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Author:	Peyman Askarinejad, Director of Structural Engineering, TJEG International
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Holistic Approach of Beehive (Hexagrid), New Innovative Approach to Supertall Free Form Buildings

蜂房(六边形网格)：一种新型的高层建筑结构系统

Peyman Askarinejad

Peyman Askarinejad

TJEG (Ted Jacob Engineering Group)
1763 Broadway
Oakland, California
USA 94612

tel (电话): +97 150.460.2404
email (电子邮箱): Pnejad@Tjeg.com
www.tjeg.com

Dr. Peyman A. Nejad is the Director of Structural Engineering for Ted Jacob Engineering Group. Throughout his career, Peyman has dedicated himself to structural innovation. His best known contribution has been to develop the "HexaGrid" structural system for tall buildings. While widely regarded for his work on super tall buildings, his expertise also extends to free form and long spans structures; he has had a notable career in the analysis and design of concrete and steel structures and is an acknowledged expert in the design of super-tall buildings.

Dr. Peyman is the recipient of multiple awards and honors. In addition to working at TJEG, he is actively involved with numerous professional organizations and Universities. He has also received an Award for Excellence in Lecturing at the IAU and St. Petersburg State Polytechnic University (SPBPU).

Peyman A. Nejad博士是Ted Jacob工程公司的结构工程部门主管。纵观他的整个职业生涯，Peyman都在致力于新型结构的研究。他最杰出的贡献是发展高层建筑“六边形网格”结构系统。他不仅因对超高层建筑的研究而广受敬重，而且他的专长也扩展到了自由形态结构与大跨度结构领域；他在混凝土与钢结构的研究和设计方面有着引人注目的职业成就，并且他更是一位公认的超高层建筑设计专家。

Peyman博士曾获得过多种奖项及荣誉，除了他在TJEG的工作，他还活跃于数家专业机构和大学中；他在IAU和圣彼得堡国家理工大学（SPBPU)的教学而获得了优秀授课奖。

Abstract

An overview of tall building structures with specific reference to the lateral systems that resist the lateral forces which dominate the design process, the building efficiency and the form of the building. The HexaGrid system is a new look from an alternative perspective on how structural engineers can achieve the requirements of designing high-rise structures while increasing the efficiency of the building through a reduction in central cores down to the foundations. This research details the comparison between two buildings, one laterally stabilized in a typical traditional way with the other utilizing the HexaGrid system. Efficiency is one of the major benefits of the Beehive; a significantly higher degree of sustainability can be achieved with radically reduced structural weight and resultant forces together in conjunction with the economic benefits from construction through reduced time execution.

Keywords: Innovative, HexaGrid, Beehive, Contemporary Lateral Structural System

摘要

本文是一篇关于高层建筑结构系统的概览，着重于抗侧力体系的研究，因为对抗侧力的处理往往主导着建筑的设计方向，建筑的功效，及建筑的形态。六边形网格系统是一种新颖的理念，因为它从另一个角度来研究结构工程师们如何在满足高层建筑结构设计要求的同时，通过减少核心筒与地基的体量来增加建筑的功效。本研究对两栋建筑进行了细致的比较，其中一栋采用了典型的传统侧力稳定方式，另一栋则应用了六边形网格系统。高功效是蜂房结构的主要优点；大大减少结构自重与各种合力作用，可以显著地提升建筑的可持续性，因为减少施工量与施工时间会带来可观的经济效益。

关键词：革新、六边形网格、蜂房、当代侧力结构系统

The design of structures has developed extensively through history, while their principal purpose as means to support gravity loads, resist lateral forces, temperature variances and vibrations have remained the same. However, driving the development over time have been the changing requirements of aesthetics, owner considerations, lettable spaces and multi-usages, together with cost and safety requirements which have significantly changed since the early 20th Century.

As cities have developed and grown in size and population, the trend to build taller structures has increased, either due to a lack of space in developed areas or a desire to challenge and develop the limits of structural engineering. In the USA, tall structures represent the requirement to build high-rises in developed areas, whereas in the Middle East space isn't so much of a premium, therefore the number of tall buildings in this region is representative of the desire to build, showcase and develop the extent of engineering.

建筑结构设计已经历了长足的发展，但是关于承重，抗侧力、温差和振动的基本方式一直没有变化。一种理论认为，促进这种发展的力量来自于不断变化的需求，例如美学、投资方的考虑、可租用的空间、混合使用，再加上造价与安全需求等等，这些因素自20世纪初期起已经历了显著的改变。

当城市在规模和人口不断扩大时，建造高层建筑的趋势也随之增强，一方面可能是因为在发达地区用地紧张，另一方面也可能是源自人们挑战结构工程极限的愿望。在美国，高层结构代表了在发达地区建造高层建筑的需求，而在中东那些空间并不是很稀缺的地区，建造高层建筑就代表了人们建造、炫耀和挑战工程极限的渴望。

与低层建筑相比，高层建筑在创造可持续的建成环境方面具有巨大的潜力，主要因为高层建筑在土地的使用方面更有效率。从高层建筑结构的历史来看，技术发展的动力来源于使用的需求和策略。在二十世纪中期，汽车的现代化允许人们在城市工作，却在郊区居住；渐渐地，城市越来越大，居住区开始迁回市中心，于是对于建筑的需求，特别是高层结构的需求开始有了明显地变化和提高。高层结构现在必须

Tall buildings have a great potential to create sustainable built environments when directly held up to comparison with low-rise buildings, principally as tall buildings use land area more efficiently. Over the history of tall building structures the developments in technology have been driven by the requirements and strategies of usage. In the mid 20th Century, the modernization of the passenger vehicle allowed people to work in the city while living in the suburbs. Over time, with cities becoming larger and the migration of residential moving back towards the central city, the requirements of buildings and most notably tall structures have significantly altered and increased. Tall structures now have to accommodate many uses: retail, office, residential and parking.

In tall structures, the principal requirement is the resistance of high magnitudes of wind and seismic forces. Thus, the lateral load resisting system becomes paramount to the design of the building. Currently, there are many structural systems that are used in the design of tall buildings to list a few: rigid frame, reinforced concrete core, belt truss, out-riggers and truss-tube. Shear walls, which resist lateral wind and seismic loads acting on a building transmitted to them by the floor diaphragms, were first typically seen as early as 1940 and are still commonly used in the industry in high-rise buildings, due to efficient material and labor costs.

Since the 1940s, structural engineers have learned and developed many alternative ways of laterally stabilizing a tall building, as the knowledge has progressed over time with regards to the materials and construction techniques in conjunction with software technology. The challenge for engineers and architects today is to integrate systems that work together competently to create a habitable, sustainable and efficient structure.

The structural systems of today are undergoing a major evolution to address the ability to provide flexibility in the design and usage of the operational requirements of the building, together with sustainability and the maintaining of cost-effective solutions. The HexaGrid, nicknamed the Beehive, is a new innovative, evolutionary structural system for use in the design of tall buildings. The principal is born from nature's beehives, which serve as the protection, homes and source of life for their inhabitants. The beehive's internal structure is a densely packed matrix of hexagonal cells called a honeycomb. The hexagonal shape perfectly distributes and disperses the external man-made or environmental forces, thus protecting its contents. By examining structures in nature, we can see where nature's building principles exist and see how these principles can be incorporated into man-made structures today. However, the comparison between natural and man-made structures is that nature uses live materials while man uses inert ones, the two do not always behave in the same manner.

Developing this natural characteristic into a man-made structure is the principal behind the use of HexaGrids in tall buildings. The hexagonal build up is located along the exterior perimeter surfaces of the building in order to maximize their effectiveness. By using the perimeter, the efficiency is by far superior to conventional lateral resisting methods. In addition, the members in the HexaGrid structural system carry gravity loads together with the lateral forces. Compared with other systems in high rise structures, HexaGrids are significantly more effective in minimizing shear deformation, principally because they carry shear by axial action, while alternative systems typically carry shear by bending of the vertical columns and horizontal spandrels.

The HexaGrid structure provides both bending and shear rigidity, thus reducing the requirement for high shear rigidity cores, as these forces can be carried by the hexagon elements located on the perimeter.

满足各种各样的功能，零售、办公、居住、停车等。

在所有的高层结构中，最主要的要求就是抵抗高等级的风力和地震力，因此抗侧力系统对于建筑的设计来说至关重要。现在有多种结构系统被应用在高层建筑的设计当中，比如，刚性框架，钢筋混凝土核心筒，带形桁架，伸臂桁架与桁架筒，等等。剪力墙，能抵抗通过楼板传递给它们的风力和地震力，最早出现于1940年，但因为相对便宜的材料和人工花费，它们依然普遍地运用于现代高层建筑工业中。

自19世纪40年代以来，随着建筑材料和施工技术知识的积累，加上工程软件的应用，结构工程师们已经研究和发展了多种其它的高层建筑抗侧力方式。今天的工程师与建筑师们所面临的挑战，是如何将各个系统整合起来，使它们一起创造一个宜居的，高效的，可持续性的建筑结构。

今天的结构系统正经历着一次重大的变革，以期为建筑的设计及操作使用提供灵活性，并在维持低成本解决方案的同时保障建筑的可持续性。六边形网格，昵称为蜂房的系统，是一种针对高层建筑设计的新型的、革命性的结构系统。蜂房结构的原理源于自然界的蜂房。蜂房，是蜂群的庇护所，居住地，和生命之源。蜂房的内部结构是一个高密度的由六边形隔间所组成的阵列，名叫蜂巢；六边形的形状能够很好地分布和分散外来的人力或者自然力的作用，从而对其内部起到有效的保护作用。仔细研究自然界中的结构，我们可以看到其中的基本原理，和这些原理将如何被应用到今天的建筑结构中去。当然，自然结构与人造结构的不同还在于，自然界使用的是活性材料，而人类采用的多为惰性材料，这两者的性质表现往往并不相同。

在高层建筑中使用六边形网格，正是基于这种将自然的特色整合到人造结构中去的基本原则。为了结构效率的最大化，六边形网格分布在建筑的外围层面；这种外围的结构形式，其效率要远远大于传统的抗侧力方式。此外，六边形网格结构系统中的组件能在抗侧力的同时也承担重力，与其它的高层建筑结构系统相比较，六边形网格在减少剪切变形方面具有更显著的效率，因为它们通过轴向作用传递剪力，而不是像其它的方式那样通过竖向柱子和横向拱的弯曲来实现剪力的传递。

六边形网格结构同时提供了抗弯和抗剪刚度，因此可以减少对于高度刚性核心筒的需求，只要这些力能被分布在建筑外围的六边形组件所传递。与其它类型的高层建筑结构设计相比，六边形的蜂巢结构通过网格单元的横力轴线来传递受力，被证明在减小横向变形方面具有更大的优势。

这个研究最初注重于六边形网格框架中斜构件的角度和拓扑构成。六边形网格由交叉的对角线和水平结构组件构成------这种体系立刻免去了建筑外围对于竖向柱子的需要。六边形网格的拓扑构成是一个非常重要的设计变量，因为斜构件之间的角度决定着抵抗内力的应力分布。这些角度应该分项目的不同而分别考

Figure1. Natural forms of beehive (Source: Dr. Peyman A. Nejad)
图1.蜂房的自然形态（出自：Dr.Peyman A.Nejad）

When compared to other design schemes of high-rise buildings, the hexagonal honeycomb structure is proven to be more effective to minimize the transverse deformation, by distributing these forces through the transverse axis of the diagonal elements.

This study initially focused on the angle and a topology of the diagonal members in a HexaGrid frame. HexaGrids consist of intersecting the diagonal and horizontal structural components, straight away eliminating the need for vertical columns on the exterior of the building. The topology of the HexaGrid system is an important design variable, since the degree of angle between diagonal members determines the stress distribution resisting internal forces. These angles should be considered on a project by project basis in order to obtain the optimal HexaGrid topology with the highest stiffness in the design phase. Distinctive geometric features of each project (i.e. building dimensions, story height and so on) influence the optimal HexaGrid topology for that project. Therefore, the diagonal angles, number of bays of HexaGrid, HexaGrid height, etc. should be carefully determined for each design.

The HexaGrid optimization process can be achieved by finite element analyses and appropriate sensitivity studies with respect to the topology of diagonal members. The objective of the optimization process is to both maximize Eigen frequency for resisting dynamic responses and minimize mean compliance for static responses. Further investigations are necessary to understand global and topological HexaGrid mechanisms in order to develop a simplified and practical analysis/design tool for the HexaGrid system.

This structural system consists of a HexaGrid perimeter network which is made up of a multi-story hex-angulated truss system, with the grid formed by intersecting the diagonal and horizontal components. This innovation transfers both the gravity and lateral loads by redirecting member forces and eliminates the need for vertical columns on the exterior of the building.

Architecturally, the absence of columns in the corners of the building provides great panoramic views from the interior.

Structurally, the degree of angle between the diagonal members consisting of HexaGird nodes is a significant design variable to determine the stress distribution resisting internal forces into the HexaGrids. In addition, the stress distribution changes depending on the height and span of the building, together with the structural member sizes and the connection design.

In order to measure the HexaGrid member and optimize angle analysis, and compare the results presented here, diverse fixed supports for the boundary conditions are deposited into a given initial design space.

Nodes are modeled by initial domain distributions of density, which is referred to as design variables. The column-shape and beam-shape depend on initial topologies into design space, i.e. angles of fixed supports. Node positions, where relatively large stresses act, are structurally weak and therefore material supplement needs to be properly stiffened there. The optimal density assignments are equal to stress distributions. As shown, stress at the center node position which is produced by a horizontal load is larger than that by a vertical load, meaning that material reinforcement for resisting a horizontal load is more necessary than one for a vertical load. The largest stress acts to the node part in all the angle models, and therefore a node part or a connection of diagonal members is the most significant reinforcement component, with respect to structural safety, in HexaGrid systems.

虑，以期在设计阶段就获取能提供最大刚度的最佳拓扑构成。各个项目各自的几何特点（例如建筑尺度，楼层高度等等）影响着其最优化的六边形网格拓扑构成的生成，因此对角线的角度，六边形格的数量，及网格的高度等等，都需要仔细的考虑。

六边形网格的优化过程能够通过有限元分析和针对斜构件组合形体的适当的灵敏度研究来实现。优化过程的目标是最大化特征频率来抵抗动力响应，并且最小化对于静态响应的平均顺应性。为了了解六边形网格的全局和表面形态的机制，以发展一种简化的实用分析/设计工具，更深入的考察是必须的。

该结构系统由处于建筑外围的六边形网格连成网络而成，这种网络实际上是一种多层的六角桁架系统，网格则由交叉的斜构件与水平组件形成。这个新型的系统能通过转变构件内力的方向来同

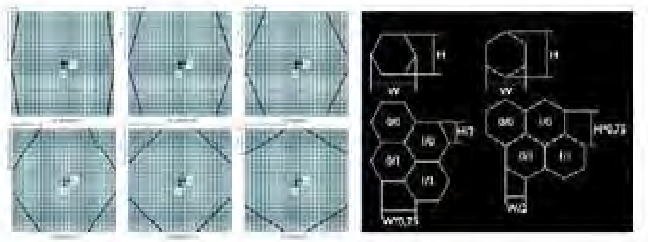

Figure 2. Optimized topography of the HexaGrid (Source: Dr. Peyman A. Nejad)
图2. 六边形网格的最佳表面形式（出自：Dr. Peyman A. Nejad）

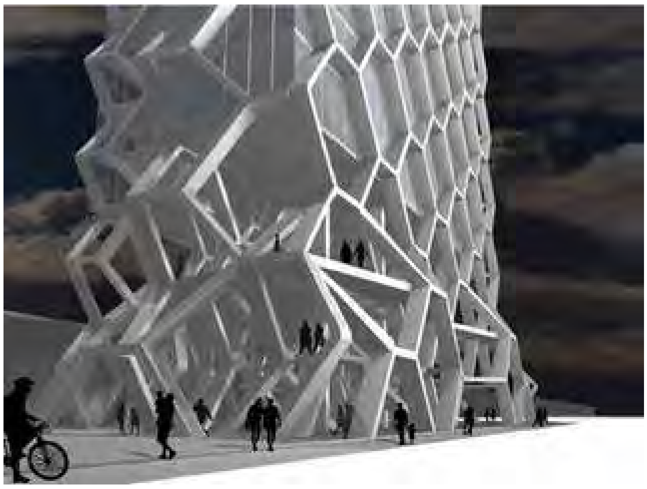

Figure 3.Redundancy of vertical elements (Source: Dr. Peyman A. Nejad)
图3. 竖向单元的重复性（出自：Dr. Peyman A. Nejad）

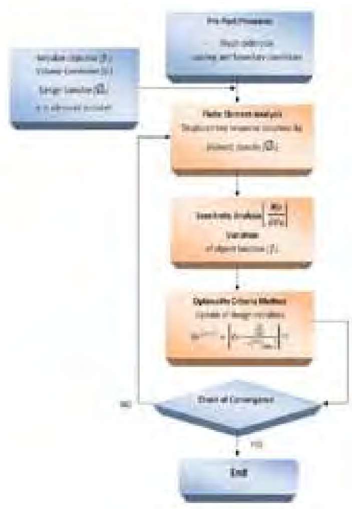

Figure 4. Pre-Post processes for FEM analysis (Source: Dr. Peyman A. Nejad)
图4. 有限元分析的前后处理（出自：Dr. Peyman A. Nejad）

The Following Points are Highlighted Regarding Analysis of HexaGrid System:

- The HexaGrids are redundant, load path following and continuous.
- The HexaGrids combine the benefits of a hollow tube with those of a truss and its chords.
- The angled setting of the columnar elements allows for a natural flow of forces through the structure.
- In this manner, both gravity loads and lateral loads are transferred through the HexaGrid to the ground below.

The HexaGrid system offers several advantages in addition to eliminating perimeter columns. Most notably it optimizes each structural element. Typically, columns are used to provide vertical-load-carrying capacity, while the diagonals/braces provide stability and resistance to large forces, such as wind and seismic loads. But in the HexaGrid system the diagonals are participating in the vertical load transfer and lateral loadings. In a HexaGrid system the two functions are working together, such as a couple, the hexagons and diagonals are all one.

Case Study

Dubai High Rise

Figure 8 shows a 3D view of a structural analysis showing a high rise building located in Dubai Marina. The 90- story building is completed and was designed and constructed using a perimeter framed tube with a core, shear walls and out-riggers as the lateral structural

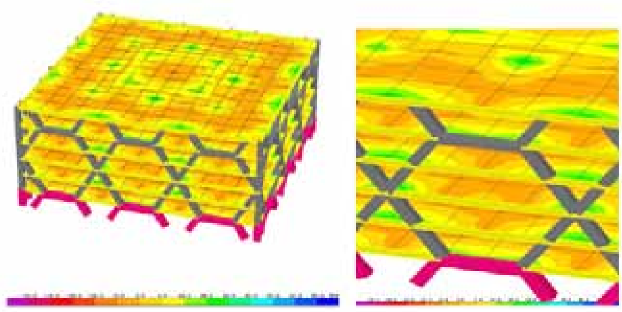

Figure 5. Stress distribution images (Source: Dr. Peyman A. Nejad)
图5.应力分布图（出自：Dr.Peyman A.Nejad）

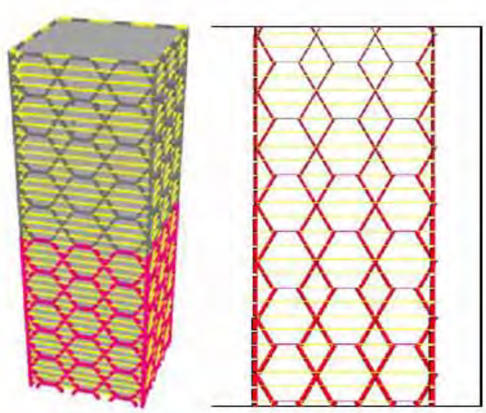

Figure 6. HexaGrid analysis, 3D & elevation(Source: Dr. Peyman A. Nejad)
图6.六边形网格分析，三维&立面（出自：Dr.Peyman A.Nejad）

时传递重力和侧推力，因此免去了对建筑外围竖向柱子的需求。

从建筑学的角度来说，在建筑的角端不设柱子，能使内部获得巨大的全景视野。

结构方面，组成六边形网格节点的斜构件之间的角度是一个重要的设计变量，它决定着抵抗网格系统内力的应力分布情况。此外，应力分布状况也随建筑的高度和跨度的不同，还有结构构件的尺寸和节点设计的不同而变化。

为了测量六边形网格组件分析，优化角度，和比较结果，在这组对照中，对于各种不同的固定约束边界条件，都被放置在一个假定的初始设计空间内。

节点根据被称为设计变量的初始域分布来建模。柱与梁的形状则由进入到设计空间的初始拓扑构成所决定，比如固定支撑的角度。相对来说承受较大应力的节点位置，是结构的薄弱之处，因此需要增加材料来适当提高其刚度。 最佳网格密度的指定与应力分布情况是相当的，在节点中心的位置，横向荷载要比竖向荷载产生更大的应力。这就意味着抗水平推力的构件比竖向受力的构件更需要材料强化。在所有的角部构件中，节点中心要承受最大的应力，因此从结构安全的角度来说，节点处或者斜构件的连接处应该是六边形网格系统中强度最大的部件。

对六边形网格系统的分析得出以下几点：

- 六边形网格是超静定结构系统， 传力路径是随动的和连续的。
- 六边形网格集中了空心管与桁架及其弦杆的优点。
- 角接的柱状支撑构件允许力在结构系统内自然传导。
- 在这种模式下，重力荷载与侧力荷载都被六边形网格传递到下面的地基上。

除了可以免去建筑外围的柱子之外，六边形网格系统还具有几个优势。最突出的是，它能对结构单元进行最优化设置；常规情况下，柱子被用来承受重力荷载，而斜杆件/支撑则负责抵抗较大的水平荷载如风力与地震力，以保障建筑的稳定性。但是在六边形网格系统中，斜撑杆件可以同时传递竖向力和侧推力。同一个结构单元承担着两种结构功能，就如同一对合作伙伴，只不过六边形与斜撑杆件都是同一个构件。

迪拜高层

案例研究

图8 是一张三维的建筑结构分析图，它是一栋位于迪拜滨海区的高层大厦。这栋90层高的大楼现已竣工，它是以外围框架束加核心筒的模式设计建造，剪力墙与伸臂桁架组成结构的抗侧力系统。此外，图8还显示了同一栋建筑，不过外围的框架和剪力墙

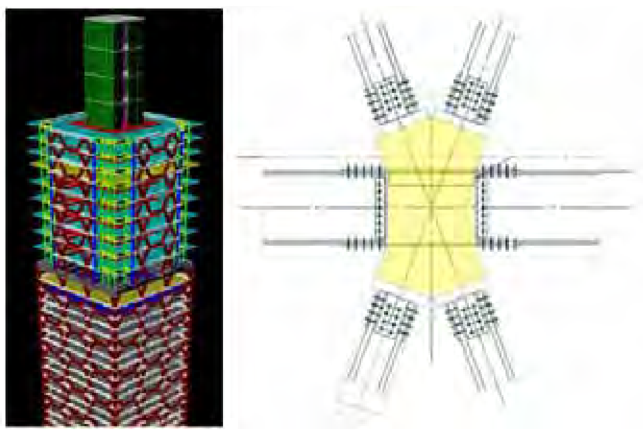

Figure 7. 3D Analysis model & nodal load paths (Source: Dr. Peyman A. Nejad)
图7.三维模型分析&节点传力路径（出自：Dr.Peyman A.Nejad）

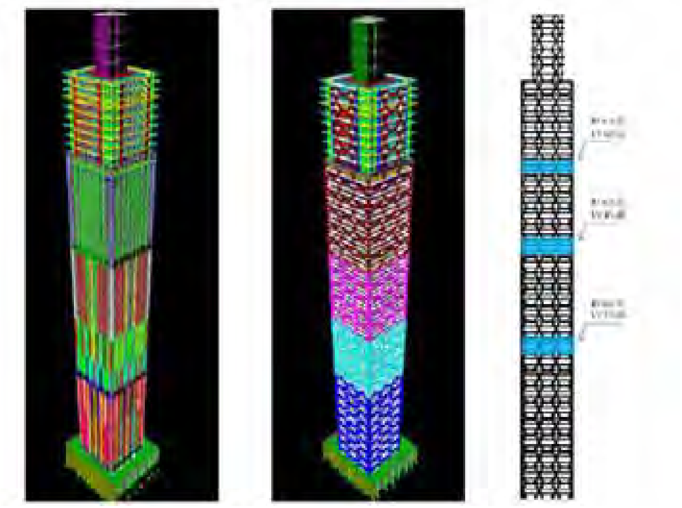

Figure 8. 3D Analysis model of the existing and HexaGrid towers, elevation indicating braced levels to HexaGrid (Source: Dr. Peyman A. Nejad)
图8. 原有高层与六边形网格大楼的三维模型分析，立面显示相对于六边形网格的支撑层（出自：Dr.Peyman A.Nejad）

system. In addition, Figure 8 also shows the same building, but having replaced the perimeter tube and shear walls with the HexaGrid system. For comparison purposes, the central core and building footprint remained constant for both systems.

The existing structural system relied on three out-rigger levels, each three stories tall, at levels 27-30, 45-48 and 60-63. At these levels, full height concrete as an out-rigger system was provided to the perimeter. In the HexaGrid system, the same levels were kept, but they were restrained by horizontal beams at the top and bottom of the mechanical floor slabs only: e.g. at Levels 27 and 30 only – the floors in between were not disrupted by any further stability solution. Similarly, this was also adopted at levels 45-48 and 60-63. (Refer to elevation in Figure 8).

These horizontal elements at the mechanical floor levels tied the top and the bottom of the HexaGrids together, restraining movement back to the central core.

The following graphs represent the results of comparison analysis between the two systems.

The core bending moments shows that at the critical location (the base), the moment is almost 20% less than the equivalent moment in the tube stability system, the lateral displacement under wind loading; the HexaGrid system results in a displacement of 200mm less than the as-built system; and finally, the storey drift graph displays a considerable saving. The initial resultant that can be drawn from this analysis is that the central core may be significantly reduced in size/properties which will yield a vast saving in the quantity of materials required to satisfy the vertical and lateral limitations.

Axial and shear forces under lateral wind loading show a uniform distribution as the HexaGrid elements share the loading down the building elevation in a regular pattern, thus spreading the forces more evenly than buildings that rely on shear walls which attract the greater part of the lateral forces.

In direct comparison with a traditional core/shear wall and out-rigger solution, the principal advantages of the HexaGrid system are as follows:

- Column free building envelope.
- Generous daylighting due to dearth of interior columns and structure.

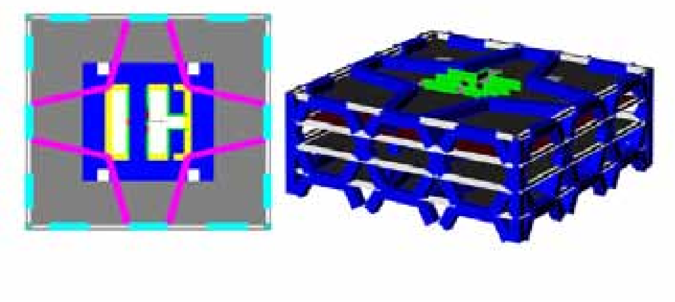

Figure 9. 3D and plan indicating braced levels (Source: Dr. Peyman A. Nejad)
图9. 三维图和平面如显示支撑层（出自：Dr.Peyman A.Nejad）

由六边形网格系统所替代。为了对照方便，大楼的核心筒与建筑面积在两个系统中保持一致。

原有的结构系统依赖于三个伸臂桁架，它们分别位于27-30层，45-48层，和60-63层；在这些楼层中，通高的混凝土结构作为建筑外围的伸臂系统。在六边形网格系统中，同样的楼层由横向的梁所加固，而这些梁只位于设备层的顶部与底端的楼板位置，比如仅在27层和30层------而之间的楼层并没有被任何其它的加固措施所干扰。同样的模式也应用到了45-48层，及60-63层。（见图8的立面图）

这些在设备层的水平向的构件将六边形网格的顶部与底端联系在一起，限制向核心筒方向的变形。

以下的图表展示了关于两种系统对比分析的结果：

核心筒弯矩图显示，在关键部位、基础位置，力矩大约要比框架稳定系统的相对力矩小20%左右；在风荷载下产生的侧向位移，六边形网格系统比原来的结构系统要小200mm；层间位移的图表也体现出相当大的节省。从分析中可以得出的初步结论，是核心筒也许可以在尺寸/属性上大大减少，从而大大节省所需材料的用量，来满足纵向和横向限制。

侧向风荷载所产生的轴向力和剪切力显示出比较均匀的分布，因为六边形网格单元以规则的模式来从上至下分担荷载，而传统建筑在剪力墙位置则集中了大量的侧推力，所以力的传播相对于依赖剪力墙的建筑来说更为均匀。

与传统的核心筒/剪力墙和伸臂桁架方式直接比较，得出以下一些六边形网格系统的主要优点：

- 无柱的建筑表皮
- 内部柱子与结构的减少，使日照的摄入更为充足。
- 更少的材料：一栋钢结构建筑材料节省可达10-15%。
- 全局性的系统机制。
- 在楼板与节点之间，六边形网格框架连接重复性高。
- 简单的施工工艺。
- 对于结构材料的充分利用。
- 作为一种典型的抗弯框架具有类似的设计/施工容许误差。
- 自由清晰，且独特的楼层平面成为可能。
- 更注重美学的表达。
- 具有一定的设计冗余度。
- 超高层的结构破坏可以由六边形网格设计减少到最低。
- 比弯矩框架更强的荷载重分布能力，因此对当今高层建筑的发展更有吸引力。
- 更轻的自重=更少的基础材料。

- Less Material: approximately 10-15% reduction in a steel building.
- Global systematical mechanism.
- Repetitive, HexaGrid frame connections between floor plates and nodes.
- Simple construction techniques.
- Full exploitation of the structural material.
- Similar design/construction tolerances as a typical moment frame construction.
- Free and clear, unique floor plans are possible.
- Aesthetically dominant and expressive.
- Design redundancy.
- Minimization of Skyscraper structural failure.
- Increased ability to redistribute loadings, more than a Moment Frame, for greater appeal in today's landscape of tall buildings.
- Lighter Building = Less Foundation Materials.

However, as with all structural systems, there are a number of disadvantages to the HexaGrid system, which through further research and common practice can be negated over time.

- Construction can be an issue, since little or no experience of HexaGrids is known.
- Architecture may have issues with the integration of windows that create a regular language from floor to floor.
- Execution of the HexaGrid is heavy-handed, if not executed properly in the design and construction phases.

Conclusion

The HexaGrid is a self reliant structural system working in tandem with a central core which, through direct comparison with traditional systems, yields a significant benefit in terms of size and saving. Similar to a typical moment frame, the HexaGrid effectively spreads its mass from its center, and thus develops strength and resistance against lateral forces through multiple sources and directions. The main departure then from a moment frame is the ability of the HexaGrid to resist lateral forces due to the stiffness inherent in its simplicity and shape. The use of the HexaGrid in skyscraper design is a relatively new idea. At this stage, the system requires additional exploration in terms of integration into building design from an architectural view point and the additional scope of applying the systems to freeform structures. The innovator is currently working in this area to research the capability of the system in freeform, twisting and tapered tall buildings.

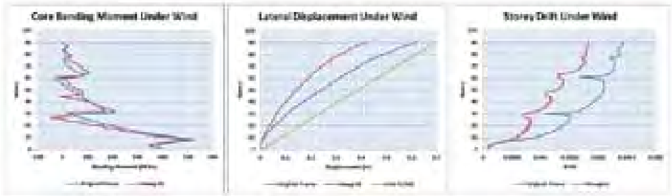

Figure 10. Bending Moment, Lateral Displacement and Storey Drift Graphs (Source: Dr. Peyman A. Nejad)
图10. 弯矩图，侧向位移，层间位移图表（出自：Dr. Peyman A. Nejad）

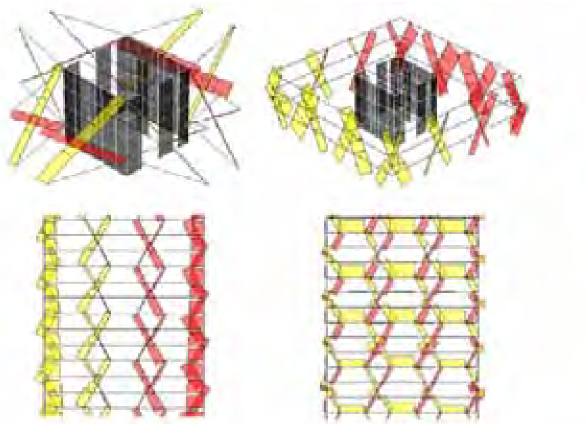

Figure 11. Axial force diagrams from lateral wind loading (Source: Dr. Peyman A. Nejad)
图11. 侧向风载下的轴力图（出自：Dr. Peyman A. Nejad）

然而，就像所有的结构系统一样，六边形网格系统也有一些缺点，需要通过进一步的研究和应用来讲它们逐步消除。

- 鉴于六边形网格系统并无多少现存的经验，施工可能会存在一定的问题。
- 建筑学来说，楼层与楼层之间规则的开窗模式语言，可能会对建筑表皮的设计造成障碍。
- 执行方面，六边形网格系统会变得相当棘手，如果在设计和施工阶段没有处理得当的话。

总结

六边形网格是一种自我依赖的结构系统，它和核心筒串联合作，与传统的结构系统比较在体量和节材方面具有显著的优势。与典型抗弯框架相似，六边形网格单元有效地将质量从中心点散布开来，从而具有抵抗多源及多向侧力的强度和能力。它与抗弯框架的主要区别在于，六边形网格抗侧力的能力来源于其自身的简单构造与形状所产生的刚度。在高层建筑的设计中使用六边形网格还是一个相对新鲜的理念。目前，在与建筑设计整合方面，或要将其应用到自由形态的结构设计中去，这个系统还需要更为深入的探索。本文作者目前正对该系统在自由形态、扭曲及锥形的高层建筑中的应用能力进行研究。

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