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LIFE SAFETY SYSTEM DESIGN FOR THE PETRONAS TWIN TOWERS

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1. Background

One of the early design meetings for the PETRONAS Twin Towers was held in New York on the date of the first explosion at the World Trade Center in February 1993, when a truck packed with explosives detonated in the basement of the North Tower. The explosion took out sections of three structural slabs but did little damage to the structural columns. This incident brought an end to the age of innocence and the possibility of terrorist attack all of a sudden became a new reality.

By that time, most of the decisions regarding the structural design of the PETRONAS Twin Towers were already made, and piling was about to begin in two months. The World Trade Center suffered limited structural damage from the explosion. Most of the chaos was caused by the confusion in the evacuation. In view of this fact, the consultant team therefore focused its attention on the enhancement of life safety systems, to ensure an expedient and safe evacuation process in the event of emergency.

2. Design Requirements

The conceptual approach to the Fire Protection and Life Safety Plan was to seek compliance with existing Malaysian codes, namely the Building By-Laws for the Federal Territory of Kuala Lumpur (UBBL) 1985 and its amendments up to March 1987, the Uniform Building By-Law 1984. Where it became necessary for the design to deviate from the code requirements, alternative reference codes were used to achieve an equivalent level of life safety requirements. Major US codes such as BOCA National Codes and the National Fire Protection Association (NFPA) Standards were used as reference standards.

Malaysian code requirements rely heavily on passive measures; their governing principles are very similar to those of British standards. The provision of egress capacity is based on the "X-1 Principle", namely: in the event if one of the stairs is out of service, the rest of the stairs should have sufficient width to accommodate 100% of the occupant load of a floor. US codes do not require this reserve capacity approach.

2.1. Egress

In the calculation of egress capacity, Malaysian code assumes a rather conservative occupant load requirement, about 40% higher than the population density of the actual occupancy. The largest net floor area at the PETRONAS Twin Towers is around 2,400 square meters (excluding the area of the building core) and this results in an occupant load of approximately 240 persons, based on an occupant load of 10 square meter of net usable area per person.

The capacity of stairs, doors, horizontal exits and corridors were determined on the basis of 100 person per unit of exit width. This number is based on a 2½ minute evacuation time, assuming an exit capacity based on 40 person per unit per minute, on a phased approach for evacuation. Each width was measured in units of 550mm or half units of 300mm.

There are minimum of two paths of egress on every floor. UBBL established a maximum travel distance of 60 meters for office occupancy. UBBL also established that the two adjacent exit paths must be at least 4500mm apart, and that the angle subtended by the egress stair to any point of the opposite perimeter wall should not be less than 45 degrees.

Based on these requirements, the lower floors of the PETRONAS Twin Towers are equipped with two 1400mm-wide stairs (two-and-a-half units) located at the core plus a third 1100mm-wide stair (two units) located at the bustle. There are two fire compartments, with an-hour-and-a-half fire separation, at the lower floors. The upper floors, because of the smaller floor plate sizes, are equipped with only two 1400mm-wide egress stairs. The two 1400mm-wide stairs are equipped with firemen's lifts for the exclusive use of firefighters.

2.2 Life Safety Design

The life safety design for the PETRONAS Twin Towers relies on a combination of passive and active measures. While it was recognized that the Kuala Lumpur Fire Authority (BOMBA) has responsibility to provide fire response services to the Project, it was intended that they be the second line of defense. The first line would include features integral to the design of the building to minimize the risk of a fire occurring, and to minimize its consequences. They include:

(a) Automatic fire detection systems designed to provide early warning.

(b) Automatic sprinkler systems designed to respond quickly with an appropriate water supply and distribution system to control or extinguish a fire in its early stages. Totally independent sprinkler and wet riser systems were provided, each with its own risers and pumps. The water storage required for both systems was combined.

(c) Smoke management system designed to minimize the spread of smoke and to provide for safe use of egress facilities. Smoke extraction system was designed to provide adequate pressure differential between the floor on fire and the adjacent floor and staircases. Smoke would be exhausted from the fire floor at a rate of 6 air changes per hour, and make-up air to the fire floor would be supplied from the staircase pressurization system and by infiltration from adjacent non-fire floor.

(d) Exit and egress facilities designed to provide for movement of individuals threatened by a fire to an area of safety within the buildings, or to the outside. All egress stairs are pressurized. Stair pressurization system was designed with a maximum capacity of having four sets of doors opened at one time, namely, one at the fire floor, one above the fire floor, one below the fire floor and one at the ground floor.

(e) Fire communication systems designed to direct fire response and occupant evacuation in the event of fire detection. They include: public address, fire brigade communication, sprinkler water flow detectors, fire detection and alarm systems, elevator status, smoke control fans and emergency power status.

(f) Fire containment features designed to maintain the integrity of structure and egress paths under fire conditions.

(g) Command and control centers and Fire Department access facilities designed to provide the responding fire brigade with an effective means to access the building.

(h) Emergency power system designed to supply power to the following: smoke control fans in operation for a single smoke control zone, emergency illumination, fire alarm systems, fire pumps, public address systems and fire lifts. Emergency systems were designed to have enough capacity and rating for the emergency operation of all equipment connected to the system including the simultaneous operation of all fire lifts and one other lift.

One of the complaints cited at the World Trade Center evacuation was the difficulty in walking down a hundred storey building. In the PETRONAS Twin Towers, we took advantage of the sky lobby and the sky bridge located at Level 41 and 42, as a place of refuge and as a means of horizontal discharge. In the event of emergency, occupants at the upper floors will walk down to the sky lobby, which is completely pressurized. Occupants could then either take the express shuttle lifts to the street level or escape across the sky bridge to the adjacent tower.

3. Design Improvements

In view of the World Trade Center incident, the consultant team identified areas which could be further improved, focusing primarily on the provision of redundancy and back-up in system design, as well as the isolation and physical compartmentalization of essential equipments.

3.1 Stair pressurization fans

In the original design, each stair pressurization system was designed with three fans, located at each of the mechanical rooms at Level 6, 38 and 84, and each has a capacity of one third of the load. The fans were re-designed so that each would serve one half of the load to ensure sufficient air would still be provided to the stair enclosure in the event of a fan failure.

3.2 Transformer room construction

The transformer room enclosures were changed from rated dry wall construction to concrete block work or reinforced concrete to provide additional protection.

3.3 Wet fire protection

The initial design was based on independent wet fire system serving each tower. The system was re-designed so that the two towers would be inter-connected to provide back-up in the event of fire.

3.4 Emergency generator separation

The generators were re-designed to size for a combined load, with synchronizing switchgear and controls to come on line for a two-tower emergency conditions, or de-coupled for a single tower operation.

3.5 Stair back-up lighting

The stairwell lighting systems were designed with normal power and emergency generator power in the event of power failure. In addition, we decided to introduce an additional battery back-up system located on each floor to provide a tertiary source of power for the egress stairs.

3.6 Switchboard isolation

The 11KV switchboard was initially configured in a double-ended formation, with a normally open bus-tie-coupling breaker connecting the two switchboards. The design was revised to introduce a physical separation for each switchboard, reducing the possibility of losing the entire switchboard.

3.7 Riser cable separation

Each section of the 11KV service switchboard was designed to provide riser cabling to double-ended substation transformers, which combined to provide 415-volt service to the towers. Again, the design was revised to introduce physical separation for the riser cable pairs, which feed each substation.

Conclusions

There is no doubt that the World Trade Center was chosen as a target because it was a prominent symbol for America. The events of September 11th notwithstanding, our prime responsibility as architects in designing tall buildings is to create civic symbols that are beautiful and culturally relevant. Our design should speak for the culture of the city, its context and its aspirations. It would be tragic if we collectively adopt a bunker mentality and lose sight of our more noble responsibilities.