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Enhancing Safety and Security in High-Rise Building through Sustainable Design

This presentation is based on a paper by the presenter and M. Zahry Othman, also from the UTM.

Safety and security measures are not limited to keeping threatening people out of buildings: they are also geared toward protecting building occupants. An effective, secure building provides mitigating measures to limit hazards and prevent catastrophic damage. Safe building design balances operational, technical, and physical principles to achieve the best mix for a given location. Since the tragedy at the World Trade Center in New York, existing design philosophies are being re-evaluated to improve the safety and survivability of buildings and their occupants.

An ever-increasing number of governments are realizing that sustainable buildings are integral for achieving long-term development, particularly in large urban areas. Stimulated by a number of government incentives, sustainable building concepts are gaining popularity within the design community. Many building owners are rising to this challenge and seriously considering the benefits of sustainable design as means to make buildings safer. This challenge calls for an integrated, synergistic approach that considers all phases of the facility life cycle.

The level of security/safety and sustainability incorporated in a facility varies from project to project. Achieving quality, high-performance facilities is associated with an integrated process that identifies and embraces the goals of the project, e.g., security/safety, sustainability, productivity, accessibility, functionality, and cost-effectiveness.

This presentation will discuss the safety/security and sustainable synergies for the planning and design of high-rise buildings to minimize environmental impacts and ensure the health, safety, security, and comfort of occupants.

ENHANCING SAFETY AND SECURITY IN HIGH-RISE BUILDING THROUGH SUSTAINABLE DESIGN

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Abstract

Safety and security measures are not just limited to keeping people out of buildings but are also geared toward protecting building occupants. An effective, secure building provides for mitigating measures to limit hazards and prevent catastrophic damage. Safe building design balances operational, technical, and physical principles to achieve the best mix for a given location. Since the tragic incident of the World Trade Centre in New York existing design philosophies are being re-evaluated in an effort to improve the safety and survivability of buildings and their occupants.

An ever increasing number of governments are realizing that sustainable buildings are integral for achieving long-term development, particularly in large urban areas. Stimulated by a number of government incentives, sustainable buildings concepts are gaining popularity within the design community. Many building owners are rising to this challenge and seriously considering the benefits of sustainable design as an available means of making buildings more safe as tenants demand a safer and secure environment. Recent answers to this challenge call for an integrated, synergistic approach that considers all phases of the facility life cycle.

The level of security/safety and sustainability incorporated in a facility varies from project to project. Achieving quality, high performance facilities is associated with an integrated process that identifies and embraces the goals of the project for example security/safety, sustainability, productivity, accessibility, functionality and cost-effectiveness.

This paper will discuss the safety/security and sustainable synergies for the planning and design of high-rise buildings to minimize environmental impacts as well as ensuring the health, safety, security, and comfort of high-rise building occupants. Illustrative examples in existing high-rise buildings will be presented.

Keywords: High-rise buildings, safety, security, sustainable design, environmental impacts

1. Introduction

High-rise building can never be viewed in isolation. Their contribution to the growth of the city, their impact on the cityscape, their relationship with neighbouring buildings and their effects upon the people who use them are the ultimate tests. Future tall buildings which are safe and secure and sustainable will rebuild the confidence of owners, developers and public for its continual use in the urban environment.

For designing the new generation of high-rise buildings designers must strive for the highest quality and appropriateness for achieving safe-security and sustainability objectives. Designing for a secure/safe and sustainable facilities for buildings must be planned from the conception stage. The level of security/safety and sustainability incorporated in a facility varies greatly from project to project. Tall and iconic buildings have greater security risks will have to be given a comprehensive analysis on the various threat, vulnerability and risk assessment before security requirements can be identified and the appropriate reasonable design responses are integrated into the building design. Technical buildings benefit from whole building design where the integration of building systems contribute to the overall performance of the building during operations and emergencies.

Following the World Trade Centre tragedy, there is increasing emphasis for a holistic approach to design taking into consideration all aspects of safety including structural, egress and fire safety to enhance building performance in emergencies. The interaction of professions in design are crucial whereby the structural, fire protection, mechanical, architectural, blast, explosion, earthquake and wind engineering communities need to work together to develop guidance for vulnerability assessment, retrofit and to mitigate the probability of progressive collapse of tall buildings under hazard scenarios. (FEMA, 2002)

One of the challenges of designing a safe/secure building will require the ability to think on trade-offs and synergies for sustainable solutions and creativeness to achieve effectiveness in designs. Day lighting, energy efficient, photovoltaic facades, wind power systems and sky gardens within high-rise buildings add up to a significant shift towards a more sustainable design of tall buildings. For a given budgetary constraint, balancing any these sustainable features with safety/security needs will be a real challenge to designers.

This paper describes the safety/security design of tall building and sustainable synergies to ensure health, safety, security, and comfort of high-rise building occupants.

2. DESIGNING FOR SAFETY

Based on the investigations of the World Trade Centre Towers (WTC), design guidelines were produced to address important issues namely, life-safety, structural safety, fire protection, egress and building security for improving the building performance (FEMA 2002). The guideline provides a useful reference, particularly for high-rise building, in making them a safe place to work and live and responding better to catastrophic events.

Current building design has been optimized to facilitate emergency evacuation, rescue, and recovery efforts through effective placement, structural design, and redundancy of emergency exits and critical mechanical/electrical systems. Through effective structural design, the overall damage levels in any catastrophic events, may be reduced hence making it easier for people to get out safely and allow emergency responders to enter safely. This is even more critical for the case of high-rise buildings as illustrated by the tragedy of the Twin Towers.

On June 2005, the National Institute of Standards and Technology (NIST) released a final draft report on the World Trade Center (WTC) disaster, along with 30 recommendations for improving building safety and security.

The recommendations which are grouped into eight categories are based on the agency's scientific analysis of the fires and collapses of the Twin Towers, and lessons learned from 9/11. The Categories include: increased structural integrity to prevent progressive collapse; enhanced fire resistance of structures; new fire resistance design methods; active fire protection; improved building evacuation; emergency response; procedures and practices; and education and training for engineers and architects.

NIST has called upon the organizations that develop building and fire safety codes, standards and practices and the state and local agencies that adopt them to make specific changes to improve the safety of tall buildings, their occupants and first responders

NIST advocates designing tall buildings to accommodate full building evacuation, with wider stairwells and exit capacity for first responders and occupants. As a whole, the report recommendations are the beginning of a needed dialogue on addressing the design and construction of buildings posed by the events on September 11, 2001

Table 1: 30 Recommendations for Safer Skyscrapers (NIST, 2005)

RECOMMENDATIONS FOR SAFER SKYSCRAPERS (NIST)

1. Increased structural integrity. The standards for estimating the load effects of potential hazards (e.g., progressive collapse, wind) and the design of structural systems to mitigate the effects of those hazards should be improved to enhance structural integrity. Among the recommendations in this group are:

- Nationwide adoption of standards and codes to prevent progressive collapse;
- More reliable means of predicting failure in structures subjected to multiple hazards; and
- Nationally accepted standards for wind tunnel testing of prototype structures and estimating wind loads for tall buildings.

2. Enhanced Fire Resistance of Structures. The procedures and practices used to ensure the fire resistance of structures should be enhanced by improving the technical basis for construction classifications and fire resistance ratings; improving the technical basis for standard fire resistance testing methods; using the "structural frame" approach to fire resistance ratings; and developing in-service performance requirements and conformance criteria for spray-applied fire resistive materials (SFRMs, commonly referred to as "fireproofing" or "insulation"). Among the recommendations in this group are:

- Evaluating, and where needed, improving the technical basis for determining appropriate construction classifications and fire rating requirements — especially for buildings greater than 20 stories in height — and making related code changes now by considering a variety of factors (including timely access by emergency responders, full evacuation of occupants and redundancy in fire protection systems critical to structural safety);
- Improving the century-old standard for fire resistance testing of building components, assemblies and systems; and
- Developing and implementing criteria, test methods and standards for measuring the in-service performance and as-installed condition of "fireproofing."

3. New Methods for Fire Resistance Design of Structures. The procedures and practices used in the design of structures for fire resistance should be enhanced by requiring an objective that uncontrolled fires result in burnout without local or global collapse. Performance-based methods are an alternative to prescriptive design methods. This effort should include: (a) the development and evaluation of new fire resistive coating materials and technologies, and (b) the evaluation of the fire performance of conventional and high-performance structural materials (such as fire-resistant steels and concretes). Technical and standards barriers to the introduction of new materials and technologies should be eliminated.

Continue

RECOMMENDATIONS FOR SAFER SKYSCRAPERS (NIST)

4. Active Fire Protection. Active fire protection systems (i.e., sprinklers, standpipes/hoses, fire alarms and smoke management systems) should be enhanced through improvements to design, performance, reliability and redundancy of such systems. Among the recommendations in this group are:

- Enhanced fire protection systems that provide redundancy and accommodate greater risks associated with increasing building height and population, more open spaces and higher threat profiles of particular buildings;
- Fire alarms and communications systems that provide continuous, reliable and accurate information on life safety conditions; and
- Real-time secure transmission of data from fire alarm and other monitored building systems for use by emergency responders at any location, and presentation of that information either off-site or in a black box that that can survive a fire or other building failure.

5. Improved Building Evacuation. The process of evacuating a building should be improved to include system designs that facilitate safe and rapid egress; methods for ensuring clear and timely emergency communications to occupants; better occupant preparedness for evacuation during emergencies; and incorporation of appropriate egress technologies. Among the recommendations in this group are:

- Improving occupant preparedness for building evacuations through joint and nationwide public educational campaigns;
- Designing tall buildings to accommodate full building evacuation of occupants if needed—including stairwell and exit capacity that accommodates counter flow due to access by emergency responders;
- Maximizing the remoteness of egress components (i.e. stairs, elevators) without making them hard to reach;
- Using pagers and cell phones for broadcast warning systems and Community Emergency Alert Networks; and
- Evaluating for future use such advanced evacuation technologies as protected/hardened elevators, exterior escape systems and stairwell navigation devices.

6. Improved Emergency Response. Technologies and procedures for emergency response should be improved to enable better access to buildings, response operations, emergency communications, and command and control in large-scale emergencies. Among the recommendations in this group are:

- Installing fire-protected and structurally hardened elevators to improve emergency response activities in tall buildings;
- Installing, inspecting and testing emergency communications systems to ensure that the systems and their protocols will function in challenging radio frequency propagation environments and can be used to track emergency responders within a building; and
- Developing and implementing protocols for ensuring effective and uninterrupted operation of the command and control system in large-scale building emergencies.

7. Improved Procedures and Practices. The procedures and practices used in the design, construction, maintenance, and operation of buildings should be improved to include encouraging code compliance by nongovernmental and quasi-governmental entities; adoption and application of egress and sprinkler requirements in codes for existing buildings; and retention and availability of building documents over the life of a building.

8. Education and Training. The professional skills of building and fire safety professionals should be upgraded through a national education and training effort for fire protection engineers, structural engineers and architects.

3. DESIGNING FOR PHYSICAL SECURITY

As highlighted above, terrorism, crime, natural disasters and emergencies have heightened the need for building security in a variety of settings. Depending on the location, adjacent uses, occupants, tenants and other risk factors, some building owners are very aware of the potential risks and vulnerabilities that may apply to their properties (Nadel, 2005).

Physical security concerns the physical measures designed to safeguard people; prevent unauthorized access to equipment, installations, material, and documents; and safeguard against terrorist attacks. As such, all security operations face new and complex physical security challenges across the full spectrum of operations (FEMA, 2002). The challenges relative to physical security include the control of populations, antiterrorism, and the use of physical security assets as a versatile force multiplier. The rapid evolution of physical security equipment technology leads to physical security challenges, which are exponentially multiplied with the information age. Understanding the physical security challenges will allow appropriate measures to be undertaken and to enhance the protection of people within a facility.

Balancing security and openness in the built environment remains the challenge for design professionals and urban planners. In USA and many parts of the world many owners and tenants have taken precautions, in tandem with local law enforcement and security consultants, to implement safety precautions in and around their properties.

Security design, like sustainability applications, varies for each project, region, and budget. The most effective way for design professionals and building owners to create a comprehensive security plan is by integrating design, technology and operations.

3.1 Design

Landscaping, architecture, interiors and engineering all play essential roles in security design. Landscaping and site planning should address restricting vehicular access to buildings as needed, such as installation of bollards and planters. Lobbies are the first point of entry, where package screening and visitor identification may occur. Egress systems must ensure a safe, code compliant and direct path to the outdoors is provided for all building occupants in getting everyone out of a burning building as quickly as possible.

3.2 Technology

Technology covers electronic devices, such as closed circuit television (CCTV), card access systems, biometric scanners, magnetometers for package screening in courthouses and high-risk facilities, motion detectors, electronic fences, and other equipment.

3.3 Operations

Operation pertains to the daily functions, policies and procedures that apply to a building, tenant or business. Training and preparation for an emergency can save lives and reduce panic in the event of an unforeseen situation. Staging regular practice drills will ensure that people know what to do and where to go in an emergency. Regular drills will familiarise building occupants with locations of exits and ensure that all fire protection systems are working, and can therefore save lives.

In developing a comprehensive security program to protect building users, business continuity and real estate assets, it is essential not only to examine the system hardware/ software, building automation systems and electronic security assets but also to identify and assess the roles of human and security personnel on the building security system (Gillick, 2002).

3.4 Levels of security

Designing building security in levels and zones will ensure the protection needed for a particular building and its occupants. A typical building security design is implemented in zones starting from the interior of the building outwards to the public domain (Gillick, 2002) These may be implemented in six levels, depending upon the building risks being assigned.

The *first zone* is the building interior. This should include a main security console in a building's lobby, employee and visitor badges, interior detectors and alarm systems, locking systems, closed circuit television and guard tours.

The *second zone* involves protecting the perimeter of a building. This include window coatings, hardening the building's exterior and curtain wall, incorporating landscaping and lighting, HVAC filtration and treatments and protecting a building's mail facilities.

The *third zone* involves using landscaping elements to protect a building's grounds.

The *fourth zone* involves protecting sidewalks and property boundaries, including utilities, roadway barriers and parking.

The *fifth zone* concerns the protection of parking structures and lanes using a vehicle identification system.

The *sixth zone* calls for integrating the public domain such as streets, emergency services, police and firefighters.

Property owners, developers and managers must take a holistic approach to security planning, programming and system design for high-rise buildings. By assessing the full range of security assets available from both human and electronic aspects an effective system can be developed to protect life and properties for every project type and location.

4. SUSTAINABILITY OF HIGH-RISE BUILDINGS

Sustainability is defined as ' the development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs' (Brundtland Commission Report, 1987). Sustainable buildings are those that respond to environmental, social and economic problems that are now confronting our cities.

The main goals of sustainable design are to avoid depletion of resources including energy, water, and raw materials; prevent environmental damage caused by buildings and facilities throughout their life; and create building environments that are liveable, healthy, and productive. A sustainable building design is based on the following objectives : Optimize Site Potential, Minimize Energy Consumption, Protect and Conserve Water, Use Environmentally Preferable Products, Enhance Indoor Environmental Quality (IEQ) and Optimize Operational and Maintenance Practices

The need for sustainable development has been argued over for many years and most governments are recognising this need after global initiatives such as the Rio Summit and the Kyoto and Montreal Protocols. Designers have a responsibility to provide a viable solution that will address these issues of density, space and sustainability. There is a general recognition that high-rise buildings have the potential to provide the necessary solution to many urban problems but how can a high-rise be sustainable? Many building designers are rising to this challenge and some have made it the focus of their professional pursuits.

As a result of current environmental and economic problems, the language of sustainability has become unavoidable for architects, building engineers, governments and developers. The number of high-rise building adopting sustainable design is increasing but no one has yet to design the ultimate sustainable building that satisfies all environmental, social and economic ideals. Whilst the environmental, social and economic aspects of high-rise buildings have been addressed extensively, the safety aspects have also been widely scrutinised since the World Trade Centre collapsed. Safety concerns have now become an added dimension to sustainability for enhancing building performance during emergencies and meeting the need of occupant comfort, building protection as well as conservation of the environmental quality in the built environment.

As for meeting the social needs, high-rise buildings have been designed to be more permeable to people and more responsive to environmental conditions to embrace sustainable development. In the past decade, office buildings have transformed as companies realized that the interior layout has a greater influence on productivity. Besides designing for comfort, new tall buildings are designed for transformation of space to embrace openness and transparency to assist daily encounters and aim at encouraging new interactive ways of working. Whilst maintaining the sustainability objectives, designers should also give considerations to features which ensures the safety and well-being of the occupants.

Sustainable buildings are high performance buildings where performance is being evaluated through benchmarking systems like LEED, BREEAM and many alike. The adoption and implementation of the LEED rating system is closely linked to performance based standards (Shafii, 2004). A wide range of issues are evaluated to include energy and water use, indoor health, recycling for occupants, access to mass transit, materials impacts, landscaping, construction waste management, building sites and maintenance.

The benchmarking system for sustainable design is one way of tracking and quantifying the potential sustainable savings and is rapidly gaining recognition by the design community as a viable convincing mechanism. Constant assessment and maintenance ensure that the building operates in accordance to design expectation and safety rules. In brief, sustainable designs are safe designs for delivering economic, environmental and social benefits to the community.

4. SECURITY / SAFETY AND SUSTAINABILITY SYNERGIES

Designing for security and safety contribute towards a sustainable building design. Security and safety measures within a total project context, including impacts on occupants and the environment must therefore be considered irrespective of the level of protection.

An understanding of the interaction between security/safety and sustainability objectives amongst designers is therefore necessary in seeking solutions from these synergies. Through the whole building design process, areas of synergy and conflicts between the two approaches can be identified thus allowing sustainability opportunities within certain security/safety strategies to be highlighted. Upon acquiring this information, the project team can then define and understand better the interrelationships between the project's needs and achieve balanced design solutions that will minimize environmental impacts as well as ensuring health, safety and comfort of building occupants.

With a given budgetary and other constraints, integrating secure/safe and sustainable design objectives may require compromise and tradeoffs. Conflicting objectives will pose challenges to the project team in finding creative solutions to a particular problem.

Examples on the safety strategies and sustainable opportunities extracted from WBDG (2001) are listed in Table 2.

Table 2: Sustainable design considerations and opportunities when employing various safe design strategies.

Safety and Security Strategies	**Sustainable Design Considerations/Opportunities**
Access Control	
Secure site perimeter	Integrate with sustainable landscaping scheme
Use barriers to prevent passage of vehicles	Use natural and/or environmentally friendly barriers (e.g., trees, retention ponds, recycled-content planters, etc.)
Minimize public entrances into the building	Integrate with day-lighting scheme
Secure vulnerable openings (e.g. doors, first floor windows)	Integrate with day-lighting scheme
Install electronic access systems (e.g., parking, elevators)	Use energy-efficient systems. Consider renewable and/or distributed energy resources
Surveillance	
Place windows and doors to allow for good visibility	Integrate with day lighting scheme
Avoid spaces that permit concealment	Integrate with day-lighting scheme
Avoid blocking lines of sight with fencing and landscaping	Integrate with landscaping and day-lighting schemes.
Designing lighting to reinforce natural surveillance	Integrate with building automation and control systems. Use energy-efficient systems. Consider renewable and/or distributed energy sources, such as solar power night lighting
Install intrusion devices and video systems	Integrate with building automation and control systems. Use energy-efficient lighting and controls. Consider renewable and/or distributed energy sources
Blast Protection	
Design structural systems to prevent or delay building collapse	Integrate with passive solar design (e.g., Trombe walls). Use sustainable materials (e.g., fly-ash concrete, slag concrete, steel columns, etc.)
Use building configurations to better resist blast shock waves	Integrate with passive solar design and day-lighting scheme
Maximize distances between parking and buildings	Integrate with alternative transportation plans
Size and locate windows with detonation points in mind	Integrate with day-lighting scheme
Increase strength of exterior cladding and non-structural elements	Use sustainable materials. Consider thermal benefits of strengthened cladding options
Chemical, Biological, Radiological Protection	Consider dedicated ventilation and/or exhaust systems
Elevate fresh air intakes	Integrate with energy-efficient HVAC system
Apply external air filtration and over-pressurization techniques	Integrate with building automation and control systems
Use internal air filtration technologies	Integrate with building automation and control systems
Energy Security	
Create redundant systems	Reduce need for energy. Use energy-efficient systems. Consider renewable and/or distributed energy resources
*Occupant Safety and Health***	
Provide designs that eliminate or mitigate hazards in the work	Integrate safety mechanisms with sustainable features. Use integrated building automation and control systems

place to prevent mishaps	
Prevent slips, trips, and falls	Integrate day-lighting into illumination scheme
Eliminate exposure to hazardous materials (e.g., volatile organic compounds (VOCs) and formaldehyde, lead, and asbestos in older buildings)	Use sustainable materials (e.g., no-VOC paint, formaldehyde-free finish panels, etc.). Use dedicated ventilation and/or exhaust systems in copy rooms, labs, loading docks, and mailrooms.
Provide good indoor air quality (IAQ) and adequate ventilation	Use day-lighting. Consider integrated natural and mechanical ventilation systems. Use integrated building automation and control systems
Perform proper building operations and maintenance	Implement total building commissioning. Use integrated building automation and control systems.

For tall building design these developments entailed a multi-disciplinary effort, where designers must understand how their efforts integrate with other design team members to provide an overall project that is attractive, cost effective, energy efficient and flexible in meeting the needs of occupants. In these regards the designer's understanding of the whole building system (integrated design process) are crucial for effectiveness in carrying out the design processes and implementations

6. CASE EXAMPLE

Freedom Tower, to be constructed in New York city, is an example of the state-of-the art tall building designed at post September 11. If the building is constructed as envisioned, rising from that will be a spire that reaches the record height of 1,776 ft. (541.32 m), in honor of the year the American colonies declared their independence from Britain.

The most ingenious aspect about the Freedom Tower is how it manages to being the one of the tallest structure in the world without actually obliging anyone to work at its highest altitudes. The offices stop at the 70th floor and there upwards topped by a tall "wind farm" with latticework of windmills that can provide as much as 20% of the building's electrical power.

The building incorporates advanced life safety systems that exceed the requirements of New York City Building Code and this will lead the way in developing new high-rise building standards. In the occupied floors below, the building will incorporate a whole spectrum of new, post-9/11 defensive features. In addition to structural redundancy and extra strong fireproofing, the building includes biological and chemical filters in the air supply system.

To assume optimum egress and firefighting capacity, extra-wide pressurized stairs, low-level emergency lighting and concrete protection for all sprinklers and emergency risers are being provided, in addition to interconnected redundant exits, additional stair exit locations at all adjacent streets and direct exits to the street from tower stairs.

All of the building's life-safety systems – stairs, communications, risers, sprinklers, elevators – are encased in a core wall that is three feet thick in most places. This building is being designed to facilitate emergency response with enhanced emergency communication cables, together with a dedicated stair for use by firefighters. These are used in conjunction with enhanced elevators housed in a protected central building core that serve every floor of the building. In addition, "areas of refuge" are located on each floor.

Freedom Tower uses new technologies and methods to maximize efficiency, minimize waste and pollution and reduce the impacts of the development for all concerned. Freedom Tower is being built according to World Trade Center *Sustainable Design Guidelines* that are unprecedented in their scope and depth. The guidelines call for cutting-edge innovation in air quality, energy efficiency, day lighting, water conservation, materials conservation and clean construction.

At the time of writing this paper, it was reported that Freedom Tower is undergoing some design changes for improvement in security.

8. CONCLUSIONS

Design professionals, building owners and tenants, especially in high-rise or multiple-occupancy buildings, must be aware of safety/security concerns, especially from design, operational and liability perspectives in the event of hazards or natural disaster.

Integrating safety, security objectives and sustainability opportunities produce innovative and balanced design solutions that will minimize environmental impacts as well as ensuring health, safety and comfort of building occupants.

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