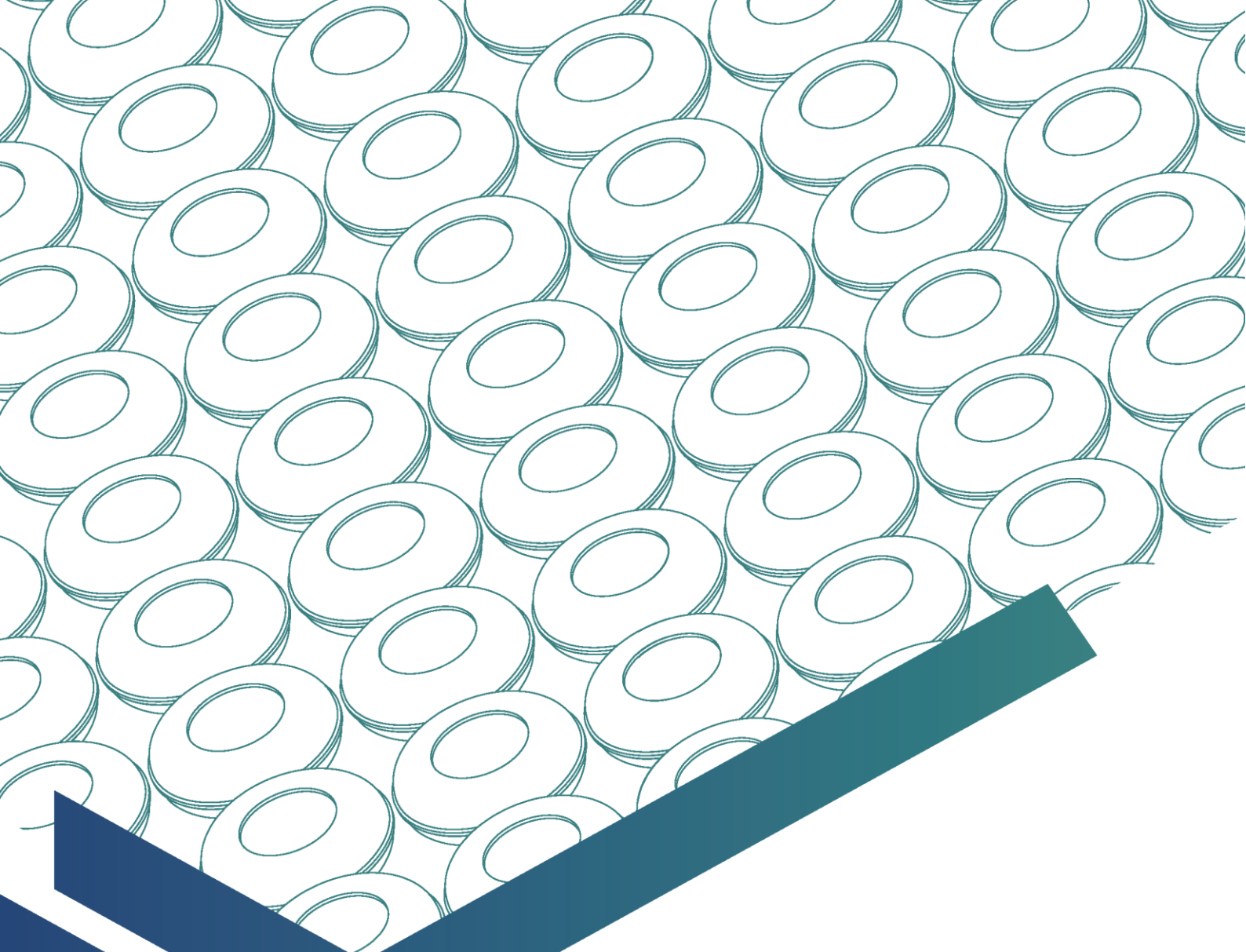




cobiax cbx<sup>FERCA</sup>

# TECHNICAL MANUAL





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# Technical Manual – COBIAX CBX System

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## INTRODUCTION TO THE COBIAX CBX SYSTEM

The **COBIAX CBX** system is based on principles of economic and environmental rationalisation that enable the construction of two-way voided slabs whose behaviour is similar to that of a traditional solid slab. The introduction of an ellipsoidal void in the zone where the concrete is not essential to the overall behaviour of the slab allows the slab thickness to be optimised, improves its behaviour and increases the efficiency of resource use.

In a world where the sustainability of natural resources is becoming increasingly important, the use of recycled materials to form the voids and the reduction in concrete requirements allow the **COBIAX CBX** system to deliver, in itself, a structure with a lower environmental impact and a significant reduction in the CO<sub>2</sub> emissions inherent to the construction process.

**COBIAX CBX** technology is of Swiss origin and is already widely used in central European markets, where it has been applied since 2004. It is the result of research work which, after being subjected to a rigorous testing programme, obtained the “National Technical Approval” from the German Institute for Construction (DIBt) and is patented internationally.

Award granted by the Swiss Federal Office for the Environment to **COBIAX CBX** Technologies AG for technical innovation in the environmental field.



The **COBIAX CBX** slab technology holds “National Technical Approval” registration number Z-15.1-307, issued by the German Institute of Construction Technology (DIBt).



The **COBIAX CBX** slab technology has an environmental product declaration.





## WHY USE THE COBIAX CBX SYSTEM

The **COBIAX CBX** system is a solution that combines the advantages of a voided slab and a solid slab, enabling reduced material consumption and the savings derived from voiding while keeping the characteristics and behaviour of the slab practically unchanged compared with a solid slab.

## COBIAX CBX SLAB VERSUS SOLID SLAB

Compared with a solid slab, and as a result of applying the system, the **COBIAX CBX** slab achieves a reduction in self-weight in the voided zone of up to 32% and a reduction in slab stiffness of only 7 to 12%. This naturally improves the slab's deflection behaviour, reduces the levels of reinforcement required and significantly reduces shrinkage effects, in addition to the resulting reduction in mass, with benefits for seismic behaviour, vertical elements and foundations.

At the same time, the **COBIAX CBX** slab retains the advantages of a faster construction process, similar to that of a solid slab, while also maintaining the characteristics relating to fire resistance and thermal and acoustic behaviour.

## COBIAX CBX SLAB VERSUS VOIDED SLAB

Conventional voided slabs generally rely on a two-way rib system that provides a significant reduction in the self-weight of the slab compared with the solid slab required for the same span. However, the reduction in stiffness of these slabs, resulting from their behaviour as a "T" section, is of the order of 2/3, producing thicker slabs and construction processes that are more complex, slower and more costly.

In direct comparison, the **COBIAX CBX** slab allows reduced thicknesses, improved behaviour, the final appearance of a solid slab and construction using simpler and faster processes.

## ENVIRONMENTAL IMPACT

As the void formers are made from 100% recycled material and at the same time promote a reduction in concrete consumption, the **COBIAX CBX** system actively contributes to the better use of natural resources and to a reduction in the CO<sub>2</sub> emissions inherent to the construction process.

In summary, the **COBIAX CBX** system is an alternative to conventional systems, with advantages that should be properly weighed according to the specific conditions of each slab, highlighting its impact on the overall building solution from both a technical and an economic standpoint.



## SPECIFIC FEATURES OF THE COBIAX CBX SYSTEM

COBIAX CBX slabs have essentially three characteristics that distinguish them from solid slabs and that must be taken into account in the calculation and detailing process:

**Self-Weight** reduced owing to the presence of the voids, resulting in lower forces in the slab and in the vertical elements. In the voided zone the reduction can reach 32%.

**Stiffness** of the slab reduced by approximately 7 to 12% owing to the presence of the voids — a factor that is largely offset by the reduction in weight in terms of the slab's behavior.

**Shear resistance** of the voided zone reduced owing to the presence of the voids. This reduction corresponds to values of 50 to 45% of the shear force of the equivalent solid slab, depending on the thickness of the COBIAX CBX.

Taking these three aspects into account in the structural design of the solution, the COBIAX CBX slab must comply with the remaining criteria and detailing of a solid slab, including non-voided zones where the shear force does not exceed the levels stated above.

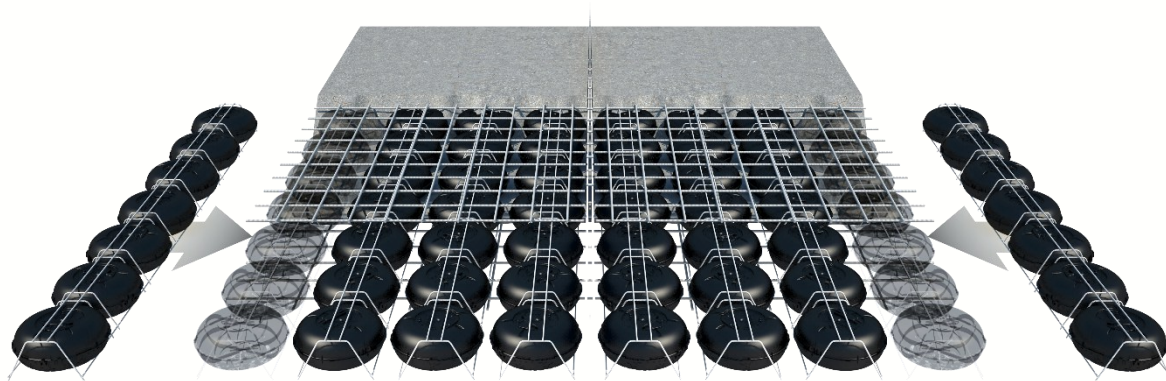


Figure 1- COBIAX CBX Slab



## CHARACTERISTICS OF THE COBIAX CBX SYSTEM

The range of COBIAX CBX solutions generally comprises a line known as Slim-Line, in which the voids consist of ellipsoidal forms of different heights intended for different slab thicknesses.

The COBIAX CBX Slim-Line modules, designated S-xxx, where xxx identifies the void height in mm.

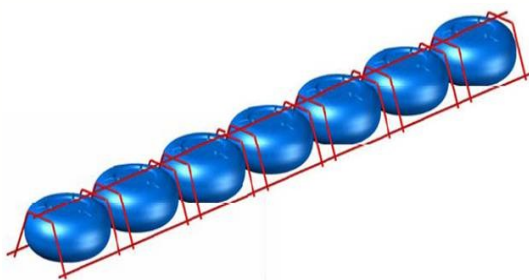


Figure 2- COBIAX CBX Grid

Comprising voids of variable height between 100 mm and 260 mm for slabs with thicknesses from 200 mm to 400 mm.

$H = 0,20m \text{ a } 0,40m$

In all cases the system consists of the void formers and the grids that hold them, which at the same time support the top reinforcement of the slab. These grids are approximately 2.50 m long and incorporate a variable number of voids.





## MAIN PARAMETERS OF COBIAX CBX SLABS

The following table contains all the data required for the correct incorporation of COBIAX CBX slabs for the purposes of calculation, detailing and quantification.

| cobiax cbx<br>FERCA                             | 200   | 225   | 250   | 275   | 300   | 325   | 350   | 375   | 400   |
|-------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                                 | S-100 | S-120 | S-140 | S-160 | S-180 | S-200 | S-220 | S-240 | S-260 |
| Load Reduction [kN/m <sup>2</sup> ]             | -1.40 | -1.64 | -1.88 | -2.10 | -2.32 | -2.56 | -2.80 | -3.10 | -3.37 |
| Stiffness Correction Factor [-]                 | 0.93  | 0.92  | 0.92  | 0.91  | 0.91  | 0.91  | 0.91  | 0.89  | 0.88  |
| Shear Reduction Factor [-]                      | 0.50  | 0.50  | 0.50  | 0.50  | 0.50  | 0.45  | 0.45  | 0.45  | 0.45  |
| Support Height (A) [mm]                         | 110   | 130   | 150   | 170   | 190   | 210   | 230   | 250   | 270   |
| Void Height (B) [mm]                            | 100   | 120   | 140   | 160   | 180   | 200   | 220   | 240   | 260   |
| No. of Voids [un/m <sup>2</sup> ]               | 8.16  | 8.16  | 8.16  | 8.16  | 8.16  | 8.16  | 8.16  | 8.16  | 8.16  |
| Void Volume [m <sup>3</sup> /m <sup>2</sup> ]   | 0.056 | 0.066 | 0.075 | 0.084 | 0.093 | 0.102 | 0.112 | 0.124 | 0.135 |
| CO <sub>2</sub> Reduction [ton/m <sup>2</sup> ] | 0.012 | 0.014 | 0.016 | 0.018 | 0.020 | 0.022 | 0.023 | 0.026 | 0.028 |
| Void Spacing (C) [mm]                           | 350   | 350   | 350   | 350   | 350   | 350   | 350   | 350   | 350   |

Table 1 – Main parameters for calculation and quantification of the COBIAX CBX system.

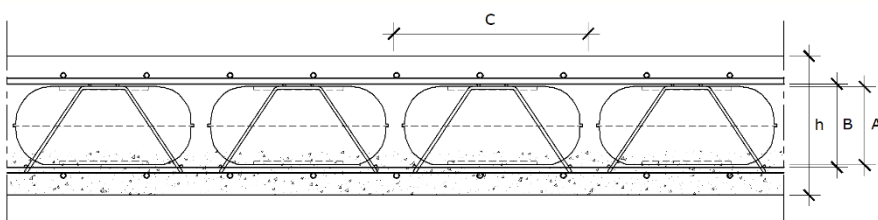


Figure 3 - Typical section of a COBIAX CBX slab



## SLAB SECTION CONFIGURATION

The COBIAX CBX system includes the support grid that holds the void formers, which must be placed directly on the bottom reinforcement while at the same time supporting the top reinforcement. The assembly sequence of the reinforcement bars and the COBIAX CBX supports must therefore consider that the first layer of reinforcement will always run parallel to them.

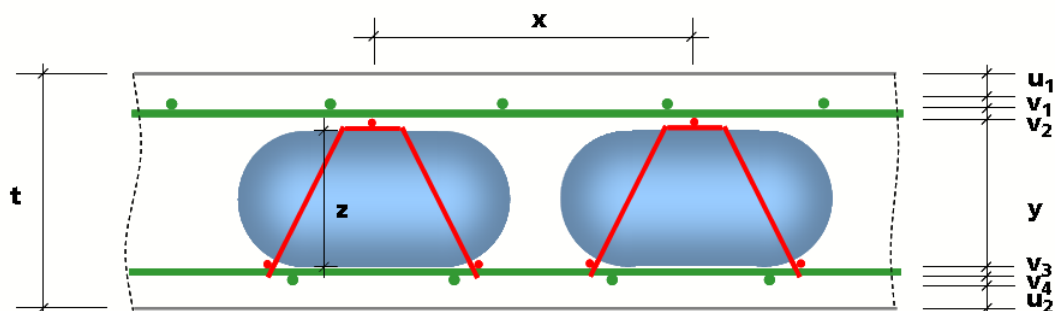


Figure 4 - Typical Slim-Line section

z: height of the COBIAX CBX void;

y: support height;

x: spacing between voids;

v<sub>1</sub>, v<sub>2</sub>, v<sub>3</sub> and v<sub>4</sub>: reinforcement bar diameters;

u<sub>1</sub> and u<sub>2</sub>: top and bottom cover;

An important check to carry out during the detailing of the COBIAX CBX slab concerns its composition and final thickness, considering the defined covers, the diameter of the selected bars and the size of the COBIAX CBX void in relation to the thickness defined in the calculation (h).

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

## TECHNICAL CONSIDERATIONS OF THE COBIAx CBX SYSTEM

This chapter describes the technical characteristics associated with the COBIAx CBX system and the constraints they impose on design.

### FLEXURAL STRENGTH

The bending behaviour of COBIAx CBX slabs has been the subject of research and laboratory testing for the various possible slab thicknesses and configurations, confirming that, in normal situations, their performance is identical to that of a solid slab.

In practice, the level of forces in the slab is limited by deflection criteria and stress-level criteria in the various codes and standards, which place the neutral axis above the COBIAx CBX void, somewhere in the compression zone created between the void and the slab edge.

In this way, the COBIAx CBX slab can be designed and sized just like a solid slab of equal thickness once the corresponding forces have been obtained using the process identified earlier; therefore, the moment resistance of the COBIAx CBX slab is identical to that of a solid slab of equal thickness.

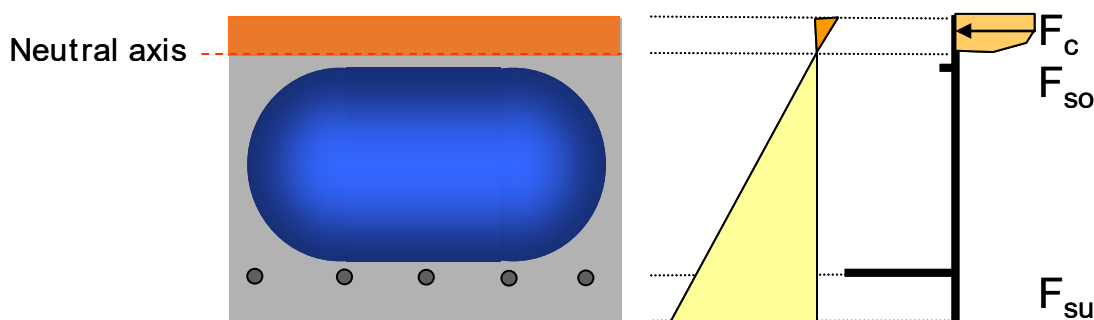


Figure 5 – Position of the neutral axis above the void in the compression zone.

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

### STIFFNESS

One of the characteristics of this system is the reduction in the stiffness of the section compared with a solid slab of equal thickness, resulting from the reduction in the section caused by the introduction of the void.

As mentioned above, introducing the COBIAx CBX system into slabs reduces the stiffness of the slab by between 7 and 12% compared with solid slabs of equal thickness, which is expressed by the corresponding correction factor given in Table 2 for certain configurations.

The stiffness correction factors represent the ratios between the three-dimensional calculation of the second moment of area ( $I_{CB}$ ) for COBIAx CBX slabs (taking the voids and their positioning into account) and the second moment of area of a solid slab ( $I$ ), with the values calculated on an uncracked section. The table below provides the stiffness correction factors  $I_{CB} / I$  for different COBIAx CBX void configurations and slab thicknesses in addition to those given earlier in Table 2.



| COBIAX CBX          |      | S-100 |      |
|---------------------|------|-------|------|
| Slab thickness [cm] | 20   | 21    | 22   |
| $I_{CB} / I$        | 0.93 | 0.94  | 0.95 |
| COBIAX CBX          |      | S-120 |      |
| Slab thickness [cm] | 23   | 24    | 25   |
| $I_{CB} / I$        | 0.93 | 0.94  | 0.94 |
| COBIAX CBX          |      | S-140 |      |
| Slab thickness [cm] | 25   | 26    | 27   |
| $I_{CB} / I$        | 0.92 | 0.93  | 0.94 |
| COBIAX CBX          |      | S-160 |      |
| Slab thickness [cm] | 28   | 29    | 30   |
| $I_{CB} / I$        | 0.92 | 0.92  | 0.93 |
| COBIAX CBX          |      | S-180 |      |
| Slab thickness [cm] | 30   | 31    | 32   |
| $I_{CB} / I$        | 0.91 | 0.92  | 0.93 |
| COBIAX CBX          |      | S-200 |      |
| Slab thickness [cm] | 32   | 33    | 34   |
| $I_{CB} / I$        | 0.91 | 0.91  | 0.92 |
| COBIAX CBX          |      | S-220 |      |
| Slab thickness [cm] | 35   | 36    | 37   |
| $I_{CB} / I$        | 0.91 | 0.92  | 0.92 |
| COBIAX CBX          |      | S-240 |      |
| Slab thickness [cm] | 38   | 39    | 40   |
| $I_{CB} / I$        | 0.89 | 0.90  | 0.90 |
| COBIAX CBX          |      | S-260 |      |
| Slab thickness [cm] | 40   | 41    | 42   |
| $I_{CB} / I$        | 0.88 | 0.89  | 0.90 |

Table 2- Stiffness correction factors for the COBIAX CBX system.

## SHEAR

The calculation of the shear force for traditional voided slabs must be based on the smallest available width of the section. Using this criterion for COBIAX CBX slabs would result in a shear force of about 10% of the shear force of a solid slab of equal thickness. However, in the COBIAX CBX slab the smallest width of a section occurs at only a single point, directly between two voids, since even at small distances from that point, in the three directions, the available section width increases rapidly.

Laboratory tests demonstrated a much higher shear resistance for COBIAX CBX slabs than the value mentioned above, and it is on the basis of these results that the approach developed for determining the maximum shear capacity of slabs incorporating the COBIAX CBX system is presented.

***This approach was approved under registration number Z-15.1-307 of the “National Technical Approval” issued by the German Institute of Construction Technology (DIBt).***

As a rule, the concept of shear force in concrete elements not reinforced for this purpose is based on the sum of several supporting and contributing mechanisms:

The shear resistance of the uncracked compression zone  $V_{c,comp}$

Internal aggregate friction along the shear surface  $V_{c,cr}$

Shear resistance provided by the flexural reinforcement  $V_{c,D}$

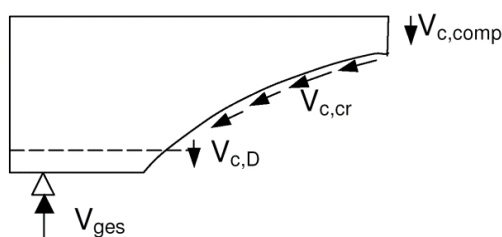


Figure 6 - Shear Force in Solid Slab

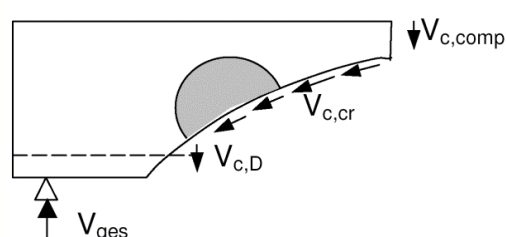


Figure 7 - Shear Force in COBIAX Slab

In the case of the COBIAX CBX slab, the contribution of internal aggregate friction is reduced owing to the presence of the voids (see Figure 3); consequently, the shear resistance of the COBIAX CBX slab is effectively lower and must be treated accordingly. The shear resistance of the compression zones and the contribution of the flexural reinforcement, however, remain unchanged.

The proportion in which these three factors contribute to the overall shear resistance is unknown, and the data in the existing literature are not consistent; therefore, the contribution of internal friction is taken as zero,  $V_{c,cr} = 0$ , and consequently the effectively contributing concrete area in the relevant section (see the figures on the following page) is considered instead of the smallest available width of the section.

The relevant section is not positioned vertically but at an inclination in the range of  $30^\circ$  to  $45^\circ$ , which is the usual range for shear surfaces.

A geometric analysis therefore makes it possible to conclude that the design value of the maximum permissible shear force for the COBIAX CBX slab is safely above 50% for COBIAX CBX slabs.

With these reduction factors, the maximum permissible shear force  $V_c$  for the COBIAX CBX slab can be calculated using the following formulas:

**Slim-Line S-100 to S-180:  $V_{c,COBIAX\ CBX} = 0.50 \times V_c$**

**Slim-Line S-200 to S-260:  $V_{c,COBIAX\ CBX} = 0.45 \times V_c$**

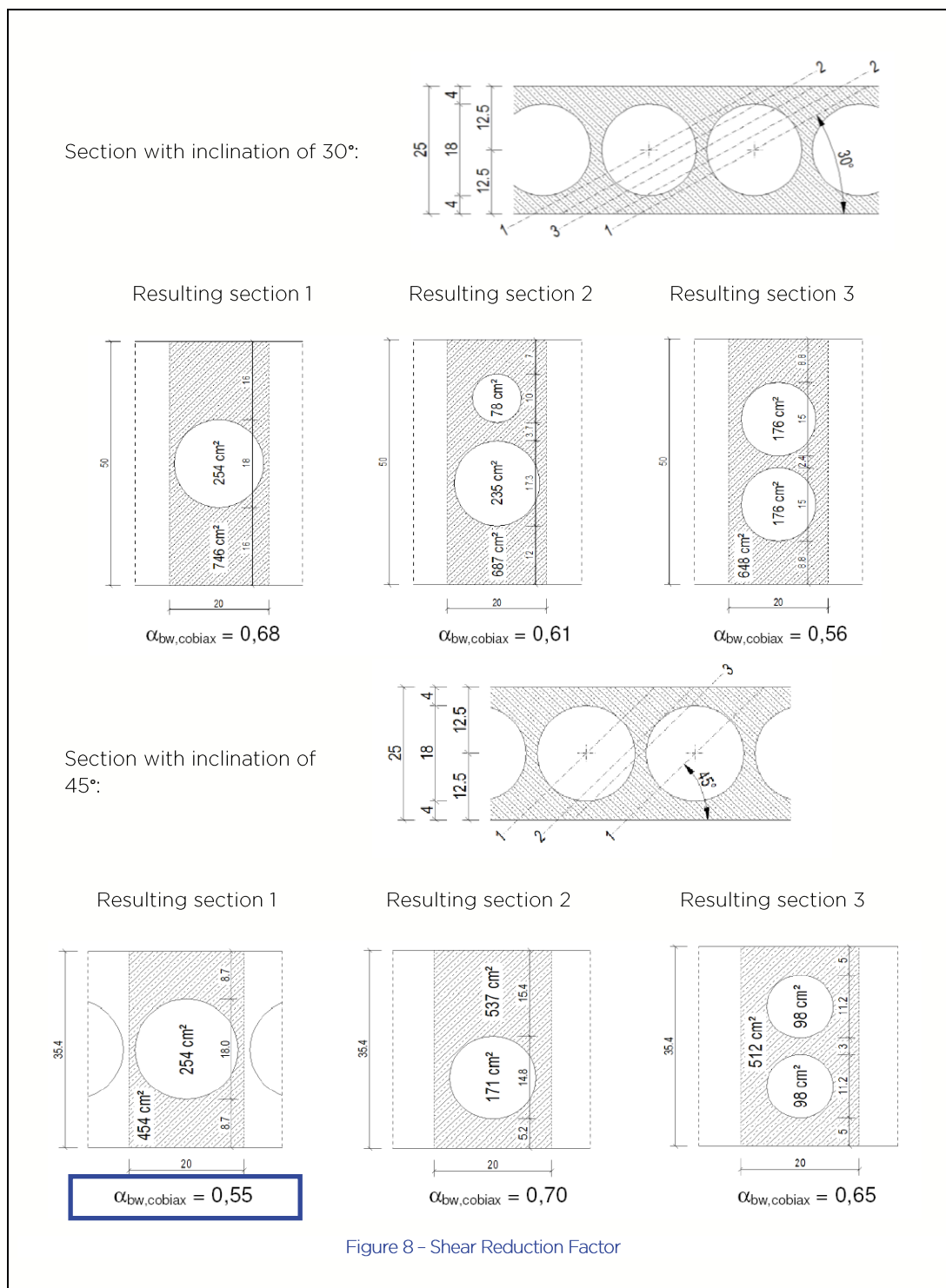
Consequently, the areas of a COBIAX CBX slab in which  $V_{c,COBIAX\ CBX}$  is exceeded owing to a high concentration of shear forces must be constructed without voids, becoming solid zones with the full concrete section.

The values mentioned above were confirmed empirically by a series of laboratory tests for a wide combination of configurations and loading conditions.

The considerations above and the tests carried out did not take into account the bars of the positioning grid, which naturally act as shear reinforcement throughout the slab. It was subsequently found in new tests that, for the COBIAX CBX, this contribution allows an increase in shear resistance of up to 66%; however, these data are not taken into account in the design assumptions of the COBIAX CBX slab as described in the previous chapters, thereby acting as an additional safety margin for COBIAX CBX slabs.



## GEOMETRIC ANALYSIS OF THE SHEAR REDUCTION FACTOR





## PUNCHING SHEAR

Owing to the limitations in terms of transverse forces, areas with a high concentration of shear forces, for example, around columns in flat slabs, must be constructed without COBIAX CBX voids, and the critical punching shear perimeter must lie within the solid zone of the slab.

The considerations regarding shear and punching shear in these zones are identical to those applied to ordinary solid slabs. It is strongly recommended to verify that the control perimeter for punching shear 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 CBX system effectively reduces the constraints related to punching shear forces, allowing a reduction in the reinforcement bars specific to this purpose.

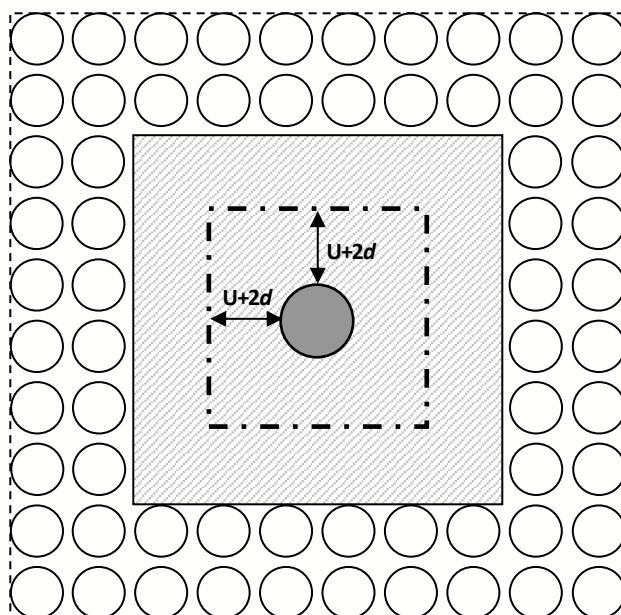


Figure 9 – Control Perimeter

For concentrated loads, a local punching shear check may be required, which may even occur over the dome of the void. Tests carried out to analyse this type of loading show that, for concentrated loads with footprints of 5 x 5 cm, 7.5 x 7.5 cm and 10 x 10 cm and different concrete covers over the void, the respective maximum failure load is as presented in Table 3, according to the concrete class used.

It should be noted that these tests considered a limit value of 75 kN. For higher concentrated loads it is recommended to leave the slab locally solid.



| Failure load [kN]     |                |          |              |            |
|-----------------------|----------------|----------|--------------|------------|
| Load area, $a_{load}$ |                | 5 x 5 cm | 7,5 x 7,5 cm | 10 x 10 cm |
| Cover [cm]            |                | 5        | 8            | 10         |
| Module COBIAX CBX     | Concrete class |          |              |            |
| S-100                 | C25/30         | 23.6     | 55.9         | 75.0       |
|                       | C30/37         | 26.6     | 63.1         | 75.0       |
|                       | C35/45         | 29.5     | 69.9         | 75.0       |
| S-120                 | C25/30         | 24.5     | 58.8         | 75.0       |
|                       | C30/37         | 27.7     | 66.4         | 75.0       |
|                       | C35/45         | 30.7     | 73.6         | 75.0       |
| S-140                 | C25/30         | 25.8     | 52.5         | 75.0       |
|                       | C30/37         | 29.1     | 70.2         | 75.0       |
|                       | C35/45         | 32.3     | 75.0         | 75.0       |
| S-160                 | C25/30         | 27.4     | 66.0         | 75.0       |
|                       | C30/37         | 30.9     | 74.5         | 75.0       |
|                       | C35/45         | 34.3     | 75.0         | 75.0       |
| S-180                 | C25/30         | 29.3     | 70.2         | 75.0       |
|                       | C30/37         | 33.1     | 75.0         | 75.0       |
|                       | C35/45         | 36.7     | 75.0         | 75.0       |
| S-200                 | C25/30         | 31.6     | 75.0         | 75.0       |
|                       | C30/37         | 35.7     | 75.0         | 75.0       |
|                       | C35/45         | 39.6     | 75.0         | 75.0       |
| S-220                 | C25/30         | 34.3     | 75.0         | 75.0       |
|                       | C30/37         | 38.8     | 75.0         | 75.0       |
|                       | C35/45         | 42.9     | 75.0         | 75.0       |

Table 3- Failure load for concentrated loads.

## CONSTRUCTION JOINT

When the COBIAX CBX slab is concreted in two phases, a horizontal joint is created. If the time interval between the two concreting phases 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 reinforcement bars of the COBIAX CBX grids located in the slab act as anchorage and provide sufficient shear reinforcement to satisfy the verification of the joint.

The first concreting phase must ensure an embedment zone of at least 20 mm.

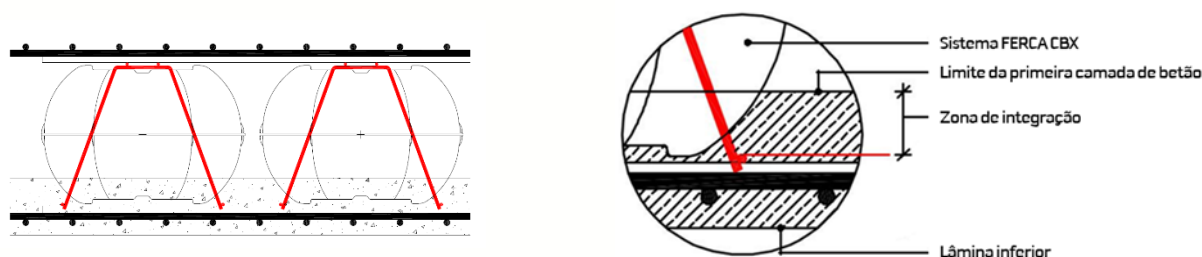


Figure 10 - Cold Joint

## MINIMUM REINFORCEMENT

Crack control is carried out in accordance with current codes and standards. To simplify the procedure, the full cross-section may be used for the necessary checks. Only for determining the minimum reinforcement for crack control should the structural cross-section including the void be taken into account, for a more rigorous and accurate consideration; in this case, an equivalent slab thickness may be used for the calculation.

The equivalent thickness is given by the following expression:

$$h_{d,eq} = h_d - h_{CBX}$$

where  $h_d$  is the slab thickness and  $h_{CBX}$  is the volume corresponding to the type of COBIAX CBX void considered.

The increase in capacity due to the presence of solid zones in a proportion of the slab must be considered when determining the minimum reinforcement.

| Concrete cross-sectional areas |        |        |        |        |        |        |        |        |        |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Slab thickness (m)             | 0,200  | 0,225  | 0,250  | 0,275  | 0,300  | 0,325  | 0,350  | 0,375  | 0,400  |
| COBIAX CBX                     | 100    | 120    | 140    | 160    | 180    | 200    | 220    | 240    | 260    |
| $A_{void} (m^2)$               | 0,0302 | 0,0357 | 0,0412 | 0,0463 | 0,0514 | 0,0568 | 0,0622 | 0,0675 | 0,0728 |
| $A_{concrete} (m^2/ml)$        | 0,1137 | 0,1230 | 0,1323 | 0,1427 | 0,1531 | 0,1627 | 0,1723 | 0,1821 | 0,1920 |

Table 4- Concrete cross-sectional areas.



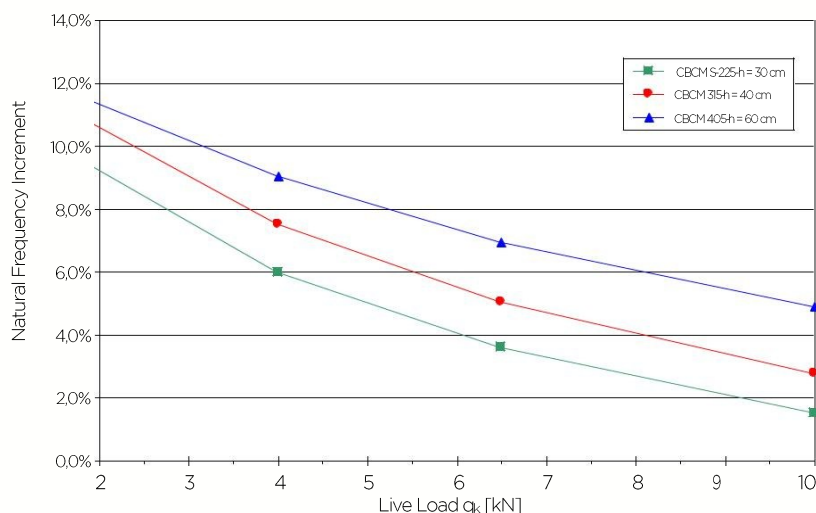
## HORIZONTAL FORCES

The dynamic properties of a building and its behaviour under an earthquake or other types of horizontal loads must be assessed individually, project by project, using the verification methods recommended by the relevant codes. However, it is well known how important the mass of the building, and in particular that of the slabs, is in amplifying the effects of this type of action; 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 CBX voided slab shows a superior modal behaviour compared with a solid slab of the same thickness, and may present a natural frequency up to 12% higher than a conventional solid slab.

This demonstrates that the COBIAX CBX slab performs better with regard to vibration modes, since it has higher natural frequencies under common loads.



[Source: Wolski, L; Natural frequency of Cobiax flat slabs, Hochschule Bochum, 2006]

This graph shows the increase in natural frequency compared with a solid slab of equal thickness, according to the live load acting on the slab. As the live load increases, the performance of the voided slab approaches the behaviour of a solid slab.



With regard to carrying in-plane axial forces in the slab, the COBIAx CBX slab, despite the presence of the voids, continues to act as a rigid diaphragm capable of transferring the horizontal loads due to wind, building inclination, earthquakes and temperature variations to the supports.

In its design, the top and bottom concrete layers of the COBIAx CBX slab may be treated as equivalent rectangular sections in order to simplify the analysis, and designed for the axial forces. For high forces — such as post-tensioned slabs that exceed the capacity of the equivalent section — it is recommended to provide solid bands along these alignments.

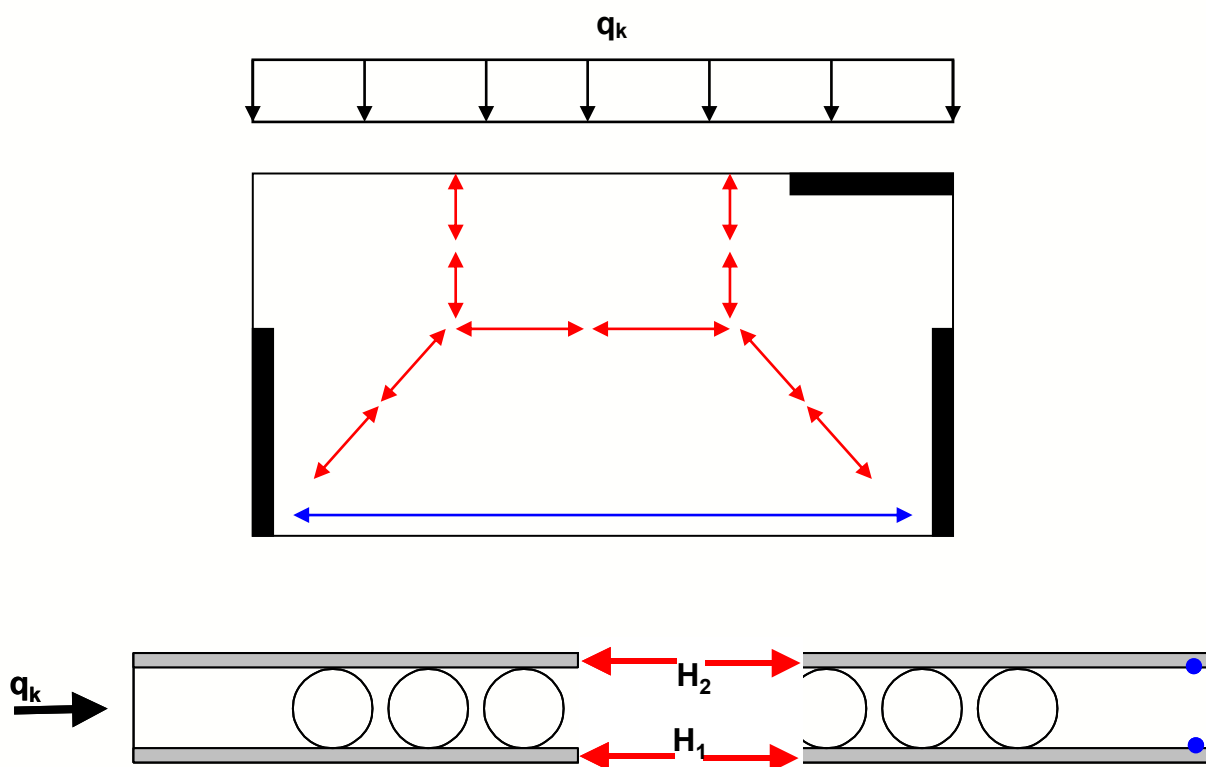


Figure 11 – Diaphragm Effect

## 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 specialised laboratories with slab samples demonstrated that the parameter and criterion used for solid slabs may be applied without any limitation to COBIAX CBX slabs, and that these can resist fire in the same way as solid slabs.

It is worth highlighting that the heat propagation recorded during the fire resistance tests of the COBIAX CBX slab samples is identical to that recorded in solid slabs. It was further observed that the voids in a COBIAX CBX slab have a retarding effect on the spalling process of the exposed concrete surface, since the voids absorb the internal vapour-pressure concentration (arising from the moisture in the concrete) that occurs in the concrete and which would otherwise immediately push against the concrete in the slab cover; however, this benefit is not quantifiable.

If exposed to direct fire, the COBIAX CBX formers (made of HD-PE or PP) would decompose into  $H_2O$  and  $CO_2$ , which are not harmful.

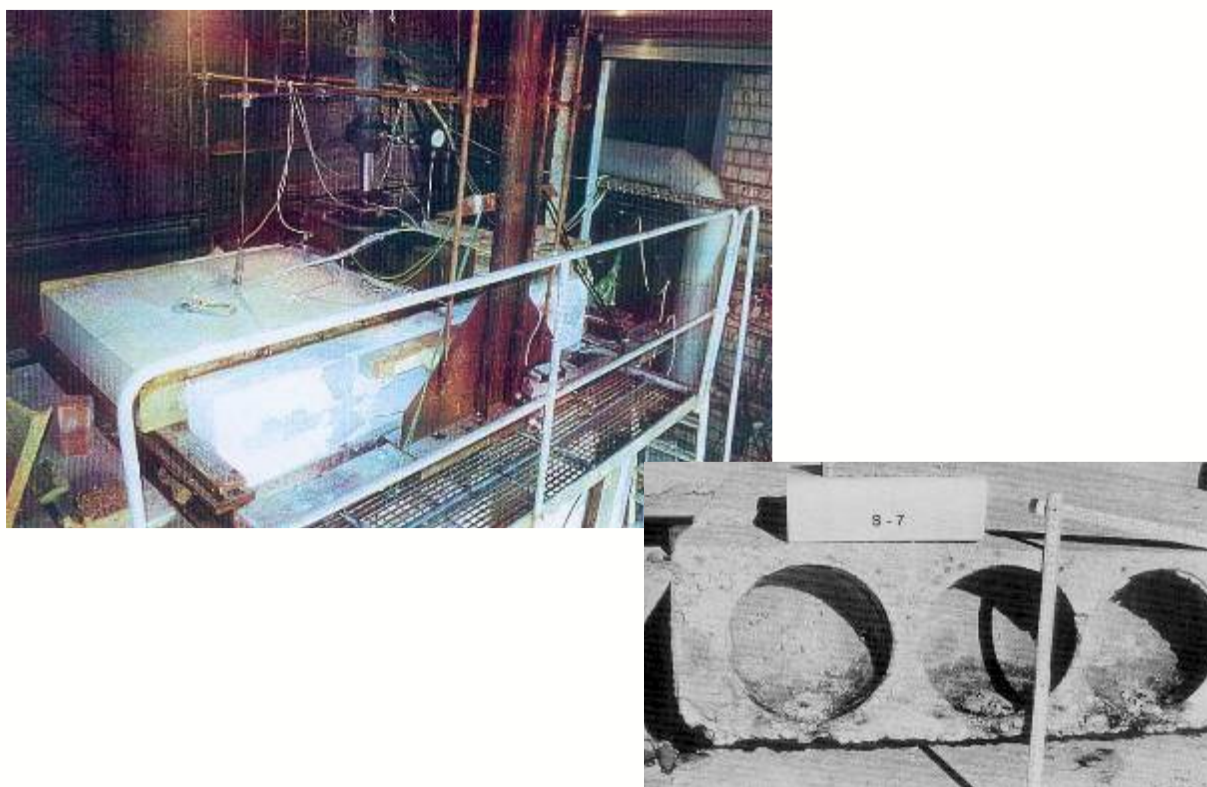


Figure 12 - Fire Tests



During the analysis of the slab, it is essential to appropriately set the distances present in the COBIAX CBX system: the distance to the axis of the first reinforcement layer  $a_{HK}$  and the dimension of the slab layer ( $d_{2,HK}$ ). Through studies and tests, the suitability of these two values demonstrated a temperature performance in the reinforcement bars similar to that of a solid slab.

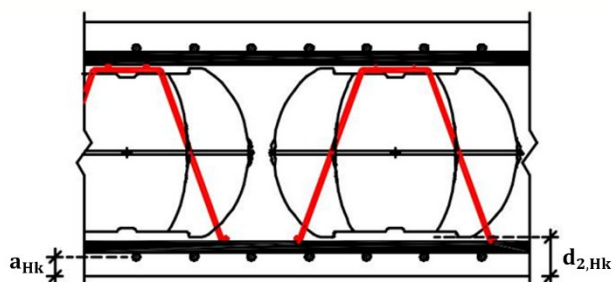


Figure 13 – Heights for Fire Resistance Calculation

This approach is described in Expert Report No. GS 3.2/16-357 (MPA Leipzig GmbH).

Tables 5, 6 and 7 present the minimum cover values for a given layer dimension of the COBIAX CBX system and the desired fire resistance class. Depending on the slab analysis in question, the respective tables are presented:

- Table 5 – two-way slabs with  $l_y/l_x \leq 1.5$
- Table 6 – two-way slabs with  $1.5 < l_y/l_x \leq 2.0$
- Table 7 – one-way and two-way slabs with  $l_y/l_x > 2.0$



|       |       | d2,Hk |    |    |    |    |    |    |     |
|-------|-------|-------|----|----|----|----|----|----|-----|
|       |       | 50    | 55 | 60 | 65 | 70 | 80 | 90 | 100 |
| S-100 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 11  |
|       | R 60  | 28    | 20 | 17 | 14 | 13 | 12 | 11 | 11  |
|       | R 90  | -     | 43 | 30 | 25 | 22 | 19 | 17 | 16  |
|       | R 120 | -     | -  | 48 | 38 | 32 | 27 | 24 | 23  |
|       | R 180 | -     | -  | -  | -  | -  | 59 | 46 | 40  |
|       | R 240 | -     | -  | -  | -  | -  | -  | -  | 67  |
| S-120 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 11  |
|       | R 60  | 28    | 20 | 17 | 14 | 13 | 12 | 11 | 11  |
|       | R 90  | -     | 40 | 30 | 25 | 22 | 19 | 17 | 16  |
|       | R 120 | -     | -  | 47 | 37 | 32 | 27 | 24 | 23  |
|       | R 180 | -     | -  | -  | -  | -  | 58 | 45 | 39  |
|       | R 240 | -     | -  | -  | -  | -  | -  | -  | 66  |
| S-140 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|       | R 60  | 28    | 20 | 16 | 14 | 13 | 12 | 11 | 11  |
|       | R 90  | -     | 41 | 30 | 25 | 22 | 19 | 17 | 16  |
|       | R 120 | -     | -  | 46 | 37 | 32 | 27 | 24 | 22  |
|       | R 180 | -     | -  | -  | -  | -  | 57 | 44 | 39  |
|       | R 240 | -     | -  | -  | -  | -  | -  | -  | 64  |
| S-160 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|       | R 60  | 28    | 20 | 16 | 14 | 13 | 12 | 11 | 11  |
|       | R 90  | -     | 39 | 29 | 25 | 22 | 19 | 17 | 16  |
|       | R 120 | -     | -  | 45 | 36 | 31 | 27 | 24 | 22  |
|       | R 180 | -     | -  | -  | -  | -  | 55 | 44 | 39  |
|       | R 240 | -     | -  | -  | -  | -  | -  | -  | 62  |
| S-180 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|       | R 60  | 27    | 20 | 16 | 14 | 13 | 12 | 11 | 11  |
|       | R 90  | -     | 38 | 29 | 24 | 22 | 19 | 17 | 16  |
|       | R 120 | -     | -  | 43 | 35 | 31 | 26 | 24 | 22  |
|       | R 180 | -     | -  | -  | -  | -  | 53 | 43 | 38  |
|       | R 240 | -     | -  | -  | -  | -  | -  | 89 | 61  |
| S-200 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|       | R 60  | 26    | 19 | 16 | 14 | 13 | 12 | 11 | 11  |
|       | R 90  | -     | 36 | 28 | 24 | 21 | 18 | 17 | 16  |
|       | R 120 | -     | -  | 41 | 34 | 30 | 26 | 24 | 22  |
|       | R 180 | -     | -  | -  | -  | -  | 51 | 42 | 38  |
|       | R 240 | -     | -  | -  | -  | -  | -  | 78 | 59  |
| S-220 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|       | R 60  | 25    | 19 | 16 | 14 | 13 | 11 | 11 | 11  |
|       | R 90  | -     | 35 | 27 | 23 | 21 | 18 | 17 | 16  |
|       | R 120 | -     | -  | 39 | 33 | 30 | 26 | 23 | 22  |
|       | R 180 | -     | -  | -  | -  | -  | 49 | 41 | 37  |
|       | R 240 | -     | -  | -  | -  | -  | -  | 72 | 57  |
| S-240 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|       | R 60  | 25    | 19 | 16 | 14 | 13 | 11 | 11 | 11  |
|       | R 90  | -     | 35 | 27 | 23 | 21 | 18 | 17 | 16  |
|       | R 120 | -     | -  | 39 | 33 | 30 | 26 | 23 | 22  |
|       | R 180 | -     | -  | -  | -  | -  | 49 | 41 | 37  |
|       | R 240 | -     | -  | -  | -  | -  | -  | 72 | 57  |
| S-260 | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|       | R 60  | 25    | 19 | 16 | 14 | 13 | 11 | 11 | 11  |
|       | R 90  | -     | 35 | 27 | 23 | 21 | 18 | 17 | 16  |
|       | R 120 | -     | -  | 39 | 33 | 30 | 26 | 23 | 22  |
|       | R 180 | -     | -  | -  | -  | -  | 49 | 41 | 37  |
|       | R 240 | -     | -  | -  | -  | -  | -  | 72 | 57  |

Table 5- Minimum cover for two-way slabs with  $l_y/l_x \leq 1,5$ .



|              |       | d2,Hk |    |    |    |    |    |    |     |
|--------------|-------|-------|----|----|----|----|----|----|-----|
|              |       | 50    | 55 | 60 | 65 | 70 | 80 | 90 | 100 |
| <b>S-100</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 11  |
|              | R 60  | 33    | 25 | 22 | 19 | 18 | 17 | 16 | 16  |
|              | R 90  | -     | 48 | 35 | 30 | 27 | 24 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 50 | 36 | 31 | 29  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 71 | 56  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-120</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 11  |
|              | R 60  | 33    | 25 | 22 | 19 | 18 | 17 | 16 | 16  |
|              | R 90  | -     | 45 | 35 | 30 | 27 | 24 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 48 | 35 | 31 | 29  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 69 | 56  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-140</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 33    | 25 | 21 | 19 | 18 | 17 | 16 | 16  |
|              | R 90  | -     | 46 | 35 | 30 | 27 | 24 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 47 | 35 | 31 | 28  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 68 | 55  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-160</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 33    | 25 | 21 | 19 | 18 | 17 | 16 | 16  |
|              | R 90  | -     | 44 | 34 | 30 | 27 | 24 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 45 | 35 | 31 | 28  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 66 | 54  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-180</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 32    | 25 | 21 | 19 | 18 | 17 | 16 | 16  |
|              | R 90  | -     | 43 | 34 | 29 | 27 | 24 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 44 | 34 | 31 | 28  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 64 | 53  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-200</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 31    | 24 | 21 | 19 | 18 | 17 | 16 | 16  |
|              | R 90  | -     | 41 | 33 | 29 | 26 | 23 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 42 | 34 | 30 | 28  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 62 | 52  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | 89  |
| <b>S-220</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 30    | 24 | 21 | 19 | 18 | 16 | 16 | 16  |
|              | R 90  | -     | 40 | 32 | 28 | 26 | 23 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 41 | 33 | 30 | 28  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 60 | 51  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | 83  |
| <b>S-240</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 30    | 24 | 21 | 19 | 18 | 16 | 16 | 16  |
|              | R 90  | -     | 40 | 32 | 28 | 26 | 23 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 41 | 33 | 30 | 28  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 60 | 51  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | 83  |
| <b>S-260</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 30    | 24 | 21 | 19 | 18 | 16 | 16 | 16  |
|              | R 90  | -     | 40 | 32 | 28 | 26 | 23 | 22 | 21  |
|              | R 120 | -     | -  | -  | -  | 41 | 33 | 30 | 28  |
|              | R 180 | -     | -  | -  | -  | -  | -  | 60 | 51  |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | 83  |

Table 6- Minimum cover for two-way slabs  $1.5 < l_y/l_x \leq 2.0$ .



|              |       | d2,Hk |    |    |    |    |    |    |     |
|--------------|-------|-------|----|----|----|----|----|----|-----|
|              |       | 50    | 55 | 60 | 65 | 70 | 80 | 90 | 100 |
| <b>S-100</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 11  |
|              | R 60  | 38    | 30 | 27 | 24 | 23 | 22 | 21 | 21  |
|              | R 90  | -     | -  | -  | 63 | 46 | 38 | 34 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 76 | 53 | 47  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-120</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 11  |
|              | R 60  | 38    | 30 | 27 | 24 | 23 | 22 | 21 | 21  |
|              | R 90  | -     | -  | -  | 61 | 46 | 37 | 34 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 73 | 53 | 47  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-140</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 38    | 30 | 26 | 24 | 23 | 22 | 21 | 21  |
|              | R 90  | -     | -  | -  | 59 | 45 | 37 | 34 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 69 | 53 | 47  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-160</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 38    | 30 | 26 | 24 | 23 | 22 | 21 | 21  |
|              | R 90  | -     | -  | -  | 56 | 45 | 37 | 34 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 68 | 52 | 47  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-180</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 37    | 30 | 26 | 24 | 23 | 22 | 21 | 21  |
|              | R 90  | -     | -  | -  | 54 | 44 | 37 | 34 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 66 | 51 | 46  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-200</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 36    | 29 | 26 | 24 | 23 | 22 | 21 | 21  |
|              | R 90  | -     | -  | -  | 53 | 44 | 37 | 33 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 64 | 51 | 46  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-220</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 35    | 29 | 26 | 24 | 23 | 21 | 21 | 21  |
|              | R 90  | -     | -  | -  | 50 | 42 | 36 | 33 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 61 | 50 | 46  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-240</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 35    | 29 | 26 | 24 | 23 | 21 | 21 | 21  |
|              | R 90  | -     | -  | -  | 50 | 42 | 36 | 33 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 61 | 50 | 46  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |
| <b>S-260</b> | R 30  | 13    | 12 | 11 | 11 | 11 | 11 | 11 | 10  |
|              | R 60  | 35    | 29 | 26 | 24 | 23 | 21 | 21 | 21  |
|              | R 90  | -     | -  | -  | 50 | 42 | 36 | 33 | 32  |
|              | R 120 | -     | -  | -  | -  | -  | 61 | 50 | 46  |
|              | R 180 | -     | -  | -  | -  | -  | -  | -  | -   |
|              | R 240 | -     | -  | -  | -  | -  | -  | -  | -   |

Table 7- Minimum cover for one-way and two-way slabs with  $l_y/l_x > 2.0$ .



## SOUND INSULATION

The two main parameters for classifying the sound insulation of slabs are:

- Airborne sound insulation;
- Impact sound insulation.

The acoustic behaviour tests carried out on COBIAX CBX slabs — both with samples in specialised laboratories and in complete buildings, with the aim of calculating 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.

In both cases — impact sounds and airborne sounds — the main element for assessing the degree of sound insulation provided by concrete slabs is the average mass per square metre of the area under study, and several publications provide these data as a function of thickness and the corresponding mass.

The insulation values provided for infill elements, floors and ceilings are then added to the values obtained from these tables, and the sum gives the sound insulation capacity of the slab. Obviously, the average mass of a COBIAX CBX slab is lower than that of a solid slab of the same thickness; consequently, the acoustic insulation capacity of the COBIAX CBX slab will be lower in proportion to its mass.

The acoustic assessment of buildings incorporating COBIAX CBX slabs can therefore be based on the same methods usually used for traditional buildings, based on the average surface mass of the COBIAX CBX slab.

By way of example, for the 20 cm slab (the thinnest slab that can be produced with the COBIAX CBX system), the following values were measured on a sample without finishes or ceilings in the laboratory:

Airborne sound insulation:  $R_{w,P} = 56$  dB

Impact sound level:  $L_{n,eq,0,w,R} = 76$  dB

The average mass of this slab corresponds to an average concrete thickness of 15 cm.

The sound insulation of a COBIAX CBX slab can thus be assessed using an equivalent slab thickness.

## THERMAL INSULATION

The voids created by the COBIAX CBX modules affect the thermal conductivity of the slab. In theory, this has a positive effect on heat transfer through the slab and consequently on its thermal insulation. However, the effect is negligible for 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.

## THERMAL CONTROL

COBIAx CBx slabs can be easily combined with systems for controlling the temperature of the core of the concrete structure. These combine heating and cooling systems through a network of pipes integrated within the structure.

The following study makes it possible to observe the effect that the voids have on the temperature storage capacity:

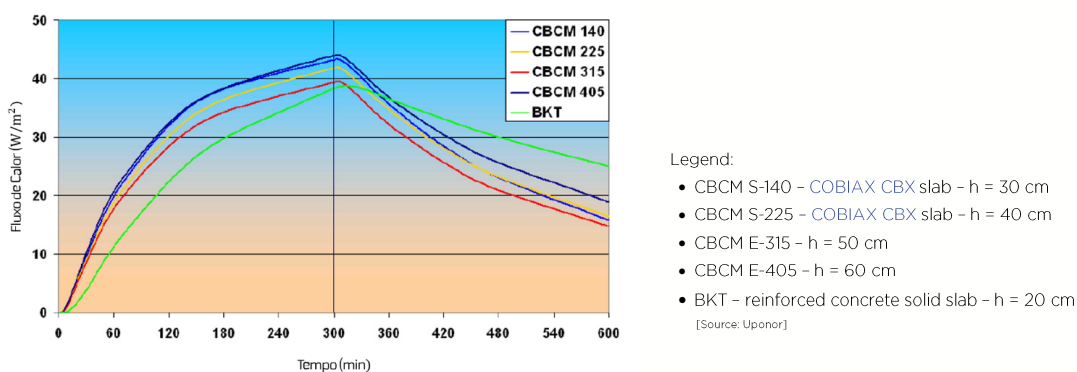


Figure 14 - Thermal Storage Capacity

For each type of voided slab, it is possible to observe the performance of slabs with the COBIAx CBx system compared with conventional solid slabs (using a dynamic load model over a period of 5 hours, with a constant ambient temperature of 26 °C and an average temperature of 18 °C).

Tests and studies over time demonstrate that, for selective temperature control, COBIAx CBx slabs perform better and more efficiently than a conventional solid slab.

The COBIAx CBx system adapts quickly to current temperature changes, owing to its rapid energy accumulation and dissipation.

For the best possible performance of the COBIAx CBx slab, the pipes are installed between the bottom reinforcement zone and the CBx voids. In this case, the bottom concrete layer should be approximately 8 cm thick. These characteristics are sufficient to provide a performance similar to that of a solid concrete slab with this type of system.

To protect the system pipes, it is recommended to use a mat layer in the bottom zone of the slab corresponding to their height.

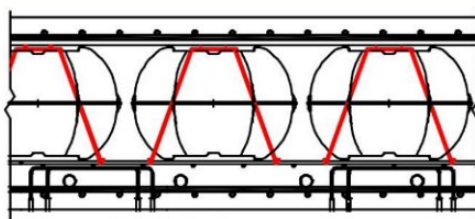


Figure 15 - Lifting chairs

## PRESTRESS

Combining prestress with the **COBIAx CBx** 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.

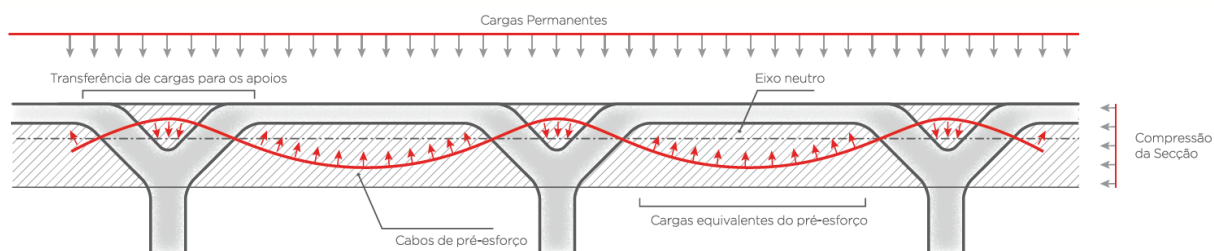


Figure 16 – Equivalent Loads

Prestress, by controlling the self-weight through the equivalent forces imposed on the slab, together with the advantage of the reduction in self-weight present in the **COBIAx CBx** slab, makes this solution highly advantageous compared with more conventional solutions.

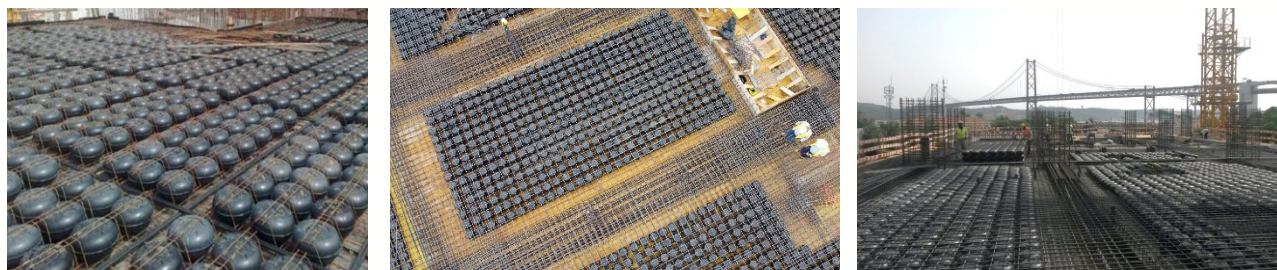


Figure 16 – Prestressed COBIAx Slabs

## PRECAST ELEMENTS

The use of **COBIAx CBx** modules in precast elements provides lighter and more economical solutions. In these cases, the weight factor offers not only static advantages but also advantages in the transport and installation of the elements. Balconies are one of the notable construction elements suited to this use.



Figure 16 – Precast COBIAx Slabs

## SUSTAINABILITY

The civil construction industry is one of the sectors that generates the greatest direct impact on the environment, with cement production being one of the main sources of CO<sub>2</sub> emissions.

During the production of a reinforced concrete slab, the production of construction materials leads to CO<sub>2</sub> emissions related to raw materials and energy. Most of the CO<sub>2</sub> emissions in concrete production are due to cement production, owing to the high energy consumption (thermal and electrical) and the CO<sub>2</sub> emissions arising mainly from the decarbonation of limestone during cement production.

In a study carried out by the Fraunhofer Institute, it was possible to show and quantify the potential of COBIAx CBX technology in reducing CO<sub>2</sub> emissions in the manufacture of slabs.

## CASE STUDY

The analysis assumed an average CO<sub>2</sub> emission of 0.70 kg per kg of cement. For cement production, an additional 0.63 kg of CO<sub>2</sub> per m<sup>3</sup> of slab is assumed for the concrete, and for the production of reinforcement steel a CO<sub>2</sub> 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<br>[kg/m <sup>3</sup> of slab] | CO <sub>2</sub> emissions<br>[kg/kg emitted] | CO <sub>2</sub> emissions<br>[kg/m <sup>3</sup> 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 8 – CO<sub>2</sub> emissions during the production of a conventional solid slab per m<sup>3</sup>.

In another approach, a similar voided slab using COBIAx CBX system technology was considered. The introduction of the voids made it possible to save 17% of the reinforcement steel required, according to a comparative calculation. The metal grids of the system used to position the COBIAx CBX voids were not taken into account in the static calculation but were included in the CO<sub>2</sub> balance, in accordance with the table below.

The energy consumption in producing a COBIAx CBX void made from 100% recycled material is approximately 0.04 kWh per unit. Assuming a CO<sub>2</sub> production of 0.70 kg per kWh, there is a CO<sub>2</sub> emission of 0.34 kg per m<sup>3</sup> of slab.

For the COBIAx CBX slab similar to the conventional solid slab considered, the following consumption values were obtained:

| COBIAx CBX Slab             | Mass<br>[kg/m <sup>3</sup> of slab] | CO <sub>2</sub> emissions<br>[kg/kg emitted] | CO <sub>2</sub> emissions<br>[kg/m <sup>3</sup> of slab] |
|-----------------------------|-------------------------------------|----------------------------------------------|----------------------------------------------------------|
| Cement                      | 210                                 | 0,70                                         | 147,00                                                   |
| Concrete (excluding cement) | 1,540                               | 0,0003                                       | 0,44                                                     |
| Steel                       | 120                                 | 1,73                                         | 207,60                                                   |
| COBIAx CBX module           | 10                                  | 0,03                                         | 0,34                                                     |
| Metal grids                 | 8                                   | 1,73                                         | 13,84                                                    |
| Total                       |                                     |                                              | 369,22                                                   |

Table 9 – CO<sub>2</sub> emissions during the production of a slab with COBIAx CBX technology per m<sup>3</sup>.



This results in CO<sub>2</sub> emissions of approximately 369.22 kg for the slab with COBIAX CBX technology.

For the comparative balance of the amount of CO<sub>2</sub> emissions between the two types of slab presented, the following expression applies:

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

In summary, there is a saving of 92.26 kg of CO<sub>2</sub> per m<sup>3</sup> of slab in direct comparison with the conventional solid slab, a reduction of the order of 20%!

The sustainability of natural resources is increasingly important today; the use of recycled materials to form the voids and the reduction in the need for concrete allow the COBIAX CBX system, in itself, to deliver a structure with a lower environmental impact and a significant reduction in the CO<sub>2</sub> emissions inherent to the construction process.

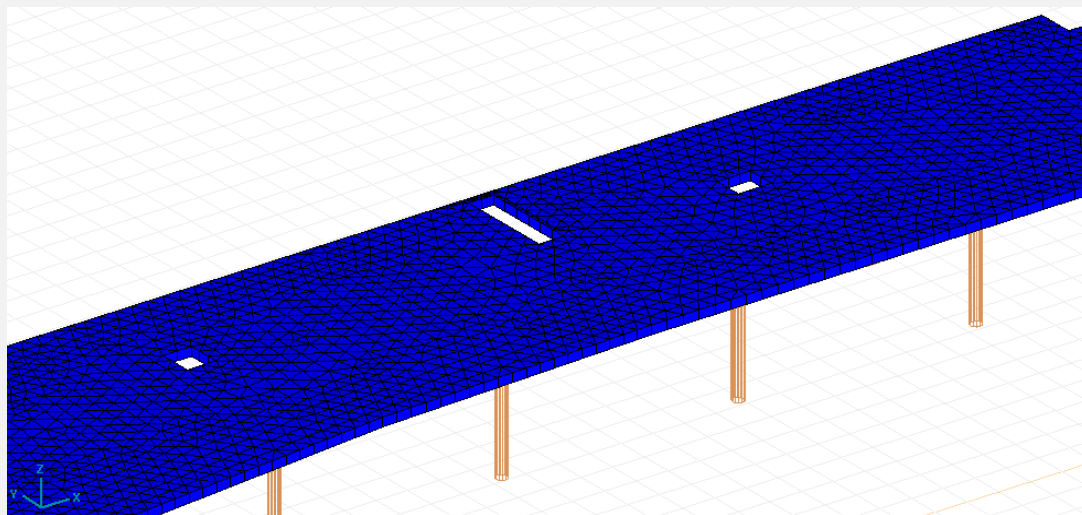
## DESIGN PROCESS FOR A COBIAX CBX SLAB

This chapter describes the calculation process for a COBIAX CBX slab using finite element software. The process is based on the methods currently used for the structural design of solid slabs and is compatible with any code or standard in force.

The example included is based on the FEM software “Axis VM9”; however, the underlying principles are applicable to any finite element software capable of calculating solid slabs.

### STEP 1 - ASSUMPTIONS, INITIAL DATA AND PARAMETERS FOR COBIAX CBX

Define the initial data in accordance with the assumptions for the structure — such as the slab geometry, 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 CBX void you wish to use, taking into account the load reduction and the stiffness correction factor in accordance with the parameters in Table 1 of this manual.



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

#### Generic design parameters

$E = 34000 \text{ N/mm}^2$ ;  $\delta = 25 \text{ kN/m}^3$ ; cover = 25 mm; thickness  $h = 300 \text{ mm}$

Selected COBIAX CBX system parameters: S-180

Permanent load reduction –  $2.32 \text{ kN/m}^2$

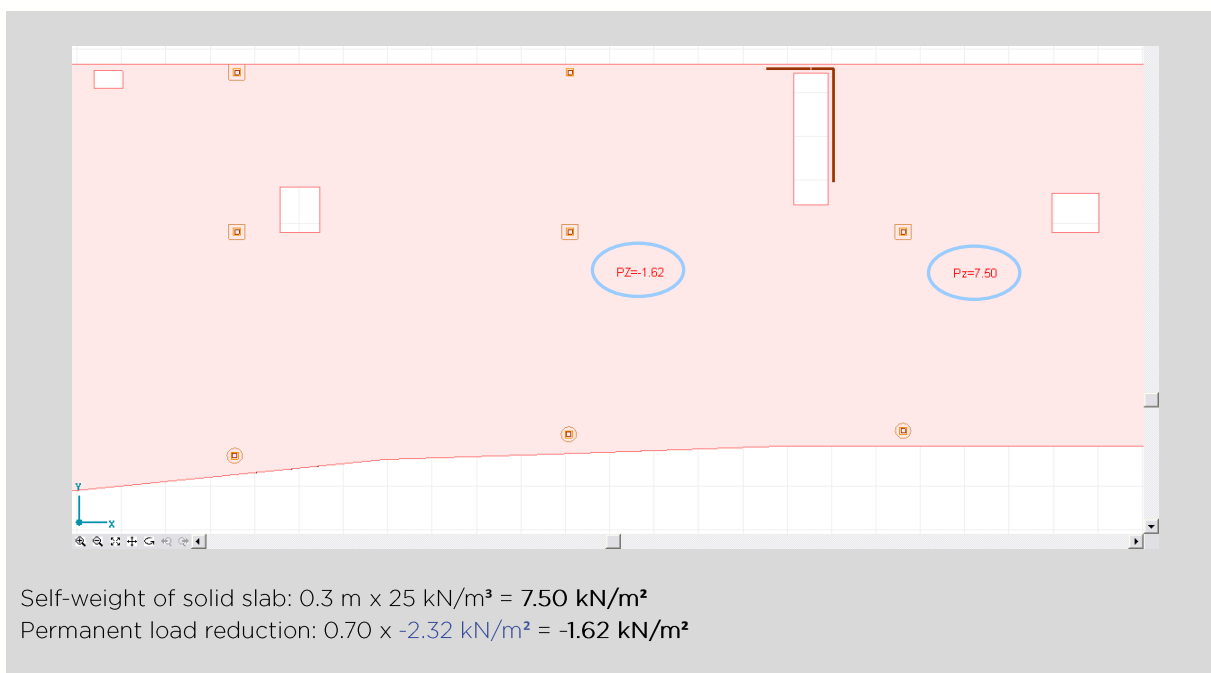
Stiffness correction factor – 0.91



## STEP 2 - ADDITIONAL PERMANENT LOAD PATTERN

As a rule, observable across a wide set of tests, the voided area represents approximately 70 to 80% of the total slab area; however, for preliminary design purposes it is recommended to use a value no greater than 70% 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 CBX voids to be installed, in accordance with the selection made in the previous step. This load must act in the opposite direction to the self-weight of the slab considered automatically.



## STEP 3 - SLAB STIFFNESS MODIFICATION

To account for the reduction in slab stiffness resulting from the introduction of the COBIAX CBX system, you should, depending on the options your software offers, carry out one of the following operations:

- Modify the modulus of elasticity of the slab concrete by applying the constant coefficient from Table 1;
- Modify the stiffness of the slab elements by applying the correction factor given in Table 1;

Calculate the resulting deformation by incorporating into the model the permanent load reduction pattern and the modified stiffness; check whether it meets your criteria, and if it doesn't, the slab thickness must be increased.

Modification of E:  $0.91 \times 34000 \text{ N/mm}^2 = 30940 \text{ N/mm}^2$

Modification of global stiffness factor from 1 to 0.91

Depending on the software used, it presents the calculation of linear deformation (State I, elastic) or non-linear deformation and allows the long-term deformation to be calculated (State II). For the linear case, the elastic deformation values obtained from the calculation are treated in the same way as for solid slabs with regard to the assessment of long-term deformation.



## STEP 4 - SHEAR RESISTANCE CRITERION AND IDENTIFICATION OF SOLID ZONES

Manually calculate the maximum permissible 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 voided zone.

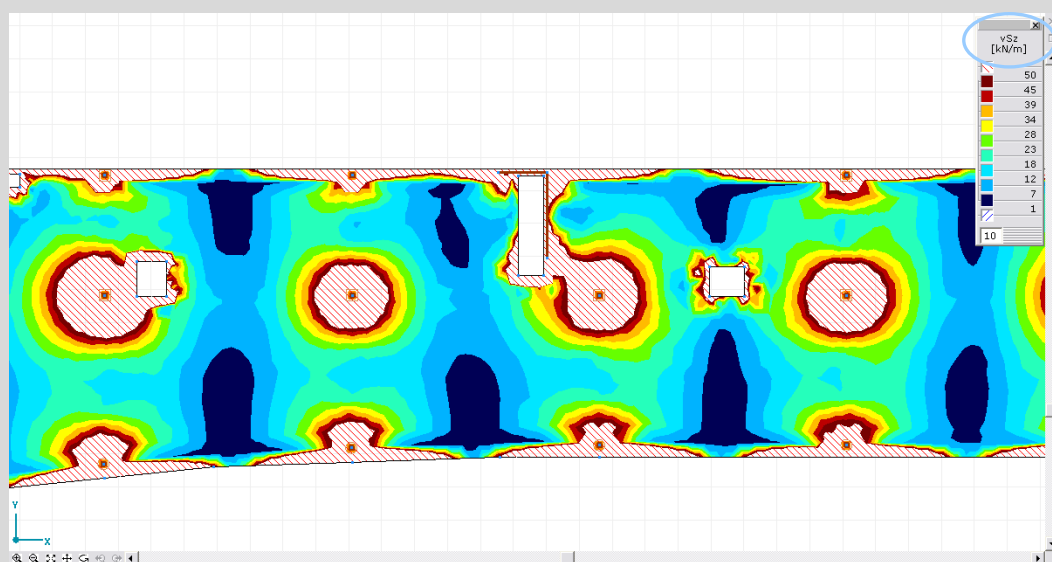
Display the distribution of the shear forces in your model and identify the areas of the slab where this value exceeds the shear capacity of the voided zone; naturally, COBIAX CBX modules must not be placed in these areas.

Assume that for the example we have  $V_{cd} = 100 \text{ kN/m}$

Shear reduction factor for COBIAX CBX S-180: 0.50

We then have, in the voided slab zone:  $V_{cd, \text{COBIAX CBX}} = 0.50 \times 100 \text{ kN/m} = 50 \text{ kN/m}$

The distribution of the shear forces in the slab, calculated while maintaining the load reduction case, makes it possible to identify the zones where these values exceed the maximum permissible shear force  $V_{cd, \text{COBIAX CBX}}$ .

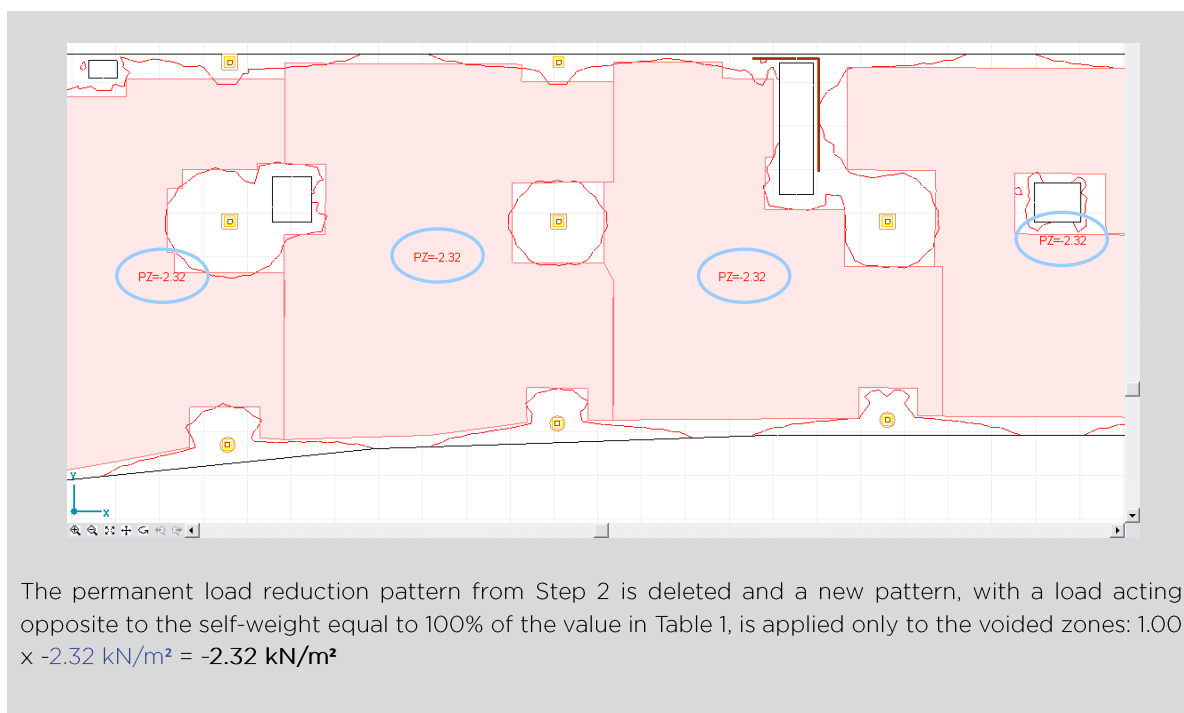




## STEP 5 - REFINEMENT OF THE LOAD REDUCTION CASE

This step is only required if you want greater refinement and accuracy of the force values, in particular in vertical elements and foundations, since their redistribution in the slab will result in a reduction of both forces and deformations.

Using the outlines of the solid zones identified earlier, redefine the permanent load reduction case, applying 100% of the reduction value given in Table 1 to the voided zones and removing this load from the solid zones.



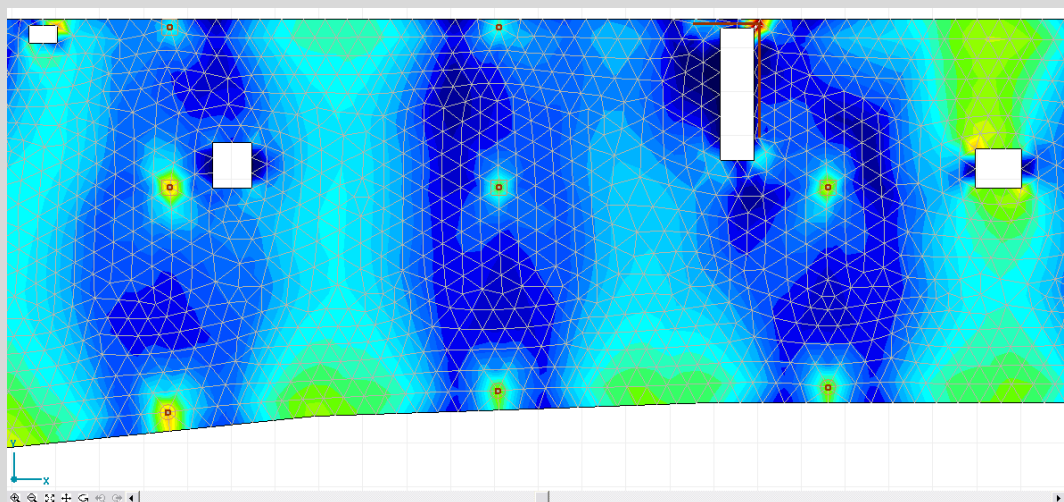
The permanent load reduction pattern from Step 2 is deleted and a new pattern, with a load acting opposite to the self-weight equal to 100% of the value in Table 1, is applied only to the voided zones:  $1.00 \times -2.32 \text{ kN/m}^2 = -2.32 \text{ kN/m}^2$



## STEP 6 - VERIFICATION AND DETAILING OF THE SLAB SECTION

Based on the analysis of forces and the design of the reinforcement bars and required covers, it is important to verify the compliance of the proposed section, in particular by confirming its feasibility.

The sum of the covers, the bar diameters and the height of the COBIAx CBX grid must be less than or equal to the defined slab thickness; otherwise, you must redefine the bars to be used or increase the slab thickness. If it is less, this difference can be compensated for by spacers placed for this purpose.



Force distribution at ultimate limit states

### Section verification after reinforcement selection

Cover: 25 mm

Diameter of bottom reinforcement bars: 12 and 16 mm (x and y directions in the voided zone)

Diameter of top reinforcement bars: 12 mm (x and y directions in the voided zone)

Support height S-180: 190 mm

→  $\Sigma 25\text{mm} + 25\text{mm} + 12\text{mm} + 16\text{mm} + 12\text{mm} + 12\text{mm} + 190\text{mm} = 292\text{ mm}$

→  $292\text{ mm} \leq 300\text{ mm}$

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

## DETAILING

### LAYOUT/GEOMETRY DRAWINGS

For the correct assembly of the **COBIAX CBX** grids 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 reinforcement bar detailing, they enable the slab works to be carried out.

The system setting-out 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 CBX** module and of the layers;
- Indication of the assembly sequence of the reinforcement bars and the orientation of the grids;
- General notes on the use, handling and assembly of the **COBIAX CBX** slab.

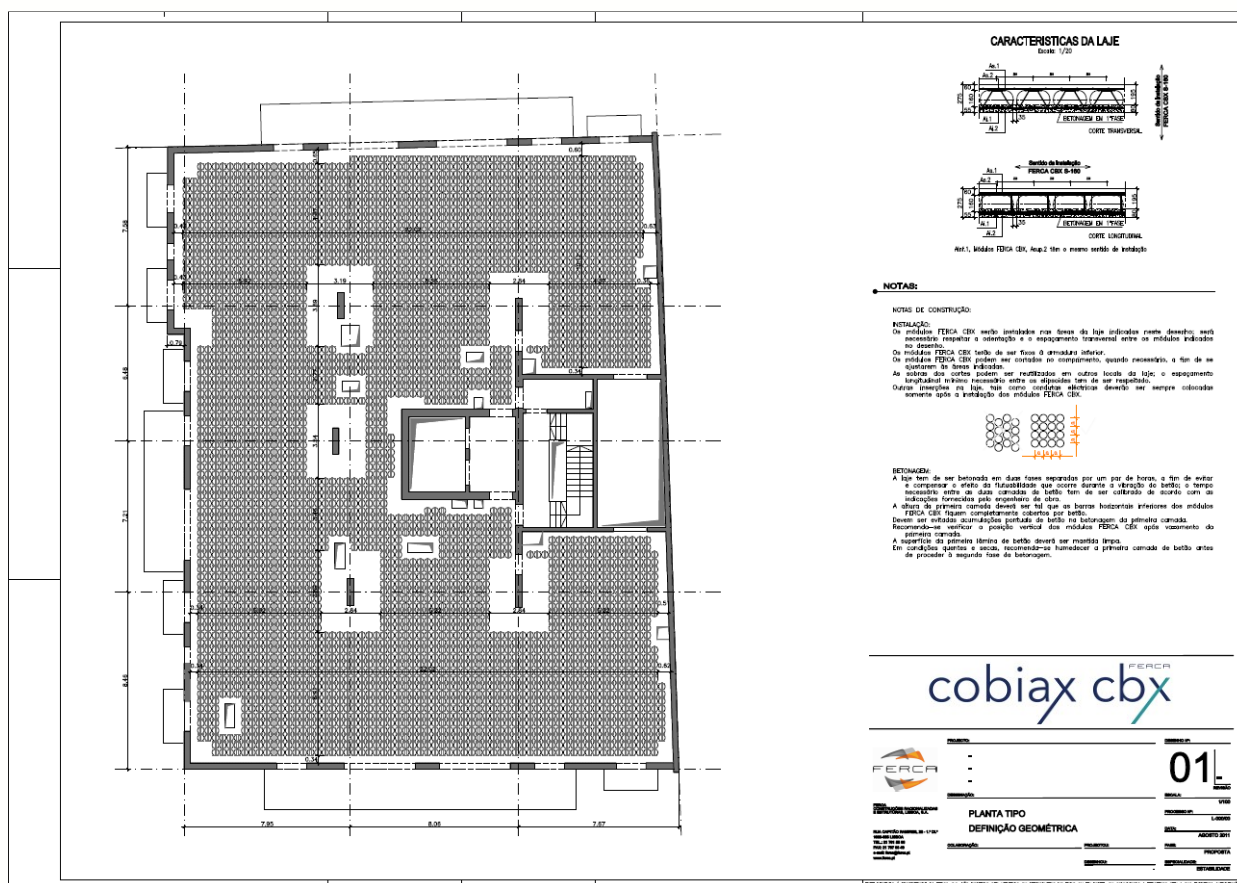


Figure 17 – COBIAX CBX distribution drawing



The following principles must be observed in the distribution of the COBIAx CBx system:

The distribution of the COBIAx CBx system must respect the zones where the shear force exceeds the capacity of the slab, leaving these as solid zones (see Figures 20 and 21);

The spacing between the axes of the COBIAx CBx voids must comply with the dimensions given in Table 1 of this document, unless specifically indicated otherwise;

Along the edge of the slab and around 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, in order to avoid interference of the COBIAx CBx grids with any additional edge reinforcement;

Whenever necessary, the COBIAx CBx grids must be cut to the required length in order to fill the defined areas, and their distribution must maintain the orthogonality of their arrangement;

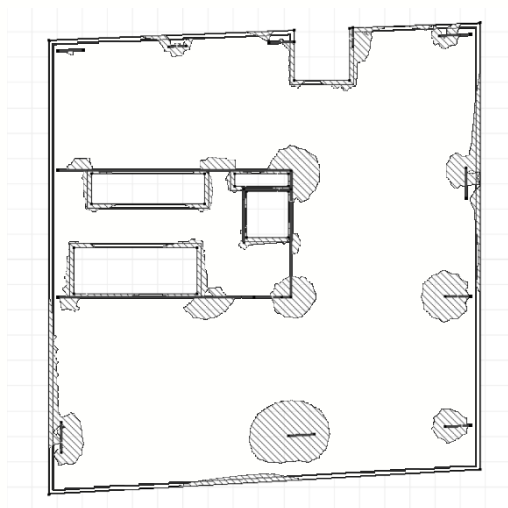


Figure 20 - Identification in the calculation model of areas where the shear force exceeds the slab shear capacity.

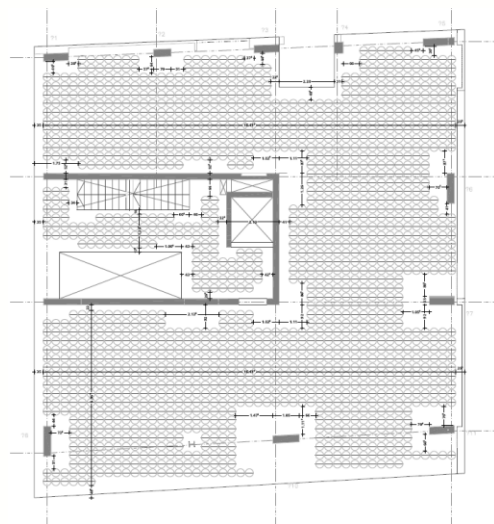


Figure 21 - Distribution of the COBIAx CBx system taking into account the necessary solid zones.

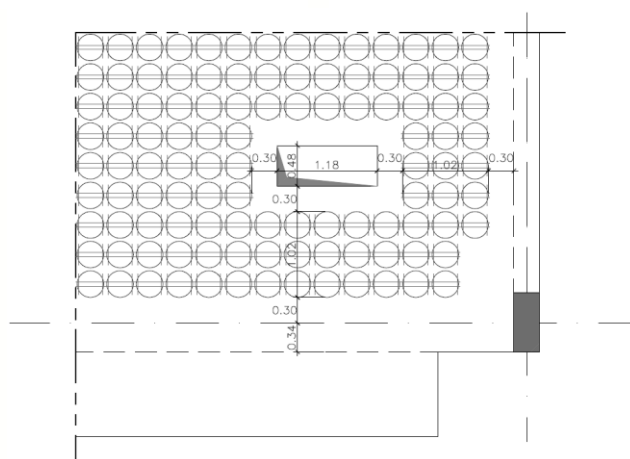


Figure 22 - Example of a layout drawing for the COBIAx CBx system

## TECHNICAL SERVICES INSTALLATION

As COBIAX CBX is a modular system, it can be made compatible with the various services to be installed in the slab; the implications for the arrangement of the COBIAX CBX modules must be anticipated in advance and shown on the distribution 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.

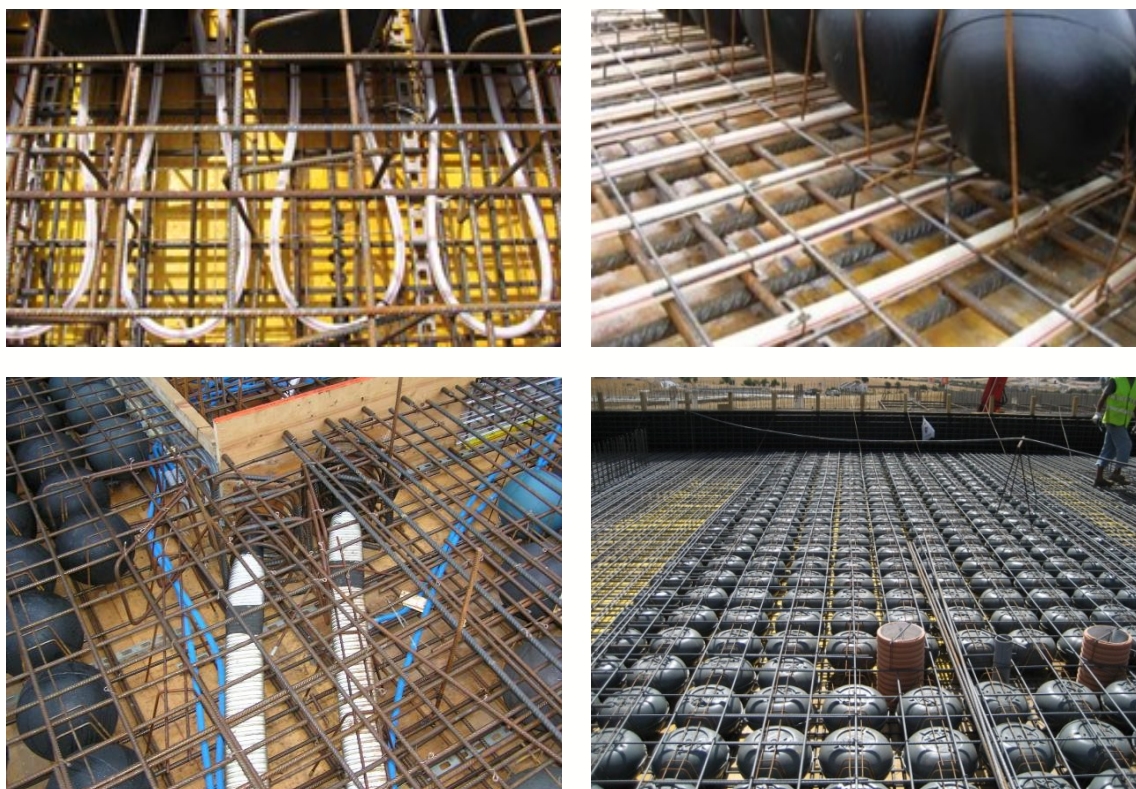


Figure 23 - Examples of various services and post-tensioning systems in a COBIAX CBX slab

## ASSEMBLY OF A COBIAX CBX SLAB

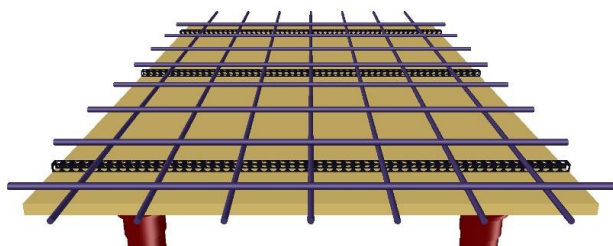
The assembly of the COBIAX CBX slab involves various procedures, from logistical factors and the transport of the material to the product assembly process and the procedures during its execution on site. Refer to the system's Procedures Manual.



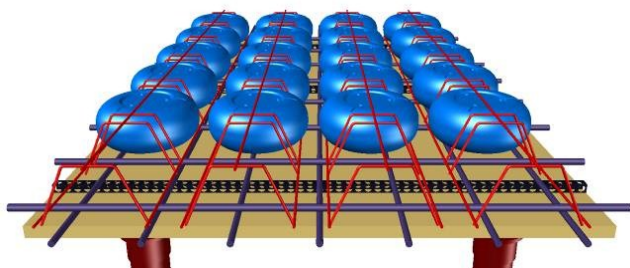
Figure 24 - Material assembly and storage process



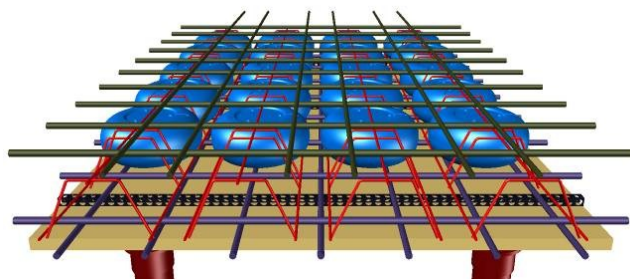
The construction of the COBIAx CBx slab fully follows the same principles and procedures as the assembly of a solid slab, with the grids placed and fixed directly onto the bottom reinforcement. It is also worth noting the particular feature that these grids support the top reinforcement, avoiding the usual “chairs” of solid slabs.



Construction of continuous deck, placement of spacers for cover and bottom reinforcement

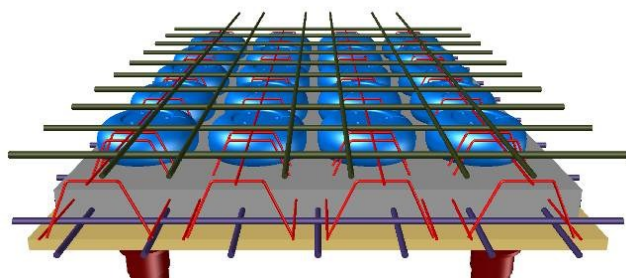


Placement of the COBIAx CBx grids directly onto the bottom reinforcement, fixed with 2 to 3 ties per grid

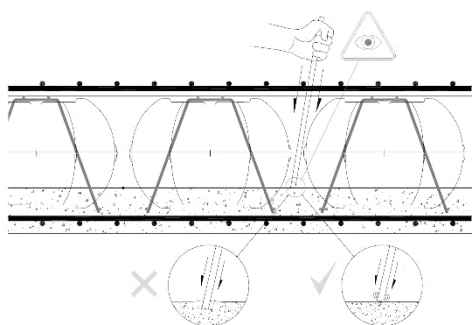


Placement of the top reinforcement onto the COBIAx CBx grids

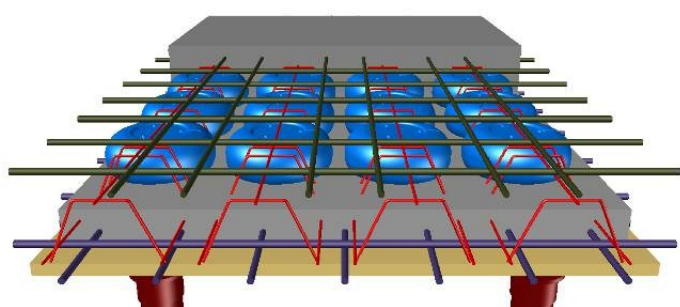




Concreting of the 1st phase, up to 1/3 of the thickness, anchoring the COBIAx CBX grids



Verification of the 1st concreting phase of the slab



Concreting of the 2nd phase, 1 to 2 hours after the 1st phase, finishing of the slab



