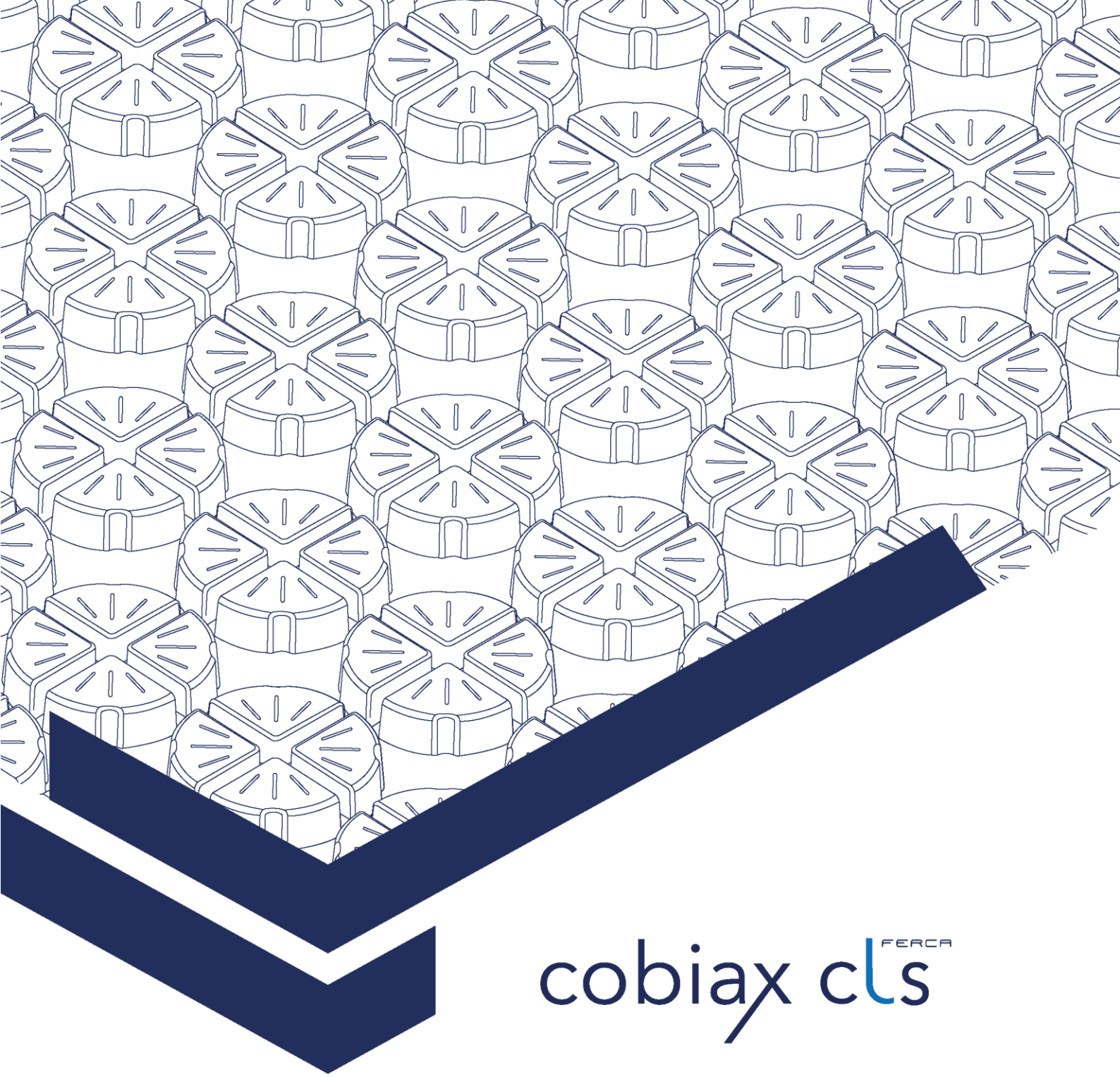


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# TECHNICAL MANUAL

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# Technical Manual – COBIAX CLS System

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# INTRODUCTION TO THE COBIAX CLS SYSTEM

The COBIAX CLS system is based on principles of economic and environmental rationalization that enable the construction of bidirectional hollow-core slabs behaving similarly to a traditional solid slab. The COBIAX CLS module is a void-forming element with an approximately square geometry in plan, internally divided into curved quarter-circle shapes. Introducing this void in the zone where concrete is not essential to the overall behaviour of the slab allows the slab thickness to be optimized, its behaviour to be improved and resources to be used more efficiently.

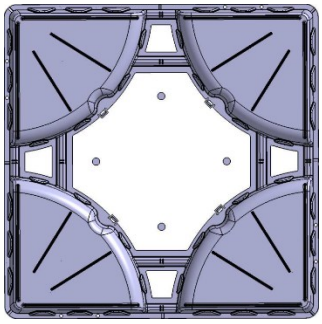


Figure 1 – COBIAX CLS module

In a world where the sustainability of natural resources is of growing importance, the use of recycled materials to form the voids and the reduction in concrete requirements allow the COBIAX CLS system, on its own, to deliver a structure with lower environmental impact and a significant reduction in the $CO_2$ emissions associated with the construction process.
COBIAX CLS technology is of Swiss origin and is the evolution of the already widely used COBIAX CBX. The system is based on a rigorous programme of tests and trials, has obtained the "National Technical Approval" from the German Institute for Construction Technology (DIBt) and is patented internationally.
COBIAX CLS was developed to improve and supplement the previous system, offering improvements in assembly speed, direct application onto the slab and a wide range of solutions for thick slabs.

COBIAX CLS slab technology holds the "National Technical Approval" registration number Z-15.1-352, issued by the German Institute of Construction Technology (DIBt).

Deutsches Institut für Bautechnik DIBt

COBIAX CLS slab technology holds an Environmental Product Declaration.

THIRD-PARTY VERIFIED EPD ISO 14025 and EN 15804 Institut Bauen und Umwelt e.V.



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## WHY USE THE COBIAX CLS SYSTEM

The COBIAX CLS system is a solution that combines the advantages of a hollow-core slab and a solid slab, allowing reduced material consumption and the savings arising from weight reduction while keeping the characteristics and behaviour of the slab practically unchanged compared with a solid slab.

## COBIAX CLS SLAB VERSUS SOLID SLAB

Compared with a solid slab, and as a result of applying the system, a COBIAX CLS slab achieves a reduction in self-weight of up to 35% in the lightened zone and a reduction in the slab's inertia of only 5 to 19%. This naturally results in improved deflection behaviour, a reduction in the level of reinforcement required and a significant reduction in shrinkage effects, in addition to the consequent reduction in mass, which has a beneficial impact on seismic behaviour, vertical elements and foundations.
At the same time, the COBIAX CLS slab retains the advantages of a faster process analogous to constructing a solid slab, while maintaining its fire-resistance, thermal and acoustic characteristics.

## COBIAX CLS SLAB VERSUS VOIDED SLAB

Conventional hollow-core slabs generally rely on a system of bidirectional ribs that provide a significant reduction in the self-weight of the slab compared with the solid slab required for the same envelope. However, the reduction in inertia of these slabs, resulting from their behaviour through a "T" section, is of the order of two-thirds, producing thicker slabs and more complex, slower and costlier construction processes.
In direct comparison, the COBIAX CLS slab allows reduced thickness, improved behaviour, the final appearance of a solid slab and construction by simpler and faster processes.

## ENVIRONMENTAL IMPACT

As the void formers are made 100% from recycled material while simultaneously reducing concrete consumption, the COBIAX CLS system actively contributes to better use of natural resources and a reduction in the $CO_2$ emissions associated with the construction process.
In summary, the COBIAX CLS system is an alternative to conventional systems, with advantages that should be properly weighed according to the specific conditions of each slab, considering the impact on the overall building solution from both a technical and economic standpoint.



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# SPECIFIC FEATURES OF THE COBIAX CLS SYSTEM

COBIAX CLS slabs essentially have three characteristics that distinguish them from solid slabs and that must be considered in the design and detailing process.

- Reduced **self-weight** owing to the presence of the voids, resulting in lower forces in the slab and in the vertical elements. In the lightened zone the reduction can reach 35%.

- **Slab stiffness** reduced by around 5 to 19%, owing to the presence of the voids — a factor that is largely offset by the weight reduction in terms of the slab's behaviour.

- Reduced **shear resistance** in the lightened zone owing to the presence of the voids. This reduction corresponds to values of 45 to 35% of the shear force of the equivalent solid slab, depending on the thickness of the COBIAX CLS.

Taking these three aspects into account in the structural design of the solution, the COBIAX CLS slab must comply with the remaining criteria and detailing of a solid slab, including non-lightened (solid) zones where the shear force exceeds the levels permitted above.

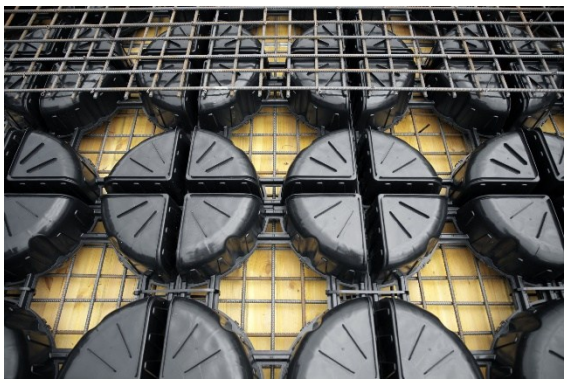


Figure 2 – COBIAX CLS slab



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# CHARACTERISTICS OF THE COBIAX CLS SYSTEM

The range of COBIAX CLS solutions generally comprises a line designated CLS-P, in which the voids consist of ellipsoidal shapes of different heights intended for different slab thicknesses.

The COBIAX CLS compartment modules, designated CLS-P-XXX, where XXX identifies the void height in mm.



Figure 3 – COBIAX CLS modules

Comprising voids of variable height between 80 mm and 560 mm for slabs with thicknesses from 200 mm to 800 mm.

H = 0,20 m à 0,80 m

The COBIAX CLS modules have a modular geometry of approximately quadrangular configuration in plan, with dimensions of about 0.60 m × 0.60 m, designed to allow their repetition in a regular grid within the slab. Each module is formed by hollow volumes with curved outlines, arranged in quarter-circle-like geometries, creating a rounded and continuous internal composition. The modules also serve as support for the upper reinforcement bars of the slab.



Figure 4 – COBIAX CLS module



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# MAIN PARAMETERS OF COBIAX CLS SLABS

The following table includes all the data required for the correct incorporation of COBIAX CLS slabs for the purposes of design, detailing and quantification.

| Slab thickness (h) | [mm] | 200 | 220 | 240 | 250 | 260 | 280 | 300 | 320 | 340 | 350 | 360 | 380 | 400 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| module | | CLS-P-110 | CLS-P-130 | CLS-P-150 | CLS-P-150 | CLS-P-170 | CLS-P-170 | CLS-P-190 | CLS-P-210 | CLS-P-230 | CLS-P-230 | CLS-P-250 | CLS-P-270 | CLS-P-290 |
| Load Reduction | [kN/m$^2$] | -1.14 | -1.42 | -1.71 | -1.71 | -1.99 | -1.99 | -2.27 | -2.48 | -2.70 | -2.70 | -2.92 | -3.20 | -3.41 |
| Stiffness Correction Factor | [-] | 0.95 | 0.94 | 0.92 | 0.93 | 0.91 | 0.93 | 0.91 | 0.89 | 0.88 | 0.89 | 0.88 | 0.85 | 0.85 |
| Shear Reduction Factor | [-] | 0.45 | 0.45 | 0.44 | 0.44 | 0.44 | 0.43 | 0.43 | 0.43 | 0.42 | 0.42 | 0.42 | 0.41 | 0.41 |
| Support Height (A) | [mm] | 110 | 130 | 150 | 150 | 170 | 170 | 190 | 210 | 230 | 230 | 250 | 270 | 290 |
| Void Height (B) | [mm] | 80 | 100 | 120 | 120 | 140 | 140 | 160 | 180 | 200 | 200 | 220 | 240 | 260 |
| No. of Voids | [un/m$^2$] | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 |
| Void Volume | [m$^3$/m$^2$] | 0.046 | 0.057 | 0.068 | 0.068 | 0.079 | 0.079 | 0.091 | 0.099 | 0.108 | 0.108 | 0.117 | 0.128 | 0.136 |
| $CO_2$ reduction | [ton/m$^2$] | 0.010 | 0.012 | 0.014 | 0.014 | 0.017 | 0.017 | 0.019 | 0.021 | 0.023 | 0.023 | 0.025 | 0.027 | 0.029 |
| Spacing between modules (C) | [mm] | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |

Table 1 – Main parameters for the design and quantification of the COBIAX CLS system – Slab from 0.20 m to 0.40 m.



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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Slab thickness (h) | [mm] | 440 | 450 | 460 | 480 | 500 | 520 | 550 | 560 | 600 | 620 | 650 | 700 | 760 |
| module | | CLS-P-310 | CLS-P-310 | CLS-P-330 | CLS-P-350 | CLS-P-350 | CLS-P-390 | CLS-P-410 | CLS-P-410 | CLS-P-410 | CLS-P-470 | CLS-P-470 | CLS-P-530 | CLS-P-590 |
| Load Reduction | [kN/m$^2$] | -3.59 | -3.59 | -3.87 | -4.13 | -4.13 | -4.38 | -4.80 | -4.80 | -4.80 | -5.47 | -5.47 | -5.98 | -6.49 |
| Stiffness Correction Factor | [-] | 0.85 | 0.87 | 0.85 | 0.84 | 0.86 | 0.82 | 0.83 | 0.84 | 0.87 | 0.81 | 0.84 | 0.81 | 0.81 |
| Shear Reduction Factor | [-] | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.39 | 0.39 | 0.39 | 0.39 | 0.38 | 0.38 | 0.36 | 0.35 |
| Support Height (A) | [mm] | 310 | 310 | 330 | 350 | 350 | 390 | 410 | 410 | 410 | 470 | 470 | 530 | 590 |
| Void Height (B) | [mm] | 280 | 280 | 300 | 320 | 320 | 360 | 380 | 380 | 380 | 440 | 440 | 500 | 560 |
| No. of Voids | [un/m$^2$] | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 | 2.78 |
| Void Volume | [m$^3$/m$^2$] | 0.144 | 0.144 | 0.155 | 0.165 | 0.165 | 0.175 | 0.192 | 0.192 | 0.144 | 0.219 | 0.144 | 0.239 | 0.259 |
| $CO_2$ reduction | [ton/m$^2$] | 0.030 | 0.030 | 0.032 | 0.035 | 0.035 | 0.037 | 0.040 | 0.040 | 0.030 | 0.046 | 0.030 | 0.500 | 0.054 |
| Spacing between modules (C) | [mm] | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |

Table 2 – Main parameters for the design and quantification of the COBIAX CLS system – Slab from 0.44 m to 0.76 m.

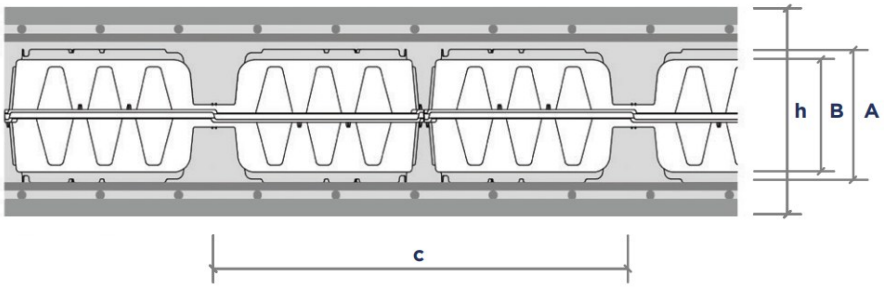



Figure 5 – Typical section of a COBIAX CLS slab.



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# SLAB SECTION CONFIGURATION

COBIAX CLS incorporates in its design all the spacings that ensure the void volume is kept away from the reinforcement bars to comply with the covers on the inner face of the former. In this way, the COBIAX CLS is placed directly on the bottom reinforcement and the former itself acts as support for the top reinforcement bars, with no restriction on the order between transverse and longitudinal reinforcement.

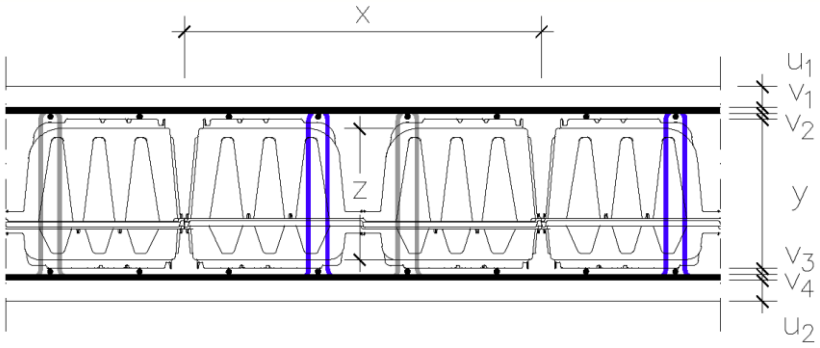



Figure 6 – Typical section of a COBIAX CLS slab.

- z – Height of the COBIAX CLS void volume;
- y – Total height of the former
- x – Spacing between voids
- $v_1$, $v_2$, $v_3$ and $v_4$ – Diameter of the reinforcement bars;
- $u_1$ and $u_2$ - Top and bottom cover

An important check to carry out during the detailing process of the COBIAX CLS slab concerns its final composition and thickness, taking into account the defined covers, the diameter of the selected bars and the size of the COBIAX CLS void as a function of the thickness defined in the design (h).

$$t = u_1 + u_2 + v_1 + v_2 + v_3 + v_4 + y + \text{construction tolerance of 5–10 mm} < h$$



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# TECHNICAL CONSIDERATIONS OF THE COBIAX CLS SYSTEM

This chapter describes the technical characteristics of the COBIAX CLS system and its design constraints.

## FLEXURAL STRENGTH

The flexural behaviour of COBIAX CLS slabs is based on the same behaviour as the COBIAX CBX, **since the behaviour of the lightening systems is identical**. The COBIAX CBX was the subject of research and laboratory testing for the various possible slab thicknesses and configurations, demonstrating that its performance in common situations is identical to that of a solid slab.
In practice, the level of forces in a slab is limited by deflection-behaviour criteria and the level of stress in the various codes and standards, which place the neutral axis above the COBIAX CLS void, somewhere within the compression layer created between it and the top of the slab.
In this way, a COBIAX CLS slab can be designed and dimensioned just like a solid slab of equal thickness once the respective forces have been obtained by the process identified above, therefore, the resisting moment of a COBIAX CLS slab is identical to that of a solid slab of equal thickness.

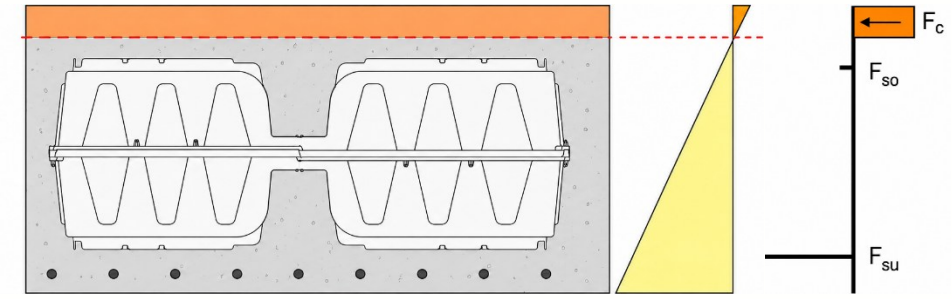



Figure 7 – Position of the neutral axis above the void within the compression layer.

In specific cases with high loads, the position of the neutral axis must be determined; however, practice shows that deflection-behaviour criteria and the limits on the amount of reinforcement prevent the neutral axis from being positioned outside the compression layer.

## STIFFNESS

One of the characteristics of this system is the reduction in the inertia of the section compared with a solid slab of equal thickness, resulting from the reduction in section caused by the introduction of the void.
As noted above, introducing the COBIAX CLS system into slabs reduces the slab's inertia by between 5 and 19% compared with solid slabs of equal thickness, expressed by the respective correction factors given in Table 3 for certain configurations.
The stiffness correction factors represent the ratios between the three-dimensional calculation of the moment of inertia ($I_{CB}$) for COBIAX CLS slabs (taking the voids into account and assuming their position) and the moment of inertia of a solid slab (I), basing the calculation of the values on uncracked sections. The table below provides the inertia correction factors $I_{CB}$ / I for different configurations of COBIAX CLS voids and slab thicknesses in addition to those given previously in Table 3.



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| COBIAX CLS | | P-110 | |
|---|---|---|---|
| Slab thickness [cm] | 20 | 21 | 22 |
| $I_{CB}$ / I | 0.95 | 0.96 | 0.97 |
| COBIAX CLS | | P-130 | |
| Slab thickness [cm] | 22 | 23 | 24 |
| $I_{CB}$ / I | 0.94 | 0.95 | 0.95 |
| COBIAX CLS | | P-150 | |
| Slab thickness [cm] | 24 | 25 | 26 |
| $I_{CB}$ / I | 0.92 | 0.93 | 0.93 |
| COBIAX CLS | | P-170 | |
| Slab thickness [cm] | 26 | 27 | 28 |
| $I_{CB}$ / I | 0.91 | 0.91 | 0.93 |
| COBIAX CLS | | P-190 | |
| Slab thickness [cm] | 28 | 29 | 30 |
| $I_{CB}$ / I | 0.89 | 0.90 | 0.91 |
| COBIAX CLS | | P-210 | |
| Slab thickness [cm] | 32 | 33 | 34 |
| $I_{CB}$ / I | 0.89 | 0.90 | 0.91 |
| COBIAX CLS | | P-230 | |
| Slab thickness [cm] | 34 | 35 | 36 |
| $I_{CB}$ / I | 0.88 | 0.89 | 0.91 |
| COBIAX CLS | | P-250 | |
| Slab thickness [cm] | 36 | 37 | 38 |
| $I_{CB}$ / I | 0.88 | 0.88 | 0.88 |
| COBIAX CLS | | P-270 | |
| Slab thickness [cm] | 38 | 39 | 40 |
| $I_{CB}$ / I | 0.85 | 0.88 | 0.88 |
| COBIAX CLS | | P-290 | |
| Slab thickness [cm] | 40 | 41 | 42 |
| $I_{CB}$ / I | 0.85 | 0.85 | 0.88 |
| COBIAX CLS | | P-310 | |
| Slab thickness [cm] | 44 | 45 | 46 |
| $I_{CB}$ / I | 0.85 | 0.87 | 0.88 |
| COBIAX CLS | | P-330 | |
| Slab thickness [cm] | 46 | 47 | 48 |
| $I_{CB}$ / I | 0.85 | 0.85 | 0.87 |
| COBIAX CLS | | P-350 | |
| Slab thickness [cm] | 48 | 49 | 50 |
| $I_{CB}$ / I | 0.84 | 0.85 | 0.96 |
| COBIAX CLS | | P-370 | |
| Slab thickness [cm] | 50 | 51 | 52 |
| $I_{CB}$ / I | 0.84 | 0.84 | 0.85 |
| COBIAX CLS | | P-390 | |
| Slab thickness [cm] | 52 | 53 | 54 |
| $I_{CB}$ / I | 0.82 | 0.84 | 0.84 |
| COBIAX CLS | | P-410 | |
| Slab thickness [cm] | 56 | 57 | 58 |
| $I_{CB}$ / I | 0.84 | 0.84 | 0.85 |
| COBIAX CLS | | P-470 | |
| Slab thickness [cm] | 62 | 63 | 64 |
| $I_{CB}$ / I | 0.81 | 0.82 | 0.84 |
| COBIAX CLS | | P-530 | |
| Slab thickness [cm] | 70 | 71 | 72 |
| $I_{CB}$ / I | 0.81 | 0.81 | 0.84 |
| COBIAX CLS | | P-590 | |
| Slab thickness [cm] | 76 | 77 | 78 |
| $I_{CB}$ / I | 0.81 | 0.81 | 0.81 |

Table 3 – Stiffness correction factors of the COBIAX CLS system.



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# SHEAR

The methodology for verifying the shear force of the COBIAX CLS slab is based on the same principles developed and validated for the COBIAX CBX system, approved by the German Institute of Construction Technology (DIBt) under National Technical Approval registration Z-15.1-307. For the COBIAX CLS system, this approach was re-evaluated, tested and validated in an analogous manner, giving rise to DIBt approval Z-15.1-352, which forms the specific normative basis of this chapter.
The underlying concept stems from the observation that, in a hollow-core slab, the direct calculation of shear force based on the smallest available width of the section — the classic criterion for traditional hollow-core slabs — would be excessively conservative. That minimum width occurs only at a single point (the edge of zone X for COBIAX CLS), increasing rapidly in all directions from that point. The laboratory tests conducted as part of approval Z-15.1-307 demonstrated, for the COBIAX CBX system, a shear resistance significantly higher than would result from that criterion.
It is concluded that the shear-force verification must follow Clause 6.2.2 of EN 1992-1-1 and its National Annex, replacing equation (6.2.a) with the following expression for the shear resistance of the COBIAX CLS slab without specific shear reinforcement:

$$V_{Rd,c,cobiax} = \boldsymbol{f} \cdot \left[\frac{0.15}{\gamma_c}\,\kappa\left(100\,\rho_l\,f_{ck}\right)^{1/3}\right] b\,d$$

Where:

- $f$ — reduction factor that accounts for the lower shear resistance due to the voids:
  - $f$ = 0.45 for thickness h = 200 mm
  - $f$ = 0.40 for thicknesses h ≥ 480 mm
  - Linear interpolation is permitted for intermediate values.
  - At end supports (supports of simply supported slabs or the end supports of continuous slabs) and for thick slabs, the factor f must be reduced linearly from $f$ = 0.40 (h = 480 mm) to f = 0.35 (h = 760 mm).

Owing to the variability of this factor with its position in plan, for simplicity the more conservative values of these two conditions are recommended. The values of $f$ in Table 1 and Table 2 are based on the type of former used, based on the end-span criterion.
In addition to the reduction in shear resistance, the following must be considered:

- Equations (6.2.b) and (6.4) of EN 1992-1-1 and its National Annex cannot be used in this verification.
- The COBIAX CLS slab has mandatory minimum shear-reinforcement requirements. In every void zone, minimum shear reinforcement must be installed that simultaneously fulfils the functions of connection reinforcement and robustness reinforcement for the assembly:
  - At least 4 sets of transverse reinforcement of Ø ≥ 8 mm (4 Ø 8) in each intermediate zone (zone X) between modules — see Figure 8
  - The sets must be dimensioned, in form, as shear reinforcement bars in accordance with Clauses 9.2.2 and 9.3.2 of EN 1992-1-1.
  - They must cross the entire height of the hollow-core slab (respecting the cover) and be properly anchored in the compression and tension zones.
  - The arrangement of the sets in plan within zone X must follow Figure 8 and Figure 9.

This minimum reinforcement is mandatory in all circumstances, even when connection reinforcement is not mathematically necessary (that is, even if concreting is carried out without interruption and no bond verification is required).
The minimum shear (or connection) reinforcement cannot be counted mathematically in the shear resistance $V_{Rd,c,COBIAX}$ of the COBIAX CLS slab.



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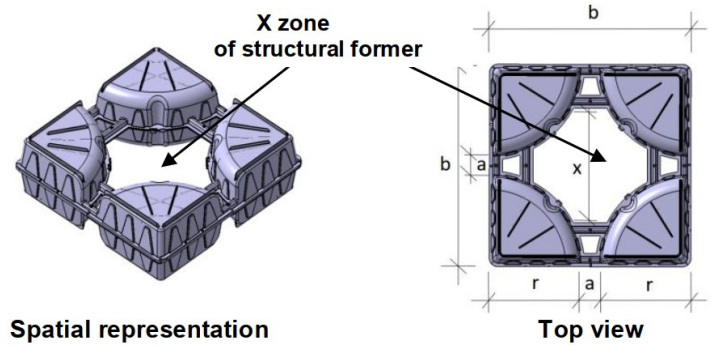



Figure 8 – Definition of zone X

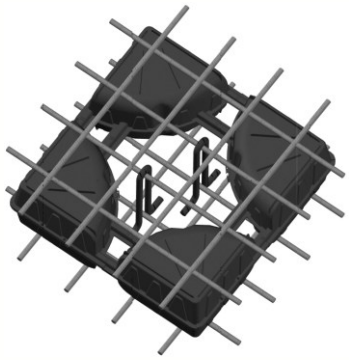


Figure 9 – Position of the omegas within zone X

# PUNCHING SHEAR

Owing to the limitations in terms of shear forces, areas with a high concentration of shear forces, for example, around columns in flat slabs, must be constructed without incorporating COBIAX CLS voids, with the critical punching-shear perimeter located within the solid zone of the slab.
The considerations regarding shear and punching shear in these zones are identical to those considered for ordinary solid slabs; it is strongly recommended to verify that the punching-shear control perimeter lies within the solid zone, as shown in the drawing below.
It should also be noted that the reduction in self-weight inherent in applying the COBIAX CLS system effectively reduces the constraints related to punching-shear forces, allowing a reduction in the reinforcement bars specific to this purpose.

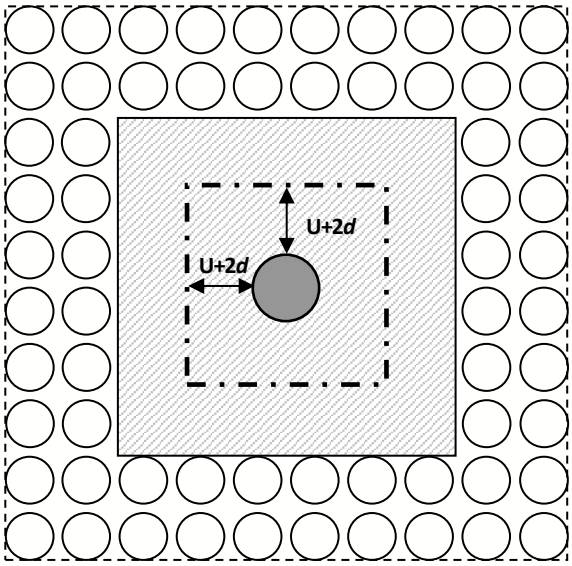



Figure 10 – Solid zone due to punching shear



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# POINT LOADS

In the zone of the lightening elements, the characteristic value of point loads cannot exceed 10 kN over a minimum application area of 100 mm × 100 mm. The tension zones of the hollow-core slab affected by these loads must be reinforced.
For columns, point loads and concentrated support reactions exceeding 10 kN, EN 1992-1-1 applies together with EN 1992-1-1/NA, section 6.4.
Punching-shear zones must be constructed as full-section solid zones, without lightening elements. The size of the solid punching-shear zones is defined as follows:

a) Definition of the solid zones through shear-force verification, considering the reduced shear resistance of the hollow-core slab $V_{Rd,c,cobiax}$ in accordance with the Shear chapter.
b) In slabs that do not require punching-shear reinforcement, the load application area, $A_{load}$. and the zone extending at least 2.0 *d* beyond the critical control perimeter, or the zone required until the shear resistance of the hollow-core slab is reached (whichever is greater), must be designed with a full section. In slabs with a drop panel, the critical control perimeter lies outside the drop panel.
c) In slabs that require punching-shear reinforcement, in addition to b), it must be verified that the solid zone extends 2.0 *d* beyond the outermost row of reinforcement. Otherwise, the solid zones must be enlarged accordingly.

The greatest of the values from points a), b) and c) above applies.

# CONSTRUCTION JOINT

With two-stage concreting of a COBIAX CLS slab, a horizontal joint is created; if the time interval between the two concreting stages is sufficient for the first layer to have fully cured, the concreting of the second layer must be treated as a cold construction joint. However, the mandatory Omega/"S" reinforcement bars (minimum of 4 legs of Ø8) in the COBIAX CLS slab act as anchorage and provide sufficient shear reinforcement for the verification of the joint.

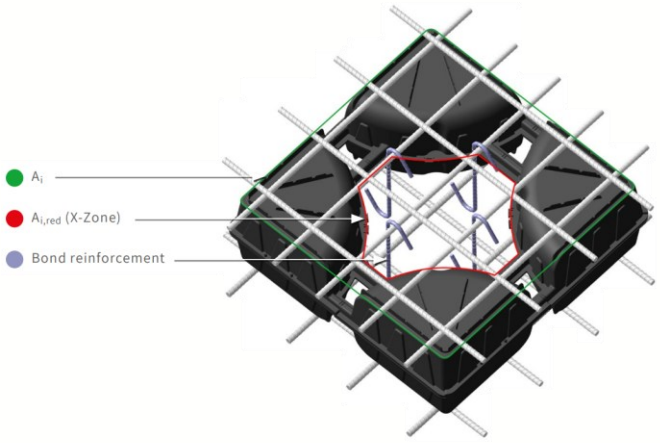



Figure 11 – Example of reinforcement in zone X of a COBIAX CLS slab



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# HORIZONTAL FORCES

The dynamic properties of a structure and its behaviour under earthquake or other horizontal loads must be assessed individually, project by project, using the verification methods recommended by the relevant codes. Nevertheless, the importance of the mass of the building — and of the slab in particular — is well known, notably in amplifying the effects of these types of actions; therefore, the reduction in permanent load provided by the presence of the voids within the slab has a beneficial effect on the behaviour of structures.

For certain usage requirements of a structure, the modal behaviour of the structure becomes relevant and important. In extensive theoretical research, the natural frequency of a COBIAX CLS hollow-core slab shows superior modal behaviour compared with a solid slab of the same thickness, potentially presenting a natural frequency up to 12% higher than a conventional solid slab.

Regarding the transmission of in-plane normal forces, the COBIAX CLS slab, despite the presence of the voids, continues to act as a rigid diaphragm capable of transferring horizontal loads due to wind, structure inclination, earthquakes and temperature variations to the supports.

In its design, the upper and lower concrete layers of the COBIAX CLS slab can be considered as equivalent rectangular sections to simplify the design and be dimensioned for the axial forces. For high forces — in the case of post-tensioned slabs that exceed the capacity of the equivalent section — it is recommended that solid bands be considered along these alignments.

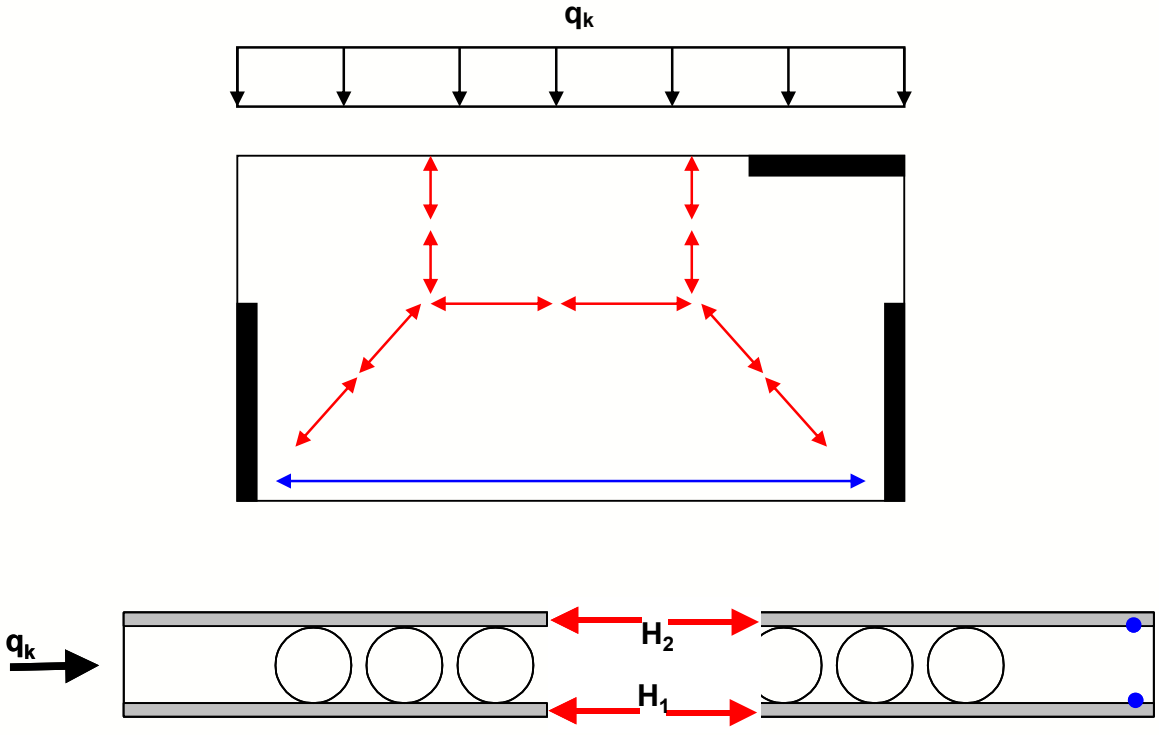



Figure 12 – Diaphragm behaviour of the COBIAX slab



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# FIRE PROTECTION

Regardless of the code or standard used, the relevant parameter for the design criteria governing the fire-resistance classification of concrete slabs is the concrete cover between the exposed surface of the slab and the first layer of reinforcement.
Fire-resistance tests in specialized laboratories on slab samples have shown that the parameter and criterion used for solid slabs can be used without any limitation for COBIAX CLS slabs, and that these can resist fire in the same way as solid slabs.
It should be noted that the heat propagation recorded during the fire-resistance tests of the COBIAX CLS slab samples is identical to that recorded in solid slabs. It was further observed that the voids present in a COBIAX CLS slab have a retarding effect on the spalling process of the exposed concrete surface, since the voids absorb the internal vapor-pressure concentration (arising from the moisture in the concrete) that occurs in the concrete and which would otherwise immediately press on the concrete in the slab cover; however, this benefit is not quantifiable.
If exposed to direct fire, the COBIAX CLS formers (made of HD-PE or PP) would decompose into $H_2O$ and $CO_2$, which are not harmful.
To ensure the fire resistance of COBIAX CLS slabs, the spacing of the flexural reinforcement must be increased from the bottom face of the slab ($a_{HK}$, Figure 13), in the same way as for solid slabs. For the fire-resistance verification, the temperature of the structurally effective flexural reinforcement is determined in accordance with EN 1992-1-2, considering the geometry of the cross-section. This temperature must not be higher than the temperature resulting from EN 1992-1-2 for the reinforcement steel of a solid reinforced-concrete slab with the same fire-resistance duration.
Any fire-resistance duration can be specified, depending on the results of the calculation performed in accordance with EN 1992-1-2.
Regardless of the fire-resistance duration, a minimum value of $d_{2,HK} \geq 7$ cm (see Figure 13) must be respected for the distance between the surface of the void module (excluding the module's spacer strip) and the bottom edge of the slab.

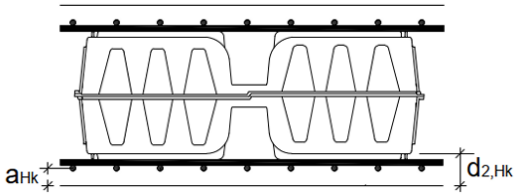


Figure 13 – Relevant distances for fire resistance

When COBIAX CLS installation elements CLS-P-110 to CLS-P-190 are used, in addition to the specifications relating to minimum thicknesses, the thicknesses of the reinforced-concrete slabs must not be less than the values given in Table 4.

| COBIAX CLS Type | CLS-P-110 | CLS-P-130 | CLS-P-150 | CLS-P-170 | CLS-P-190 |
|---|---|---|---|---|---|
| Minimum slab thickness $h_{min}$ [cm] | 21 | 23 | 25 | 27 | 29 |

Table 4 – Minimum thickness for CBX slab from CLS-P-110 to CLS-P-190



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# SOUND INSULATION

The two main parameters for classifying the sound insulation of slabs are:
– Airborne sound insulation;
– Impact sound insulation.
The acoustic performance tests carried out on COBIAX CBX slabs, both with samples in specialized laboratories and in complete buildings, with the aim of determining their acoustic behaviour and comparing the results with the behaviour of solid slabs, made it possible to define a suitable method for classifying the insulation.
The interpretation of the measurements taken shows that, for the COBIAX CBX slab, the same sound-insulation assessment methods already used for solid slabs can be applied.
The same applies to the COBIAX CLS slab.
In all cases, impact sound and airborne sound, the main factor for assessing the degree of sound insulation provided by concrete slabs is the average mass per square meter of the area under study, and there are various publications that provide these data as a function of thickness and the corresponding mass.
The sound insulation of a COBIAX CLS slab can therefore be assessed using an equivalent slab thickness.

# THERMAL INSULATION

The voids created by the COBIAX CLS modules influence the thermal conductivity of the slab. Theoretically, this has a positive effect on heat transfer through the slab and consequently on its thermal insulation. However, the effect is negligible for the practical application of the system, since only 5–10% of the improvement could be achieved (for a flat slab without any insulation).
The improvement in thermal insulation becomes even smaller when considered as an insulated slab, where the thermal-insulation material provides most of the performance.

# PRESTRESS

Combining prestress with a COBIAX CLS slab is one of the possible approaches, and when the two effects are combined it is possible to obtain positive economic factors and very efficient solutions.

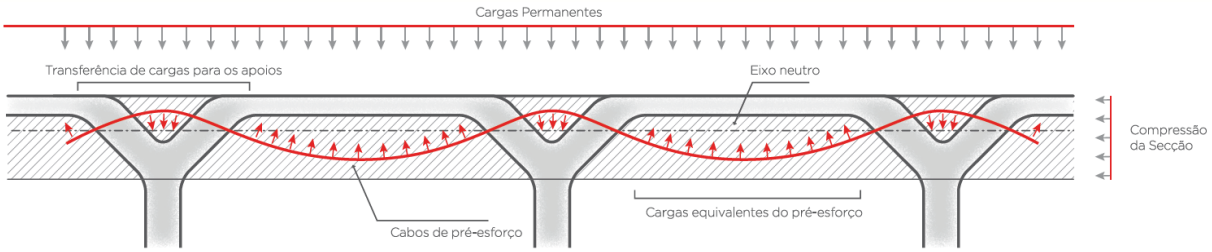



Figure 14 – Equivalent prestress loads on the COBIAX CLS slab

Prestress, by controlling self-weight through the equivalent forces imposed on the slab, together with the advantage of the reduced self-weight of a COBIAX CLS slab, makes this solution highly advantageous compared with more conventional solutions.



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# SUSTAINABILITY

The construction industry is one of the sectors with the greatest direct impact on the environment, with cement production being one of the main sources of $CO_2$ emissions.
During the production of a reinforced-concrete slab, the manufacture of construction materials leads to $CO_2$ emissions related to raw materials and energy. Most of the $CO_2$ emissions in concrete production are due to cement production, owing to the high energy consumption (thermal and electrical) and the $CO_2$ emissions arising mainly from the decarbonation of limestone during cement production.
In a study carried out by the Fraunhofer Institute, it was possible to demonstrate and quantify the potential of COBIAX technology to reduce $CO_2$ emissions in slab manufacture.

# CASE STUDY

The analysis assumed an average $CO_2$ emission of 0.70 kg per kg of cement. For cement production, an additional 0.63 kg of $CO_2$ per $m^3$ of slab is assumed for concrete, and to produce reinforcing steel a $CO_2$ emission of 1.73 kg per kg of steel was considered.
For a conventional solid slab, the following consumption values were obtained:

| Solid slab | Mass [kg/m³ of slab] | $CO_2$ emissions [kg/kg emitted] | $CO_2$ emissions [kg/m³ of slab] |
|---|---|---|---|
| Cement | 300 | 0.70 | 210.00 |
| Concrete (excluding cement) | 2,200 | 0.0003 | 0.63 |
| Steel | 145 | 1.73 | 250.85 |
| | | Total | 461.48 |

Table 5 – $CO_2$ emissions during the production of a conventional solid slab per $m^3$.

In another approach, a similar hollow-core slab using COBIAX system technology was considered. The introduction of the voids made it possible to save 17% of the required reinforcing steel, according to comparative calculation.
The energy consumption in producing a COBIAX void from 100% recycled material is about 0.04 kWh per unit. Assuming a $CO_2$ production of 0.70 kg per kWh, there is a $CO_2$ emission of 0.34 kg per $m^3$ of slab.
For a COBIAX CLS slab similar to the conventional solid slab considered, the following consumption values were obtained:

| COBIAX CLS Slab | Mass [kg/m³ of slab] | $CO_2$ emissions [kg/kg emitted] | $CO_2$ emissions [kg/m³ of slab] |
|---|---|---|---|
| Cement | 210 | 0.70 | 147.00 |
| Concrete (excluding cement) | 1,540 | 0.0003 | 0.44 |
| Steel | 120 | 1.73 | 207.60 |
| COBIAX CLS module | 10 | 0.03 | 0.34 |
| Steel grids | 8 | 1.73 | 13.84 |
| | | Total | 369.22 |

Table 6 – $CO_2$ emissions during the production of a COBIAX CLS slab per $m^3$.



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This results in $CO_2$ emissions of approximately 369.22 kg for a slab using COBIAX CLS technology.
For the comparative balance of the amount of $CO_2$ emissions between the two types of slabs presented, the following expression applies:

$\Delta = 461.48 - 369.22 = 92.26$ kg/m$^3$

In summary, there is a saving of 92.26 kg of $CO_2$ per m$^3$ of slab in direct comparison with the conventional solid slab, a reduction of around 20%.
The sustainability of natural resources is of growing importance today; the use of recycled materials to form the voids and the reduction in concrete requirements allow the COBIAX CLS system, on its own, to deliver a structure with lower environmental impact and a significant reduction in the $CO_2$ emissions associated with the construction process.



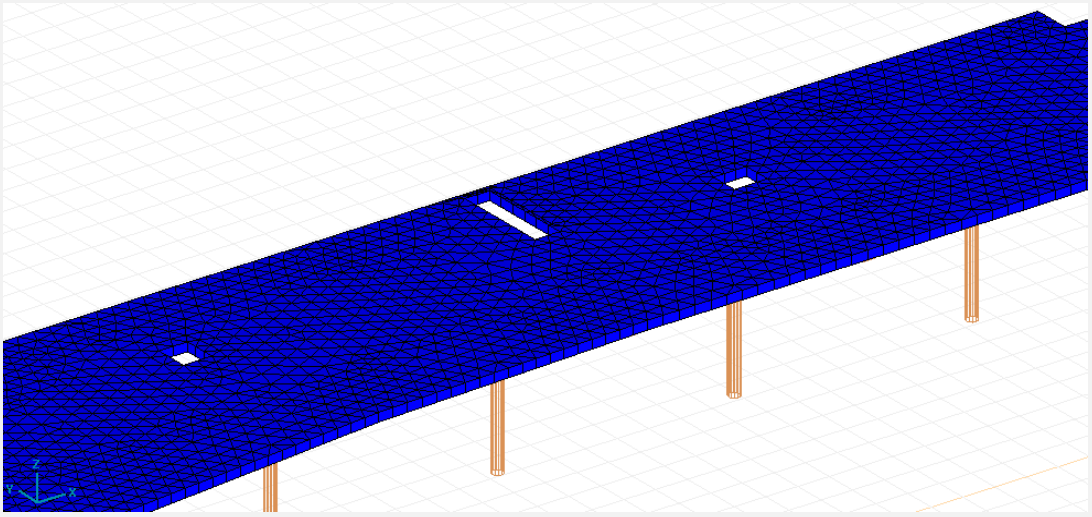
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# DESIGN PROCESS FOR A COBIAX CLS SLAB

This chapter describes the process of designing a COBIAX CLS slab with the aid of finite-element software. The process is based on the methods commonly used for the structural design of solid slabs and is compatible with any code or standard in force.
The example provided is based on the FEM software "Axis VM9"; however, the underlying principles are applicable to any finite-element software that allows the design of solid slabs.

## STEP 1 - ASSUMPTIONS, INITIAL DATA AND COBIAX CLS PARAMETERS

Define the initial data in accordance with the assumptions for the structure — such as the geometry of the slab, the supports, the loads and the materials — in the same way as you would for a solid slab, assuming the intended slab thickness from the outset. Based on the defined slab thickness, select the COBIAX CLS void you intend to use, considering the load reduction and the inertia correction factor in accordance with the parameters in Table 1 of this manual.



Calculation model of a slab (3D view) containing some openings and supported on columns

General calculation parameters
E = 34000 N/mm²; δ = 25 kN/m³; cover = 25 mm; thickness h = 300 mm

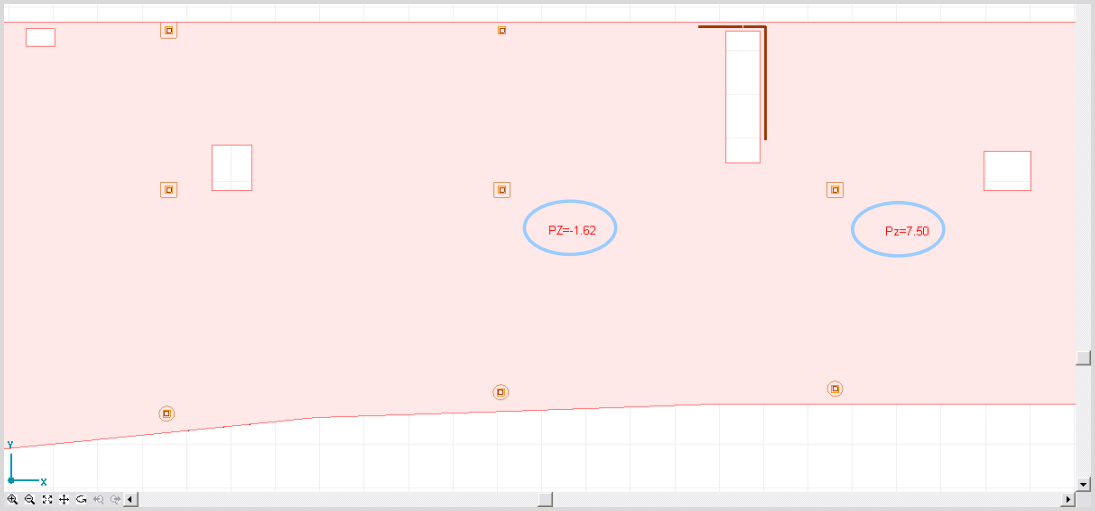
Parameters of the selected COBIAX CLS system P-190
Permanent-load reduction – 2.27 kN/m²
Inertia correction factor – 0.91



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# STEP 2 - ADDITIONAL PERMANENT-LOAD PATTERN

As a rule, observed across an extensive set of tests, the lightened area represents approximately 70 to 80% of the total slab area; however, for preliminary design purposes, the use of a value not exceeding 70% is recommended for the reduction of the permanent load in the first phase of the calculation.
We therefore propose that you create an additional permanent-load case representing the load reduction arising from the COBIAX CLS voids to be installed, in accordance with the selection made in the previous point. This load must act in the opposite direction to the self-weight of the slab considered automatically.




Self-weight of the solid slab: 0.3 m × 25 kN/m$^3$ = 7.50 kN/m$^2$
Permanent-load reduction: 0.70 × -2.27 kN/m$^2$ = -1.59 kN/m$^2$

# STEP 3 - MODIFICATION OF THE SLAB INERTIA

To account for the reduction in slab inertia resulting from the introduction of the COBIAX CLS system, one of the following operations should be carried out, depending on the options your software offers:
– Change the modulus of elasticity of the slab concrete by applying the constant coefficient from Table 1;
– Change the inertia of the slab elements by applying the correction factor given in Table 1;
Calculate the resulting deflection by incorporating the permanent-load-reduction pattern and the modified inertia into the model; check that it meets your criteria, and if not, increase the thickness of your slab.

Modification of E: 0.91 × 34000 N/mm² = 30940 N/mm²
Change of the global stiffness factor from 1 to 0.91
Depending on the software used, it presents the calculation of the linear deflection (State I, elastic) or non-linear deflection and allows the long-term deflection to be calculated (State II). For the linear case, the elastic deflection values obtained from the calculation are treated in the same way as for solid slabs regarding the assessment of long-term deflection.

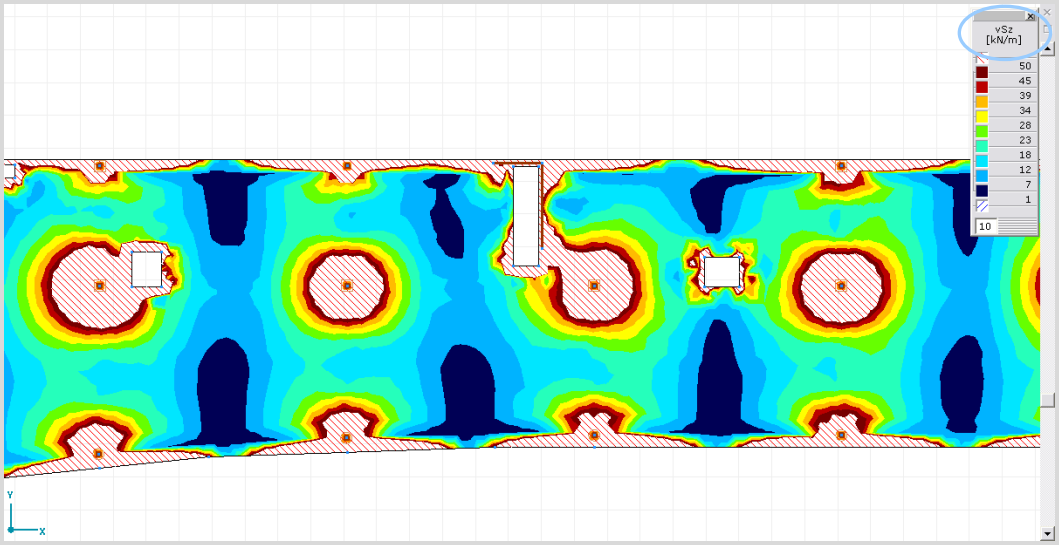


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# STEP 4 - SHEAR-RESISTANCE CRITERION AND IDENTIFICATION OF THE SOLID ZONE

Manually calculate the maximum permitted shear resistance $V_{cd}$ for a solid slab of equal thickness and multiply this value by the shear correction factor given in Table 1 to obtain the shear resistance of the slab in the lightened zone. View the distribution of shear forces in your model and identify the areas of the slab where this value exceeds the shear capacity of the lightened zone; naturally, the COBIAX CLS must not be placed in these areas.

Assume that for example we have $V_{cd}$ = 100 kN/m
Shear reduction factor for the COBIAX CLS P-190: 0.43
We then have, in the hollow-core slab zone: $V_{cd,COBIAX\ CLS}$ = 0.43 × 100 kN/m = 43 kN/m
The distribution of shear forces in the slab, calculated while keeping the load-reduction case, makes it possible to identify the zones where these values exceed the maximum permitted shear force $V_{cd,COBIAX\ CLS}$.

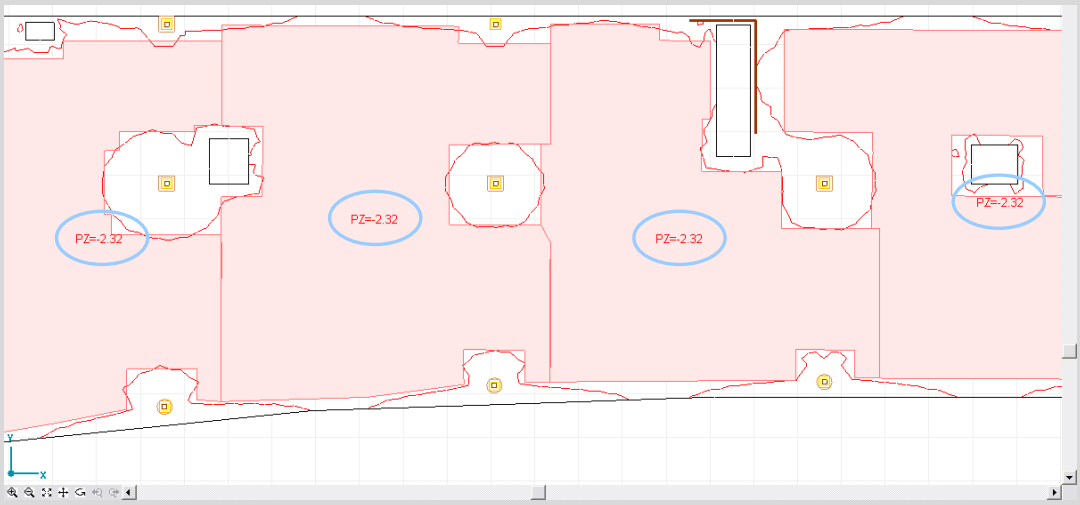





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# STEP 5 - REFINEMENT OF THE LOAD-REDUCTION CASE

This step is only required if you want greater refinement and accuracy of the force values, particularly in vertical elements and foundations, since their redistribution in the slab will result in a reduction in both forces and deformations.
Using the outlines of the solid areas identified previously, redefine the permanent-load-reduction case, applying 100% of the reduction value given in Table 1 to the lightened zones and removing this load from the solid zones.



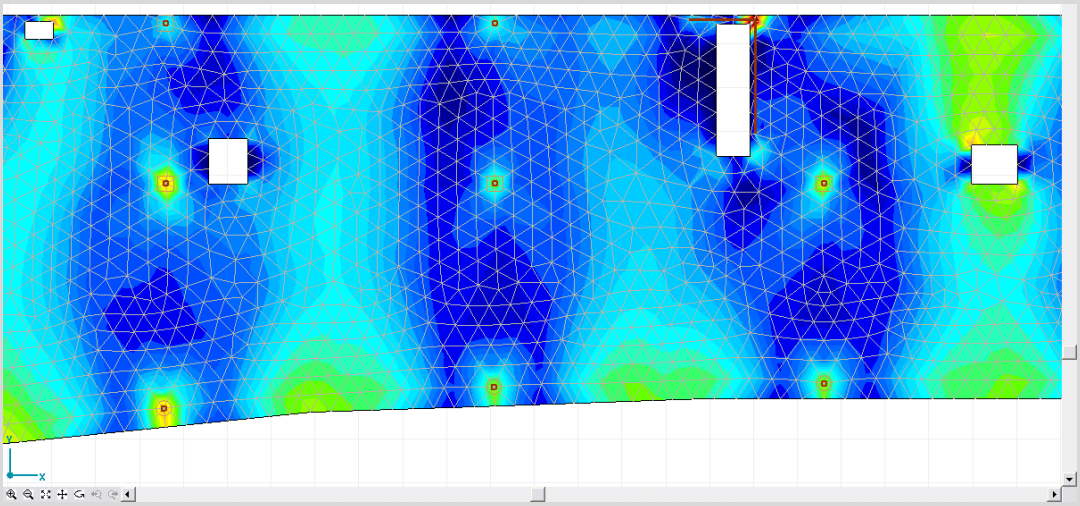

The permanent-load-reduction pattern from the previous step is deleted and a new pattern, with a load opposite to the self-weight equal to 100% of the Table 1 value, is applied only to the lightened zones:
1.00 x -2.27 kN/m$^2$ = **-2.27 kN/m$^2$**



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# STEP 6 - VERIFICATION AND DETAILING OF THE SLAB SECTION

From the force analysis and the dimensioning of the required reinforcement bars and covers, it is important to verify the conformity of the proposed section, by confirming its feasibility.
The sum of the covers, the bar diameters and the height of the COBIAX CLS must be less than or equal to the defined slab thickness, otherwise, the bars to be used must be redefined or the slab thickness increased. If it is less, this difference can be compensated for by spacers placed for this purpose.



Distribution of forces at ultimate limit states

**Section verification after selecting the reinforcement**
Cover: 25 mm
Diameter of the bottom reinforcement bars: 12 and 16 mm (x and y directions in the lightened zone)
Diameter of the top reinforcement bars: 12 mm (x and y directions in the lightened zone)
Height of module P-190: 190 mm

→ Σ 25mm + 25mm + 12mm + 16mm + 12mm + 12mm + 190 mm = 292 mm
→ 292 mm ≤ 300 mm

The section is correctly dimensioned, including a construction tolerance of 8 mm.



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# DETAILING

## LAYOUT/GEOMETRY DRAWINGS

For correct assembly of the COBIAX CLS on site, geometry drawings must be produced that include the characterisation, quantity, orientation and setting-out dimensions of the voids, so that, together with the formwork geometry drawings and the detailing of the reinforcement bars, they allow the slab works to be carried out.

- The system layout drawings must contain the following elements:
- Dimensions relative to the axes or to the edge of the structure for setting out the voids;
- Characteristic section of the slab identifying the heights of the COBIAX CLS module and of the layers;
- Dimensions of the omegas
- General notes on the use, handling and assembly of a COBIAX CLS slab.

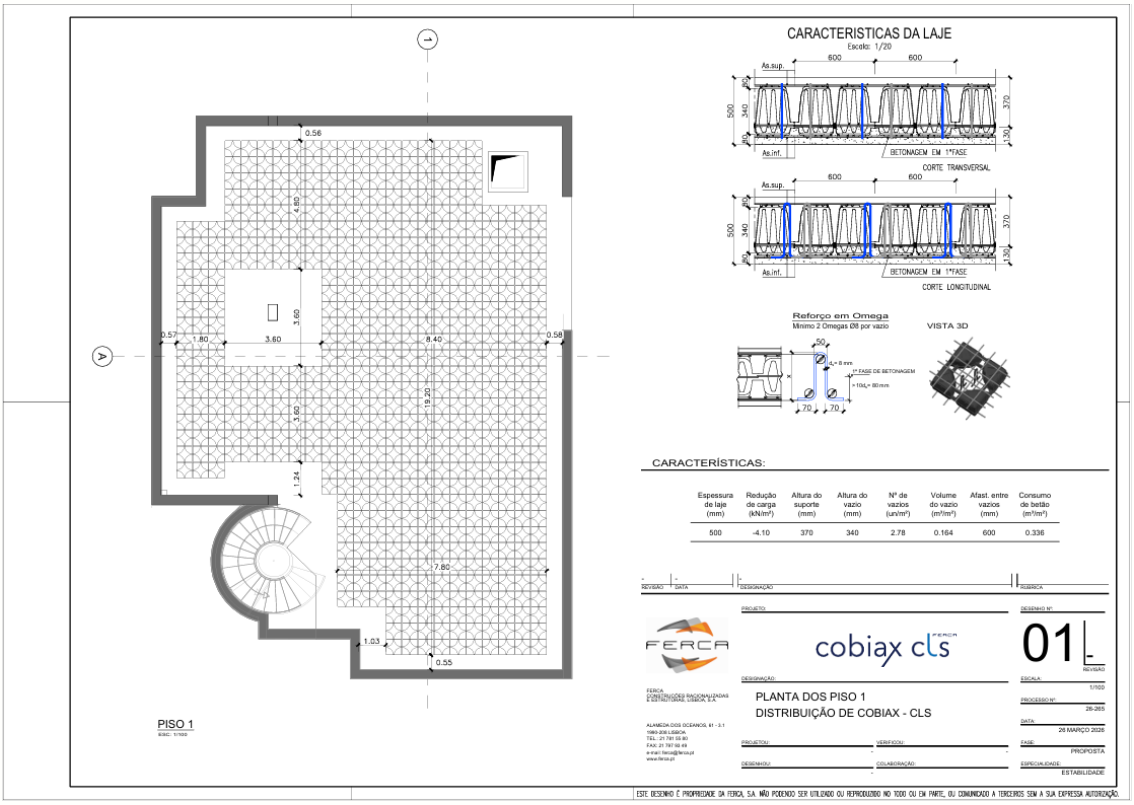



Figure 15 – COBIAX CLS layout drawing



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The following principles must be respected in the layout of the COBIAX CLS system:

- The layout of the COBIAX CLS system must respect the zones where the shear force exceeds the capacity of the slab, leaving these areas solid; see Figure 10;
- The centre-to-centre spacing of the COBIAX CLS voids must respect the dimensions given in Table 1 of this document, unless specifically indicated otherwise;
- Along the edge of the slab and openings, it is recommended to leave a solid strip of approximately 0.30 m, even where the shear force of the slab is not exceeded, to avoid interference between the COBIAX CLS modules and any edge-reinforcement bars;

# TECHNICAL SERVICES INSTALLATION

As COBIAX CLS is a modular system, compatibility with the various services to be installed in the slab is possible; the implications for the arrangement of the COBIAX CLS modules must be anticipated in advance and shown on the layout drawings. The voids can be removed individually for the passage of pipes, or in lines for the passage of various services — for example, the application of post-tensioning in the slab.

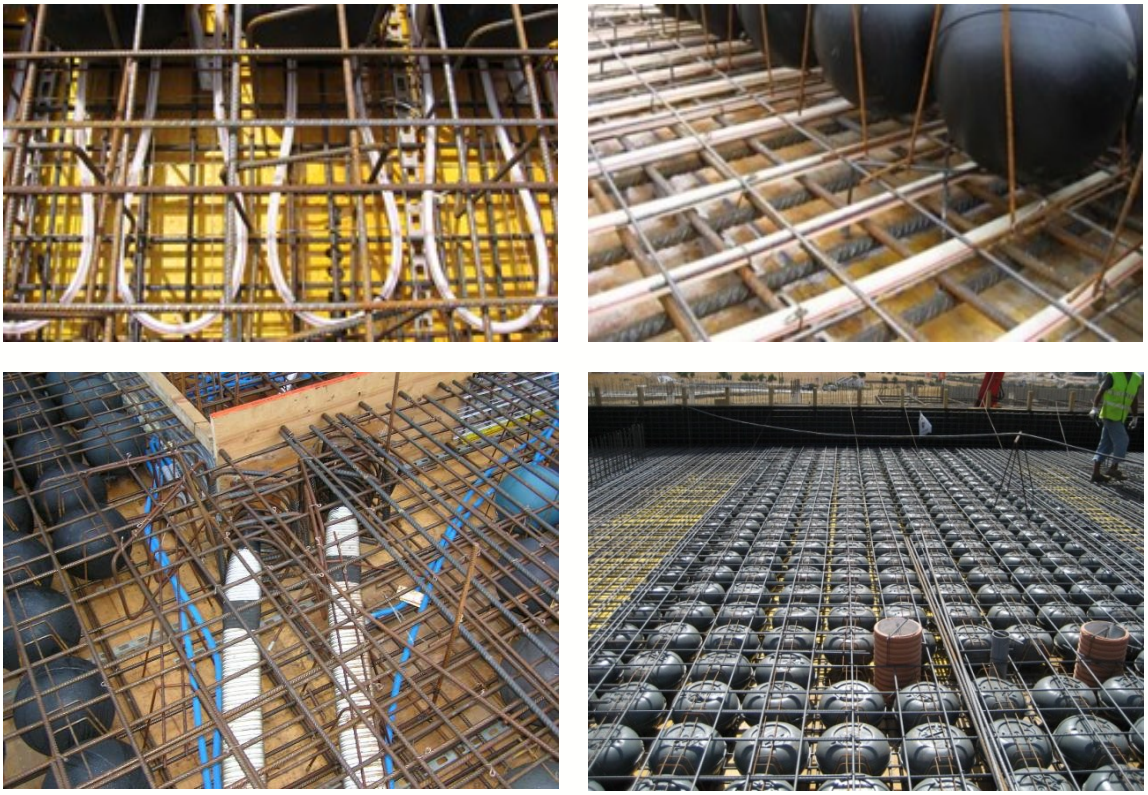


Figure 16 -Examples of various services and post-tensioning systems in a COBIAX CLS slab



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# ASSEMBLY OF A COBIAX CLS SLAB

The assembly of a COBIAX CLS slab comprises various procedures, from the logistical factors and the transport of the material, as well as the product assembly process, through to the procedures during its execution on site. Refer to the system's Procedures Manual.

The construction of a COBIAX CLS slab fully respects the same principles and procedures as the assembly of a solid slab, with the modules being placed directly on the bottom reinforcement. It is also worth noting the particular feature that these serve as support for the top reinforcement bars, avoiding the usual "chairs" of solid slabs.
The following sequence of images illustrates the steps to follow





1- Assembly of the COBIAX CLS modules (preferably near their installation zone in plan).
2- Closing the COBIAX CLS by "clicking" the 4 edges of the modules.



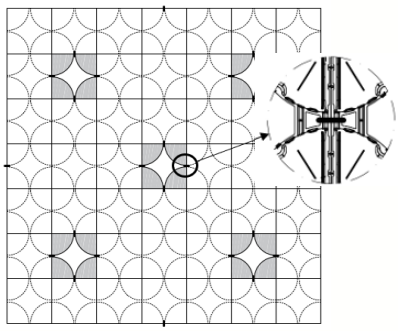


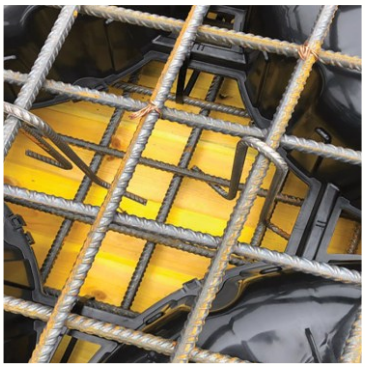
3- After placing the bottom reinforcement, they are transported to the zone where they will be installed in plan according to the structural design.
4- The formers are placed in a chain, always together, with no gap between the COBIAX CLS modules.



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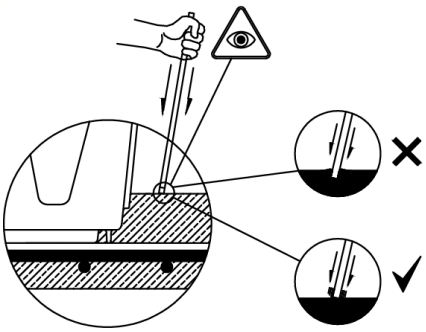






5- After placing the COBIAX CLS modules, they must be tied with a “Zip Cable” to ensure they are held in place during the concreting phase.
6- The top reinforcement is then placed and, once this stage is complete, the omegas are installed to connect across the concreting joints.





7- Once the assembly of the reinforcement bars is complete, the first concreting phase is carried out up to the level specified in the detail, anchoring the omegas in the first layer.
8- Verification of the first concreting phase.



9- Second concreting phase.



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