COMPARATIVE ANALYSIS OF MONOLITHIC CONSTRUCTION AND THE „CUBIAX„ SYSTEM IN COMERCIAL BUILDING

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Abstract

Objective: This study presents a comparative analysis between conventional monolithic construction and the **CUBIAX** system in commercial buildings.
The paper examines traditional monolithic construction alongside contemporary construction techniques that incorporate prefabricated void-forming elements made of plastic and rubber within reinforced concrete slabs and foundations. The innovative **CUBIAX** system enables faster and more rational construction by reducing concrete consumption, thereby decreasing the self-weight of the structure. Reduction of dead load is a fundamental objective in structural engineering; achieving this enhances the ductile behavior of structures under dynamic and seismic loading. Consequently, the application of the **CUBIAX** system represents a highly effective solution, particularly for structures located in seismically active regions.
Methodology: The study involves structural analysis of systems designed using the conventional monolithic method, employing established reinforced concrete design procedures in accordance with national regulations and European standards, specifically Eurocode 2 (EC2) and Eurocode 8 (EC8). Similarly, the analysis of structures utilizing the **CUBIAX** system is conducted using verified design approaches based on Eurocodes and widely adopted European engineering practices.
Results: In direct comparison with conventional reinforced concrete slabs, **CUBIAX** voided flat slabs demonstrate superior technical performance and are generally more cost-effective due to reduced material consumption. Furthermore, the overall costs of the supporting structural system and foundations can be significantly reduced as a result of the decreased dead load of the optimized slab system. The degree of optimization varies depending on project-specific conditions.
The increased span capacity and optimized cross-sections of load-bearing elements contribute to enhanced flexibility in load distribution and allow for larger usable floor areas. Due to the reduced permanent load, **CUBIAX** slabs can be designed to be approximately 5–10% thinner than conventional reinforced concrete slabs while maintaining equivalent service loads and deformation limits. Additionally, construction execution is faster, resulting in time savings without compromising structural safety, stability, or ductility as prescribed by relevant standards.
Conclusion: Based on the conducted analyses, the **CUBIAX** system proves to be a more suitable and efficient solution within the fields of structural engineering and architecture. Comparative evaluation with conventional monolithic construction indicates that the **CUBIAX** system offers advantages across multiple aspects of design and construction, including structural performance and efficiency. It effectively reduces:

- Structural self-weight
- Construction time
- Project costs
- Labor requirements
- Complexity of installation

while improving seismic performance and overall structural behavior.
The findings demonstrate that the **CUBIAX** system addresses many of the limitations associated with traditional reinforced concrete construction methods.
Keywords: Monolithic construction; reinforced concrete slabs; reinforced concrete foundations; **CUBIAX** system; construction methods; cost efficiency; construction time; Eurocodes; European standards.

Introduction

Rubber is a substance that plays a significant role in modern society. It contributes to construction, forms the structure of tires, and even supports the soles of shoes. However, since

its identification around three millennia ago, rubber has undergone substantial development into the material we recognize today.
First identified and collected in Central and South America around 1600 BCE, early rubber was primarily used for games. Harvested from plants, ancient peoples shaped this substance into balls and used them for primitive bouncing games.
Although games were its primary use at the time, traces of rubber have also been found in the construction of metal and stone tools, mainly used to secure these materials to wooden handles. Over time, these early societies discovered that rubber was waterproof and could be used to create water-resistant clothing. When Europeans first encountered rubber, they were so astonished by its properties that they believed it to be magical.
However, it was not until 1770 that rubber was introduced into English society by Joseph Priestley. He observed that rubber could erase pencil marks, which led to the name "rubber." As its consumption increased in Western countries, demand for the product intensified. Consequently, the forests of South America and Africa where rubber trees grew were unfortunately exploited, and local populations were forced into the labor-intensive process of harvesting the substance. Eventually, rubber cultivation was transferred to Southeast Asia, where it continues to be produced today.
Unfortunately, natural rubber is sticky, brittle, and has an unpleasant odor, which limited its use during the 18th and 19th centuries. Due to increasing demand—especially for motor vehicle tires—a special sulfur-based rubber processing method called vulcanization was introduced in 1844 by Charles Goodyear. Soon after, synthetic rubber was developed as a way to keep up with the growing demand for durable rubber products.
Today, numerous advancements have been made in the sourcing, processing, and manufacturing of rubber worldwide. Used in industry, vehicle production, and the manufacture of various smaller mechanical components, rubber continues to be an essential component of modern life and construction

Fig. 1.1. Natural rubber process

Monolithic Construction

From a structural standpoint, monolithic buildings are designed as reinforced concrete frame structures. The buildings consist of a system comprising the foundation slab, columns, slabs, and beams. Other elements of the building include the masonry façade, partition walls made of lightweight ceramic blocks, floor structures, and thermal insulation of the façade and roof.

Earthworks and preparatory works

For the execution of the foundation structure, after prior site clearing and removal of the humus

layer to a depth of 20–25 cm, excavation is planned for the foundation slab to the depth required for compaction.
The entire excavation area, namely the foundation slab base, is compacted with crushed stone of 40–120 mm grain size, after prior soil compaction. This sub-base layer, due to the material structure, serves not only as a load-bearing surface but also ensures a certain level of groundwater drainage.

Complete construction

The foundation is constructed of reinforced concrete. The foundation slab is executed with a thickness determined by structural calculations, placed on the previously compacted crushed stone layer.
Due to the fact that the basement level is largely excavated, the basement walls are constructed of reinforced concrete up to the height defined in the architectural design, measured from the level of the foundation slab.

Load-bearing skeletal structure

The above-ground load-bearing structure consists of reinforced concrete elements: columns, walls, beams, slabs, and stairs. These elements form a skeletal structural system across multiple levels.
Columns have rectangular cross-sections or other shapes as defined by the design. Beams are dimensioned according to structural calculations.
Floor slabs have thicknesses determined by structural analysis.

Brief Introduction To Cubiax Technology

The function of the Cubiax system is based on lightweight plastic void formers that replace solid concrete within reinforced concrete slabs. As a result, both the weight and the volume of concrete are reduced, enabling thinner slabs and significantly larger spans in buildings. The Cubiax system allows for bidirectional load transfer. The structural performance and external appearance of the flat slab remain fully unaffected.Furthermore, due to the reduced material consumption, overall structural costs can be lowered. Owing to the achieved load reduction, Cubiax voided flat slabs are also an ideal solution for foundation optimization in cases of weak soil conditions, as well as for economical renovation and vertical extension of existing buildings. Lightweight slabs allow for a reduction in the dimensions of load-bearing elements within a building. This system is also environmentally friendly, as the void formers reduce material consumption and are made from 100% recycled plastic.

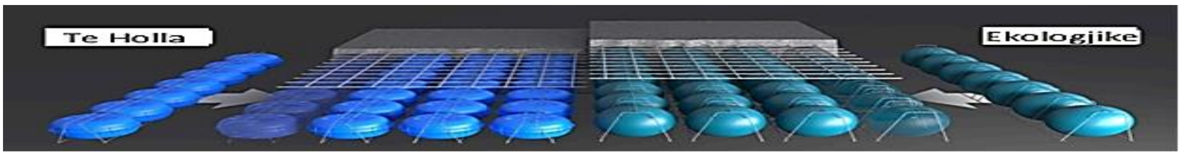


Fig.3.1 Slim line and Eco line system

The internationally patented Cubiax system consists of linear positioning elements approximately 215 cm or 250 cm in length, within which void formers are integrated. At the

same time, these elements serve as support components for the upper reinforcement layer. The practical modules are available in two variants: Eco-Line and Slim-Line. In the Eco-Line system, the void formers are spherical and are intended for slab depths ranging from 40 cm to 70 cm. The flatter Slim-Line void formers, on the other hand, are ideally suited for slab depths between 20 cm and 56 cm. Each Slim-Line void former consists of two ნახევერსфера (hemispheres) and is therefore particularly suitable for application in international markets, as it increases modularity and optimizes space and transport possibilities.
A Cubiax voided flat slab can be planned and designed by any structural engineer in accordance with the relevant country-specific standards.
The modules are installed according to the Cubiax installation plan between the upper and lower reinforcement layers. This can be carried out easily on site or by using a prefabricated construction method. Furthermore, Cubiax technology can be readily combined with other construction methods, such as the incorporation of building elements, conventional monolithic concreting, prestressing, etc. The high degree of flexibility in the layout and positioning of the modules (voids) also enables their combination with other embedded elements or the creation of local stiffening strips and solid zones without void formers.
A Cubiax voided flat slab can be planned and designed by any structural engineer in accordance with national standards, taking into account information from general technical approvals. Additional expert reports, test certificates, and declarations on various specific topics are also available. In principle, analysis and design can be performed using any structural analysis software (including international FEM software) or manually.

1. Estimation of slab depth (if necessary, using diagrams for preliminary sizing).
2. Selection of a design variant, definition of slab cross-sections, and choice of a suitable Cubiax module.
   This can be done quickly and easily using the Cubiax fast and user-friendly software tool.
3. Determination of Cubiax-specific input parameters for calculation:
   • Load reduction through void formers
   • Factor for flexural stiffness (stiffness factor) fEI
   • Factor for shear resistance (shear factor) fV (international standards)
   or reduced shear resistance VRd,c,cubiax = fV · VRd,c (according to Eurocode)
   This can also be performed quickly using the Cubiax software tool.
4. Initial calculation procedure considering input parameters analogous to a conventional reinforced concrete slab. During this process, both the reduced load and reduced flexural stiffness are initially applied over the entire slab area.
5. Consideration of internal shear forces leads to the identification of required solid zones. Areas where VEd > VRd,c,cubiax must be designed without void formers. In critical punching zones, it must be verified whether the solid zone extends by a dimension of 2d beyond the critical circular section or beyond the last reinforcement layer. Otherwise, the solid zones must be extended accordingly, as illustrated in Figure 3.2.

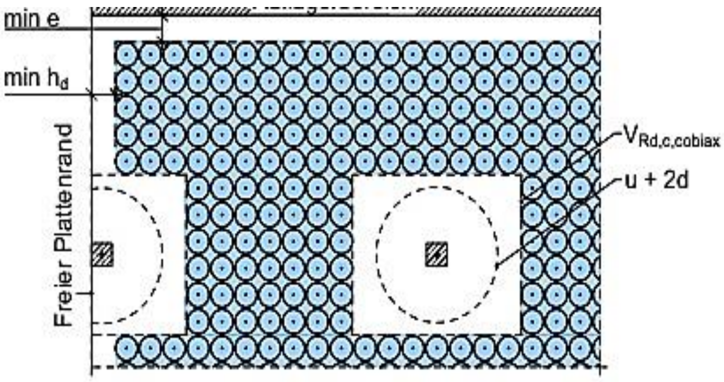


Fig.3.2 Support space with Cubiax at the facility

6) In the defined rigid areas, the permanent load, or bending stiffness, must be adjusted and the second and final calculation procedure must be started.
For concreting in two work steps (securing the hollow modules against movement) and for execution using semi-precast elements, the transmission of the shear force in the concreting joint is to be verified with a reduced bonding surface. This can be done quickly and easily using Cubiax tools.

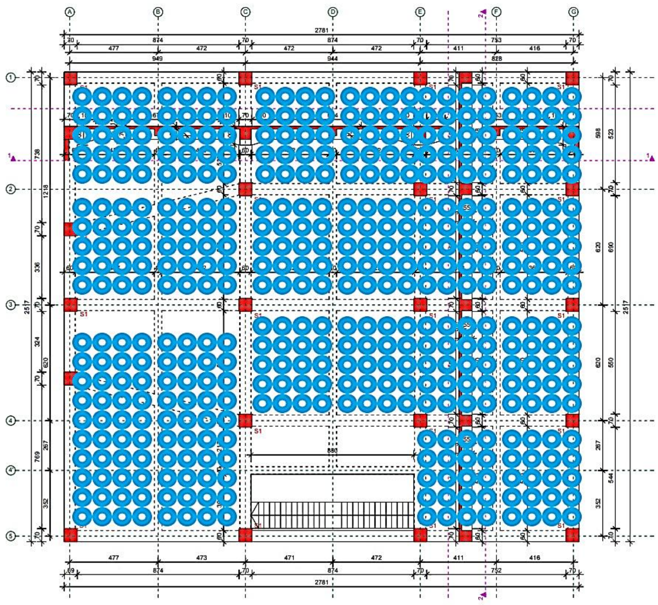


Fig. 3.3 Design of the Cubiax slab on the floors of the building

Fig. 3.4 Placing Cubiax balls on the plate

For the calculation of deformations, a suitable stiffness factor fEI must be taken into account to determine the bending stiffness in the previously hollow area. Otherwise, the deformation calculation occurs analogously to the procedure for a conventional-monolithic reinforced concrete slab. The stiffness reduction through the void is approx. 5% to 13% (stiffness factor approx. 0.95 to 0.87).

The easily applicable concept for verifying the shear resistance of Cubiax hollow flat slabs aims at using an estimated reduction factor (shear factor fV) in comparison with a solid slab. A comprehensive test program has been implemented to determine the reduction factor and the most unfavourable values determined by it. As a result, the actual existing load. Bearing capacity is not utilized in most cases, which means that a higher level of safety can be assumed compared to a reinforced concrete slab.

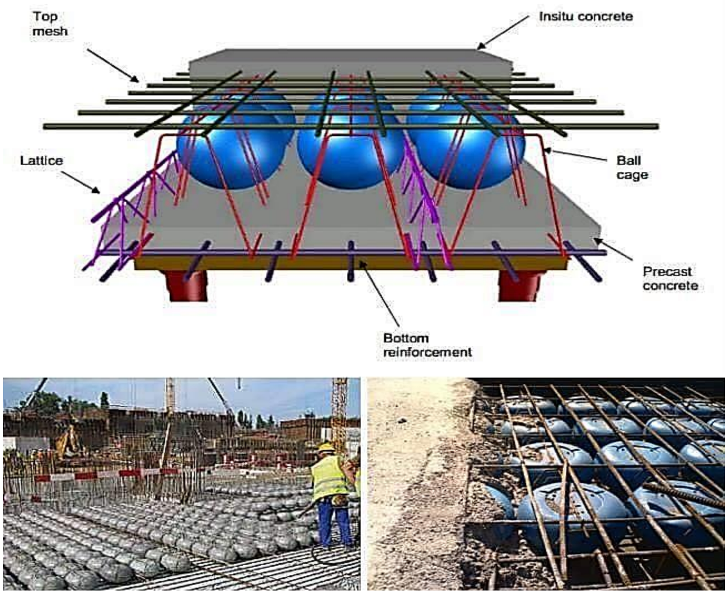


Fig. 3.5 Placing Cubiax balls on the slab and filling with concrete

For slab depths exceeding the maximum slab depth hd,max (ADB) up to the highest value, only the maximum slab depth and not the actual slab depth can be applied for the calculation of the shear resistance.

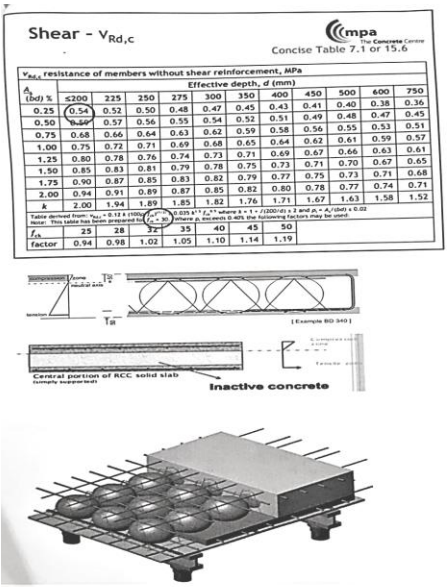
The calculation of the reduced shear resistance VRd,c,cubiax = fV · VRd,c can be performed quickly and easily using the fast and easy software tool Cubiax.

The construction elements with the shear reinforcement required for the calculation.

If a shear reinforcement is required, then the hollow flat slab, structurally designed and executed as a ribbed slab with shear reinforcement acc. DIN EN 1992- 1-1, 5.3.1 or the relevant international design regulations, must be verified.

Information on optimizing the proportion of the previous void area

In certain cases, it may be necessary to optimize the proportion of the previous void area in order to maintain the maximum possible load reduction. For this purpose, a "comb-like installation" can be executed in the transition areas from the previous void area to the solid area. By alternating the strips with the void formers and solid areas, a shear factor determined by the structural engineer can be applied.



Shear - $v_{Rd,c}$

Concise Table 7.1 or 15.6

$v_{Rd,c}$ resistance of members without shear reinforcement, MPa											
	Effective depth, d (mm)										
$\frac{A_s}{(bd)}$ %	≤200	225	250	275	300	350	400	450	500	600	750
0.25	0.54	0.52	0.50	0.48	0.47	0.45	0.43	0.41	0.40	0.38	0.36
0.50	0.59	0.57	0.56	0.55	0.54	0.52	0.51	0.49	0.48	0.47	0.45
0.75	0.68	0.66	0.64	0.63	0.62	0.59	0.58	0.56	0.55	0.53	0.51
1.00	0.75	0.72	0.71	0.69	0.68	0.65	0.64	0.62	0.61	0.59	0.57
1.25	0.80	0.78	0.76	0.74	0.73	0.71	0.69	0.67	0.66	0.63	0.61
1.50	0.85	0.83	0.81	0.79	0.78	0.75	0.73	0.71	0.70	0.67	0.65
1.75	0.90	0.87	0.85	0.83	0.82	0.79	0.77	0.75	0.73	0.71	0.68
2.00	0.94	0.91	0.89	0.87	0.85	0.82	0.80	0.78	0.77	0.74	0.71
k	2.00	1.94	1.89	1.85	1.82	1.76	1.71	1.67	1.63	1.58	1.52

Table derived from: $v_{Rd,c}$ = 0.12 k (100ρ f_{ck})$^{1/3}$ ≥ 0.035 $k^{1.5}$ $f_{ck}^{0.5}$ where k = 1 + √(200/d) ≤ 2 and ρ = A_s/(bd) ≤ 0.02
Note: This table has been prepared for f_{ck} = 30. Where ρ exceeds 0.40% the following factors may be used:

f_{ck}	25	28	32	35	40	45	50
factor	0.94	0.98	1.02	1.05	1.10	1.14	1.19

Fig .3.6 Tabela e rezistencës të topthave Cubiax në betonin e armuar

Concrete has many applications in building construction, but its use for horizontal slabs is limited by its relatively high self-weight which reduces the maximum span. The common method of correcting this disadvantage is to incorporate some type of reinforcement, which allows the concrete slab to be used for a wide range of spans and loading conditions. Traditional approaches to structural reinforcement involve inserting another material within the concrete, however, biaxial slabs offer an alternative solution in the form of a biaxial slab which incorporates orthogonal concrete "beams" within the slab. This allows for greater support in both horizontal directions in order to transfer the load to a vertical member.

The general concept of biaxial hollow slabs relies on voids created within the concrete at the time of casting-incorporation. This creates an internal array of hollow boxes in the slab, which act as a horizontal support grid for the flat surface at the top. Another advantage is the weight reduction, achieved by removing mass that does not directly transfer weight to a vertical member. Typical solid-monolithic slabs have a load capacity of about one-third of their own weight, which can create problems for long spans and high loads. By reducing the weight of the slab without compromising its structural strength, it is possible to create a thicker slab to support more weight over a longer span.

Hollow core slabs, also known as hollow core slabs, first appeared as single-sided elements in Europe during the 1950s and are still commonly manufactured in prefabricated form for applications where rapid construction and low deadweight are required. Waffle slabs are a common type of hollow core slab that uses the same principle as biaxial hollow core slabs. However, their voids are located at the bottom of the slab rather than embedded within the slab, leading to lower shear strength and fire resistance. There have been a number of applications of biaxial hollow slab products, including the use of polystyrene blocks as void filler. However, many applications have suffered from flexural cracking and lack of shear strength….

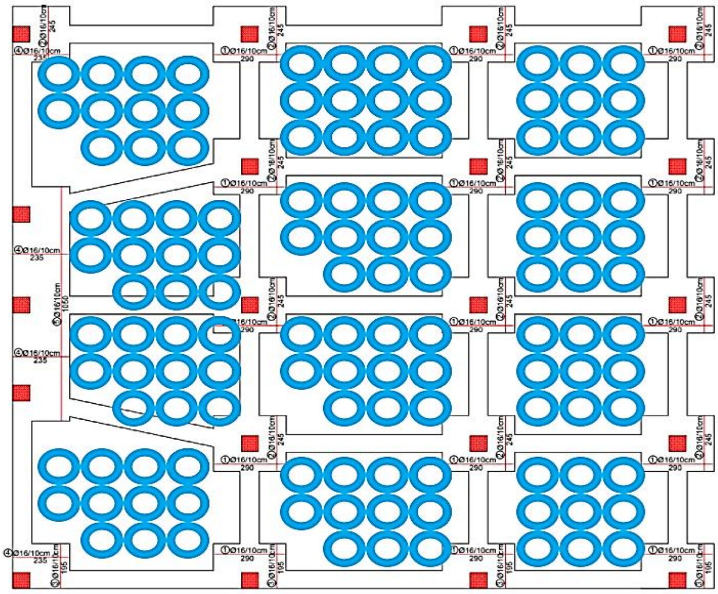


Fig .3.7 Topthat Cubiax në pllakën e themelit

Fig. 3.8 Cubiax balls on the Foundation plate in practice

Classic Slab – Difference Between Monolith And Cubiax Method

For the determination of the slab depth, national regulations for the limitation and minimum of deformation must be observed for slabs with small depths. The required slab depth can be calculated through appropriate deformation calculations. The same methodology applies to the Cubiax system. Considering the reduced stiffness and bending factor and load reductions according to the application data or the fast and easy software tool, normally up to 10%. Result of the thinner slab using the Cubiax application compared to a solid-monolithic slab. The diagrams that enable the rapid pre-design of the slab depth-thickness are described below. Systematic deformation calculations have been executed to create the diagrams, taking into account certain assumptions, different static systems, loads and deformation limits. The diagrams require a certain engineering interpretation for the transition to other boundary conditions and therefore do not replace any explicit calculations.
However, they are suitable and useful as an initial assessment.

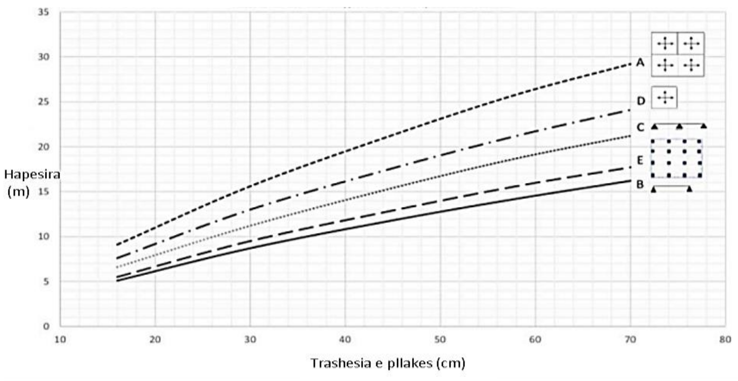


Fig.4.1 Diagrams for pre-design with Cubiax Balls on slabs

Execution variations and slab cross-sections

The determination of the slab cross-section and the selection of a suitable Cubiax module can be carried out more quickly and easily using the fast and easy Cubiax software tool.

Standard execution

The selection of a suitable Cubiax module occurs by determining the possible support height hu. This depends on the required concrete cover, the thickness of the reinforcement layers, and if required, other intermediate layers (e.g. for additional spacers or installation levels).

Companies are working on ways to optimize the concrete structure remaining outside the void formers. The aim of the previous void-forming technology (Cubiax system) was to manage without any additional reinforcement; Cubiax also conducted research that focused on creating the most ideal possible X-Zone. The solution was to move away from rectangular void formers and develop spherical or ellipsoidal void formers, which formed a concrete structure with webs that expanded up and down so as not to require additional reinforcement.

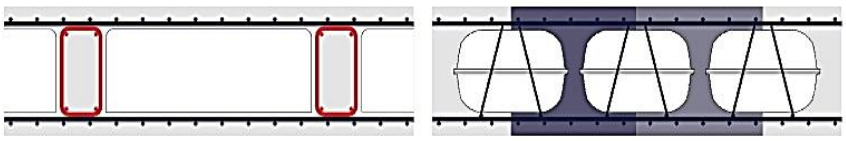


Fig.4.2 The difference between a regular plate and Cubiax

Over the decades, Cubiax has continued to optimize the shape of the structural formers to achieve the ideal shape of the concrete between the modules in terms of structural engineering. It is this X-shaped concrete structure that provides the unique stability and safety of Cubiax hollow core slabs. No other previous hollow core element that does not have any additional reinforcement achieves such an optimized X-area as the Cubiax systems.

All other optimizations in the product lines, such as the two-part design or the elements that ensure assembly, are additions that have no effect on stability or weight reduction, but mainly offer economic benefits or make their assembly easier.

This means that the previous Cubiax systems are the only products on the market that combine the best possible load-bearing capacity with maximum resource saving and particularly economical assembly.

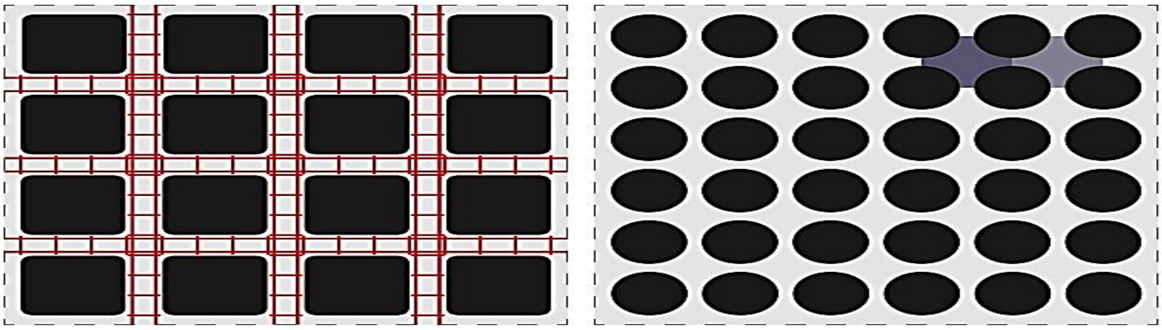


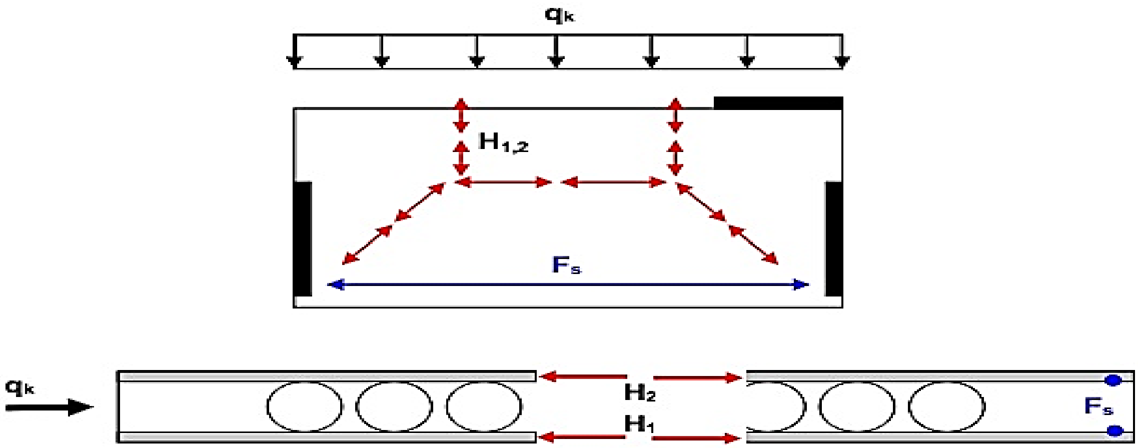
Fig. 4.3 Different shapes in the regular and Cubiax slab

The monolithic concrete system, on the other hand, is a mixture of coarse and fine aggregates (generally sand or crushed stone) with a binding material (usually Portland cement) and water with a combination of reinforcement. When cement is mixed with a small amount of water, it hydrates to form microscopic, opaque crystalline lattices that encapsulate and lock the aggregate into a rigid structure. The aggregates used to make concrete must be free of harmful substances such as organic impurities, silt, clay, lignite, etc. Typical concrete mixtures have high compressive strength (about 4,000 psi (28 MPa)) and fire resistance; however, any significant stress (e.g., due to bending) will break the rigid microscopic lattice, resulting in cracking and spalling of the concrete. For this reason, typical unreinforced concrete must be well supported to prevent the development of cracks.

If a material with high tensile strength, such as steel, is placed in concrete, then the composite material, reinforced concrete, resists not only compression but also bending and other direct tensile actions. A composite section where the concrete resists compression and the reinforcement resists tension can be made in almost any shape and size for the construction industry.

Fig. 4.4 Conventional method – monolithic system, Reinforced Concrete

The Cubiax hollow core slab allows the panel forces to be transferred. In the case of a section analysis, only the sum of the lower and upper slab levels (net cross section) is applied. It should be noted during the design that the forces to be transferred can be clearly conveyed. If necessary, additional stiffeners can be developed in the design for greater transmission of concentrated slab forces or planned tensile and compressive forces.



Cost Comparison

Due to the reduced permanent weight, Cubiax hollow core slabs can be executed with common traffic loads and with the same deformation up to approx. 5 to 10% thinner than conventional reinforced concrete slabs.

Such a cost comparison under certain assumptions (varies depending on market prices for concrete, reinforcement costs) for all relevant slab depths is shown in the examples in the diagram below.

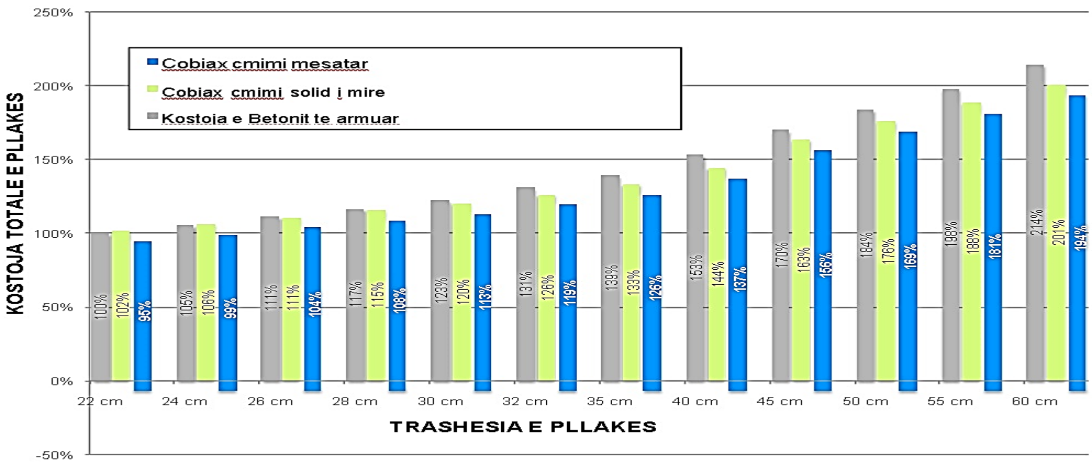


Fig. 5.1 Slab thickness / Total slab cost / REINFORCED/CUBIAX concrete slab

Conclusion

The main goal of this Cubiax system is to reduce the self-weight of concrete, where as we know the self-weight is also the main enemy and the biggest disadvantage of this material. This has been the motive that has encouraged and developed this technology, namely the reduction of the self-weight of concrete. Today this technology is so widespread that it is spread all over the world and about 14 million square meters of buildings have been built. Where in addition to saving in the amount of concrete in the world, 180,000 tons of CO_2 have also been saved without being released into the atmosphere.

The advantages of the Cubiax system over other classic reinforced concrete slab systems is that through this system we manage to save up to 30% of the amount of concrete.
Cubiax technology not only saves valuable construction material, but also offers a variety of static advantages: Cubiax lightweight slabs allow for larger spans with the same weight as conventional concrete slabs, making execution easier since there is no formwork.
Cubiax lightweight slabs are built to meet the highest international standards. As a result of the reduced weight of the slabs, the risk of sudden loads is low (e.g. during earthquakes, since the reduction in self-weight also reduces seismic forces on the floors).
In our case, if we were to use ordinary concrete slabs for reinforcement, the amount of concrete would be around 600 m3, but if the cubiax system is used, the amount of concrete would be 420 m3, which would mean that we would save around 180 m3 of concrete, we would also save 1.20 m from the total height of the floors, we would save around 1400 tons of CO_2 without being released into the atmosphere, and we would reduce the amount of plastic from the environment since it is known that the entire plastic material from Cubiax is recycled plastic.
Since this system is realized in the form of flat slabs without frames, this system allows us to benefit in height, for example, if on each floor we save 30 cm from the lower height of the frames, then for a 10-story building we benefit from a full floor.
The use of plastic material replaces at least 25-30% of the concrete used in traditional construction. It reduces the CO_2 footprint during production, the amount of aggregate, water, cement and energy required are also reduced. Cubiax balls are made of 100% recycled plastic; the construction is stable for decades and centuries.

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