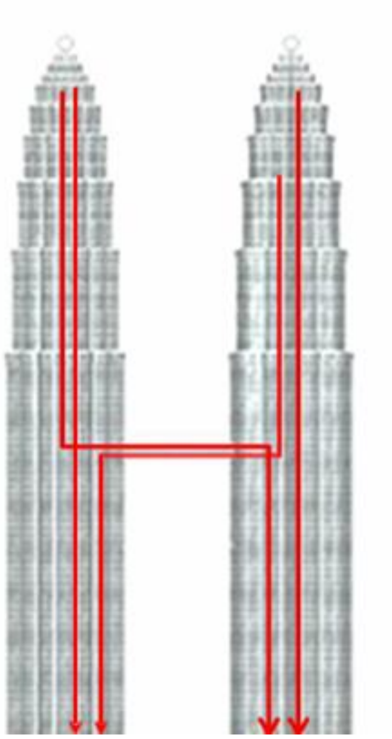

Fig.7: Evacuation Elevators
Source: Ibid

d. Occupant Evacuation

The fire safety plan of the towers is designed so that the shuttle elevators are to be in use for evacuating occupants, in case a fire took place on a floor served by the high-rise elevator banks. This plan includes occupants' relocation on the fire floor and the ones above and below. While other floors would be evacuated only when needed. Because of the zoning position of the elevator and the sky bridge, each tower can be divided into two parts at levels 41 and 42, due to a shield zone providing horizontal exit to the adjacent tower. By applying phased evacuation to the sky lobby, according to the study of evacuation, the time to clear the top three floors ranges from 69 seconds to 1.3 minutes for floors 35 to 37, and 40 seconds for floors 85 to 86. Considering the sky lobby, a safer discharge level for stairs serving the floors beyond, making the maximal overall time to egress ranges from 5.9 to 17.8 minutes.

e. Fire Fighting Operation

The fire alarm system (FAS) is created using particular fire detection systems including smoke and heat detectors, tamper and flow switches for sprinkler-system monitoring, manual call points, a public address system and a fireman's telephone / two-way intercom system. Where by each tower has its own fire alarm system that is linked via an LAN allowing management to be central at the fire command center (CFCC), and is connected to the Fire and Rescue Department of

Malaysia, that controls the fire alarm and detection systems, smoke control systems, automatic sprinkler systems, lift status, emergency power and firemen' telephone systems, located at the street level. The fire safety system is monitored and controlled through the building control system (BCS), during ordinary operations, whereas the fire alarm system is in charge in the case of fire.

10.3. Marina Tower

The Marina Towers is a residential complex designed by architects Kohn Pedersen and Fox Associates, located in Beirut Central District, Lebanon, on land area of 7000 sqm. The project is made up of three components, the Marina's Tower, Garden, and Court; on around 2000 squared meter of land. It also includes one high-rise apartment building and two mid-rise apartment buildings, duplex apartments, ultra-luxurious simplex, and a penthouse. Where the main tower is considered the highest building in Lebanon reaching 150 meters in height. The Marina tower is being designed and built before the proper implementation of fire safety and fire preventions requirements in Lebanon.

10.3.1. Design Concept

On the radial axis of the harbor, the orientation of the Marina Tower is positioned, emphasizing its vibrant connection with the Beirut Western Marina. Embracing the naturally waterfront architecture rounded forms in the design of the structure where a crescent shape has been used, giving each of the apartments with an outstanding scene to the sea, the Marina, the mountains and the Beirut Central District Park. The clean-lined architecture extends 150m above sea level composed of 26 floors. Where the structure is basically made from stone and clear double-glazing with aluminum curtain walls that stretches along the building. However, a nearby floating slip can be used by occupants who owns boats giving them means of entry to the sea.

10.3.2. Evaluation of the Fire Safety of the Marina tower

Marina Towers project is a residential complex. Lebanon's building code that was amended in 2004, requires new construction safeguards against fires, collapse risks, and earthquakes. However, the tower was built in 2008 before the actual application of the fire safety codes in Lebanon. Whereas the design should include measures to control fire spread, channel smoke out of the building and make residents escape in a short period of time. The breach found between fire codes and implementation in Lebanon run to leading code enforcement before beginning construction.

10.3.3. Safety Considerations

a. Type of Construction

The tower is built with reinforced concrete core and held by a ring of twenty-two high-strength cylindrical reinforced concrete columns, set on the surrounding facades with a module of 4.5 m. Where the columns become taper as they rise up by the floors, beginning with 1 meter in diameter at the building base.

b. Compartmentation

According to the construction drawings stairs were required to be constructed from "fire resistant materials", nevertheless separation from the rest of the buildings was not mentioned, in which the stairs shared a common landing, meaning that in case smoke enters the shaft it makes both staircases inaccessible. In which the location of stairways shall be as far apart as possible, leading to separate exits. On the other hand, the parking area should be separated by 2-hour fire rated walls.

c. Areas of Refuge

Area for refuge was not provided in this building.

d. Occupant Evacuation

Elevators for Evacuation is not provided. Whereas, the escape stairs are not pressurized and poorly naturally ventilated. Regarding the basement users, it is not provided with protected lobbies to reach the exits.

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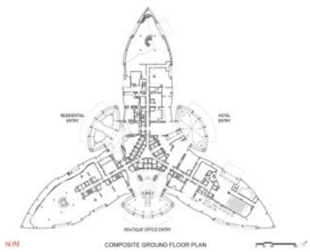
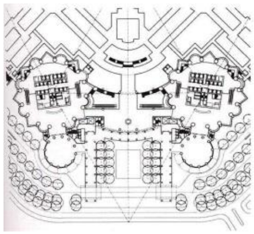
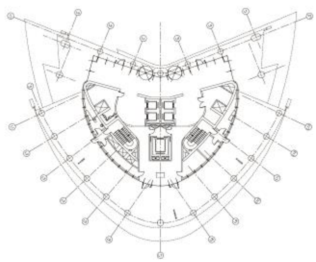
e. Fire Fighting Operation

The building is lacking a firefighting shaft

A number of fundamental challenges that almost fire safety codes enhance to be implemented to provide a reasonable level of safety from fire and its effects. The table 2 shows the comparison between the implementation of these design considerations for high-rise structures including egress points, emergency systems, and structural integrity (Website 5).

Table 2: Comparison between the Three Case Studies
Source: The author

	Project	**BURJ KHALIFA**	**PETRONAS TOWER**	**MARINA TOWER**
Basic information of Case Studies	Architect	Adrian Smith	César Pelli	Kohn Pedersen Fox
	Date	2010	1996	2008
	Location	Sheikh Mohammed bin Rashid Boulevard, Dubai, United Arab Emirates	Jalan Ampang, Kuala Lumpur, Malaysia	Beirut, Lebanon
	Height	828 m The highest occupied floor is 88th floor at 535meters high	378.6 m The highest occupied floor is 88th floor at 375 meters high	150m The highest occupied floor is 26th floor at 122 meters high
	Project's photo			
Plan of the case study				
Refuge Areas		Provided	Provided	None Provided
Fire Resistance		Columns: 3 Hours Floors: 2 Hours	Columns: 3 Hours Floors: 2 Hours	Columns: 2 Hours Floors: 2 Hours
Compartmentation Occupant Evacuation	Fire Compartment	1 per floor	2,000 m² in office	Not noticed
	Smoke Compartment Size	1 per floor	2,000 m² in office areas	None noticed
	Fireman's Elevator	2 to most levels 1 to every level	2 provided	None Provided
	Smoke Protected Exit Stairs	Pressurized	Pressurized	Poorly naturally ventilated
Fire Command Center		Primary and Secondary Provided	Provided	provided

Buildings are built to different standards, the response by the fire service is different. There are so many ways in which each country require a different approach to fire safety.
The implementation of the safety requirement affects the buildings design concept. Burj Dubai and Petronas tower are considered to be safe buildings in regard to fire and wind. In which occupants can be assured that the buildings are stable and well handled in the case of crisis. However, the Marina tower would benefit from improving the fire safety requirements, to eliminate the chance that the occupants might be stuck in the building due to the absence of certain fire safety requirements.

11. CONCLUSION

To sum up, the fire safety legislation influences significantly the design of high-rise buildings. Consequently, in any tall building the fire safety needs a fusion between submissive fire protection and functional fire precautions making altogether a structure that allows it to mask fire and provide ways of escape for the building residents. Based on the case studies we considered in this paper, we can conclude that having a national fire safety guides which is followed and enforced by authorities is fundamental to ensure the safety of residents. More specifically the example of Burj Kalifa which had high standard of safety requirement, had several fire incidents without any loss of life.

Fire safety in buildings can be significantly improved by advanced design and construction. Therefore, fire service should follow the demands of the emerging technologies in buildings by periodically reviewing the latest techniques and equipment's adapted.

Additionally, Fire safety education provide people with good knowledge of fire prevention and protection and create awareness among young people on the need to implement the fire safety requirements.

Accordingly, architects, engineers and fire professionals need to communicate to update their fire safety knowledge. Finally, if we aim to improve the buildings and environment safety, we should comprehend safety schemes, initiatives, strategies and new products that have been adopted all over the globe.

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