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Considerations and Challenges for Refuge Areas in Tall Buildings

高层建筑避难区域的考虑和挑战

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Abstract

Within the last two decades, concentrating all or many occupants of many floors of a tall building onto refuge floors during an emergency has become a concept that has gained increased use. However, the refuge floor concept can pose challenges to efficiency, sustainability and life safety goals; and should be used only with careful consideration. The challenge is to identify the problems that refuge floors endeavor to solve, and determine if there are more efficient, less costly, more sustainable solutions that provide the same or greater levels of life safety. The benefits of providing dispersed refuge areas may be greater during many extreme events, and may provide a more sustainable and cost effective solution. The CTBUH Fire Safety Working Group intends this paper to foster better understanding of the concepts and of refuge areas/floors prior to application in the overall design of any tall building.

Keywords: Refuge floors, refuge areas, sustainability, ventilation, evacuation.

摘要

近二十年来，在紧急状况下将高层建筑若干楼层内人员集中疏散到避难层的方法，已逐渐成为一种广泛使用的设计概念。然而，避难层的设计概念对建筑的使用效率、使用的持续性以及生命安全等因素均存在一定程度的不利影响，必须加以慎重考虑。具体而言，需要明确避难层可以解决的问题，是否有其他更有效、更经济、更可靠的解决方案可以提供相似或者更高水平的安全设计。当然，在许多极端事件中，建筑内若干分散的避难空间的确可以为安全疏散提供非常可靠和有效的解决方案。CTBUH消防安全专业组将通过文本的探讨，阐述对避难层功效的进一步理解和认识。

关键词：避难层、避难空间、可持续性、通风、疏散

Introduction

Tall buildings offer the advantages of housing people and business operations efficiently and vertically in urban areas. One of the great efficiencies is that relatively few independent exit stairs are needed to serve the population of a tall building, housing potentially thousands of occupants. Given a floor plate with reasonable (meets code limitations) travel distances to the exit stairs, it is common that only two or three independent exit stairs would be required to fulfill legal requirements for a tall building whether it be 20, 50 or 100 stories high. The provision of automatic sprinkler systems and compartmentation features afforded by fire resistive floor systems are generally accepted measures, which safely allow for evacuation of only a few selected floors during a fire or similar emergency to other floors remote and protected from the fire or similar emergency. Of course, there are concerns for scenarios or events that may warrant a more wide-scale evacuation or even total evacuation of a tall building.

Although elevators may play a bigger role in total building evacuations (Proulx et al 2009) in the future, there are a variety of reasons and concerns that stairs (Peacock et al 2009) and elevators alone (Heyes 2009) are not

引言

高层建筑可以容纳大量人员和商务场所，为城市的立体发展提供有效的利用空间。其中的一个突出特点是，仅需要相对较少的独立疏散楼梯即可为高层建筑内数以千计的人员，提供所需的疏散通道。无论是20层、50层或是100层的高层建筑，当楼面满足规范要求的疏散距离时，通常两到三个独立的疏散楼梯就可以符合高层建筑规范对疏散的要求。其安全理论依据是，基于耐火楼板体系的自动水喷淋系统和防火分区等安全措施，可以允许在火灾或其他紧急状况发生时，仅疏散几个特定的楼层即可保证建筑内人员的安全。当然，一些可能会导致大范围甚至整栋高层建筑疏散的场景或状况也是需要注意的。

虽然电梯有可能在未来的高层建筑疏散中发挥重要的作用（Proulx et al 2009），基于各种相关因素的考虑，仅单独依靠楼梯(Peacock et al 2009)或者单独依靠电梯(Heyes 2009)，都难以为部分或整栋建筑内人员的疏散提供充足的疏散能力。建筑界所普遍认知的高层建筑疏散有如下特点：

- 高层建筑内人员较多，疏散时间较长（1至3小时）
- 楼梯疏散距离长，体力消耗大
- 残疾或行动不便人员难以使用楼梯

adequate to support occupant needs during a partial or total building evacuation process. Major points that have been recognized in the building community are as follows:

- Tall buildings with large occupant loads are subject to long evacuation times (1-3 hours)
- Evacuation down long stair routes can be physically demanding or tiring for occupants with low stamina
- Stairs are not conducive for movement of people with permanent or temporary disabilities (Proulx and Pineau 1996) that include:
  –Mobility impaired occupants – wheelchairs, walkers, canes
  –Health impaired occupants – those with respiratory or cardiac issues
  –Temporary conditions – pregnancy, broken limb or injury
- Total evacuation may not always be desirable or feasible. A partial evacuation may be appropriate to move only those occupants in or near the affected fire or emergency zone to another area of relative safety. (Lay 2008, O'Connor and Cohn 2008)
- Stairs (even pressurized stairs) can become contaminated by smoke when multiple doors are open or doors fail to close. (Bukowski 2009)
- Fire department personnel will often rely on exit stairs for staging and hose deployment operations. Such fire department operations can conflict with occupants egress movement and result in smoke entry into the stairway while doors are held open by hose lays.

One or more of the above points have been cited as the basis for justification for refuge spaces or refuge floors in tall buildings. The global experience of refuge spaces in tall buildings varies, but includes at least two basic approaches: dispersed protection and consolidated protection. . The dispersed approach views all floors as potential refuge areas, while the consolidated approach considers that only several selected floors will serve the refuge function.

The refuge area/floor concept can pose issues related to design efficiency, sustainability, and even life safety. These issues are addressed in the following pages. The challenge is to identify the problems that refuge floors solve or endeavor to solve, and then determine how those problems can be solved using other techniques that are safer, more sustainable and more cost effective. There may be conditions in which a refuge floor is an appropriate technique in the overall design of a tall building, but potential problems and risks of refuge floors should be understood and adequately considered to in the overall design of any building that utilize refuge floors.

The Dispersed Approach

Refuge areas in tall buildings have been developed for a variety of reasons in various parts of the world. These include both life safety for all occupants, and to respond to the needs of people with disabilities. The dispersed approach is most common in Europe, the Middle East and North America. In the United States, for example, the dispersed approach is reflected in the Federal Law, the Americans with Disabilities Act (ADA) initially implemented in 1991 The document that defines building design standards to implement that law is the "Accessibility Guidelines for Buildings and Facilities" (ADAAG) (US DOJ 1991), which established two key premises regarding the design of exits in tall buildings:

疏散(Proulx and Pineau 1996)，其中包括：
–行动不便人员，如使用轮椅、拐杖的人员
–病患，如呼吸、心脏系统病患人员
–临时行动不便人员，如孕妇、伤员

- 当高层建筑内人员不需要或不便于全体疏散时，仅将受到火灾或其他紧急状况直接威胁区域的人员撤离的局部疏散则更为可行（(Lay 2008, O’Connor and Cohn 2008)
- 烟气可能会从开敞的楼梯门进入疏散楼梯间（即使楼梯间设有正压送风）(Bukowski 2009)
- 消防扑救人员通常需要使用疏散楼梯展开扑救，这样将会与楼内人员疏散产生冲突，并且楼梯门可能因消防水带阻挡无法完全关闭，导致烟气进入楼梯间。

上述特点通常被用作衡量高层建筑避难层/间的设计和使用的基本要素。尽管在世界范围内，高层建筑避难空间的构成形式多种多样，但大致可以划分为分散保护和集中保护两个基本类型。分散式方法会利用所有的楼层作为可能避难区域，而集中式方法只考虑几个选定的楼层提供避难功能。

避难层的设计概念对建筑的使用效率、使用的持续性以及生命安全等因素均存在一定程度的不利影响，必须加以慎重考虑。具体而言，需要明确避难层可以解决的问题，是否有其他更有效、更经济、更可靠的解决方案可以提供相似或者更高水平的安全设计。即使某些高层建筑总体设计适于安排避难层，全面了解和思考避难层潜在的问题和风险也是十分必要的。

分散式方法

世界各地高层建筑避难层设计的发展各自有不同的目的，其中既包括建筑内全体人员安全的考虑，也包括针对残障人士特殊要求的措施。分散式方法的使用在欧洲、中东和北美等国家和地区较为常见。以美国为例，1991年颁布的联邦法规“美国残障法案”（ADA）体现了分散式方法的实际应用。在“建筑设施无障碍指南”(ADAAG) (US DOJ 1991)中，详细规定了建筑设计标准必须执行残障法案。该指南有两个关键的条文涉及了高层建筑的疏散设计。

- 当多层建筑利用楼梯疏散时，考虑到残障人士使用楼梯的实际困难，无障碍指南(ADAAG)要求提供“救援协助区”或“平面安全出口”，以便残障人士避险。平面安全出口由连续的防火间隔和自动关闭的防火门构成，用以将楼面分割成为数个相对独立的防火/防烟分区。
- 另外一个常见的“救援协助区”或“平面安全出口”的替代方案是，通过具有监控功能的自动水喷淋系统，实时监控建筑内的安全状况。事实上，自动水喷淋系统集成监控和发送信号的功能，从而指示喷淋系统损坏的情况。监控功能是这一替代方案的关键之处。

无障碍指南(ADAAG)通过下列四种方法中的一种，为火灾事故中的人员提供安全防护。

高层建筑最常见、最有效的分散式解决方案是可监控喷淋系统的方法。“救援协助区”方法由于额外的成本以及损失可用面积等缺点，常常不被建筑设计师和开发商所采用。

集中式方法：设置避难层

近年来，集中式方法（集中楼内人员到数个避难层）被亚洲许多国家和地区广泛采用。世界上的几起火灾事故也对避难空间的应用起到了推动的作用，如发生在1996年的香港嘉利大厦大火。1996年至2005年间香港政府为强化高层建筑的安全性能逐步修改了当地的消防规范。这些修改特别集中反映在，要求40层以

- Where a multi-floor building used stairs for exits, it was recognized that some disabled individuals could not avail themselves of such exits and, therefore, ADAAG required protected "Areas of Rescue Assistance" or the provision of a "horizontal exit" which enables disabled occupants to readily seek refuge. Horizontal exits are constructed using continuous fire barriers (2-hour or greater) and self/automatic-closing fire doors to divide a floor area into independent fire/smoke-protected zones.
- Another alternative to providing "Areas of Rescue Assistance" or a "horizontal exit", and the most commonly practiced alternative, is for the building to have a supervised automatic sprinkler system. The fact that supervised automatic sprinkler systems have integrated monitoring and signaling features used to indicate conditions that could impair the satisfactory operation of the sprinkler system(s) is key to this alternative.

Effectively, the ADAAG recognized any one of four methods to provide for the safety of occupants during a fire event in the building.

The most common and effective solution for tall buildings is the supervised sprinkler system approach. The "areas-of-rescue-assistance" option is generally not an option desired by architects or developers for reasons of cost and loss of useable and/or leasable area.

The Consolidated Approach: Using Refuge Floors

The consolidated approach (gathering of occupants onto a few refuge floors) has become most common in many areas of Asia in recent years. The impetus for the refuge area in some parts of the world is attributed to several accidental fires, including the 1996 Garley Building fire in Hong Kong. It is noted (Chow and Chow 2009) that the Hong Kong government modified its existing fire code requirements from 1996 to 2005 to address the concerns for occupant safety in high-rise buildings. These requirements focused more on providing refuge areas in terms of an entire floor or large portion of a floor in those high-rise residential buildings taller than 40 stories.

Refuge floors provide the option for occupants to pause during the evacuation process, and they provide the option of being an assumed safe holding area for occupants. Occupants who are exiting can pause and rest at the refuge floor until they feel they are ready to descend further down the exit stairs (either to the next refuge floor or to the exit discharge). Alternatively, occupants may be directed to the refuge floor and kept there awaiting further instructions.

Specific requirements vary by jurisdiction, but typically refuge floors are required for buildings greater than approximately 100 meters (328 feet) in height. For such buildings, every 16th to 20th floor is required by the applicable building codes or regulatory authority to be reserved and designated as a refuge floor. Theoretically the occupants from the 15 to 20 floors immediately above a refuge floor can (or perhaps in some circumstances are required) to exit down to the refuge floor, either to rest or to await further instructions or permission to egress out of the building (see Figure 2).

One interesting design configuration that is frequently incorporated in to the refuge floor concept is the interruption of exit stairs. Typically, the exit stairs above the refuge floor discharge onto the refuge floor, so that stair users must leave the stair enclosure before entering the refuge floor. From the refuge floor it is possible to re-enter the stair if they desire to continue down. The interruption has the dual advantage of making the exiting occupants aware of the availability of

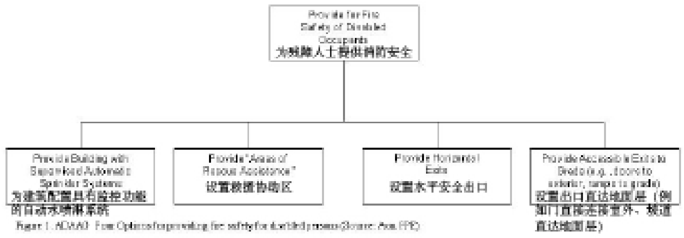

Figure 1. ADAAG Four Options for providing fire safety for disabled persons (Source: Aon FPE)
图1. ADAAG基于消防安全的四种方案（由Aon FPE提供）。

上的高层住宅设置占据整层或一层大部分的避难空间。

由于避难层的设置，疏散过程中建筑内人员可以选择在避难层短暂停留，也可以选择避难层作为安全的目的地。建筑内人员可以在避难层休息停留后继续下行（至下一个避难层或直至室外出口），也可以在避难层等待进一步的疏散指示。

尽管各个地区对避难层的具体要求各有不同，通常在高度超过100米（328英尺）的建筑内要求设置避难层，一般情况下，避难层需每隔16至20层设置。理论上，一个避难层以上15至20层内的人员可以（或是必须）下行至避难层，休息停留或者等待进一步的疏散指示或疏散许可（见图2）。

避难层设计中经常会要求疏散楼梯在避难层分隔、同层错位或上下断开。通常，避难层以上楼层的人员经疏散楼梯到达避难层时，会离开楼梯间进入避难层。如需继续下行则在避难层内重新进入疏散楼梯。疏散楼梯在避难层的分割有两个优点，一是便于建筑内人员容易找到避难层，二是分割为若干段的疏散楼梯可以减小烟囱效应的影响，增强正压送风系统的性能。

高层建筑内设置整层的避难层似乎可以作为一个完美的设计，为建筑内的大量人员提供一个良好的安全空间。然而，进一步的分析发现，避难层的设置会带来一些新的问题，如避难层到底是增强还是降低了建筑的安全性，是否有更有效的措施可以替代避难层的功能等等。

设计中的问题与挑战

使用避难层的人员数量通常依靠粗略估计，或是理论上最不利情况（依据规范计算）下使用该避难层的所有楼层内人员数。例如，一座楼层面积为2,325平方米/层（25,000平方英尺）的写字楼每层人员数约为250人（2,325平方米除以9.3平米/人）。因

Figure 2. Occupants leaving a protected refuge floor area in the Burj Khalifa (Source: Dan O'Connor)
图2. Burj Khalifa（迪拜哈里发塔）内人员自避难层撤离（由Dan O'Connor提供）。

the refuge floor; and the interruption or segmentation of the stairs into separate compartments, can mitigate stack effect, and thus improve the performance of stair pressurization systems over the full height of each segment of the stairs.

Initially, it seems like a very compelling idea to create an entire floor that will function as an area of refuge within a building where a large number of building occupants can be gathered. However, upon further examination, questions arise about whether a refuge floor provides an increased or a decreased level of safety, and whether there are more effective and efficient ways to accomplish the goals that refuge floors attempt to achieve.

Design Issues And Challenges

The occupant load anticipated to use a given refuge area is based on good-faith design estimates or theoretical worse-case (full code calculated) population loads of the floors being served. For example, an office building with about 2,325 m^2 (25,000 ft^2) of floor area per floor would have about (2,325 m^2 divided by 9.3 m^2 per occupant =) 250 occupants per floor. Therefore the refuge floor would theoretically need to accommodate about (15 floors x 250 occupants per floor =) 3,750 occupants. For some jurisdictions, it has been proposed that refuge floors might only be every 20th floor. For those locations the theoretical maximum would increase to be about (19 floors x 250 occupants per floor =) 4,750 occupants on the refuge floor. The density of occupants would be high and the resulting crowd poses building design and crowd management challenges (see Figure 3).

The actual utilization of a refuge floor is, however, not easily estimated or predictable and is dependent on highly variable factors at the time of an emergency incident. Such factors include the fire incident location, extent of fire spread, nature of the occupants and nature of the emergency communications/alarms in the building.

Assuming that the estimated hundreds or thousands of occupants would assemble on a given refuge floor, this approach then poses a number of issues related to the comfort and safety of those occupants for the duration of the stay. Amenity and safety features that need to be considered are as follows:

- Toilet and drinking water provisions
- Seating facilities or standing room accommodations only
- Emergency power for lighting and refuge floor amenities
- Protection of floor from increasing /spreading fire effects
- Ventilation/HVAC design and reliability for duration of the event

The issue of ventilation/HVAC system design for a refuge floor is perhaps the most significant cost and implementation concern. Natural ventilation concepts where two or more sides of the building façade are open to the atmosphere have been implemented in a number of constructed buildings. Several studies have reviewed the viability of this concept and cited issues with the reliability of this method of ventilation showing problems with smoke contamination of the refuge floor (Chow and Chow 2009; Kwok et al 2000; Cheng 2006). For enclosed refuge floors an HVAC system approach system would need to be designed to maintain a reasonable level of comfort for the occupants on a fully utilized refuge floor (see Figure 4).

The HVAC systems need to perform three functions: 1) provide adequate fresh air to occupants; 2) maintain any pressurization necessary to keep the building occupants and the exits clear of smoke; and 3) maintain the temperature within the refuge floor at a range

Figure 3. Signage at the highest mechanical floor of the Burj Khalifa indicating the locations of refuge floors in the tower at floors 42, 75, 111 and 138 (Source: Dan O'Connor)
图3. Burj Khalifa（迪拜哈里发塔）最高设备层内指示避难层位置（位于塔楼的第42、75、111和138层）的标识（由Dan O’Connor 提供）。

此理论上避难层需能够容纳3,750人（15层x250人）。在某些地区，避难层每隔20层设置，理论上避难层需容纳4,750人（19层x250人）。拥挤的避难层中人员密度较大，对建筑的设计和高密度人群的管理提出了挑战(见图3）。

避难层的实际使用状况是较难准确估计的，会有许多随紧急状况发生时间变化而变化的因素。其中包括火灾发生的位置、火灾蔓延的范围、建筑内人员的特点以及建筑内应急通讯报警系统的设置等诸多因素。

当数以百计或千计的建筑内人员聚集在某一避难层，在避难层停留期间会伴随产生一些与舒适性、安全性相关的问题。一些诸如方便、安全方面的设施需要在避难层的设计中加以考虑：

- 厕所用水及饮用水供给
- 座椅或站立区设施
- 照明和避难层设备的应急供电系统
- 防护措施，以保证避难层不受火灾的威胁和影响
- 通风空调系统，以确保避难层在事故期间运行的可靠性

避难层通风空调系统的相关设计可能是其中最为昂贵和不易实施的问题。众多的建筑中采用了在建筑两侧或多侧外表面自然通风的设计概念，针对这一设计概念灵活性和可靠性的研究表明，自然通风的方法存在着避难层可能会受到火灾烟气威胁的问题（Chow and Chow 2009; Kwok et al 2000; Cheng 2006）。而密闭的避难层中，空调系统的设计需要在避难层满员的情况下保证合理的舒适度(见图4）。

空调系统必须能够实现以下三个功能：1）提供充足的新鲜空气；2）维持一定的正压，保证疏散通道和避难层人员不受烟气威胁；3）维持避难层一定的室温，确保人员生存和行动能力不致受到影响和威胁。第三个功能在高温气候地区尤为重要。如果空调系统不能实现上述三个功能中的任意一个，就需要将该避难层中的人员转移至其他位置。显然，为大量人员聚集在避难层这样的零星偶发事件而投入的资金和能源消耗，与建筑的可持续使用的设计目标是不相符的。另外，还需要注意其他的一些与空调系统的失效有关的问题。假如空调系统的进风口恰好位于火灾楼层的上方，已经开始吸入火灾烟气，空调系统必须关闭时，需要如何处理？当空调系统不能工作时，避难层内人员可以继续停留多久？如果该避难层需要疏散时，多长时间可以疏散完毕？

that does not negatively impact human survival or the ability those occupants to be mobile. This third function is of a greater concern for buildings in high temperature climates. If the HVAC system cannot perform any one of those three functions, it will become necessary for the occupants on the refuge floor, to relocate from the refuge floor to another location. The costs and energy needed to provide for the large population on a refuge floor for the occasionally (if not rare) event are counter to sustainable building design objectives. Other potential concerns are related to HVAC system failure. What if the intakes for the HVAC for the refuge floor are located above the fire floor, and begin drawing in smoke from the fire floor, and therefore must be shut down? How long can occupants remain on a refuge floor that has lost its HVAC system, and if it becomes necessary to evacuate that refuge floor, how much time will be required to evacuate that refuge floor?

Challenges Of Life Safety

Human behavior is an area of concern and uncertainty when refuge floors are implemented. Although training and evacuation drills are important factors to encourage proper evacuation actions there are potential issues that may not simply be addressed by evacuation drills (Bukowski 2008). Factors such as crowding, uncertainty about the conditions, increased heat, difficulty breathing, physical discomfort from long standing or sitting, and other factors can increase levels of stress and impatience. Large crowd behavior under such conditions can be difficult to predict and difficult to manage.

The provision of a refuge floor does not mean that occupants will utilize the floor as intended. Overcrowding or non-use are both potential outcomes. However, assuming a refuge floor is "appropriately" utilized, it should be recognized that the refuge floor becomes an assembly occupancy. The increased density poses crowd management risks and subjects a large percent of the building population to fire/smoke exposure risks in a single location. Should the refuge floor need to be evacuated there can be crowd management issues due to the large number of occupants competing for access to a limited number of evacuation routes (stairs and elevators).

Additionally, from the perspective of security it can be of concern that known gathering spaces can be potential target areas. For this reason security precautions and access to dedicated refuge floors during non-use may need special consideration.

Challenges Of Cost Effectiveness

Refuge floors result in a reduction in the usable floor area and therefore the efficiency within a building. The dedicated refuge floor concept, where an entire floor or large portion of a floor is given over to the exclusive (single purpose) use as an area of refuge, is an exceptionally expensive requirement. It will result in an increase in construction cost, and will add to ownership and operations costs over the life of a building after construction is completed.

This applies to buildings that are leased or rented, (including offices, apartments and hotels) and results in a continuing loss of revenue for building owners over the life of a building. It also applies to residential buildings, as the refuge floors will either result in a decrease of the size of living units (a prospective owner will only have a fixed amount of money to spend on the purchase of a new unit) or the use of refuge floors will increase the cost of units (if the units are not reduced in area, but remain constant, and the costs of the refuge floor is passed on in the form of an increase in purchase cost), or a combination of both.

Figure 4. Entrance into the 2 hour protected refuge floor area at floor 138 in the Burj Khalifa (Source: Dan O'Connor)
图4. Burj Khalifa（迪拜哈里发塔）内位于138层，进入2小时耐火保护的避难层的入口（由Dan O' Connor 提供）。

生命安全的挑战

紧急状况下人的行为是一个值得关注的领域，特别是涉及到避难层设置使用时的不确定性。尽管疏散演习可以帮助人们在疏散时采取的正确方法，但是仍然有许多潜在的问题不易在疏散演习中发现(Bukowski 2008)，例如拥挤程度、环境条件的不确定性、室内温度的升高、呼吸困难、身体长时间站、坐而带来的不适，以及其他一些可能加剧焦虑不安的因素。在这样的条件下，对大量高密度人群行为的预测和管理都将是十分困难的。

避难层的设置并不意味着建筑内人员一定会按照设计的意图使用避难层。避难层过度拥挤或者不被使用的现象都会发生。即使假设避难层会被正确的使用，也必须认识到避难层在使用时会转变成为一个人员密集的场所。人员密度的增加必将导致管理风险的上升，而且在将建筑内大量人员集中的同时，也将火灾及烟气的重大风险集中在了一个位置上。当避难层需要疏散，大量人员竞相使用有限的疏散通道（疏散楼梯或电梯）时，问题必将转化成为高密度人群管理的问题。

此外，从安防的角度来看，人员聚集的位置可能会成为袭击目标。因此，必须考虑避难层在日常未使用情况下的安防和门禁管理。

成本效率的挑战

避难层需要占用建筑空间，势必降低建筑的使用效率。显然，占据整层或一层大部分的避难层用途单一，是一个建筑成本很高的设计要求。这样的设计概念必然会增加建筑造价，同时也增加建筑建成后的运行成本。

同样，在租赁建筑中（用做办公楼、公寓、酒店等），会造成业主收入的损失。在住宅建筑中，避难层的设置会减小实际使用面积（准业主在购买新的房型时就会有金额限制），或者增加房型的价格（如果房型面积没有减少但保持不变，避难层的成本将通过购买成本增加的形式体现），或者二者兼有。

由于避难层间隔楼层数的不同要求（15层至19层不等），需要在建筑中设置一两个、甚至更多的避难层。这样，一个50层高的典型办公楼就需要52或53层的建筑高度以满足避难层的要求。因为高层建筑中增加楼层的成本并不是简单的线性加法，简而言之，两三层额外的楼层，会增加建筑成本4%至6%。

这里并没有详细包括其他的一些增加的建筑成本。总计起来，避难层会增加不少的建筑成本。增加的成本因地域不同会有较大差异，其中的分类估算应当包括以下一些内容：

Depending on the requirements of spacing (refuge floors every 15 to 19 floors) this would result in a minimum of one or two additional floors to be used solely as refuge floors. So, instead of constructing 50 typical office floors, the need would be to construct 52 or 53 floors in order to provide the same amount of office space. Therefore, in the simplest of terms, these two or three additional floors would result in a minimum increase in construction costs of approximately 4% to 6%. Of course, in high-rise construction the cost of additional floors is not linear and the cost of the next higher floor is likely to cost more than the previous floor.

There are a number of other added costs which are not estimated at this time, but collectively are significant. These differ from city to city and market to market, and therefore the extent will vary from building to building. An estimate of these costs is not made at this time, but these costs are acknowledged and itemized here as follows:

- Added Costs from Additional Construction Time to add floors
- Increased Maintenance Cost – cleaning, HVAC for normally empty space
- Loss of Efficiency/impact on leasing, usability for multi-floor tenants
- Property Tax Issues – floor area that fails to generate revenue, yet taxes are to be paid
- Loss of Zoning Potential – reduced building height or area allowed in a given zoning space

Challenges Of Sustainability

Is a refuge floor consistent with sustainability? In brief, based on the information noted above, the answer would be "no". They require a significant increase in use of material and energy resources, both during construction and operation during the life of a building, but they do not provide a commensurate increase in use or value.

Alternatives And Solutions

For many buildings, the thoughtful implementation of a combination of "defend-in-place" and evacuation of floors in a selective and strategic sequence would provide the same, or better level of life safety, and at a less financial cost than a refuge floor system. This approach has been effective for many of the world's tall buildings. There are always methods that can be implemented to improve that approach, and continued effort to do so, should be encouraged. Some key ideas to consider in lieu of the dedicated refuge floor or to minimize the impact of the concept are as follows:

- Most, if not all floors, can serve as refuge space.
- Refuge floors can double as useable occupancy.
- Buildings with bridge connections need not rely on refuge floors.
- Cost savings of eliminated refuge floors can be better spent on highly-reliable fire safety systems and "defend-in-place" strategies.
- Property tax and zoning regulation relief for buildings using a refuge floors concept

Most, if not all, floors of a building can effectively be viewed as a refuge floor. Given appropriate levels of floor-to floor compartmentation, highly reliable sprinkler/water supply systems, and effective facilities

- 增加避难层会因工期的延长而增加成本。
- 增加建筑运营成本于平时空置空间的清洁、空调等费用
- 多层租赁单位的使用、租赁效率降低
- 由于避难层的空置空间损失建筑的收益，却不能减免地产赋税
- 分区可能性的降低——给定的分区空间内减少建筑的高度与面积

可持续性的挑战

避难层的设置是否跟可持续性是一致的呢？简而言之，根据上述分析可以发现，避难层的设置影响建筑使用的持续性，在施工期间和建成使用期间都会显著增加建筑材料、能源的消耗，却不能在日常的使用过程中发挥效益。

替代方案与解决方法

一些建筑中创造性地使用了“就地保护”和有计划地疏散事故楼层相结合的安全策略，可以提供与设置避难层相似、且具有同等安全性能、然而更为经济的方法。世界上的许多高层建筑中使用了这种安全设计概念。这种安全设计概念，也在不断的改进和完善中。其中一些重要的、用以替代特定避难层或减小避难层影响的考虑如下：

- 利用大部分楼层（如果不能利用全部楼层的话）作为避难空间
- 避难层平时可以考虑日常使用
- 建筑之间如有天桥连接则不需要设置避难层
- 省去避难层所节约的费用可以用作强化其他更可靠的消防安全措施和“就地保护”的安全策略
- 避免因避难层设置带来的不必要的赋税和建筑高度面积分区限制

建筑的绝大部分楼层（如果不能利用全部楼层）都可以作为避难层进行有效地使用。基于合理的楼层与楼层间的防火分区、可靠的水喷淋系统、有效的消防设施和消防部门及时快速的反应，可以省去占用大量空间的避难层。即使避难层是规范要求必须设置的，仍然有可能减轻避难层带来的经济负担。其中一个重要的选择是，允许避难层在非紧急状况下可以作日常使用。建筑高度面积分区限制可以“恢复”避难层所占用的空间；税务法规应适当减免避难层空间的地产赋税。这些方案涉及到工程技术和管理的诸多因素。

结语

总之，与建筑建设成本和运营成本相比，避难层经济性的影响并不是主要的。问题最终归结到，是否有其他更有效、更经济、更可靠的解决方案可以实现替代避难层的功能？

CTBUH消防安全专业组认为有必要重新思考避难层的设计概念。针对超高层建筑的某些区域、某些特定人群，设置避难层是合理的，但也必须审慎，以避免上述讨论中所提到的建筑设计和生命安全相关的问题。避难层的设置可能是解决某些特定问题的合理方案，但不应当在没有仔细分析之前，就认定为所有高层建筑设计必然的第一选择方案。

一个先进的避难层设计概念应当是可以利用适当设计和装备的一些普通楼层（租赁使用楼层）中的区域作为避难层。这些楼层应当根据建筑内人员的需要，提供必要的空间、设置必要的设施和

for prompt and capable fire department response it is believed large refuge areas or floors can be effectively eliminated. If refuge floors are mandatory there are several potential opportunities for mitigating the financial impact of refuge floors. One of the most significant changes would be to permit refuge floors to have uses during non-emergency times. The zoning regulations could be modified to "recapture" floor area lost to refuge floors; tax regulations could be modified to eliminate costs for the areas of refuge floors. Such solutions pose both technical and political complications.

Conclusion

In conclusion, the opportunities for mitigation of the negative financial impact of refuge floors seem minimal compared to the costs of construction and ongoing costs of operation and maintenance. And so the question remains, is there a more cost effective, sustainable method of accomplishing what refuge floors are endeavoring to accomplish?

The CTBUH Fire Safety Working Group believes the concept of a refuge floor needs to be reconsidered. It may make sense for some areas of buildings of exceptional height or special occupancy conditions, but should be used only with caution, and with implementation of strategies or design elements which eliminate the design and life safety problems noted above. Refuge floors may be an appropriate solution for special or unique situations, and should not be a strategy of first choice without careful consideration.

An advancement of the concept of refuge floors might be to designate and equip certain typical floors (usable tenant floors) grouped in one area, as refuge floors. Such floors would be designed to provide the necessary area, amenities, and HVAC system performance required to accommodate the building occupants. However, the effectiveness of such an approach returns to the question of what is it that refuge floors can provide that cannot already be adequately provided on typical floors? What is the benefit of concentrating many occupants into one area, verses having them protected-in-place, or evacuated in an orderly manner with their colleagues and neighbors? These questions and others will continue to be discussed and evaluated by the CTBUH Fire Safety Working Group with the intent of delivering a full and complete treatise on this subject in the near future.

空调系统。但是，这种方法是否有效的问题同样最终归结到了，什么是避难层可以提供、而普通楼层不能的安全功能？将大量人员集中在避难层的方法，与“就地保护”或者同邻居、同事一道疏散的方法相比较，优点是什么？针对这些问题以及其他相关问题的继续讨论，将在近期由CTBUH消防安全专业组提交的完整文件/论文中详细说明。

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