Title: **Increased High-Rise Resilience to Stabilize Cities of the Future**

Author: Rudi Scheuermann, Director, Arup

Subjects: Architectural/Design
Building Materials/Products
Sustainability/Green/Energy

Keywords: Energy Consumption
Green Roofs
Green Walls
Security
Sustainability

Publication Date: 2016

Original Publication: Cities to Megacities: Shaping Dense Vertical Urbanism

Paper Type:
1. Book chapter/Part chapter
2. Journal paper
3. **Conference proceeding**
4. Unpublished conference paper
5. Magazine article
6. Unpublished

Increased High-Rise Resilience to Stabilize Cities of the Future

提高高层建筑韧性，稳定未来的城市

Rudi Scheuermann
Arup Fellow, Director
总监

Arup | 奥雅纳全球公司

Berlin, Germany
德国，柏林

Rudi Scheuermann has studied architecture in Karlsruhe/Germany and architecture and membrane engineering in Bath UK. He has worked for architects, developers, contractors and engineers in Germany, Netherlands, England and the United States before joining Arup Façade Engineering in London/UK in 2000 with the aim to establish Façade Engineering in Berlin/Germany.

He has developed the German Building Envelope Team and became European and Global Leader of the Building Envelope Team.

Rudi's focus is Façade Engineering and the overriding aim for multidisciplinary design with the aim to enhance sustainability for all kinds of buildings and in particular for tall buildings.

Rudi Scheuermann 在德国卡尔斯鲁厄(Karlsruhe)攻读建筑学，并在英国巴斯(Bath)攻读建筑与薄膜工程学。他曾为德国、荷兰、英国和美国的建筑师、开发商、承包商和工程师们工作，随后于 2000年加入英国伦敦的奥雅纳幕墙工程公司(Arup Facade Engineering)，负责在德国柏林建立幕墙工程业务。

他创建了德国建筑围护结构团队，成为建筑围护结构团队的欧洲和全球领导者。

Rudi 专注于幕墙工程，以及跨领域设计的最高目标，致力于改善各种建筑，尤其是高层建筑的可持续性。

Abstract | 摘要

Dense urban city environments consist of an agglomeration of tall buildings. The resilience of cities as a whole depends, among other components, on the resilience of each single element: the tall buildings which together make a city a functional place. City resilience has a range of challenges, ranging from protecting the property against aggression and vandalism to the influence of extreme weather conditions. If we look at single tall buildings then we find that in many places that air tightness is one of the biggest challenges. Therefore the mechanical operation of these buildings is essential to keep them operational. Catastrophes like in Fukushima, Japan – but also usual simple power failures as we find them taking place in less stable civilizations – lead to situations where the buildings cannot be kept in operation easily. Where natural ventilation options have been part of the envelope design strategy, buildings can be kept operational with greater resilience.

Keywords: Envelope Design, Natural Ventilation, Operational Continuity in Emergencies, Resillience, Sustainability, and Tall Buildings

稠密的都市环境由成群的高层建筑组成。在诸多要素中，城市的整体恢复力依赖于每个单一要素的恢复力，而高层建筑则共同让城市成为一个功能性空间。如果观察单体高层建筑，我们会发现在很多地方，气密性是最大的挑战之一。因此这些建筑的机械运转对于自身的运营必不可少。像日本福岛那样的灾难，以及在不够稳定的文明社会经常发生的简单电源故障，都会导致建筑无法轻易维持运营。自然通风功能一直是建筑围护结构设计战略的一部分，在这种情况下，建筑无法在上述状况中维持运营。展示能够提高恢复力，同时能够提高正常运营期间可持续性的选项，这也是一个目标。

关键词：围护设计、自然通风、突发事件中的操作连续性、弹性、可持续性、高层建筑

Cities of the future will become significantly more populated. Denser cities will run higher risks of getting into difficulties if any parts of the city are not operating at an optimum level. In order to keep the dense urban agglomeration of buildings of the cities of the future stable and operable, it is necessary that the single components of the cities remain as stable as possible. City resilience is an important aim in society, particularly for ever denser cities. Denser and taller cities mean more high-rise buildings. And high-rise buildings bear more risks than ordinary buildings. Therefore, we need to ensure the resiliency of single high-rise buildings first of all. If each high-rise building in itself is resilient and stable in operation, the city as an agglomeration of all individual high-rises will have a higher chance of being resilient as a whole.

There are a whole series of challenges in terms of city resilience that apply to a single building, such as:

- Vandalism, including damage and graffiti
- Access control against undesirable access

未来的城市人口将大大增加。对于更为拥挤的城市来说，如果任何部分没有运行在最佳状态，城市就更容易陷入困难。为了让未来城市更为稠密的建筑群保持稳定可用，单一的城市元素必须尽量保持稳定。城市韧性是一种非常高的社会要求，尤其是对更稠密的城市来说。更高更稠密意味着更多的高层建筑。高层建筑比普通建筑要承受更多的风险。因此我们首先要保证单体高层建筑的韧性。如果每一栋高层建筑本身的运营具有韧性和稳定性，作为所有单体高层建筑集合体的城市，其具有整体韧性的可能性就更高。

就城市韧性而言，单体建筑面临各种各样的挑战，例如：

- 故意破坏行为，包括损坏和涂鸦
- 针对不受欢迎来访的门禁控制
- 侵略，例如来自建筑外部和内部的炸弹爆炸
- 玻璃破碎时的主动安全和被动安全，也需要针对高空落物进行防护
- 更好的运营可持续性，以降低城市的能耗

- Aggression, such as bomb blasts from outside and from within
- active and passive safety in case of glass breakage, and required protection against falling through glass at greater heights
- greater sustainability in operation to reduce energy consumption in cities
- natural ventilation as a big contribution for more sustainable building operation
- increased business continuity strategies due to natural ventilation
- night temperatures for free cooling of thermal mass
- reduced heat island effect for lower natural ventilation temperatures for free cooling
- improved air quality to enable natural ventilation
- reduced noise levels to enable natural ventilation
- reduced level of aggression due to more green in cities
- reduced level of stress due to greener cities
- green building envelope strategy to improve living in cities due to
- improved external air quality
    - reduced external temperatures
    - lowered external noise levels
    - aggression de-escalation
    - reduced stress levels for inhabitants
    - happier living environments

The fact that aggression levels in denser populated environments will increase is not a big secret and cannot be easily avoided. There are individuals with uncontrolled or unpredictable aggression levels as there are aggressions deriving from whole groups of people, for example demonstrations. While individuals or a number of individuals might tend to cause more vandalism such as graffiti sprayed on ground floor opaque or even glazed surfaces of buildings, there might be more aggression in smaller and larger groups which encourage bigger damage such as destroying foyer and other ground floor entrance façades or other larger glazed areas. If this happens, the building will not only be damaged but could also be exposed to uncontrolled access and possible theft in a crisis situation. This can be prevented using layers of glass bonded with interlayers that stabilize glass breakages due to giving them residual strength by binding different glass layers structurally together. Despite the damages of broken glass, the basic building functions will remain in place and the operation can be secured.

For graffiti, there is a range of surface treatment available that ensures it can be erased much easier. Natural stone and glass can to a degree be reasonably well protected as much as exposed concrete and plaster. Those are damages that are annoying, but they will not prevent the building from remaining operable.

A bigger focus should be given to the aims of making particularly larger high-rise buildings more accessible for the public, opening lower floors for occasional public purposes such as underground station access, public car parking, or uses that are of a more public nature, as for example restaurants and cafes or sometimes even public social infrastructure uses like libraries or governmental authorities. The desire to open these buildings up at lower floor levels is contradictory to the desire for being able to control access and therefore to reduce the risk of unwanted intruders. The desire for access control, however, should not lead to buildings that prevent the free flow of movement. Therefore, elements of intelligent access control and elements of surveillance will be required to enable the free flow of people movement in a normal condition, but which can be quickly activated to execute a high level of control or even prevent uncontrolled access entirely. CCTV surveillance has become almost standard for larger developments and has become an essential tool to maintain the resilience of buildings and even whole parts of cities.

In terms of dangers that individual buildings are facing, there is the danger of aggression from the outside onto the façade but equally the risk of unwanted intruders acting from within. The risk of possible bomb attacks has to become part of the standard evaluations for larger buildings, and have to be considered when designing the building components. If the evaluation of possible bomb blasts will generate requirements for safety, the façade has to be designed accordingly. The possible impact for which the façade has to be designed will have to be defined, and

- 自然通风作为对更具可持续性建筑运营的巨大贡献
- 利用自然通风改善业务连续性战略
- 夜间温度对蓄热体的自然冷却
- 减少热岛效应，获得较低的自然通风温度，实现自然冷却
- 改善空气质量，实现自然通风
- 降低噪音水平，实现自然通风
- 增加城市绿化，以减少入侵
- 城市绿化减少压力
- 绿色建筑围护结构战略通过以下途径改善城市生活
    - 改善外部空气质量
    - 降低外部温度
    - 降低外部噪音水平
    - 减少入侵
    - 减轻居民压力
    - 更快乐的居住环境

人口密集环境中的入侵水平会增加，这是个事实，也无法轻易避免。有些个体拥有不受控制或无法预测的入侵水平，而有些入侵来自成群的人，例如示威游行。个体或者许多个体可能倾向于造成更多的破坏，例如在建筑一楼的不透明表面甚至玻璃表面涂鸦，但较小或较大群体的侵略性更强，这些群体支持更大的破坏，例如破坏大厅或者一楼的其他入口幕墙，通常是较大的玻璃区域。如果出现这种情况，建筑不仅会遭到破坏，而且在危急形势中容易出现不受控制的来访，并且可能发生盗窃。为了防止出现这种情况，可以使用与夹层相结合的玻璃层，夹层在结构上将不同的玻璃层结合在一起，使破裂的玻璃拥有残余强度，保持稳定。尽管遭受玻璃破碎的损坏，但基本的建筑功能将得以保留，建筑的运营能够得到保障。

至于涂鸦，有不少表面处理方法可以保证很容易将涂鸦擦除。天然石材和玻璃，以及裸露的混凝土和灰浆可以在一定程度上得到合理保护。涂鸦是恼人的破坏行为，但不会妨碍建筑的正常运营。

以下目的更值得注意：让公众更容易进入特别大的高层建筑，有时候为了公共用途开放较低的楼层，例如地下车站通道、公共停车场，或者更具有公共性质的用途，

then it will be possible to design the façade accordingly to ensure that a possible bomb blast impact on the outside of the façade components will prevent, for example, glass façades from bursting into countless pieces that will shoot with high speed into the lower parts of the building and endanger everybody anywhere near the blast-exposed façades by the highly accelerated glass fragments. To prevent this from happening, lamination as mentioned above is a good alternative. It is however important to then also secure the laminated glass panels to ensure they will not fly inside the building as a whole under any blast impact, but that they are securely anchored in the framing.

Similarly, the impact of any bomb going off on the inside has to be evaluated. Particularly where the building is easily accessible to the general public, blast impacts from within can be an issue. Therefore, lamination is again a tool to protect the public on the outside of the building envelope from suffer impacts of highly accelerated glass fragments from within.

Lamination is not only a suitable means to facilitate building resilience under terror attacks, but it is also useful to protect glass façades from becoming flying debris as is often the case in very heavy storms and hurricanes. Again, it might not prevent the building from getting damaged, but the resilience of ensuring continuous building operation is an important issue. And it is in many cases not even an additional cost, as lamination might be needed for securing people within floor-to-ceiling spanning glazed façades from falling though the glazing in case of breakage of in case of falling against the façades. Therefore, lamination is an appropriate precautionary tool for contemporary glass façades to keep up building operation.

While a greater degree of sustainability for a more energy efficient operation of the building might not primarily be seen as necessary to ensuring the resiliency of high-rise buildings, it may play an important role in maintaining all relevant functions to keep the building in operation. We have no doubts that significantly reduced energy consumption would increase city resiliency. But if this is true, decreased energy consumption of individual buildings and complexes also strengthens the resilience of the high-rise building.

In cases of power failure due to power shortages or in cases of catastrophic events, any building with lower energy consumption stands a greater chance of operational continuity, possibly in conjunction with the use of power generators. But the fewer power generators that will be required, the more resilience can be assured for keeping the building in operation. However, this will require a degree of design considerations not yet considered the standard in building design.

One of the biggest factors is the reduction of cooling requirements and a greater independence from mechanical ventilation. Big catastrophic events such as earthquakes or hurricanes have shown that power cuts often lead to situations where the building operation cannot be kept up if the building is designed with an airtight, fully sealed façade only kept in operation with mechanical systems such as ventilation and cooling. After the nuclear disaster in Fukushima, Japan, which also lead to a particularly long power failure, designers recognized that any high-rise building with natural ventilation options, no matter how reduced, could be kept in operation to a degree, while fully sealed buildings depending on mechanical systems stood no chance of maintaining operation.

Therefore, a high-rise envelope design with natural ventilation options ensures a much greater resiliency for the building. Even where we are not facing such drastic conditions as the people in Fukushima have been exposed to, there are plenty of advantages of increased high-rise building resiliency due to natural ventilation options.

Natural ventilation can reduce the mechanical cooling requirements due to a mixed-mode design of ventilation for significant parts of the year, depending on the weather conditions of the relevant location. And it can help to create a much higher degree of user satisfaction due to being able to influence their environment within the building.

Another suitable idea is the design of a night cooling concept where operable and building automated vents enable an efficient wall and ceiling wash of cooler night air to charge the exposed thermal mass with lower temperatures, which can then balance the internal thermal loads as generated during the day to shift peak temperature within the building towards later hours in the day, ideally into the early evening hours when the building occupants are no longer present and the next night cooling cycle can be started.

The air traffic control building project in Langen near the Frankfurt am Main airport in Germany is an example where we have been able to execute such a night cooling system. A vent box is used with a low velocity fan to exhaust the air of the building to the outside, and a vent at floor level enables a low-level cooler night air wash to charge the floor, the

例如餐厅、咖啡馆，或者有时候甚至为了公用社会基础设施用途而开放，例如图书馆甚至政府部门。在较低楼层开放这些建筑的期望与控制门禁，从而降低不速之客来访风险的期望互相矛盾。因此需要智能门禁控制元素和监控元素，以实现正常情况下的人员自由流动，但又可以迅速开启门禁和监控，以实施高水平的控制，甚至完全阻止不受控制的来访。闭路电视监控几乎已经成为大型建筑的标配，并且已经成为维持建筑甚至整个城市韧性的一种基本工具。

在单体建筑面临的危险方面，存在幕墙受到外来入侵的危险，但同样存在来自内部的有害入侵者的风险。对于大型建筑，潜在炸弹袭击的风险必须成为标准评估的一部分，在设计建筑组成部分时也必须加以考虑。如果潜在炸弹爆炸的评估产生对安全性的要求，幕墙就必须进行相应的设计。这种情况下，必须确定导致必须设计幕墙的可能影响，这样才能相应地进行幕墙设计，确保防止潜在的炸弹爆炸对幕墙组件外侧的冲击导致玻璃幕墙爆裂成无数玻璃碎片，高速射入建筑的下方，使靠近炸裂幕墙的每个人不会受到高速飞溅玻璃碎片的伤害。为了防止幕墙炸裂，上述夹层玻璃是一个好选择。但同时必须加固夹层玻璃，使夹层玻璃在任何爆炸冲击下都不会飞入建筑内部，而是牢牢固定在框架上。

同理，建筑内部任何炸弹爆炸的影响也必须评估。尤其是公众容易进入的建筑，由内而外的爆炸冲击将会是个问题。因此夹层玻璃再次发挥作用，保护建筑围护结构外部的民众不被高速飞溅的玻璃碎片击中。

但夹层玻璃不仅是在恐怖袭击情况下保持建筑韧性的合适方法，还可用于保护玻璃幕墙免受飞行碎片的破坏，这种情况常常发生在猛烈的暴风雨和飓风天气中。虽然夹层玻璃也不能防止建筑受损，但确保建筑正常运营的韧性是一个重要的问题。夹层玻璃在很多情况下都不是一种额外开支，因为夹层玻璃能够用于保护楼层里的人，防止破裂的玻璃伤人。因此，夹层玻璃对于当代玻璃幕墙是一种工具，一种保持建筑运营的恰当预防措施。

虽然为了保证高层建筑的韧性，为实现更高能效建筑运营的更大程度可持续性可能从根本上不会被视为必要手段，但这种可持续性可以发挥基本的作用，以保持所有重要功能，使建筑维持运营。我们毫不怀疑能耗大大降低会提高城市的韧性，但如果这是真的，大型单体综合建筑较低的能耗也能增强高层建筑的韧性。在电力短缺导致停电，以及在灾变情况下，任何能耗较低的建筑保持运营连续性的机会都更大，比如使用一些发电机来达到此目的。所需的发电机越少，就能确保更大的韧性，来保持建筑的运营甚至是标准化运

Figure 1. Air Traffic Control Center Langen, as built façade view (Source: Arup)
图1. 兰根空中交通管制中心幕墙竣工图（来源：Arup）

walls, and the ceiling with the cooler night air. The low velocity fan enables us to control the amount of air exchanges to ensure the amount of cooler night air depending on the temperature difference between outside and inside the building. In this case, the building is not very tall and therefore a fully exposed external louver system could be used to control the heat gains during the day. Protection screens and vent louvers have been placed to ensure that weather influences will not be in conflict with the night cooling requirements and operation (Figures 1, 2 , and 3).

营。但这将需要一定程度的设计考量，这在建筑设计领域尚未经常成为标准。 其中最大的因素是减少冷却需求，以及减少对机械通风的依赖。地震或飓风等大型灾变事件已经表明，如果建筑采用完全密封的幕墙设计，仅仅通过通风和冷却等机械系统来保持运转， 断电就会经常导致建筑运营无法维持。日本福岛的核灾难也导致特别长时间的停电，此后人们意识到，任何拥有自然通风功能的高层建筑，无论这种功能多么简单，这些建筑都能保持一定程度的运营，而依赖机械通风的完全密封建筑没有任何机会保持运营。

因此，拥有自然通风功能的高层围护结构设计可以确保建筑的韧性大大提高。即使我们面临类似福岛人民所遇到的极端状况，自然通风功能也能带来诸多优势，并提高高层建筑的韧性。根据相关位置的天气状况，借助能够适应一年中大部分时间的混合通风模式设计，自然通风可以减少机械冷却需求，。由于能够影响建筑内部的环境，自然通风也有助于大大提高用户满意度。

一个合适的概念是夜间冷却概念设计，活动式建筑自动通风孔让凉爽的夜间空气流过墙壁和天花板，以较低的气温接触蓄热体，随后可以平衡白天产生的内部热负荷，将建筑内部的最高温度转移到当天晚些时候，刚好到傍晚时分，建筑的占用者都已下班，可以开始进行下一个夜间冷却循环。

位于德国兰根（Langen），靠近法兰克福机场的空中交通管制建筑项目就是我们可以使用这种夜间冷却系统的一个例子。使用一个通风箱和一台低速风扇，将建筑的空气排放到室外，楼面水平的通风孔使低层凉爽的夜间气流能够接触楼层、墙壁和天花板。低速风扇使我们能够控制气体交换量，以便根据建筑的内外温差来保证凉爽的夜间空气量。在这个案例中，这栋建筑并不是很高，因此可以用一个完全暴露的外部气窗系统来控制白天的得热量。放置了保护罩和气窗，以确保天气影响不会与夜间冷却需求和运营相冲突（图1–3）。

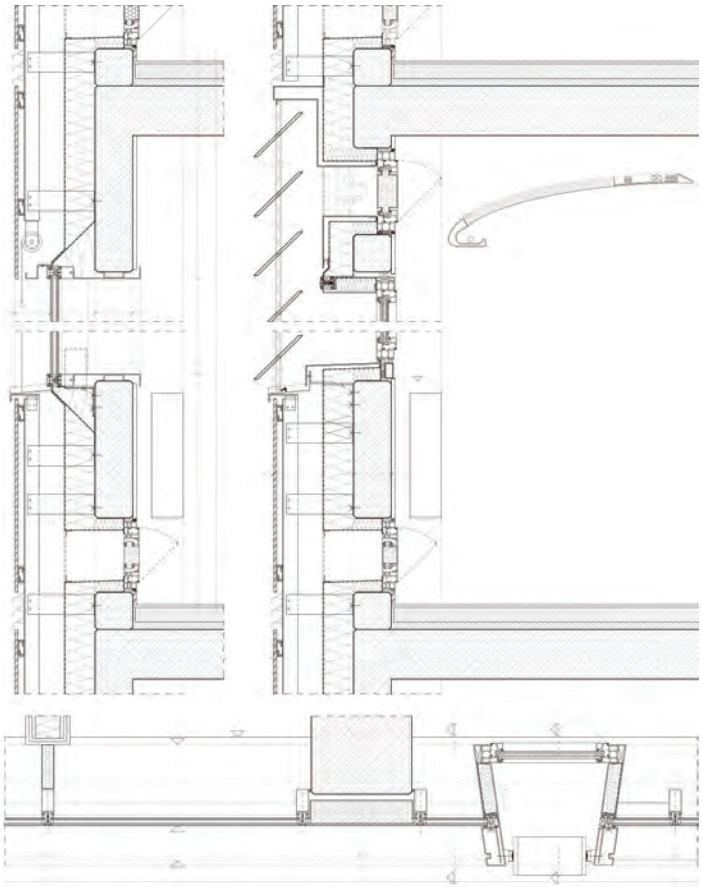

Figure 2. Air Traffic Control Center Langen, façade details (Source: Arup)
图2. 兰根空中交通管制中心幕墙详图（来源：Arup）

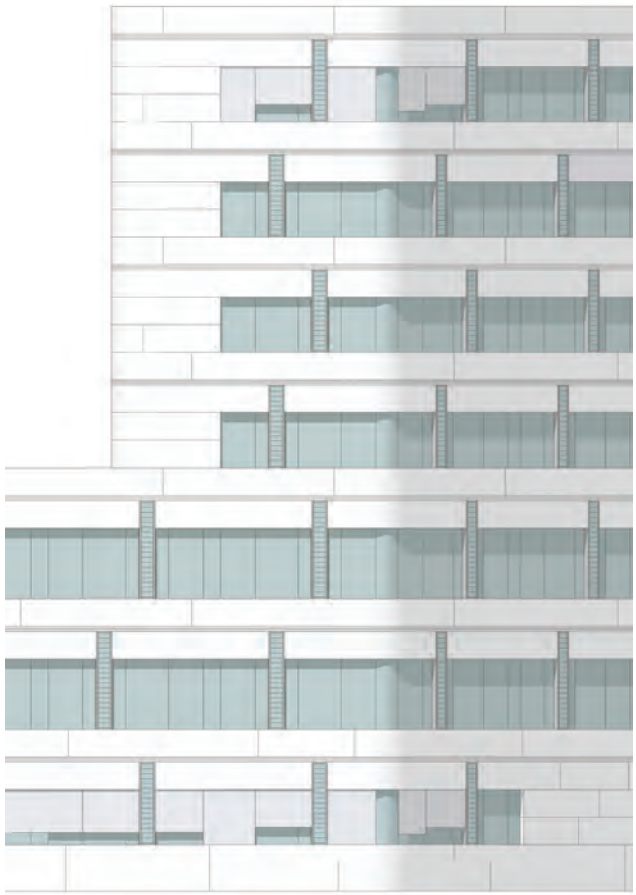

Figure 3. Air Traffic Control Center Langen, detail elevation (Source: Arup)
图3. 兰根空中交通管制中心立面详图（来源：Arup）

Figure 4. Detail facade view, natural ventilated high-rise design for Warsaw (Source: SHL)
图4. 华沙自然通风高层建筑设计幕墙详图（来源：SHL）

The project Warsaw One in Poland, however, is a high-rise building where a similar system has been used for the building envelope. A fully sealed double façade has been used with maintenance access from within the building into the cavity to maintain the louver system required to control the thermal impact due to solar radiation. But between the fully sealed elements there is always a narrow vertical strip vent which allows natural ventilation directly from the outside to the inside. Again it is protected so that exposure to the weather conditions does not cause any damage.

In both cases, energy consumption can be significantly reduced as standard operation includes a high degree of natural ventilation, and energy not spent for mechanical ventilation and cooling corresponds to a significant improvement in the buildings' resiliency. While this is true with regards to normal operation, it also ensures that in case of any unusual conditions the operational continuity can be maintained, even when there might be a power failure for a longer period of time (Figures 4, 5, and 6).

However, natural ventilation is only as good as the air one can get into the building. And it is not just the air quality, but also the air temperature and the noise level from the outside that may cause issues. Heat island effects within dense urban settings can be a significant issue which could prevent effective natural ventilation. Therefore, we have to understand that building skins don't just have the potential to impact significantly upon the building performance within, but they also have a significant impact upon the urban environment immediately influencing the air temperature outside the building.

Figure 5. Streetscape of naturally ventilated façades for a high-rise building in Warsaw (Source: SHL)
图5. 华沙一栋高层建筑自然通风幕墙街景图（来源：SHL）

然而波兰的 Warsaw One 项目是一栋高层建筑，高处的围护结构使用了一个类似的系统。完全密封的双层幕墙与建筑内部凹处的维护通道结合使用。维护通道用于维护控制日光辐射的热冲击所需的气窗系统。但在完全密封的元素之间都留有狭窄的垂直条状通风口，使外部空气直接进入内部，实现自然通风。气窗系统同样受到保护，暴露在天气条件中不会受到任何损坏。在两个案例中，能耗都可以大幅降低，因为标准运营时的自然通风程度很高，能源没有用于机械通风，冷却系统大幅改善了高层建筑在正常运营时的韧性，同时由于采用自然通风，能够确保在任何异常情况下维持运营连续性，即使遇到长时间的停电（图4–6）。

然而，自然通风只有在空气能够进入建筑内部时才能发挥作用。不仅是空气质量，外部的气温和噪音水平都可能成为问题。稠密城市环境中的热岛效应会阻碍有效的自然通风，可能会成为一个重大问题。因此我们必须明白，建筑的外围结构不仅拥有对建筑内部性能产生重大影响的潜力，而且对城市环境也有重大影响，直接影响着建筑外部的气温。

研究表明，稠密市中心地点与同一个城市边缘地带之间的温差可以高达 10–12 度。这是非常大的温差，意味着10–12 度的温差导致潜在的冷却负荷更高，除非我们设法降低市中心的温度，即所谓的热岛效应。

市中心的建筑群充当了蓄热体，白天吸收日光辐射。如果稠密的市中心区域无法通过街道峡谷范围内足够的绿色基础设施来抵消这种热量吸收，气温就会升高，超过周围的气温。但是，通过在街道层面上没有足够区域建设绿色基础设施的地方设计一个绿色建筑围护结构，也可以抵消这种效应。

这种绿色围护结构设计还有助于大幅改善空气质量。可以将街道峡谷中的交通污染空气中很大一部分粉尘过滤掉。此举不仅能让路过这种建筑的人们吸入更健康的空气，还表明了一个事实：在建筑的极低位置也可以实现自然通风，因为正确和适当的绿色建筑围护结构设计可以大幅改善空气质量， 人们再也不会暴露于粉尘之中。有一种观点认为，在街道峡谷范围内的较低位置，噪音水平太高以至于无法使用自

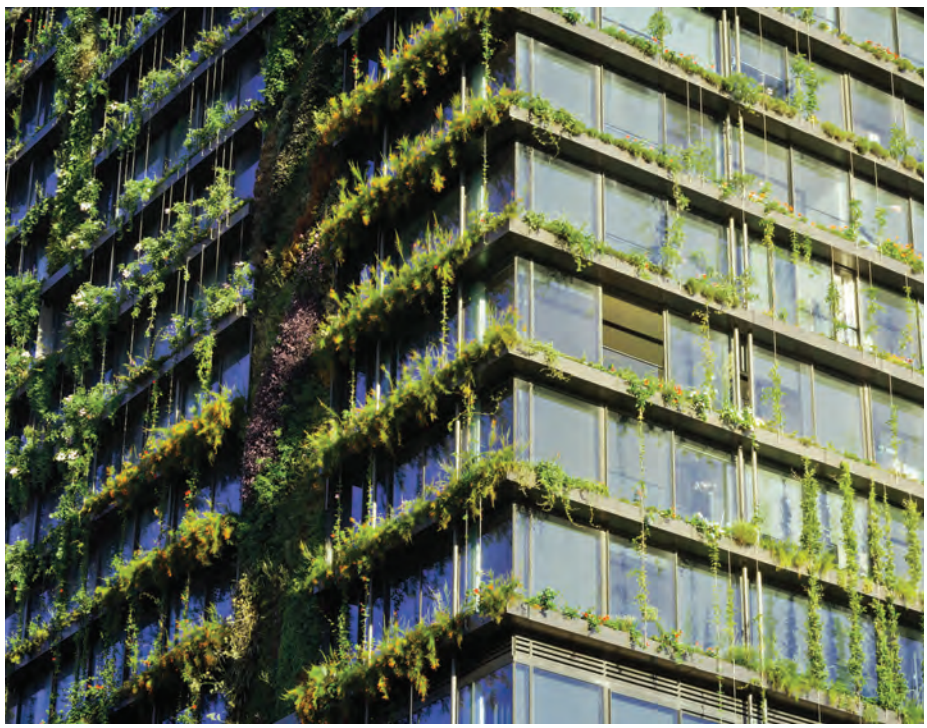

Figure 6. Green building envelope project in Australia (Source: Arup)
图6. 澳大利亚的绿色建筑围护结构项目（来源:Arup）

Figure 7. Bosco Verticale, high-rise project in Milan (Source: Arup)
图7. 米兰高层建筑项目“垂直森林”（来源：Arup）

Figure 8. Vision of London covered in green building envelopes (Source: Arup)
图8. 采用绿色建筑围护结构的伦敦愿景（来源：Arup）

Research has shown that temperature differences between dense inner city locations and the fringe of the very same city may vary as much as 10 to 12 degrees. This is a very large difference and it means that the potential cooling load is higher by those 10–12 degrees unless we manage to reduce the inner city temperatures, the so-called heat island effect.

The mass of construction in inner cities acts as thermal mass that is being charged with solar radiation during the day. If the dense inner city areas are no able to counterbalance such heat absorption with sufficient green infrastructure within the street canyon, the temperatures will go up and above the surrounding temperatures. But such an effect can also be counteracted by designing a green building envelope where there is not sufficient space to provide for green infrastructure at street level.

Such a green envelope design can also help to improve air quality significantly. A very large proportion of fine dust can be filtered out of the traffic polluted air in a street canyon. This will not only enable the people passing by the building to breath healthier air, but it will also improve natural ventilation, which would be possible much lower down the building as the fine dust exposure is no longer an issue as the air quality will be significantly improved by the right and appropriate design of a green building envelope.

The fact that noise levels are often far too high to employ natural ventilation lower down within the street canyon can also be improved by a proper design for a green envelope. The substrate upon which a green building envelope will grow brings acoustic mass which can be placed properly to make use of it in the sense that the street noise impact can be reduced, too.

If we now consider that we have an influence with a green building envelope, if designed in the right way and with the appropriate care, to reduce not only the local external temperatures subject to natural ventilation for our buildings, but also that we can influence the air quality significantly by filtering a high degree of the harmful fine dust out of the air where we use a green building envelope, there is no reason not to make much more use of natural ventilation. In addition, the ambient noise levels can be reduced too, if we manage to place the substrate trays in the right positions relative to operable windows. Therefore we should make significantly more use of natural ventilation than has been done in the more recent past. With green building envelope designs, the resiliency of dense inner cities can be significantly improved. And the individual high-rise complexes benefit of an increased level of resilience, too (Figure 7).

And it ought to be mentioned that green city infrastructure, such as a green building envelope, has a significant impact upon society. The factor that green building envelopes are providing with healthier living conditions allow society as a whole to enjoy less harmful inner city living conditions, while the higher degree of inner city plants has a deescalating effect with regard to societal aggression. A very simple example is that façades overgrown with plants are very rarely subject to graffiti and do not typically invite mechanical façade damage. And even if someone throws a stone, the green building envelope would act as a buffer and would spoil the effect that the person was hoping for when throwing the stone.

But not only does it deescalate vandalism, it also reduces stress levels of everyone exposed to green envelope covered façades. The degree of improvement for the individual high-rise building resilience is significant and adds up at urban level to improve the resilience of a city as a whole, while creating much healthier and happier living environments for human beings in future cities of much increased density (Figure 8).

然通风功能，但通过合理的绿色围护结构设计也可以改变这种观点。用于搭建绿色建筑围护结构的基底带有隔音层，合理放置隔音层也可以减轻街道噪音的影响。

如果我们现在考虑到，通过设计正确、护理得当的绿色建筑围护结构，我们可以产生影响，不仅可以根据建筑的自然通风来降低局部外部温度，还可以利用绿色建筑围护结构进行局部过滤，空气中的大部分有害粉尘都可以忽略，从而对空气质量产生重大影响，我们就没有理由不大幅提高自然通风的使用率。此外，我们如果设法将基底盘放在与活动窗相对的准确位置上，也可以降低周围的噪音水平。因此，我们应该大幅提高自然通风的使用率。借助绿色建筑围护结构设计可以显著提高稠密市中心的韧性，恢复水平的提高不仅有益于整个城市，还有益于独栋高层综合建筑（图7）。

值得一提的是，绿色城市基础设施，例如绿色建筑围护结构，对社会也有重大影响。绿色建筑围护结构提供了更为健康的居住条件，因此社会整体上将获得危害性较小的市中心居住条件，更大面积的市中心植物能够降低社会攻击性。一个非常简单的例子是，长满植物的幕墙很少遭到涂鸦，也不会遭致人为的幕墙破坏。即使有人扔石头，绿色建筑围护结构也会起到缓冲作用，破坏扔石头的人想要起到的效果。

长满植物的幕墙不但能够减少破坏行为，还能减轻接触到覆盖着绿色围护结构的幕墙的每个人的压力。单体高层建筑韧性的提高程度是显著的，并且在城市层面上积累，提高了城市的整体韧性，并为比现在稠密得多的未来城市的人类创造远比现在健康和快乐的居住环境（图8）。