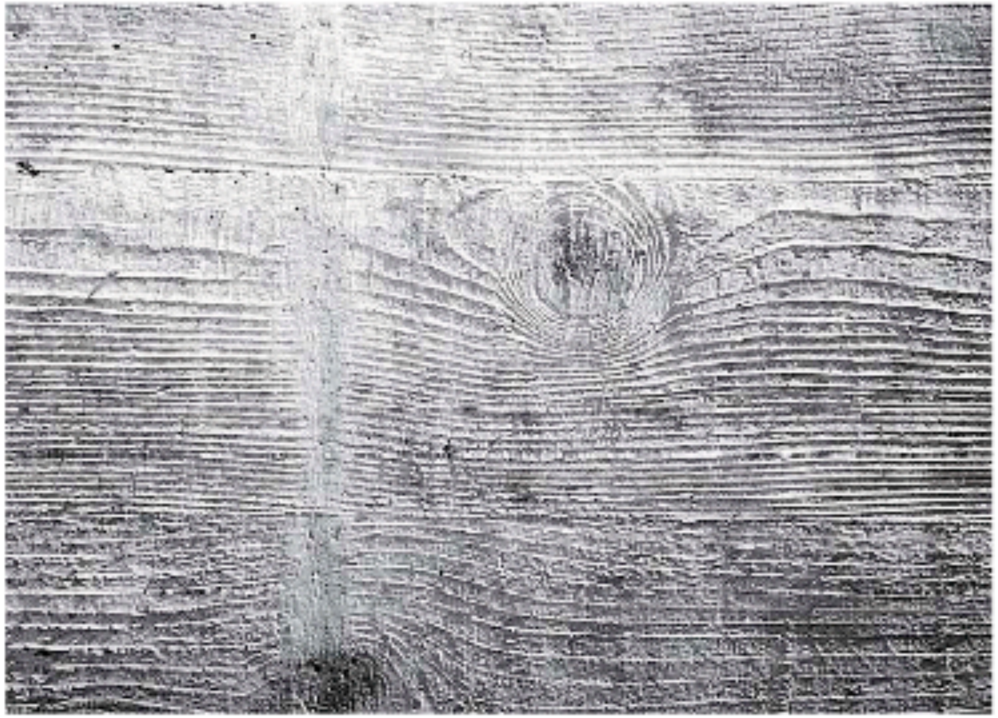


architektura material beton cegla drewno stal

The perception of architectural space

Tectonics — Form — Space

Physics of the space

Material
- Mass
- Massiveness
- Heaviness
- Lightness
- Hardness
- Softness
- Filigreeness
- Compactness
- Transparency

Boundaries
- Opaque
- Transparent
- Translucent
- Surface
  - flat
  - sculpted

Structure
- Tectonic, divided
- Non-tectonic, homogeneous
  - amorphous, "without form"
  - monolithic – layered
  - hierarchical – chaotic
  - non-directional – directional

Figuration
- Euclidian
- Mathematical – rational
- Geometrical
  - abstract
  - concrete
- Organic
  - biomorphic
  - intuitive

Dimension
- Scale
  - broadness
  - narrowness
  - tallness
  - depth

Physiology of the perception

Sight
- Light
- Colour
- Materiality
  - abstract
  - concrete

Touch
- Texture
  - rough
  - fine, smooth
  - fibrous

Feeling
- Moist
- Dry
- Hot
- Cold

Odorous
- Smell
- Agreeable
- "neutral"

Sense of time
- Movement
- Permanence
- Scale effect (feeling)
  - "broadness"
  - "narrowness"
  - "depth"

Hearing
- Noise
- Resonance, reverberation
- Echo
- Muffled
- Harsh

↓

Thinking
Interpreting
Synthesising

Beton eksponowany

plaszczyzna

szalunek

monolit

hybryda

konstrukcja szkieletowa

swobodny

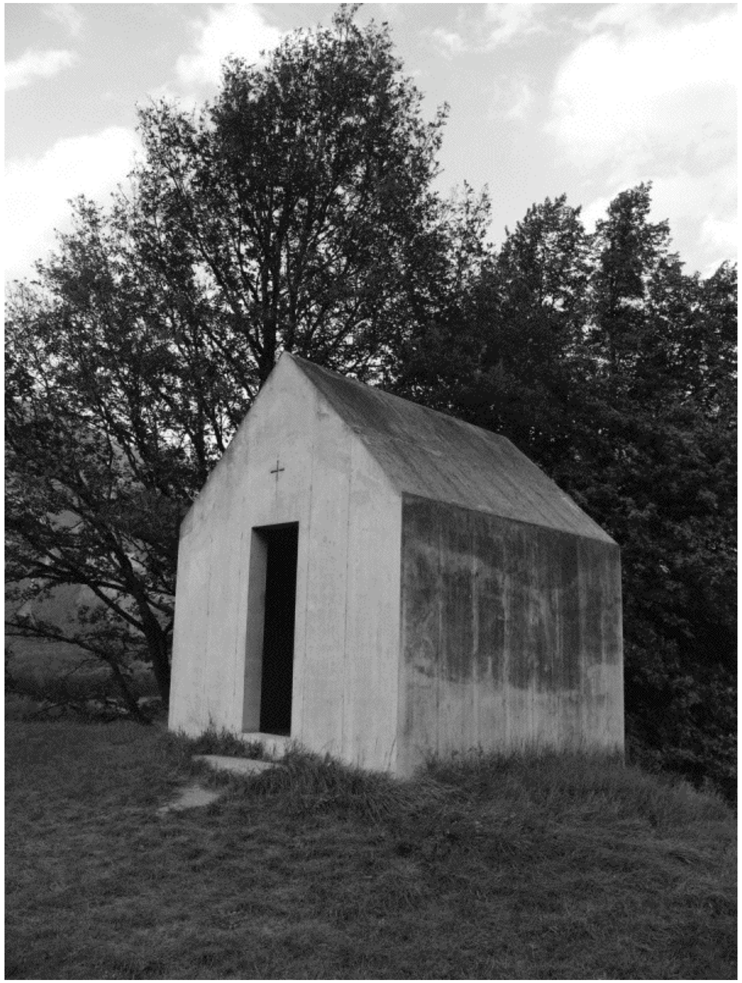
konstrukcja betonowa

elementy konstrukcji linearnej

systemy z elementow linearnych

struktura slupowo plytowa

systemy struktur plytowych



"Beauty is a splendour of the truth"

Mies van der Rohe

"Ornamentetions deveps from tectonics interface"

Louis Kahn

Beton eksponowany

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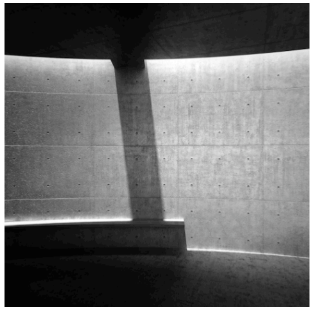



Beton eksponowany

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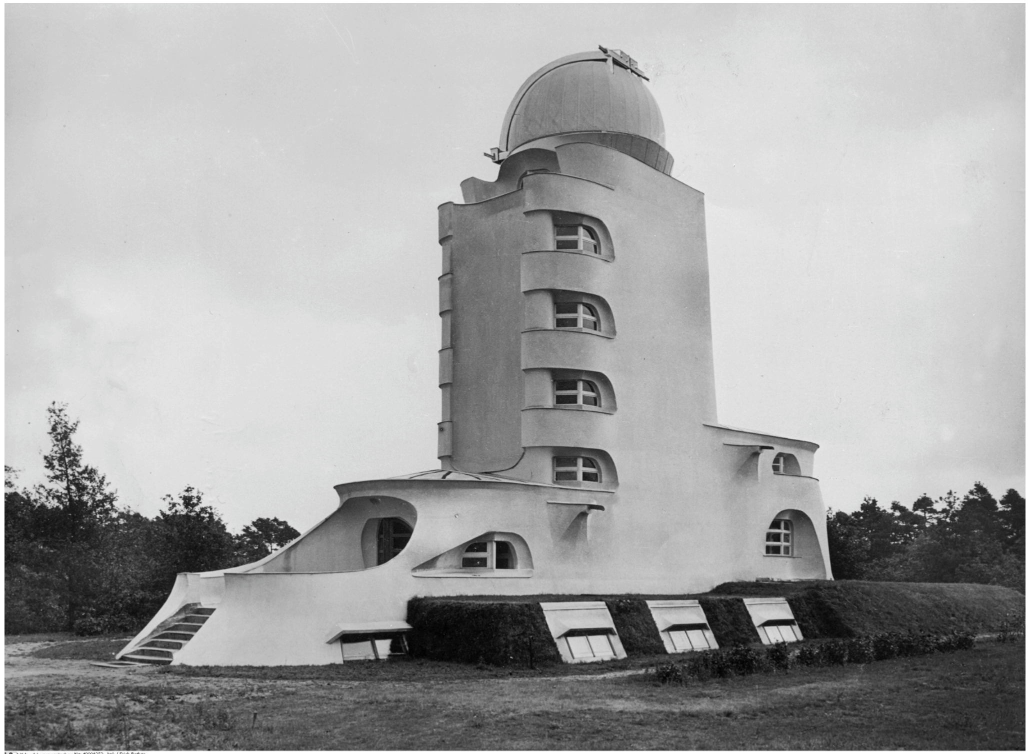

bildarchiv preussischer kulturbesitz No: 40001252, bpk / Erich Bethge
Einsteinturm (Astrophysikalisches Observatorium)

Beton eksponowany

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3eams

3eams are structural members primarily loaded in bend-ng. The magnitude of the bending moments influences :he dimensions (depth, slenderness, shape of cross-sec-:ion) and the type of reinforcement (conventional or pre-stressed). Structural beams occur in various forms – with ends fixed, simply-supported, continuous, above the floor (upstand), below the floor (downstand) and in frames.

The conventional rectangular beam is rather rare in n situ concrete because it is frequently cast monolithi-cally with a floor slab (T- or L-beam) and then functions together with this. If the compression zone in such a beam s wholly within the slab, the depth of the beam is less than that of a standard rectangular member.

Abb. 52: Precast concrete beams in a framed building
Angelo Mangiarotti: industrial building, Bussolengo Barese (I), 1982

Owing to the cost of formwork, adjusting the beam sizes to suit the loads exactly is only advisable in precast-ng works, where forms can be reused economically. For example, the depth of a beam can be designed to track the bending moment diagram, the width can be varied n line with the shear force diagram. On large spans the cross-section can therefore be optimised to save material and hence weight and the beam constructed as a girder or trussed beam (trussing above or below).

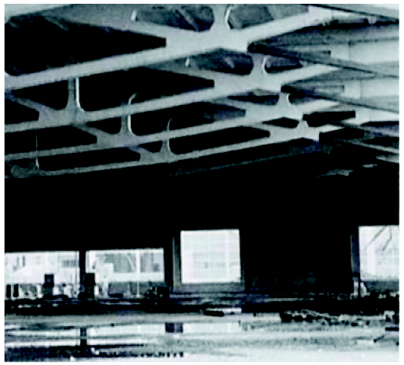

Abb. 53: Trussed beams
Factory building, Lustenau (A)

Columns

The function of a column is to transfer the vertical loads to the foundation. Carrying horizontal loads simultaneously (shear forces due to wind, earthquakes) calls for corre-spondingly large cross-sections.

Thanks to the mouldability of concrete, the shape of the cross-section can be chosen virtually at will, but the cost of the formwork and the fixing of the reinforcement place practical limits on this. The "perfect" form is circular because the flexural strength is the same in all directions. However, in situ concrete columns are frequently square or rectangular to make the formwork easier and less costly. An in situ column must be at least 200 mm wide, a precast column 150 mm. The latter are cast horizontally, the surfaces are trowelled smooth or given subsequent treatment depending on the quality required. Spin-cast-ing can be used for both square and round precast con-crete columns. In this method the form is filled, closed and rotated to compact the concrete. This results in an absolutely smooth and consistent surface finish.

Slender columns loaded in compression are at risk of buckling; in other words, the more slender a column is, the lower is its permissible load (buckling load). The length of a column is therefore governed by its relation-ship to its smallest cross-section dimension. The buckling length depends on the type of support at each end, and maybe shorter (= high buckling load) or longer (= low buckling load) than the actual length of the column. Nor-mally, however, columns with pinned ends are met with in superstructure works.

Abb. 54: Spun-concrete columns, connected to reinforced concrete roof via steel web plates. Axel Schultes: art gallery, Bonn (D), 1992

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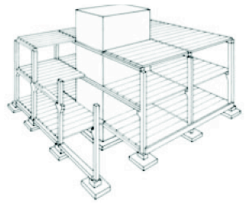

Fig. 55: Principle of a multi-storey framed building using precast concrete columns, beams and floor elements. The in situ concrete core stabilises the building by resisting the horizontal forces.

Arches

The arch is a curved linear member. Irrespective of the loading, the arch is subject to axial compression and bending. But if the arch has an accordingly favourable form, it can carry a uniformly distributed load exclusively by way of axial compression (no bending). The "perfect" form for an arch is the inverse of a spanned rope, which deforms only under the action of its own weight (catenary curve).

In reinforced concrete construction the arch is frequently used as the loadbearing element for long-span bridges. Whereas in times gone by – when the relationship between cost of labour and cost of materials was totally different – in situ concrete arches were also used in buildings for spanning over large areas (e.g. single-storey sheds), they are seldom met with today and then only in precast form.

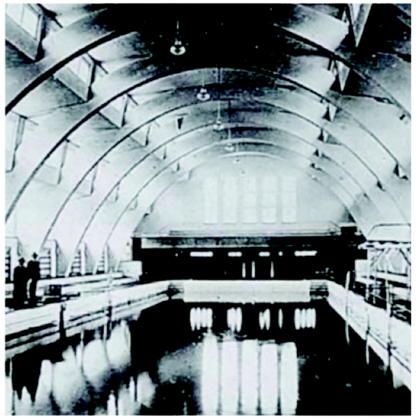

Abb. 56: Fixed-based arch
Stuttgart Building Department (F. Fischle, F. Cloos): swimming pool, Heslach (D), 1929

Portal frames

Connecting horizontal and vertical linear members together rigidly produces a portal frame. The vertical members are sometimes known as legs, the horizontal ones as rafters. Owing to the bending moments at the corners it should be ensured that the cross-section of the legs is greater than that of conventional columns carrying concentric loads.

The portal frame represents a braced, stable system in the plane of the frame which can carry both vertical and horizontal loads and thus assume the function of a bracing "plate" in a building. Inherently stable portal frame systems are particularly economic in single- and two-storey buildings, but plates in the form of slabs and walls are the preferred form of bracing in multi-storey buildings.

Abb. 57: Fixed-based portal frame
Auguste + Gustave Perret: Ponthieu garage, Paris (F), 1906

Frames

Frames consist of prefabricated loadbearing elements such as columns, beams and floor slabs. In conjunction with fixed columns, such systems can form a rigid framework.

Horizontal forces are resisted by fixed columns (acting as vertical cantilevers) in single- and two-storey buildings, whereas in multi-storey structures the horizontal loads are transferred to the foundations by vertical wall plates (shear walls).

A frame provides maximum flexibility with respect to utilisation requirements because the loadbearing function is essentially separate from the other building functions.

Abb. 58: Use of precast concrete elements and glass
Hermann Hertzberger: extension to LinMij plant building, Amsterdam (NL), 1964

Beton eksponowany

plaszczyzna

szalunek

monolit

hybryda

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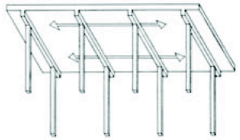

Fig. 59: One-way-spanning continuous slab

Slab depth for one-way span:

cantilever slab:	h/l = 1/12
simply-supported slab:	h/l = 1/25
continuous slab (end span):	h/l = 1/30
continuous slab (other spans):	h/l = 1/35

Slab depth for two-way span:

simply-supported slab	h/l = 1/30
continuous slab (corner span):	h/l = 1/40
continuous slab (other spans):	h/l = 1/45
min. slab thickness (h) (fire protection and sound insulation)	180 to 200 mm

Economic spans:

one-way-span slabs:	l < 6 to 7 m
two-way-span slabs:	l < 8

Fig. 60: Ribbed slab

Structural depth of ribbed slabs:

overall depth (h)	h = l/20 to l/35
clear spacing of ribs (s)	s = < 2h
slab depth (h_p)	h_p > 50–80 mm
or 0.1 x rib spacing (centre-to-centre)	

Economic spans:

ribbed slab	l = 7 to 12 m
prefabricated, prestressed	l = up to 18 m

Fig. 61: Flat slab

Structural depth of flat slabs:

rectangular slab (one-way span):	h/l = 1/30
square slab (two-way span):	h/l = 1/35
min. slab depth (h) (fire protection and sound insulation)	200 mm

Economic spans:

flat slab	l ≤ 8 m

Slabs

Concrete slabs are loadbearing elements loaded perpendicular to their plane and primarily subjected to bending. We distinguish between one-way-spanning and two-way-spanning slabs. Examples of one-way-span slabs are cantilever slabs or those spanning between two walls placed opposite each other. The ideal two-way-span slab is square on plan and supported on all four sides. The loads are carried in (at least) two directions and the structural depth of the slab can be reduced accordingly. The ratio of slab depth to span depends on the form of support (cantilever, simply-supported, continuous).

On longer spans the slabs would be so heavy that they are resolved into lighter flooring systems. Flooring systems for buildings are divided into those with linear supports such as ribbed slabs (one-way span) and waffle slabs (two-way span), and those with discrete supports such as flat slabs (with or without column heads).

Compared with solid slabs, ribbed slabs and waffle slabs supported on walls or downstand beams have the advantage of being much lighter (reduction of material in tension zone), but their formwork is more elaborate (prefabricated formwork elements are essential).

Slabs supported on individual columns carry the loads entirely by means of the slab alone, without any beams or ribs. The high stresses around the columns calls for appropriate reinforcement or additional strengthening in

Fig. 62: Basement garage, c. 1960
Ribbed slab

the form of (flared) column heads. The structural depth of a flat slab is small compared to the resolved flooring systems. But concentrating the bending moments and shear forces around the columns does bring with it the risk of punching shear. Increasing the bearing area and the thickness of the slab at this point and including reinforcement or steel “studrails” to withstand the punching shear will guarantee the load-carrying capacity around the columns. Today, the flared column heads and columns are usually produced in precast concrete to optimise operations on site.

Abb. 63: Flared column heads transfer the loads from the upper floors into the columns.
Robert Maillart: warehouse, Giesshübelstrasse, Zurich (CH), 1910

Plates

Plates are used in buildings in the form of walls. They function as loadbearing and/or enclosing components. In contrast to a slab, which is primarily subjected to bending, a plate carries forces in its plane and therefore has to resist axial forces.

We distinguish between plates supported along their full length (linear supports), which can transfer the vertical loads directly, and those supported at individual points similar to beams, which transfer the loads to these supports (deep beams).

Owing to their high stiffness, plates are used for resisting horizontal forces (bracing) and as transfer structures.

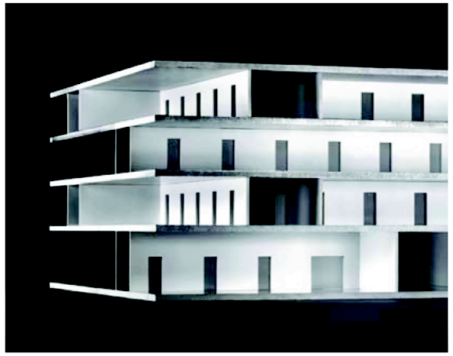

Abb. 64: Model of loadbearing structure with shear walls offset or rotated through 90°
Morger & Degelo: Reinach community centre, Basel (CH), 1997–2000

Beton eksponowany

plaszczyzna

szalunek

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hybryda

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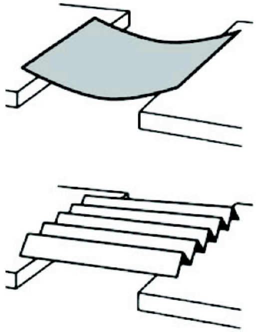
systemy z elementow linearnych

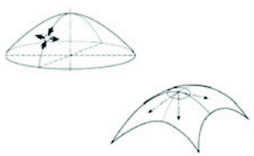
struktura slupowo plytowa

systemy struktur plytowych



ig. 65: Stiffening a piece of paper by folding it the principle of the folded plate

ig. 66: Forms with single curvature



ig. 67: Forms with double curvature

Folded plates

If you place two pieces of paper on two supports, fold one concertina fashion and leave the other unfolded, you will notice that the unfolded sheet deforms under its own weight, but the folded piece remain stable. This is the principle of the folded plate.

Folded plates are inclined, flat surfaces with shear-resistant connections along the edges (the "folds"). The forces are carried by slab and plate action. Whereas slabs are loaded perpendicular to their plane and primarily in bending, the considerably stiffer plate with its higher load-carrying capacity can accommodate forces in its plane and transfer these to the supports.

Folded plates therefore enable large areas to be spanned without intermediate columns; they are used mainly for long-span roof structures.

Abb. 68: Folded plate roof supported on Y-columns
Hans Hofmann: waterworks, Birsfelden, Basel (CH), 1953/54

Shells

Shells are three-dimensional, thin-wall structures. Owing to the mouldability of reinforced concrete and prestressed concrete, the majority of shells have been built in these materials.

The form not only governs the architectural appearance but also determines the loadbearing behaviour. Like with an arch there is also a "perfect" form for a shell structure. This is the case when, subject only to self-weight, the so-called membrane tension state is reached, i.e. exclusively axial and shear forces in the plane of the shell throughout. Consequently, a shell

Abb. 70: Shell designed as a fluid form
Heinz Isler (with P. Wirz, architect): Kilcher factory, Recherswil (CH), 1965

structure can have a slenderness ratio (ratio of span to depth) of 500 or more.

The structural engineer Heinz Isler developed three form-finding principles by means of various experiments:

- membrane form: subject to compression from inside
- suspended form: hanging fabric subject to self-weight (free forms)
- fluid form: escaping, solidified foam

The formwork requirements for a shell structure are relatively high. Three different methods of construction are available for reinforced concrete shells:

- concreting over centering
- the use of precast elements
- the use of pneumatic formwork

Of these three, centering is the one most widely used in practice.

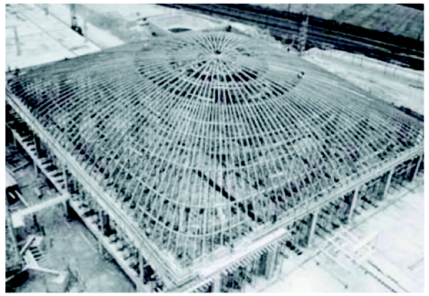


Abb. 71: Shell designed as membrane form, built over centering
Heinz Isler (with VSK and Frei Architekten): COOP warehouse, Olten (CH), 1960

Beton eksponowany

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Element (loadbearing)	**Span** l (m)	**h*/l**
Slab on walls	– 10 m	1/24 – 1/40
Flat slab on columns, conventional reinforcement	6 – 12 m	1/16 – 1/24
Flat slab with flared column heads	8 – 12 m	1/20 – 1/30
Slab with downstand beams, conventional reinforcement	8 – 20 m	1/12 – 1/16
Waffle slab	10 – 20 m	1/14 – 1/20

*Prestressing can reduce the structural depth of the slab by up to about 30%.