CTBUH: A Historical Sketch

Zimmer Gunsul Frasca Firm Profile

What does September 11th Mean for Building Structure Design?

Saving Lives Through Structural Engineering
Dear Colleagues:

Welcome to the inaugural issue of the Council on Tall Buildings and Urban Habitat’s journal, CTBUH Review. We are very proud of the launch of this journal. It represents the culmination of work from members of the Council, including our editor, Brad Hinthorne.

Prior to this issue, the CTBUH Review was an on-line journal started in 2000 by then-editor Dr. Mir Ali of the University of Illinois, Urbana-Champaign. The Council would like to express its deepest appreciation to Dr. Ali and his assistant Abbas Aminmansour for their hard work and dedication in making the journal a reality.

This new journal is a very big step for the Council, as it is the first magazine-type publication that we’ve ever done that will be marketed to members and non-members alike. We hope that this will significantly raise the profile of the Council to do our work and give our members new exposure to a world-wide audience.

We hope you enjoy this inaugural issue. If you’re not already a member of the Council, we hope you will become one soon.

David M. Maola
Executive Director, CTBUH
Dear Colleagues:

It is with great excitement that we launch the inaugural issue of the newly updated CTBUH Review! In each issue, you will find compelling case studies, technical research articles, member/firm profiles and news related to tall buildings and the urban habitat. Published quarterly, the CTBUH Review aims to provide insight into the development, design and construction communities that will lead to a better and safer built environment.

The CTBUH Review is one of a number of benefits that CTBUH members receive. As a member, we call upon you to contribute to the CTBUH Review frequently. As a non-member, we hope you enjoy this issue and look forward to your future membership in the Council on Tall Buildings and Urban Habitat (ctbuh.org)

If you have any comments, suggestions or input, please feel free to contact me directly at rk@mka.com.

Sincerely,
Ron Klemencic
Chairman, Council on Tall Buildings and Urban Habitat
President, Magnusson Klemencic Associates

Dear Colleagues:

I am pleased to officially begin my duties as the first Editor of the CTBUH Review. Issue One is the first of what we hope are several meaningful and informative quarterly publications dealing with the range of issues relating to tall buildings and the urban habitat.

Through the process of gathering content for this first issue, I have learned a great deal about the challenges and realities of the publishing process. I would like to thank Ron Klemencic, Chairman of the CTBUH, for his strong suggestion that I “volunteer” to be Editor of this CTBUH Review, and David Maola, Executive Director of CTBUH, for his guidance and support in compiling this first issue.

I sincerely hope you enjoy this inaugural issue and look forward to your contributions to and thoughts about future issues. Please feel free to contact me at bhinthorne@zgf.com

Very truly yours,
Brad Hinthorne, AIA
Editor, CTBUH Review
About the Council on Tall Buildings and Urban Habitat

CTBUH: A Historical Sketch
  Author: Lynn S. Beedle

Lynn S. Beedle Honored by CTBUH

Firm Profile
  ZGF Firm Profile

Featured Project
  IDX Tower, Seattle, Washington
  Shoring Wall and Subsurface Structural Systems: IDX Tower, Seattle Washington
  Authors: David G. Winter, E. Douglas Loesch, and Robert Hollister

Technical Articles
  What does September 11th Mean for Building Structure Design?
  Author: Jon Magnusson
  Where Do We Go From Here?
  Author: Ron Klemencic
  Educating the Public of Safety in Tall Buildings
  Author: Jeffrey E. Harper
  Emergency Evacuation Core Proposal: 25 May 2002
  Author: Jeffrey Heller
  Engineering Systems an Incremental Response to Terrorist Threat
  Authors: Norman D. Kurtz, Andrew Hlushko, and Dan Nall
  Protective Design: Saving Lives Through Structural Engineering
  Authors: Ted Rittenhouse and Robert Smilowitz
  Tall Building Fire Safety -- Post 9/11
  Author: Joe Zicherman

Council Contributors

CTBUH Steering Group

Upcoming Conferences and Call for Papers
About the Council on Tall Buildings and Urban Habitat

- The Council on Tall Buildings and Urban Habitat, based at Lehigh University in Bethlehem, Pennsylvania, is an international organization sponsored by architecture, engineering, planning and construction professionals, designed to facilitate exchanges among those involved in all aspects of the planning, design, construction, and operation of tall buildings.

- The Council’s mission is:
  1. Disseminate information on healthy urban environments and tall building technology.
  2. Maximize the international interaction of professionals involved in creating the built environment.
  3. Make the latest knowledge available to professionals in a useful form.

- The Council is the recognized source for information on tall buildings worldwide.

- The Council focuses on the role of tall buildings in the urban environment. Providing adequate space for life and work involves not only technological factors, but social and cultural aspects as well.

- The Council publishes the CTBUH Review, which includes papers submitted by researchers, scholars, suppliers, and practicing professionals who are engaged in the planning, design, construction, and operation of tall buildings and the urban environment throughout the world.

- The Council maintains the “High-Rise Buildings Database” which contains data on thousands of tall buildings: the latest facts and statistics, visual images, and listings of professional firms linked to specific buildings and specialty categories.

- The Council hosts global conferences on the topics of tall buildings and the urban habitat.

- For more information, please go to www.ctbuh.org.
It all started with the IABSE. It is not often that one can remember the precise start of something...right back to the moment he had the idea. But in the case of the Council on Tall Buildings and Urban Habitat, I can: The afternoon of Friday, September 13th 1968 at the 8th Congress of the IABSE in New York. Prof. H. Beer of Austria was summarizing the theme, “Tall Steel Buildings”, and I was struck by the significant tall building research he was describing. This research was not being coordinated or evaluated in a form useful to the designer. It spoke of the need for an international effort to bring information together.

Acting upon that idea, I wrote to Prof. Beer and in due course he responded that international exchange indeed should be started. By that time, it was February, 1969 and at a meeting of the U.S. Group of IABSE in New Orleans, then chairman Elmer Timby, asked us to suggest a topic that we could “gather around” as a basis for more frequent exchanges with our professional colleagues overseas. Here was the opportunity to implant the idea: the preparation and updating of a Monograph that would provide a focus for continuing exchange. It would be a joint activity between the IABSE and ASCE – hence its original name “Joint Committee on Tall Buildings”.

Jewell Garrlets made the presentation to IABSE at its following meeting in Britain in September of 1969. Approval by the American Society of Civil Engineers came shortly afterwards. National Science Foundation funding was approved and we were on our way. The Headquarters was established at Lehigh University, Bethlehem, PA, USA.

A tall building is not defined by its height or number of stories. Rather, the important criterion is whether or not the design is influenced by some aspect of “tallness.”
The need for the Joint Committee was more than just the desire to get together. It stemmed from things like the exploding urban population, creating an increased demand for tall buildings; the need for economy in construction; the frequent neglect of human factors at the expense of livability and the quality of life; the need for new research required in the field; and the necessity of establishing priorities for such reasons.

The timing was right, too. There were very few high-rise buildings built in the 1950s. But by the 1970s, tall building construction increased substantially.

As a result of the increased emphasis on planning and environmental criteria in 1973, the American Institute of Architects, the American Planning Association, the International Federation for Housing and Planning, and the International Union of Architects were invited to join the forming organizations as equal participants with IABSE and ASCE. Since then, the American Society of Interior Designers, the Japan Structural Consultants Association and the Urban Land Institute also have become sponsoring societies. Then, in 1976, the “Joint Committee” changed its name and became known as the Council on Tall Buildings and Urban Habitat.

In 1979 it was admitted as a Category B non-governmental organization of UNESCO.

One of the well-remembered Steering Group meetings was one of the first, at which Les Robertson and the late Fazlur Khan were debating the question of “What is a tall building?” After all, if we were going to do a Monograph on tall buildings, one needed a definition. The final decision: A tall building is not defined by its height or number of stories. Rather, the important criterion is whether or not the design is influenced by some aspect of “tallness.” It is a building whose height creates different conditions than those that exist in common buildings of a certain region or period.

The Steering Group next organized the 1971 conference in Bled, Yugoslavia, to bring together specialists from all over the world to decide what this Monograph would be all about. Delegates reviewed the abstracts of papers that later would be presented at the First International Conference (they are now called World Congresses) held at Lehigh University. More than 700 people attended this later five-day event from August 21 through 26, 1972. Adhering to a strictly enforced 7-minute time limit, 261 “reporters” and over 200 discussers participated, coming from 30 countries. Twenty-seven preprint volumes were available to the participants, followed by a five-volume set of Proceedings. It is still known around the world by Council members as the “Lehigh Conference.”

That conference was followed by an intensive series of follow-up conferences – 20 being held in the 1972-1975 period. Their essential function was to disseminate the information coming out of the Lehigh Conference and to collect material for the Monographs.

Throughout it’s over 30-year history, the Council has continued to strive toward the dissemination of information and the stimulation of research on tall buildings throughout the world. It continues to have a major concern with the role of tall buildings in the urban environment and their impact. It is not an advocate for tall buildings per se; but in those situations in which they are viable, it seeks to encourage the use of the latest knowledge in the implementation. In addition to sponsoring conferences on a regional and international basis, the Council has continued the work of the original Monograph, publishing update volumes, a regular newsletter, and other reports and support documents.

Much has been accomplished by the Council, but most important, perhaps are the relationships that have been established with colleagues from a wide range of professions and from all over the world. We thank Prof. Beer for lighting the spark on September 13, 1968. And we thank Elmer Timby for asking the right question.

[Reproduced from the Structural Engineering International with the permission of the publisher and the author.]
Lynn S. Beedle
Honored by CTBUH

“... a man of ample vision, an energetic organizer, and international relations person and, above all, a warm human being.”

The New York Marriott Marquis was the setting for the Council’s First Annual Awards Gala, which was held on September 26, 2002 to honor Dr. Lynn Beedle for his contributions to the profession and 30 years of dedicated service to the Council. In attendance were more than 100 colleagues, former students, family and friends. The evening kicked off with a cocktail reception that, despite the rain, provided a beautiful view of Times Square. During the reception Mrs. Frances Tomoko Takemoto presented Dr. Beedle with a Japanese traditional fan on behalf of her father Kiyoshi Yoshikawa “to celebrate this happy occasion and to commemorate our friendship since December 7, 2000 from Japan.”

After dinner Ron Klemencic opened the program by reading notes on behalf of former chairman Gilberto do Valle and Ignacio Martin. Martin described Dr. Beedle as “a man of ample vision, an energetic organizer, an international relations person and, above all, a warm human being.”

Dr. Mohamed El-Aasser, Dean of the P.C. Rossin College of Engineering and Applied Sciences, representing Lehigh University, commended Dr. Beedle for his “tireless enthusiasm for sharing what he knows and for bringing people together to talk about structural engineering....visiting elementary schools to talk to children about skyscrapers....and for selflessly promoting the achievements of others, particularly the late Fazlur Rahman Khan.”

Former chairman R. Shankar Nair talked about how he met Dr. Beedle while a graduate student in the 1960’s, a time when “every civil engineering graduate student recognized Dr. Beedle as a giant in...”
About CTBUH

George Tamaro’s relationship with Dr. Beedle began 43 years ago when he came to Lehigh University and was chosen by Dr. Beedle for a Research Assistantship where he admitted that while Dr. Beedle’s detailed review and criticism of his writing drove him to tears, in hindsight, it well prepared him for the future. Tamaro thanked Dr. Beedle for taking his son Mark under his wing during his studies at Lehigh and concluded that the best characterization for him was the Energizer Bunny, “…you will never run out of energy, you will always be an inspiration and a driving force, and a role model for that which we should do and be,” after which he presented Dr. Beedle with an Energizer Bunny in recognition of that drive and endurance.

Dan Sesil reading a message from Les Robertson, commended Dr. Beedle for being the one to “carry the heavy load, with the rest of us, burdened with only light packs, following you up the mountain.” Robertson concluded that if “an attempt were made to examine (tonight) the remainder of your contributions to our profession and to society, the night would never end.” Concluding the tributes was a video, produced and narrated by son David Beedle, reviewing the life of Lynn Beedle as a family man and a professional.

Dr. Beedle was then presented with a 10-inch crystal replica of the Council’s new logo, designed by Crystal Signatures of Bethlehem, PA, designer of pieces for several U.S. presidents. Dr. Beedle reminisced about his years with the Council and closed with his “ten reasons why retirement is so good.” The list includes, what I think everyone looks forward to - time with the family and the fact that TGIF becomes, “Thank God it’s Friday – and Monday, and Tuesday, and …”

The event was considered a great success and one that the Council plans to build on in years to come with the main objective being the presentation of the “Lynn S. Beedle Achievement Award,” to be given to an individual who has significantly contributed to the betterment of the built environment. The 2003 dinner is being planned for Chicago in late September or early October. An awards committee will be assembled to consider nominations, select the recipient, and consider the addition of other awards.

Colleague Charles DeBenedittis met Dr. Beedle at Lehigh University in 1972 at the Council’s first international conference of what was at that time known as the Joint Committee of Tall Buildings. DeBenedittis described Dr. Beedle as a man of vision and perseverance and in discussing his attributes with several colleagues on the Council other words that came out were “energetic, organizer, fundraiser, optimist (that applies to his financial projections), planner, focused, meticulous, knowledgeable, affable, renowned, patient, respectful, and always a gentleman in every way.” He finished by thanking Prof. Beedle, “Mr. Tall Buildings,” for leading us along in furthering and exchanging our knowledge of tall buildings and the urban habitat.”
Zimmer Gunsul Frasca Partnership (ZGF) is a 380-person architecture, planning and interior design firm with offices in Seattle, Portland, Los Angeles and Washington, DC. The firm is internationally recognized for design excellence encompassing a diverse portfolio of public and private projects in settings ranging from major urban centers to small farming communities and college campuses.

From the design of high rise office and mixed-use buildings to light rail systems, museums, research buildings, corporate campuses and airports, ZGF is recognized for our ability to consider the unique qualities of each place and to create buildings that go beyond simply enclosing their programs to make a lasting contribution to the communities of which they become a part.

ZGF’s achievements for design excellence have been recognized through over 250 national, regional and local design awards, most notably the American Institute of Architects (AIA) Architecture Firm Award. The firm has also received awards from Modern Healthcare Magazine, three Lab of the Year Awards from R&D Magazine, two Federal Design Achievement Awards, GSA Design Awards, numerous AIA Awards, Progressive Architecture Awards, and a Presidential Design Award for Design Excellence. Most recently, USA Today Magazine highlighted our Westside Light Rail project in Portland as one of the five most important buildings of the 21st century.

In addition, ZGF projects have been featured in a number of publications, including four monographs: Building Community, published by Rockport Publishers, Between Science and Art, published by L’Arca Edizioni, Building the Doernbecher Children’s Hospital, by L’Arca Edizioni, and most recently, Building the Church of Latter-day Saints Conference Center, also by L’Arca Edizioni.

Recent clients include Hines, Equity Office Properties, Boston Properties, Catellus Development, Slough, Commonwealth and Trammell Crow Company, as well as corporate clients including Microsoft Corporation, Amazon.com, SAFECO, Amgen and Pfizer. Institutional clients include the National Institutes of Health, the Fred Hutchinson Cancer Research Center, Memorial Sloan-Kettering Cancer Center, Johns Hopkins University, Cornell, Northwestern University, Williams College and a number of other public and private institutions. The firm has also designed projects for the US Department of State, including the New Office Building for the US Consulate General in Instanbul, Turkey and the US Embassy New Office Building in Sophia, Bulgaria. Most recently we were selected to design the US Embassy New Office Building in Capetown, South Africa. The following photos show some of ZGF’s completed projects.
Firm Profile
Zimmer Gunsul Frasca Partnership

Photo Credits

National Institutes of Health
Mark O. Hatfield Clinical Research Center
Bethesda, MD

Second & Seneca Office Building
Seattle, WA

Microsoft Redmond West Campus
Redmond, WA

Amazon.com Corporate Headquarters
Seattle, WA

Memorial Sloan Kettering Cancer Center
New Research Building
New York, NY

Bellevue Regional Library
Bellevue, WA

Oregon Convention Center
Portland, OR

Oregon Convention Center
Timothy Hursley

Portland International Airport
Portland International Airport
Timothy Hursley

California Science Center (previous page)
Timothy Hursley

National Institutes of Health
renderings by Zimmer Gunsul Frasca

IDX Tower (following pages)
Eckert & Eckert

Photo Credits

Millennium Tower (cover)
Mark Griffith
Memorial Sloan-Kettering
courtesy of Zimmer Gunsul Frasca
Amazon.com Headquarters
Strode/Eckert Photography
Second and Seneca Building
Fred Housel
Microsoft Corporation
Nick Merrick (Hedrich-Blessing)
Bellevue Regional Library
Timothy Hursley

Portland International Airport
Portland, OR
IDX Tower  
Seattle, Washington

The IDX Tower, completed in December 2002, is the largest commercial office building to be built in downtown Seattle in more than a decade. The 40-story, 1.2 million SF mixed-use development provides 850,000 SF of office space, 15,000 SF of retail and 637 underground parking spaces. State-of-the-art electrical, emergency power and communications amenities are designed to meet demanding technology needs of 21st century tenants. Primary objectives for the design of IDX Tower were to maximize the size and efficiency of the individual floor plates, to create an architectural expression that distinguishes the building from its taller neighbors in Seattle’s financial district, to respect the adjacent historic YMCA, and to relate to each of the four surrounding streets, as well as take full advantage of views.

Design Solution

The tower mass was designed with its long dimension in the east-west direction and was set to the north side of the site to the extent allowed by the Seattle Zoning Code. This solution maximizes the size of individual floor plates, preserves views past adjacent office buildings and maintains the architectural prominence of the historic YMCA. The south façade of the tower cantilevers over the YMCA and is expressed as a glass curtain wall to appear visually light and to create a uniform backdrop to the YMCA building.
The exterior design solution of the IDX Tower is expressed as a slender modern tower sheathed in light colored granite, tinted glass and metal curtail wall resting on a base podium. Vertically proportioned windows and exterior columns clad in blue-gray granite create a strong vertical expression. The tower’s height, the maximum allowable for the site, is enhanced by the mass rising uninterrupted from the street to a detailed crown that is clad in light colored metal and silver spandrel glass and designed to visually contrast with the body of the building. At the street level, the exterior design extends the level of finely-scaled detail exhibited on the YMCA building in order to continue a high level of interaction between the new building and the pedestrians on the surrounding sidewalks.

**Project Team**

Hines  
*Owner/Developer*

Zimmer Gunsul Frasca Partnership  
*Design Architect*

Kendall/Heaton Associates, Inc.  
*Architect-of-Record*

Magnusson Klemencic Associates  
*Structural Engineer*

Flack + Kurtz Consulting Engineers, LLP  
*Mechanical/Electrical Engineer*

Coughlin Porter Lundeen  
*Civil Engineer*

Hart Crowser  
*Geotechnical Engineer*

Persohn/Hahn  
*Vertical Transportation*

Walker Parking Consultants  
*Parking*

HMA Consulting, Inc.  
*Security*

Hornall Anderson Design Works  
*Graphics*

Cerami and Associates  
*Acoustics*

Rolf Jensen & Associates, Inc.  
*Life Safety*

Martin Smith Development Corporation  
*Preconstruction*

James Carpenter Design Associates  
*Artist*
Shoring Wall and Subsurface Structural Systems:
IDX Tower, Seattle, Washington

David G. Winter, E. Douglas Loesch, and Robert Hollister

The 40-story IDX Tower is located in the Seattle financial district adjacent to the historic Downtown Seattle YMCA. Excavations extending as deep as 97 feet below the adjacent streets were modeled and monitored. Underpinning and interfingered tieback anchors supported the YMCA and the associated re-entrant corner. This paper reports on the performance of the excavation shoring. The new building is supported on a mat footing that varies in thickness from 6 to 14 feet. This paper also discusses the design of the mat, and the building core wall support.

The IDX Tower Development at Fourth and Madison

Groundbreaking for the 512-foot IDX Tower at Fourth and Madison took place in October 2000. The Tower is a 40-story, 1,053,000-ft² (846,000-ft² leasable) office development in the center of downtown Seattle’s Financial District. The office tower, the

Built on one of Seattle’s hills, this building deals efficiently with the steeply sloped site.
Featured Project
David G. Winter, E. Douglas Loesch, and Robert Hollister

IDX Tower at Fourth and Madison

eighth largest in Washington and the first to top the 500-foot height mark in Seattle in over a decade, sits atop a retail podium highlighted by a dramatic 5-story atrium entrance. The structure consists of steel framing with a concrete core. Clad in a combination of light gray, figured granite, metal and glass curtain wall, the tower has views encompassing Mount Rainier, Puget Sound and the Olympic Mountains. At 24,400-24,900 square feet, the highly efficient floor plates of tower feature core-to-wall dimensions exceeding 42 feet.

The $95.8 million project is being built for National Office Partners, a Hines Limited Partnership. Hines has developed more than 125 million square feet of commercial space around the world. Zimmer Gunsul Frasca Partnership of Seattle served as Design Architect with Kendall/Heaton Associates as Production & Construction Administration Architect. PCL Construction Services, Inc. of Bellevue Washington is the general contractor. The building is named for IDX Systems Corporation, a Burlington, Vermont company that develops health-care information systems, that will occupy approximately 300,000 square feet.

Built on one of Seattle’s hills, this building deals efficiently with the steeply sloped site. There is an elevation difference of 41 feet between the main entries off Fourth and Third Avenues; tenants enter on the fourth floor on Fourth Avenue and the first floor on Third Avenue. Two levels of office space, the loading dock, the parking garage entries, and the building management spaces are located entirely on floor levels between the two main entries.

Subsurface Conditions Disclosed
Overconsolidated Soils and Potential Obstructions

Eight new explorations were drilled to explore the site. Together with sixteen others from nearby projects, they formed the basis for geotechnical design parameters. Ground surface elevations range from 145 feet along Fourth Avenue to 105 feet along Third Avenue. Subsurface soils generally consist of about 5 to 10 feet of surficial sand fill overlying interbedded silt and sand down to about elevation 80 feet. Below this interbedded material is a more consistent unit of clay and silt, varying in thickness from 10 to 40 feet. Some of the clay soils were blocky and had slickensided surfaces. A cemented silt and sand underlies the clay to below the bottom.
of the excavation. Except for the fill, all soils are overconsolidated and very dense or hard.

Isolated wet zones exist in the upper soils, and more significant groundwater was encountered above the silt and clay units between about elevation 80 and 100 feet.

During pre-excavation remodeling of the YMCA, the soils beneath the existing basement floor slab had been revealed as loose or poorly compacted fill. Voids had also been encountered. The reconstruction of the floor slab and installation of new shear wall footings had improved the conditions beneath the YMCA, but the uncertain conditions remained as a design consideration for the support of the building during excavation.

On the east side, below Fourth Avenue is the Burlington Northern Santa Fe railroad tunnel located at a depth of approximately 100 feet and below Third Avenue on the west side is the Seattle Metro bus/transit tunnel at depth of 56 feet. These tunnels are both quite sensitive to disruption of their geotechnical environment. The railroad tunnel was built largely by hand methods in the late 19th century and allowed considerable disturbance of the soil above the bore. The transit tunnel is built of segmental construction and relies for stability on soil pressures to maintain its shape. Consideration of the performance of the tunnels and their locations was a major factor in establishing the configuration of the subgrade levels for the project.

The office tower cantilevers 12 feet over the adjacent historic Downtown YMCA building, to create a gracefully arcing glass facade. Covering 3/4 of a block in the form of a 200 by 200-foot “L,” the project also includes shoring for three streets with a maximum excavation depth of 97 feet, a 4-story basement, and complicated underpinning of the brick and terra-cotta YMCA building. The historically registered YMCA built in 1930 occupies the southeastern quarter block of the site.

Design and Construction Criteria and Challenges

General Shoring Wall

Conventional soldier piles and tieback anchors were the obvious and appropriate choice for excavation support. This approach has been used extensively in Seattle, with good and documented results. The method consists of a W-section steel beam installed in a predrilled hole that is then filled with lean concrete. Soldier piles are spaced at 6 to 10 feet laterally.
Tieback anchors are drilled into the soil adjacent to the soldier piles at angles of about 20 degrees below horizontal, affixed with locking pins, and prestressed. They are installed at vertical spacings of about 8 to 10 feet. This method of installation is intended to limit post-installation deflections. Installation difficulties can arise from groundwater or unstable soil, requiring that the soldier pile holes be cased, from obstructions (such as boulders or remnant concrete foundations) that may require coring, or from previously installed (though destressed) tieback anchors from adjacent excavations.

Estimates of the lateral soil pressure envelope on deep excavation shoring walls are usually made using a combination of theoretical relationships, such as those from Terzaghi and Peck (1), Schnabel (2), and others (3, 4), and local experience (5, 6, 7, 8). Since relatively few deep excavations are instrumented to allow measurement of actual loads, local experience and the observations of past successfully completed excavations becomes increasingly important. Typically, the design envelope is accompanied by an expectation of about 1 inch of lateral deflection at the ground surface, a value repeatedly shown to be protective of adjacent streets, utilities, and buildings.

Expressed in terms of the excavation height, H (in feet), the design wall pressure envelope for the IDX Tower was set at 22H psf adjacent to the city streets, and 27H psf adjacent to the YMCA. The additional 5H psf adjacent to the walls adjacent to the YMCA represented an attempt to reduce the deflections of the wall and thus settlement of the YMCA. Surcharge loads from the YMCA footings were added to the soil pressure envelope. The pressure diagram is shown below. The diagram is intended not to predict the actual pressures on the wall, but rather to envelop the maximum pressure at any individual tieback location.

The shoring system selected for the IDX Tower included 137 steel soldier piles ranging in size up to W14 X 159 pounds per foot and a maximum length of 112 feet. Eighteen of the piles are used for underpinning for the northern elevation of the YMCA over a width of approximately 80 feet. A total of 677 tieback anchors up to 96 feet in length restrain the soldier piles.

The project required a complex shoring system, as the site is located in a crowded urban environment. The project had to contend with many existing underground utilities including the railroad and transit tunnels in the adjacent rights-of-way. The project also required demolition and staging coordination with existing buildings on site. A temporary, intermediate shoring wall approximately 15 feet high was designed to allow demolition of existing structures to proceed on the west half of the site.

Support of the YMCA

The west side of the YMCA was set back about 7 feet from the face of the shoring wall, although the YMCA perimeter footings were within a few feet of the wall. Accordingly, all of the loads from the YMCA were applied to the shoring wall as lateral loads on this side. On the north side of the YMCA the renovation had included construction of a new continuous perimeter shear wall along and flush with the face of the exterior wall face. On this side, the new wall was underpinned, transferring the footing loads to the soldier piles as vertical loads. Only the lateral pressures from the interior footings were applied to the shoring as lateral loads.

Tieback anchors passed within about two feet vertically of the bottom of the perimeter footings on the west side of the building, and as close as 4 to 8 feet below interior footings on the west and north sides. In addition, for approximately one-third of the wall the tiebacks were interfingered – with tiebacks from the west wall crossing those from the north wall. The design separation between the ties was two feet.

Shoring of a re-entrant corner such as this is relatively uncommon, and the performance is made more critical by the size and construction of the retained building. Some of the designs of these projects have modified the no load zone behind the wall, or reduced the available frictional resistance of the tiebacks, or increased the design lateral pressures in the area of the tieback interfingering. This design incorporated none of these extra measures because the designers could find no compelling theoretical or performance-based evidence that these modifications better modeled the actual conditions.
Featured Project
David G. Winter, E. Douglas Loesch, and Robert Hollister

“No-load” Zone Modification

Along Fourth Avenue and the eastern half of Madison Street the street widths were not sufficient to allow construction of upper tieback anchors of traditional length. The no-load zone is an area of soil behind the shoring wall that is approximated by the active wedge. Since the shoring walls are generally designed for some deflection, and thus active pressure conditions, the anchor zones of tiebacks must be behind this yielding soil. The no-load zone is typically defined by a line extending upward from the base of the excavation to the ground surface at a 60-degree angle, and set back by a value of one-third to one-fourth of the height of the excavation. This can result in very long upper row tiebacks. In fact, this traditional construction resulted in a no load zone that intersected the ground surface about 75 feet behind the face of the excavation. On Fourth Avenue the property line to property line measurement (and thus maximum tieback length) was only 83 feet. On Madison Street the available tieback length was only 66 feet. Shorter tiebacks supporting the deepest section of the excavation was a cause for some concern, but truncation of the no-load zone is not unprecedented. Applying a more accurate estimate of the active pressure failure surface results in a log spiral shape that is near vertical at the top. In addition, other excavations in Seattle, most notably for the Columbia Tower (6) faced similar length restrictions and demonstrated that the no-load zone truncation does not necessarily lead to greater deflections of the wall.

Foundation Support

The core mat bearing pressure and settlement design considered not just the competence and consistency of the supporting soil, but also the nature of the applied loads (dead, live, and seismic or wind), the timing of the likely settlement (during construction or long term), and the resulting rebound and recompression caused by the removal of an average of 80 feet of overburden. The resulting allowable soil bearing pressure of 12 ksf beneath the mat was one of the largest values ever used in Seattle. One-dimensional and two-dimensional FLAC analyses gave similar estimates of settlement response – a value of 2-1/2 inches.

Earthquake Design

The project advances the state of the art in earthquake engineering using a performance-based design concept for the concrete shear-wall core. The core walls rise 553 feet above the 14-foot thick, concrete mat foundation. In order to meet the Seattle Building Code’s (UBC) height limits, a building of this size would traditionally require dual lateral systems. A similar design, not performance-based, could, for example, employ very large columns and diagonal steel bracing combined with a costly, intrusive moment frame. The height limit mandated by the building code for a traditional concrete shear-wall core for a high-rise building is 240 feet. The design of the IDX Tower insures that the concrete shear-wall lateral system meets the ductility performance objectives of the Building Code by more accurately analyzing the performance of the building under a seismic loading in excess of the requirements of the Building Code. The resulting design produces a highly economical structure. The lateral system maximizes value for the project by taking less space in plan and elevation. The concrete core is very stiff and minimizes damage to interior, skin and building contents during earthquakes. Additionally, more stringent steel reinforcement detailing requirements are employed which significantly enhance the performance of the structure in the event of large earthquake ground motions. The core also enhances occupant comfort under the effects of wind-induced sway.
The geometry of the shear-wall core is switched over a height of 42 feet from a rectangular box section to a cruciform section, with the same outside dimensions, 101 by 32 feet at the base. The concrete core walls range in thickness from 1 foot at the top to four feet thick in the parking garage. The walls are much less intrusive to the parking layout and leasable space than large built-up or composite columns or an exterior braced frame system, while creating a building stiff enough to minimize damage to non-structural elements (partition walls, windows, etc.) in the event of a large ground motions.

Subsurface Structural Elements

This building faces severe structural challenges from the slope of the site. The elevation difference of 41 feet between the high and low sides on Fourth and Third Avenues, respectively, imposes a net unbalanced soil loading on the basement structure in excess of 6,000 kips plus an additional allowance for seismically induced pressure in the soil. This large lateral earth pressure is resisted primarily by the shear-wall core. In the lower levels the earth pressure combines with the maximum magnitudes of seismic lateral force. The central wall of the cruciform shape core section is 4 feet thick by 101 feet long in the direction of the principal earth pressure.

The large interacting set of lateral forces result in a very high overturning effect on the concrete core. The foundation is a mat is 237 by 119 feet overall, with a 6 feet thick perimeter zone that receives all the tower columns. The interior section of the mat is thickened to 14 feet in the region of the core walls; a zone 87 by 157 feet. For design of the mat, the bearing strength of the extremely competent native soil was taken as 12 ksf. This cross-section of the mat was selected as structurally optimum. The mat employed vertical shear reinforcement in limited areas where detailed
finite element computer modeling indicated the punching effects at the corners of the core exceeded the strength of the 14-foot solid concrete section. A conventional concrete mixture with a strength of 5000 psi was employed for the mat, which was placed in a continuous pour of 10,952 cubic yards. The mat pour, second only to AT&T Gateway Tower in Seattle history, took place flawlessly over a period of 12 uninterrupted hours. It was determined to take no special measures for the massive nature of the concrete placement. Conditions were cool and moist and the placement on grade allowed for ideal curing conditions. No cracking of the mat has been noted.

As a side note, the 14-foot height of the upper reinforcing layers in the mat required extraordinary consideration of the design of the support system for the top bars. Collapse of the reinforcement during placement would essentially destroy the entire mat. Normal rebar “standees” just weren’t going to make it. Trusses and similar solutions were considered but these had long lead times and were too costly. Skilling designed a system of supports using reinforcing bar in a three-dimensional matrix. The rebar matrix was, in effect, a very large space-truss. The bars were interconnected using twisted, soft iron wire connections of known strength plus limited welding. The resulting assembly was designed for live loads from the placement equipment and workers, and reviewed for hydrodynamic forces resulting from concrete placement. The system proved very cost-effective and functioned perfectly.

**Computer Modeling to Predict Performance**

*Interfingered Tieback Anchors Beneath the YMCA*

Skilling developed a complete three-dimensional computer model of the shoring system around the YMCA. The model was intended to review the complex geometry of the 38 soldier piles along this corner of the excavation. The piles were supported laterally by up to 6 rows of tiebacks per soldier pile. With so many tiebacks crossing each other at varying angles, there was a potential for tieback conflicts. The model allowed us to adjusted the soldier pile and tieback locations so that there were no conflicts.
Displacement-Based Analyses Using FLAC

FLAC is a two-dimensional finite difference program used to model soil-structure interaction problems. Instead of a factor of safety result, such as from limit-equilibrium analyses, FLAC calculates forces and displacements directly based on the input structural elements and the soil properties. The two key output values from the FLAC model were displacements along the soldier pile and loads on the tieback anchors. Carefully designed soldier pile/tieback walls rarely fail catastrophically. Rather, they deflect more than anticipated, resulting in ground surface settlement behind the wall, and potential distress to adjacent streets, utilities, and buildings. Overstressed tiebacks deflect much like friction piles can settle. When they deflect, they shed load to other nearby tiebacks causing them to deflect. The result can be a section of wall that rotates toward the excavation before measures (such as additional new tiebacks) can be installed to pick up the excess loads. Thus the relationship between tieback loads and soldier pile deflections predicted by FLAC is a critical check of the traditional design process.

To confirm the key input soil parameters from the geotechnical engineering design report additional field studies were completed using three pressuremeter tests in two new explorations near the YMCA. The pressuremeter test provides a good estimate of the modulus of the soil, which is critical for deformation-based analyses. An outside consultant completed the tests, and recommended the resulting soil modulus values. This same consultant had recently completed pressuremeter testing at another downtown Seattle site with similar soils, and a FLAC analysis had followed. This allowed the analysis for the IDX Tower to be calibrated more accurately to the soil conditions based on actual predicted and observed results at a nearby site. The analysis was further checked by predicting the deflections and loads from a typical cross section of soils combined with a typical cross section of shoring. Under such conditions the actual...
Featured Project
David G. Winter, E. Douglas Loesch, and Robert Hollister

deflections had been well documented from other sites, so the “accuracy” of the FLAC model and the appropriateness of the many input parameters could be assessed before the IDX Tower combination of soil and shoring was analyzed.

The FLAC model was used to predict deflections for three actual/typical conditions: a soldier pile underpinning the north wall of the YMCA; a soldier pile supporting the lateral loads from the west wall of the YMCA; and a soldier pile along the east wall of the excavation representing the maximum required truncation of the no-load zone.

The plots below show the predicted deflections of the two soldier piles supporting the YMCA. Note that the magnitudes of the maximum expected deflections are similar – about 3/8 inch occurring in the lower quadrant of the soldier pile. The maximum expected deflections are similar even though the underpinning soldier pile on the north YMCA wall is about 30 feet longer, and the excavation about 15 feet deeper than at the soldier pile location on the west wall. This indicates that the relationships between soldier pile deflection, pressure envelope, and tieback loads are consistent, regardless of the depth of the excavation and magnitude of surcharge loads. The deflection of the west soldier pile into the soil near the top suggests that the pressure envelope or surcharge loads are overestimated and that the upper tiebacks are overdesigned.

The displacement plot below demonstrates the potential effect of the modified no-load zone. Note that the FLAC model predicted less than $\frac{1}{2}$ inch of additional deflection as a result of the modified no-load zone. Maximum predicted deflections of about 1-1/4 inches again verified both the pressure proposed pressure envelope and the acceptability of a modified no-load zone.

The modified no load zone is a truncated wedge. The wedge is truncated at a distance of H/2 feet behind the excavation for the tiebacks along Fourth Avenue, and as close as H/3 feet for a portion of the excavation along Madison Street.

---

Excavation Monitoring and Instrumentation

Installation of the 137 soldier piles and 677 tieback anchors, and excavation of the 105,000 cubic yards of soil took five months. During excavation the performance of the shoring system was monitored in several ways:

- Five inclinometers installed in borings adjacent to and just behind the shoring wall at soldier pile locations E5, E10/11, E20/21, E30/31, and W15/16;
- Hydraulic load cells attached to tiebacks on seven soldier piles: N21, N30, E5, E20, S6, S16, and W19; and
- Optical survey monitoring of the soldier piles, YMCA, and adjacent streets by both the contractor and an independent surveyor.
**Featured Project**

David G. Winter, E. Douglas Loesch, and Robert Hollister

*Instrumentation Results – Inclinometers Compared to FLAC*

Inclinometer data for E5 and E20/21 are presented below. Both deflection shapes are comparable to each other, and generally consistent with the predicted deflection shape of the FLAC analysis. They both indicate greater deflections near the base of the excavation than at the top, and a bulge in the 20 feet or so above the base of the excavation. At E5, the soldier pile is in the deepest part of the excavation, and should be compared to the FLAC analysis for the no-load zone truncation. These two compare reasonably well, although the actual deflections were slightly greater than the FLAC predicted deflections, suggesting that the soil modulus values were slightly too stiff, and that the design soil pressures may have been too low for the planned deflection. It may also indicate that the effects of the reduced no-load zone were greater than predicted.

At E20/21 (located adjacent to the west wall of the YMCA) the surcharge loads from the YMCA are applied to this soldier pile/tieback system, and the FLAC analysis. The actual deflected shape suggests that either the soil modulus in the FLAC analysis is too stiff, or that the surcharge components from the YMCA were underestimated, or that the tieback anchors were underdesigned. These tiebacks were interfingered with those from the north wall of the YMCA. Note also that the load cell on the lowest tieback registered zero load on that tieback despite being locked off at 100% of the design load. This tieback may actually have failed after installation, resulting in load shedding to the other nearby tiebacks, and increased deflection of the soldier pile near the bottom of the pile.

Inclinometer W15/16 and E30/31 (not shown) demonstrated a consistent pattern of deflection. Above the first tieback level, a spike of deflection...
occurred into the excavation that was pushed back by each successive anchor installation, gradual increases in lateral deflection as the excavation deepened, and then a bulge in the 10 to 15 feet above the bottom of the base of the excavation. This shape suggests that the pressures are higher than at the top, although the design values were not inappropriate, since the magnitude of the deflections was less than ½ inch.

Instrumentation Results – Load Cells

Twenty-two of the forty-three installed load cells on seven soldier piles were still functioning and accessible at the end of the excavation. All instrumented anchors were locked off at between 80% and 100% of the design values. So any measurements on the load cells that were below the lockoff load represents a relaxation of pressure. Only two of the load cells showed post-lockoff tieback loads exceeding 90% of the design values. Twelve of the load cells showed post-lockoff loads of between 70% and 90% of the design values, and eight showed loads below 70% of design. There was no apparent correlation between the load cell pressure and the observed deflection.

One conclusion to draw from the load cell data is that the wall pressures were overestimated by an average of about 20%. If the wall pressure envelope had been defined as $18H$ for the shoring walls adjacent to the streets and $22H$ for the walls adjacent to the YMCA, only four of the load cells would have shown loads greater than 105% of design, and only one would have exceeded the 130% proof test value applied to each anchor installation. Since the tiebacks are designed with a safety factor of at least 2.0, plenty of capacity would remain with the lower design value.

Instrumentation Results – Optical Survey

Lateral deflections into the excavation were greater than ½ inch only along Fourth Avenue, the deepest part of the excavation and one of the areas with a truncated no-load zone. Independent surveyors measured lateral deflections of about 1-1/2 inches in the middle of the block, and ¾ inch to 1 inch near the corners. By comparison, lateral deflections on the west wall (Third Avenue) and the north wall (Madison Street) were ¼ inch to ½ inch. Vertical settlements were typically ¼ inch around the site except along Fourth Avenue, where the settlements were generally 1-3/4 inches to 2-1/2 inches. The optical survey data clearly showed the three-dimensional effects of corner support. Within about 15 feet of a corner (two soldier piles) the lateral deflections and the vertical settlements are smaller than elsewhere. This additional restraint from the adjacent wall should allow lateral soil design pressures to be reduced in this zone.

Instrumentation Results – YMCA

None of the shoring supporting or adjacent to the YMCA performed outside of the expectations of the design. Lateral deflections from the optical survey were generally less than ½ inch to ¾ inches at the top, and that deflection did not result in distress to the YMCA. If the deeper deflections shown on inclinometer E20/21 were typical, this further demonstrates the point that these walls are flexible, and that small lateral deflections do not affect conditions behind the wall.

This positive result further demonstrates another important point with regards to the interfingered tiebacks and the reentrant corner. The presence of tieback anchors parallel to and just behind the wall (and within the no-load zone) does not apparently affect the performance of the wall, nor reduce the mobilization of soil friction along the tieback.

Proposed New Design Criteria

The data support four modifications in the traditional lateral soil pressure design for soldier piles and tiebacks. Modifications of this type have appeared in the literature in the past, and build on the continually increasing availability of research and instrumentation results from deep excavations in overconsolidated soils.

1. Design future shoring walls in these types of soils using a lateral pressure envelope that is 80% of the conventional value. Lower pressures will result in lighter soldier pile sections, shorter or smaller or fewer tieback anchors, thinner lagging, and a less costly shoring wall.
2. Unless the lower one-fourth of the excavation is clearly and consistently in hard silt/clay soil, do not truncate the bottom of the pressure envelope. Truncation leads to lower pressures, underdesigned tiebacks, and increased soldier pile deflection.

3. Reduce the soil pressures near the corner to account for the three-dimensional support of the wall. Based on observed reduced deflections, a one-third reduction in the design pressures for soldier piles within 15 feet of a corner is appropriate.

4. Interfingered tieback anchors beneath reentrant corners can be completed successfully, with no changes in design, nor reduction in expected performance.

5. No-load zone truncation is appropriate, and will not result in significant increases in wall deflection. The no-load zone need not extend any farther behind the face of the wall than H/2.

References


About the Authors

David G. Winter, P.E., is Vice President of Shannon & Wilson, Inc.; E. Douglas Loesch, P.E., is Vice President of Magnusson Klemencic Associates, and Robert Hollister is the Northwest Regional Manager of Hines.
What does September 11th Mean for Building Structure Design?

Jon Magnusson

The horrible events of September 11th have aroused many emotions and created many questions in the minds of the public, the media, political leaders, and design professionals. For officials charged with developing building codes and designers charged with creating buildings the question is very specific: Is there something wrong with our codes and can we change them so that this doesn’t happen again?

However, even though this appears to be a specific question, it is not. What does “this” mean in the question? Does it mean making buildings more resistant to a terrorist attack? Or, does it mean giving buildings the ability to resist a direct airplane hit? These are two very different questions.

Can we make building structures more resistant to terrorist attack?

All building codes develop requirements based on performance objectives for specific hazards. The primary environmental hazards are gravity, wind, and earthquake. When a building is designed, the demand placed on the building by each of these is well understood. The capacity to meet these demands can be supplied.

Another primary hazard is fire. Even though care is taken to minimize the risk of fires, they do occasionally happen. The fire demand placed on a structure is also understood and systems can be supplied to meet life safety objectives.
The problem with trying to develop code requirements for terrorist acts is that the demand is not understood, because it can not be predicted. Any defined attack “load” could be made inadequate by a larger attack. The “design” attack can not be determined in the same technical ways that wind or earthquake loads are determined. Rather, the design approach will need to be determined in the political realm, as it is related to societal values rather than a scientific approach.

Can we make building structures more resistant to terrorist attack? Yes. But, the critical decisions of how big of an attack, how much to spend on hardening building structures, and which buildings should be hardened will need to be made by our legislative representatives. Of course, building officials, architects, and engineers will need to assist in this process.

**Can buildings structures be given the ability to resist direct airplane hits?**

If the “design” terrorist attack is similar to that of September 11th, can buildings be given the capacity to meet this demand? To answer this question, it is important to understand the physics at work when a plane in flight is stopped by a building.

If the performance objective is to “resist” a direct airplane hit then, to protect people inside the building, the plane can not be allowed to penetrate the exterior wall. To stop a Boeing 767 traveling in excess of 500 mile per hour in a distance of a few feet would take a deceleration force in excess of 400,000,000 pounds. The total design wind load on each of the World Trade Center Towers was about 15,000,000 pounds. The total design wind load for a more commonly sized high-rise, say, 40 stories tall, would be about 4,000,000 pounds. To generate resistance in the ratio of demand of 400 to capacity of 15, or even 4, is not practical.

This is looking at the impact load on a “global” basis for the entire lateral load-resisting system of the building. Before the global system can even try to resist the load, the forces would need to be transferred from the impact area at the exterior through the floor diaphragms. No known floor system can take this kind of axial and shear force.

Figure 1.
So why did the World Trade Center Towers not collapse immediately due to the impact load on the system? The planes did not stop in a few feet, but had an effective stopping distance of over 100 feet. This would drop the deceleration force down to something close to the capacity of the building. Another part of the answer to this question lies in the way that the exterior of the building was structured. In Figure 1, the exterior wall structure can be clearly seen. The exterior columns were fourteen-inch square welded steel box columns spaced at forty inches on center. This means that there was only 26 inches clear between each column. The columns were integral with the steel spandrels beams and formed essentially a solid wall of steel with perforations for windows. This wall construction was able to form a Vierendeel “bridge” over the hole created in one side of each of the towers.

Both of these facts, that the plane was not stopped at the exterior and that the columns and spandrels were extremely dense, were necessary to prevent the building from collapsing immediately upon impact.

The final point in answering the question of airplane impact loading is that, even if some miracle technology could be invented to take these kinds of loads from a 767, there are larger planes to be considered. The B-25 that hit the Empire State building was a fraction of the size of a 767. The Rockwell Commander that hit the high-rise in Milan earlier this year was about half the size of the B-25. Figure 2 gives a comparison of two planes that have actually hit buildings and two planes that would control the design loads if a building structure needed to resist the impact of planes.
The larger square in each frame was the floor plate size of the World Trade Center (209’x209’) and the smaller square is a more common size for a major high-rise (140’x140’). The figure reveals that the design loads for an Airbus A380 would need to be based on about 4.5 times the weight and over 8 times the fuel that was on-board the 767’s used in the attack on each of the Trade Center Towers.

Can buildings be designed for direct airplane hits? Yes and no. Yes, for small aircraft. A definite no, for large commercial aircraft.

**What should be done about code provisions to minimize the chance of progressive collapse?**

This is still one more question that some people are asking. Because the towers ultimately collapsed with one floor crashing down upon the next, it has been called a progressive collapse.

Again, it is important to think carefully about the question. Aren’t all collapses progressive? Something breaks, then something else breaks, and so on. Normally, when the term progressive collapse is used, it specifically refers to the loss of one or two columns or bearing walls that cause a collapse to propagate vertically.

In the case of the World Trade Center there were about forty columns lost on one face of each of the towers and there was no propagation of collapse from this loss. So did the World Trade Center have good resistance to progressive collapse? By normal use of the term “progressive collapse” it did. The collapse that did ultimately occur was progressive, like all collapses, but was not “progressive collapse” that some other international codes address.

The difficulty in understanding this concept is illustrated with the following story. A New York Fire Chief wrote that experienced firefighters know that the buildings that are most susceptible to progressive collapse are buildings that are well-tied together. Wait, “well-tied together” is bad. Virtually every structural engineer will tell advise that one of the best way to prevent progressive collapse is to tie the building together. How can there be this kind of a contradiction?

The difference is that the engineer is thinking about losing a column or two and the Fire Chief is talking about losing a whole part of a building. As the event that initiates the progressive collapse becomes larger than losing a column the risk becomes that the strong horizontal ties of a building will cause the collapse to propagate horizontally.

Any discussion of code provisions with respect to progressive collapse must recognize that both the engineer and the Fire Chief are right depending on the kind of hazard that is defined.

**Conclusions**

There are structural techniques that can increase the capacity of building structures to resist certain kinds of terrorist attacks. However, there is absolutely no reliable way to design for the impact of a large scale commercial airliner. Any code changes to address these kinds of hazards will depend on decisions within the political realm. However, building officials and designers must assist to help arrive at rational solutions. There will be great difficulty in trying to legislate which new building structures have any risk of terrorist attack. And, finally, every building professional must be careful to think through these new sets of problems in order to get to the right questions so that the right solutions can be found for society and real increases in safety can be achieved.

**About the Author**

Jon Magnusson is Chairman/CEO of Magnusson Klemencic Associates in Seattle, Washington.
Where Do We Go From Here?

Ron Klemencic

The attacks on the World Trade Center Towers in New York City and the Pentagon outside Washington, D.C., on September 11, 2001, mark the beginning of a new age of awareness of safety and security in the built environment. Many say the world changed that fateful day, yet terrorism has existed for decades. Until recently, most threats had been foiled or failed. What did change on 9/11 is our awareness of these threats.

As architects, engineers, planners, and building officials, we are problem solvers by nature and training. In the aftermath of the attacks, we all felt the urge to “do something.” An enormous “problem” had been presented, and we were compelled to find a solution. Since 9/11, many have questioned the appropriateness of our building codes and suggested that immediate and sweeping changes are required. Yet, before making any modifications to the codes and standards, we must first determine which issues we are attempting to address.

Improving Safety and Security: The First Step

There is no doubt that we are all in favor of improving the safety and security of our built environment, particularly if this can be accomplished without significant economic burden or relinquishment of our freedoms. How can and should we accomplish this? An appropriate first step is to ask the “right” questions: What types of threats exist that we should be considering? Which of these threats do we, as a society, want to address by fortifying our buildings and infrastructure? Which of these threats should we address through alternate means? Which buildings
are most susceptible to terrorist threats? If we are to enhance the built environment, or specific buildings, what is the most effective way to do so?

As we have studied the events of 9/11, one thing has become clear: we should NOT design buildings for airplane attack. The nature and magnitude of these attacks were of a scale that buildings cannot respond to in any realistic way. Furthermore, the Boeing 767-300 aircraft used in the attacks are not even the largest aircraft flying today. Still-larger airplanes are planned for the future. Building design will never overcome this threat; enhanced airport and airplane security is clearly the most effective use of our resources.

The buildings, in particular the World Trade Center Towers, performed heroically in light of the damage they sustained. At least six safety systems present in the towers were completely and immediately disabled or destroyed upon impact: fire proofing, automatic sprinklers, compartmentalization and pressurization, lighting, structure, and exit stairs. No building can be expected to perform with the total destruction of multiple safety systems.

**Careful Evaluation of Code Changes**

It is the position of the Council on Tall Buildings and Urban Habitat (CTBUH) that no immediate building code changes are required in response to the terrorist attacks of 9/11. In the months and years ahead, there will undoubtedly be building code modifications proposed as a result of the attacks. We must be careful not to over-react. The impact of proposed code changes must be carefully considered, including possible economic and/or social implications. It is important to remember that not ALL buildings are subject to the same risks or threats.
As an example, there has been a great deal of focus in recent months regarding exit stairs. Should our building codes require wider stairs, or more stairs? Is staged evacuation of high-rise buildings an appropriate safety strategy, or do we need to plan for the mass evacuation of all towers? The evacuation of the World Trade Center Towers on 9/11 does not provide any clear evidence that any changes are required. In fact, 99% of all those building occupants located at, or below, the impact floors were able to safely exit the building.

Another example is the effectiveness, or lack thereof, of spray-on fireproofing in the World Trade Center Towers. In the investigation following the collapse of the towers, there was clear evidence that the spray-on fireproofing was likely knocked off the steel during the initial impact of the aircraft, leaving the steel exposed to the heat of the fire. Similar conditions existed in the surrounding buildings hit by falling debris. Increasing the thickness of this material would have not changed the outcome.

Having said this, threats do exist of a nature and scale that perhaps should be directly addressed by some portion of our built environment. Car bombs, bio/chemical attacks, and deliberately set fires fall into this category. Still, not every building requires enhancement against such threats. We must consider the potential threat as it relates to the nature of the building. Is the building in question a potential terrorist target? Is it an icon? Does the building house a high-risk tenant such as the FBI or the corporate headquarters of a major financial institution?

High-risk buildings account for only a small percentage of our overall building inventory. Addressing these buildings on a case-by-case basis is a rational response to the potential threat of terror. Penalizing all buildings by imposing well-intended, yet ill-conceived, building code provisions is not the answer to a safer world.

An Obligation of Leadership

It has become clear in the months following the attacks that there is a great need for leadership in the building industry. The public is demanding more information about safety, and design professionals are wondering how best to respond. Faced with these demands, the CTBUH has identified what is not only a need for leadership, but an obligation for ALL design professionals and building officials. An obligation exists to educate the general public so that appropriate expectations can be formulated regarding building performance in response to various hazards and threats.

Towards this end, the CTBUH has published two guidebooks:

The “Building Safety Assessment Guidebook” is aimed at the general public. It is intended as a resource to educate the reader about the various safety systems present in modern buildings. The Assessment Guidebook provides an overview on how buildings are expected to perform when faced with hazards such as fire, explosions, bio/chemical attacks, windstorms, and earthquakes. In a sense, the Assessment Guidebook is to buildings what Consumer Reports Magazine is to appliances and automobiles. Using the guidebook, the average employee, business owner, or apartment dweller will be able to compare the safety aspects of different buildings and make a more informed personal safety choice.

Specific examples of the Guidebooks contents include questions that an individual could ask a potential landlord such as: “Does the building have a formal, written emergency response plan?” or “Are there at least two exit stairs, in good repair, from each floor of the building?” The Guidebook is intended to give the reader a basic understanding of what safety systems should be present in a building constructed according
to modern day codes and standards. Ultimately, the Guidebook should ease concerns about high-rise safety by empowering the reader's ability to make informed choices when comparing one building to the next.

The “Building Safety Enhancement Guidebook” is aimed at building owners, managers, and designers. The Enhancement Guidebook provides a listing of possible enhancements that, if incorporated, can fortify a building beyond the requirements of standard building codes. Examples of the suggested enhancements range from the structural strengthening of columns, beams, and connections against the effects of a blast to locating a building’s electronic/security control center away from public access areas.

While the “Building Safety Enhancement Guidebook” discusses enhancements beyond basic building codes, it is important to note that the CTBUH is NOT promoting code changes to incorporate the enhancements presented. Instead, the CTBUH is advocating a “Performance-Based Design” approach when considering safety and security enhancements. Under such an approach, each building is evaluated relative to its unique set of circumstances and possible threats. Once the specifics for each building are identified, appropriate design criteria can be developed.

**Why Performance-Based Design?**

It is clear that all buildings are not subject to the same level or type of potential threat. For instance, a 100-story office building in a downtown environment is subjected to significantly different risks than a distribution warehouse located in the suburbs. Likewise, the performance we expect from a hospital or school is different than the performance we expect from a shopping center.

A “Performance Based Design” approach provides a framework for designers to directly address specific hazards and desired performance levels. For any specifically defined hazard, appropriate design solutions can be developed which result in clearly defined performance objectives. Identifying the possible hazards and performance levels should be the result of a dialogue between building owners and designers.

For instance, an office building housing a high-risk tenant such as the FBI may consider the effects of a street-level blast directed at the building. The size and proximity of the blast threat can be defined, such as a 50-pound explosive located 25 feet from the building. Next, the performance objective of the building can be defined, such as “operational.” In other words, if the defined blast were to occur, the desired performance would be for the building to remain operational, even while sustaining some damage. By specifically defining desired performance criteria, appropriate design solutions can be developed and implemented.
Researching a Safer World

More research is required in support of a Performance-Based Design approach. Today, much of what we know about enhanced safety design is qualitative rather than quantitative. Research is needed in areas such as blast protection, air quality management, fire protection, and building egress to understand the effectiveness of various enhancement proposals. The National Institute of Standards and Technology in the United States, for one, is embarking on a multi-year research program to determine some answers. Moving forward, clear and quantitative information will allow the development of appropriate and effective design solutions.

Our new awareness of the possible threats to our built environment will undoubtedly result in a safer world. We must, as an industry, provide the leadership necessary to ensure an appropriate and effective use of our common resources. The CTBUH hopes to continue to contribute to this positive end. For more information about CTBUH or the Guidebooks, refer to www.ctbuh.org.

About the Author

Ron Klemencic is Chairman of the Council on Tall Buildings and Urban Habitat, and President of Magnusson Klemencic Associates in Seattle, Washington.
Educating the Public of Safety in Tall Buildings

It is prudent to understand the philosophy under which the tall buildings of yesterday, and the current building code requirements of today were developed.

Since the terrorist attacks on September 11 to the twin towers of the World Trade Center, many questions have been asked, by both building designers and the general public, regarding what could have been done differently during the design or construction of the WTC to have changed the outcome of that day. What could have been done to increase the time for evacuating the buildings’ occupants? To prevent the collapse of the Towers? And most importantly, what can now be done to minimize the impact of a similar event in the future?

Building technology will advance, identifying methods and materials that can be designed and incorporated into the construction of tall buildings of tomorrow to better resist the resulting collapse of the WTC. Many comparisons have been drawn between the hardened buildings of Europe and other nations who have dealt with terrorist attacks prior to 9/11. Such comparisons leave one with the question of why are buildings in the United States not built in a manner similar to those in Europe?

Societal fears and desires to prevent another catastrophic outcome from occurring will determine whether building owners and developers of the icon buildings of tomorrow will need to change how tall buildings are constructed to thwart terrorist attacks, ultimately increasing overall construction costs. Another question is how far will architects and engineers need to go to design future buildings to be resistant to such attacks (i.e. what other, unforeseen assaults on our buildings must we plan for in order to minimize the impacts upon the building)?
Society will best answer this question in the demands placed on the market place in the form of available building stock that is better capable of resisting such attacks. But what do we, as the owners, developers and managers, as the consumers and society who will ultimately bear the costs, of the existing tall buildings do with the stock of buildings on hand? Must we spend significant amounts of dollars upgrading these existing buildings to better withstand impacts from airplanes used as weapons of destruction? How many other scenarios must we consider in retrofitting our existing buildings with protective features to mitigate the outcome of such attacks?

Several task groups, composed of prominent engineers and scientists, have spent significant amounts of time since last September studying the remains of the building skeleton from the WTC and have formulated theories about what specific events led to the collapse of the Towers. The task groups addressed everything from the type of hardware used to connect the steel floor joists to the perimeter load bearing elements to the brittleness of the gypsum based stair enclosure walls that reportedly disintegrated upon impact of the aircraft. Changes will be enacted in how future tall buildings, and other icon structures possibly targeted by terrorists are designed based on the evaluations and theories put forth by these task groups. Other design professionals, not specifically involved in the task groups, and journalist accounts have suggested the need for providing additional exiting capacity (increasing the number and/or width of stairs), providing slide-escapes that travel every ten floors, providing separate stairs for firefighter access up into the building, using elevators as part of the evacuation scheme, and the list goes on.

Some of these design enhancements will make clear improvements in the ability of occupants to evacuate a building and for the building to withstand an attack similar to WTC. Others changes mentioned are an overreaction to a perceived problem that occurred within the building. Journalists and the general public have asked numerous questions, specifically about the (perceived lack of) fire protection features of the WTC. Unfortunately, many journalists and the general public do not clearly understand the underlying philosophy of tall building occupant life safety protection.

It is prudent to understand the philosophy under which the tall buildings of yesterday, and the current building code requirements of today, were developed. That philosophy was one of “defend-in-place”. The world-renowned engineers and architects that comprised the many various high-rise building task forces in the 1970's recognized the impracticality of attempting to evacuate an entire high-rise building for what was considered to be a common potential fire scenario. That fire scenario, up until September 11, 2001, considered most foreseeable, reasonable events that could threaten the occupants of our tall buildings.

The tall buildings of yesterday are, and continue to be made, “resistant” to the effects of fire. There are several examples of “successful” high-rise building fires in which the buildings endured significant fires, and stand today. The First Interstate Bank Building fire in Los Angeles in 1988 is such an example. Another is the One Meridian Plaza fire in Philadelphia that occurred in 1991. Both buildings are constructed of protected steel construction and neither of the locations in which these fires broke out was sprinkler protected. Both buildings endured significant fires that burned for hours, until much of the fuel for the fire was consumed or intervention from sprinkler systems several floors above began to cool the fire-engulfed areas, which allowed firefighters access to further control and eventually suppress the fires.

Evacuating an entire tall building was not a consideration. It was reasoned that evacuating the occupants of the 90th floor of a building was not prudent for a common fire event that may occur on the 20th floor, a fire event that, with properly designed and installed sprinklers, would be controlled or suppressed early in its development and would likely not impact those that are not near to the room of fire origin. So, exit systems were developed so that only a certain number of floors were to be evacuated, typically only relocated to a place of safety somewhere else in the building, located somewhere below the floor of fire origin. The exits were to be constructed to provide an atmosphere of protection from the rest of the building. That included enclosing the stairs in fire resistive construction. Over time, the use of increased air pressures in stairs relative to the adjacent floor spaces to limit the potential of smoke
migration into the stair became a standard design concept, and even a current code requirement.

Building communications systems were also addressed. Two different systems are usually included in most modern high rises (those constructed during and after the mid-1970’s). One of those systems is a two-way system of communications for use by the fire department, since many of their radio systems operate sporadically in these steel and concrete monsters. The other system includes a building wide one-way communication system that allows either automatic or manual voice messages to be delivered to specific areas of the building, or throughout the building, if desired.

Another important feature of such buildings is the ability to provide emergency and stand-by power for such systems as emergency exit illumination, elevators, mechanical equipment for smoke management and stair pressurization systems, and fire detection and alarm system operation. In comparison studies of the evacuations of the WTC bombing in 1993, and the attacks on 9/11, one significant difference cited by evacuees which contributed to the relative success of the evacuation in 2001 was the improved exit stair illumination.

Many of the design and construction changes proffered by the task groups may have little cost impact in the grand scheme of constructing future tall buildings. However, some changes could have significant cost impacts upon the overall cost of tall building construction. Furthermore, other changes may have significant cost impacts on the operation of the building. One such example is the revenue lost from incorporating a dedicated firefighter stair into the structure. In general, firefighters use elevators to gain access to the floors directly below an incident, which were unavailable in the WTC. Using the elevators saves time and preserves the endurance of the firefighters. Other “cost” impacts that will be difficult to quantify include the loss of exterior glass in favor of hardened exterior concrete walls. Many studies have shown the value to productivity and overall health of being able to visualize the outside world.

As outlined in the television show on the WTC on NOVA, theories on the types of building materials that could have been used to harden the stair enclosures, and perhaps not have resulted in the obliteration of the envelope of protection surrounding the exit stairs were addressed. But what happened to these hardened materials when the third plane hit the Pentagon puts into question whether these hardened materials would have survived the impacts of the 9/11 attacks. Gypsum based fire rated wall assemblies pass the same fire tests to which concrete-based wall assemblies are subjected. In other words, a 2-hour fire rated wall is a 2-hour fire rated wall. The difference in the wall assemblies is their ability to resist external forces, such as impact from moving objects. The fire tests used to evaluate fire rated assemblies are not meant to evaluate impact resistance. These types of scenarios were not considered in the development of current high-rise features of protection.

The owners and designers of future tall buildings will have many decisions to make regarding the design and construction of their buildings.

The owners and designers of future tall buildings will have many decisions regarding the design and construction of their building. Some of those decisions will undoubtedly be made by societal demands. Perhaps companies will want to move into less prolific structures than those of similar stature as the WTC.
And others may even be made by future building code changes. Most building code changes are made as a direct result of lessons learned the hard way (i.e. documented failures of building features). One such example is the swing of doors in an assembly occupancy. It was determined in several assembly occupancy fires, including the Beverly Hills Supper Club fire (which actually occurred in Southgate, Kentucky), that doors swinging against the flow of egress was a primary contributor to a number of the many deaths experienced in this tragic loss.

If anything positive came of the two major incidents that occurred at the WTC, it is that prior preparation for and planning of emergency evacuation has significant improved ability of occupants of such tall buildings to deal with emergency events. The 1993 bombing ultimately showed that the occupants of the structure, and the building management and operations staff, were not well prepared for evacuating the structure. It showed that there is a general lack of knowledge among the general public for their surroundings, and a lack of understanding of the importance of fire safety features provided in these buildings. The WTC building management made improvements to the life safety systems, developed management plans for maintaining the systems and overall improved the ability of the occupants to deal with the events of the 2001 attacks. Imagine how bad the outcome could have been had building management not addressed the life safety systems nor developed emergency evacuation plans?

Unfortunately, it took the catastrophic outcome of the attacks on 9/11 to raise public awareness of their safety in these buildings and the value of both life safety systems and a well planned emergency evacuation plan.

All over the country, building managers are updating their evacuation plans, and becoming better prepared for emergencies, whether mandated by the local jurisdiction (such as recently occurred in Chicago) or not. Many, if not most or all, tall buildings are now practicing their evacuation plans. It is certainly advantageous to develop updated evacuation plans. But the occupants, and particularly the building staff, need to practice these plans. Evacuation plans will need to be continually revised to reflect the ever-changing environment of the building, and its occupants. One important consideration is the need for plans to reflect the availability of staff throughout the entire day, not just the primary occupancy periods.

The evacuation plans also need to consider occupant familiarity. Even though a high-rise hotel and a high-rise apartment or condominium are both residential occupancies, the occupants of the former are far less familiar with their surroundings than the occupants of the latter.

Although the collapse of the WTC is certainly considered a catastrophic failure, there were, in fact, many successes observed in the events that unfolded that day. Deliberate considerations by task groups will identify many changes in the way we design and build such tall buildings, but we cannot allow overreactions to the failures to drive those changes. One of the most important lessons to be learned here is the need for educating the public about the fire safety features of the buildings they occupy and for practicing evacuation drills. Why else would we make our children practice them throughout grade school?

**About the Author**

Jeffrey E. Harper, P.E. is the Engineering Manager for the Chicago and Minneapolis offices of Rolf Jensen and Associates, Inc. (RJA). He began working with RJA in 1989. Mr. Harper received his first Bachelor of Science degree in Fire Science Management from Southern Illinois University in 1986 and another Bachelor of Science degree in Fire Protection Engineering from the University of Maryland in 1989. He is a registered Professional Engineer in three states.

Prior to and while attending the University of Maryland, Mr. Harper worked for over ten years in the field of firefighting and emergency medicine. Mr. Harper has worked for three fire departments and for a paramedic rescue department. In that capacity, he has had training and experience in tactics and strategies associated with fireground operations and fire suppression activities.
Emergency Evacuation Core Proposal: 25 May 2002

Jeffrey Heller

On September 11th, one of the world’s great icons was destroyed in an act of vicious barbarity, and we, as design professionals, are compelled to look not only at the human costs of the event, but at the technical aspects as well. By looking at the lessons of this profound tragedy, we might further improve the life-safety aspects of high-rise buildings and provide a greater margin of safety for the people who inhabit them. In doing so, we honor those who were lost on September 11th with a lasting legacy to their sacrifice.

This proposal for an enhanced emergency core was inspired by the images of the courageous firefighters climbing the stairs of the World Trade Center against the torrent of occupants pouring down the stairs. The

By looking at the lessons of this profound tragedy, we might further improve the life-safety aspects of high-rise buildings and provide a greater margin of safety for the people who inhabit them.
stories of individuals interrupting their exiting to stand aside while badly injured workers were brought to ground-level further motivates us to develop designs to enhance exiting options in the future.

**Existing Layout**

Most contemporary high-rises have fire stairs at opposite ends of their core, with elevators, bathrooms, and various utility and air handling shafts located between those stairs. During an emergency, tenant elevators are usually recalled to the ground floor and building occupants head for the fire stairs to exit to the relative safety of the street.

High-rise buildings, particularly those over 30 stories, typically have dedicated freight elevators adjacent to the tenant hi-rise elevator bank. These freight elevators typically have dedicated service lobbies. Because the freight elevator services every floor of the building, it is usually the one unit set up for operation during an emergency, controlled by the fire department from the fire control room in the lobby. Sometimes, firefighters have more than one elevator at their disposal, but normally, the freight unit provides emergency elevator access.

**Proposed Layout**

In light of the World Trade Center experience, we are proposing an enhanced emergency exiting concept. This proposal combines the fire stairs and freight lobby into a unified evacuation core that can be pressurized and strengthened. In the case of an emergency, able-bodied people would go to the staircase, as usual. People who were injured or disabled, however, would have the option of going into the pressurized service lobby, now transformed into an area of refuge. Once in the refuge area, the disabled and injured could either be assisted down the staircase by able-bodied building occupants, or, if conditions permit, wait safely in the pressurized evacuation core until rescued by emergency personnel.

With this proposed layout, the service elevator would become the major access route for firefighters and other emergency workers. The evacuation core could provide an opportunity for advanced communications so that people in the refuge area could advise the fire control room of the status on that particular floor. Smoke and fire sensors as well as camera units within the refuge core could help firefighters determine whether it was safe to stop the elevator at the floor in question. If firefighters felt the floor (or floors) with the emergency zone was too dangerous to stop at, they could, as is their normal practice, get off at a lower floor and ascend one or two floors to the scene of the emergency.
While the human costs of September 11th were profound, this disaster has caused all design professionals to reconsider the technical aspects of high-rise safety.

**Benefits of Layout**

This concept for an enhanced emergency core has parallels with Britain’s requirement for a dedicated fireman’s lift at each stair, but it differs in two significant ways. Rather than building separate freight and firefighter lifts, this enhanced evacuation core concept has the service elevator doing double duty ... with little additional cost or additional area required. Furthermore, incorporating the fire stair with the freight elevator and its service lobby creates a viable area of refuge for disabled and injured occupants at every level of the building.

Because the elevator service lobby and stair would be a single hardened and pressurized unit, there would be a substantial level of security within that area. Even if the service elevator was inoperable and/or
the emergency was so urgent it was infeasible for occupants to wait for firefighters to come by elevator, the interconnecting door to the fire stair would allow an alternative means of evacuation.

Having an area of refuge at each level of the building is more disabled-friendly than an alternate scenario that calls for occupants and emergency personnel to move vertically to intermittent refuge floors. In the case of badly injured occupants, the opportunity to have an area of refuge at their level would clearly provide a far more viable option.

While the human costs of September 11th were profound, this disaster has caused all design professionals to reconsider the technical aspects of high-rise safety. By incorporating new concepts such as the enhanced emergency core and other proposals by the Tall Building Council, we may be able to reduce the loss of life during high-rise emergencies in the future.

**About the Author**

Jeffrey Heller is President of Heller Manus Architects, a multi-disciplined San Francisco firm founded in 1984. Mr. Heller’s professional achievements include Fellow of the American Institute of Architects, Vice President of the California Architects Board, Member of the Bay Bridge East Span Design Advisory Panel, Chair of the Urban Land Institute’s Development Regulation Council, and Director and Advisory Board Member of SPUR. Mr. Heller has both Bachelor’s and Master’s degrees in Architecture and Urban Design from the Massachusetts Institute of Technology.
Engineering Systems an Incremental Response to Terrorist Threat

Norman D. Kurtz, Andrew Hlushko, and Dan Nall

Buildings designed and constructed in accordance with present day codes and standards provide a fundamentally safe environment. Safety guidelines have been developed and modified over time with fire and natural hazards in mind. Present day threats, including terrorist attacks, are much more difficult to predict since they can take many forms.

The design approach of a new building, or safety assessment of an existing one, must look at the overall performance of the integrated building systems. The performance of the structural systems, curtain wall, security systems, mechanical, electrical, fire protection systems, etc. must be analyzed against the threat and perceived risks. The building location, occupancy, function, setting and stature must be considered in this assessment.

The primary motivating factors for designing high-performance buildings are to:

- Decrease the exposure to terrorism.
- Mitigate the effects of an attack.
- Increase the probability of achieving full evacuation in the event of a disaster.

The application of techniques such as diversity, proximity, redundancy, decentralization, material selection and hardening/rigidity can help in improving the performance of a building.
Accessibility Control

The goals of perimeter security and access control systems are to identify and control a threat before it enters a facility. Many building owners have put new measures in place for controlling access to their buildings, including pre-screening visitors, visual identification and tenant escorts throughout the building.

The parameters of surveillance, security and detection have expanded to include non-traditional areas. CCTV can now be found at air intake louvers, mechanical rooms, electrical rooms, telecommunication spaces, rooftops, etc. Security and access control points now make use of card access controls to lock MER’s, limit elevator stops to certain floors and monitor the movements of personnel in restricted areas.

Identifying and Containing the Threat

Biological and chemical threats have required that building owners and managers review mail receiving operations, truck dock access, security of ventilation and air intake and the monitoring of maintenance access to the building.

For example, with the threat of bio-chemical weapons, mail-receiving and truck dock areas have been provided with dedicated ventilation and air conditioning systems which limit the spread of contaminants should they enter the building. These rooms can be structurally isolated from the rest of the building by increasing the strength of the envelope that encloses them. The box around high-risk areas could be constructed of reinforced concrete or block to increase its blast resistance.

A quick response to the possibility of a bio-chemical attack increases the chance for the safe isolation of a building’s occupants. If a bio-chemical release is suspected, a complete HVAC system shutdown may be the best approach. The building’s HVAC systems should ideally be controlled by the building automation system, with a single instruction resulting in the quick shutdown of all systems. Once the details of the event are investigated, the appropriate action for these systems can be identified and implemented.

Redundancy

Introducing redundancy into a building’s system will strengthen its integrity, eliminating single points of failure in a building’s critical life safety systems. A building’s response is a function of availability when it is called upon to operate. Run redundant services, such as emergency power distribution feeders, life-safety wiring and communications, and water and oil risers, through hardened pathways. For example, employ masonry walls for all stair shafts containing standpipes and employ a “sonnet ring” approach to critical systems.

Multiple, looped, sprinkler and standpipe risers reduce the possibility of an event severing available water supply. Redundant water services, including supply for each sprinkler zone, increase the reliability of fire suppression. Appropriate valving, where services are combined, will help isolate portions of the system in an emergency. Redundant fire pumps,
Redundant sources should be remotely located from each other, for example on the roof and in the basement. Redundant sources, reliant on different sources, could be provided in remote locations. For instance, one electric pump supplied from utility and/or generator power, and a second, diesel fire pump.

Redundant fire command centers remotely located from each other allow system operation and control from alternate locations. Hardened construction of the local fire command center in a blast-resistant area, adjacent to the building entrance will maintain capability for on-site monitoring and response.

Proximity

Locate the emergency power source directly at the load. Fire alarm system design, consisting of distributed intelligent fire alarm panels, connected in a peer-to-peer network allows each panel to function independently, and process alarms and initiate sequences within its respective zone. Exit signs along egress pathways, and emergency lighting, could be provided with integral battery packs to facilitate egress in a utility power outage. Emergency communication can be enhanced by providing extra emergency phones separate from PBX that connect directly to a central office, an in-building repeater system for emergency response team radios, and redundant or wireless fireman’s communications in the building.

An emergency generator system provides a crucial alternate should utility power become unavailable. Redundant sources should be remotely located from each other, for example, on the roof and in the basement. Reduce the outside air requirements for an internal generator by using a combination of remote radiators and air conditioning to limit the intake louver requirements to combustion air only. Non-traditional emergency sources, such as photovoltaic cells, provide a self-sufficient power source for the most critical loads without depending on remote fuel sources.

In combination with other smoke control systems, pressurization of the stairwell and vestibule maintain a clear path of egress to safe areas or to building evacuation. This two-step protection for the stairway system is not required in the United States in buildings where sprinklers are provided. This is an example of an incremental response. In high-rise buildings, the system should be distributed rather than centralized. Although the provision of a pressurized fire service elevator speeds response to higher floors, one of the bigger questions is the application of elevator lobby pressurization for evacuation. A further consideration may involve the addition of elevator lobby pressurization to provide a safe haven refuge area in the event of an emergency.

Biological/Chemical Attack Identification and Response

Building air conditioning systems are provided with filters, which trap a percentage of particles of all sizes. Air filtration efficiency can be improved by providing multiple layers of filters, and increasing from the standard 85% to 95% DOP filters, electrostatic filters, or 99.97% HEPA filters. Air filtration for bio/chemical hazards could be increased with the installation of activated carbon filters and ultraviolet light systems. Filters, however, do not identify the presence of hazardous agents and cannot provide 100% removal of these agents. In existing buildings, increased filtration may result in major costs to upgrade HVAC system motors and associated electrical power.
Measures vary depending upon a building’s functionality. The U.S. State Department advocates cascading pressure relationships in combination with HEPA use, and does not allow internal re-circulation within the spaces. Typically, there are three pressure zones, the lowest for public spaces, the second for state department work areas, and the highest for critical areas requiring clearance. This helps to minimize distribution of an internally released contaminant.

Sensors quick and reliable enough to automatically initiate the appropriate protection mode are not readily available, however, air quality detection systems are one of the primary focuses of major manufacturers’ research and development divisions. For instance, a system employing a monoclonal antibody approach through the application of electronic chips with chemical or biological receptors on their surface, is currently under development. Beyond most air filtration systems, these receptors are tuned to particular chemical or biological agents which, when detected, provide an immediate response by the building automation system to operate in a safe mode.

Technology is changing on a daily basis, and advances must be closely analyzed for potential application in the building service arena.

Conclusion

All security and system hardening measures are not advocated for all buildings. The building owner must assess the potential threat to his building and his tenants and identify the most prudent performance based solutions.

Each system upgrade, beyond those common for the built environment, will undoubtedly require a cost/benefit analysis. Unfortunately, in this new period of American history, the costs entering into the equation are not only counted in dollars and cents.

The building owner must assess the potential threat to his building and his tenants and identify the most prudent performance-based solutions.

About the Authors

Norman Kurtz is a managing principal at Flack + Kurtz, Inc., a longstanding contributor to the Engineering community, and a member of the Council on Tall Buildings and Urban Habitat. Andrew Hlushko is the Director of Technical Services and Electrical Department Head at F+K’s NY Headquarters, and spearheads the design of MEP systems for many high profile projects. Dan Nall is the Director of Advanced Building Sciences, a LEED-Certified Professional, and co-chair of the US Green Building Council’s Energy and Atmosphere Technical Advisory Group.
Protective Design: Saving Lives Through Structural Engineering

Tod Rittenhouse and Robert Smilowitz

In recent years the engineering community has had to consider new design criteria, the terrorist explosive threat. Whether developing new or renovation projects, protective design and dynamic analysis has become part of the structural engineering service. The difficult task faced by design teams is to create facilities that are desirable workspaces while at the same time provide protection from terrorist explosive threats. Typically situated on urban sites, these structures are limited in the ability to restrict terrorist access to effective keepout distances and architectural design criteria often violates the blast-mitigating objectives. Given these conditions, along with the limited resources dedicated to physical protection, the design objectives are to protect life safety for the occupants. However, physical security alone does not assure a safe structure. A comprehensive security plan requires a balance between operational, technical and physical security measures. When site conditions do not provide adequate keep-out distance, or technical security...
does not identify an explosive device, or lapses in operational security permit threats to approach the structure, then physical security is required to provide the last line of defense.

The four basic features of physical protection for buildings involve the establishment of a secure perimeter, the prevention of progressive collapse, the isolation of internal threats from occupied spaces and the mitigation of debris resulting from the damaged façade. Other considerations, such as the tethering of non-structural components and the protection of emergency services, are also key design objectives that require special attention. The size of the explosive threat will determine the effectiveness of each of these protective features and the extent of resources needed to protect the occupants. The selection of the appropriate threat is fundamental to the design process and therefore requires careful consideration.

**Defined Threat and Standoff Distance**

The definition of the design threat is based on history and expectation; however, it is limited in size by the means of delivery. Conventional explosives weigh approximately 100 pounds per cubic foot. Therefore, a small hand-carried device could easily be concealed in a large brief case or small luggage. The hand carried satchel threat, though limited in size may be introduced deep into the structure where it can do considerable damage. As a result, screening stations at the entrances, mailrooms and loading docks provide the best means of preventing these threats from entering the occupied spaces. A vehicle can carry significantly larger explosive charge weights. As a result, perimeters must be secured and the presence of underground parking or loading docks require comprehensive screening procedures. Physical protection recognizes the limitations of screening procedures and the potential for threats to bypass their scrutiny. Therefore, the selection of the design level explosive threat depends on the features of the building, the site conditions and the level of risk the client is prepared to accept.

The intensity of the blast is a function of the charge weight and the standoff distance to the protected space. Charges situated extremely close to a target structure impose a load over a localized region of the structure. As a result, the hazard potential in increased over a larger portion of the structure.

While it may be possible to predict effects of a given charge weight at a specified standoff distance, the actual charge weight of explosive used by the terrorist, the efficiency of the chemical reaction and the source location are not reliably predictable. One approach, adopted by regulatory agencies is the use of predefined levels of protection. These levels are associated with a perceived risk to the facility and are based on relative costs to mitigate the hazards. The perception of risk considers factors such as symbolic importance, criticality and consequence of loss. Although this approach provides a framework for performing a risk analysis, once the perception of
risk is acknowledged, the most rational assumption regarding the charge weight of the terrorist threat, is to determine the capacity of the delivery vehicle. Given the uncertainties, the most significant observation which one draws from blast pressure phenomenology is that the most effective means of protecting a structure is to keep the bomb as far away as possible, by maximizing the keep-out distance.

To guarantee the maximum keep-out distance, sufficiently sized anti-ram bollards or large planters must be placed at the curb around the perimeter of the building. Furthermore, public parking abutting the building must be secured or eliminated, and street parking should not be permitted adjacent to the building.

Façade and Glazing

The building’s exterior is its first real defense against the effects of a bomb. The key to protective glazing is preventing blast waves and broken glass shards from entering the building. Therefore the design philosophy might best be served by concentrating on the improvement of the post-damaged behavior of the façade. For new construction, this may correspond to the specification of laminated glass. For existing glazing, this may correspond to the application of an anti-shatter film. While these features will do little to improve the strength of the glass, they attempt to hold the shards of glass together and better protect the occupants from hazardous debris. The effectiveness of Mylar films depends on the method of application and the thickness of the film. The common film systems range from a simple edge-to-edge (daylight) application to a wet glazed adhesion and finally a mechanical attachment to the existing window frame. The mechanical attachments are most effective when they are anchored to the underlying structure. Regardless of the method, there are architectural issues and life cycle costs associated with the use of anti-shatter films. Laminated glass possesses the best post-damage behavior, may be used with a wide variety of glazing materials and thickness, and provides the highest degree of safety to occupants.

Equally important to the design of the glass is the design of the window frames. For the window to properly fail, the glass must be held in place long enough to develop the proper stresses that cause failure. Short of that, the glazing will dislodge from the housing intact and cause serious damage or injury. Therefore, the frame system should be designed to develop the full capacity of the chosen glazing type. The bite, including the possible use of structural silicone sealant, must be adequate to assure the failed glass is retained within the frame. The Mullions in turn must be capable of withstanding the reactions of a window loaded to failure. Finally, the walls to which these windows are attached, must be able to accept the reaction forces.

Beyond the simple punched window or ribbon window system is the curtain wall systems which can also be designed to withstand the effects of explosive loading. The effectiveness of this system is more dependent on the performance of the various elements that comprise the curtain wall system. While the glazing may be the most brittle component, the performance of the system and the reduction of hazard to the occupants depend on the interaction between the capacities of the various elements. In addition to hardening the individual members that comprise the curtain wall system, the attachments to the floor slabs or spandrel beams require special...
attention. These connections must be adjustable to compensate for the fabrication tolerances, accommodate the differential inter-story drifts and thermal deformations, and yet be designed to transfer gravity loads, wind loads and blast loads.

An alternative approach is to allow the window systems to absorb a considerable amount of the blast energy through deformation while preventing debris from entering the occupied space. Curtain wall systems, which are considerably more flexible than the conventional hardened windows, have been subjected to explosive tests and the flexibility of their response allowed the glazing to survive greater blast environments than rigidly supported counterparts.

**Structural Response and Progressive Collapse**

In addition to the hazard of impact by façade debris propelled into the building, the occupants may also be vulnerable to much heavier debris resulting from structural damage. Progressive collapse occurs when an initial localized failure causes adjoining members to be overloaded and fail, resulting in an extent of damage that is disproportionate to the originating region of localized failure. A protective design may avoid structural systems that either facilitate or are vulnerable to a progression of collapse resulting from the loss of a primary vertical load-bearing member. In particular, new facilities may be designed to accept the loss of an exterior column for one or possibly two floors above grade without precipitating collapse to an extent disproportionate to the original cause of the damage. These design requirements are intended to be threat independent, resulting in adequate redundant load paths in the structure should damage occur due to an unspecified abnormal loading. This threat independent requirement is intended to protect against an explosion of indeterminate size that might damage a single column. The upgrade of existing structures to prevent localized damage from developing into a progressive collapse may not be easily accomplished through the alternate path method. The loss of support at a column line would increase the spans of all beams directly above the zone of damage and require different patterns of reinforcement and different types of connection details than those typically detailed for conventional structural design.

Alternatively, columns may be sized, reinforced or protected to prevent critical damage resulting from the explosion of the design threat charge weight placed in close proximity to the column. The vulnerable concrete columns may be jacketed with steel plate or wrapped with composite materials, and the vulnerable steel columns may be encased in concrete to protect the cross sections and add mass. For the upgrade of existing structures, the strengthening approach offers a better opportunity to prevent a progressive collapse than attempting to supplement the capacity of the connecting beams and girders. However, the effectiveness of these approaches is predicated on the operational and technical security procedures that will limit the magnitude of the explosive threat. This includes the establishment of effective perimeter protection, adequate screening of vehicles entering...
an underground parking facility or loading dock, and inspection of parcels that may be hand carried into the building.

Transfer girders and the columns supporting transfer girders are particularly vulnerable to blast loading. Transfer girders typically reduce the load bearing system into a fewer number of structural elements which runs contrary to the concept of redundancy desired in a blast environment. Typically, the transfer girder spans a large opening, such as a loading dock, or provides the means to shift the location of column lines at a particular floor. Damage to the transfer girder may leave one or more columns, which terminate at the girder from above, totally unsupported. Similarly, the loss of a support column from below, will create a much larger span carrying critical load-bearing structure. Transfer girders are therefore critical structural elements whose loss may result in a progressive collapse. If a transfer girder is required and is vulnerable to an explosive loading, it is desirable that the girder be continuous over several supports and have substantial structure framing into it to create a two-way redundancy and thereby an alternate load path in the event of a failure.

Non-Structural Considerations

The walls surrounding the loading docks, mailrooms and lobbies, into which explosive threats may be introduced prior to inspection and screening, must be hardened to protect building occupants in adjacent spaces. Non-structural building components, such as piping, ducts, lighting units and conduits, must be sufficiently tied back to competent structure to prevent failure of the services and the hazard of falling debris.

To mitigate this hazard, these non-structural systems should be located below the raised floors or tied to the ceiling slabs with Seismic Zone IV restraints.

The improved performance of a building in response to an explosive threat requires the services of a trained professional engineer, experienced in both the conventional and the protective design of structures. The design professional will be able to perform a blast Threat Assessment and Risk Analysis (TARA) to identify the vulnerabilities and hazards associated with a given facility. Working with the owner and the security staff, the protective design consultant will help balance the three disciplines of security services, operational, technical and physical that will combine to provide the desired level of protection within the available design budget.

About the Authors

Tod Rittenhouse, PE and Robert Smilowitz, PE are Principals of Weidlinger Associates Consulting Engineers. They both participated in the development of the US Department of State’s Embassy Anti-Terrorist Design Guidelines and collaborated on the GSA/ISC Security Criteria. Together they have completed over 150 Embassy and GSA building evaluations, designs, and upgrades. Since September 11th 2001, they have provided similar services for the commercial non-government building community, who are now addressing the concern for building safety related to terrorist events. Mr. Rittenhouse is a member of the Council on Tall Buildings and Urban Habitat Task Force on Building Protection. Dr. Smilowitz was a member the World Trade Center Building Performance Assessment Team.
Tall Building Fire Safety — Post 9/11

Joe Zicherman

Fire safety is a most crucial issue associated with tall building design and technology. The importance of fire safety issues has been acknowledged by The Council on Tall Buildings and Urban Habitat (CTBUH) in a number of ways. One of these has been through the periodic preparation of monographs on fire safety, the latest of which was published in 1992 (Zicherman, 1992).

However, nowhere in that 1992 monograph—which includes 15 chapters on diverse subjects, which include amongst others smoke control, fire service operations and discussions of evacuation & human behavior issues - does the text address emergency response under extreme conditions or mitigation of problems posed by acts of terrorism.

Now, in 2003 we may ask ourselves “why are we so surprised at what transpired on 9/11 and the impact of that incident?” One reason that is clear to this author is that in the early 1990’s terrorist assaults of the magnitudes we have seen in the last decade in Oklahoma City, Nigeria and most recently at the World Trade Center were not considered foreseeable by the majority of the community whose job it was to assess safety levels in such buildings. Certainly, some can argue that the signs were there, beginning with the destruction of buildings in Lebanon and with the initial bombing attempt at WTC in 1993. However, hindsight is always 20:20.

1 Since 9/11 a CTBUH task group has prepared two handbooks, “Building Safety Assessment Guidebook” and “Building Safety Enhancement Guidebook” (CTBUH, 2002), for use by building owners and managers that provide enhanced emergency assessment information and methodologies.
Currently, we do know that the rules and the playing field have changed in terms of safety issues and tall buildings. Now we are beginning to apply a new set of rules to address emergency response issues for both existing and new building designs. In the fire safety community we will be challenged in particular to address access and evacuation issues for existing buildings designed with long, relatively safe histories until the onset of the class of incidents listed above.

It is the objective of this paper to address evacuation issues under extreme conditions, which are a component of this problem area.

Background

Looking back at watershed events, a series of fire incidents occurred through the 1970’s and early 1980’s that suggested problems with evacuation designs and facilities in complex tall buildings. While none of these led to losses of life that approach those created by terrorist attacks since then, unexpected substandard performance of exiting facilities has led to an awareness that increased vigilance is important not just in building design but in pre-fire planning and building management and administration.

High profile examples of these can be found in the cases of the MGM Grand fire in Los Vegas in 1980 (Klem, 1980) and the DuPont Plaza fire in San Juan in 1986 (Bryan, 1986). In both cases, life losses occurred remote from the fire locations and in both cases rescuers attempted helicopter evacuations when conventional means of egress proved inadequate. Less well known are other incidents where fire department access became limited and occupants of tall buildings were trapped due to blockages of stairways and other means of egress. These are described in articles by Isner (1988) and Lathrop (1976).

By definition it is this author’s opinion that when events occur, which result in [such] breakdowns in the emergency exiting facilities mandated for such buildings, then those designs are inadequate. In fairness to the tall buildings community, increased vigilance led, after those incidents of the late 1970’s and early 1980’s to improved levels of fire safety in such buildings until the community was confronted by the large-scale events beginning in the USA with the Oklahoma City bombing.

Looking prospectively, new tall building designs will doubtless encompass new structural designs and arrangements of features for emergency exiting so that these are isolated from one another. Survivability of facilities, not considered heretofore will become part of the design process. However, for existing buildings there must be total reliance on existing exiting facilities and ways to complement these exist as well. These complementary alternatives are available in the form of unconventional exiting systems which are being either re-examined by potential users or examined for the first time. Some are also just now being developed in response to the realities of the changing political landscape.

Before the September 11, 2001 terrorist attack in New York City, the World Trade Center had already withstood a number of insults, including two fires in 1975 (Lathrop, 1976) and a terrorist bombing in 1993. Those incidents led to perhaps the most intensive fire safety planning of any high rise building worldwide and given the nature and extent of the insult which the towers absorbed, it can be argued convincingly that building occupants below the impact floors - while exposed to grave conditions - evacuated effectively and in an orderly fashion. What was not foreseen in the preparations made were conditions developing above incident floors which became so severe that building occupants there had no means of escape and emergency access facilities. They exist currently in the three formats listed below and each has particular strengths and weaknesses:

- Lowering Devices
- Chutes and Slides
- Airfoils

One reason that discussion of these proposed evacuation methods has become relevant, are suggestions that deployment of some of these devices and systems could
have helped on 9/11 at the WTC. It is up to the reader to consider whether, had they been available to occupants of WTC floors above the aircraft impact zones, their presence might have led to the safe escape of some of the people trapped there?

To date unconventional means of egress have not been included in design processes, emergency planning or regulatory reviews for tall buildings in the US. Overseas, various systems are available and have been deployed for some years. Certain of these systems however, are not unknown in the US where evacuation chutes and slides are addressed – albeit to a limited extent - in the NFPA 101 “Life Safety Code”. 2

The common feature of all of these systems is the necessity to address dissipation of kinetic energy generated when a body – in this case in the form of an evacuee – moves from a high elevation to a lower one. In all cases, the systems designed for unconventional evacuation account for dissipation of that kinetic energy in one way or another, be it by reducing descent speed – as through use of friction and reduction of velocity when descending in tube like devices, use of an air resistance with some of the descending devices and air-foils as with parachutes and finally use of friction and counterweights with some of the older pulley based devices.

Discussion

There are numerous important issues that need to be addressed when assessing the applicability of these alternative existing methods in emergency situations. These include planning and risk issues, human factors related issues and regulatory issues, amongst others.

Planning and Risk Issues

Critics of alternative means of exiting raise a number of important issues when discussions of this subject take place. Most of these have merit and warrant careful consideration. At the head of the list, this author believes, is how we perceive emergency planning – including the economic impact of such systems - in the future.

We can, as noted earlier, point to a certain history of failures of emergency response systems in tall buildings in previous years – not just in major fires – but also in serious fires which involved fewer people. As such, we can point to issues of preparation and performance by building managers, security guards and planners that contributed to the outcome of these situations.

If we add another layer of cost – for the purchase, training and maintenance of this new class of exiting devices – what will this do to tall buildings safety budgets? Might we do better spending these resources on existing, state of the art systems? This is an important issue.

What about the final levels of safety and performance attained? What is the threshold of acceptable performance for these systems? As with conventional

---

2 These sorts of systems have been deployed for some years for rapid evacuation of industrial facilities such as oil cracking towers or aircraft control towers on military bases.
Exiting systems, we would hope and strive for 100% success in evacuation using the unconventional systems. However extraneous and uncontrollable factors such as the nature and impact of the emergency on a given structure, winds, nature of the evacuating population, etc., all will have an impact on levels of success attained. At the end of the day, if we can save 80% of those exposed to what would have been certain death – an outcome that would have been welcomed on 9/11 - one would also have to assume that representatives of the other 20% would call for damages and file lawsuits. Thus, expectations for success and conversely liability issues associated with any failures need to be addressed before such systems are deployed for use.

Human Factors and Human Behavior

In spite of demonstrations of the technical feasibility of these systems, this author does not believe that human factor issues associated with use of these devices and evacuation approaches have been adequately addressed to date. A reasonable test in this case would involve considering and somehow testing – and perhaps demonstrating the likelihood that a population encompassing the ages and physical abilities of those that use existing tall buildings today, would be able and/or agreeable to using these methods. If not, how do we address this situation?

More conventional questions of human behavior can be considered baselines in considering application of these unconventional exiting approaches. A telling, anecdotal example of human behavior issues – that touches on behavior of both occupants and first responders can be found in “Rescuing the Occupants”, an article that discusses the difficulties encountered during a high rise fire in January 1988 at 135 East 50 St. in New York City (Isner, 1988).

More conventional treatments about how people move and respond to fires during emergencies in tall buildings are available in Chapters 12-14 of the most recent SFPE handbook (Bryan, 2002).

Emphasis on issues related to human behavior in Hotels – many of which are tall buildings – as well as evacuations procedures in other tall buildings have also been addressed by Bryan and Pauls in the earlier SFPE handbook and in the NFPA Fire Journal including references from 1982 and 1983. The same issues have been addressed in detail in reports from Europe including those which provide descriptions of times required for high rise evacuations during drills (Kendik, 1983).

Regulatory Issues

Codes and Standards

As with any life-safety measure, regulatory issues to address expanded use of emergency building evacuation systems are significant. Of primary importance and as suggested previously, it should be acknowledged that application and use of unconventional existing methods to new and existing building designs must not supercede or lead to downgrading of the design, maintenance and training of conventional [pressurized] stair ways in emergencies. As such it must be acknowledged that controlled descent devices are only intended as a last resort for use when conventional exits are no longer serviceable.

In addition, expansions of existing high rise fire safety regulations – as in the model codes- to address unconventional exiting must define and include a new set of expectations for conditions and risks under which these systems may be used and these must be developed by a consensus process. These regulations must also address the significantly different expectations for exposures to risk in these situations when compared to expectations under conventional emergency exiting strategies.

Precedent for use and application of unconventional exiting approaches already exists in regulations. The NFPA 101 Life Safety Code includes examples which can be found in Sections 7.2 as well as Chapters 11 and 40. It can be anticipated that similar text will be developed for other model codes in the future and standards addressing component performance can be readily developed to supplement existing ad hoc approaches being applied by groups such as Underwriters Laboratories to existing systems.
Listing Issues

References in existing regulations for unconventional exiting components already exist which carry the familiar reference to “approved systems,” a term which suggests third party review and possible listing of these systems and/or their components.

Some of the components and devices described above are already listed by Underwriters Laboratories and are subject to the ongoing UL inspection programs to maintain those listings. UL’s description of the product category “Controlled Descent Devices” [EIXI] for example describes these items as, “reusable Controlled Descent Devices intended primarily for controlled lowering of persons from various heights during emergency situations.”

Most important though, that description notes that the devices have been evaluated for mechanical operation only and [they] are not intended for use as a means of egress during fire situations.

The latter disclaimer from UL is consistent with the absence of ANSI, NFPA or UL standard protocols providing guidance for the systematic evaluation of unconventional evacuation systems. Factors needing to be addressed in the development of such standards should include measures of overall performance, human factors aspects and safety of these systems. Third party evaluations conducted to date address specific properties such as descent speed, capacity and durability-resistance to corrosion. However, rating and qualifying the performance of these systems under emergency conditions needs to be addressed and realistic expectations for their effectiveness should be established if they are to be accepted for widespread use.

Emergency exiting Technology Review

A survey of specific, available systems and devices follows for those unfamiliar with the concept being discussed here. It is recommended that readers interested in obtaining additional information review web site data.

Lowering Devices

The common feature in these devices is the use of cables to reach from evacuation floors to grade. How those cables are deployed - and most important-
how their braking is controlled separates the various systems available. Of interest is the fact that one of the older lowering device concepts available; the Oriro Decenter has been in use in Japan, for over 30 years with over 100,000 units in the field. This system includes a friction-based braking system with a maximum descent rate of approximately 3 feet per second. Designed and manufactured in Japan, it operates like a controlled pulley, with woven cotton harnesses at each end of a steel rescue cable that passes through the device. In the event of an emergency, an evacuee puts on a harness and steps away from the side of building and is lowered to the ground. The manufacturer reports that the device has been used to help evacuate victims during fire incidents in Asia, although there are no statistics available describing the number of times it has been used and outcomes of use during emergencies. The Decenter is listed by Underwrites Laboratories, and it has been certified for use by the Japanese government (www.evacuation.net).

A device similar to the Decenter and manufactured in the U.S. is the BEST Rescue System (BRS). The main difference between this and the Oriro system is in the type of harness used to lower an evacuee to safety. Instead of cotton harnesses, the BRS unit employs two fire resistant suits. These suits extend above an evacuee’s head and attaches to the pulley above. The suit’s design is intended to reduce the evacuee’s exposure to heat, and to possibly ease their anxiety by not allowing them to see the ground below. Commercially available since 1999, approximately 200 are reported to been sold. www.bestrescue.com

The SafirRosetti ResQline system is the newest and represents perhaps the most sophisticated lowering approach available. Developed in Israel, this system differs from the preceding products in that it doesn’t use a centrifugal friction brake to control descent speed. Rather, an air turbine system is employed to dissipate kinetic energy generated during lowering. To use the ResQline system, in the event of an emergency, an evacuee puts on a harness which is attached to a cartridge which includes a spool of pre-cut cable. After attaching the spool to the axle of the turbine, the evacuee steps away from the building, and descends as the turbine spins to control their descent. Descend speeds can be as fast as 15 feet per second. In addition to higher, safe rates of descent, the ResQline system includes has been designed for use on multiple floors and demonstrated successfully evacuating disabled personnel in high rise applications. In addition portable versions of this unit are available and have been deployed by fire services.

According to recent information ResQline systems have already been installed in small number of high-rise buildings in the City of New York as well as in one high rise in Tel-Aviv. Bezeq On Line, a subsidiary of the largest telecommunication company in Israel, has installed the ResQline solution and has provided all its employees with the ResQline personal safety gear. The U.S government has completed its analysis process and as of January 1, 2003, ResQline will be listed on the GSA schedule. www.ResQline.com.

Chutes and Slides

A second type of alternative evacuation system involves chute and slide devices which typically feature a fabric tube deployed in a variety of ways from evacuation locations which may be as high as up 30 stories above the ground. Use of these chutes requires run-out room to allow for an evacuee to slow down prior to exiting.
The most widely used escape-chute-type device is the Baker Life Chute (BLC), made by Baker Safety Equipment. The Baker Life Chute is composed of a tube of nylon netting attached to 3’ diameter metal rings located at each end. During use, one ring is secured to the structure from which the evacuation is taking place and the other end which has been secured to a fixed object on the ground as part of pre-use deployment. Evacuees escape by sliding down though the tubular net, slowing themselves down as needed by applying outward pressure on the net with their feet and hands. The BLC is reported to be capable of carrying a continuous flow of as many as 30 people at one time. Several models are available and have been demonstrated, including one that can be airlifted to the top of a building during an emergency, and another that can be attached to the bucket of a fire department rescue ladder. The BLC has been commercially available since the mid-1980’s, and approximately 40 are reported to be in use today in the U.S., Europe, and Japan. Roughly 80% of the units sold have been installed for use in air traffic control towers and NASA tested and approved the BLC for use on its shuttle platforms, though none are currently used in that specific application. A number of other BLC systems have been sold for rapid evacuation of facilities such as oil cracking towers and other high industrial platforms where emergency conditions can develop rapidly. www.lifechute.com.

Another chute system, developed recently by AES in Israel is the Advanced Modular Evacuation System (AMES) made. This system is based on an enclosed chute made of fire resistant material that is automatically deployed from a portal inside a building. During a fire, the fire alarm triggers automatic chute deployment to a pre-designated location either on the ground or at an adjacent building. Evacuees slide down the chute to safety, with flat sections in the slide serving to control descent speed, allowing the evacuee to be deposited onto a cushioned landing pad. After evacuees have been safely evacuated, rescue personnel can also enter the building using a winch system built into the chute hardware. www.aes-systems.com.

Figure 4. Lowering system in use by numerous evacuees
Parachute Systems

The last category under discussion is the parachute system. These present the greatest challenge for safe use in that even trained personnel acknowledge that use of parachutes in urban environments is accompanied with major safety issues.

The Executive Chute is made in the US by the Destiny Aircraft Corporation. This chute is deployed by a static line, which requires the evacuee to secure the ripcord to a fixed object within the building before jumping. This is intended to minimize operator error and to allow the parachute to deploy even in the event that the evacuee loses consciousness during free fall. Currently 200 Executive Chutes have reportedly been sold although there have not been any documented cases of this system having been used in a highrise emergencies. Private individuals have purchased the majority of these devices. Executivechute.com.

The Evacuchute, made by Emergency Evacuation Systems is another parachute evacuation system currently available. The Evacuchute employs a cone-shaped canopy design to provide forward movement away from an affected building, to give the evacuee steering capability, and to give added stability. Two models are available, one designed for civilian use, and the other is designed for rescue professionals. The civilian chute is not fire-resistant, while the rescue chute has a fire-resistant harness. These devices have been commercially available since July of 2002, though none are yet reported to be in use (Evacuchute.com).

Summary

While the technical and engineering aspects of the available controlled descent systems appear reasonable, their application to large structures represents an untried concept especially when human behavior must be taken into account. It is the author’s opinion that these unconventional exiting systems will become part of the accepted tools available for tall building emergency response. This may take the form of use by first responders only in portable form which is progressing already. More comprehensive solutions may prove acceptable to regulators, and building designers and owners with increased familiarity and research.

There is obviously a lot work to be done and development of a sufficient knowledge base as well as well defined codes and standards to address the performance of these systems presents a formidable challenge.

References


About the Author

Joe Zicherman is a fire scientist with Fire Cause Analysis of Point Richmond, California. He received his Ph.D. degree from the University of California in 1978, and his work in the fire safety community has included editing the last “tall building fire safety monograph” published by CTBUH in the 1990s. Joe’s consulting work involves a mix of fire safety design and research work, investigative work and participation in fire safety related forensic activities.
Council Contributors

SUPPORTING CONTRIBUTORS
Al Rayes Group, Kuwait
Hongkong Land Ltd., Hong Kong
KLCC (Holdings) Bhd., Kuala Lumpur
KONE International S.A., Brussels

Zuhair Fayez Partnership, Jeddah

PATRONS
Kuwait Foundation for the Advancement of Sciences, Kuwait
Schindler Elevator Corporation, Morristown
Skidmore Owings & Merrill, L.L.P., Chicago

DONORS
Walter P. Moore & Associates, Atlanta
Mori Building Company, Ltd., Tokyo
Multiplex Constructions (NSW) Pty. Ltd., Sydney
Saudi Consulting Services, Riyadh
The Thornton-Tomasetti Group Inc, New York
Tishman Speyer Properties, New York
Wong & Ouyang (HK) Ltd., Hong Kong

CONTRIBUTORS
Arup, London
The Blume Foundation, Hillsborough
Halvorson + Kaye Structural Engineers, Chicago
Hochtief AG, Essen
Hong Kong Housing Authority, Hong Kong
Invensys plc, Kansascity
Meinhardt Group

DeSimone Consulting Engineers, New York
The Durst Organization, New York
EUROPROFIL SA, Luxembourg
INTEMAC, Madrid
KHP Konig, Heinrich und Partner, Frankfurt
Mueser Rutledge Consulting Engineers, New York
NFP International, Quincy
Nishkian-Menninger, San Francisco
PSM International Corporation, Chicago

Shannon & Wilson, Inc., Seattle
Shenzhen University, Institute of Architectural Design & Research, Shenzhen
Skilling, Ward, Magnnusson, Barkshire, Inc., Seattle
Solomon Cordwell Buenz & Associates, Inc., Chicago
Werner Voss & Partner, Riyadh
Nabiib Youssef & Associates, Los Angeles
Zimmer Gunsul Frasca Partnership, Seattle

CONTRIBUTING PARTICIPANTS
BMT
Fluid Mechanics Ltd., Middlesex
Botti Rubin Arquitetos Associados S/C Ltda., Sao Paulo
Boundary Layer Wind Tunnel Laboratory, (U. Western Ontario), London, Canada
Brandow & Johnston Associates, Los Angeles
Callon Architecture, Inc., Seattle
CBM Engineers Inc., Houston
The Chamber of Construction Designing, Warsaw
Code Consultants Professional Engineers P.C., New York
Connell Mott MacDonald, Neutral Bay
Construction Technology Labs, Inc., Skokie
Edgett Williams Consulting Group, Mill Valley
Flack + Kurtz Inc, New York
Fox & Fowle Architects, New York
Gold Coast City Council, Queensland

Haynes Whaley Associates, Inc., Houston
Heller Manus Architects, San Francisco
Hellmuth, Obata & Kassabaum, Inc., San Francisco
Hijjas Kasturi Associates Sdn., Kuala Lumpur
HL-Technik AG, Munich
Horvath Reich CDC Inc., Chicago
Housing and Development Board, Singapore
IGH Ingenieurgesellschaft Hopfner mbH, Cologne
International Union of Bricklayers and Allied Craftworkers, Washington D.C.
Japan Structural Consultants Association, Tokyo
Jeffrey Associates, Seoul
Dennis Lau & Ng Chun Man, Architects & Engineers (HK) Ltd., Hong Kong
Lerch Bates & Associates Ltd., Littleton
Stanley D. Lindsey & Associates, Nashville
Margolin Bros. Engineering & Consulting Ltd., Givat Shmuel

Martin & Huang International Inc., Pasadena
Enrique Martinez-Romero, SA, Mexico
McKenzie Group Consulting Pty. Ltd., So. Melbourne
McNamara/Salvia, Inc., Boston
Middlebrook & Louie, San Francisco
Murphy/Jahn, Chicago
Nikken Sekkei Ltd., Tokyo
Cesar Pelli & Associates, New Haven
John Portman & Associates, Inc., Atlanta
Rosenwasser/Grossman Consulting Engineers, P.C., New York
Rowan Williams Davies & Irwin Inc., Guelph
Security Industry Association, Alexandria
Chris P. Stefanos Associates, Inc., Oak Lawn
STS Consultants, Ltd., Vernon Hills
The Stubbins Associates, Inc., Cambridge
Teng & Associates, Chicago
Trade Centre Company Limited, Riyadh
Turner International, New York
U.S. Gypsum Company, Chicago
Yolles Partnership Inc., Toronto

Supporting Contributors are those who contribute $10,000 and above. Patrons: $6,000 and above. Donors: $3,000 and above. Contributors: $1,500 and above. Contributing Participants: $750 and above.
CTBUH Steering Group

EXECUTIVE COMMITTEE

CHAIRMAN
Ron Klemencic, Skilling Ward Magnusson Barkshire, Seattle, Washington, USA

EXECUTIVE DIRECTOR
David M. Maola, Lehigh University, Bethlehem, PA, USA

VICE CHAIRMEN
Sabah Al-Rayes (Middle East), Al-Rayes Group, Kuwait
Joseph P. Colaco (North America), CBM Engineers, Houston, Texas, USA
Henry J. Cowan (Australia), Consultant, Mosman, Australia
Fu-Dong Dai (Northern Asia), Tongji University, Shanghai, China
Ryszard M. Kowalczyk (Europe), University de Beira Interior, Covilha, Portugal

Edison Musa (South America), Edison Musa Arq. Construcoes Ltda., Rio de Janeiro, Brazil
Syd Parsons (Africa), Parsons & Lumsden, Kioof, South Africa
Kenneth Yeang (Southern Asia), T. R. Hamzah & Yeang Sdn. Bhd., Kuala Lumpur, Malaysia

PAST CHAIRMAN
R. Shankar Nair, Teng & Associates, Chicago, Illinois, USA

MEMBERS (EX-OFFICIO)

Brad Hinthorne, Zimmer Gunsul Frasca Partnership, Seattle, Washington, USA
George von Klenk, Edgett Williams Consulting Group, Mill Valley, California, USA

GROUP LEADERS (EX-OFFICIO)

Mir M. Ali (Planning & Architecture), University of Illinois, Champaign, Illinois, USA
Frans Bijnald (Tall Steel Buildings), TNO Building & Construction Research, Delft, The Netherlands
Peter Bressington (Design Criteria and Loads), Arup Fire, London, United Kingdom
William Gene Corley (Tall Concrete & Masonry Buildings), Construction Technology Labs, Skokie, Illinois, USA
Thomas K. Fridstein (Development & Management), Tishman Speyer Properties, Chicago, Illinois, USA
James G. Forbes (Building Systems & Concepts), Scott Wilson Irwin Johnston, Sydney, Australia
Nicholas Isyumov (Design Criteria and Loads), Southwold, Canada
Peter Lenkei (Tall Concrete & Masonry Buildings), Pecs Polytechnic, Pecs, Hungary

MEMBERS-AT-LARGE

Ali A. Al-Shamlan, Kuwait Foundation for the Advancement of Sciences, Kuwait
Eli Attia, Eli Attia Architects, Brooklyn, New York, USA
Georges Binder, Buildings & Data, Brussels, Belgium
Joseph Bittar, Consultant, Farmington, Connecticut, USA
Daniel Cerf, Value Asset Management Sdn. Bhd., Kuala Lumpur, Malaysia
John E. Chapman, Schindler Elevator Corporation, Morristown, New Jersey, USA
Charles DeBenedittis, Tishman Speyer Properties, New York, New York, USA
Gilberto M. do Valle, Projest Consultoria e Proj. Sc. Ltd., Rio de Janeiro, Brazil
Zuhair Faye, Zuhair Faye Partnership, Jeddah, Saudi Arabia

Michael Fletcher, Walter P. Moore & Associates, Atlanta, Georgia, USA
Chandra K. Jha, PSM International Corporation, Chicago, Illinois, USA
A. Eugene Kohn, Kohn Pedersen Fox Associates, New York, New York, USA
Ishwarel B. Patel, Mangat I. B. Patel & Partners, Nairobi, Kenya
Wayne Petrie, HPA Architects, Milton, Australia
Leslie E. Robertson, Leslie E. Robertson Associates, New York, New York, USA
Sjef van Beek, Aronsohn Consulting Engineers bv, Rotterdam, The Netherlands
Werner Voss, Werner Voss & Partner, Braunschweig, Germany
Bob Williams, Invensys plc, Kansas City, Missouri, USA

SPONSORING SOCIETY REPRESENTATIVES

Finley Charney (ASCE), Schnabel Engineering, Denver, Colorado, USA
Lee Polisano (ULI), Kohn Pedersen Fox Associates, London, United Kingdom

Jeffrey Soule (APA), American Planning Association, Washington, D.C., USA
Koichi Takanashi (IABSE), Chiba University, Chiba, Japan
Takeyuki Teramoto (JSCE), Chiba, Japan

AFFILIATED ORGANIZATION REPRESENTATIVES

Ian Chin (Chicago Committee on High-Rise Buildings), Wiss Janney Elstner Associates, Chicago, Illinois, USA
Arzu Erdem (High-Rise Buildings Working Group), Istanbul Technical University, Istanbul, Turkey
Albert K. H. Kwan (Centre for Asian Tall Buildings and Urban Habitat), The University of Hong Kong, Pokfulam, Hong Kong, China

Marshall Lew (Los Angeles Tall Buildings Structural Design Council), Law/Crandall Engng. & Environmental Services, Los Angeles, California, USA

Edison Musa (CTBUH-Grupo Brazil), Edison Musa Arq. Construcoes Ltda., Rio de Janeiro, Brazil
David Norris (Australian Council on Tall Buildings and Urban Habitat), McWilliam Consulting Engineers, Spring Hill, Australia
Jerzy Skrzypczak (Polish Group on Tall Buildings and Urban Habitat), The Chamber of Construction Designing, Warsaw, Poland
Jan J. N. A. Vambersky (Dutch Council on Tall Buildings), Consmit Consulting Engineers, Amsterdam, The Netherlands
UPCOMING CONFERENCES AND CALL FOR PAPERS

**Strategies for Performance in the Aftermath of the World Trade Center and The 2nd CIB Global Leaders Summit on Tall Buildings**

May 8-10, 2003
Kuala Lumpur, Malaysia

Hosted by the International Council for Research and Innovation in Building and Construction (CIB) in cooperation with the Council on Tall Buildings and Urban Habitat (CTBUH).

The joint CIB-CTBUH conference on “Strategies for Performance in the Aftermath of the World Trade Center” will be landmark gathering of professionals, researchers, building owners, authorities and stakeholders of the tall buildings community to discuss and exchange information on performance issues and development of appropriate strategies for enhancing the performance of buildings during emergencies. Discussions will focus on the multi-faceted issues involving performance of existing and new buildings, infrastructure and facilities, their options and the challenges facing the industry. The theme provides for multidisciplinary discussions through the state of the art knowledge and technology where presenters from the research community, industry leaders, stakeholders and governments will discuss problems, options and viable solutions examined in terms of technical, safety, security, operational and economic aspects.

Keynote speakers include Sherif Barakat, President of CIB and Director General of the Institute for Research in Construction National Research Council on Canada; Ron Klemencic, Chairman of CTBUH and President of Skilling Ward Magnusson Barkshire Inc.; Wim Bakens, Secretary General of CIB The Netherlands; Norman Kurtz, Flack and Kurtz; W. Gene Corley, Senior Vice President of Construction Technology Laboratories and head of the ASCE Building Performance Study Team for the investigation of the World Trade Center and the Pentagon bombings; and Jack E. Snell, Director of the Building and Fire Research Laboratory for the National Institute of Standards and Technology.

Registration for participation will be open until March 2003. A discount rate is offered to registrants before January 31, 2003.

**Contact**
Assoc. Prof. Dr. Faridah Shafii
CIB Coordinator on Tall Buildings/Conference Chair
Construction Technology and Management Centre
Faculty of Civil Engineering, Universiti Teknologi Malaysia
81310 UTM Skudai, Johor, Malaysia
Tel: 60-7/553-1935; Fax: 60-7/554-2669;
Email: drfaridah@hotmail.com or cibkl@cibklutm.com or cibkl@utm.com
www.cubklutm.com
Upcoming Events

Tall Buildings and Transparency
October 5-7, 2003
Stuttgart, Germany

Hosted by the Institute for Lightweight Structures and Conceptual Design (ILEK), in cooperation with the Council on Tall Buildings and Urban Habitat (CTBUH).

The conference is dedicated to innovative concepts and structures as well as new materials and their future application in high-rise buildings. “Tall Buildings and Transparency” will thus open new perspectives for the design and construction of lightweight and transparent structures.

Invited speakers include Norman Foster, Helmut Jahn, Christoph Ingenhoven, David Childs, and Joseph Burns.

Call for Papers
Deadline for submitting abstracts: April 1, 2003.
Deadline for submitting papers: July 1, 2003.

Contact
Dipl.-Ing. Martin Kobler
University of Stuttgart
Institute for Lightweight Structures and Conceptual Design
Pfaffenwaldring 7 and 14
70569 Stuttgart, Germany
Tel: 49-711/685-6252; Fax: 49-711/685-6968;
Email: info@ctbuh-stuttgart.de

www.ctbuh-stuttgart.de/

CIB World Building Congress 2004 – Building for the Future
May 2-7, 2004
Toronto, Ontario, Canada

Hosted by the Institute for Research in Construction National Research Council of Canada (CIB) and sponsored by the Council on Tall Buildings and Urban Habitat (CTBUH).

The CIB World Building Congress 2004 will provide an excellent forum for the presentation and exchange of new research results on a wide range of timely issues in building construction. Topics will include the construction process, trends in codes and regulatory systems, construction in developing countries, ventilation requirements, strategies and control systems, safety considerations in HVAC system design, indoor air quality and energy conservation, occupant issues in highrise buildings, and fire and structural safety and security in tall buildings.

Call for Papers
Deadline for submitting abstracts: February 15, 2003
Notification of acceptance of abstracts: April 15, 2003
Deadline for submitting manuscripts for reviewers: October 15, 2003
Deadline for submitting final manuscripts: February 1, 2004

Contact
Ms. Monique Myre
Conference Secretariat
Institute for Research in Construction
National Research Council of Canada
1200 Montreal Road, Building M-20
Ottawa, Ontario, Canada K1A 0R6
Tel: 613/993-0435; Fax: 613/952-3142;
Email: cib2004@nrc.ca

www.cib2004.ca
Tall Buildings in Historical Cities – Culture &
Technology for Sustainable Cities
October 10-14, 2004
Seoul, Korea

Hosted by the Architectural Institute of Korea (AI) in cooperation with the Council on Tall Buildings and Urban Habitat (CTBUH).

The paradigm shift of the last century in the dwelling culture and the way we inhabit space, along with the advancement in the engineering technology, has led the urban civilization to a proliferation of tall buildings, which, notwithstanding the ongoing debates on their economic and functional feasibility, have already become an epitome of city life with socio-cultural importance. Today, there is no denying that the quality of these large towers plays a significant part in defining our living conditions in the city.

The conference will examine the conceptual, historical, and technological conditions of today’s tall buildings, review the advancements in related theories and practices, and suggest an outline of future developments with an emphasis on culture and technology for sustainable cities.

Call for Papers
Notification of acceptance of abstracts: December 31, 2003

Deadline for early registrations is May 31, 2004.

Contact
Secretariat
INTERCOM Convention Services, Inc.
4Fl, Jiseong Bldg., 645-20 Yeoksam1-dong
Gangnam-gu
Seoul 135-910, Korea
Tel: 82-2/3453-2937; Fax: 82-2/3452-7292;
Email: ctbuh2004@intercom.co.kr
www.ctbuh2004.org