



UNIVERSITY OF TEHRAN

TEHRAN - IRAN

پست‌فایل



سیستم‌های ساختمانی

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Contemporary Structural Systems

Study of the structural systems, materials, and technology of contemporary buildings.

The influence of structural systems on the architectural forms.

Contemporary scientific developments in architectural engineering.

The influence of structural systems on today's architecture.

Introduction to the evolution of construction techniques and structural methods.

structural economy. Having the structural parts bigger than they need to be wastes material and demands that the structure be even bigger, to carry its own superfluous weight – a vicious circle that is ever more critical as scale increases. For instance, if you spanned a wooden metre rule across a gap it would be stiff and could carry a load much greater than its own weight. But if you increased all the dimensions a hundredfold, creating a plank spanning 100 m, the plank would sag and break under its weight alone. This is called *scale effect*. Suppose a 1 cm cube is increased in size to a 2 cm cube, and then to a 3 cm cube. The area of a cross-sectional slice goes up in the ratio 1 : 4 : 9, but the volume goes up in the ratio 1 : 8 : 27. Volume increases faster than cross-section, so to speak. As we increase the plank size, the volume and, hence, weight, soon outstrip the ability of the cross-sectional area, i.e. the plank's 'thickness', to cope. Weight overtakes strength. In nature, it is the reason why spiders have thin legs and elephants have fat ones. In building structure, it is the reason why a room can be economically spanned by a wooden joist, while the factory roof-span needs, say, an open-web truss, and a long river span, the ultimate efficiency of a lightweight suspension bridge.

But stress calculations do not define the shape of structure, they simply allow an exactness of sizing so that available strength is tailored to the loads with maximum economy, always allowing a known margin of safety. Exactness checks and trims the idea, it gets it right the first time, but we do not need the same exactness to understand the idea. The vaulted roofs of Sydney Opera House needed computers to solve the structural problems they posed and yet their final shape reflects the first idea of an architect watching the sails of yachts in a bay.

THE ARCHITECTURE OF COMPRESSION

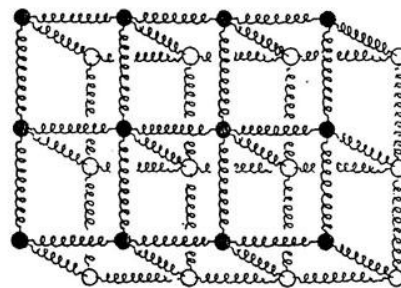
As soon as man learnt to pile up stones for shelter, he started to play the compression game. Stone is strong under compression but pulls apart fairly easily under tension and, moreover, stones in a wall lock together under compression but under tension can pull apart at the joints. The need to keep stones or bricks, or other blocks, under compression has influenced the shape of every masonry building ever built.

HOW MATERIALS RESIST LOAD – THE WALL

Think of just one stone at the base of a wall. It must carry its share of the weight of the stones above – the wall's *deadload* – and so must 'press up' as much as that weight is pressing down. If it pressed too little, the wall would squash, if it pressed too much, the stones above would presumably fly away. But it presses just the right amount and the system is stable. And, if someone sits on the wall, a minute part of their added *liveload* must reach the stone and the stone obliges by pushing up that fraction more. The system is still stable. But how does the stone and, for that matter, the earth below it, always know how much to push up? The answer to this apparently silly question has only been known for the past few decades, in fact: it lies at the microscopic scale of the atom and sheds light on the whole nature of structural strength.

The molecular 'grid'

The component molecules of every substance are connected by forces which, for our purposes, can be regarded as magnetic springs. The rather notional three-dimensional grid (1.2) gives the general idea. It is these springs which compress or extend when a material is squeezed or stretched – a tiny deformation often, but it is there, for nothing is ever truly rigid. Even a marble slab is like a very stiff internally-sprung mattress and will compress locally as an ant walks over it, as will the ant's feet. The world is a springy place. So, in fact, structure – materials – do not actively 'push back', but they deflect and, in doing so, find their passive reaction to loads placed upon them. You can see the deflection of a tree branch when you swing on it, and the flapping of an aircraft's wings when it hits air turbulence, and you can just about feel the sway in some tall steel-frame buildings when the wind blows strongly. Wood and steel are relatively elastic. You will not notice the sag in a stone-arch bridge when a car crosses it, nor the compression in the wall stone, but they are there.



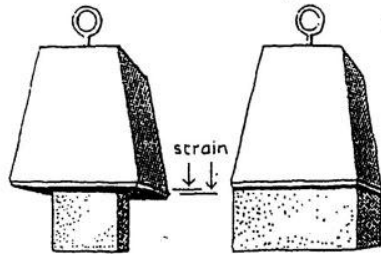
1.2 All matter is 'springy'

Stiffness and strength

However, just because one material gives more, i.e. is more elastic than another, it is not necessarily weaker. A brittle dry twig will snap under load long before a green springy one, although the green one may, at first, have seemed the weaker. So *stiffness* is not the same as *strength*, although both qualities are needed in the materials we use for building. We will come back to this distinction later, particularly when talking of beams and frames.

Stress and strain

If the load on a stone is two tonnes, the stone must react with two tonnes' force, but without knowing the bearing area of the stone, we cannot tell how hard the material is having to work (1.3). Instead, we must think in terms of *stress*. If the stone's bearing area is 1000 square centimetres (cm²), then the compressive stress in the material is 2 tonnes (or 2000 kilograms) force per 1000 cm² – i.e. 2 kgf/cm². The units do not matter. The same information could be given in pounds force per square inch or dynes per square centimetre, for stress is simply a ratio of load to bearing area – much more useful. Strain is the linear distortion in response to

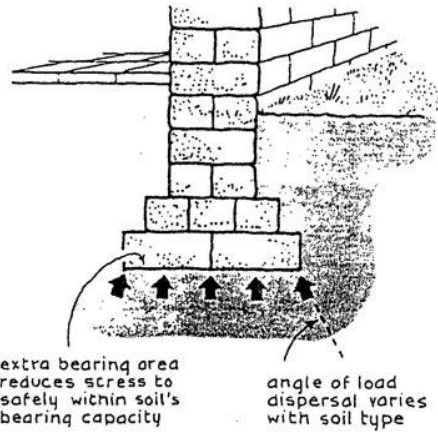


'stress' is load divided by area, a measure of how hard the material is having to work. 'Strain', here an imperceptible compression, is deformation per unit length

quadrupling the stone's bearing area, quarters the stress and, in proportion, the strain

1.3 Load and bearing area, stress and strain

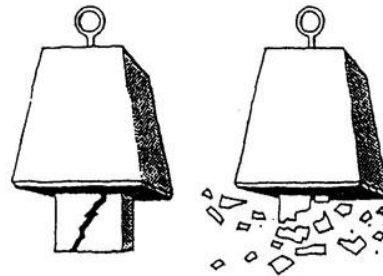
stress. Nails are pointed so that the impact load of the hammer is concentrated on a tiny area of the material pierced – maximum stress and strain to yield point, for minimum load. Obviously, the same load that produces a high stress in a thin wall will produce a safer, lower stress in a thick one. Foundations are made wider than walls to reduce compressive stresses to a level that weaker subsoils can bear. In contrast to the nail, the foundation (1.4) spreads the load, preventing the wall from punching through the ground, which would cause settlement and eventual building collapse.



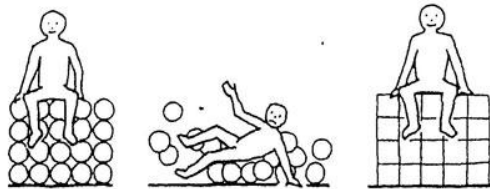
1.4 Foundation, i.e. increased bearing, reduces soil stress

Shear

It may, at first, be hard to see how compressive stress could ever crush stone, instead of just compressing the atoms more tightly together. In fact, what happens at the point of failure is that the stone squashes out sideways, rather as clay will under the weight of a modeller's hand, except that stone, being more brittle than clay, fails by cracking or even a virtually explosive release (1.5). The compressed material is actually failing



1.5 Compression induces inner tensions and eventual failure by shear



1.6 Masonry is more stable and strong if well fitted . . .