国外高等院校土建学科基础教材（中英文对照）

承重结构

LOADBEARING SYSTEMS

[德] 阿尔弗莱德·梅斯特曼 编著

文捷 译

中国建筑工业出版社

国外高等院校土建
BASICS

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前　言

建造建筑时，我们需要知道其结构性能如何。承重结构可以是设计中的主导因素，也可能是我们平时看不见的辅助结构，但无论如何建筑总是要基于这些承重结构的。它将结构组合在一起，将荷载传递到地面并保持结构的稳定性。对于承重结构的理解，包括结构基本原理和各种承重系统的特性，是将这些原理合理地应用于设计并找到合适的材料及建造方法的基础。

课程的开始通常是很困难的，特别是要消化这么多的新材料，了解复杂的静力学以及承载理论。承重结构基础将建筑学科与土木工程学科联系在一起，并深入浅出地全面阐述了承重结构理论的基本知识。为了使读者更好地理解，作者首先用示例和简单的背景知识解释了建筑内的荷载和力，介绍设计中可能用到的典型承重结构构件及不同类型的承重系统和结构。这里介绍的简明知识使得学生可以完整地认识承重结构并进行创造性的设计。

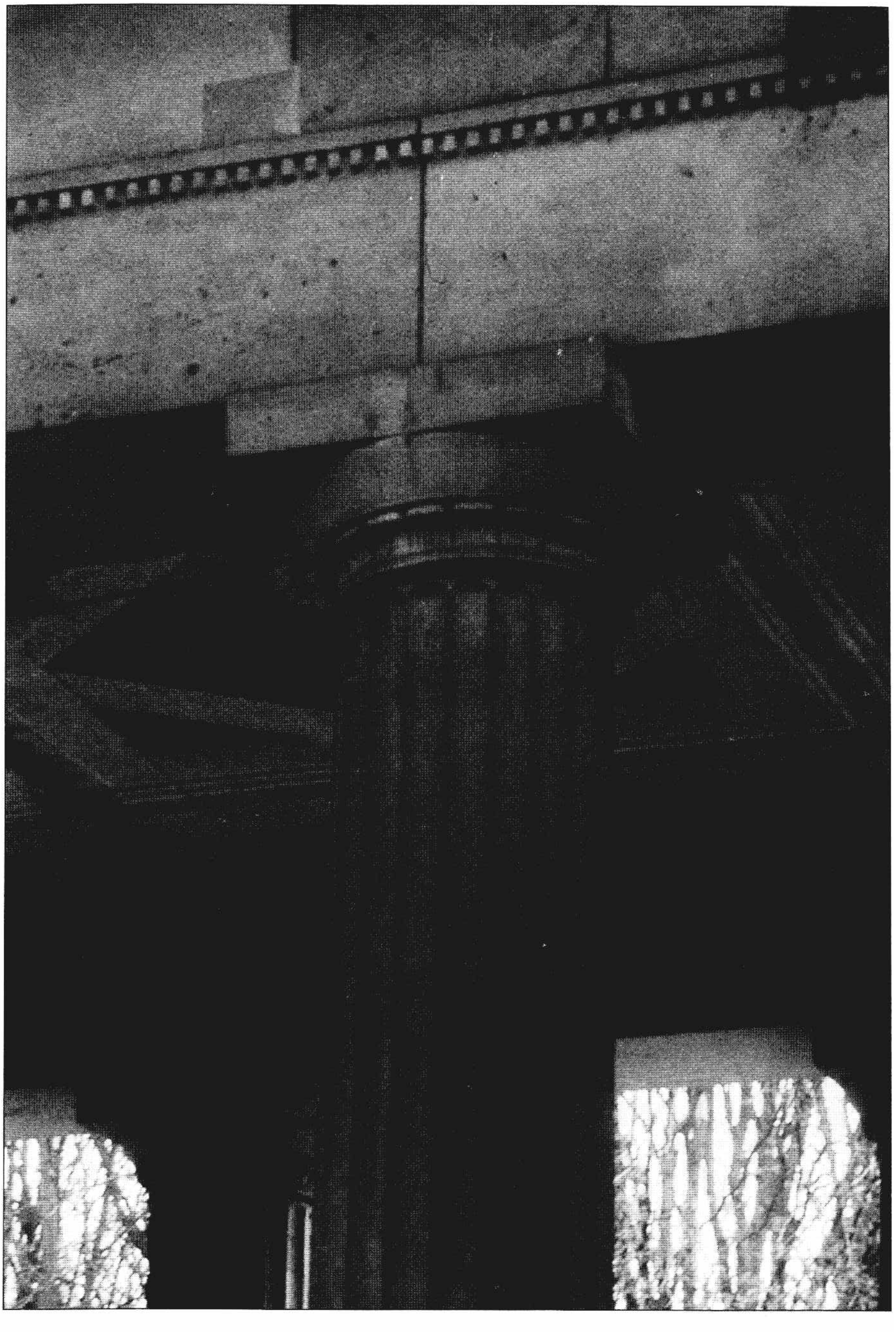
编者：Bert Bielefeld

FOREWORD

When constructing a building, we need to know how its structural properties function. Loadbearing elements can be the dominant features of the design, or simply an invisible substructure – but a building is always based on its loadbearing structure. It holds the building together, distributes loads into the ground, and guarantees stability. An understanding of loadbearing – its structural principles and the specific qualities of individual loadbearing systems – is fundamental to applying these principles sensibly in the design process and developing a solution that suits the materials and the construction method.

It is often difficult, particularly at the beginning of a course when there is so much new material to assimilate, to work one's way into the complexities of statics and loadbearing theory. *Basics Loadbearing Systems* bridges the fields of architecture and civil engineering and explains the fundamentals of loadbearing structure theory simply, comprehensibly and chronologically. To help general understanding, the author first explains the loads and forces occurring in a building using examples and simple contexts. He introduces typical loadbearing structural elements and shows loadbearing systems and structures for the different building types that planners can use for their designs. The compact knowledge conveyed here makes it possible for students to work with loadbearing structures in an integrated way, and thus be able to design creatively.

Bert Bielefeld, Editor



LOADS AND FORCES

LOADBEARING STRUCTURES AND STATICS

A great deal of philosophizing can be done about how design relates to construction. Very different positions can be taken, but they are always two sides of the same coin. Designing spaces means defining them, by applying theory to structures that will need to be realized. Knowing about structures is therefore one of the fundamentals of architectural theory. It is very rare for the architect him- or herself to vouch for the stability of constructions. But he or she should be in a position to select structural elements correctly at the early design stages and to assess the dimensions needed for them realistically. The next step is usually to develop the loadbearing system with a structural engineer. To be able to work together effectively, fundamental knowledge is needed about loadbearing systems and structures, their advantages and disadvantages and the forces that come into play. These different forces seem complex at first, but they are logically coherent.

It is easiest to explain how they fit together in the order in which they are addressed for a statical calculation. A calculation of this type usually follows these steps:

- Analysing the overall structure and the function of the individual structural elements in it – statical system
- Determining all the forces working on the structural elements – assumed loads
- Calculating the forces affecting a particular structural element and the forces that it transmits to others – calculating the external forces
- Calculating the forces within the structural element itself – investigating internal or static forces
- Determining the stability of the planned structural element
- Proof that the planned structural element can withstand the forces determined

FORCES

$F = m \cdot a$

Force is defined as mass times acceleration.

Newton

The unit used for measuring force is the newton; a newton corresponds roughly to the weight of 100 grammes. In building the newton is complemented by the kilonewton and the meganewton.

Kilonewton: 1 kN = 1000 N, Meganewton: 1 MN = 1,000,000 N

A force is determined by magnitude and direction. Its action is linear, and is expressed by its line of application and the direction of this line. › Fig. 1

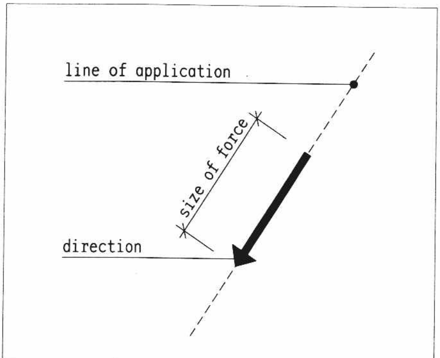


Fig.1: Force

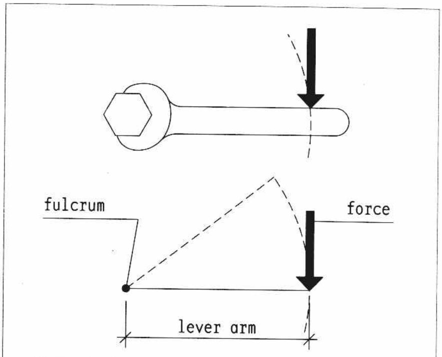


Fig.2: Torque

Moments, torque

Forces can also work in a circle around a point. They are then called torque or moments, and are defined by their size multiplied by the distance from the fulcrum (lever arm).

A simple example of torque is tightening a screw with a screwdriver. This also demonstrates the link between force magnitude and lever arm. The longer the lever arm, the greater the torque. › Fig. 2

Action = reaction

Statics describes the distribution of forces in a system at rest. Buildings or parts of buildings are usually motionless, and all the effective forces balance each other out. This can be summed up in the law "action = reaction". It is used as a starting point in statical calculations, on the basis that the sum of all forces in any one direction and its counter-direction is zero. If the action is known, the reaction can be determined immediately. The chapter External forces, Support forces explains the methods that apply this possible to loadbearing systems.

STATICAL SYSTEM

A structural engineer first establishes the connections within the construction in the statical system. A statical system is an abstract model of the real, complex structure of the component parts. Supporting members are considered as lines even if they have a wide cross section, and their load is treated as a point. Walls are presented as disc structures and their loads are applied in lines. Additional information the statical system gives is how the structural elements are joined together, and how their forces are distributed from one element to another. This is crucial to the calculations. The symbols used in statical systems are explained in the chapter External forces, Support forces › Fig. 8, p. 16 and are used subsequently in the text.

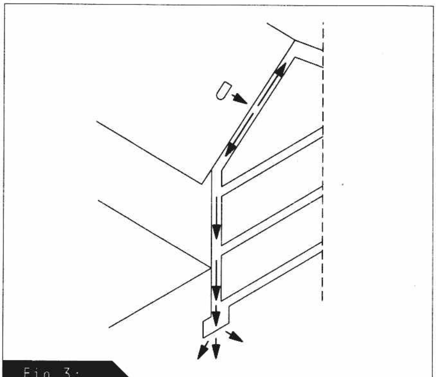


Fig. 3:
Load path

Positions

The next working stage involves identifying all the structural elements in sequence as positions and numbering them. Here it is also important to establish which structural elements load which others.

Load path

For example, roof tiles are not just supported by the roof structure, but also affect the walls, right down to the foundations. It must be established with absolute precision which structural elements absorb the loads from the upper storeys. › Fig. 3

›✎

EXTERNAL FORCES

If we consider a building element such as a roof beam, we distinguish between two types of force. First, there are the forces exerted on it by the roof structure above it, and those that it transfers to the masonry supporting it. If we do not consider its dead weight, it does not matter in the first

✎

\\Tip:
For good cooperation with structural engineers, it is important that designers be familiar with these specialists' part of the work in a project and understand their working methods and aims. It therefore makes sense to look at their calculations and positional and working plans and compare them with the architect's documents. After the structural engineer has devised the structure with the architect in the design phase, the main thrust of his or her work is to draw up the statics for planning permission and later to draw the plans for constructing the shell. Here the interest is above all in the loadbearing parts of a building. All the non-loadbearing elements, even non-loadbearing walls, for example, are only significant as loads, and may not feature in the plans at all.

place whether this beam is thick or thin, weak or strong, as we are dealing with external forces that do not include the beam itself.

We must distinguish between external forces and the internal forces operating in the beam itself. For example, how great is the bending force in the roof beam exerted by the roof construction it supports? This bending moment is one of the internal forces that will be explained in the corresponding chapter.

Actions

Everything that can affect a structural element is called an action. Actions are usually forces with different causes. Forces that affect structural elements mechanically are also called loads.

Loads

Loads affect structural elements from the outside, and we must distinguish between them and the reaction forces explained in the subsection Support forces. Loads are divided into various categories. We distinguish between point, line and area loads, according to the degree of abstraction of the statical system. › Fig. 4

In addition, we distinguish between constant, variable and extraordinary actions, in relation to the duration of the action.

Permanent loads

Constant action includes, above all, the weight forces of the structural elements, called permanent loads.

Working loads

The working loads include the variable actions wind, snow and ice loads. Working loads have to be planned in at standard levels for the building's intended use. The most important are the vertical working loads that must be worked out for floors. Whether the rooms are for homes, offices, meeting rooms or some other purpose, they must be given an appropriate working load value as an area load. Largely horizontally applied loads also have to be taken into account, such as loads on railings and parapets, braking, acceleration and collision loads for vehicles, dynamic loads for machines, and earthquake loads. The size of these loads is fixed in national standards, which give them in tables. › Appendix, Literature

Assumed loads

After using the statical system to explain how the structure functions, the next step is to determine the actions. All the acting forces must be identified, assigned a value and added together. They are generally related to a metre or square metre of the structural element. Loads acting obliquely are usually divided into a horizontal and a vertical element.

Vertical load
Horizontal load

For further calculations we distinguish between vertical loads, horizontal loads and torque.

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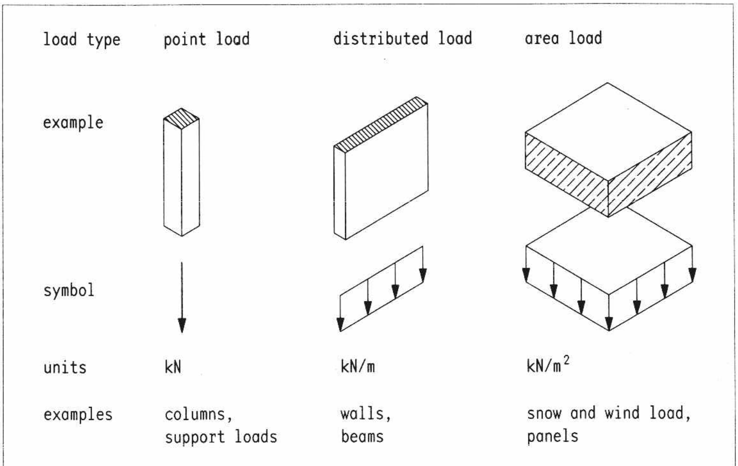

Fig.4:
Types of load: point, line and area load

Load absorption area

Load absorption area describes the particular reference area for loads on a structural element. It is part of an overall surface whose load is being dissipated to a certain structural element. It relates to the nature and span of a structure.

Example: The beams of a timber beam floor are 80 cm apart. Which part of the floor is acting on an individual beam? The load absorption area extends from the middle of the space between the beams on the left-hand side to the middle of the space on the right-hand side, twice 40 cm. So overall it is again 80 cm wide. › Fig. 5 This is a simple example, but determining

\\Important:
Loads acting vertically per square metre in a structural element: dead weight, working loads for floors, stairs, balconies
Acting vertically per square floor plan metre: snow load
Acting at right angles to the area of the structural element: wind load
Generally acting horizontally: loads on parapets and railings, braking and acceleration loads, collision loads from vehicles, earthquake loads

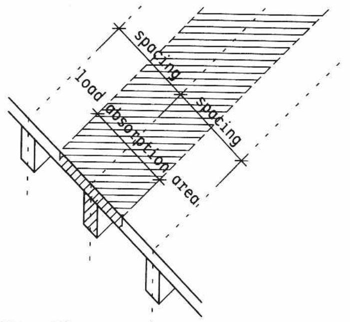

Fig. 5:
Load absorption area

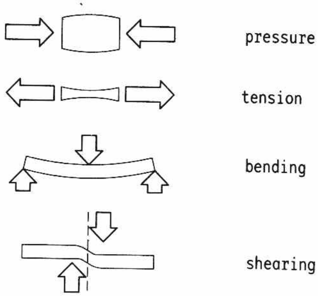

Fig. 6:
Forms of force action

the load absorption area can be more complicated according to the particular structural element.

Force action forms

So far we have considered loads and their magnitude, but how a load, or more generally a force, acts on a structural element is also important. Here we distinguish between the following action forms:

- Compression: one stone lies on top of another, exerting pressure on it.
- Tension: tensile load is most clearly explained using the example of a rope, which can absorb only tensile forces.
- Bending: a beam is fixed at both ends and then loaded from above. It sags, i.e. it is subject to a bending load.
- Shearing: this load is explained by the way a pair of household scissors loads paper to cut it. Two forces work on each other slightly offset and transversely to the structural element. This load often acts on connecting devices such as screws. › Fig. 6

Supports

Points of contact between structural elements at which forces are transmitted are called supports. A simple example is a ceiling beam supported on masonry. The beam has its support on the crown of the wall. In building the idea of the support is somewhat broader, and covers many different points of contact between structural elements. For example, when a flagpole is fixed into the ground or a steel beam is connected to a steel

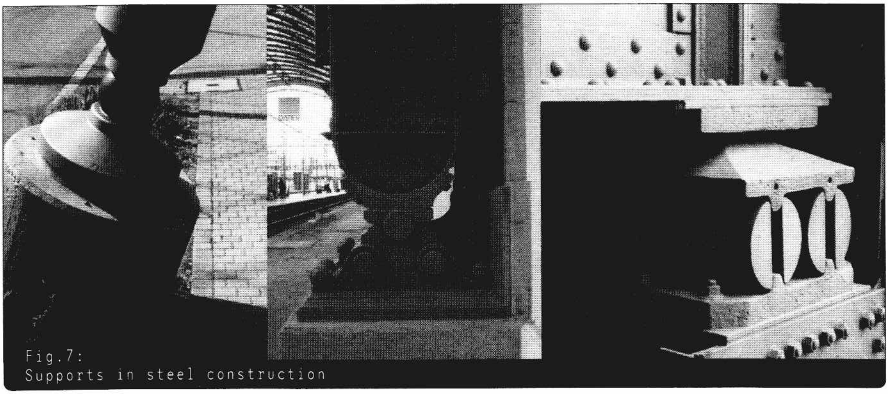

Fig. 7:
Supports in steel construction

column, this is also called a support. In terms of structural engineering they differ primarily in the forces that they can dissipate.

It is very easy to look at the different forms of supports in old steel bridges. Large bridge girders are supported on very small points or narrow strips. This means that the girders can deflect without interference from the supports, which are then known as articulated supports. These are used on one side of the bridge, while those on the other side are additionally supported by steel rollers.

Expansion bearings

When the bridge girders expand with heat, the supports move on these rollers in order to compensate for the difference in length. Bearings of this kind can absorb the vertical forces affecting the bridge, but do not resist horizontal forces such as those caused by expansion movement as a result of temperature change, and they do not prevent the girders from deflecting either. For this reason they are called expansion bearings.

Fixed, articulated bearings

These supports are not on rollers and thus transfer horizontal as well as vertical forces. They are known as fixed bearings or simply articulations.

Restraint

What happens to the above-mentioned flagpole fixed into the ground? Its anchorage can transfer vertical and horizontal forces from the mast into the ground, and thus also prevent the mast from tipping over – a turning movement around the support. A support of this kind is called a restraint. › Fig. 8

We distinguish between three forms of support:

_ Simple supports can dissipate forces from one direction only. They slide and are articulated.

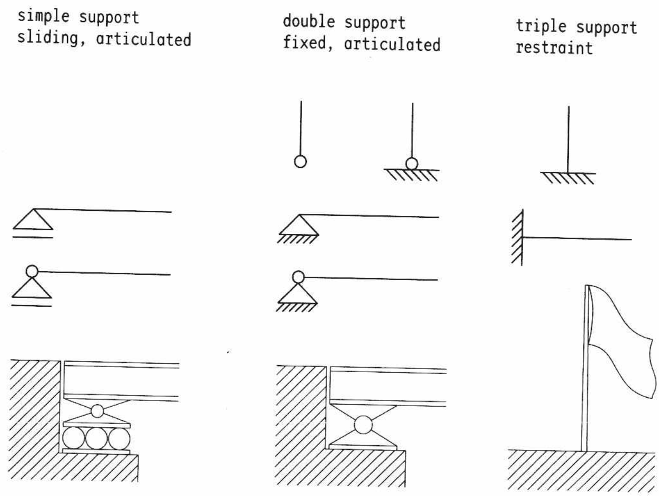

Fig.8:
The three types of support, the different ways of representing them in statical systems and examples

- Double supports can absorb forces from several directions. They are fixed and articulated.
- Restraints are triple supports and can absorb forces from different directions, as well as moments.

The correct choice of support is very important in construction, and must therefore be represented in statical systems. › Chapter Statical systems

Support forces

Let us assume that a beam is supported on a spiral spring rather than masonry. The spring is compressed by the load from the beam, thus creating a counter-force to the load that the beam exerts.

Support reaction

This force is called support reaction. › Fig. 9 If the beam does not move, the reaction force of the spring is exactly the same as the force exerted by the beam. Put simply: action equals reaction. › Fig. 10 It is not possible to see this in the masonry that usually provides support, but it is compressed just like the spring, so that it can generate the support reaction force.

When calculating a construction it is necessary to know the magnitude of the forces that the supports have to apply to support the structural element above them. The support forces are therefore always calculated