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Kingdom Tower: A New Icon for Saudi Arabia

王国大厦：沙特阿拉伯新标志

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Talal Al Maiman is a member of the board and executive committee of Jeddah Economic Company, a corporation established in 2009 to develop Kingdom Tower in Jeddah, Saudi Arabia. Mr. Al Maiman is also Chairman and CEO of Kingdom Real Estate Development Company, based in Riyadh. KREDC is a division of Kingdom Holding Company, whose chairman is His Royal Highness Prince Alwaleed Bin Talal Bin Abdulaziz Alsaud, nephew of Saudi Arabia's King Abdullah.

Talal Al Maiman是吉达经纪公司董事会和执行会员会成员。创建于2009年的吉达经济公司开发了位于沙特利雅得的王国大厦。Al Maiman先生也是位于利雅得的王国房地产开发有限公司主席兼CEO。王国房地产开发有限公司是王国地产公司的一个子公司，公司主席是王子殿下Alwaleed Bin Talal Bin Abdulaziz Alsaud，他是沙特阿拉伯国王的侄子。

Abstract

This paper provides an introduction to, and overview, of Kingdom Tower - expected to be the world's tallest building, at over 1,000 meters, when completed in 2017 in Jeddah, Saudi Arabia. The paper outlines the project's history, including the competitive process that led to the selection of the design scheme; its architectural and structural designs by Adrian Smith + Gordon Gill Architecture and Thornton Tomasetti respectively; its sustainability features; and its construction schedule.

Keywords: Kingdom Tower, Talal Al Maiman, Jeddah Economic Company, Adrian Smith, Gordon Gill

摘要

本文介绍了位于沙特阿拉伯利雅得的王国大厦，其高度超过1000米，2017年竣工时有望成为世界第一高楼。文章概述了项目的历史（包括从竞赛阶段到设计方案的选择）、来自Adrian Smith + Gordon Gill建筑设计事务所和Thornton Tomasetti的建筑设计与结构设计、可持续性特点以及施工进度。

关键词：王国大厦 Talal Al Maiman 吉达经纪公司 Adrian Smith Gordon Gill

It has been the author's great pleasure to be involved in the planning of Kingdom Tower, which, at more than 1,000 meters, will be the world's tallest building when completed in 2017 in Jeddah, Saudi Arabia (see Figure 1). The intention of His Royal Highness Prince Alwaleed Bin Talal Bin Abdulaziz Alsaud and Jeddah Economic Company (JEC), on whose executive committee the author serves, is for this magnificent soaring structure to express the vitality, the aspirations and the greatness of our Kingdom and its people for generations to come.

At a total construction area of 550,000 square meters, Kingdom Tower will be the centerpiece and first construction phase of the 5.3 million-square meter Kingdom City development in north Jeddah, overlooking Obhur Creek and the Red Sea (see Figure 2).

Expected to be constructed at a cost of US$1.2 billion, Kingdom Tower will be a mixed-use building featuring a luxury hotel, office space, serviced apartments, luxury condominiums and the world's highest observatory. Kingdom Tower's height will be at least 173 meters taller than Burj Khalifa, the world's current tallest building (see Figure 3), which was designed by Adrian Smith while at Skidmore, Owings & Merrill.

作者一直非常高兴参与王国大厦的规划。王国大厦高度超过1000米，2017年竣工时将成为世界第一高楼（图1）。王子殿下Alwaleed Bin Talal Bin Abdulaziz Alsaud和作者作为执行委员会成员所在的吉达经纪公司决定建造这一宏壮美而直达云霄的建筑来表达王国以及世世代代人民的活力、雄心和伟大。

总建筑面积为55万平方米的王国大厦将成为吉达北边王国城530万平方米发展的核心和第一建设阶段。大厦可以俯瞰Obhur河以及红海（见图2）。

建造预算为12亿美金的王国大厦将成为涵盖豪华酒店、办公空间、酒店式公寓、豪华公寓和世界最高的观光厅的综合体项目。王国大厦将会至少现在的世界第一高楼比哈利法塔高173米（见图3）。哈利法塔由SOM建筑设计事务所设计。

由Adrian Smith + Gordon Gill建筑事务所设计的王国大厦既体现了高技术，同时也明显带有有机性。其纤细又略显不对称堆叠的形态让人联想起如同从地上突然生长的一束枝叶——预示着将激发出地上周围更多新的生活。

光滑并呈流线型的塔楼形式可以比作沙漠中茁壮成长的植物的折叠状叶状体。叶状体从地上以单一的形式向上冒出，然后在顶端开始彼此分离，这比喻新的增长伴随技术的融合。

Figure 1 : Kingdom Tower, Jeddah, Saudi Arabia. (Source: Jeddah Economic Company/AS+GG)
图1. 王国大厦，吉达，沙特（出自： 吉达经济公司/AS+GG建筑事务所）

Figure 2 : Aerial view of the tower overlooking Obhur Creek. (Source: Jeddah Economic Company/AS+GG)
图2. 鸟瞰三瓣状的地面印记，王国大厦，吉达，沙特（出自： 吉达经济公司/ AS+GG建筑事务所

Figure 3 : Burj Khalifa, Dubai. (Source: AS+GG/ Tim Griffith)
图3. 哈利法塔，迪拜，阿拉伯联合酋长国（出自：AS+GG建筑事务所/ Tim Griffith摄影）

Adrian Smith + Gordon Gill Architecture's design for Kingdom Tower is both highly technological and distinctly organic. With its slender, subtly asymmetrical massing, the tower evokes a bundle of leaves shooting up from the ground – a burst of new life that heralds more growth all around it. This symbolizes the tower as a catalyst for increased development around it.

The sleek, streamlined form of the tower can be interpreted as a reference to the folded fronds of young desert plant growth. The way the fronds sprout upward from the ground as a single form, then start separating from each other at the top, is an analogy of new growth fused with technology.

While the design is contextual to Saudi Arabia, it also represents an evolution and a refinement of an architectural continuum of skyscraper design. The three-petal footprint (see Figure 2) is ideal for residential units, and the tapering wings produce an aerodynamic shape that helps reduce structural loading due to wind vortex shedding.

The result is an elegant, cost-efficient and highly constructible design that is at once grounded in built tradition and aggressively forward-looking, taking advantage of new and innovative thinking about technology, building materials, life-cycle considerations and energy conservation.

For example, the project will feature a high-performance exterior wall system that will minimize energy consumption by reducing thermal loads. In addition, each of Kingdom Tower's three sides features a series of notches that create pockets of shadow that shield areas of the building from the sun and provide outdoor terraces (see Figure 4) with stunning views of Jeddah and the Red Sea.

The great height of Kingdom Tower necessitates one of the world's most sophisticated elevator systems. The Kingdom Tower complex will contain 59 elevators, including 54 single-deck, 3 double-deck, and 2 triple-deck elevators, along with 10 escalators. Elevators serving the observatory will travel at a rate of 10 meters per second in both directions.

尽管设计考虑沙特阿拉伯的地域性特征，但同时展现了超高层建筑设计进程中的不断进化与完善。三个花瓣状的地面印记（见图2）是居住单元的理想形态，尖细的侧翼呈现出空气动力学形态则有助于减少由风力漩涡脱落产生的结构荷载。

最后的结果呈现出一个优雅、高成本效益并具备高水准的构造设计，一经建成必将重塑传统同时体现前瞻性，并表达对于技术、建造材料、生命周期以及节能等方面的创新性思考的进步性。

例如，本项目独具特色的高性能外墙系统会通过减少热负荷最大限度地减少能量消耗。此外，王国大厦在其三个面上都独具特色地设置了一系列凹口从而创造出阴影区来遮蔽阳光，同时提供了室外露台（见图4）来欣赏吉达以及红海的壮丽景象。

超高的王国大厦需要世界上最先进的电梯系统。大厦有59个电梯，其中54个单轿厢电梯、3个双轿厢电梯以及2个三轿厢电梯，还有10个自动扶梯。直达观光厅的电梯双向都可保持每秒10米的速度运行。

设计上另外一个独具特色的部分是在157层有一个直径大约为30米高空露台（见图5），这是一个利用大厦顶部的阁楼而创造出的舒适的室外空间。值得注意的它最初被设计为直升机停机坪。之后经过设计团队的研究认定在这一高度，大厦四周的风力具有不可预知的运动性，因此设置直升机停机坪是无法实现的。然而在那个时候，设计团队和吉达经纪公司（JEC），特别是王子殿下Alwaleed已经喜欢上了这一独特的设计元素，所以决定保留它。

项目历史

王国大厦的规划过程大约在四年前在Alwaleed王子的授意下开始展开。Alwaleed王子一直设想在吉达建造超高层建筑作为王国的象征以及作为国际社会一份子的卓越地位。

为此，吉达经纪公司于2009年成立成为开发王国大厦的法人实体。吉达经纪公司（JEC）最初的合伙人是王国地产公司（KHC），其主席是Alwaleed王子和吉达杰出的 商人Samaual Bakhsh和Abdulrahman Hassan Sharbatly。2011年，沙特历史最悠久最富

Another unique feature of the design is a sky terrace, roughly 30 meters in diameter, at Level 157 (see Figure 5). It is an outdoor amenity space intended for use by the penthouse floor. It's worth noting that this feature was originally designed as a helicopter pad. Later, research by the design team determined that the unpredictable movement of wind around the tower at that altitude made a helicopter pad impractical. By that time, however, the design team and JEC – in particular His Highness Prince Alwaleed– had become attached to the feature as a design element. And so it was decided to keep it.

The History of the Project

The planning process for Kingdom Tower began about four years ago at the instruction of Prince Alwaleed, who has long envisioned a great tower to be built in Jeddah as a symbol of the Kingdom and its place of eminence as a member of the international community.

To that end, Jeddah Economic Company was formed in 2009 as the corporate entity charged with developing Kingdom Tower. The initial partners of JEC were Kingdom Holding Company (KHC), whose chairman is Prince Alwaleed, and prominent Jeddah businessmen Samaual Bakhsh and Abdulrahman Hassan Sharbatly. In 2011, the Saudi Binladin Group (SBG), Saudi Arabia's oldest and most established contractor, was selected as general contractor for the project, and subsequently joined JEC as the fourth partner in the venture.

Beginning in 2009, JEC conducted a multi-stage competitive process in which several international firms were invited to submit design schemes for Kingdom Tower. Besides Adrian Smith + Gordon Gill Architecture, the invited firms included Skidmore, Owings & Merrill, Pickard Chilton, Kohn Pedersen Fox, Pelli Clarke Pelli and Foster + Partners.

After the process of elimination and a lengthy deliberation that lasted more than six months, the author was entrusted to give the shareholders the final recommended design. All of the entries were beautiful, innovative and impressive. But ultimately the scheme by AS+GG was selected (see Figure 6), whose partners on the design team included the structural engineer Thornton Tomasetti and MEP engineer Environmental Systems Design (ESD).

Prince Alwaleed, Mr. Bakhsh, Mr. Sharbatly and the client team were impressed by the recommended design of the AS+GG team, which showed boldness and simplicity. Kingdom Tower's height is remarkable, obviously, but the building's iconic status will not depend solely on that aspect. Its form is brilliantly sculpted, making it one of the most beautiful buildings in the world of any height.

Kingdom Tower is intended to become both an economic engine and a proud symbol of the Kingdom's economic and cultural stature in the world community. The tower will be a landmark structure that will greatly increase the value of the hundreds of other properties around it in Kingdom City and indeed throughout North Jeddah.

We are confident that, upon completion, Kingdom Tower will become one of the world's great tourist destinations as well as one of the most attractive places to live and work in the region. In the meantime, it will create thousands of jobs, spurring the local economy.

In addition to these considerations, we at JEC were also guided by the fact that Kingdom Tower will enjoy great cultural significance. The tower is envisioned as an iconic new marker of Jeddah's historic importance as the traditional gateway to the holy city of Mecca. It's worth noting that the southeast leg of the tripedal base of Kingdom Tower design is on a direct line with the Ka'ba, Islam's holiest site.

Figure 4 : Kingdom Tower balconies. (Source: Jeddah Economic Company/AS+GG)
图4. 王国大厦的阳台（出自： 吉达经济公司/ AS+GG建筑事务所）

盛名的承建商沙特Binladin集团（SBG）被选定为项目的总承包商，随后加入吉达经纪公司（JEC）成为第四大投资合作伙伴。

创立于2009年的吉达经纪公司（JEC）举办了一个包含多阶段的设计竞赛，其中好几家国际设计公司受邀提交王国大厦的设计方案。除了Adrian Smith + Gordon Gill建筑设计事务所，受邀设计公司还包括SOM建筑设计事务所、Pickard Chilton建筑事务所、KPF建筑事务所和佩里·克拉克·佩里建筑事务所+福斯特建筑事务所。

历时长达六个多月的排除选择和慎重考虑，笔者被委任向股东提供最终的设计方案。所有参赛方案美观、新颖、令人影响深刻。但最终AS+GG建筑事务所的方案被选中（见图6），其设计团队的合作者还包括结构工程设计公司Thornton Tomasetti以及机电水暖（MEP）工程公司Environmental Systems Design (ESD)。

Alwaleed王子、Bakhsh先生、Sharbatly先生以及客户团队对AS+GG设计团队既富有张力又很简洁的设计方案印象深刻。王国大厦的高度是显而易见的，但建筑的标志地位不应仅限于此。它迷人的造型使之成为世界上最漂亮的建筑（无论高度怎样）之一 。

王国大厦目标成为经济引擎以及王国在国际社会经济与文化令人自豪的象征。大厦将成为里程碑式建筑，这必将极大地增加王国城内基地周边其他数百个房地产的价值，影响贯穿吉达北方区域。

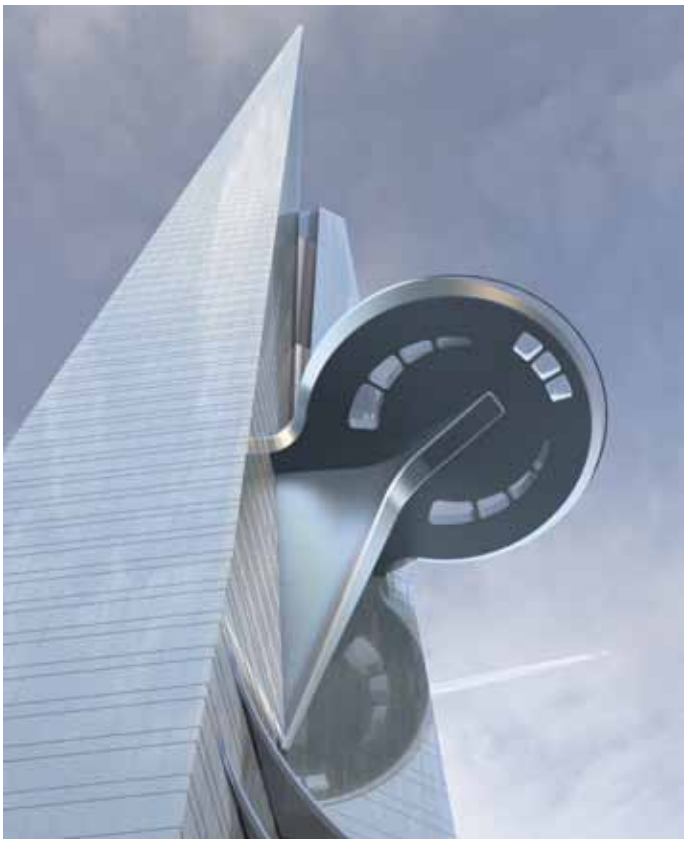

Figure 5 : Kingdom Tower sky terrace. (Source: Jeddah Economic Company/AS+GG)
图5. 王国大厦的高空露台（出自： 吉达经济公司/ AS+GG建筑事务所）

Figure 6 : Adrian Smith + Gordon Gill Architecture partners (from left) Robert Forest, Gordon Gill and Adrian Smith. (Source: AS+GG)
图6. Adrian Smith + Gordon Gill建筑事务所合伙人Robert Forest（左起）、Gordon Gill、Adrian Smith与王国大厦模型 （出自： AS+GG建筑事务所）

Sustainability

Both the design team and JEC are committed to sustainability as a goal. This is being pursued in a myriad of ways.

For example, each of Kingdom Tower's three sides features a series of notches that create pockets of shadow that shield areas of the building from the sun, decreasing solar heat gain in those areas. The tower will also feature energy-efficient MEP systems, including condensate recovery, which captures and re-purposes moisture from the atmosphere within the building.

The design team is also studying opportunities for other sustainability features, including innovative ways of generating energy, taking advantage of the building's great height, its surfaces and the space available in the spire. Water distribution within the tower is made more efficient by the creation of two primary zones, increasing economy of operations. Another strategy, affecting electrical and cooling systems, is the division of the tower into about twenty 30-story districts stacked on top of one another. This shortening of cable and ductwork runs for the building systems allows both efficiency of construction and more efficient distribution of electricity and cool air within each district – a concept borrowed from urban infrastructure systems that is turned vertical here.

Another context in which Kingdom Tower can be viewed as sustainable is that of land use. At over 1,000 meters high, Kingdom Tower will occupy a single footprint, which will have far less environmental impact than, for example, 10 towers of 100 meters, which would consume 10 times more land and require significantly more traffic and utilities infrastructure. Consequently, for people living in supertall buildings such as Kingdom Tower, the land footprint per resident is quite low.

我们有信心王国大厦在建成后必将成为世界最伟大的旅游胜地之一，并将成为这一区域最吸引人的生活和工作地点之一，同时创造数以千计的工作机会，刺激当地的经济。

除了这些考虑，我们吉达经纪公司（JEC）也遵循这一事实，即王国大厦将享有重大的文化意义。吉达作为通往圣城麦加的传统门户具有重要的历史意义，大厦将被看做是代表这一意义新的标志。

可持续性

设计团队和吉达经济公司（JEC）都致力于实现可持续性的目标，并为此做了诸多努力。例如，王国大厦在其三个面上都独具特色地设置了一系列凹口从而创造出阴影区来遮蔽阳光，在这些区域降低太阳辐射热。大厦还采用高效节能的机电水暖系统，其中冷凝水回收可以收集再利用建筑室内空气中的水分。

设计团队同时还在研究其他实现可持续性的可能，其中包括利用建筑巨大的高度、表面以及塔尖可用空间产生能源的新方式。通过建立两个主要的区域来提高大厦内水分配的效率，使得运营起来的更经济。另外一个策略是通过将大厦分为大约

王国大厦另外一个可持续性的背景是土地使用。超过1000米高的王国大厦只占用了一块土地，这比10座100米高的塔楼对环境的影响更小，因为10座100米高的塔楼要消耗十倍多的土地且需要更多的交通和基础设施。相应地，居住在诸如王国大厦这样的超高层建筑中，居民人均土地占有量相当低。

超高层建筑在规模上也更经济，因为只有一个屋顶和一个地基。而创造相等的面积则需要一群建筑，这样就需要多个屋顶和地基。

运用了各种手段降低王国大厦的碳含量，包括通过设计减少施工中废物的产生、在钢筋中增加可再生材料的比例、用诸如高炉矿

There are also economies of scale with a supertall tower. One has to build a single roof and a single foundation, rather than the multiple roofs and foundations that a group of buildings with the same cumulative area would require.

The embodied carbon of Kingdom Tower will be reduced by various means, including designing it so that less waste is produced during construction, by specifying reinforcing steel with a high percentage of recycled content, and by partially replacing aggregate with supplementary materials such as blast-furnace slag and pulverized fly ash.

In addition, because Jeddah is a major port city, building materials, particularly those used during fit-out, can be shipped to the construction site by sea rather than using more carbon-intensive road transport. Opportunities for using pre-cast elements are also being explored.

The form of Kingdom Tower is also highly sustainable in terms of its reduction of wind forces against the building, which in turn will mean that less material will be needed to build its structure. Each of Kingdom Tower's three asymmetrical wings travels upward with a slightly different geometry and terminates at a different height from the other two, all of which further reduces effective wind forces by preventing vortices from organizing themselves around the building (see Figure 7). When wind hits the building, the modulations of cross-sectional area in the tapering form disrupt the resulting wind vortices and force them to spin off at different frequencies. The result is a significant reduction of movement in the tower due to wind forces, compared to a prismatic tower form.

Solar heat gain through the exterior wall is obviously an issue, which the design team is addressing by using a high-performance, low-emissivity reflective glass that will reduce heat gain as much as possible while at the same time providing the panoramic views that building occupants want. Where the glass is not needed for viewing, the design team is planning an insulated spandrel panel that minimizes heat gain and will have essentially the same thermal performance that a stone panel would.

Finally, Kingdom Tower will be sustainable from the perspective of its life cycle. Elements such as gaskets, sealants and glass panels do wear out or break, and have to be updated periodically. But with proper maintenance, the structural longevity of Kingdom Tower should easily be 100 years or more. It's worth noting that the Empire State Building, still one of the tallest buildings in the world, is almost 80 years old and as structurally sound as it was when completed in 1931. We expect that Kingdom Tower will have a life span at least as long, and perhaps significantly longer.

The Structure of Kingdom Tower

Designing the world's tallest tower obviously requires tremendous experience and expertise. In particular, the task requires a unique and seamless integration of architectural design and structural engineering, particularly in terms of the need to address the issue of wind forces on the building, which can lead to lateral movement within the tower that can be sensed by occupants.

Fortunately, AS+GG and Thornton Tomasetti have collaborated since the very beginning of the design process (see Figure 8). As two of the world's most experienced firms in the field of supertall building design, they have anticipated and prepared for a great variety of contingencies that may come into play with Kingdom Tower.

Figure 7 : Kingdom Tower wings resolving upward at three different heights. (Source: Jeddah Economic Company/Adrian Smith + Gordon Gill Architecture)
图7. 王国大厦向上分解出的高度不同的三个侧翼（出自： Adrian Smith + Gordon Gill建筑事务所）

渣和磨成粉状的煤灰的辅料代替聚合材料。此外，因为吉达是重要的港口城市，装配期使用的建筑材料可以通过海运到达施工现场，而不是利用高耗碳的公路运输。预制材料使用的肯能性也在探索中。

在减少作用在建筑上的风力方面王国大厦的形式具有高度的可持续性，而且建筑结构需要的材料反而更少。王国大厦三个对称的侧翼在向上发展时，几何形状略有不同且终止在不同的高度上，这样会通过防止在建筑四周形成漩涡而进一步降低有效风力（见图7）。当风在冲击建筑时，尖端纤细的形态拥有的不同横截面积，这种调节性会破坏生成的风漩涡，并迫使其以不同的频率旋转。

通过外墙获取太阳热量显然也是个问题。设计团队通过一种高性能低辐射率的反光玻璃来尽可能减少热量吸收同时给住户想要的全景式视野。对于一些不需要观景的玻璃，设计团队正在设计一

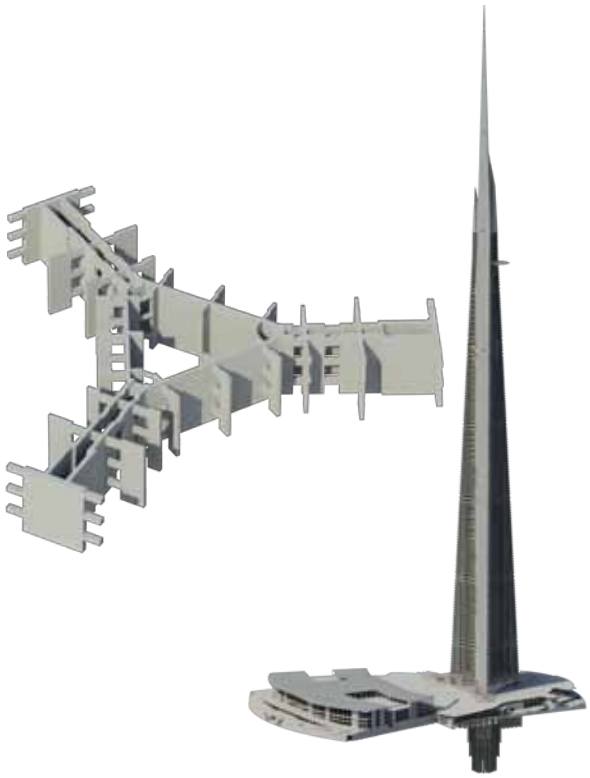

Figure 8. Kingdom Tower structural scheme. (Source: Jeddah Economic Company/ Thornton Tomasetti)
图8. 王国大厦的结构方案（出自： 吉达经济公司/ Thornton Tomasetti）

Figure 9. : Kingdom Tower wind tunnel testing. (Source: Jeddah Economic Company/ Thornton Tomasetti)
图9. 王国大厦的风洞试验（出自： 吉达经济公司/ Thornton Tomasetti）

For the design team, the key criterion is the perception of movement by building occupants. An exhaustive program of wind tunnel testing has been performed on the building, with models at different scales and in multiple laboratories completed (see Figure 9). Based on this testing, the tower is predicted to comfortably meet the stringent International Standardization Organization (ISO) guidelines for acceleration at the upper occupied floors.

Almost all of this very slender tower's structural frame will be of reinforced concrete, which gives the frame additional weight and strength to resist overturning forces on the structure caused by wind. For reasons related to aesthetics and constructability, about 30 meters of the spire at the top of the building will probably be made of steel. The exterior wall system will be an aluminum-framed, unitized system with high-performance insulating glass.

Why would we use glass in a building like this in a desert climate? It's true that most buildings in a desert environment are optimally built with more solid materials because of their higher insulation values. In a supertall building such as Kingdom Tower, however, weight is a major structural issue. Using an opaque surface made of stone or precast concrete, for example, would add a tremendous amount of weight to the exterior of the building, which in a tower of more than one kilometer would be a serious issue. The amount of structural material required to support that additional weight would be significant. Construction would also be more complicated and expensive because of the weight of the stone or precast panels being hoisted to such great heights. Maintaining such a stone or masonry exterior would also be much more costly and difficult.

Perhaps most important, one of the main reasons for building such a tall structure is for the spectacular views. For this reason, maximum visibility through the exterior wall is key.

Additionally, the structure and systems of Kingdom Tower have been designed to address the issue of the stack effect. To that end, the

种绝缘的拱肩面板来最大程度的减少热量吸收，基本与石头面板的热性能一致。

最终，王国大厦会在其生命周期的角度实现可持续。一些像垫圈、密封胶、玻璃面板这样的部件会磨损或者损坏，所以必须定期更新。通过适当的维护，王国大厦的结构寿命应该很容易达到100年以上。值得注意的是至今仍是世界最高建筑之一的帝国大厦已经建成快80年了，但其结构的坚固程度仍像1931年刚建成时的样子。我们希望王国大厦的结构也能至少达到这样的寿命，也许会比帝国大厦的寿命长得多。

王国大厦的结构

设计世界第一高楼显然要求极为丰富的经验与专业支持，其中建筑设计与结构工程的合作是独特而又紧密的，特别体现在解决作用在建筑上的风力的问题时。作用在建筑上的风力会导致大厦的水平移动，而这种移动是居住者能够感受到的。

幸运的是AS+GG和Thornton Tomasetti从项目最开始的设计阶段就展开合作（见图8）。作为全球超高层建筑设计领域最有经验的两家公司，他们预测并准备了作用在王国大厦上的各种可能性。衡量设计团队的一个重要标准是建筑居住者行动的感受。一个已经完成的彻底的建筑风洞测试包含了在各种实验室建造的各种尺度的模型（见图9）。基于这一测试，预计大厦将很容易满足国际标准化组织（ISO）对于上部使用楼层加速度的苛刻标准。

几乎所有这样纤细修长的塔楼的结构框架都是由钢筋混凝土做成，材料本身会给框架增加额外的重量和强度抵抗由作用在结构上的风力产生的倾翻力。从美学性和结构性出发，长约30米的建筑顶部的塔尖将可能用钢做成。外墙系统会是一种统一的高性能绝缘铝框玻璃体系。

我们为什么会在沙漠气候下在这座建筑中使用玻璃？事实上是这样的：大多数建筑在沙漠环境下适合尽可能多地使用密实的材料，因为这种材料具有高的绝缘值。然而对于想王国大厦这样的

exterior wall will be largely sealed to prevent infiltration of air into the building. Where there are openings in the wall for balconies, those openings will be air-locked between the balcony and the corridor to prevent the formation of pathways for air to travel vertically inside the shafts between floors of the building. Nuisance alarms will alert users whenever doors are left open. The stairs will be compartmented with the use of baffles within the shaft to prevent air from moving up or down. The building's concrete structure also helps with stack-effect mitigation because it's more monolithic and easily sealed than a structure in which steel beams are connected to floor slabs.

The building has also been designed with earthquakes in mind. The potential for seismic activity, primarily from the Red Sea fault, was considered. However, seismic activity in Jeddah and most areas of Saudi Arabia is relatively low. The Kingdom is on the Arabian Plate, which is moving away from the African plate. The risk of earthquake is roughly comparable to New York City rather than San Francisco. Supertall buildings tend to perform well in seismic events due to their flexibility. Wind is a much more important environmental factor in the structural engineering design of Kingdom Tower.

The design team has also been asked about the potential structural implications of the wide range of temperatures in Saudi Arabia. The answer is: Not as much as one might think. During temperature swings, the building simply expands a little up or down, which is not a problem because it's not highly restrained vertically. It's true that it's very hot in Saudi Arabia and other parts of the Middle East, but the temperature differential there is actually less of an issue than in Chicago, where the swings from the mean temperature – because it gets very cold in the winter – are wider. The biggest issue with the high temperatures in Saudi Arabia is the construction aspects of concreting and curing of the material under these conditions.

Finally, we have closely studied the soil on the construction site in preparation for building Kingdom Tower. The soil in Jeddah and elsewhere in Saudi Arabia is composed mostly of fairly uniform strata of coralline limestone and sandstones; there is no bedrock layer near the surface. That will require a series of about 270 reinforced concrete piles, ranging in length from 45 to 105 meters long, to be drilled into the ground. This brings the load of the building into the ground through friction along the sides of the piles. It's a complex process, in part because of the issue of soil settlement, but the technology is well-developed in the region.

We at JEC have every confidence that all of these challenges will be met brilliantly by the design team and the contractor, and that the end result will be one of the greatest artistic, architectural and technological wonders of the world.

Construction Schedule

Work began on the construction site on January 1, 2012. On February 21, Prince Alwaleed announced that JEC had received the final license to construct Kingdom Tower. The soil and pile testing programs were completed by the end of April. Installation of the piles was scheduled to begin in June, and the foundation of the building is expected to be complete by next spring.

At this point, we are confident that with the help of the design team and our contractor, Kingdom Tower will be ready to open as scheduled in 2017.

超高层建筑，重量是结构的一个大问题。例如，表面使用石材或预制混凝土这样不透明的材料将极大地增加建筑外墙的重量，这对于超过1千米的塔楼来说是非常严重的问题，同时支持这些额外重量所需的结构材料的数量也会明显增加。这些要被悬挂在高空的石材或者预制板的重量会令结构变得更复杂、更昂贵。维护这样的石材或者砌块外墙也将更加昂贵、更加困难。

也许最重要的是：建造这样的超高层建筑的一个主要原因是为了观看壮丽的景色。出于这个目的，外墙最大程度地可视性是关键。

此外，王国大厦的结构和系统也有设计来解决烟囱效应的问题。为此，外墙将在很大程度上密封以阻挡空气渗入建筑内部。阳台处外墙的开口会把空气封锁在阳台与走廊之间防止形成空气在建筑楼层之间的井道内垂直流通的通路。滋扰警报将提醒用户什么时候门没有关。楼梯被带有井道的隔板分隔开以防止空气向上或向下流通。同时，建筑的混凝土结构因为比带有钢梁的楼板结构更具整体性和密封性也有助于降低烟囱效应。

建筑在抗震方面的设计也格外用心，考虑了主要来自红海断层的潜在的地震活动。然而在吉达和大多数沙特阿拉伯地区，地震活动相对较低。吉达王国位于阿拉伯板块，远离非洲板块移动。地震风险大概相当于纽约而不是旧金山。超高层建筑因其挠性而在地震发生时会有好的表现。风是影响王国大厦结构工程设计更为重要的环境因素。

设计团队一直被问到有关在沙特阿拉伯大温差对结构潜在的影响。答案是：并不像人们想象的有那么大的影响。在温度骤变的时候，建筑只是稍稍向上活向下延展一点，因为在垂直方向上没有很高的收缩限制所以不是问题。沙特阿拉伯和中东其他地方确实非常炎热，但实际上温差造成的问题比芝加哥小，因为芝加哥的温度较其平均值波动很大——冬天非常寒冷。在沙特阿拉伯的高温对结构影响最大的问题是在这些条件下材料的浇筑与固化。

最后，我们仔细研究了王国大厦施工现场的土壤。吉达和沙特阿拉伯其他地方的土壤主要由包含珊瑚石灰岩和砂岩的比较均匀的岩层组成，表层附近没有基岩。这需要约270个长度为45米到105米的一系列钢筋混凝土桩来钻到地下。这一过程会把建筑荷载通过桩侧边的摩擦带到地下。造成这一复杂的过程的部分原因是土地沉降，但在这一地区，技术已经非常成熟。

我们吉达经济公司（JEC）对设计团队与承建商能出色应对所有这些挑战非常有信心，最终结果将成为世界上最伟大的艺术、建筑和技术奇迹之一。

施工进度

建造工作于2012年1月1号在施工现场启动。2月21号，Alwaleed王子宣布吉达经济公司（JEC）获得建造王国大厦的最终许可证。4月底完成了土壤和打桩测试。桩的安装计划于6月开始，建筑的地基预计明年春季完成。

这一方面，我们有信心在设计团队和承建商的配合下，王国大厦将在2017年如期竣工投入使用。