Architectural Material & Detail Structure

建筑材料与细部结构

（德）埃克哈德·盖博 编　常文心 译

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图书在版编目（C I P）数据

建筑材料与细部结构．新材料 /（德）盖博编 ；常文心译．-- 沈阳 ：辽宁科学技术出版社，2016.3
ISBN 978-7-5381-9379-4

Ⅰ．①建… Ⅱ．①盖… ②常… Ⅲ．①建筑材料 Ⅳ．①TU5

中国版本图书馆 CIP 数据核字（2015）第 185862 号

出版发行：辽宁科学技术出版社
（地址：沈阳市和平区十一纬路 29 号　邮编：110003）
印 刷 者：利丰雅高印刷（深圳）有限公司
经 销 者：各地新华书店
幅面尺寸：245 mmx290 mm
印　　张：20
插　　页：4
字　　数：100 千字
出版时间：2016 年 3 月第 1 版
印刷时间：2016 年 3 月第 1 次印刷
责任编辑：鄢　格
封面设计：周　洁
版式设计：周　洁
责任校对：周　文

书号：ISBN 978-7-5381-9379-4
定价：368.00 元

联系电话：024-23284360
邮购热线：024-23284502
http://www.lnkj.com.cn

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Preface 前言

THE LANGUAGE OF MATERIAL

Dialogue between Structure,
Material & Form

材料的语言

结构、材料与形式之间的对话

During the architectural design process, form finding and the choice of materials come into play already in the early stages and they relate together in such a manner that a mutual influence is almost unavoidable. From Louis Sullivan's still relevant claim: "form ever follows function", which is which is up today subject of debate, could be derived in this regard yet another statement: material follows form to describe the tension between form and material. The material, from an artistic point of view, through its intrinsic visual and haptic properties, influences the subjective perception of architecture. Not only the form but also transparency, translucency, reflectivity, colour and texture regulate the relation between the interior and the exterior and between light and shadow. Whereas from the technical-constructive perspective, the physical properties of the material like mass, static strength or thermal conductivity can be either beneficial or disadvantageous for certain usages. Like from a construction kit, the architect operates with the material for his building, he knows the material's properties and how to choose the appropriate material to best achieve not only the desired impact on the architecture but also the value of the architecture. (Image 1)

The invention of steel, in the late 19th century, was certainly a milestone in the history of architecture. The use of steel, with its static strength, fundamentally changed architecture and leveraged the development of radically new building typologies like the skyscraper. Since the beginning of the last century ongoing research efforts are being put in place to create and develop new and ever more complex building materials: polymers and synthetic materials for example have been constantly developing and have since become firm components, either in bare form or in form of composite materials, in modern buildings ranging from thermal insulation to sandwich panels or fibre-reinforced materials. Especially composite materials, where two or more materials with different properties are firmly bound together to a single high-tech material with improved technical properties, play a big role in contemporary architecture. Advanced composite materials, despite being a par with mass, show a higher stress loading capacity than the original materials, and are therefore ideally suited for a large-scale use in innovative façade design. (Image 2)

In complex and large-scale buildings, the use of high efficient materials is a basic prerequisite for as neutral as possible energy balance. The shape and the orientation of a building as well as the relation between transparent and solid building materials have a big impact on the heating and cooling loads. It is therefore essential to design the distribution of the materials already in the early phases of the design process and calculate them among other things according to the annual solar path to make the most of lighting and shading.

With the beginning of the digital age in the 21st century, the architects' design tools change radically, drawings which previously where meticulously hand drawn, are now being design with the aid of computers. Special programmes (BIM) allow architects not only to experiment with an unexplored three-dimensional form language but furthermore to design and calculate the needed building materials and components and forward the digital data to the manufacturer, where then all components can be individually prefabricated in high efficient industrial production process and subsequently be delivered assembly ready to the construction site. White, modular fibre-reinforced concrete components moulded from 3d-data for instance decorate the ornamental facade of the Prince Salman Science Oasis, a sustainable science museum in Riyadh, Saudi Arabia, which is almost before completion.

The client's requirements are the basis for the development of our design concepts. Deductions from the site's specific characteristics and history, the surrounding structures, climate and access paths, as well as energy and ecological needs – aspects of particular importance today – are all parameters of our design process. Ultimately, the building or urban landscaped ensemble, should, as a unique element, reflect the genius loci, formulating a distinctive and memorable idea of structure and space in all its parts.

By reducing design concepts developed in this way, all important ideas should – in the form of a small logo – be visually imparted, make an impression and set a sign. When the building is

建筑的形式和材料的选择在设计初期就已经被决定了，它们不可避免地相互影响。路易斯・沙利文曾说过："功能决定形式。"这并不是我们的讨论主题，但是我们可以由此衍生出"形式决定材料"，以此来形容形式与材料之间的关系。从艺术观点来看，材料通过其固有的视觉和触觉属性来影响人们对建筑的主观感受。不仅是形式，通透度、透明度、反射率、色彩和纹理都能调节室内外空间之间以及光影之间的关系。但是从技术和建造层面来看，材料的物理属性（如体量、静强度、热传导性等）对特定的用途可能造成有利或有害的效果。建筑师就像从一个建造工具箱里选择材料，他了解材料的特性以及如何挑选合适的材料，以实现建筑的预期效果和建筑的价值。（图 1）

19 世纪末，钢的发明无疑是建筑史上的里程碑。钢的运用从根本上改变了建筑，促成了摩天大楼等新建筑类型的开发。从 20 世纪初开始，人们一直不断研发更复杂的建筑材料，例如，高分子聚合材料和合成材料。经过不断的开发和巩固，无论是单一形式还是复合形式，新材料在现代建筑中的运用越来越自如，构成了隔热层、夹层板、纤维增强板等形式。复合材料是由两种或两种以上具有不同性能的材料稳固地融合在一起的单一高科技材料，具有更好的技术性能，它们在现代建筑中扮演了重要的角色。与原始材料相比，高级复合材料具有更高的应力载荷能力，因此非常适合被大规模应用在创新型立面设计中。（图 2）

在复杂的大规模建筑中，为了实现能源平衡，高效材料的运用十分必要。建筑的造型和朝向以及透明和不透明建筑材料之间的关系对供暖和制冷负荷的影响极大。因此，必须在设计初期就决定材料的分配，并且根据年度太阳路径来进行计算，以最大程度地利用采光和遮阴。

在 21 世纪初——数字时代的开始，建筑师的设计工具产生了巨大的变化，细致的手绘图纸现在已经被电脑图纸所取代。特殊的程序（BIM 建筑信息模型）让建筑师不仅可以试验未开发的三维形式语言，还能设计并计算出必须的建筑材料和构件，将数据传给制造商并在制造商那里实现所有构件的预先制作。通过高效工业制造流程制成的建筑构件随后将在施工现场进行快速的装配。例如，由盖博建筑事务所设计的萨尔曼科学中心就采用了三维建模数据制成的白色模块化纤维增强混凝土构件作为外墙装饰。

委托方的要求是建筑师设计开发的基础。项目场地的特色和历史、周边的建筑结构、气候和出入路线以及能源和生态要求（在先进的设计中格外重要）都是设计过程的参考因素。最后，作为一个独立的元素，建筑或城市景观集合体应当反映当地特色，形成一个独特而令人印象深刻的结构和空间。

Image 1 The King Fahad National Library Kingdom of Saudi Arabia by Gerber Architekten

Image 2 Gold Souk in Beverwijk by Liong Lie Architects

图1 由盖博建筑事务所设计的法赫德国王国家图书馆

图2 吉巴欧文化中心

used and experienced, this conceptual sign should be perceptible as a structure and in all its parts recognisable through its clarity and conclusiveness, right down to the use of materials and colour. This is only possible, however, when the design's basis is a rational, functionally intelligent, innovative and thus formally expressive concept.

Our goal, as a team of architects, interior designers, engineers, urban planners and landscape designers, is to create built environments that affect people and stir their desires; places people like to visit and linger in; spaces that are tangible and logically accessible. These should be structures that improve the urban and landscaped environment with their beauty and in their simplicity, as well as being exciting in their spatial arrangements, which are clear and self-evident with regards to the orientation between inside and out.

The main aspect of our efforts is to focus within the existing multiplicity of what is right, to distill that to a well proportioned concentrate and to connect things with one another aesthetically, thus creating solutions to the tasks at hand for our fellow beings.

Eckhard Gerber (Gerber Architecten)
2015.7

在整个设计概念的开发过程中，所有重要的想法都应当以视觉的形式呈现出来，形成印象并建立一个标志。当建筑经过使用和体验后，这种概念标志应当成为一个可感知的结构，从各个方面都能清晰的辨识，对应着材料和色彩的运用。当然，前提是设计师的设计基础是合理、智能、创新且具有表现力的概念。

作为建筑师、室内设计师、工程师、城市规划师和景观设计师，我们的目标是打造能够影响人类并激发他们欲望的建筑环境、人们喜欢访问并停留的场所以及切实合理的空间。这些结构应当能够通过它们的美来改善城市和景观环境，并且拥有清晰合理的室内外空间设计。

我们努力的重点是聚焦已有的多样性设计，从中汲取合适的精华，以美观的方式将各种事物连接起来，从而为我们的同伴打造出合理的解决方案。

埃克哈德·盖博（盖博建筑事务所）
2015.7


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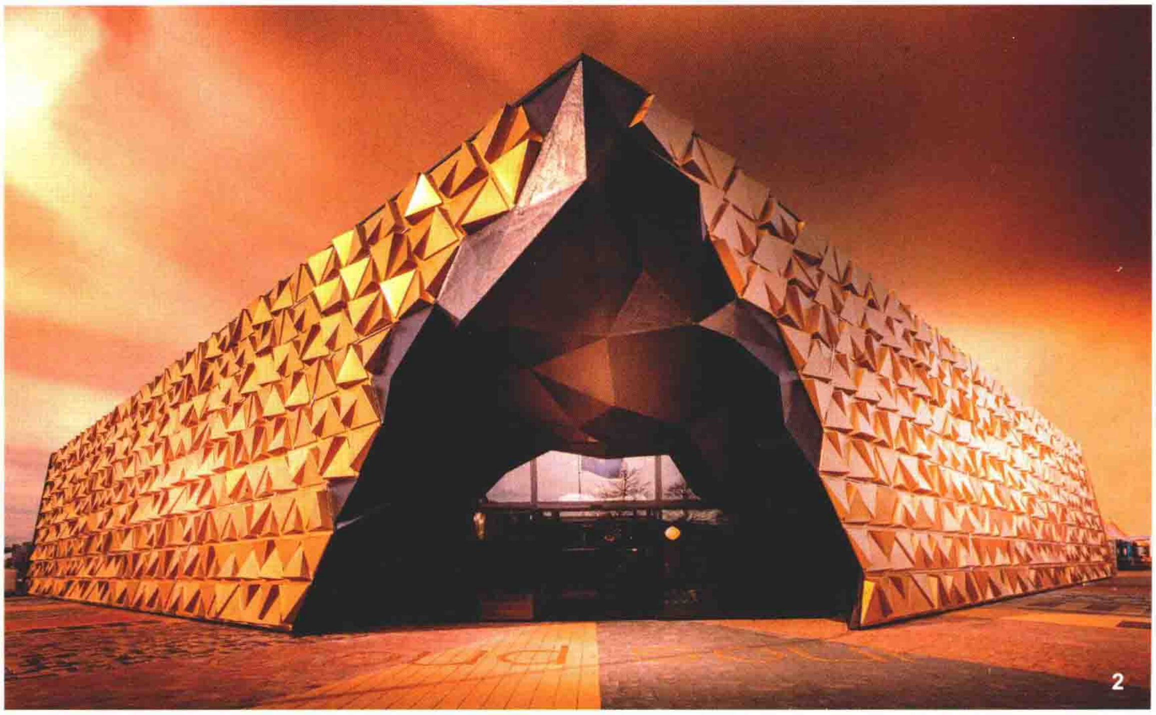
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FIBRE REINFORCED COMPOSITE MATERIALS

纤维增强复合材料

The history of manufactured composite materials dates back to the beginning of construction when straw was mixed with mud to form adobe bricks. The straw provides the structure and strength while the mud acts as a binder holding the straw together and in place. Several thousand years later in the early 1900's the first modern composite was invented combining cellulose, reinforced fibres and cement with the fibre cement becoming a part of everyday building and architectural avant-garde. Widely acknowledged for its toughness and strength fibre cement has been used by architects for roofs, façades and interiors along with stretching into quite different fields such as furniture design and art... a material in a continuous reinvention.

As part of a continuous process Ludwig Hatschek's invention in 1981 introduced a synthetic organic fibre made from polyvinyl alcohol signaling the manufacture of a new generation of asbestos-free cement products. The same patent application dated 28th March 1900 for "a process for the manufacture of artificial stone sheets with hydraulic binders using fibrous materials" is still in use today to produce fibre cement panels adopting the Hatschek process on Hatschek machines.

In a story of innovation and experiment fibre cement soon became the perfect example of modernity with renowned architects having used its products and contributed to its development. Le Corbusier as early as 1912 chose fibre cement sheets for cladding the roof of the "Maison Blanche" his parents' villa. Although the most comprehensive use of fibre cement products by Le Corbusier took place 45 years after in his "Unitéd'habitation" (International Building Exhibition in Berlin, 1957) in the form of façades and balconies, sun blinds, stair balustrades, floor coverings, ceiling linings, heater cladding, bath panels, window sills, meter panels, refuse ducts and installation pipe work.(See Figure 1)

Beyond the application in building construction, the material has also been given consideration and usage in other unusual and diverse fields. The already classic furniture design of the fibre cement chair "Loop" by the Swiss designer Willy Gulh in 1954 or the paintings on fibre cement of the Spanish artist Pablo Picasso are some outstanding examples.

Even in heritage protection the grey cement material succeeded after the first reservations of professionals and over the year, fibre cement products have managed to set themselves in the renovation of prominent listed buildings such as the Postsparkasse in Viena where Otto Wagner specified it for the roof parapet and also outside of Europe in the 1957 home of the architect Kenzo Tange in Tokyo where traditional Japanese motifs and construction are blended with modern based materials. In the latter case, fibre cements panels designed by Tange had to negotiate directly between internal and external space traditionally a function performed earlier by thin paper slide walls.

Four residential buildings incorporating fibre cement have become landmarks of 20th century architecture: the 1935 single family house by Le Corbusier in Les Matthes, southern France, the 1949 Case Study House nº 8 by Ray and Charles Eames in California, the 1960 Haus Lieb by Robert Venturi along with the 1980 house By Frank O Gehry in Santa Monica. The material experienced a high point of popularity in 1987 when it was taken up by the new architectural avant-garde and used for the warehouse of the Swiss candy manufactured Ricola, in Laufen by architects Herzog& de Meuron. The slanting fibre cement panels that make up of the cladding articulates and provides rhythm to the façade, as well as defines a visual reference to the traditional stacking of sawn timber boards around the numerous saw mill of the area. (See Figure2 to Figure 4)

Furthermore, fibre cement has found its place in high-rise developments such as the student hall of residence built by Coop Himmelb(l)au at the historic Gasometer site in Vienna in 2001 and in sculptural office buildings such as the 2005 Caltrans Headquarters built in Los Angeles by Thom Mayne.

In a global approach the architects MVRDV used corrugated fibre cement sheets to completely clad the roof and façade of various single-family houses in the 2001 residential development in Ypenburg situated in the Netherlands and this has been

加工型复合材料的历史可以追溯到人类建造活动的早期，当时人们把稻草与泥巴混合起来，制成风干砖坯。稻草负责提供结构和强度，而泥巴则起到了黏合剂的作用。数千年后，在 20 世纪早期，第一种现代复合材料诞生了。它混合了纤维素、增强纤维和水泥，成为了日常建筑和先锋建筑的一部分。纤维水泥以良好的韧性和强度而著称，被建筑师广泛应用于屋顶、建筑立面和室内设计中。此外，它的应用范围还进一步拓展到了家具设计、艺术等其他领域，是一种不断进化的材料。

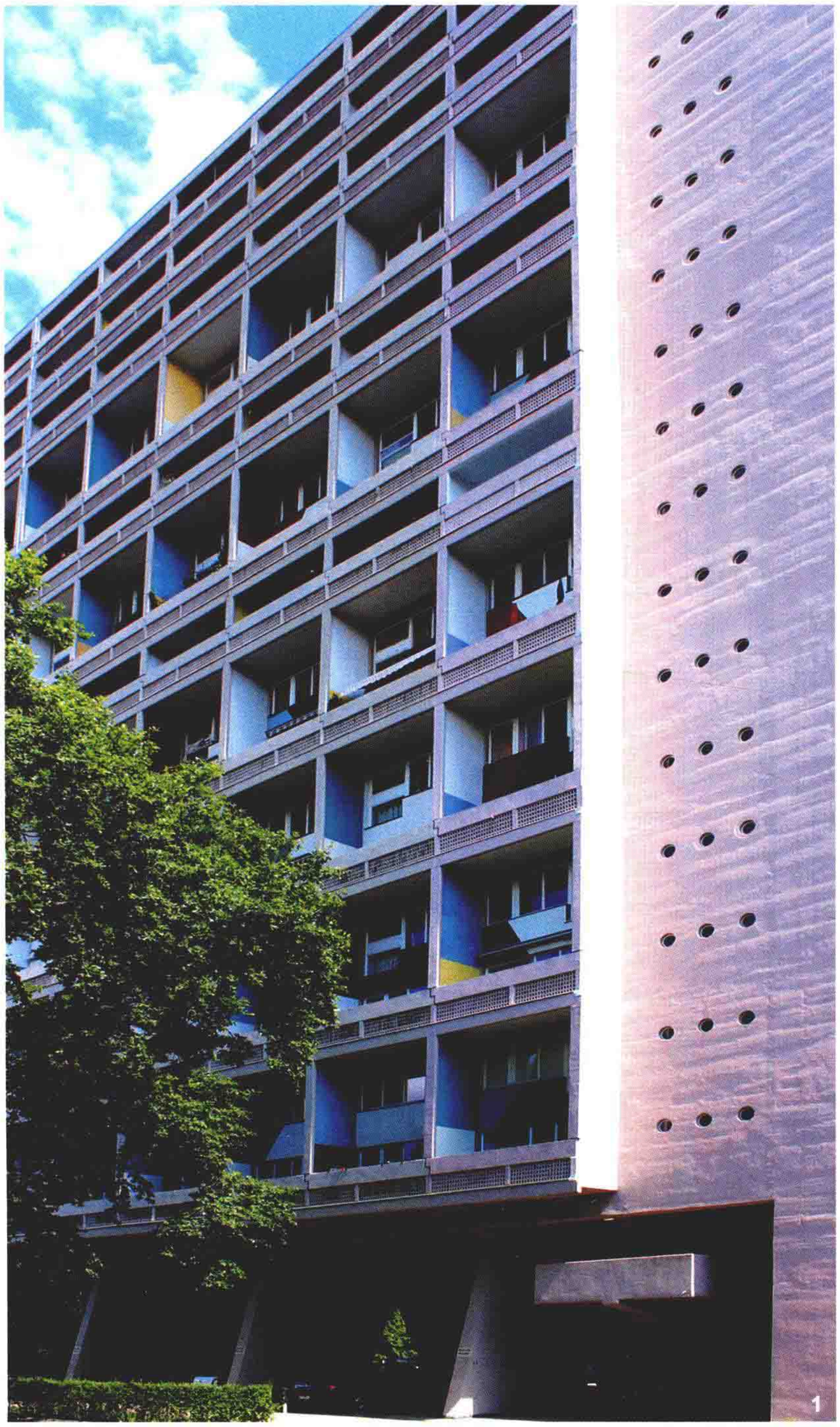
作为不断发展进程的一部分，路德维格·哈切克于 1981 年发明了一种由聚乙烯醇制成的合成有机纤维，标志着新一代无石棉水泥产品制造的开始。1990 年 3 月 28 日，“利用纤维材料制作水硬性胶凝材料人造石板的方法”获得了专利，目前，人们仍然沿用这种方法通过哈切克机械来生产纤维水泥板。

在创新和试验的过程中，纤维水泥快速成为了现代材料的完美典范，大量知名的建筑师选用了纤维水泥产品并促进了它的发展。柯布西耶早在 1912 年就选择纤维水泥板作为他父母的住宅——“布兰奇宅邸”的屋顶材料。45 年后，柯布西耶在 1957 柏林国际建筑展的“联合住宅”中综合运用了纤维水泥产品，其应用范围从立面、阳台、遮阳板、楼梯扶手、地面覆盖物、天花板衬线、暖气包层、浴室隔板、窗台、仪表板一直延伸到垃圾管道和安装管道系统，极为广泛。（见图 1）

除了被应用在建筑施工中，纤维水泥还被应用在许多不常见的领域。例如，瑞士设计师威利·古尔在 1954 年设计的纤维水泥椅“环”，西班牙画家巴勃罗·毕加索的纤维水泥画作等。

在遗产保护中，纤维水泥同样占有一席之地，许多著名历史保护建筑的修复都选择了纤维水泥制品。例如，奥托·瓦格纳将纤维水泥用于维也纳的奥地利邮政储蓄银行的屋顶护墙；在日本建筑师丹下健三 1957 年的住宅中，传统的日式浮雕和建筑结构与现代材料完美融合。由丹下健三所设计的纤维水泥板必须替代传统的日式薄纸拉门，在室内外空间实现直接的过渡。

在 20 世纪的标志性建筑中，有 4 座使用纤维水泥的住宅建筑：1935 年，柯布西耶在法国南部设计的独户住宅；1949 年，伊姆斯夫妇在美国加州设计的第 8 号案例研究住宅；1960 年，罗布特·文图里设计的利布住宅；1980 年，弗兰克·盖里在美国圣塔莫尼卡设计的住宅。纤维水泥的应用在 1987 年达到了顶峰，被 Herzog& de Meuron 建筑事务所应用在瑞士利口乐糖果工厂仓库的设计中。构成外包层的倾斜式纤维水泥板将建筑立面连接起来，营造出独特的韵律感，同时也与当地常见的传统的锯木板堆垛实现了视觉联系。（见图 2~ 图 4）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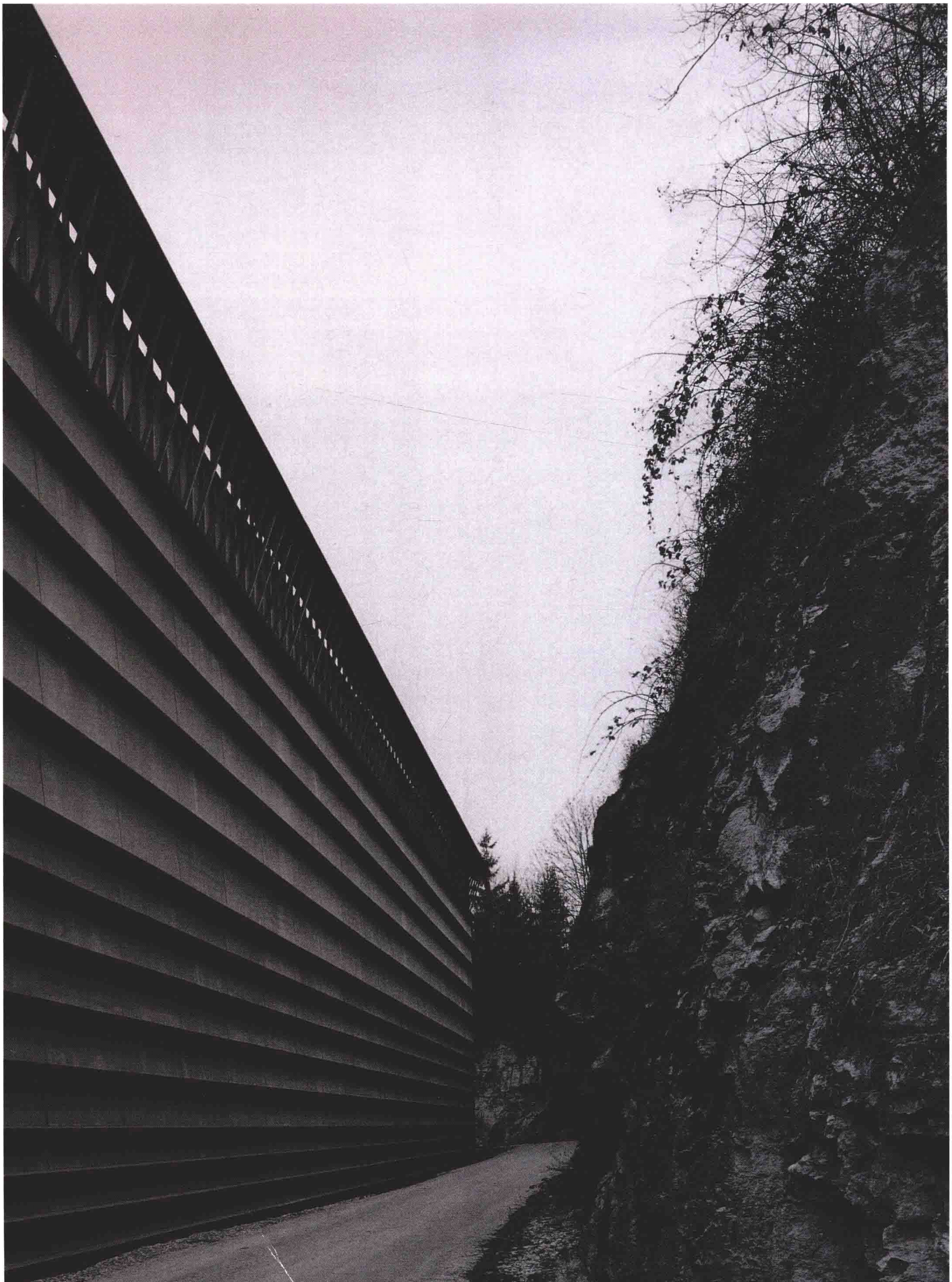
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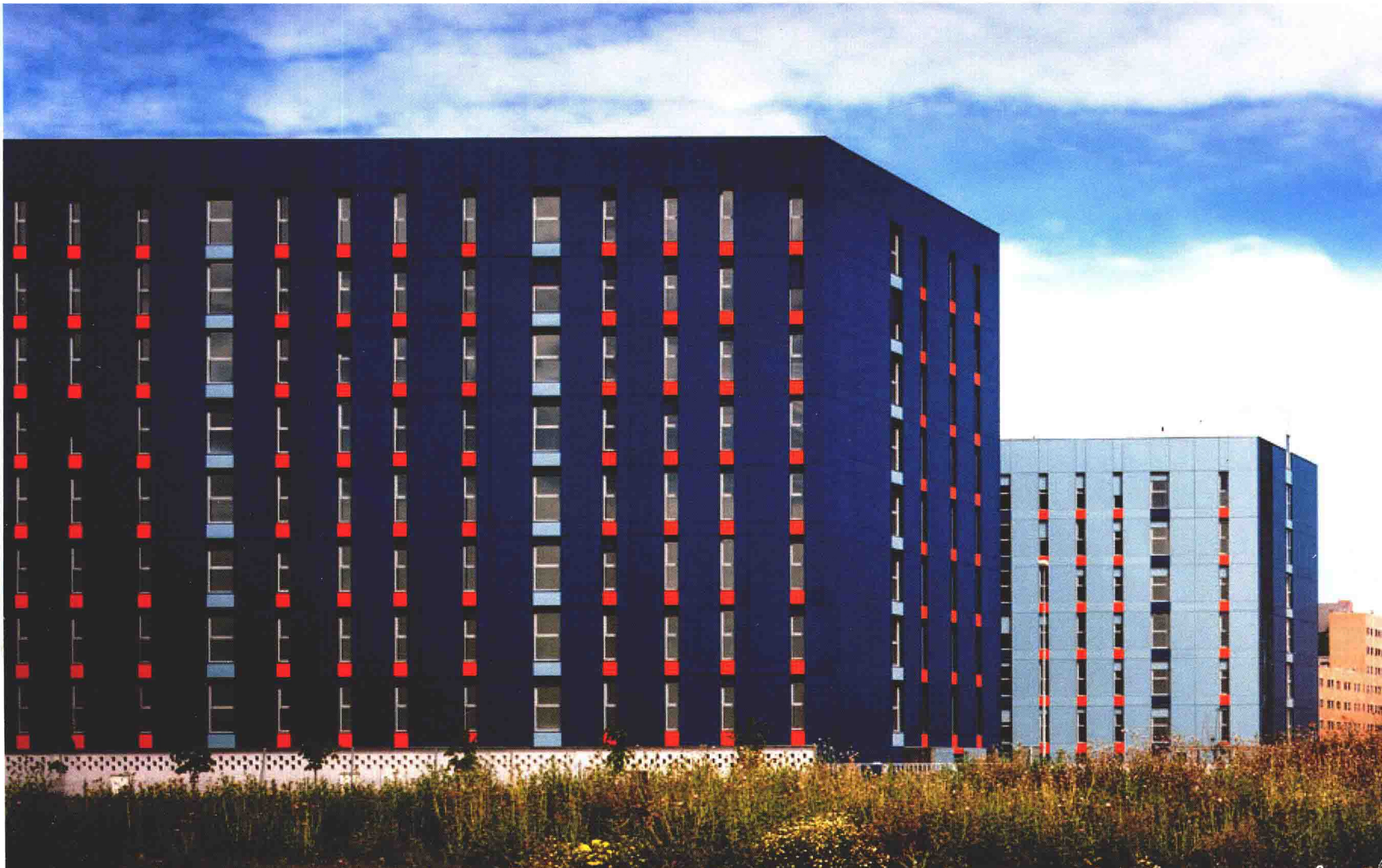

adopted in other designs too. For instance, Willem Jan Neutelings used large format fibre cement sheets and small format shingles in elegant combinations with wood and masonry in dwellings in the Netherlands. (See Figure 5)

As a noble material fibre cement transmits a force that comes from within through the depth of its surface, its texture and its velvetiness which can change quickly with light and weather, a natural appearance that can be enhanced with silicate mineral paint resulting in a durable and balanced connection.

Because of the versatility, durability and formability of fibre cement the construction industry has always seen and promoted tremendous interest in producing innovative composites. However, only after 1970's when asbestos needed to be replaced due to scientist evidence of health damage was industry able to give rise to a wide range of new materials that had been accepted as a viable alternative, such as asbestos-free fibre cement or high pressure laminated panels and metal composites with the latter acquiring a more synthetic appearance. In our opinion, because of its nature, fibre cement combine better with concrete while laminated composites are recommended where metal structure prevails. (See Figure 6, Figure 7)

Currently significant changes in the design of external walls have been produced by a growing interest in energy conservation, water tightness and a reduction in air filtration with these changes leading to a shift in design properties. Durable, lightweight façade panels define the formal aspect and tension therefore the industry is focused on producing a diversity of materials, finishing and dimension that allow an appropriate response. The specific formalisation of composite panels, fixings and seams will be the result of these requirements and approaches.

In construction composites have enjoyed a widespread use; however, new opportunities are open towards structure wall panels, foundations, building cladding and roofing. Furthermore, the use of composites are much lighter than traditional materials and can significantly reduce building dead load which translates to manageable seismic design and smaller structure definition resulting in material and cost savings that cascade through the entire project and in great advantages in prefabricated light constructions.

Nowadays architecture is moving away from flat surfaces with composites being anything but geometrically confining. Unlike other materials the composite has the potential to make practically even the most imaginative designs. The material can be transformed into any size or shape in the workshop or on-site as well as being perforated or printed. Currently it is possible to produce via CAD the entire design for a building and transfer the data files seamlessly to cutting tools to create the different sections and raise all sorts of prefabricated constructions.

In view of sustainable development new directions in research and lifecycle analyses have shown that composites are actually more environmentally friendly than concrete, aluminum and other conventional building materials. There is a focus on composite waste management with various technologies having been developed to improve and ease the recyclability of these materials.

In the future the versatility and formability of composite materials will still offer more scope for development, invention and experiment, enabling considerable benefits for building culture as far as architects' dreams can take them.

Text by Fernando Suárez Corchete / Lorenzo Muro Álvarez

此外，纤维水泥在高层建筑开发中的应用也十分广泛。例如，Coop Himmelb(l)au 建筑师事务所于 2001 年在维也纳设计的学生公寓、托姆·梅恩于 2005 年在洛杉矶设计的加州交通厅总部等。

在荷兰勇堡的独户住宅开发工程中，MVRDV 建筑事务所利用波纹形纤维水泥板将住宅的屋顶和立面完全包覆起来。这种设计被沿用至其他项目中，例如，在荷兰的一处住宅开发项目中，威廉·扬·纽特灵斯将大块纤维水泥板和小块木瓦与木材和砖石结构完美地融为一体。（见图 5）

透过自身的表面、纹理和特有的柔和感，纤维水泥向外散发出力量，并可以随着光和气候快速地变化。硅酸盐矿物涂料能够有效改善纤维水泥的自然外观，形成持久均衡的连接。

由于纤维水泥用途广泛、经久耐用、可塑性强，建筑业一直对制造创新复合材料保持着巨大的兴趣。然而，直到 20 世纪 70 年代，科学家认证石棉有害健康之后，建筑业才开始大规模使用无石棉纤维水泥、高压层压板、金属复合材料等新材料。其中，金属复合材料的外观更为综合多样。我们认为，纤维水泥的性质使其能更好地与混凝土融合，而层压复合材料则更适合于金属结构。（见图 6、图 7）

当前，建筑外墙的设计正发生着巨变，人们越来越注重节能、防水和隔气性。耐用、轻质的立面板材是发展的趋势，因此，建筑业正聚焦于打造与之相对应的各种材料、饰面和规格尺寸。复合板材所特有的可塑性、方便固定性和接缝特性足以满足这些设计要求。

在施工过程中，复合材料有着广泛的应用；但是它们在结构墙壁板材、地基、建筑覆盖层、屋顶等方面仍然有着巨大的潜力。此外，复合材料比传统材料更轻，能大幅缩减建筑的静负荷，从实现更易控制的抗震设计和更小的结构，节约整个项目的材料和成本，有利于预制构件轻型结构的建造。

复合材料帮助建筑远离平板表面，脱离几何结构的限制。不同于其他材料，复合材料能帮助你实现最富想象力的设计。复合材料可以在车间或施工现场被塑造成任意的尺寸和造型，还能实现穿孔和印花。目前，CAD 软件已经能为建筑提供完整设计，并将数据文件完全传送到切割工具中，实现各种预制施工。

在可持续开发的层面上，研究新动向和生命周期分析显示：复合材料比混凝土、铝材和其他传统建筑材料更加环保。科学家正对复合废料处理技术进行研究开发，以提升这些材料的可循环利用能力。

未来，用途广泛、可塑性强的复合材料将呈现更多的开发、创造和试验潜力，为建筑文化乃至建筑师实现梦想的过程助力。

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