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leverworks: one principle, many forms
杠杆作：一个原理、多种形式

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Vito Bertin

China Architecture & Building Press

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杠杆：一个原理、多种形式

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柏庭卫 著

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柏庭卫 著 Vito Bertin

principle, many forms

我是1986年与柏庭卫相识，那时候我刚刚在东南大学（当时是南京工学院）硕士毕业后留校任教。当时一群年轻教师开始筹划新的一年设计教案，而柏庭卫则是挂在历史教研室名下的一位瑞士留学生，带二年级的设计课。他采用的以模型来推动设计的方法给我们很大的启发，于是我们就邀请他加入我们的团队。和他接触多了，渐渐看到他做的其他一些小玩意，如用瓦楞纸板、竹签和纸做的台灯，以及用纸板和棉线做的精致的多面体模型。那时候我们没有见过多少瑞士人，所以就幼稚地以为任何一个来自以制作高档机械手表闻名的国家的人都具有这样的制作技能，后来我们才渐渐认识事实并非如此。

如果说精致的手工制作技能与对建筑设计的独特洞察力相结合是柏庭卫学术研究的一个独有品质，那么这本书中所呈现的关于杠作结构的研究则是将这一独特品质推到了一个极致。这本来并不是一个庞大的研究计划，在开始时也远未能预见最终会有成果，一切开始于他对设计教学中遇到的一个微不足道的问题的观察。以一颗独特的好奇心为驱动力，以一系列的疑问为线索，以手工操作为手段，他从一个简单的结构现象入手，逐渐建立起一个相当复杂的设计研究体系。本书的制作基本上依循着他的研究线路来编排，既有他个人的研究探索，也有在香港、杭州和南京的实际教学；既有理论推理和实验验证，也有实际的建筑设计尝试；既有小尺度的实物模型和足尺的大型结构，也有图解和电脑模型的操作。如此，该书完整地将这个独特的设计研究呈现给读者。

这本书的内容虽然是关于杠作这一独特的结构现象，但是该书所呈现的设计研究方法却具有普遍的意义。如今在建筑学的五花八门的学术研究中所采用的方法大都可以溯源到其他的学科，而我们对如何通过设计的方式——建筑学固有的方式——来研究，却往往不得要领。柏庭卫在这本书里以他独特的方式向我们提供了一个示范。

顾大庆

I met Vito Bertin in 1986, when I had just completed my master's study and became a design teacher at the Department of Architecture of Southeast University (then Nanjing Institute of Technology). At that time, we – a group of young teachers – began to formulate a new design foundation course, while Vito was an assistant in the Unit of Architectural History and Theory and participated in the second year studio teaching. Very much impressed by the model method that he introduced in his studio, we invited him to join our team. Getting to know him more, we were further amazed by some gadgets he made with simple materials such as desk lamps made from corrugated cardboard, bamboo sticks and paper, and fine polyhedral models made from paper and cotton strings. We did not know many Swiss at that time, so we naively thought that any person from a country known for the production of high-end mechanical watches should have the same production skills like him, but later we realised that this is not the case.

If the combination of exquisite craftsman skills and a unique insight into architectural design is a special quality of Vito Bertin's academic research, the study on leverworks presented in this book has pushed this quality to an extreme. Without an ambitious research plan to begin with or an expectation of huge results at the end, it all started from his observation of a trivial problem encountered in the teaching of design. With a unique curiosity as the driving force, a series of questions as a clue, and by means of high level craftsman skills, he started from a simple structural phenomenon and gradually built up a very complex system of design inquiry. The production of the book basically follows the line of his research, which contains not only his

personal research and exploration, but also the teaching experiments in Hong Kong, Hangzhou and Nanjing; not only theoretical reasoning and experimental verification, but also the actual architectural design attempts; not only with finely made physical scale models and full size structures, but also through graphic diagrams and CAD model manipulations. So, the book can successfully present his research to the reader.

Although the content of the book is about leverworks as a unique structural phenomenon, the research method he adopted has far more significance for architectural research in general. Today, the methods used in architectural research can mostly be traced back to other disciplines. But, we often fail in using our own method – design – in architectural studies. Here, Vito Bertin gives us a perfect demonstration in his own way how this kind of design inquiry can be done.

Gu Daqing

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背景 background

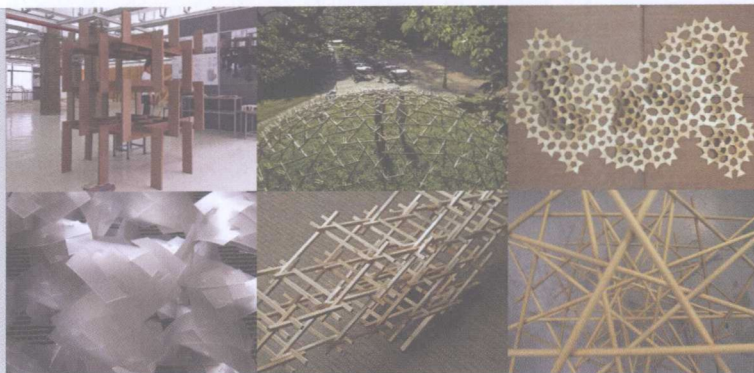
关于本书 about the book

1 介绍 introduction

一个原理、多种形式 one principle, many forms

这个对页中展示了第二型杠杆的图解和18个不同尺寸、形式丰富的杠作作品。大部分作品将会出现在此书的其他章节

second class lever
第二型杠杆

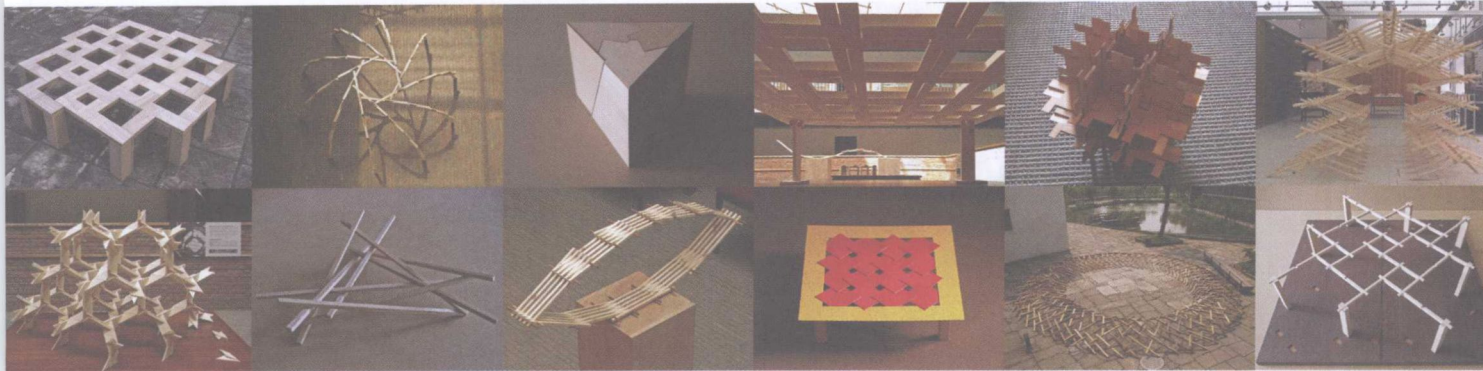


互承构架，格构结构，栅格，互承棒式结构，这种结构有多个名称。长久以来，我一直称其为杠梁结构，德语中叫Hebelstabwerk，将这种结构的基本原理和构件的基本形式结合起来。然而，随着构件形态的变化，从单一的直杆到包括板在内的多种形式，这一名称就不合适了。因此，我在此书中将其称为“杠作”，与德语中的Hebelwerk相对应。这个名称的重点在工作原理上，而忽略其形式。还有与这个杠杆原理相关的其他必要特征——构件的相互性及自连接的属性——都必须包含在这种结构研究的框架中。因此，我在杠作这个新名词中暗含了更为周全、准确而略显冗繁的定义：相互承载及自我搭接的杠杆结构。许多其他特性的变化作为参数变量使这种结构产生了丰富的形态。

在这项研究之初，我并不知道这方面的先例，或者别人对这种结构的研究，直到后来才逐渐有所了解。因此，我可能重复了某些前人的研究，但也因此，使我得以不带成见地进行研究。我惊讶于由一个发现导致另一个发现的连锁反应，并因此试图考察我的工作方法，正是这一方法使初始单一的构型衍生出了多种形式。

与学生合作时，我并不强调结构的类型，亦或生成的形式，而是由工作方式（而非设计意图）所决定的产生多种形式的过程。当然，过程产生的结构形式也非常吸引人，我很荣幸能有多次机会向人们展示这些成果。

A diagram of a second class lever and 18 photos of leverworks of various sizes and a wide range of forms. Most of them will appear in other parts of the book.



Reciprocal frame, grillage structure, bar grid, mutually supported stick structure – there are several names for this type of structure. I used the name *leverbeam structure* – and *Hebelstabwerk* in German – for a long time, combining the basic principle of the structure with the basic form of the element. But with the change of the element from a straight stick into a wide range of forms, including slabs, I found this name no longer appropriate. So I suggest for this book the name *leverwork* – equivalent to the German *Hebelwerk*. With this name I emphasise the working principle and ignore the form. But there are other defining properties associated with the lever principle, the mutuality of the elements and their self-connecting nature, which have to be maintained to constitute the studied type of structure. So I imply with the new term leverwork the more complete and correct but clumsy and wordy definition *mutually supporting and self-connecting lever structure*. The variations of many other properties as changing parameters generate the richness of the possible forms that this type of structure can take.

When I started this study, I was neither aware of historical precedents nor of other people studying this type of structure, which at a later stage changed. For this reason I must have initially duplicated studies already done, but it also gave me a chance to study without the prejudice of the already known. I was myself surprised how one discovery led to the next and therefore tried to observe my working method through which from a simple starting configuration a wide range of forms emerged.

When I had chances to work with students I didn't emphasise the type of structure or the resulting forms but the process which led to all these forms not through a design intention but through a way of working. But I find of course the results also very fascinating and was glad to be given opportunities to show them in exhibitions.

四根梁 four beams

相互搭接 supporting each other



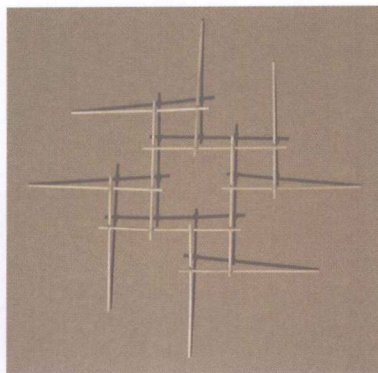
我对杠作的研究始于1999年的一门课。当时，香港中文大学建筑学系每年会组织一个纵向设计练习，不同年级的学生组合在一起共同完成一个大型任务，通常与结构问题相关。1999年的题目是用给定量的材料完成一定的跨度，最后看哪个结构能承受更多的荷载。其中一个组造了四根梁，相互搭接，每条梁由更小的构件组成。这个结构让我想起1992年石井和紘设计的熊本县清和闻乐馆的顶棚。学生们也承认确实是受了这个作品的启发。这令我很感兴趣。我特别想知道这一结构是否有扩展的可能。学生们不知道，也明确地表示没有兴趣去探究。于是我决定自己找答案。我用从超市买回的一些竹签做模型，成功地实现了这一结构的扩展。接下来我向可算得上是结构专家的两位同事展示了几个这类模型，向他们打听这类结构，以及它的名字。他们既不知晓也无兴趣。这反倒加剧了我的好奇心。

研究开始一段时间后，我偶然发现了一幅图解，从中知道互承结构这个术语，并得知约翰·奇尔顿和他的同事们也正在研究这种结构。之后我又发现欧洲及中国的先例竟可上溯几百年。1999年我作了初步的资料整理，2001年在两个会议上展示了研究成果，并在2002年的arch+建筑杂志上发表了一篇文章。在那之后，我断断续续地进行着研究，发现了更多有趣的方面。接下来对这项研究较正式的呈现是2009年春季在香港中文大学的一门选修课，2010年1月在香港圣言中学的展览，2010年3至4月间在杭州中国美术学院的工作坊，及2010年5至6月间在南京东南大学的工作坊。

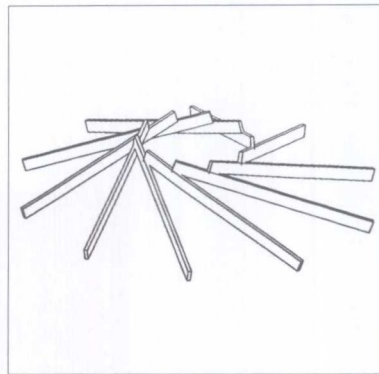
单元可否扩展? can the unit be expanded?



通过模型确认 confirmed by model



互承构架 reciprocal frame



I started my studies of leverworks in 1999 reacting to a student project. At that time, the Department of Architecture of the Chinese University of Hong Kong organised each year a vertical project in which students from different years would collaborate, usually on a structural issue. In 1999 the students were asked to span a certain area with a given amount of material. It was then tested which structure could support the highest added load. One group made four beams, each composed of smaller elements, which supported each other. The structure reminded me of a ceiling by Ishii Kazuhiro in the Seiwamura Bunraku-kan 1992. The students confirmed that this was also their inspiration. I got very interested. I especially wanted to know if it was possible to expand such a structure. The students didn't, and when I asked them if they were interested to find out, they replied with a clear no. So I decided to find out by myself. I made some models with bamboo skewers from the supermarket, and was successful in extending the structure. Subsequently I showed several models to two colleagues who were considered specialists in structure and asked them

if they knew this type of structure and if there was a name for it. They didn't know and also showed no interest. This only reinforced my curiosity.

Only after having proceeded with my studies, I found by chance a small diagram with such a structure, which gave me the term reciprocal frame, and I learned that John Chilton, and others working with him, were also studying this type of structure. Later I also found that there were precedents in Europe and China going back hundreds of years. I compiled preliminary documentation in 1999, presented my studies at two conferences in 2001 and published an article in the architectural magazine *arch+* in 2002. Since then I continued the studies in waves, and found more interesting aspects. The next more formal occasions to present my studies were an elective course at the Chinese University of Hong Kong in Spring 2009, an exhibition at Sing Yin Secondary School in Hong Kong in January 2010, a studio at the China Academy of Art in Hangzhou in March and April 2010, and a studio at Southeast University in Nanjing in May and June 2010.



本书是系列丛书的一本。第一本，柏庭卫、顾大庆和胡佩玲合著的《香港集装箱建筑》是对香港集装箱建筑的研究。第二本，顾大庆和柏庭卫合著的《建筑设计入门》介绍了香港中文大学1994年至2000年的建筑学一年级教学课程。第三本，顾大庆和柏庭卫合著的《空间、建构与设计》探讨了香港中文大学2001-2009年的建筑学二、三年级的教学课程。本书与以上的几本持有同样的态度及志趣，唯研究对象不同。

本书与上述第三本书的主要研究方法尤为相近：不断循环的制作、观察和设问。它实际上是这种方法的一个极端的案例，在首个循环中就可以辨识出：学生搭建了结构物，我的观察及我的第一个设问。其他的循环也有迹可循。本书中展示的许多结构都可以通过这种循环彼此联系在一起。但随着研究的发展，某些问题并不是导向下一个循环，而是对结果的反思以及对异于其产生过程的将不同形式关联在一起的新模式的发现。

本书分为五个部分。关于研究、学习、展示的三章构成了核心。第一章是简要的介绍，最后一章在我的研究之上进行了扩展。

“研究”一章包含三个部分。第一部分“原理”描述了杠作原理的决定性特质，亦即：作为承载原理的杠杆作用，作为构件关系的相互性，以及作为构件连接原理的自连接特性。第二部分“疑问”我列举了研究过程中制作、观察和设问循环的一些例



背景 background
关于这本书 about the book

1 介绍 introduction

一个原理，多种形式 one principle, many forms



原理 principles
疑问 questions
议题 issues

2 研究 study

一系列的疑问 a series of questions

This book is part of a series. The first – Vito Bertin, Gu Daqing, Woo Pui-leng: Vernacular Contained – is a study of Hong Kong's container architecture. The second – Gu Daqing, Vito Bertin: Introduction to Architectural Design – describes a first year teaching programme at CUHK 1994-2000. The third – Gu Daqing, Vito Bertin: Space, Tectonics, and Design – discusses a teaching programme at CUHK 2001-09 for second and third year students. This book shares an attitude and an interest with these, applied to a different subject.

It especially shares with the third the main working method: repeated cycles of making, observing and questioning. It is actually an extreme case of this method, as the first cycle can be identified, with the structure made by students, my observation of it, and the first single question I had. And many other cycles can still be traced. The many structures illustrated in the book can all be linked to each other through such cycles. But as the study developed, certain questions led not to a next cycle but to the reflection of the results and the finding of patterns which link the different forms in other ways than their process

of discovery.

The book is structured into five parts. The three chapters study, learn and show form the core. The first chapter gives a short introduction, and the last expands the view beyond my own work.

The chapter "study" consists of three parts. In the first part – principles – I describe those properties of leverworks which I consider the defining principles: the lever as the load-bearing principle, mutuality as the principle of element relationship and self-connection as the principle which joins the elements together. In the second part – questions – I give examples of the study process, with selected sections of cycles of making, observing and asking questions. In the third part – issues – I discuss several topics which, taken out of these cycles, reveal how the differentiation of certain properties can be used to find order within the different forms.

The chapter "learn" consists of four parts, one for each opportunity that I had to work with students: an elective at the Chinese University of Hong Kong, a workshop at Sing Yin Secondary School in Hong



香港中文大学 cuhk
香港圣言中学 syss
中国美术学院 caa
南京东南大学 seu

3 学习 learn

直接经验 direct experience



香港 hong kong
杭州 hangzhou
南京 nanjing

4 展览 show

欣赏、体验、感知 appreciate, experience, perceive

子。第三部分“专题”从这些循环中截取一些话题进行讨论，揭示了如何利用某些特性的变化在不同的形式中寻找规律。

“学习”一章包含四个部分，每部分对应一次我与学生的合作：香港中文大学的选修课，香港圣言中学的工作坊，杭州中国美术学院的工作坊，及南京东南大学的工作坊。基于这四个场合的巨大差异性，我将着重描述如何以不同的方式与学生们进行合作。

“展示”一章的三个部分分别展示了我与学生的三次教学成果，其中包含了我个人的研究与与学生合作的成果。香港圣言中学的展览是学校内部的，包含了我与香港中文大学选修课的学生们制作的小型结构，后来也在杭州和南京的展览中出现。杭州展览的主要内容是学生们在工作坊中完成的大型结构。从中选取的一些结构和南京工作坊完成的大型结构一同构成了南京展览的主体。

附录中提到了建成的结构实例和他人的研究，在此我特别向在研究各阶段中提供帮助的同事及学生们，以及香港中文大学选修课的学生，中国美术学院和东南大学工作坊的学生们致以衷心的感谢。