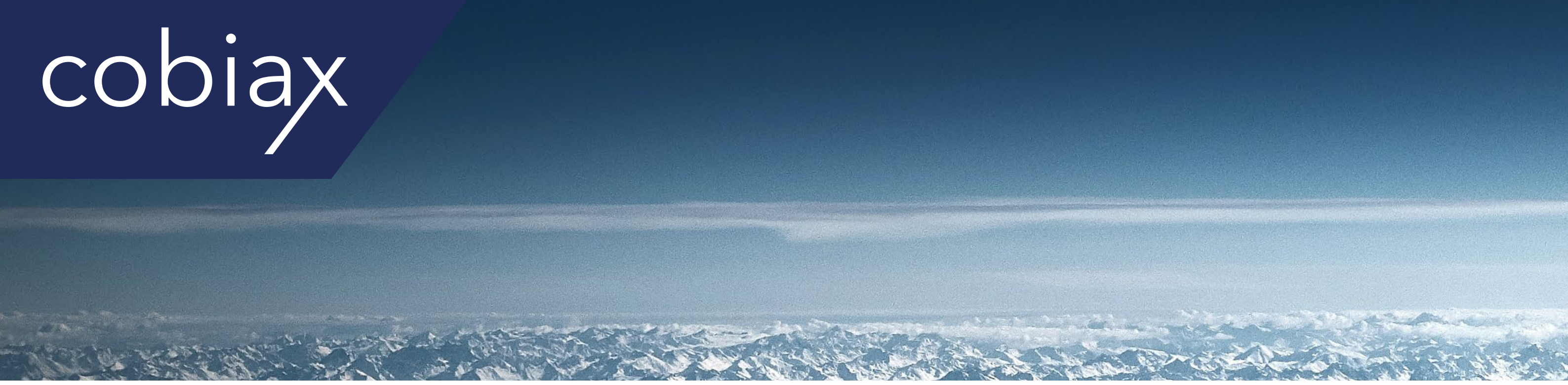
A DEEP-DIVE INTO COBIAX CLS

Technology and execution in detail.



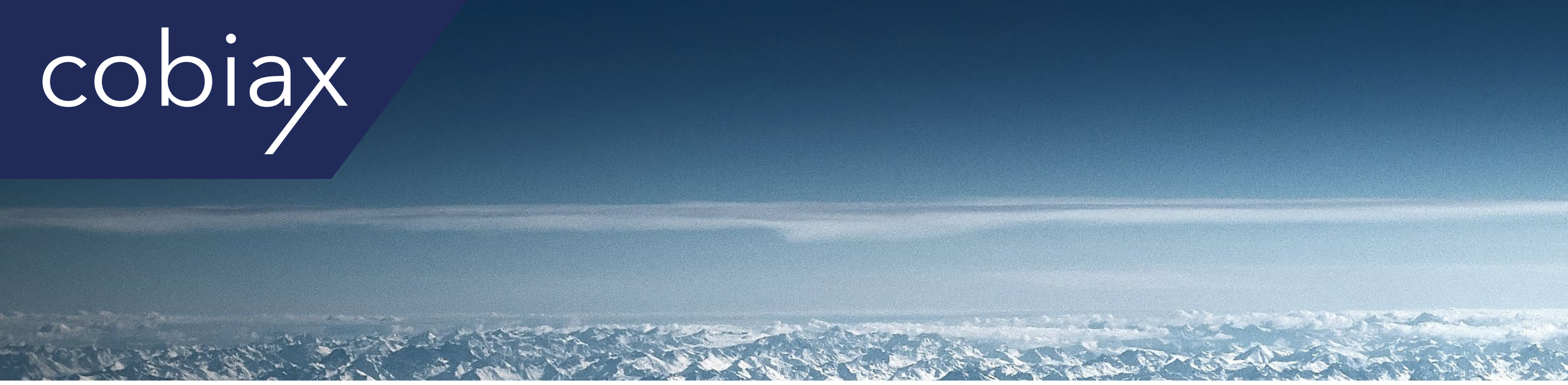
Welcome to this deep dive into the Cobiax technology.

We are proud to present our technology manual "A Deep-Dive into Cobiax CLS".

The design has been adapted from the existing brochures. We have scrutinized every letter, each figure and formula once again, so that we can now provide you with a very detailed and informative guide.

You will find all the important contact details for your cobiax contact at the end of the book.

Or go directly to **cobiax.com**



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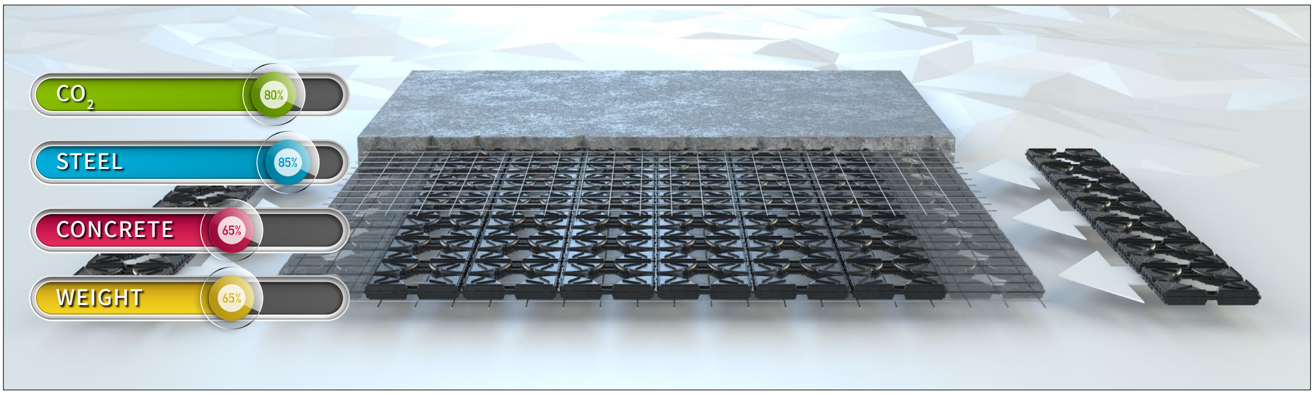
1. Introduction

1.1. Brief introduction to the Cobiax technology

The core of Cobiax systems is a lightweight void former made from recycled plastic which replaces solid concrete in the interior of a reinforced concrete slab. As a result, not only weight and concrete are saved but also thinner slabs in buildings and significantly larger spans are possible. The Cobiax system permits a load transfer in two directions. The static performance and external appearance of the Cobiax voided slab remain completely intact. Furthermore, thanks to the materials saved, the costs of the overall load-bearing structure of a building can thus be reduced. Due to the achieved load reductions, Cobiax voided slabs are also the ideal solution for optimizing foundations in case of poor subsoil and also in case of economic renovation and the addition of further storeys to existing buildings. The light-weight slabs enable us to reduce the dimensions of load- bearing elements within a building. This is also environmentally-friendly, as the void formers reduce material consumption and consist of 100 percent recycled plastic.



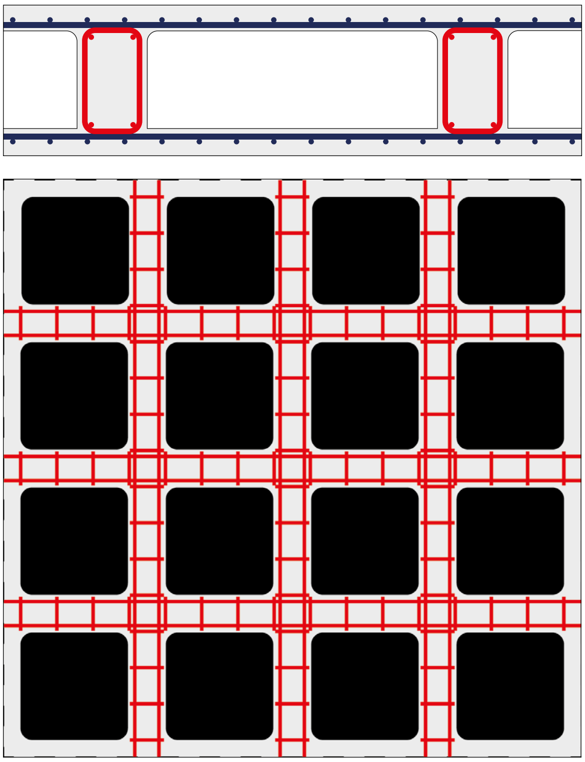
The internationally patented and building authority approved Cobiax CLS system is worldwide unique with its product integrated X-Zone!

Cobiax CLS structural formers are characterized by a uniform base area of 60 x 60 cm. They are particularly easy to install on site and can be laid close together without any intermediate spacing. The CLS installation elements also serve as support elements for the upper reinforcement layer and are suitable for all slab thicknesses from 20 to 80 cm.

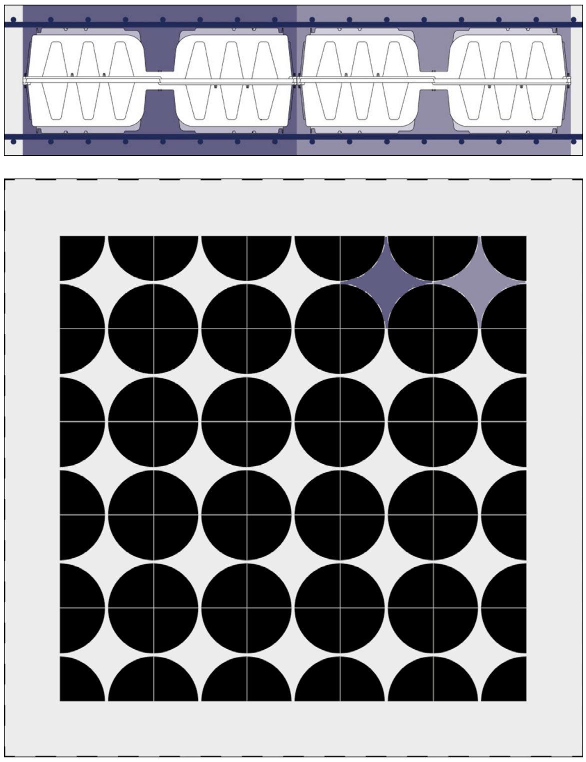
A Cobiax voided slab can be designed and dimensioned by any structural engineer in accordance with the relevant country-specific standard. A national technical approval (abZ) from the German Institute for Building Technology (DIBt) is also available. Installation is carried out by the contractor without any additional work on the construction site. The installation elements are installed between the upper and lower reinforcement layers in accordance with the Cobiax installation plan. This can be done in pure in-situ concrete or precast construction. Cobiax technology can also be easily combined with post-tensioning or concrete core cooling.

1.2. The Cobiax X-Zone

The X-zone is the load-bearing area between the individual Cobiax voids. With Cobiax technology, this area is crucial for the load-bearing capacity of the slab. Many alternative voided slab systems for weight reduction are designed according to the principle of a ribbed or waffle slab. The weak point of these structures is the continuous narrow web, which usually requires additional shear reinforcement. It is the concrete structure in X-shape that accounts for the unique stability and thus safety of Cobiax voided slabs and thus does not require additional shear force reinforcement.



Ribbed, waffle slab
Additional shear force reinforcement required.



Cobiax voided slab
No additional shear force reinforcement required.

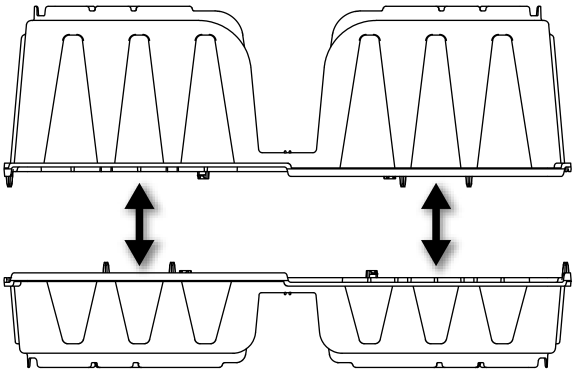
1.3. Product line

The key product details can be found in the Application Data Sheets (ADS, see Chapter 3 from page 74).

Cobiax CLS

Structural formers consisting of 2 half shells, square base area, with quarter circle segments.

For slab thicknesses from 20 to 80 cm.

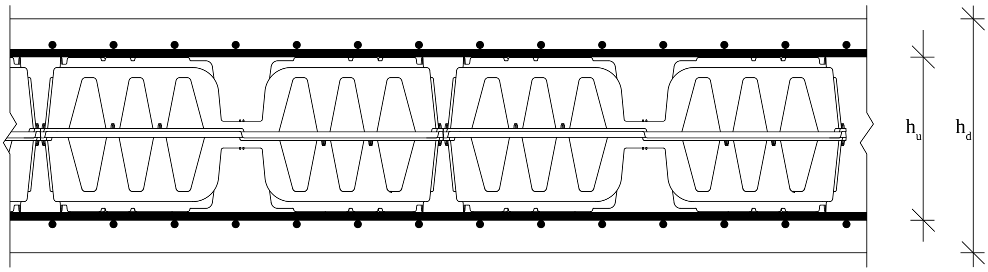


1.4. Illustration of the cross-section structure

The key product details can be found in the Application Data Sheets (ADS, see Chapter 3 from page 74).

h_d	Slab thickness	
$h_{d,min}$	min. slab thickness	ADS, line 5
$h_{d,max}$	max. slab thickness	ADS, line 6
h_u	Support height	ADS, line 4
h_{cx}	Volume displacement	ADS, line 2

Cobiax CLS



1.5. The Cobiax effect

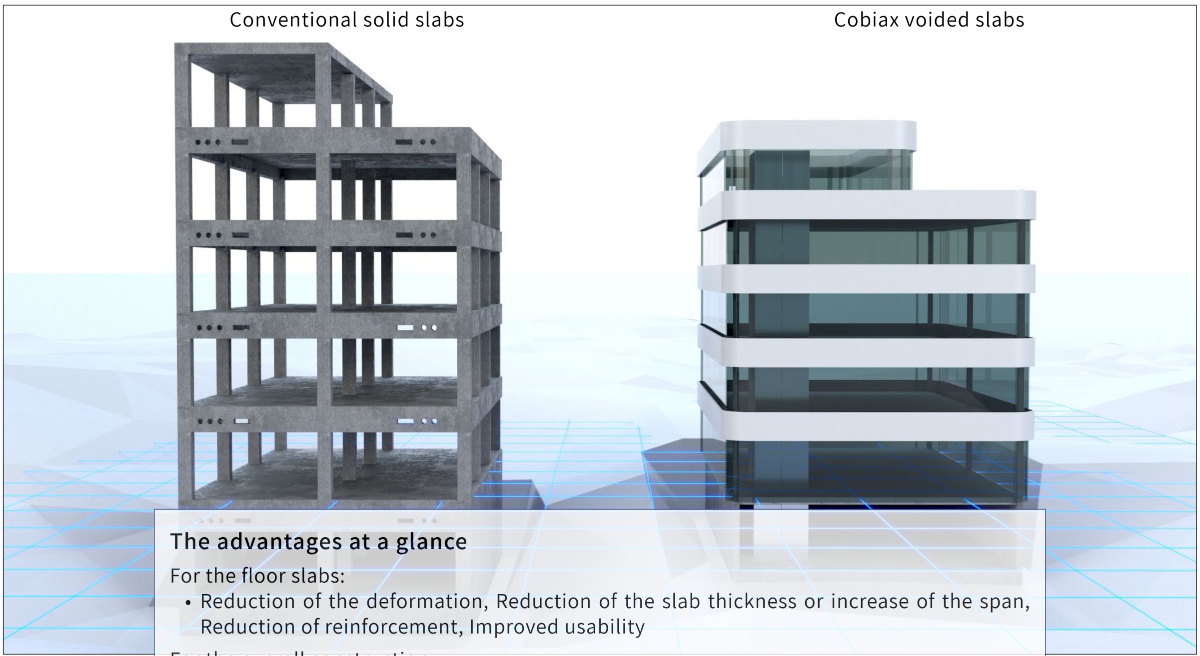
The Cobiax effect compared to the design with conventional solid slabs.

Primary (at slab level):

- Up to 35% concrete and weight reduction due to the void formers
- Up to 10% additional concrete and weight reduction due to decrease of slab thicknesses
- Up to 15% reduced steel reinforcement
- Up to 25% reduction in punching shear reinforcement
- Elimination of support cages for upper reinforcement in the voided area

Secondary (at building level):

- Optimization of vertical support members such as columns and walls
- Optimization of support structures and levels
- Optimization of the bracing system, especially for earthquake loads
- Optimization of foundations and footings, especially for special foundations such as piles
- Up to 20% reduction in CO_2 emissions due to material-efficient, sustainable construction methods



The advantages at a glance

For the floor slabs:
- Reduction of the deformation, Reduction of the slab thickness or increase of the span, Reduction of reinforcement, Improved usability

For the overall construction:
- Reduction of building load, Optimization of all load-bearing components
- Advantages for the bracing system, especially in seismic areas

For the foundation:
- Optimization of the entire foundation, especially in poor subsoil and special foundations such as piles

For the environment:
- Conservation of resources due to material-efficient construction method
- Positive influence on sustainability rating due to CO_2 reduction
- Increase in property value

1.6. Project flow chart

Design phase	Ideally, Cobiax voided slabs are determined as the slab system at an early stage in order to be able to take full advantage of all the benefits of load reduction, also for the overall design.	Cobiax advises and informs owners, project developers, architects, structural engineers, further persons involved in the project and generally interested parties.
▼	▼	▼
Planning phase	Planning and static calculation of the overall building and the Cobiax voided flat slabs by structural engineers. Creation of the formwork and the reinforcement plans.	Cobiax provides technical support.
▼	▼	▼
Bidding phase	Tendering of Cobiax voided slab systems by the client's planning team.	Cobiax creates offers regarding the delivery performance of Cobiax products.
▼	▼	▼
Execution phase	Installation, and if required, prior assembly of the Cobiax void former modules according to the installation plan and installation instructions by the executing construction company.	After commissioning, Cobiax creates installation plans based on the structural calculations and formwork plans, supplies the construction site with Cobiax products and supervises the execution of the construction.

1.7. Documentation and information material

All of the following listed Cobiax documentation and information material is available on request or directly for download at cobiax.com:

THIS IS COBIAX - The image brochure

The patented and award-winning void and structural forming technology from Cobiax.

CHECK OUT COBIAX - The business brochure

The essentials in a nutshell.

HOW TO COBIAX - CLS

The Quick Guide to Cobiax CLS.

A DEEP-DIVE INTO COBIAX - The Technology Manual

Technology and execution in detail. You are reading it now ...

CQL-Softwaretool (Cobiax Quick and Light)

An in-house produced software for determining the slab cross-section, selecting a suitable installation element and determining the Cobiax-specific input parameters for the structural calculation.

To the login: **https://cql.cobiax.com/**

General German national technical approval (abZ)

Z-15.1-352 for Cobiax CLS structural formers

Sustainability assessment of Cobiax voided slabs

Ecological Life Cycle Analysis (LCA)

Environmental Product Declaration (EPD)

Expert reports, test certificates and statements

Various documents on the topics:

Fire resistance, sound insulation, local punching shear strength, fastening technology, etc.

2. Technology

2.1. Designations

2.1.1. General designations

h_d	Slab thickness	
h_{ft}	Semi-precast panel thickness	
$h_{d,min}$	Min. slab thickness	ADS, line 5
$h_{d,max}$	Max. slab thickness	ADS, line 6
$d_{2,Hk}$	Concrete overlay to void (top/bottom)	
$d_{2,Hk,min}$	Min. concrete overlay to void (top/bottom)	ADS, line 7
c_{nom}	Concrete cover	
h_{bew}	Thickness of the reinforcement layer	
c_i	Thickness of the intermediate layer	
h_v	Void height	ADS, line 23
h_u	Support height	ADS, line 4
h_k	Height of fixing element	ADS, line 33
$h_{dis,o}$	Distance void to upper edge of installation element	ADS, line 8

$h_{dis,u}$	Distance void to lower edge of installation element	ADS, line 9
h_{ks}	Height special fixing element	ADS, line 46
$c_{ft,min}$	Min. distance void to upper edge of semi-precast panel	ADS, line 45
h_{cx}	Volume displacement	ADS, line 2
g_{cx}	Associated weight reduction (25 kN/m3)	ADS, line 3
f_V	Shear factor	ADS, line 11
f_{EI}	Stiffness factor	ADS, line 12

ADS = Application Data Sheet, see chapter 3 from page 74.

2.1.2. Product designations

Cobiax CLS

Installation element: structural former (example)

CLS-P-210	Ready-to-install structural former (ADS, line 1)
CLS	Product line
P	Professional (sealed void former)
210	Support height h_u

This installation element consists of

CLS-H-115	Single component: half shell top (ADS, line 21)
CLS-H-095	Single component: half shell bottom (ADS, line 22)
CLS	Product line
H	Half shell open
115	Height of half shell top
095	Height of half shell bottom

2 half shells are required per installation element.

ADS = Application Data Sheet, see chapter 3 from page 74.

2.2. Slab cross-sections and design variations

The determination of the slab cross section and the selection of a suitable Cobiax installation element can be conducted most quickly and easily using the CQL software. Links on page 12.

The essential product details can be found in the Application Data Sheets (ADS, see chapter 3 from page 74).

2.2.1. General conditions

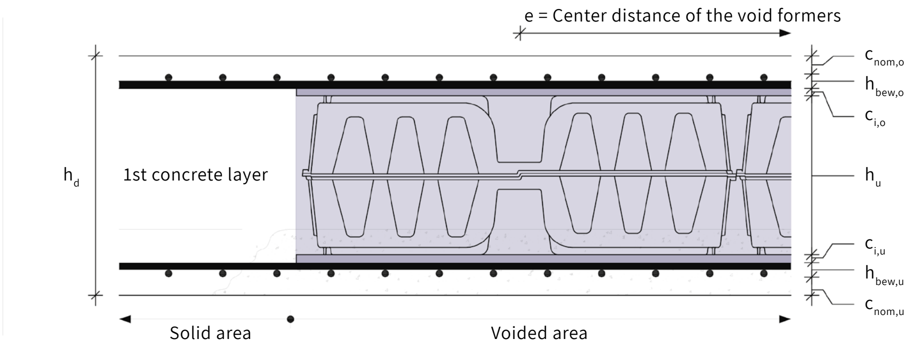
$h_{d,min} \leq h_d \leq h_{d,max}$	Slab thickness
$d_{2,Hk,min} \leq d_{2,Hk,o} = c_{nom,o} + h_{bew,o} + c_{i,o} + h_{dis,o}$ $d_{2,Hk,min} \leq d_{2,Hk,u} = c_{nom,u} + h_{bew,u} + c_{i,u} + h_{dis,u}$	Concrete overlay to the void Method 1, In-situ concrete construction
$d_{2,Hk,min} \leq d_{2,Hk,o} = c_{nom,o} + h_{bew,o} + c_{i,o} + h_{dis,o}$ $d_{2,Hk,min} \leq d_{2,Hk,u} = h_{ft} + h_{bew,u} + c_{i,u} + h_{dis,u}$	Concrete overlay to the void Method 2, Semi-precast construction

2.2.2. Cobiax CLS structural former

According to national technical approval Z-15.1-352.

2.2.2.1. Method 1, in-situ concrete construction

Selecting a suitable Cobiax structural former is made by determining the possible support height h_u. This depends on the required concrete cover, the thickness of the reinforcement layers and, if necessary, other intermediate layers (e.g., for additional spacers or installation levels).



Condition

$h_u \leq h_d - (c_{nom,o} + h_{bew,o} + c_{i,o} + c_{nom,u} + h_{bew,u} + c_{i,u})$

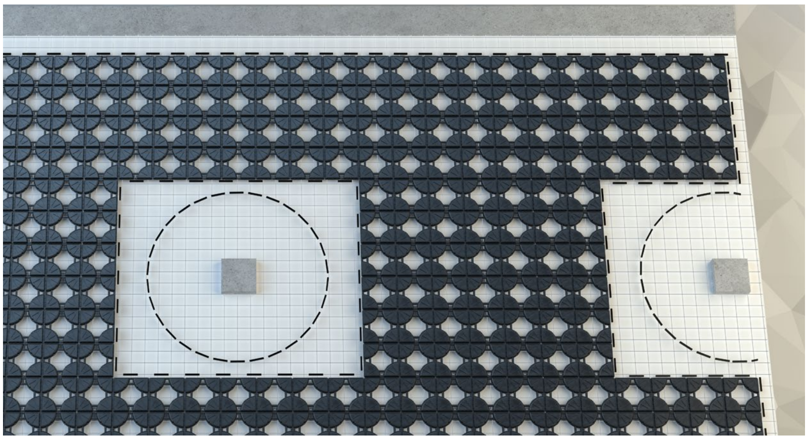
▷ Enables the selection of a suitable Cobiax CLS structural former.

2.3. Design & dimensioning

2.3.1. Procedure

A Cobiax voided slab can be designed and planned by any structural engineer in compliance with the country-specific standards and the national technical approval (abZ) of the German Institute for Construction Technology. Additional expert reports, test certificates and statements exist regarding different special topics. In principal, the calculation and design may occur using any static software (also international FEM Software) or manually.

- Estimation of the slab thickness h_d
- Decision on a design variation, determination of the slab cross sections and selection of a suitable Cobiax installation element. Quick and easy with the CQL software. Links on page 12.
- Determination of the Cobiax specific input parameters for calculation. Quick and easy with the CQL software. Links on page 12.
    - Load reduction due to the void formers g_{cx}
    - Factor for bending stiffness (stiffness factor) f_{EI}
    - Factor for the shear resistance (shear factor) f_V bzw. or the reduced shear resistance $V_{Rd,c,cobiax} = f_V \cdot V_{Rd,c}$
- First calculation run under consideration of the input parameters analogous to a conventional reinforced concrete slab. During this process, the load reduction and the reduced bending stiffness are initially applied across the entire slab surface.
- Consideration of the shear internal forces leads to the required solid zones. Areas with $V_{Ed} > V_{Rd,c,cobiax}$ are to be designed without void formers. In punching areas, it is to be checked whether the solid zone extends by the dimension $2\ d$ beyond the critical round section or beyond the last row of reinforcement. Otherwise, the solid zones are to be enlarged correspondingly. Along the support edges and free plate edges, additional solid zones are to be planned into the design.



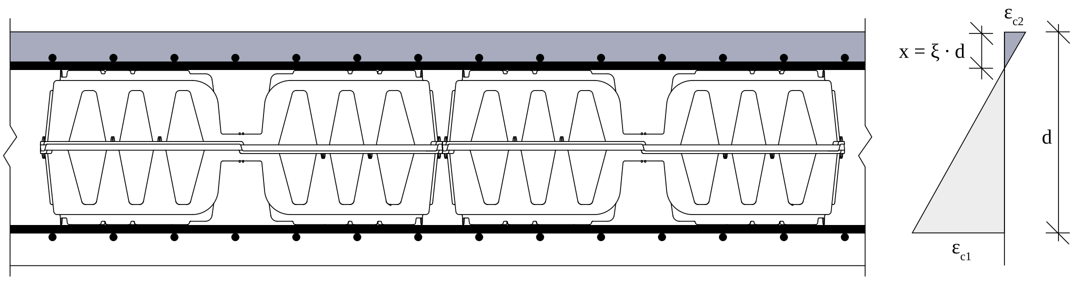
- In the defined solid zones, the dead load, or possibly the bending stiffness, is to be adapted and a second and final calculation run started.
- For concreting in two layers (to prevent uplift of the void formers) and for the design using semi-precast elements, the shear force transmission in the concreting joint is to be verified with a reduced bonding surface. Quick and easy with the CQL software. Links on page 12.

2.3.2. Bending

2.3.2.1. Bending resistance

The design for bending occurs acc. DIN EN 1992-1-1, 6.1 or other national design regulations for reinforced concrete structures. In the decisive section, the shortage of space due to the void formers must always be taken into consideration. However, influences by the void formers on the bending dimensioning can be excluded under observation of the following boundary conditions, so that the proof can be provided analogous to the rectangular cross section.

The inspection occurs analogous to the consideration of a T-beam using conventional design aids for the rectangular cross section (e.g., acc. general design diagram, k_d panels or ω panels).



Cobiax CLS: $x = \xi \cdot d \leq d_{2,Hk} - h_{dis} - 0{,}5\ cm$

The proof of the applicability of a rectangular section is done quickly and easily by calculating the bending moments limit with the CQL software. Links on page 12.

2.3.2.2. Bending stiffness

For the deformation calculation, an appropriate stiffness factor f_{EI} must be taken into consideration for the determination of the bending stiffness in the voided area. Other than that, the deformation calculation occurs analogous to the procedure for a conventional reinforced solid slab. The stiffness reduction through the void former is approx. 4% to 21% (stiffness factor f_{EI} approx. 0.96 to 0.79).

$$I_{cobiax} = I_{vollmassiv} \cdot f_{EI}$$

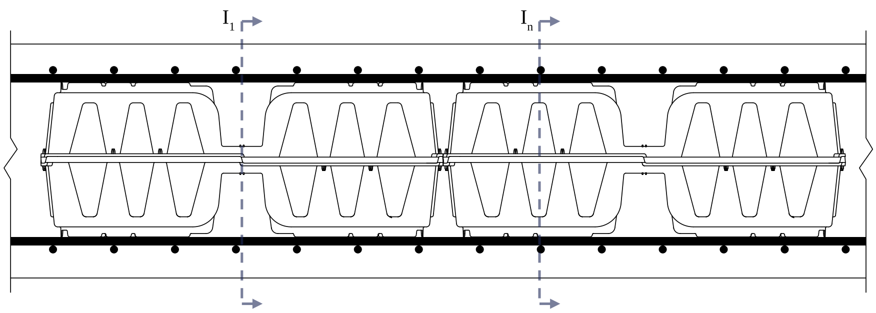
Notes:

Due to the load reduction through the void formers, more favourable values arise during the deformation calculation than for conventional reinforced solid slabs.

The values of the stiffness factors are based on calculations for state I. The influences for state II were checked by means of bending tests. According to the evaluation of these tests, the reduction in state I is decisive.

The stiffness factor is determined at n points with the same increment depending on the slab thickness and both the shape and the position of the void in the cross-section.

$$f_{EI} = I_{cobiax} / I_{vollmassiv} \text{ mit } I_{cobiax} = 1/n \cdot \Sigma I_1 + \ldots + I_n \text{ und } I_{vollmassiv} = I_1$$



The exact calculation of the stiffness factors f_{EI} for any slab cross sections can be conducted quickly and easily using the the CQL software. Links on page 12.

2.3.3. Shear force

2.3.3.1. Shear resistance

Components without shear reinforcement required for the calculation

The easily applicable concept for the proof of the shear resistance of Cobiax voided slabs intends the use of an estimated reduction factor (shear factor f_V) in comparison to a solid slab. A comprehensive test program has been implemented for the determination of the shear factor and the most unfavourable values determined resulting from it. As a result, the actual existing load bearing capacity is not exploited in many cases, meaning that a higher safety level can be assumed in comparison to a solid slab.

DIN EN 1992-1-1, 6.2.2 applies with the following adapted equation (6.2a):

$$V_{Rd,c,cobiax} = f_V \cdot V_{Rd,c} = f_V \cdot (C_{Rd,c} \cdot \kappa \cdot (100 \cdot \rho 1 \cdot f_{ck})^{1/3}) \cdot b \cdot d$$

Cobiax CLS: f_V dependent on slab thickness

$f_V = 0{,}45 - 0{,}05 \cdot (h_d - 20) / 28$ (for 20 cm ≤ h_d < 48 cm)

$f_V = 0{,}40$ (for 48 cm ≤ h_d)

The equations (6.2.b) and (6.4) of DIN EN 1992-1-1 do not apply.

The consideration of the shear internal forces leads to the required solid zones. Areas with $V_{Ed} > V_{Rd,c,cobiax}$ are to be designed without void formers.

For slab thicknesses that exceed the limit slab thickness $h_{d,grenz}$ (ADS, line 10) up to the maximum slab thickness $h_{d,max}$ (ADS, line 6), only the limit slab thickness $h_{d,grenz}$ and not the actual slab thickness h_d may be used in the calculation of the shear resistance.

The calculation of the reduced shear resistance $V_{Rd,c,cobiax} = f_V \cdot V_{Rd,c}$ can be conducted quickly and easily using the the CQL software. Links on page 12.

Components with shear reinforcement required for the calculation

In case a shear reinforcement is required, then the voided slab is to be proven, constructionally designed and executed as a ribbed slab or waffle slab with shear reinforcement acc. DIN EN 1992-1-1, 5.3.1 or the corresponding international design regulations.

Notes regarding the optimisation of the voided area proportion

In certain cases, it may be necessary to optimise the voided area proportion in order to maintain the maximum possible load reduction. For this purpose, a “comb-like installation” may be executed in the transition areas from the voided area to the solid area. By alternating strips with void formers and solid areas, an increased engineering-determined shear factor can be applied.

$$V_{Rd,c,cobiax,opt.} = 0,5 \cdot V_{Rd,c,cobiax} + 0,5 \cdot V_{Rd,c,vollmassiv}$$

2.3.3.2. Shear force transmission in the concreting joint

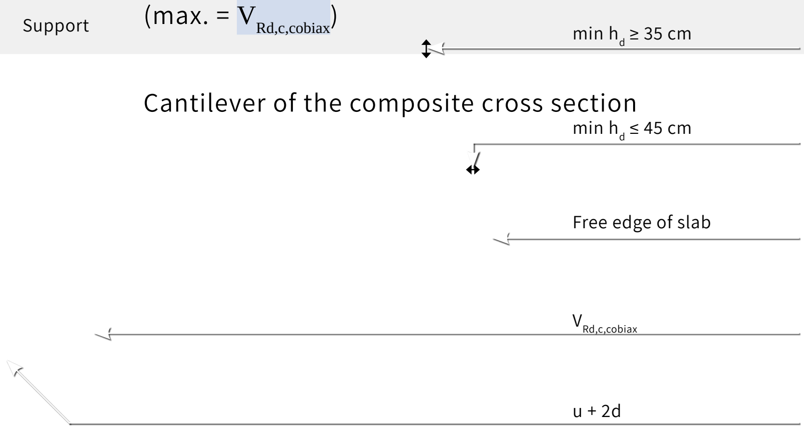
If a slab is concreted in two layers, then the concreting joint is to be proven acc. DIN EN 1992-1-1, 6.2.5 or comparable international design regulations for the net area of the construction joint $A_{i,red}$. The net area takes the missing areas due to the void formers into consideration. For $A_{i,red}$ it may be necessary to design and install bonding reinforcements. The concreting joint is to be laid out as smooth. In the case of the design variations with subsequently installing Cobiax installation elements on the semi-precast panels, the joint formation is to be laid out as rough.

$$v_{Edi} \leq v_{Rdi,cobiax}$$

Design value of the shear force:

$$v_{Edi} = V_{Ed} / z$$

V_{Ed}	Design value of the effective shear force (max. = $V_{Rd,c,cobiax}$)
z	Cantilever of the composite cross section



Approx. 50% to 80% of the slab area is fitted with void formers (may vary according to different structural configuration).

Design value of the shear resistance in the joint (6.25):

$$v_{Rdi,cobiax} = A_{i,red} / A_i \cdot c \cdot f_{ctd} + \mu \cdot \sigma_n + \rho \cdot f_{yd} (1{,}2\mu \cdot \sin\alpha + \cos\alpha) \leq 0{,}5 \cdot \nu \cdot f_{cd} \cdot A_{i,red} / A_i$$

A_i	Bonding area without deduction
$A_{i,red}$	Reduced bonding area (ADS, line 13)
ρ	A_s / A_i
A_s	Cross section of the bonding reinforcement crossing the joint

Converted and for $v_{Rdi,cobiax} = v_{Edi}$ gives in the required bonding reinforcement:

$$a_{s,erf} = (v_{Edi} - A_{i,red} / A_i \cdot c \cdot f_{ctd} - \mu \cdot \sigma_n) \cdot A_i / (f_{yd} (1{,}2\mu \cdot \sin\alpha + \cos\alpha)) \leq a_{s,vorh}$$

Cobiax CLS:

In any case, at least 4Ø8 must be provided as bonding reinforcement in each X zone.

$a_{s,vorh,cx} = 5{,}58\ cm^2 / m^2$

In general:

Adequate anchoring on both sides of the contact surfaces must be verified and ensured during execution.

Proof of shear force transmission in the concreting joint is quick and easy with the CQL software. Links on page 12.

2.3.4. Punching

The chapter Punching is divided into the two sub-chapters “Global punching” and “Local punching”. In the case of “Global punching” the global failure of the slab element due to point supports or individual loads is addressed. In contrast, the chapter “Local punching” is concerned with the failure of the concrete overlay below or above the voids due to punctiform-applied individual loads with small contact areas.

2.3.4.1. Global punching

Punching critical areas are to be executed as solid areas with solid cross sections without void formers. As a result, punching verifications can be implemented for these areas. The sizes of the solid punching critical areas are to be determined as follows:

Shear force verification

Under consideration of the shear resistance of the respective Cobiax voided slab, first the required solid areas are defined.

Areas without required punching reinforcement

Check whether the solid area selected from the shear resistance extends beyond the critical round section by at least dimension $2\,d$. Otherwise, the solid areas must be correspondingly enlarged.

Areas with required punching reinforcement

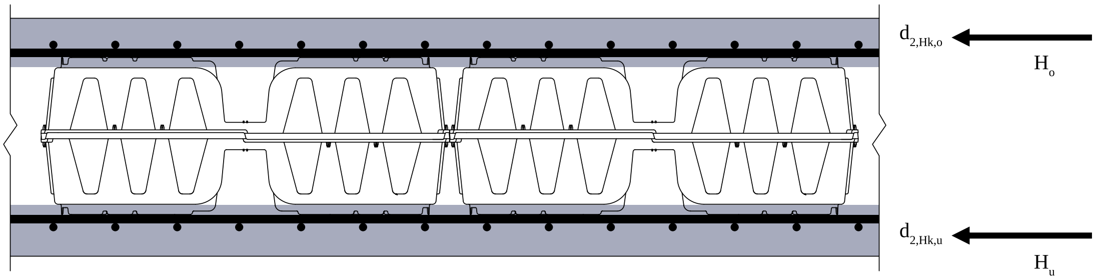
Check whether the solid area selected from the shear resistance extends beyond the last reinforcement row by at least the dimension $2\,d$. Otherwise, the solid areas must be correspondingly enlarged.

2.3.4.2. Local punching

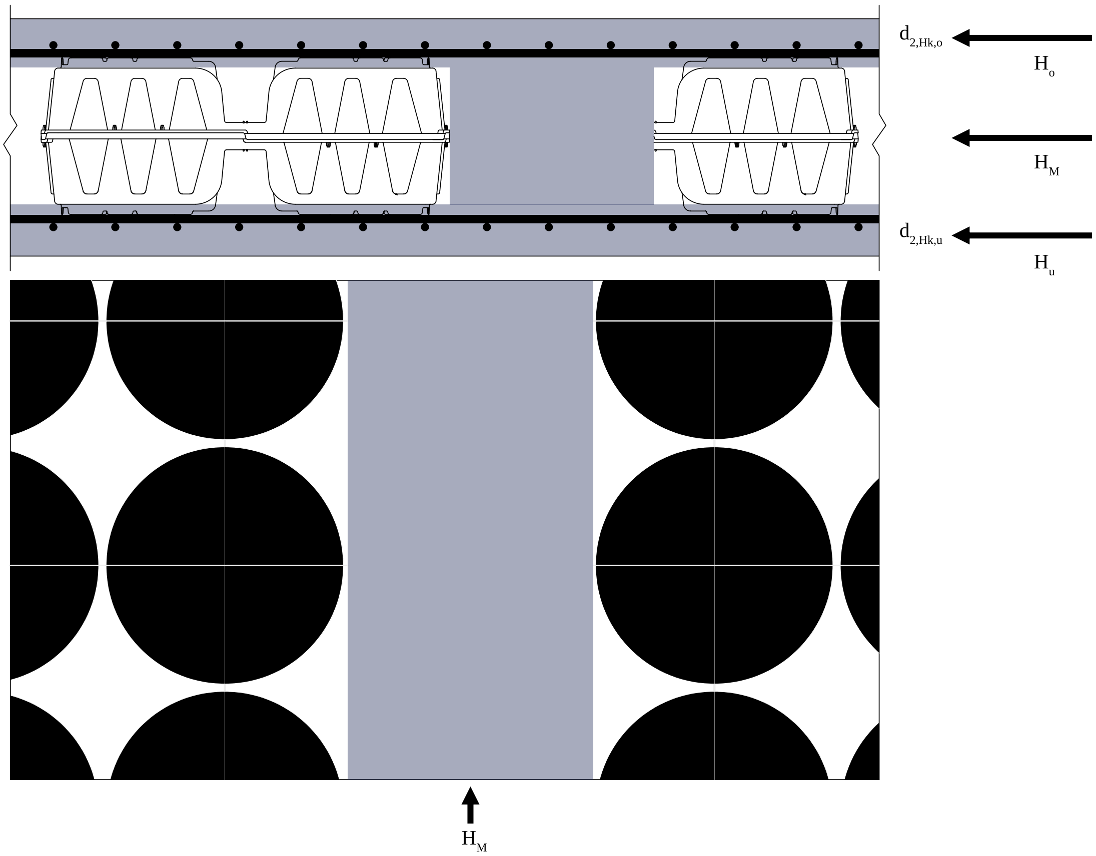
The resistance values for local punching can be determined according to the expert report "Numerische Untersuchungen zur lokalen Durchstanztragfähigkeit" - by BORAPA of 30.04.2024", unfortunately, this report is currently only available in German. As an upper limit, a design resistance value of F_{comp} depending on concrete cover and concrete grade is recommended. The specified design values for the local punching shear capacity $F_{Rd,l,comp}$ can be used to verify the load-bearing capacity of the slab surface under concentrated loads. Regardless of this, the global shear force capacity must also be examined for the same stress situation.

2.3.5. Slab load capacity

If the Cobiax voided slab is loaded as a slab, only the sum of the lower and upper concrete overlay to the void with their net cross sections is applied. It should be observed during the design that the forces to be transferred can be clearly forwarded on.



For the transmission of large and concentrated slab forces or of planned tensile and compressive forces, additional solid strips without void formers can be developed by design.



2.3.6. Serviceability

2.3.6.1. Limitation of crack sizes

The proof of the limitation of the crack size takes place according to standards (e.g. acc. Eurocode, DIN EN 1992-1-1, 7.3). For all related proofs, the complete cross-section shall be used without taking the voids into account.

2.3.6.2. Limitation of deformations

The proof of the limitation of deformations takes place according to standards (e.g. acc. Eurocode, DIN EN 1992-1-1, 7.4). All related proofs must take into account the reduced bending stiffness and load reduction due to the voids.

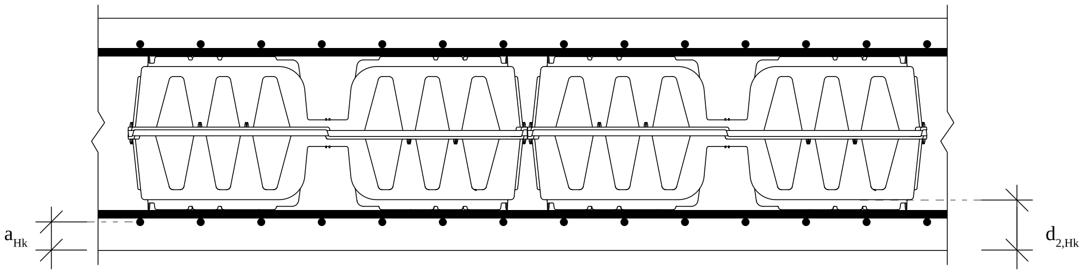
2.3.7. Building physics

2.3.7.1. Fire resistance

Analogous to solid reinforced slabs, Cobiax voided slabs meet the requirements for components made of non-combustible building materials.

To achieve the same fire resistance, the center distance a_{HK} of the statically effective flexural strength rebar from the underside of the slab must be increased for Cobiax voided slabs compared to solid reinforced concrete slabs. For this purpose, the temperature in the statically effective flexural reinforcement is determined in accordance with Eurocode, DIN EN 1992-1-2, taking into account both the void's shape and the concrete overlay to the void $d_{2,Hk}$. This temperature must not be greater than the temperature of a solid reinforced concrete slab with the same fire resistance duration according to Eurocode, DIN EN 1992-1-2.

The background as well as tables for suitable combinations of the center distance a_{HK} to the reinforcement and the concrete overlay to the void $d_{2,Hk}$ depending on the static system, the fire resistance duration and the void's shape are summarized in the expert report No. GS 3.2/19-167-1 of MFPA Leipzig.



Regardless of the duration of the fire resistance, a minimum value of $d_{2,Hk} \geq 7$ cm must be maintained for the concrete overlay to the void in accordance with the national technical approval(abZ).

The proof of fire resistance is done quickly and easily with the CQL software. Links on page 12.

2.3.7.2. Sound insulation

In terms of airborne and impact sound insulation, a Cobiax voided slabb can be classified as a fully solid reinforced concrete slab in accordance with DIN 4109 as per the expert report "On the sound insulation of Cobiax voided slabs" issued by ita Wiesbaden. The area-related mass is to be determined as the decisive architectural acoustics parameter, taking into account the volume displacement by the void formers. In this way, an equivalent slab thickness is calculated for the assessment of the sound insulation, for which the usual sound insulation verification of a solid slab can be checked.

Equivalent slab thickness:

$h_{d,eq} = h_d - h_{cx}$ with h_{cx} in meter (ADS, line 2)

2.3.7.3. Heat insulation

The voids created through the void formers influence the thermal conductivity of the slab. This theoretically has a positive effect on heat insulation, but this effect is negligible for practical application.

2.3.8. Construction rules

2.3.8.1. Recesses and breakthroughs

The planned slab recesses and subsequent large-sized breakthroughs are to be planned and executed according to the respective valid standard. A solid strip is to be executed circumferentially in the size of the slab thickness h_d, but not more than 45 cm.

For the execution of subsequent holes or core drillings which affect the intermediate areas between the void formers, the following rules have to be observed:

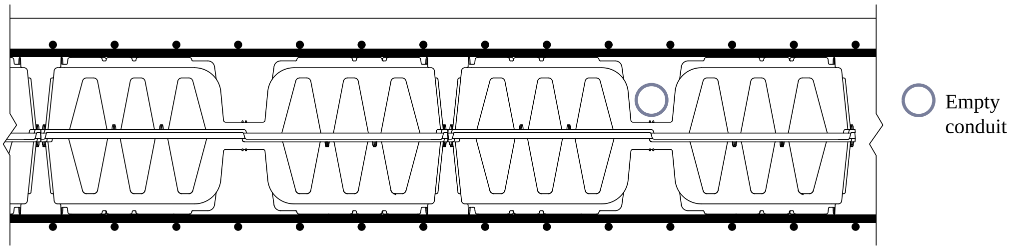
- The following regulations apply for core drillings with a diameter up to 35 cm.
- The load-bearing capacity is to be verified statically, whereby the shear resistance in this area is to be reduced to 50% in comparison to the remaining area with void formers: $V_{Rd,c,cobiax,red} = 0{,}50 \cdot V_{Rd,c,cobiax}$
- The center distance of the core drillings in each direction must not be less than 2.40 m.
- Several core drillings in a row at closer intervals are to be considered like a subsequent large-sized breakthrough and are to be considered separately in static terms.

2.3.8.2. Empty conduits (d ≤ 25 mm)

This section applies to empty conduits and cables whose outer diameter does not exceed 25 mm. For diameters larger than 25 mm, additional solid areas with full cross-section must be formed.

If an isolated empty conduit or cable with an outer diameter ≤ 25 mm is installed inside the slab, this is to be viewed as harmless in engineering terms.

- **Cobiax CLS:** With a minimum distance of 1.20 m for empty conduits and cables with an outer diameter ≤ 25 mm, one empty conduit or one cable may be arranged in both directions at the height of the connecting webs. At this height, the empty conduits and cables may also cross each other. The empty conduits and cables must be secured against uplift in the area between the connections.



However, if many empty conduits and cables are installed at a more or less regular distance (e.g., in the case of a concrete core cooling system), the following regulations must be observed:

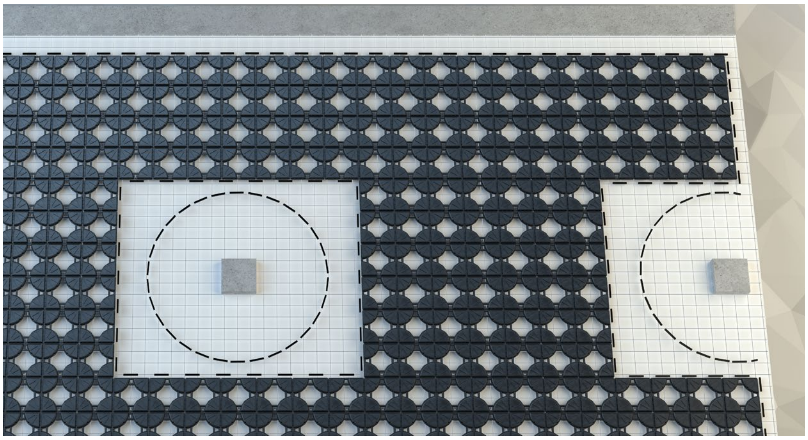
- As a matter of principle, empty conduits and cables should not be laid within the required concrete cover.
- Empty conduits and cables must be fastened to the reinforcement to secure their position.
- If empty conduits and cables are installed within the compression zone, this must be taken into account in the bending design.
- For empty conduits and cables with an outer diameter ≤ 25 mm, an additional installation level of at least 25 mm must be provided in the slab cross-section between the Cobiax installation element and the relevant reinforcement layer. If necessary, the support height of the installation element must be reduced for this purpose. In this case, the statical effective depth must be reduced by 25 mm for the proof of the shear resistance. The minimum center distance between the empty conduits in this area must not be less than 17.5 cm (or not less than 15.0 cm for empty conduits ≤ 20 mm).
- Crossings and penetrations of empty conduits and cables to the removed slab surface should be avoided. If these are nevertheless required, solid areas without void formers should be provided.

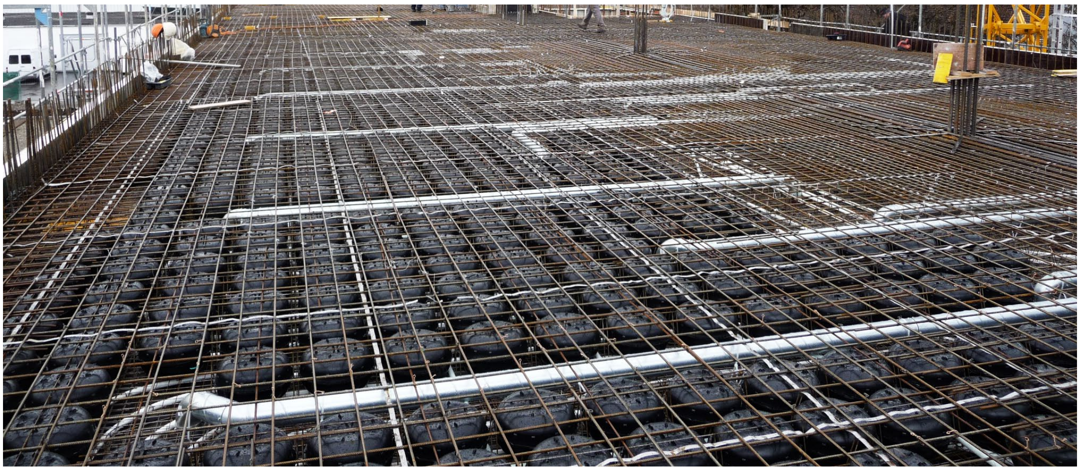
In the case of possible early planning, it is recommended to bundle the empty conduits or cables in a solid strip without void formers.

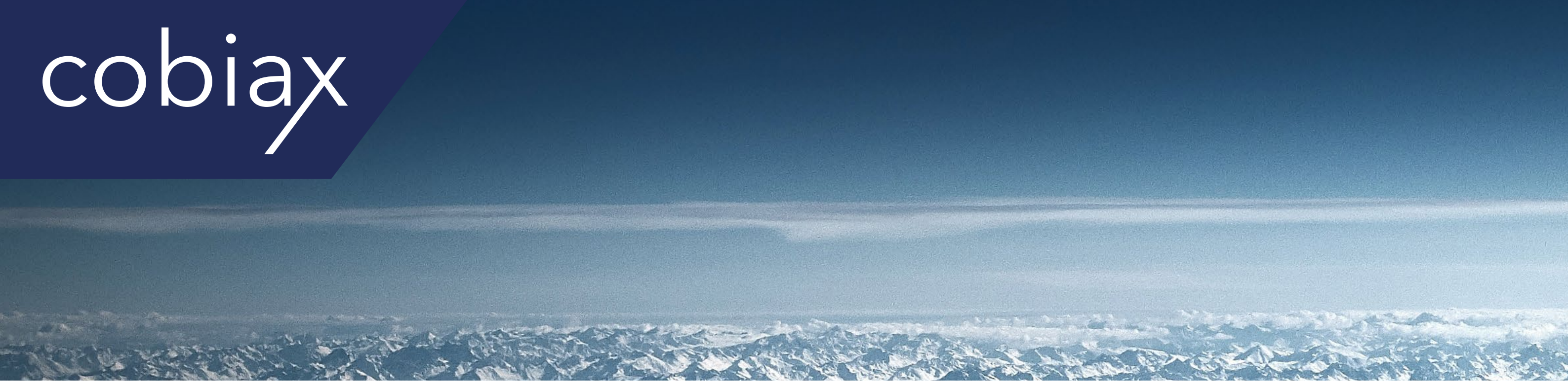
2.3.8.3. Design-selected areas without void formers

Statically required solid areas are defined according to the shear resistance. Besides these, there are several additional areas in which void formers are not installed for design reasons. This affects the following situations:

- In general, void formers are not to be installed above the supports of the slab. A solid strip of at least the width of the slab thickness h_d, but not less than 35 cm, must be provided laterally to the support edge.
- For slab edges and recesses, a circumferential solid strip of the width of the slab thickness h_d, but not more than 45 cm, must be executed.
- Required edge distances of Cobiax installation elements to other components, installation parts, etc. must be taken into consideration in the design planning and execution.
- A corresponding solid strip must be provided for empty conduits and cables with an outer diameter of more than 25 mm. In the case of possible early planning, it is recommended to bundle the empty conduits or cables.







2.3.9. Fastening technology

Cobiax voided slabs offer sufficient fastening options for cable trays, building services installations in general, suspended ceilings and partition walls, for example. Depending on the cross section of the slab, the necessary minimum net cross section thicknesses of at least 8-10 cm for conventional dowel systems are selectively fallen short of at the corresponding vertex of the void formers.

For this reason, suitable dowel systems have been determined for combination with the Cobiax voided flat slab in cooperation with different manufacturers. In the process, among others, load-bearing capacity tests have been executed by different manufacturers and testing institutes. Likewise, supplementary expert reports are available.

Würth also offers approved dowels for Cobiax slabs (ETA-11/0309).

Furthermore, there is additional information available from the manufacturers regarding the use of the dowel systems. The table below indicates example recommendations by Hilti.

The following rule applies: Planned suspended loads in the area of the lower concrete overlay of the void are to be sufficiently anchored. Only actually existing concrete cross sections may be applied for the proofing. A sufficiently large solid area is to be provided by waiving the layout of individual void formers if necessary.

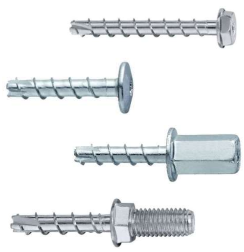
RECOMMENDED LOADS FOR HUS3 8, 10, 14
IN COBIAX SLABS
STARTING FROM 50 MM CONCRETE OVERLAY IN ACCORDANCE WITH ETA-13/1038

Dowel system in COBIAX slabs	Recommended load in cracked concrete, considered partial safety factors γ_F = 1,4 and γ_M = 1,5		Expert report	ETA
Hilti HUS3-H 8 **Concrete overlay above/ underneath the void 50 mm - 95 mm**	Concrete overlay [mm]	**req. load [kN]**	Expert report 22010_de dated February 22nd, 2020 by apl. Prof. Dr.-Ing. C. Thiele Individual fastenings in dry environment	**ETA-13/1038**  Assembly with SIW 22-A, Power Level I - III
	50	**0,57**		
	60	**1,05**		
	70	**1,62**		
	≥ 80	**2,00**		
Hilti HUS3-H 10 **Concrete overlay above/ underneath the void 50 mm - 95 mm**	Concrete overlay [mm]	**req. load [kN]**	Expert report 22010_de dated February 22nd, 2020 by apl. Prof. Dr.-Ing. C. Thiele Individual fastenings in dry environment	**ETA-13/1038**  Assembly with SIW 22-A, Power Level I - III
	50	**0,52**		
	60	**1,1**		
	70	**1,86**		
	80	**2,67**		
	≥ 90	**3,05**		
Hilti HUS3-H 14 **Concrete overlay above/ underneath the void 50 mm - 95 mm**	Concrete overlay [mm]	**req. load [kN]**	Expert report 22010_de dated February 22nd, 2020 by apl. Prof. Dr.-Ing. C. Thiele Individual fastenings in dry environment	**ETA-13/1038**  Assembly with SIW 22-A, Power Level I
	50	**0,57**		
	60	**1,19**		
	70	**1,95**		
	80	**2,86**		
	95	**4,19**		

The data are only valid for assembly according to ETA.
If you have any questions, please contact the technical support of Hilti Deutschland AG.

Hilti fasteners in COBIAX slabs | Torben Kaben, Martin Reuter I March 23rd, 2020 1

RECOMMENDED LOADS FOR THE HILTI SCREW ANCHOR HUS3 6
IN COBIAX SLABS
STARTING FROM 50 MM CONCRETE OVERLAY IN ACCORDANCE WITH ETA-13/1038

Dowel system in COBIAX slabs	**Recommended load in cracked concrete, considered partial safety factors γ_F = 1,4 and γ_M = 1,5**	**Expert report**	**ETA**
Hilti HUS3 6 **Concrete overlay above/ underneath the void 50 mm - 95 mm**	Concrete overlay [mm] **req. load [kN]** 50 **0,47** 60 **0,90** 70 **1,42** ≥ 80 **2,00**	Expert report 21939_1 dated September 30th, 2019 by apl. Prof. Dr.-Ing. C. Thiele **Individual fastenings** in dry environment	**ETA-13/1038** 
Hilti HUS-P 6 **Hilti HUS-I 6** **Hilti HUS-H 6** **Hilti HUS-A 6** **Concrete overlay above/ underneath the void ≥50 mm**	Concrete overlay [mm] **req. load [kN]** ≥50 **1,42** in COBIAX Eco-Line and in COBIAX Slim-Line	Expert report 054.1.11 dated May 6th, 2011 by TU Darmstadt and letter of comparison "Confirmation concrete screw HUS3 size 6, all versions" dated March 30th, 2020 **Multiple fastenings** in dry environment	**ETA-10/0005** 
Hilti HUS-P 6 **Hilti HUS-I 6** **Hilti HUS-H 6** **Hilti HUS-A 6** **Concrete overlay above/ underneath the void ≥50 mm**	Characteristic load for fire exposure R90: **0,25 kN** R120: **0,15 kN**	Expert report GS 3.2/11-066-1 dated April 13th, 2011 by MFPA Leipzig and letter of comparison "Confirmation concrete screw HUS3 size 6, all versions" dated March 30th, 2020 **Multiple fastenings** under fire exposure	

The data are only valid for assembly according to ETA.
If you have any questions, please contact the technical support of Hilti Deutschland AG.

HILTI Hilti fasteners in COBIAX slabs | Torben Kaben, Martin Reuter I March 23rd, 2020 / 2

RECOMMENDED LOADS FOR THE HILTI HIT-RE 500 V3
IN COBIAX SLABS
STARTING FROM 50 MM CONCRETE OVERLAY IN ACCORDANCE WITH ETA-13/1038

Dowel system in COBIAX slabs	**Recommended load in cracked concrete, considered partial safety factors γ_F = 1,4 and γ_M = 1,5**	**Expert report**	**ETA**
Hilti **HIT-RE 500 V3** **+ Perforated sleeve** **+ Anchor rod or internal threaded sleeve** **Concrete overlay above/ underneath the void** **≥55 mm**	**req. load [kN]** **HIT-V-Anchor rod** **M 8** **2,2 kN** **M10** **2,7 kN** **Internal threaded sleeve** **HIT-IC M 8** **3,1 kN** **HIT-IC M12** **4,2 kN**	Expert report 129.02.09 dated December 4th, 2009 with supplement 129.3.09 dated November 19th, 2913 and expert report 217.1.17 dated August 15th, 2017 Dr.-Ing. K-H. Lieberum, TU DA: Anchor rod HAS-C, HAS-U or internal threaded sleeve HIT-IC, galvanized steel and A4 steel, with perforated sleeve and injection mortar HIT-RE 500 V3	**ETA-16/0143** 

The data are only valid for assembly according to ETA.
If you have any questions, please contact the technical support of Hilti Deutschland AG.

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If the loads to be supported exceed the manufacturer's recommendations, it is still possible to leave out individual void formers. This can be taken into account both during the planning phase and locally at the construction site.

2.3.10. Concrete core cooling

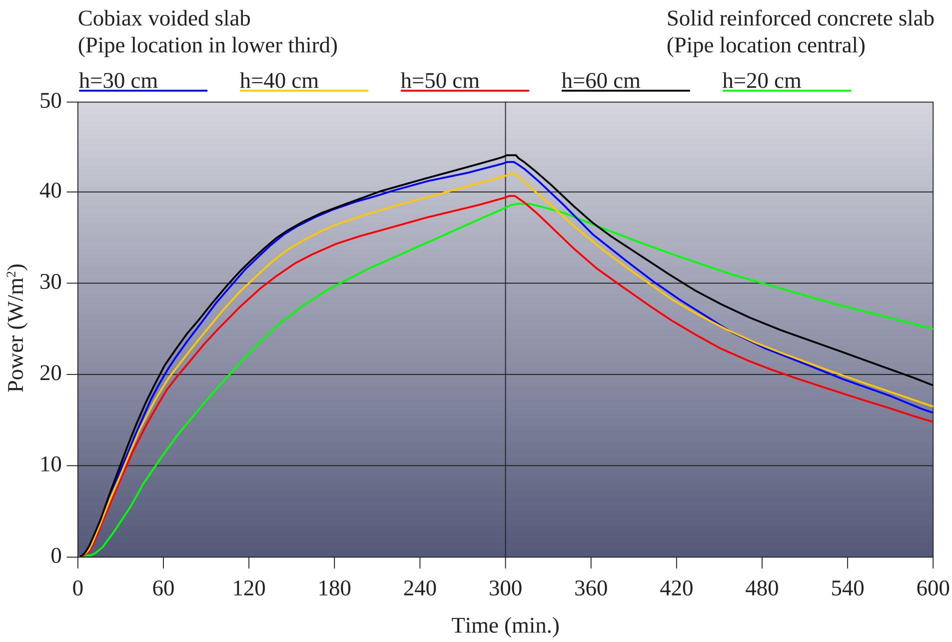
General information

Cobiax voided slabs can be easily combined with concrete core cooling. For optimum use of the available performance, pipes are installed in the lower third of the slab between the bottom reinforcement layer and the Cobiax installation elements. The concrete layer below the void formers should be approx. 8 cm thick. This is sufficient to create a similar performance as in the case of a usual concrete core cooling of a solid slab.

Comparative calculation of performance

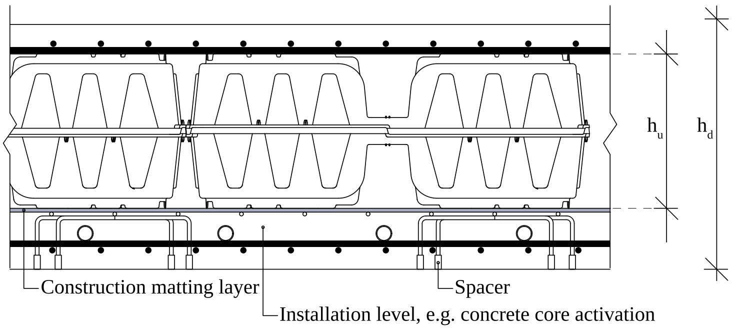
Based on this cross-section structure, Uponor GmbH simulated the effect of the void formers on the storage capacity of the slab using a Finite Element Calculation and compared this to a comparable 20 cm thick solid slab (dynamic model of a load over a period of 5 h, cooling case at a constant 26°C in the room and a medium average temperature of 18°C). The results can be taken from the diagram for selected void formers and slab thicknesses.

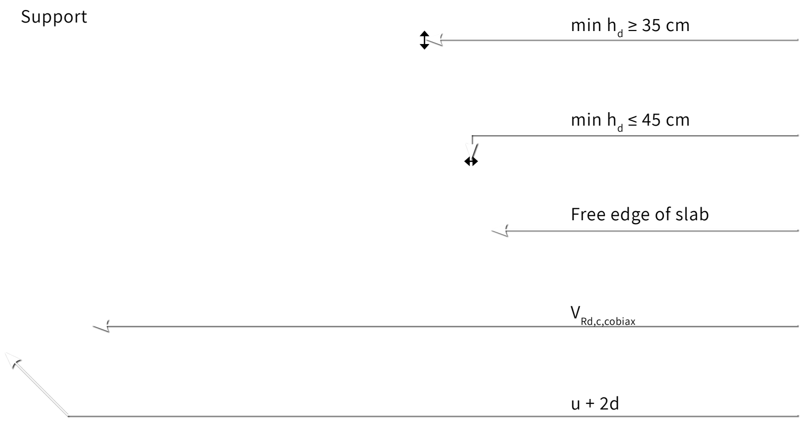
The Cobiax voided slab and the solid slab have almost the same performance with a similar behaviour. Whilst the Cobiax voided slab achieves a higher performance in the same load period, a minimally higher storage capacity is determined for the solid slab after switching off. The reaction times for the Cobiax voided slab are quicker, whereby more selective regulation is possible ("agile slab").



Cross-section structure

To protect the pipes of the concrete core cooling against damage, it is recommended to use a construction matting layer on the corresponding spacers below the installation elements.





Approx. 50% to 80% of the slab area is fitted with void formers (may vary according to different structural configuration).

2.3.11. Precast panels

The use of Cobiax installation elements in precast panels provides both lightweight and cost- effective precast panel constructions. In such cases, the lightness factor not only provides static advantages, but also advantages for transportation (more precast panels per delivery) and assembly (optimization of the assembly crane or precast panel dimensions). Balconies are to be highlighted here as a particularly suitable component. The load reduction has a particularly large influence on large cantilevers and the designing of the thermal separation to the building. Sufficient anchoring and sufficient distance to the void formers should be observed for the installation of transport anchors.

2.3.12. Post-tensioning

The combination of post-tensioning and Cobiax is possible and provides technically and economically extremely efficient solutions. However, it must be differentiated between subsequent post-tensioning (subsequent bond or without bond) and post-tensioning which is applied in a precast plant (immediate bond).

Post-tensioning with subsequent bond

The combination of post-tensioning with subsequent bond leads to extremely slim and cost-effective slab constructions, even with relatively large spans.

Solid strips and tracts must be provided for this type of post-tensioning, as post-tensioning of the actual voided area is not regulated within the scope of the existing technical approvals for the Cobiax voided slab.

Post-tensioning with immediate bond

This variation is used for precast and semi-precast panels. The combination with post-tensioning semi- precast panels is particularly suitable for Cobiax installation elements. This combination is mainly used if improved serviceability and/or if extremely slim slabs are required.

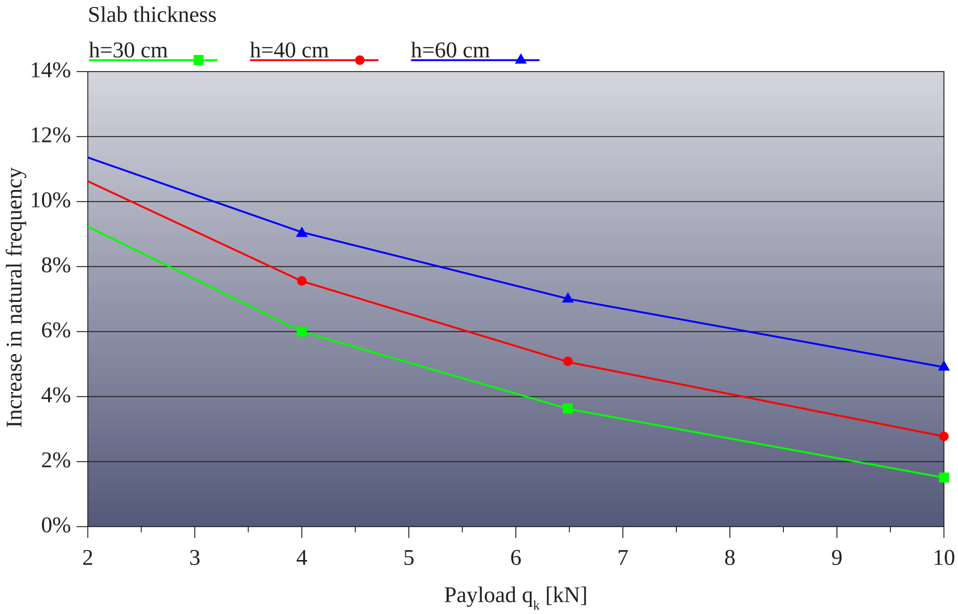
2.3.13. Vibration behaviour

For certain usage requirements, e.g., for concert halls or special production sites, the vibration behaviour may have to be checked. The perception of vibrations of a slab in a building can negatively influence the user's comfort. In order to prevent a vibration excitation of the slab, a high natural frequency is to be aspired to.

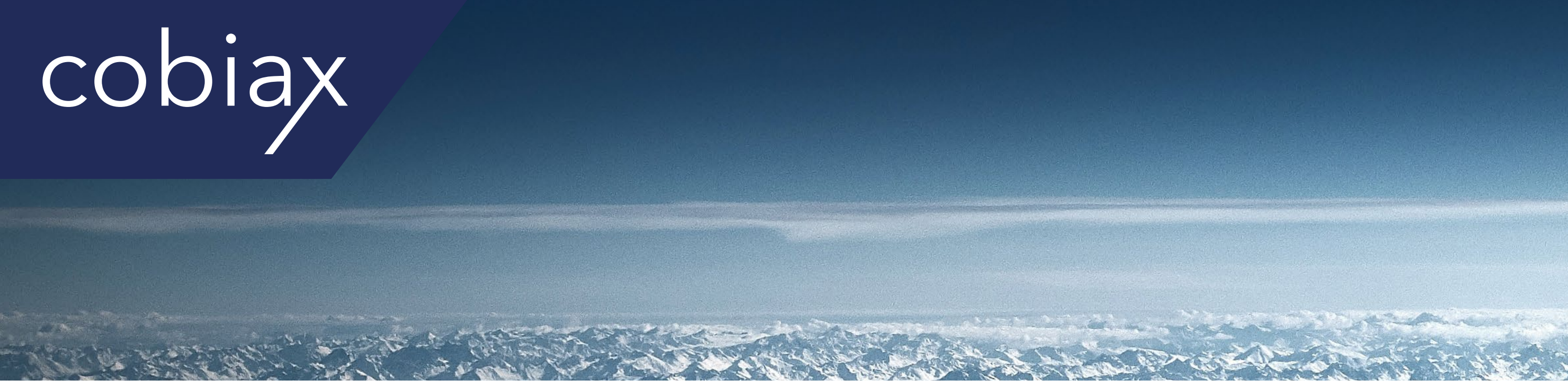
In an extensive theoretical investigation, the natural vibration behaviour of the two-way spanning voided slab has been compared to a solid slab. Despite the lesser stiffness of the Cobiax voided slab in a non-cracked state, natural frequencies up to 12% higher resulted from the load reduction. This behaviour can be illustrated based on the following base equation for vibration calculation:

Natural frequency	$f = \frac{1}{2\pi} \cdot \sqrt{\frac{k}{m}}$
k	Stiffness
m	Mass

The advantage over a solid slab is therefore relativized as the traffic load increases, until ultimately the same natural frequency is achieved as for a solid slab. In the following diagram, the increase in natural frequency is represented in summary compared to a solid slab of equal thickness.



(Source: Wolski, L; Natural frequency of cobiax flat slabs, Bochum University, 2006



2.3.14. Earthquakes

The earthquake regulations of all countries are based on the model that a structure is excited by an earthquake from its foundation by horizontal vibrations.

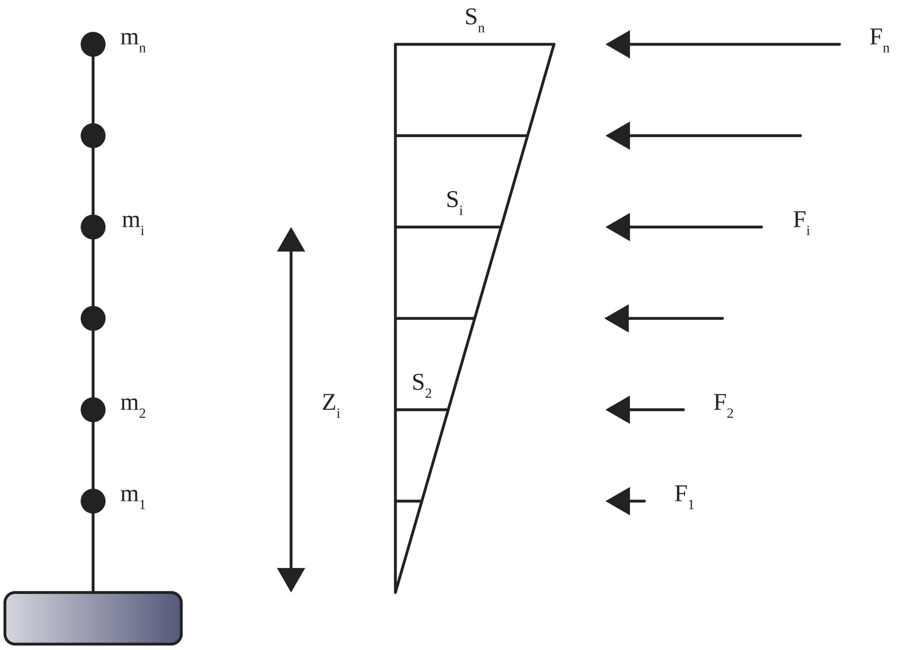
Modern standards and regulations use the response spectrum method as the control method for the computed proof of earthquake safety. Thus, the following simple equation applies for the so-called static equivalent force:

$Fi = f(\alpha 1, \alpha 2, \alpha 3, \alpha 4, \alpha 5, \alpha 6, \alpha 0, mi)$ whereby the individual quantities mean:

α1	Seismic factor
α2	Dynamic factor
α3	Subsoil factor
α4	Damping factor
α5	Ductility factor
α6	Risk or importance factor
α0	Horizontal acceleration
mi	Mass of the corresponding section of the building

For the earthquake analysis of buildings, the masses involved in the vibrations from dead load, probably existing live load and, if applicable, snow loads are to be applied. The live load is partly taken into account with only 15% of the maximum live load and therefore has only a minor influence on the earthquake proof for usual high-rise buildings.

The dead load of reinforced concrete floor slabs is usually the verification-determining variable for the determination of the static equivalent force for the earthquake investigation. By designing Cobiax voided slabs instead of solid reinforced concrete slabs, this primary load can be reduced by up to 35%, thus minimizing the risk of damaging earthquake loads.



2.3.15. Softwaretool CQL (Cobiax Quick and Light)

The in-house software tool CQL (Cobiax Quick and Light) offers the possibility of convenient determination or proof of the cross-section structure. Furthermore, the Cobiax-specific input parameters are determined and proven for the structural analysis. The software tool is available free of charge. Links on page 12.

Program features

Languages	German, English In planning: French, Italian, Dutch, Spanish
Standards	Eurocode 2 (with and without German annex) In planning: ACI
Product line	Cobiax CLS
Variants	In-situ concrete and semi-precast construction

Functionalities:

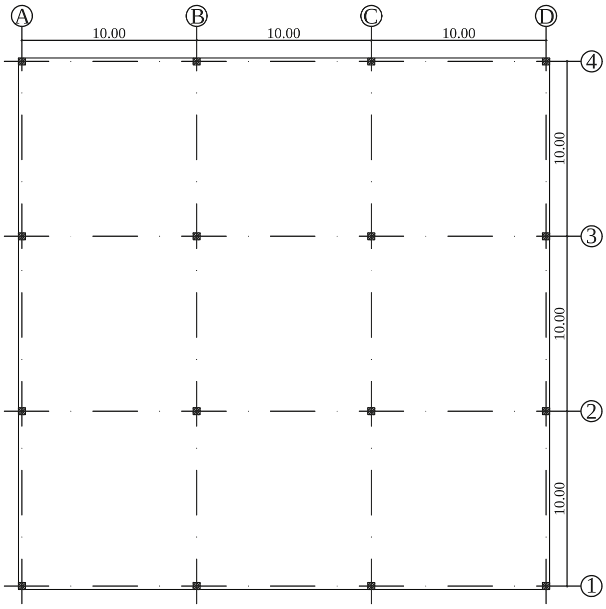
- Determination of the slab cross section
- Selection of the suitable void former
- Determination of the load reduction
- Proof of the bending moments limit
- Determination of the stiffness factor
- Calculation of the reduced shear resistance
- Proof of the concreting joint
- Proof of fire resistance
- Export of results as PDF file

2.3.16. Calculation example

In the following calculation example, the results of a solid slab are compared with those of a Cobiax voided slab, and the significant differences are displayed.

2.3.16.1. System

Point-supported flat slab with 10.00 x 10.00 m span (diagonal 14.14 m)



2.3.16.2. Boundary conditions

Dead load	According to the cross-section of the slab
Additional dead load	1,5 kN/m²
Live load	3,5 kN/m² (of which 30% quasi-permanently for the deformation calculation)
Concrete quality	C30/37, XC1
Concrete cover	$c_{nom,o} = 3{,}0$ cm $c_{nom,u} = 3{,}0$ cm
Deformation limitation	$f_\infty \leq l/300 = 14{,}14\ \text{m} / 300 = 47\ \text{mm}$

Fire resistance requirement	REI 90
First run of structural calculation	The load reduction and reduced bending stiffness due to Cobiax is initially applied over the entire slab area. The consideration of the shear internal forces leads to the determination of the required solid zones.
Second run of structural calculation	To determine the support reactions, the dead weight and, if necessary, the bending stiffness are adjusted in the specified solid zones. In addition, the other results from the first calculation run can be checked. As a rule, the differences are negligible.

2.3.16.3. Determination of the required slab thickness

About the limitation of the bending slenderness

According to Eurocode, DIN EN 1992-1-1, 7.4.2, the required slab thickness can be determined without direct calculation by limiting the bending slenderness. For a Cobiax voided slab, this verification is only suitable to a limited extent, since the positive influence of the lower dead load, but also the somewhat lower bending stiffness, is not taken into account in this verification.

In general, the bending slenderness of a solid reinforced concrete slab should be limited to the maximum value

$$\frac{l}{d} \leq K \cdot 35 = 1{,}2 \cdot 35 = 42$$

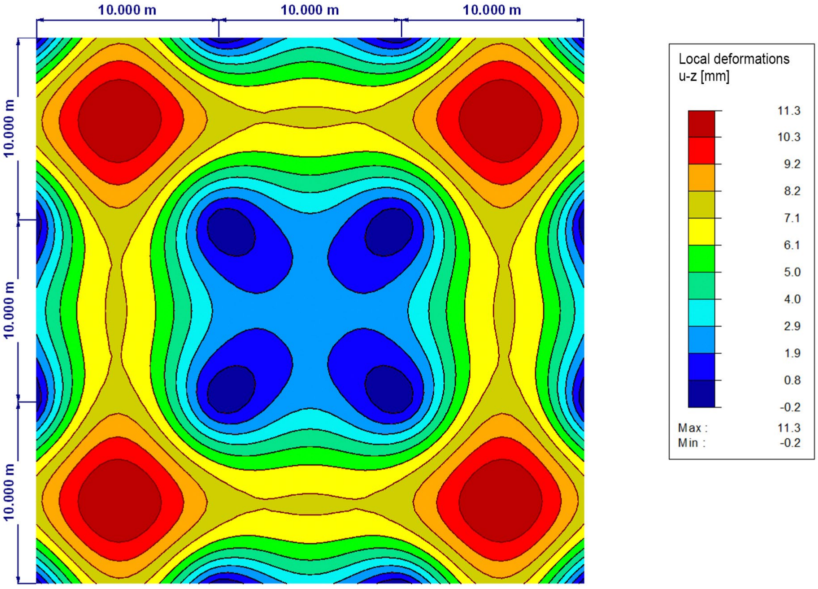
$$d = \frac{14{,}14\,m \cdot 100}{42} = 33{,}7\,cm$$

► **selected: h = 38 cm**.

About a deformation calculation (First calculation run)

Various methods are available for the deformation calculation. In some cases, it is possible to determine the deformation (also the long-term deformation) by means of common FEM programs. Also according to Eurocode, DIN EN 1992-1-1, 7.4.3, a proof for the limitation of deformations with direct calculation is available. All these methods can also be used for the Cobiax voided slab. For this purpose, only the adjusted bending stiffness $I_{cobiax} = I_{vollmassiv} \cdot f_{EI}$ in the uncracked state I and the load reduction g_{cx} need to be considered. For simplification, the long-term deformation is determined below using a selected increase factor of 4.0 to account for cracking and time-dependent deformations. This provides an easy way to highlight the difference between the deformation of a solid slab and the Cobiax voided slab.

Solid slab with h = 38 cm

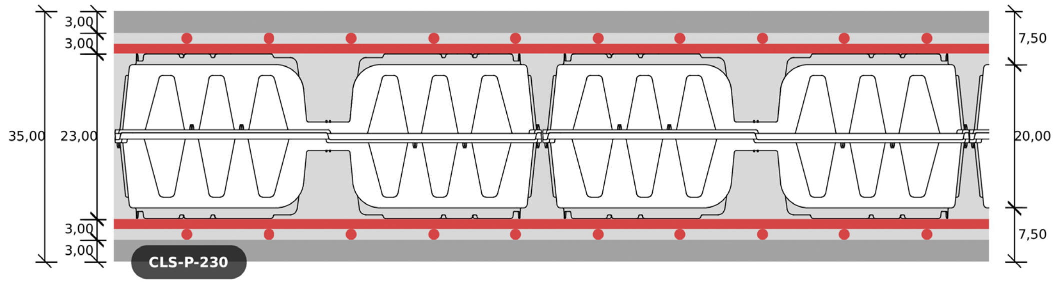


$f_{I,\,max} = 11{,}3\ \text{mm} \rightarrow f_{\infty,\,\text{Faktor 4}} = 45{,}2\ \text{mm} < 47\ \text{mm}$ ✓

Cobiax voided slab with h = 35 cm

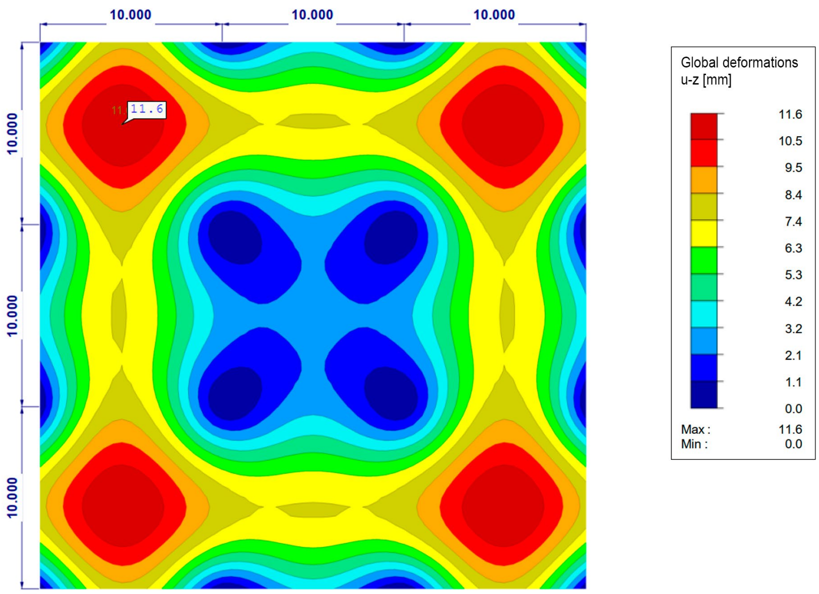
With identical boundary conditions, the slab thickness of a Cobiax voided slab can be selected up to 10% lower. The determination of the cross-section structure and the determination of the Cobiax specific input parameters can be done with the CQL software. Links on page 12. For the h = 35 cm thick Cobiax voided slab, type CLS-P-230 with a basic reinforcement of Ø12-10 (11.31 cm^2/m) is selected.

Cross-section design and input parameters:



Dead load 6.06 kN/m² | Load reduction 2.7 kN/m² | Shear resistance $V_{Rd,c,cobiax}$ 61.9 kN/m | Stiffness factor [-] 0.89

For the deformation calculation (first calculation run), the load reduction g_{cx} = 2.7 kN/ m2 (e.g., as negative load) and the stiffness factor f_{EI} = 0. 89 (e.g., by adjusting the modulus of elasticity) are applied over the entire slab area.



$f_{I,\,max} = 11{,}6\ mm \rightarrow f_{\infty,\,Faktor\ 4} = 46{,}4\ mm < 47\ mm$

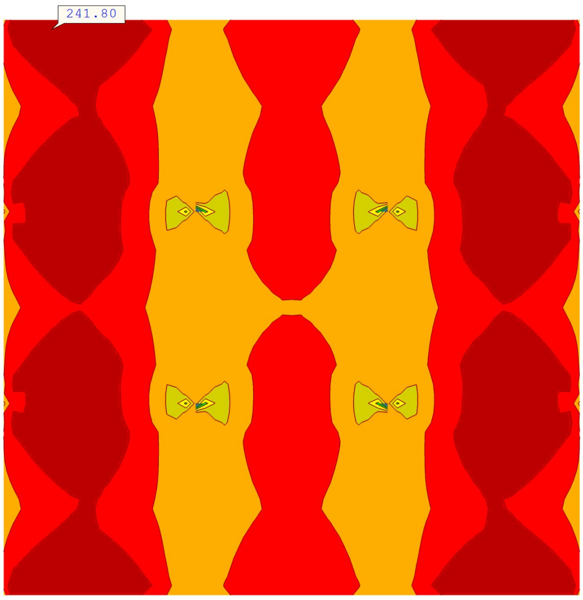
Difference:

In addition to the concrete and weight reduction due to the void formers, the slab thickness can be additionally reduced by approx. 8% with identical deformation.

2.3.16.4. Bending resistance

(First calculation run)

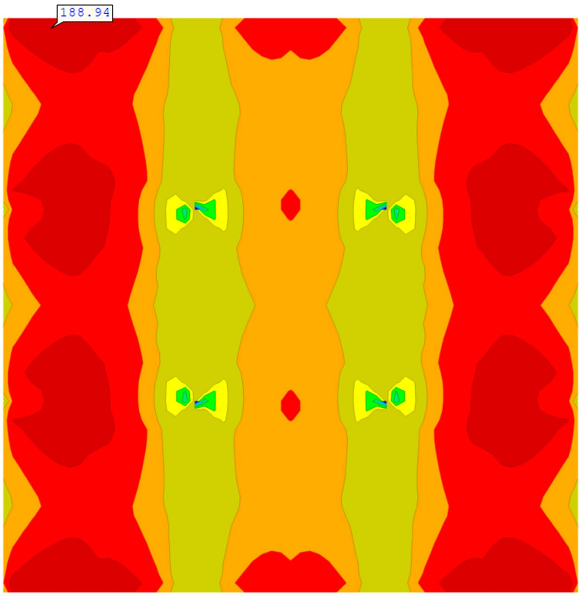
Solid slab with h = 38 cm



Example max. span moment:

M_{Ed} = 241,80 kNm/m, with d = 33 cm → req. a_s = 18,1 cm²/m

Cobiax voided slab with h = 35 cm



Example max. span moment:

M_{Ed} = 188,94 kNm/m, with d = 30 cm → req. a_s = 15,1 cm^2/m

Difference:

The statically required bending reinforcement can be reduced by approx. 16%!

Check compression zone height

An influence of the void formers on the bending design can be excluded if the compression zone remains above the void formers. The maximum design value for the bending moment in the void former area is:

$$M_{Ed} = 188{,}94 \text{ kNm/m}$$

E.g., with the help of design tables with dimensionless coefficients, the related design moment as well as the associated compression zone height can be determined.

$$\mu_{Eds} = \frac{M_{EDs}}{b \cdot d^2 \cdot f_{cd}} = \frac{0{,}189}{1 \cdot 0{,}30^2 \cdot 17} = 0{,}124 \approx 0{,}12$$

$$x/d = 0{,}159 \rightarrow x = 0{,}159 \cdot 30\ cm = 4{,}77\ cm \leq d_{2,Hk} = 6{,}00 \text{ cm}$$ ✓

The compression zone remains above the void former!

A faster way of checking is to compare with the limit bending moment from the calculation with the CQL software. Links on page 12.

$$M_{Ed} = 188{,}94 \text{ kNm/m} \leq 207{,}45 \text{ kNm/m}$$ ✓

2.3.16.5. Shear resistance

(First calculation run)

The shear resistance in the voided area is determined with the given flexural strength rebar. Areas with $V_{Ed} > V_{Rd,c,cobiax}$ are designed as solid zones without void fomers. Unfavorably, only the Ø12-10 (11.31 cm²/m) basic reinforcement is considered in this example. The simplest way to calculate $V_{Rd,c,cobiax}$ is by using the CQL software. Links on page 12.

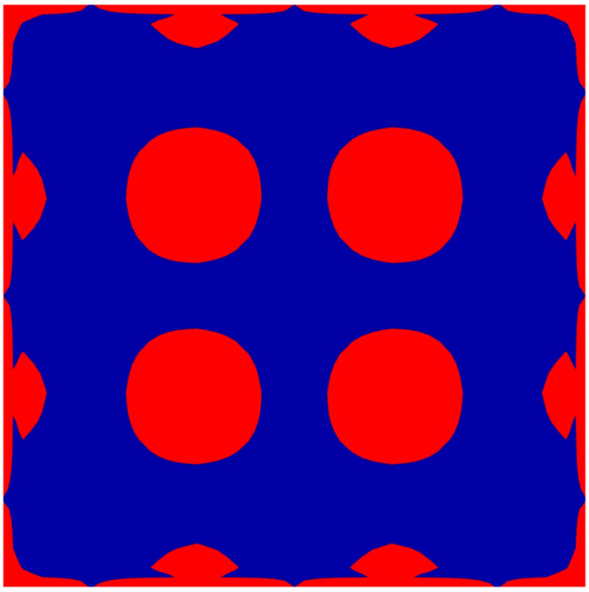
$$V_{Rd,c,cobiax} = f_V \cdot \left[\frac{0{,}18}{\gamma_c} \cdot \kappa \cdot (100 \cdot \rho_l \cdot f_{ck})^{\frac{1}{3}}\right] \cdot b \cdot d$$

$$= 0{,}43 \cdot \left[\frac{0{,}18}{1{,}5} \cdot 1{,}82 \cdot (100 \cdot 0{,}0038 \cdot 30)^{\frac{1}{3}}\right] \cdot 1 \cdot 0{,}30 \cdot 1000 = 63\ \frac{kN}{m}$$

f_V = 0,43 (ADS, line 11)

$$\kappa = 1 + \sqrt{\frac{200}{300}} = 1{,}82 \leq 2{,}0$$

ρ_l $= 11{,}31 / (100 \cdot 30) = 0{,}0038 \leq 0{,}02$



Display of the shear force areas with $V_{Ed} \geq 63{,}0$ kN/m $= V_{Rd,c,cobiax}$

Difference:

The degree of occupancy with void formers is approx. 65% of the slab area. Together with the reduced slab thickness, a total of 26% concrete or dead load can be saved for this slab component.

2.3.16.6. Proof of the concreting joint

(First calculation run)

The concreting joint must be proven as a smooth joint ($c = 0{,}2;\ \mu = 0{,}6;\ \nu = 0{,}2$).

Design value of the shear force:

$v_{Edi} = V_{Ed} / z = V_{Rd,c,cobiax} / z = 63{,}0$ kN/m / $(0{,}9 \cdot 0{,}30) = 0{,}233$ MN/m^2 (for $v_{Rdi,cobiax}$)

Reduced bonding area (ADS, line 13):

$A_{i,\,red} = 0{,}21\ A_i$

Design value of shear resistance in the joint:

$v_{Rdi,max,cobiax} = 0{,}5 \cdot \nu \cdot f_{cd} \cdot A_{i,red}/A_i = 0{,}5 \cdot 0{,}2 \cdot 17{,}0 \cdot 0{,}21 = 0{,}357$ MN/m^2 > 0,233 MN/m^2 = v_{Edi} ✓

$v_{Rdi,cobiax} = A_{i,red}/A_i \cdot c \cdot f_{ctd} + \mu \cdot \sigma_n + \rho \cdot f_{yd}\ (1{,}2\mu \cdot \sin\alpha + \cos\alpha)$

Converted and for $v_{Rdi,cobiax} = v_{Edi}$ results in the required bonding reinforcement:

$a_{s,erf} = (v_{Edi} - A_{i,red}/A_i \cdot c \cdot f_{ctd} - \mu \cdot \sigma_n)\ .\ A_i / (f_{yd}\ (1{,}2\mu\ .\ \sin\alpha + \cos\alpha))$

$a_{s,erf} = (0{,}233$ MN/m^2 - $0{,}21 \cdot 0{,}2 \cdot 1{,}13$ MN/m^2) $\cdot$ 1 m^2 / (435 MN/m^2 $(1{,}2 \cdot 0{,}6 \cdot \sin 90 + \cos 90))$

$a_{s,erf} = 5{,}92$ cm^2/m^2 = 2,13 cm^2/X-Zone → 2,01 cm^2/X-Zone = Minimum reinforcement ✗

In this case, the minimum reinforcement is not sufficient.

Verification of shear force transmission in the concreting joint is quick and easy with the CQL software. Links on page 12.

2.3.16.7. Fire resistance

Solid slab with h = 38 cm

(According to standard)

Table 5.8: Minimum dimensions and center distances for statically determinate, uniaxially and biaxially tensioned reinforced concrete and post-tensioned concrete slabs according to EC 2-1-2.

Fire resistance class	Slab thickness h_s (mm)	Minimum dimensions – Center distance a: uniaxial	biaxial $l_y/l_x \leq 1{,}5$	biaxial $1{,}5 < l_y/l_x \leq 2{,}0$
REI 30	60	10 *	10 *	10 *
REI 60	80	20	10 *	15 *
REI 90	100	30	15 *	20
REI 120	120	40	20	25
REI 180	150	55	30	40
REI 240	175	65	40	50

l_x und l_y are the spans of a biaxially spanned slab (both directions at right angles to each other), where l_y is the longer span. […] The center distance a in columns 4 and 5 applies to biaxially spanned slabs supported at four edges. If this does not apply, the slabs are to be treated as uniaxially spanned slabs.

* Typically, the concrete cover required by EN 1992-1-1 is sufficient.

The required center distance to the reinforcement must be at least 15 mm!

Cobiax voided slab with h = 35 cm

(According to technical approval or expert report)

Appendix 2: Center distances for biaxially spanned slabs with $l_y/l_x \leq 1{,}5$ – Cobiax CLS Reinforced and post-tensioned concrete slabs according to EC 2-1-2.

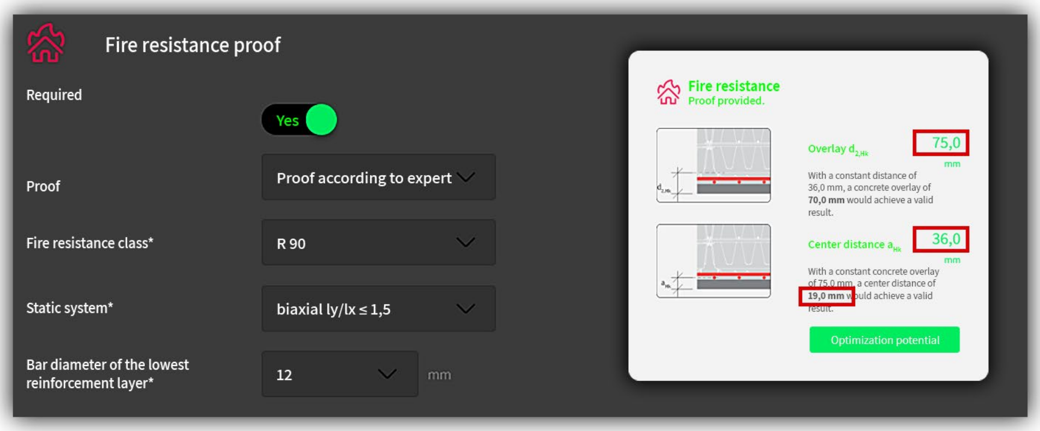
	Fire resistance class	$d_{2,Hk}$ 55	60	70	80	90	100	110	120
CLS-P-200	R 30	-	-	11	11	11	11	11	-
	R 60	-	-	11	11	11	11	11	-
	R 90	-	-	20	18	17	16	16	-
	R 120	-	-	31	27	24	22	22	-
	R 180	-	-	-	54	44	39	36	-
	R 240	-	-	-	-	-	62	54	-
CLS-P-240	R 30	-	-	11	11	11	11	11	-
	R 60	-	-	11	11	11	11	11	-
	R 90	-	-	20	18	17	16	16	-
	R 120	-	-	31	27	24	22	22	-
	R 180	-	-	-	55	44	39	36	-
	R 240	-	-	-	-	-	63	54	-

Interpolation for CLS-P-230:

$d_{2,Hk}$	75 mm
a_{Hk}	19 mm

The required center distance to the reinforcement must be at least 19 mm!

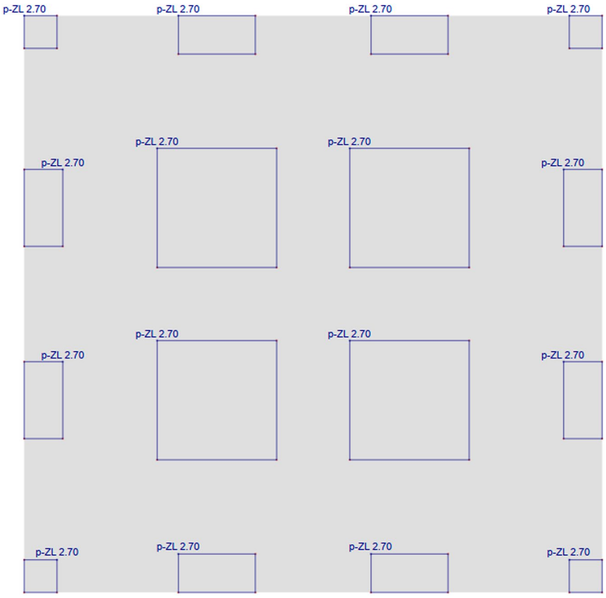
The proof of fire resistance is done quickly and easily with the CQL software. Links on page 12.



The actual center distance to the reinforcement is 36 mm.

2.3.16.8. Load transfer

Areas with $V_{ED} \geq 63{,}0$ kN/m are to be designed solid without void formers. The increased dead load must be considered in these areas (here: + 2.7 kN/m²).



Areas with increased dead load

Solid slab with h = 38 cm

Dead load			
0,38 m x 25 kN/m²	=	9,50	kN/m²
Additional dead load	=	**1,50**	**kN/m²**
Live load	=	**3,50**	**kN/m²**
Total load	=	**14,50**	**kN/m²**

Cobiax voided slab with h = 35 cm

Dead load			
0,35 m x 25 kN/m² - 65% x 2,7 kN/m²	=	7,00	kN/m²
Additional dead load	=	**1,50**	**kN/m²**
Live load	=	**3,50**	**kN/m²**
Total load	=	**12,00**	**kN/m²**

Difference:

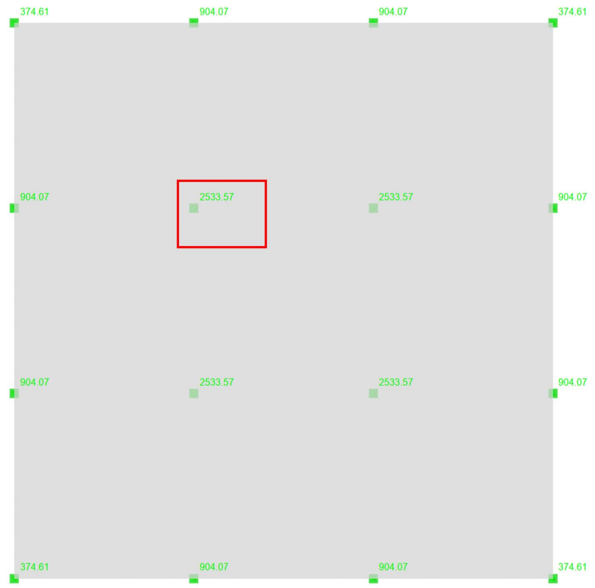
Dead weight reduced by approx. 26% and total load reduced by approx. 17%!

2.3.16.9. Punching

(Second calculation run)

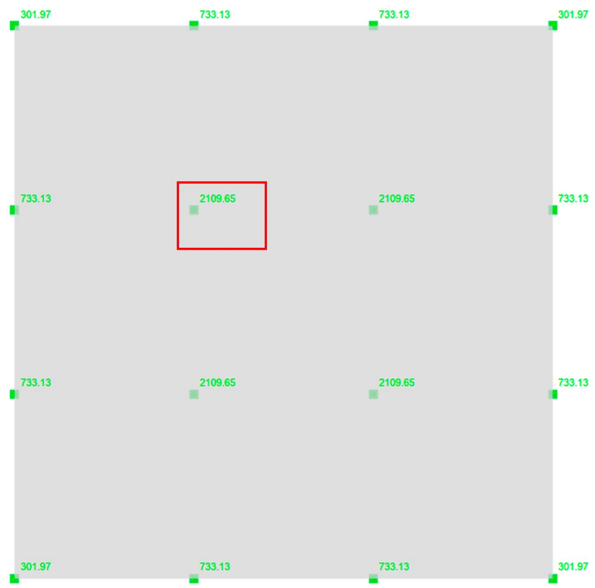
Support reactions

Solid slab with h = 38 cm



Example max. support force:
$V_{Z,Ed}$ = 2.533,57 kN

Cobiax voided slab with h = 35 cm

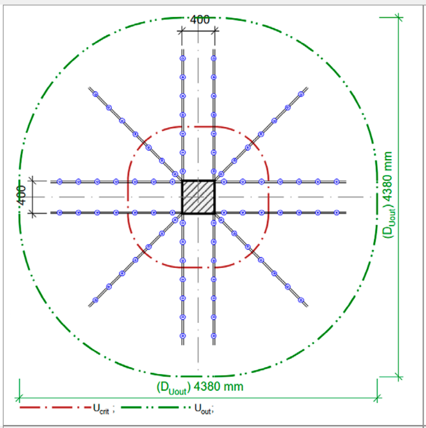
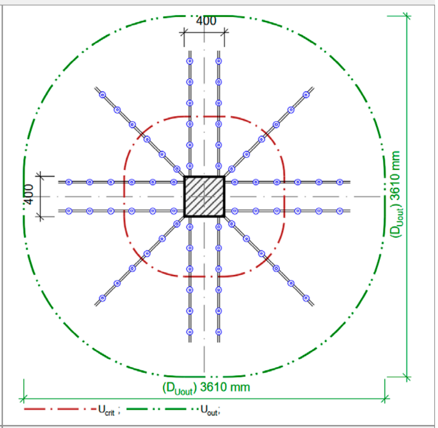
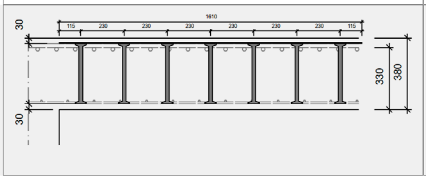
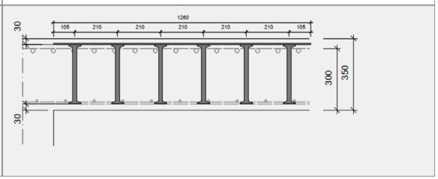


Example max. support force:
$V_{Z,Ed}$ = 2.109,65 kN

Difference:

Design load reduced by approx. 17%!

Punching reinforcement

	Solid slab with h = 38 cm	**Cobiax voided slab with h = 35 cm**
Input value	2.534 kN	2.110 kN
Result	12x Schöck BOLE O 20/320-7/A1610	12x Schöck BOLE O 20/290-6/1260
Layout		
Section		

Difference:

Punching reinforcement reduced by approx. 15%!

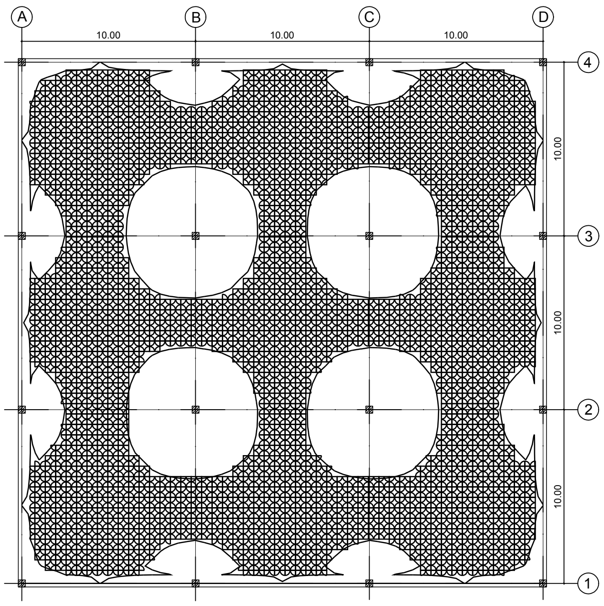
Check punching critical area

The solid area without void formers must extend beyond the last reinforcement row by at least dimension 2 d The area around the maximum loaded internal support (40/40 cm) has a size of approx. 700/700 cm. The length of the reinforced area is 126 cm:

0,5 x column width + 126 cm + 2d = 20 cm + 126 cm + 60 cm = 206 cm ≤ 700/2 = 350 cm

2.3.16.10. Cobiax installation plan

The degree of occupancy with void formers here is about 65% of the slab area.



2.4. Sustainability

2.4.1. General information

Worldwide, around 2.8 billion tons of CO_2 are emitted each year through the production of cement. This corresponds to around eight percent of global CO_2 emissions. In Germany, Austria, and Switzerland alone, more than 42 million tons of cement are produced each year. A large proportion of this is required for the concrete of floor slabs in building construction.

Cobiax void formers are made from 100% recycled plastic. They reduce a slab's need for concrete by up to 35% and for reinforcing steel by up to 15%. As a result, Cobiax void former systems have an excellent environmental footprint. Emissions of environmentally toxic pollutants such as CO_2 are reduced by up to 20 percent, and primary energy requirements can even be reduced by up to 22 percent.

Additional material savings can be achieved in the entire building structure. In a large number of projects, Cobiax technology has already had a highly positive effect on the sustainability certification of the building being assessed.

After the service life and deconstruction of the building, the plastic of the void formers can be reintroduced into the material cycle as recycling material after appropriate preparation and treatment of the demolition material.

For their ecological effectiveness and innovative strength, the void former systems from Cobiax have received several international awards in recent years. These include the Swiss Environmental Award, the German Material Efficiency Award and the German Sustainability Award.

2.4.2. Assessment basis

Ecological life cycle analysis (LCA)

An LCA (Life Cycle Assessment) is a systematic analysis of the environmental impacts of products throughout their entire life cycle (from production through the use phase to disposal of the product).

The LCA for the Cobiax void former system for concrete slabs, prepared by CSD Ingenieure and externally audited, demonstrates the positive environmental impact of using Cobiax voided slabs instead of conventional solid reinforced concrete floors. The aim of this LCA is to provide basic data for an ecological life cycle assessment that offers planners an evaluation basis for implementing sustainable and holistic optimizations of building concepts.

Environmental Product Declaration (EPD)

An EPD (Environmental Product Declaration) contains the data basis for ecological building assessment. It is based on ISO standards and is therefore internationally harmonized.

To consider the ongoing positive influence of Cobiax also on international sustainability certificates of buildings (e.g., according to DGNB, LEED or BREEAM), the basic data of the LCA were summarized in an EPD. The EPD for the Cobiax void former slab system was published by the Institut Bauen und Umwelt e.V.

2.5. Building Information Modeling (BIM)

2.5.1. General information

With Building Information Modeling (BIM), in contrast to conventional planning, the individual components are described as "intelligent objects". Corresponding software can distinguish between a wall and a slab, for example. In addition, further attributes (for example, information on costs, construction time, maintenance work) can be assigned to the objects.

This enables a holistic digital information management with three principles:

- Object-related building model as a source of information and data hub for collaboration between project participants.
- Digital capture and networking of all relevant data for mapping the physical, functional as well as cost- and time-related properties of a structure.
- Accompaniment of the entire life cycle - data acquisition from inventory through planning and realization to use.

2.5.2. Cobiax BIM objects

For implementation in modeling software, Cobiax BIM objects for the programs "Autodesk Revit" and "Graphisoft ArchiCAD" are available for download at **cobiax.com**. Currently, the object catalogs are especially suitable for the architect's preliminary, draft and approval planning (LOD 200 and LOD 300).

Cobiax objects provide, for example, information on

- General slab geometry such as thickness, possible span, type and location of the void former system
- Quantities and costs
- Material savings and information on sustainability and CO_2 reduction accordingly
- Positions in the tender

2.6. Costs and tendering

2.6.1. Economic efficiency

At slab level, Cobiax voided slabs are technically more efficient in direct comparison with conventional solid slabs and, due to the lower material consumption, are also always cheaper on average.

Primary (at slab level)

- up to 35% concrete and weight reduction due to the void formers
- up to 10% additional concrete and weight reduction due to reduction of slab thicknesses
- up to 15% reduced steel reinforcement
- up to 25% reduced punching reinforcement
- Elimination of support cages for the upper reinforcement in the voided area

In addition, at the building level, the reduced dead load of the slab can significantly reduce the costs of the entire load-bearing structure, the bracing system and the building foundation. This optimization potential varies greatly depending on the project. Experience shows that it is up to 115% of slab area.

Secondary (at building level)

- Optimization of vertical support members such as columns and walls
- Optimization of interception structures and levels
- Optimization of the bracing system, especially for earthquake loads
- Optimization of foundations, especially for special foundations such as piles
- Up to 20% reduction in CO_2 emissions due to material-efficient, sustainable construction methods.

The large slab spans and the optimized cross-sections of the load-bearing components lead to a high degree of flexibility in the room layout and also increase the usable floor space. Together with the positive influence of Cobiax on building certification (e.g., according to DGNB, LEED or BREEAM), the value of a property can thus be increased even more sustainably.

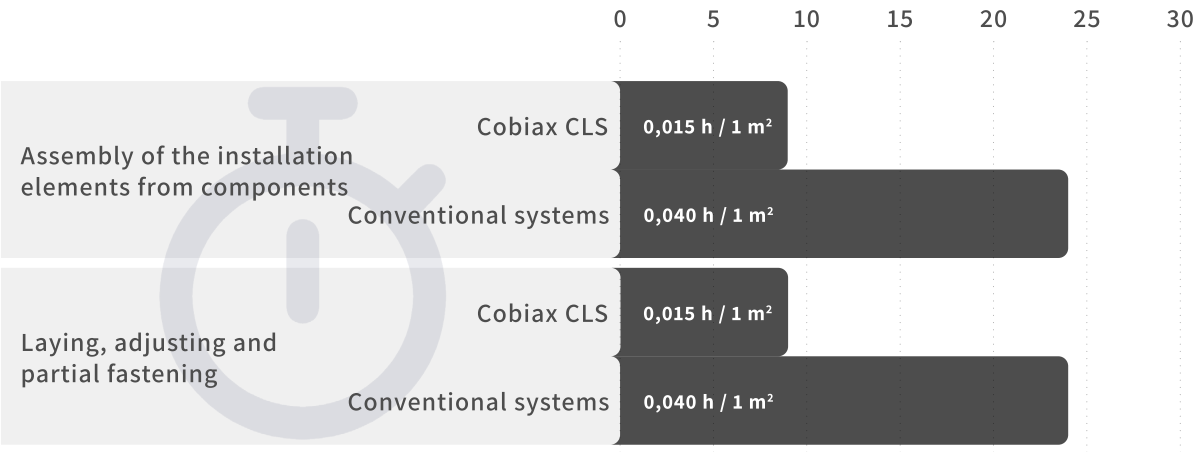
Total cost of the slab

Based on the costs of a structurally equivalent solid slab, the additional and reduced costs are presented in relation to the Cobiax slab.

(*) = Optimization of all load-bearing components (walls, columns, foundations/ground slabs, special foundation, bracing), reduction of facade areas due to lower construction height, advantages in sustainability certification.

2.6.2. Effort values

Cobiax installation elements are only installed in partial areas of the slab. Under normal boundary conditions, 65% of the slab area can be assumed for simplicity. The effort values listed below refer to the pure voided areas and result from empirical values from completed projects.



2.6.3. Tender

The tender for the construction of a Cobiax voided slab is basically similar to the tender for a conventional reinforced concrete slab. To be able to calculate the installation of Cobiax elements and their concrete reduction, it is necessary to specify the percentage of the voided slab area (percentage of the slab area that will be covered with void formers). If this is not yet known, a simplified assumption of 65% of the slab area can be made for normal boundary conditions.

All other Cobiax-specific parameters can be found in the Application Data Sheets (ADS, see chapter 3 from page 74).

2.6.3.1. Sample of a tender text for Cobiax CLS

Sample data: Voided slab h = 30 cm, concrete C30/37, Cobiax CLS structural former CLS-P-190, 1,000 m2 slab area, 65% of which is covered with void formers.

In-situ concrete of the voided slab made of reinforced concrete C30/37, h = 30 cm.

In-situ concrete of the two-axis voided slab made of reinforced concrete including completely closed structural formers consisting of squares segmented into 4 quarter circles with load-bearing concrete zone (X-zone) inside.

Slab thickness	30 cm	
Concrete quality	C30/37	
Void former system	Cobiax CLS	
Type	CLS-P-190	
Volume displacement in the voided area	0,0906 m^3/m^2	ADS, line 2
Support height	19 cm	ADS, line 4
Void height	16 cm	ADS, line 23
Portion of the voided area	65%	

Formwork, reinforcement and finishing of the fresh concrete surface as separate item.

Delivery and installation of the structural formers (with national technical approval) on the lower reinforcement layer as a support element for the upper reinforcement in accordance with the manufacturer's installation guideline and installation plan. The structural formers are secured against uplift, e.g., by casting the voided slab in 2 working steps.

The tendered quantity refers to the total slab area (voided and solid area portions).

Contact address:
Cobiax Deutschland GmbH • Am Stadtholz 56 • D-33609 Bielefeld • Germany
info@cobiax.com • www.cobiax.com

1.000,00 m^2

Unit price (UP): ______________

Total price (TP): ______________

2.7. Execution

2.7.1. General information

Delivery

Cobiax installation elements are delivered to the installation site as individual components and assembled on site to form CLS structural formers. The transport-relevant parameters can be found in the application data sheets, lines 49 to 58 (ADS, see chapter 3 from page 74).

Assembly instructions

Cobiax voided slabs are installed in accordance with the national technical approval and the installation instructions contained therein. The aforementioned regulations must be observed in all cases of execution.

Installation plans

Cobiax can prepare project-specific installation plans based on the structural analysis and the formwork plans. In addition to the representation of the voided areas and the void former types, these plans also contain all other information relevant for the execution.

Assembly procedure

The installation elements are installed according to the installation plan between the lower and upper reinforcement layers in the specified grid. Staggered arrangement is not permitted. If necessary, intermediate layers (e.g., for additional spacers or installation levels) must be provided between the reinforcement layers and the installation elements. To secure the position, the installation elements are partially fixed to the reinforcement, e.g., with wire or cable ties. It is recommended to always install the void formers with the smaller half-shell at the bottom.

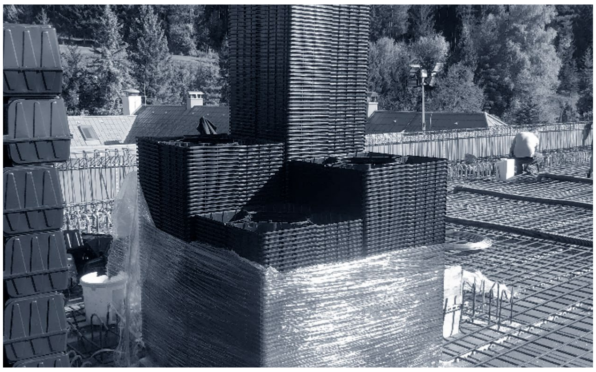
Casting procedure

The required concrete properties can be taken from the Application Data Sheets, lines 14 to 16 (ADS, see Chapter 3 from page 74). During the casting process, the installation elements must be secured against uplift by suitable measures. This is usually done by casting in 2 working steps. The first, already stiffened concrete layer fixes the installation elements when the second concrete layer is casted. Bonding reinforcement must be placed in the voided area. The fixing elements of Cobiax SL can be applied as bonding reinforcement under concrete exposure class XC1. The concrete must be carefully casted and compacted so that the reinforcement and the void formers are tightly encased in concrete. Air pockets, especially under the void formers, must be avoided; if necessary, compaction must be carried out in each intermediate area. The second concrete layer must not be casted until the first concrete layer has hardened sufficiently. However, depending on the outside temperature and the concrete used, this may already be done after a few hours. The concrete of the second layer must be compacted carefully and cautiously so as not to cause any structural and bonding disturbances in the already hardened first layer. Also in this step, an uplift of the void formers must be reliably avoided.

Special notes

Due to the system, the void formers are not completely sealed against water. It must therefore be ensured before installation that there is no water in the void formers. The void formers must also be protected against water inflow between installation states. The type of protection is the responsibility of the company carrying out the work. Holes drilled from above into the finished concrete slab in the void former area must be closed again immediately.

2.7.2. Cobiax CLS

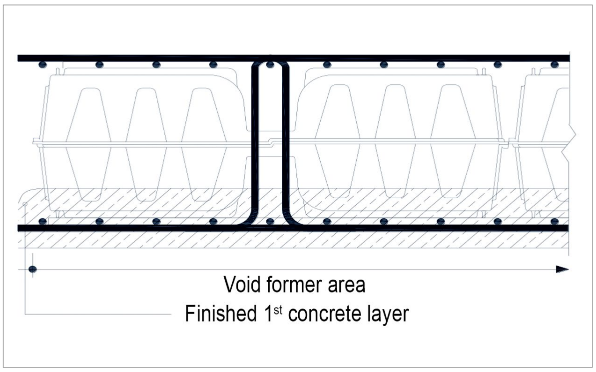


Delivery of the half-shells on pallets

Assembling the half-shells to void formers

Laying of the void formers close together without gaps acc. to Cobiax installation plan, smaller half-shell at the bottom

Bonding reinforcement (supplied on site)



For uplift control, the voided areas are casted in two working steps. Depending on the concrete used and the outside temperature, the second concrete layer can be applied after only a few hours.

Link to the Cobiax CLS installation video:
https://www.youtube.com/watch?v=e_qrcblU4Gs

3. Application data sheets

3.1. Cobiax CLS

Installation element

				CLS-P-110	CLS-P-130	CLS-P-150	CLS-P-170	CLS-P-190
2	Volume displacement	h_{cx}	m³/m²	0.0456	0.0569	0.0683	0.0794	0.0906
3	Associated weight reduction (25 kN/m³)	g_{cx}	kN/m²	1.14	1.42	1.71	1.99	2.27
4	Support height	h_u	cm	11	13	15	17	19
5	Min. slab thickness	$h_{d,min}$	cm	20	22	24	26	28
6	Max. slab thickness	$h_{d,max}$	cm	38	40	42	44	46
7	Min. thickness of concrete overlay to void (top/bottom)	$d_{2,Hk,min}$	cm	6				
8	Distance void to upper edge of installation element	$h_{dis,o}$	cm	1.5				
9	Distance void to lower edge of installation element	$h_{dis,u}$	cm	1.5				
10	Limit slab thickness for $V_{Rd,c,cobiax}$ calculation	$h_{d,grenz}$	cm	76				
11	Shear factor	f_v		0.45	0.45	0.44	0.44	0.44
12	Stiffness factor (with $hd_{,min}$ and centric position)	f_{EI}		0.96	0.94	0.93	0.91	0.89
13	Reduced bonding area	$A_{i,red}$		0.21 A_i				
14	Concrete strength class			C20/25 to C45/55				
15	Aggregate for max. grain size		mm	16				
16	Concrete consistency class			F3 to F4				
17	Max. diameter of reinforcing steel		mm	16				
18	CO_2-emission reduction		t/m²	0.010	0.012	0.014	0.017	0.019
19	Associated area per installation element		m²/pc	0.36				

Component - Void former

				CLS-P-110	CLS-P-130	CLS-P-150	CLS-P-170	CLS-P-190
21	Top half-shell type			CLS-H-055	CLS-H-075	CLS-H-075	CLS-H-095	CLS-H-095
22	Bottom half-shell type			CLS-H-055	CLS-H-055	CLS-H-075	CLS-H-075	CLS-H-095
23	Void height	h_v	cm	8	10	12	14	16
24	Diameter / outer dimensions		cm	60.0/60.0				
25	Void volume		dm³/pc	16.4	20.5	24.6	28.6	32.6
26	Min. center distance of void formers	e	cm	60				
27	Min. web width	a	cm	6				
28	Void formers per square meter		pc/m²	2.78				
29	Associated area per void former		m²/pc	0.36				
30	Void formers per installation element		pc/pc	1				

Transport components (semi-trailer 13.50 m)

			CLS-P-110	CLS-P-130	CLS-P-150	CLS-P-170	CLS-P-190
50	Installation elements per truck	pc/pc	4,784			4,725	4,680
51	Associated voided area per truck	m²/pc	1,722			1,701	1,685

Installation element

				CLS-P-210	CLS-P-230	CLS-P-250	CLS-P-270	CLS-P-290
2	Volume displacement	h_{cx}	m^3/m^2	0.0992	0.1078	0.1167	0.1278	0.1364
3	Associated weight reduction (25 kN/m^3)	g_{cx}	kN/m^2	2.48	2.70	2.92	3.20	3.41
4	Support height	h_u	cm	21	23	25	27	29
5	Min. slab thickness	$h_{d,min}$	cm	32	34	36	38	40
6	Max. slab thickness	$h_{d,max}$	cm	48	50	52	54	56
7	Min. thickness of concrete overlay to void (top/bottom)	$d_{2,Hk,min}$	cm	7				
8	Distance void to upper edge of installation element	$h_{dis,o}$	cm	1.5				
9	Distance void to lower edge of installation element	$h_{dis,u}$	cm	1.5				
10	Limit slab thickness for $V_{Rd,c,cobiax}$ calculation	$h_{d,grenz}$	cm	76				
11	Shear factor	f_v		0.43	0.43	0.42	0.42	0.41
12	Stiffness factor (with $hd,_{min}$ and centric position)	f_{EI}		0.90	0.88	0.87	0.86	0.85
13	Reduced bonding area	$A_{i,red}$		0.21 A_i				
14	Concrete strength class			C20/25 to C45/55				
15	Aggregate for max. grain size		mm	16				
16	Concrete consistency class			F3 to F4				
17	Max. diameter of reinforcing steel		mm	16				
18	CO_2-emission reduction		t/m^2	0.021	0.023	0.025	0.027	0.029
19	Associated area per installation element		m^2/pc	0.36				

Component - Void former

				CLS-P-210	CLS-P-230	CLS-P-250	CLS-P-270	CLS-P-290
21	Top half-shell type			CLS-H-115	CLS-H-115	CLS-H-175	CLS-H-175	CLS-H-175
22	Bottom half-shell type			CLS-H-095	CLS-H-115	CLS-H-075	CLS-H-095	CLS-H-115
23	Void height	h_v	cm	18	20	22	24	26
24	Diameter / outer dimensions		cm	60.0/60.0				
25	Void volume		dm^3/pc	35.7	38.8	42.0	46.0	49.1
26	Min. center distance of void formers	e	cm	60				
27	Min. web width	a	cm	6				
28	Void formers per square meter		pc/m^2	2.78				
29	Associated area per void former		m^2/pc	0.36				
30	Void formers per installation element		pc/pc	1				

Transport components (semi-trailer 13.50 m)

				CLS-P-210	CLS-P-230	CLS-P-250	CLS-P-270	CLS-P-290
50	Installation elements per truck		pc/pc	4,558	4,472	4,508	4,455	4,346
51	Associated voided area per truck		m^2/pc	1,641	1,610	1,623	1,604	1,565

Installation element

				CLS-P-310	CLS-P-330	CLS-P-350	CLS-P-370	CLS-P-390
2	Volume displacement	h_{cx}	m^3/m^2	0.1436	0.1547	0.165	0.1639	0.175
3	Associated weight reduction (25 kN/m^3)	g_{cx}	kN/m^2	3.59	3.87	4.13	4.10	4.38
4	Support height	h_u	cm	31	33	35	37	39
5	Min. slab thickness	$h_{d,min}$	cm	44	46	48	50	52
6	Max. slab thickness	$h_{d,max}$	cm	58	60	62	64	66
7	Min. thickness of concrete overlay to void (top/bottom)	$d_{2,Hk,min}$	cm	8				
8	Distance void to upper edge of installation element	$h_{dis,o}$	cm	1.5				
9	Distance void to lower edge of installation element	$h_{dis,u}$	cm	1.5				
10	Limit slab thickness for $V_{Rd,c,cobiax}$ calculation	$h_{d,grenz}$	cm	76				
11	Shear factor	f_v		0.41	0.40			
12	Stiffness factor (with $hd,_{min}$ and centric position)	f_{EI}		0.86	0.85	0.84	0.83	0.82
13	Reduced bonding area	$A_{i,red}$		0.21 A_i				
14	Concrete strength class			C20/25 to C45/55				
15	Aggregate for max. grain size		mm	16				
16	Concrete consistency class			F3 to F4				
17	Max. diameter of reinforcing steel		mm	16				
18	CO_2-emission reduction		t/m^2	0.030	0.032	0.035	0.034	0.037
19	Associated area per installation element		m^2/pc	0.36				

Component - Void former

				CLS-P-310	CLS-P-330	CLS-P-350	CLS-P-370	CLS-P-390
21	Top half-shell type			CLS-H-235	CLS-H-235	CLS-H-175	CLS-H-295	CLS-H-295
22	Bottom half-shell type			CLS-H-075	CLS-H-095	CLS-H-175	CLS-H-075	CLS-H-095
23	Void height	h_v	cm	28	30	32	34	36
24	Diameter / outer dimensions		cm	60.0/60.0				
25	Void volume		dm^3/pc	51.7	55.7	59.4	59.0	63.0
26	Min. center distance of void formers	e	cm	60				
27	Min. web width	a	cm	6				
28	Void formers per square meter		pc/m^2	2.78				
29	Associated area per void former		m^2/pc	0.36				
30	Void formers per installation element		pc/pc	1				

Transport components (semi-trailer 13.50 m)

				CLS-P-310	CLS-P-330	CLS-P-350	CLS-P-370	CLS-P-390
50	Installation elements per truck		pc/pc	4,255	4,218	4,128	3,082	3,060
51	Associated voided area per truck		m^2/pc	1,532	1,518	1,486	1,110	1,102

Installation element

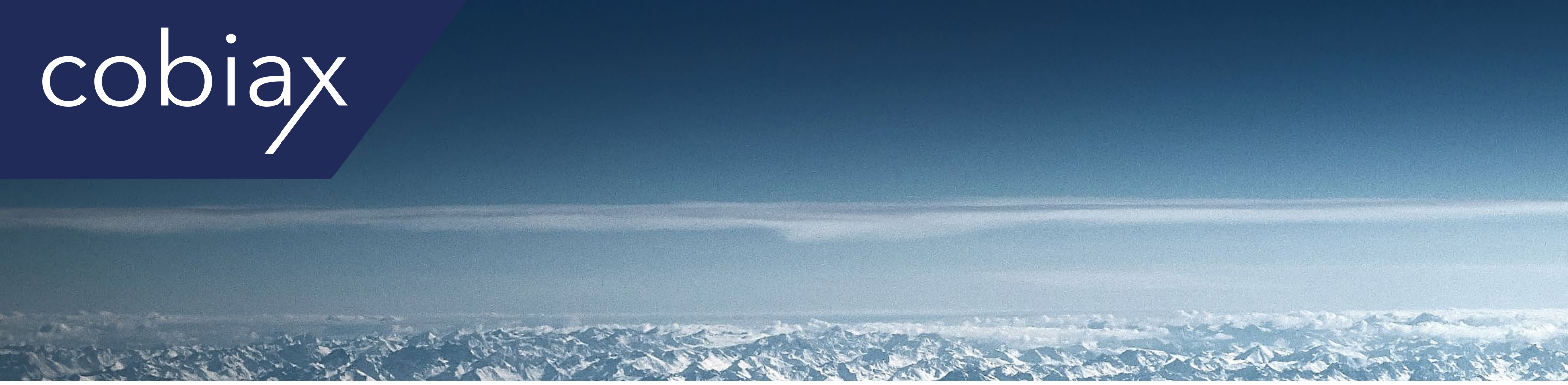
				CLS-P-410	CLS-P-470	CLS-P-530	CLS-P-590
2	Volume displacement	h_{cx}	m^3/m^2	0.1919	0.2189	0.2392	0.2594
3	Associated weight reduction (25 kN/m^3)	g_{cx}	kN/m^2	4.80	5.47	5.98	6.49
4	Support height	h_u	cm	41	47	53	59
5	Min. slab thickness	$h_{d,min}$	cm	56	62	70	76
6	Max. slab thickness	$h_{d,max}$	cm	68	74	80	80
7	Min. thickness of concrete overlay to void (top/bottom)	$d_{2,Hk,min}$	cm	9		10	
8	Distance void to upper edge of installation element	$h_{dis,o}$	cm	1.5			
9	Distance void to lower edge of installation element	$h_{dis,u}$	cm	1.5			
10	Limit slab thickness for $V_{Rd,c,cobiax}$ calculation	$h_{d,grenz}$	cm	76			
11	Shear factor	f_v		0.40			
12	Stiffness factor (with $hd,_{min}$ and centric position)	f_{EI}		0.83	0.81	0.80	0.79
13	Reduced bonding area	$A_{i,red}$		0.21 A_i			
14	Concrete strength class			C20/25 to C45/55			
15	Aggregate for max. grain size		mm	16			
16	Concrete consistency class			F3 to F4			
17	Max. diameter of reinforcing steel		mm	16			
18	CO_2-emission reduction		t/m^2	0.040	0.046	0.050	0.054
19	Associated area per installation element		m^2/pc	0.36			

Component - Void former

				CLS-P-410	CLS-P-470	CLS-P-530	CLS-P-590
21	Top half-shell type			CLS-H-235	CLS-H-235	CLS-H-295	CLS-H-295
22	Bottom half-shell type			CLS-H-175	CLS-H-235	CLS-H-235	CLS-H-295
23	Void height	h_v	cm	38	44	50	56
24	Diameter / outer dimensions		cm	60.0/60.0			
25	Void volume		dm^3/pc	69.1	78.8	86.1	93.4
26	Min. center distance of void formers	e	cm	60			
27	Min. web width	a	cm	6			
28	Void formers per square meter		pc/m^2	2.78			
29	Associated area per void former		m^2/pc	0.36			
30	Void formers per installation element		pc/pc	1			

Transport components (semi-trailer 13.50 m)

			CLS-P-410	CLS-P-470	CLS-P-530	CLS-P-590
50	Installation elements per truck	pc/pc	3,010	2,970	2,860	2,288
51	Associated voided area per truck	m^2/pc	1,084	1,069	1,030	824



4. Contact to Cobiax

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