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Sky Bridges – Pedestrian Circulation Through the Urban Fabric

天桥——城市肌理中的人行流线

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Bashar accomplished his studies in the field of BS Mechanical Engineering (Production & Design) in Aleppo University, Syria, and a MS in Construction Project Management at Heriot Watt University. Currently, he holds the position as General Manager of Al Ghurair Construction – Aluminium LLC. He has worked on the Burj Khalifa, Burlington Towers, Corporate Executive Hote l and Office, and Business Parks Phase 1 & 2.

巴沙尔拥有叙利亚阿勒颇大学机械工程学士学位（生产与设计），和赫瑞瓦特大学建设项目管理硕士学位，拥有超过18年在施工和项目方面的工作经验。目前，他担任Al Ghurair Construction- Aluminium 有限公司总经理。他在工程和施工管理方面有着多年的实践经验。已成功组织完成位于阿联酋，埃及，叙利亚，巴林，沙特和印度的多个著名项目。通过参与从2004年的12个项目到2013年的70个项目，他对公司的盈利和良好形象的树立做出了贡献。这其中包括世界最高楼哈利法塔，伯灵顿大厦，the Corporate Executive Hotel and Office，以及Business Parks一、二期项目。

Michelle graduated as an Architect from the Catholic University of Parana, Brazil. In the first years of her career she gained experience as an architect working in Brazil and Australia. In 2004, she completed a Masters Degree in Structural and Construction Engineering with Griffith University in Australia. She furthered her engineering experience working as a structural engineer in offices and projects based in Australia, UK and the Middle East.

In 2008, she joined the growing field of Façade Engineering, working as a façade consultant combining her experience in the Architectural and Structural fields and in 2011 she has moved to façade construction where she joined Al Ghurair Construction-Aluminium.

米歇尔毕业于巴西巴拉那天主教大学。早年在巴西和澳大利亚从事建筑师的工作。2004年，获得了澳大利亚格里菲斯大学结构和建筑工程硕士学位。她在澳大利亚、英国和中东地区进一步拓展了在工程领域的经验，并作为结构工程师加入了工作室参与当地项目。

2008年，她投身迅速发展中的幕墙工程领域，利用在建筑和结构方面的经验担任幕墙顾问。2011年，她加入Al Ghurair Construction – Aluminium（幕墙专业公司）。

Abstract

Interconnecting sky bridges provide the building occupants and pedestrians an alternative to using vehicles as a way of transport in the urban fabric. In extreme climate environments the added advantages of linked networks are immediately apparent as they provide pedestrians shelter from the environment. Sky bridges have been proven successful in several locations worldwide such as the Minneapolis skywalk system in USA and the Calgary +15 skywalk in Canada, both systems connecting dozens of city blocks with an overall length of over 18km.

When introduced early in the design process, the sky bridges can be an economic and effective solution to a more sustainable way of circulation within the vertical urban environment.

The Skywalks in King Abdullah Financial District (KAFD) - KSA will be presented as a case study.

Keywords: Skywalks, Pedestrian Bridges

摘要

互相连通的人行天桥为建筑的使用者和行人提供了另一种能够代替机动车在城市中穿梭的交通方式。在极端的气候条件下，这种连接系统的好处立即显露了出来——它可以为行人提供庇护而免于室外环境的干扰。人行天桥已在世界上很多地方被证明是可行的，例如：美国明尼阿波利斯的天桥体系和加拿大卡尔加里的"+15 Skywalk"系统，这两个天桥系统都连接了数十个街区，总长度超过18公里。

如能在设计过程的早期引入，垂直城市环境中的人行天桥可以成为实现更可持续的交通流线的一个经济有效的解决方案。

本文以位于沙特阿拉伯阿卜杜拉国王金融区 (KAFD) 的人行天桥为研究案例 。

关键词：空中通道，人行天桥

Urban Fabric and Skywalk Systems

Inter connecting sky bridges provide the building occupants and pedestrians an alternative to using vehicles as a way of transport in the urban fabric. In extreme climate environments the added advantages of linked networks are immediately apparent. Sky bridges have been proven successful in several locations worldwide such as the Minneapolis skywalk system in USA and the Calgary +15 skywalk in Canada, both systems connecting dozens of city blocks with overall length of over 18km (http://www.skywaydirectory.com/history.php and http://www.calgary.ca/PDA/LUPP/Pages/Centre-City/centre-city-projects/Calgarys-plus-15-skywalk/Calgarys-Plus15-Skywalk.aspx

The group of buildings connected by sky walks became "more than just a unique shopping experience but a complete indoor experience for the businessman. A downtown worker can drive to work and park in the convenience of covered parking, pick up a hot coffee, go to work, lunch, back to work then return to his car to go home at the end of the day without going outdoors." (http://www.bycitylight.com/spotlight-archive.php?article=1) (see Figure 1)

城市肌理与天桥系统

互相连通的人行天桥为建筑的使用者和行人提供了另一种能够代替机动车在城市中穿梭的交通方式。在极端的气候条件下，这种连接系统的好处立即显露了出来——它可以为行人提供庇护而免于室外环境的干扰。人行天桥已在世界上很多地方被证明是可行的，例如：美国明尼阿波利斯的天桥体系（参见图1）和加拿大卡尔加里的"+15 Skywalk"系统，这两个天桥系统都连接了数十个街区，总长度超过18公里。（请参考http://www.skywaydirectory.com/history.php和http://www.calgary.ca/PDA/LUPP/Pages/Centre-City/centre-city-projects/Calgarys-plus-15-skywalk/Calgarys-Plus15-Skywalk.aspx

被人行天桥连接起来的一组建筑物"不仅仅是独特的购物体验，对商人来说，这更是一种完全的室内体验。 想象一个在市中心工作的人可以开车上班，将车停在方便的有盖停车场，买一杯咖啡，上班，午饭，继续工作，然后下班开车回家，这一系列过程甚至都不需要到户外。"（请参考http://www.bycitylight.com/spotlight-archive.php?article=1）（见图1）

KAFD Skywalks

The KAFD Skywalks project is a prestigious and complex project within the King Abdullah Financial District in Riyadh- KSA. The circulation strategy within the development is to decrease the traffic in the central area by limiting the number of vehicles within the district. The solution is proposed by locating parking areas on the periphery of the development, then transporting people into the development centre via a monorail system. Due to the size of the project 6 monorail lines are provided to link the necessary carpark areas. In addition, the monorail system is also linked to the Riyadh metro system, linking the users to the skywalks network. There are a total of 98 skywalks within the development linking all the building in the district and covering a total length of over 11 Km.

The KAFD skywalks are located at the buildings level 1, which is in average about 6-8m above the ground and road levels. At this level, the towers and buildings will have cafes, restaurants and small shops to encourage the pedestrian circulation.

The skywalks have various lengths depending on the distance between the buildings that they are connecting. The maximum skywalk length for a single span is 42m. For longer lengths, an intermediate support is introduced and the longest double span skywalk is approximately 80m long. The skywalk width also varies depending on its location and the calculated traffic flow in the area, with two typical internal widths of 4m and 6m.

The design intent of all the skywalks is the same across the whole development. A systemized approach was provided with each bridge consisting of a combination of individual octagonal module units 4.7m long. The modules are repeated as required in order to achieve the total bridge span.

The typical module is formed by two different octagonal frames which forms the module "rings". The two rings are connected by at their nodes by the "diagonal" members, forming a closed diagrid triangulated structure- refer Figure 2.

At the connection between the bridge and the building, there is a non typical module, which is unique at every connection. The non typical end module provides the final length adjustment to the bridge and absorbs any required skew and level differences between the buildings.

System Design and Main Challenges

Although the design of the bridge span is relatively simple, the design of the end modules proved to be extremely challenging. The complexity arose due to the great amount of coordination required with each individual building within the district and their respective different disciplines: structural, internal finishes, mechanical and façades.

The main components required to make up the bridge are:

- Structural Steel Framing
- Glazed Façade System
- Concrete Works (required on double span bridges)
- Structural Steel Sub floor framing
- MEP fixtures and items
- Internal finishes including timber floor, fabric ceiling and glazed handrails

Figure 1. Map of Mineapolis skywalk system and the first skywalk built in Mineapolis spanning the 7th Street between Marquette and Second Avenues and connecting the new Northstar Center with the Northwestern National Bank (now Wells Fargo)- sources www.skywaydirectory.com/minneapolis-skyway.php and Minosota Historical Society

图1. 明尼阿波利斯的天桥系统和该市第一座人行天桥 (位于Marquette和第二大道之间，横跨第七大街，连接了Northstar Center和西北银行，即现在的富国银行) (出自www.skywaydirectory.com/minneapolis-skyway.php和Minosota Historical Society)

阿卜杜拉国王金融区的人行天桥

位于沙特阿拉伯首都利雅得的阿卜杜拉国王金融区 (KAFD) 的人行天桥是个著名的复杂项目。该项目中的流线策略是通过限制市中心车辆数目，减少中心的交通流量。该解决方案提出，将停车场置于项目地块的边缘，然后通过一个单轨铁路系统把人们运送入市中心。考虑到项目的规模，将有6条单轨线连接所需要的停车场区。此外，单轨系统也将连接利雅得的地铁系统，将人们连接到人行天桥网络中。这个发展计划共有98座人行天桥连接区域内所有建筑，总长度超过11公里。

KAFD项目中的人行天桥位于建筑物的一层，距离地面和道路层面平均约6至8米。在这一层面上，建筑物都设有咖啡馆、餐馆和小商店，鼓励人流。

人行天桥的长度依据它们所连接建筑物之间的距离有所不同。最长的行人天桥为单跨达42米。对于更长的长度，需引入中间支撑，最长的双跨人行天桥长约80米。人行天桥的宽度也根据它的

All of the components above required coordination with the adjoining buildings to ensure a smooth transition between the building and the skywalk.

Structural Framing

The bridge modules can be classified as truss a tubular structure with all elements made out of uniform diameter pipes with varying wall thickness. The diagonals pinned members while the octagonal "ring" frames form a rigid frame.

The pedestrian platform is part of the structural system of the bridge and it is structured in a way to span between the ring frames. It is made of UB sections tailored to provide access for the MEP installation below the platform and to provide stiff support for the glass parapet at each side of the walkway- refer figure 3 for the bridge structural steel typical general arrangement. (See Figure 3)

The bridge support are pinned vertically with some free lateral movement and rotations designed to incorporate all the movements that can occur due to differential temperatures and movements born from the connecting buildings including building deflections, vertical column shortening, movements due to seismic and wind action and differential settlements.

In order to accommodate all the movements expected, the bridge is supported on a combination of fixed, guided and free pot bearings which in many cases have been custom designed to suit the specified combination of reaction loads, movements, rotations, bearing support material- concrete or steel- and the dimension constrains within the bearing position. Also, the structural steel over the bearing has been designed to incorporate "ears" to allow for hydraulic jacking of the bridge in order to carry out bearing inspections and replacement if required.

Steel Fabrication and Erection Methodologies

The KAFD skywalks triangulated diagrid frame, although repetitive, requires a high level of precision during fabrication. Because of the nature of the structure shape, the fabrication of the nodes are dimensionally sensitive and must be fabricated to very tight tolerances in order to ensure that the overall structure will hold its shape when the members are assembled.

Steel Member's Fabrication

In order to ensure the highest level of quality during the structural steel fabrication, the fabrication drawings have been prepared in 3D software in which the drawing files could be uploaded directly into the steel cutting CNC machines. This approach not only considerably minimizes the amount of fabrication drawings and paper work produced, but it also ensures 100% accuracy in the steel cutting as there is no room for human errors.

Frame Pre-Assembly

After fabrication of the steel members, the whole bridge was pre assembled in the work shop and all the overall dimensions were checked. The pre-assembly of the structure is a final way of controlling the structure shape accuracy before the steel is sent to site. In case any discrepancies are found during the pre-assembly, the structure can be easily corrected as it is still in the workshop.

位置和所在地段的计算交通流量变化，两种典型的宽度为4米和6米。

在整个的发展项目中，所有人行天桥的设计意图都是一样的。系统化的方法得到了应用——每座桥由4.7米长的八边形模块单元组成。模块根据需要重复，以达到总的桥跨。

典型的模块由两个不同的八角形框架构成模块"环"。两个环在的节点处由"对角线"杆件连接，形成一个封闭的斜交三角网格结构(参见图2)。

在桥梁和建筑物的连接处没有典型的模块，因为每处连接都是唯一的。不同的终端模块为桥梁进行最终的长度调节并负责与建筑物连接所需的所有偏移和高差调整。

系统设计与主要挑战

虽然桥的跨度设计较为简单，但端部模块的设计被证明是极具挑战性的。其复杂性在于协调区内各个建筑不同的系统: 结构，内部装修，机械 (水电) 和幕墙。

人行天桥主要构成的部分是:

- 钢结构框架
- 玻璃幕墙系统
- 水泥工程 (用于双跨度桥梁)
- 钢结构楼板骨架
- 水电设备装置
- 内部装修，包括木地板，天花板和釉面扶手

以上所有的构件都需要与毗邻的建筑物协调，以保证建筑物和人行天桥之间的平衡。

Figure 2. Skywalk typical module (source AGC-A)
图2. 典型天桥模块

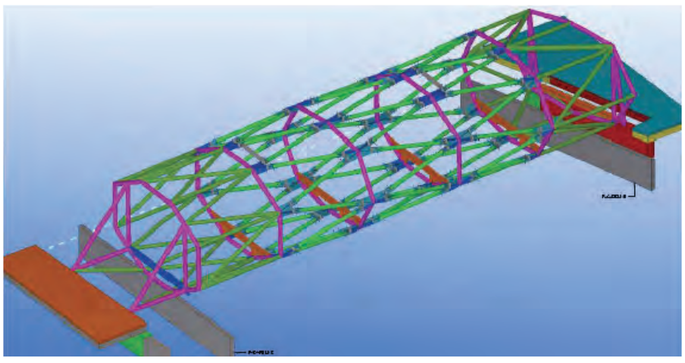

Figure 3. Structural steel framing general arrangement (source AGC-A)
图3. 典型桥梁的钢结构

Figure 4. structure pre-assembly in the steel workshop (source AGC-A)
图4. 车间内的预组装结构 (出自AGC-A)

After the structure is pre-assemble and the accuracy of the dimensions are satisfactory, the structure is cut into manageable pieces for transportation, numbered and sent to site. (see Figure 4)

On Site Workshop

A steel workshop has been set up on the KAFD site. The workshop is located in a strategic area near one of the development entries and main roads to facilitate the transportation of the steel to its final location. The purpose of this workshop is to re-assemble the steel members into modules. These modules are then transported to each respective final bridge location for erection.

Steel Erection

Several method statements for the steel erection have been developed in order to satisfy all the different site situations with regards to access, site location (road, wadi, plaza, tunnel, podium), load capacity of the floor below the erection area (slab, ground) and available area on the site for the bridge pre-assembly.

Some of the methods developed and used during the steel erection are described below:

Erection of Full Bridge Span

This construction method consisted of bringing in pre-assembled modules to the bridge location, the modules were positioned on the ground just below the bridge area. The modules are then linked together with purposed designed individual bolted members. At this stage, the MEP ducts and the façade brackets can also be installed to the structural steel. Once the full bridge span is assembled, the structure is erected using two mobile cranes lifting operation. Although this was the preferred method of erection, it was rarely used due to site access constraints.

Erection Of Bridge Modules

This method was used at locations where the assembly of the whole span was not possible due to limited available area for the bridge pre-assembly or areas where the access of big mobile cranes was not possible.

In this method, temporary supports were built under the bridge and the steel structure was erected by sections of one, two or three modules connected together depending on crane capacity are available area at the ground for modules pre-assembly. (see Figure 5)

结构框架

桥模块可以被归类为管状的桁架结构，所有部分都由相同直径、不同壁厚的管组成。对角线固定结构使八角形的"环"形成一个刚性框架。

行人平台是天桥结构系统的一部分，它使结构能在环形框架之间跨越。平台由定制的H型钢制成，以便水电系统能安装于平台底部，并为通道两侧的玻璃护栏提供刚性支撑，典型桥梁的钢结构如图3所示。

桥梁支座在垂直方向固定并允许一定的自由横向移动和扭转，以便适应由于温差和相连建筑物位移导致的移动，包括建筑物变形，垂直柱缩短，地震和风力作用产生的位移以及不均匀沉降。

为了适应所有预期的位移，桥梁支承采用在固定支座、滑动支座和盆式支座相结合的方式，在许多情况下需要定制设计，以适应反应负载、位移、扭转、支座材料 (混凝土或钢) 以及支撑位置尺寸的特殊限制条件等。此外，支座上方的结构钢在设计时还需能容纳"盘"，以便能允许必要时应用液压起重器进行支座的检查和更换。

结构钢的制造和安装方法

人行天桥的三角斜交网格框架虽然是重复的，但制造时仍要求有较高的精确度。因为该结构的形状的特性，制造时各节点对尺寸非常敏感，并且必须依照严格的公差生产，以确保整体结构在部件组装时能保持形状。

钢构件的制 造作

为了保证结构钢在制造过程中的最高质量水准，制造图纸在三维软件中创建，这样图纸文件就可以直接上传到可进行钢切割的数控机床。这种方法不仅可以极大地减少制造图纸和文件的产生量，也保证钢板切割时100%的准确率，避免人为错误。

框架预组装

完成钢构件的制作后，整座天桥在Al Ghurair车间进行预组装，对所有构件的尺寸进行检查。该结构的预装配是在钢构件被运送至场地前控制结构的形状精度的最后一道工序。由于仍是在工厂车间内，若预装配过程中发现任何差异，结构可以很容易被纠正。

当最后预组装结构的尺寸和精度达到令人满意的程度后，该结构被分成可运输的尺寸，编号并运送至工地 (参见图4) 。

现场施工现场车间

在工地设立钢构件车间。车间应位于项目地块和主要道路附近的一处区域，方便钢材的运输到最终位置。设立车间的目的是为了重新将钢构件组装成模块。这些模块将被运送至每个各自桥梁的最终位置进行架设。

钢结构的安装

开发几种安装方法以满足各种不同的工地情况，以结合不同的交通状况，场地位置 (公路，河床，广场，隧道，平台)，地板下面的负载能力 (楼板，地面)，以及可供桥梁预装配的工地面积。

一些在钢结构安装过程中开发和使用的方法如下:

全桥跨架设

这种施工方法包括把在预装配的模块运送到桥应搭建的位置，这些模块被放置在桥区域正下方的地面上。接着用带有螺栓的构件将这些模块连接起来。在此阶段，水电管道和立面支架也可以安装到结构钢上。一旦全桥跨度组装完成，结构将被两台移动式起重机吊装竖立起来。虽然这是建造天桥的首选方法，但由于场地的限制很少被使用。

Stick Type Construction

This method was used at areas where there were no access or no ground capacity for mobile cranes. This method consisted in building a full scaffolding under the bridge and erecting member by member on a stick build fashion using very small cranes. This method is time consuming and it was only used where no other alternatives were available. (see Figure 6)

Façade System

The original façade system selected for this project was based on a stick façade type solution in which the aluminium framing is connected to the structural steel using a stick build fashion (member by member), followed by the glass installation and finally the internal back pan at the spandrel areas. In this system, the glass is supported via cover caps, which are installed once the glass is erected into position.

During the design process, a mock up of one complete bridge module was produced and the façade was built based on the original stick type proposal. A number of challenges were faced during the installation of the stick façade, specially the inclined panels at the bottom of the bridge which had to be temporarily supported on an angle until all fixings of the external cover cap were completed. (see Figure 6)

After the mock up construction, it was decided to change the façade design to a semi-unitized solution, which was adopted and it is the current solution used in the project. In this solution, the façade consists of an aluminium sub frame connected to the bridge structure and a glazing panel supported on the panel frame. The sub frame has two purposes: to support the external panel and to provide a back up drainage to the façade system. The glazing is structurally bonded to the panel frame. In the case of spandrel panels, the back pan and insulation will also be attached to the panel frame, this will allow for a one stage installation of glazing and spandrel panels.

The sub-frame and the panel frame are interlocked via a hooking mechanism and an aluminium extrusion member is fixed between two panels to mechanically fix the panels in position to ensure that the panels will not un-hook. – refer Figure 7

The glazing consists of double glass insulated unit with laminated glass on the outside. The outer plane of the laminated glass is stepped in order to have a flush finish with the external aluminium trim.

The glazing consists of double glass insulated unit with laminated glass on the outside. The outer plane of the laminated glass is stepped in order to have a flush finish with the external aluminium trim.

Figure 5. Erection of bridge module (source: AGC-A)
图5. 桥模块的安装 (出自AGC-A)

Figure 6. stick built construction (source: AGC-A)
图6. 现场组装架设 (出自AGC-A)

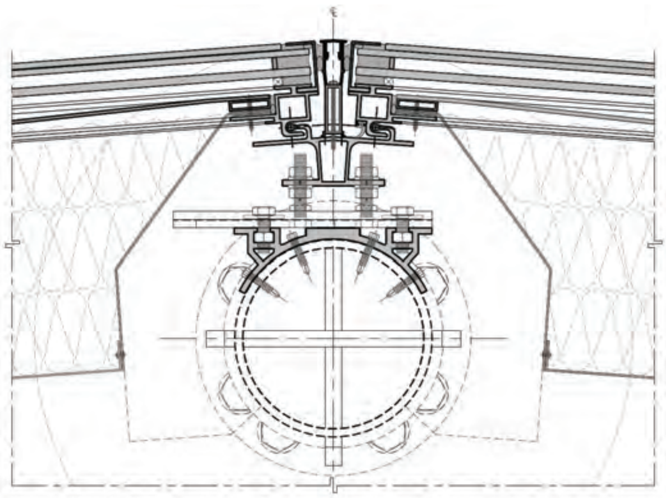

Figure 7. Façade system typical detail
图7. 幕墙系统细部

桥梁模块架设

在由于场地面积不能进行预装配或大型起重机不能到达施工地点，无法应用全桥跨架设时，将使用桥梁模块架设法。

该方法中，在桥下搭建临时支撑，根据起重机承载能力和场地内可预装配的程度，钢结构模块被分成一、两或三个模块一组进行架设 (参见图5) 。

现场组装架设

这种方法用在地面没有使用大型移动式起重机能力的工况下。该方法包括在桥下建立一个完整的脚手架支撑并利用小型起重机一个一个地搭建。这种方法非常耗时，因此只用在不能使用其它安装方式的情况下。 (参见图6)

幕墙系统

该项目原来选定的幕墙系统是基于现场搭建幕墙的构建方式，即现场 (一根一根) 将铝框架连接到钢结构上，再安装玻璃，最后安装内部的背板。在这个系统中，罩盖在玻璃被放到相应位置时安装，玻璃由罩盖支撑。

在设计过程中，制作一个了完整的桥梁模块模型，并按照原先的方案安装了幕墙。在现场安装幕墙的过程中遇到了很多问题，特别是在安装倾斜的底板部分时，不得不暂时先将其支撑起一个角度上，直到外部罩盖的所有固定装置完成。 (参见图6)

在完成施工过程模拟后，决定将幕墙设计改为一个半单元式的解决方案，也就是目前项目中采用的方案。在这个解决方案中，幕

The façade frame hooking interlock system proved to be extremely advantageous during the façade erection, once the panels were hooked to the sub-frame, the crane used for the erection of this panel could be released and start the erection of a new panel as no temporary support is required on this system. This system has significantly improved the installation rate on site reaching the record installation rate of 15 panels per shift per installation team.

External Lighting Proposal

Due to the prominent location of these bridges, especially those spanning over the major collector roads within the development, it was concluded that external façade lighting would be an appropriate proposal.

An idea to introduce high resolution screens replacing some of the façade panels was presented to the client as an alternate design solution. The key purpose was to use the screens predominately for advertising purpose to generate a profitable income from the bridges façade, whilst further enhancing the external envelope.

The screens are triangular shaped, in line with the architectural design intent and they are located on the panels that are slightly inclined downwards. The position for the screens has been purposely selected to gain the clearest image the public could view whilst driving within the development area- refer to Figure 8 showing the high resolution screen on a prototype.

Nineteen bridges have been selected to incorporate the high resolution screen, the location of these bridges have been selected based on studies of the traffic flow on those areas.

Providing façade lighting not only brings the bridge architecture to life at night, but in this case, it also provides means of generating revenue from the bridges façade.

MEP and Internal Finishes

The interior space of the skywalks follows the external geometry. The interior space is very open to allow for the pedestrian flow inside the bridge.

The internal walls and ceiling are covered by a stretched fabric panels on large triangular shapes. The panels are prefabricated and supported on an aluminium frame. The flooring consists of raised flooring with word finish. At either side of the skywalk corridor glass balustrades are placed. All the internal finishes in the skywalk are modular and matching with the structure module size, this has ensured a effective design and installation due to the repetition of the modular elements.

All the services are located under the bridge flooring deck. The skywalks have their own ventilation and cooling system with supply coming from one of the adjoining buildings. Fresh air intake is achieved by a grill integrated in the faced at the bottom of the bridge. Illumination is provided by a linear modular LED located along the balustrades base.

墙由一个连接到桥梁结构的铝框架和依靠面板框架支撑的玻璃板组成。铝框架有两个目的: 支持外部面板，并提供幕墙的排水系统。玻璃板连接在面板框架上。在拱肩板的情况下，背板与隔离层也将被连接到面板框架上，可以实现玻璃板和拱肩面板的一次性安装。

铝框架和面板框架通过一个挂钩装置实现联锁，一个铝制的挤压部件被固定在两层面板之间，机械固定两板的位置，以保证面板不会脱钩 (参见图7) 。

玻璃板由具有隔热夹层的双层玻璃构成，外侧为夹层玻璃。夹层玻璃的外表面与铝框架齐平。

玻璃窗的外表面是三角形的熔融图案。熔融图案样式的密度取决于玻璃接收的日光照射强度。

幕墙框架的挂钩联锁系统在幕墙的搭建过程中被证明是极为有利的，一旦面板被挂在铝框架上，起重机就可以撤出并开始下一块面板的安装，无须暂时支撑。该系统显著改善了现场安装效率，达到每个安装队伍一次轮班可安装15块板的记录。

外墙彩光灯饰方案

由于这些人行天桥都位于道路的明显位置 (特别是跨越主干道的那些桥梁)，因此外墙彩光灯饰将是一个合适的方案。

一个引进高分辨率的屏幕代替部分玻璃幕墙板的想法被提交给客户作为一种设计方案选择。使用屏幕的主要目的是通过桥梁幕墙上广告的增加盈利收入，同时进一步增强了幕墙的面貌。

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目前已有19座桥梁被纳入安装高清屏幕的范围，这些桥梁位置的选择建立在对所在地区交通流量的研究基础上。

外墙彩光灯饰方案不仅在夜间给桥梁带来了生气，在安装屏幕的情况下，也提供了使桥梁外观产生收益的方法。

Figure 8. Prototype of a typical module with high resolution external screen solution
图8. 安装了高分辨率外屏幕的典型模块

Conclusion

The KAFD development master planning has incorporated the skywalks very early in the design, when a lot of the buildings were still under design stage. This has permitted the building owners to integrate the skywalks into the building at early design stages. This is an advantage when compared to other skywalk systems in the world which the provision for skywalks came after all the buildings were completed, thus requiring the building design to be adapted to provide adequate circulation and the building structure to be stiffened to support the bridges, which can be a time consuming and expensive exercise.

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水电系统和内部装修

人行天桥的内部空间遵从幕墙的几何形式。内部空间非常开放，以适应桥内的行人流量。

内墙和天花板都由三角形的拉伸织物面板覆盖。面板是预制的，由一个铝框架支撑。在人行天桥走廊两侧设有玻璃栏杆。天桥的所有内部装修都是模块化的，并与结构模块的尺寸相匹配，重复的模块确保了有效的设计和安装。

所有的配套服务设备都位于桥梁的地板下方。行人天桥的通风和制冷系统来自一座与之相连的建筑物。新鲜空气通过桥底部的格栅输送。照明由位于沿栏杆基座的线性模块LED灯提供。

结论

KAFD项目在总体规划的早期，当大量的建筑仍在设计阶段时，就加入了人行天桥设计。这允许业主在早期设计阶段就将人行天桥融入建筑。相比于世界上其他人行天桥系统，在所有建筑物落成后规定建设天桥，这是一个优势。因为在那种情况下，就要求建筑设计能提供足够的交通流线以及对建筑结构进行加固以支撑桥梁——这将是一个耗时且昂贵的过程。

如能在设计过程的早期引入，垂直城市环境中的人行天桥可以成为实现更可持续的交通流线的一个经济有效的解决方案。KAFD项目中的人行天桥系统也带来了一些其他好处，比如: 联系商业活动与步行区，增加发展项目中的物业价值，节省出行时间 (目的地之间直接连接以及行人不必花时间等待道路交通)，减少行人过马路时的意外发生。