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Sustainable Urban Rehabilitation in Europe

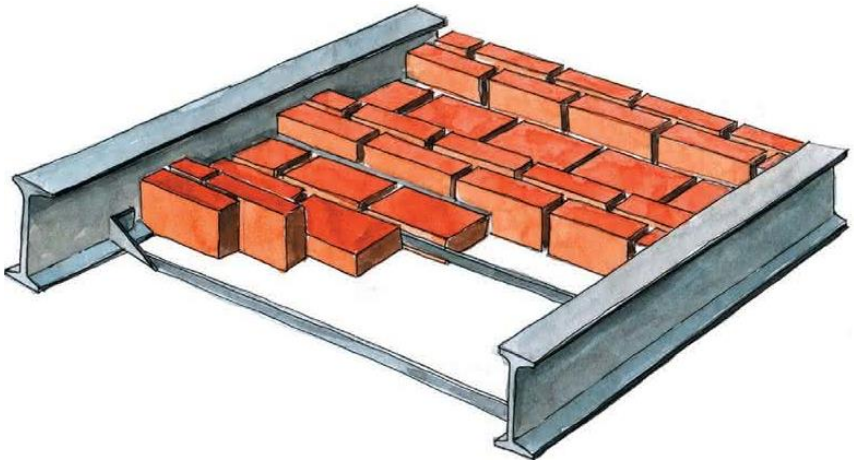
GENERAL BUILDING ENGINEERING

MASSIVE CEILINGS IN HISTORIC BUILDINGS

Erasmus+

FUNCTIONS OF CEILINGS

Ceilings are horizontal divisions dividing buildings into storeys. They consist of a supporting structure and - depending on the function they perform - from the floor, ceiling and insulation. The supporting structure transfers the own weight of the ceiling, service loads and weight of partition walls. It is also responsible for stiffening the building in a horizontal direction, increasing spatial stiffness and protecting individual storeys against heat and sound penetration. Floating floors commonly used, suspended ceilings, damping layers under the floor are intended to improve acoustic insulation. [1]

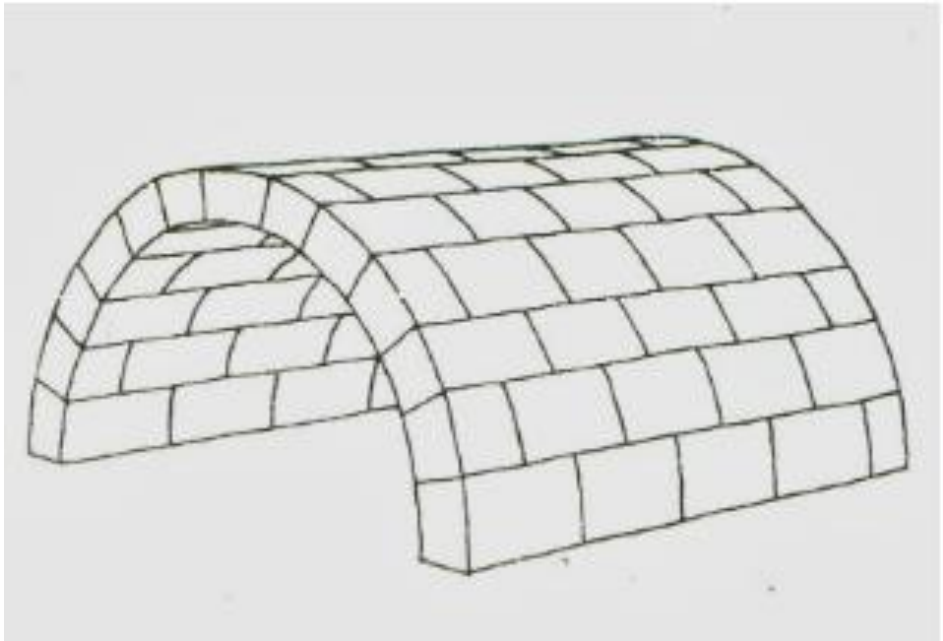


Klein Ceiling [1]

FUNCTIONAL FORMS OF FOUNDATIONS

The barrel vaults have been used since the early civilizations, in Ancient Egypt and Mesopotamia, later disseminated by the Persians and Romans. After the fall of the Roman Empire for several centuries only a few buildings with barrel vaults were built, and their return took place in the Roman period.

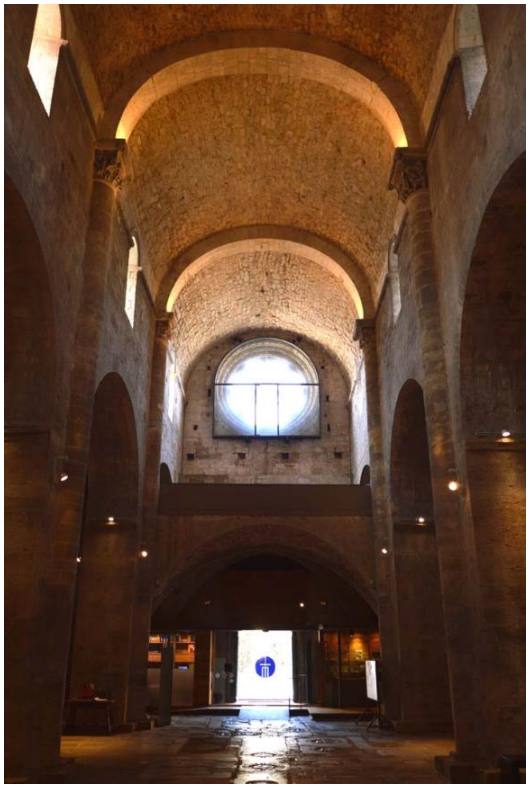
The barrel vaults (barrel) are in the shape of a half-lying cylinder, cut along a horizontal plane, made of stone blades in the shape of a gusset. The cradle of the vault is based on longitudinal walls arranged along the axis of the vault. The walls take vertical and horizontal loads. [2]



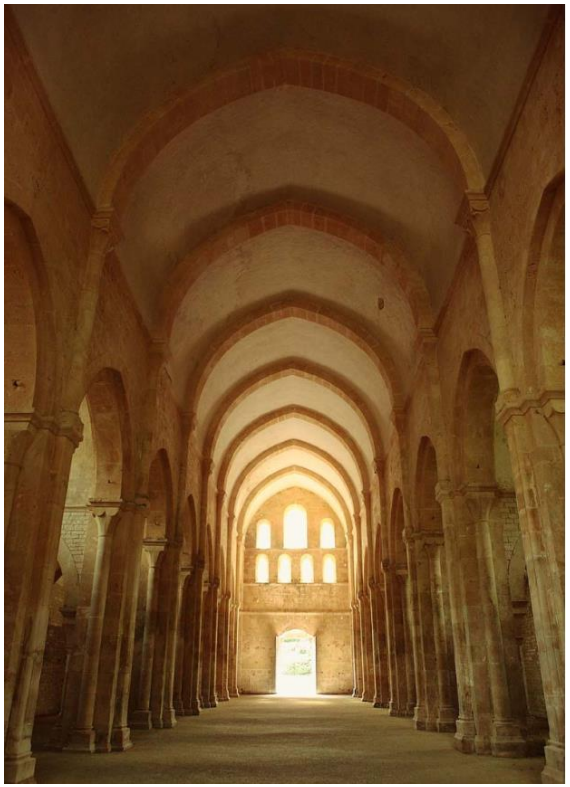
Scheme of barrel vaults [3]

FUNCTIONS OF FOUNDATIONS

The cradle vault in the collegiate church of Santa Maria in Aisna, XI / XII century, Spain [2]



The arched barrel arch in the monastic church in Fontenay, 12th century, France [2]



The barrel vault in the church of Sant Pere de Galligants, 12th century, Spain [2]

FUNCTIONS OF FOUNDATIONS

In the renaissance architecture, cradle with lunettes are very popular, allowing to light up the vaulted surface. The interiors covered with traditional barrel vaults were very dark. [3]

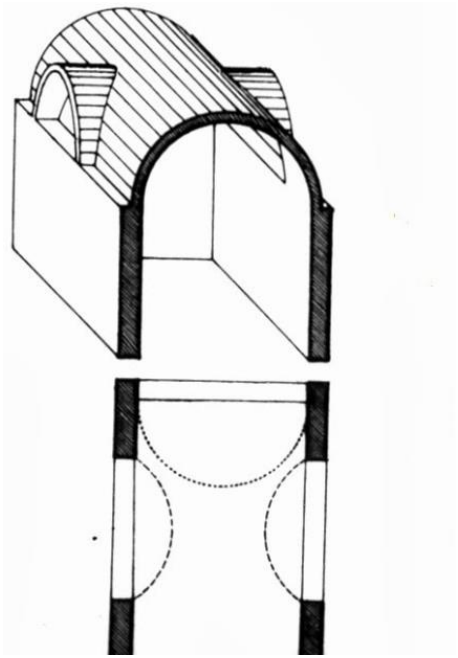


Fig Scheme of barrel vault with telescopes [3]

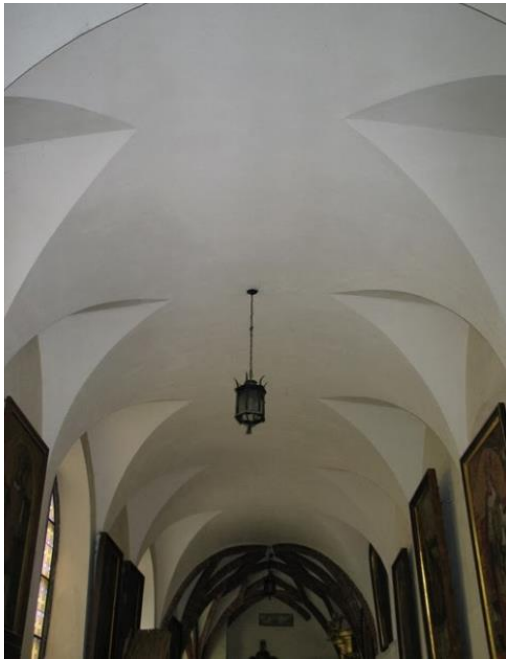


Fig. Barrel vault with lunettes [3]

BRICK CEILINGS ON STEEL BEAMS

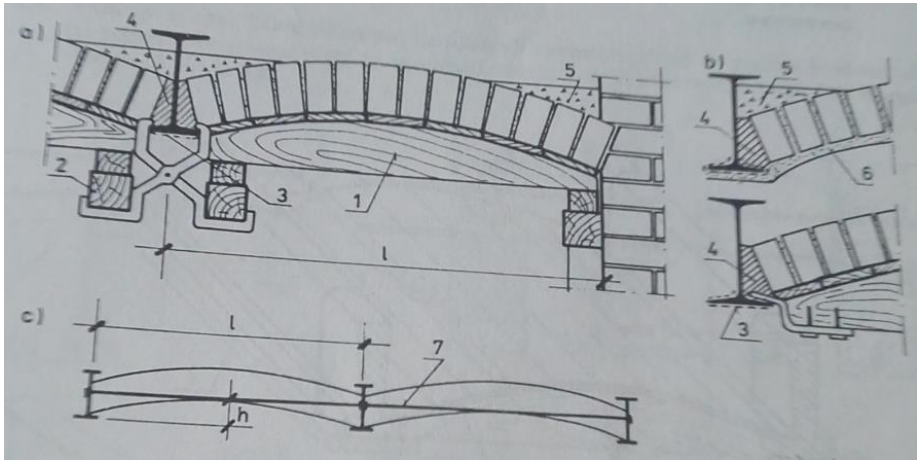
In 1888 Monier patented a ceiling with steel beams and a filling made of monolithic reinforced concrete slabs. They gained popularity only in the years 1905-1915, because in the publications from 1886 one could find the statement that "it should be considered unlikely to use steel and cement in one construction".

The first patented ceiling consisting of steel beams and fillings in the form of ceramic plates reinforced with a bedding machine was Klein's ceiling. The author of the patent is Johann Franz Kleine, mason master from Essen (Germany). The ceiling was a good alternative to wooden ceilings and quickly became one of the most-used solutions.

At the turn of the 19th and 20th centuries, ceramic vaults supported by steel beams were also made - these vaults are called staple or Prussian ones. [4]

FUNKCJONALNE ROZWIĄZANIA STROPÓW

Sectional ceilings (Prussian, basement) are made of ceramic vaults based on I-sections. Most often used as basement ceilings in residential and industrial buildings, they are currently rarely used. [4] Used in the renovation of historic structures.
Basic features of staple floors:
1) span 1.2-1.5 m (less often 2.0 m)
2) masonry for a thickness of ½ of brick, and for larger spans (more than 2.5 m), stiffening ribs with a cross-section of ½ x 1 to 1 x 1 brick, protruding above the vault - connecting, or under the vault - connection.
3) the staple vault arrow is 1/7 to 1/12, usually 1/10 of the span. [1]



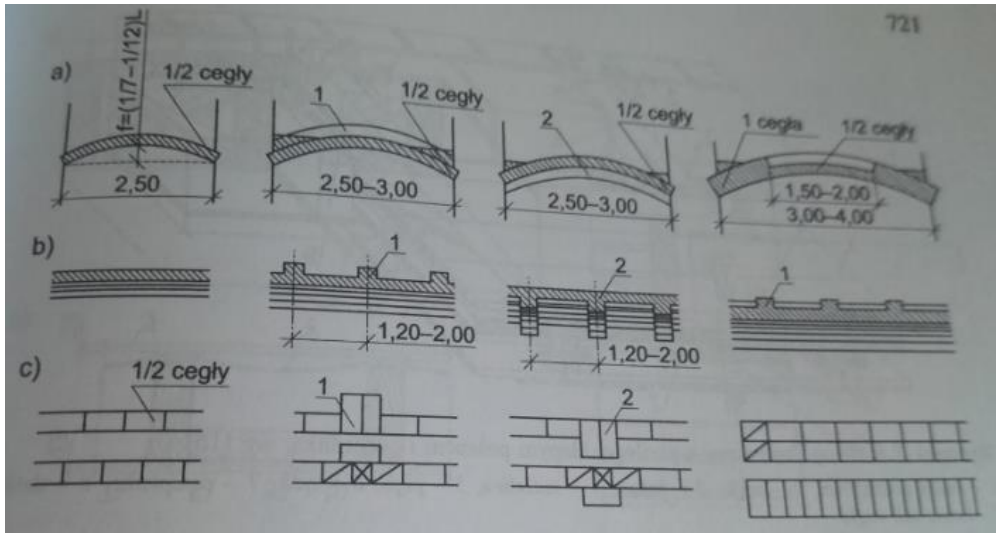
Sections of the segmental ceiling: a) in the course of execution, b) groin detail, c) steel braces connecting the beams; 1- cradle, 2-edge marker 12x12cm, 3-net, 4-concrete, 5-debris, 6-sided plaster [5]

FUNCTIONS OF FOUNDATIONS

4) most often I-beam sections with heights from 160 to 300 mm, depending on the roof span,

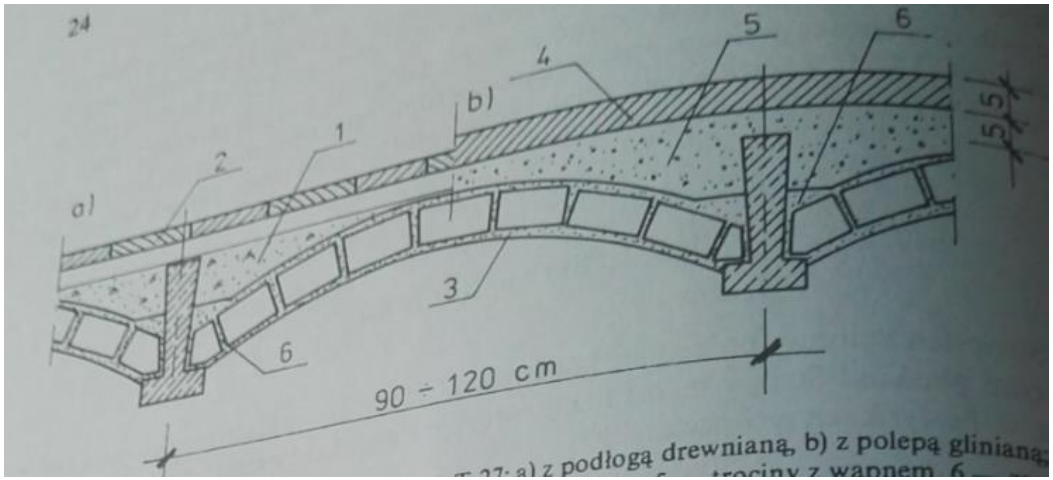
5) spacing of steel beams was usually from 1000 mm to 2000 mm, sometimes up to 3000 mm, (depended on the total ceiling load and the thickness of the ceiling)

6) in buildings with low functional loads, they were also made on reinforced concrete beams, often prefabricated T-27 beams. [4]

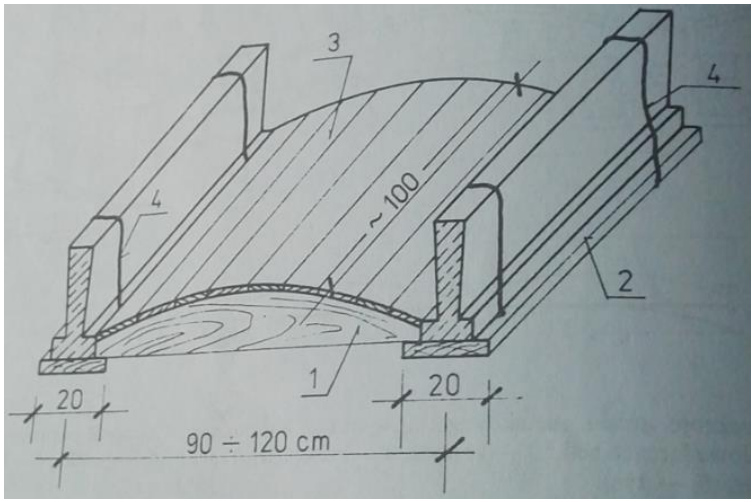


Examples of solutions of staple vaults depending on the span, a) cross-section, b) longitudinal section, c) detail of binding of common bricks; 1-connection, 2-connections [1]

FUNCTIONS OF FOUNDATIONS



Ceiling of brick with T-27 beams: a) with a wooden floor, b) with clay; 1-slag, 2-floor wooden, 3- plaster, 4- polepa, 5- sawdust with lime, 6-cement mortar [5]



Climbing of the ceiling of the sectional ceiling suspended on reinforced concrete beam T-27: 1-cradle, grub. 32 mm, 2-retaining plank thickness 32 mm, 3 boards thick 25 mm, 4-wire ϕ 2-3 mm [5]

FUNCTIONS OF FOUNDATIONS

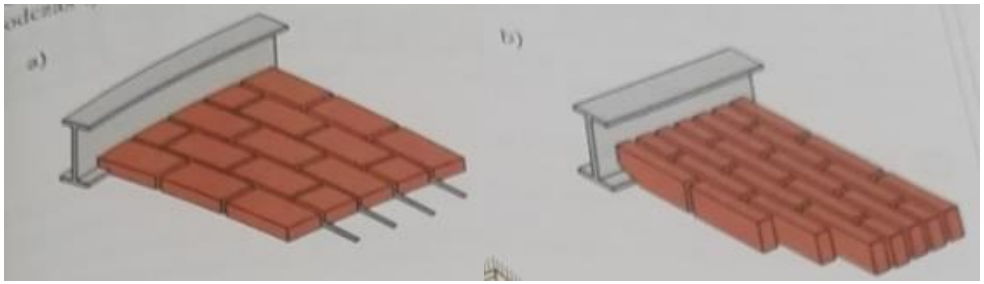
View of the segmental ceiling [4]

Segment ceiling from around 1908 [6]

FUNCTIONS OF CEILINGS

Klein ceilings, a type of brick flat ceilings, are ordinary brick or perforated boards reinforced with flat bars or round steel and bonded with cement mortar. The backrests of Klein panels are steel beams. [7]

Three types of Klein boards are used:
1) Heavy - ½ of the thickness of bricks, bricks set on a tree
2) Light-thick ½ bricks, flat bricks
3) Light-weight - ¼ of the brick reinforced with ribs, part of the bricks arranged flat, and the remaining on the tree [7]



Kinds of Klein brick slabs: a) light board made of brick flat, b) heavy slab of brick lying on the floor [8]

PRINCIPLES OF MAKING FOUNDATIONS:

1) The plates are reinforced with flat bars (banding) with a cross-section from 1x20 to 2x30 mm or rods with a diameter of usually 5.5 to 8 mm, depending on the load,

2) The bottom of the reinforcement should be located 10 mm above the bottom surface of the slab in plastered ceilings and 30 mm in ceilings not plastered,

3) Welded longitudinal welds should have a thickness of 20 mm, longitudinal non-reinforced 15 mm, transverse 10 mm,

4) In the support zone on a steel beam the making should be appropriately cut off,

5) Bricks in the tile are laid on a cement mortar of 1: 3 plastified with limestone milk,

6) In order to make it possible to make a plaster thickness of 15 mm on the board, it should be lowered 10 mm below the bottom of the steel beam,

7) The lower beam shelf should be retracted,

8) With a span of more than 5 m, Klein ceiling beams have quite large deflections, therefore it is recommended to support these beams in the half of the span during works and to top their top. [1]

FUNCTIONS OF FOUNDATIONS

Making the Klein ceiling around 1928 [6]

Klein's ceiling from underneath [6]

Renovated Klein ceiling in a historic building

Renovated Klein ceiling in a historic building

FUNCTIONAL BIOGRAPHY OF BUILDINGS

[1] praca zbiorowa pod kierunkiem dr. hab. inż. Lecha Lichołai Budownictwo ogólne, tom 3, *elementy budynków podstawy projektowania*, Arkady, Warszawa 2010

[2] https://medievalheritage.eu/pl/strona-glowna/slownik/sklepienie-kolebkowe-beczkowe

[3] http://butterfield-reignbeau.blogspot.com/2014/01/rodzaje-sklepien

[4] Drobiec Ł., Pająk Z. *Stropy z drobnowymiarowych elementów*, Wydawnictwo Politechniki Śląskiej, Gliwice 2011

[5] Byrdy C., Kram D., Korepta K., Śliwiński M. *Podstawy budownictwa, część II*, Politechnika Krakowska, Kraków 2001

[6] Nicer T. *Stropy płaskie w budowlach zabytkowych*, Budownictwo i Architektura 5 (2009) 85-100

[7] Popek M., Wapińska B. *Budownictwo ogólne*, WSiP

[8] Kozłowski M., Maj T., Popek M. *Wykonywanie i kontrolowanie robót konstrukcyjno-budowlanych*, WSiP, 2017

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