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# Replacement Of A Monolith Reinforced Concrete Slab With A Lightweight Cobiax System Construction

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**Abstract.** The purpose of this system is the application of lightweight slabs in mid-floor construction. In the case of a conceptual hotel design, which currently is predicted to be built in a classical mid floor reinforced construction, the practice of COBIAX lightweight construction without beams will highlight the advantages of this system. The system uses circular or oval hollow spheres, which are placed in the slab. This results in the creation of a lightweight slab, due to the reduction of mass, also a considerable reduction of columns, avoiding beams, reduction of the foundation plate thickness, decrease in floor height, etc. In this case, the architects will have the opportunity to design large and spatial structures, where the distance between the columns can reach up to 20 m. Reducing the amount of concrete of lightweight slabs in the COBIAX system, affects directly the reduction of CO<sub>2</sub>(carbon dioxide) emission. Based on studies made by a German research organization, each m<sup>3</sup> of concrete replaced with COBIAX, reduces approximately 210 kg of CO<sub>2</sub> emission, which makes COBIAX method an ideal system for eco designers. 1. Hollow spheres are placed in neutral axis where concrete has less shear or compression forces, reducing the volume of concrete. 2. Reducing of the concrete mass that is under tension force up to 35 %, has a positive impact in the whole structure which enables saving building material. The Slab thickness varies from 240 mm to 600 mm. While most standard slabs, transmit stress forces in two or one direction, lightweight COBIAX slab system distributes the stress forces in several direction. COBIAX slab needs up to 40% less load bearing columns, which offers architects better flexible opportunities in design.

**Key words:** stability, flexibility, economic cost, ecology, feasibility.

## 1 Introduction

Cobiax system has been applied in numerous structures in Europe, validating the acceptance of this system in Europe. This system of construction in our country (Kosovo) for the first time began to be applied in 2011/2012 in to a building called "World Trade Center" WTC-Pristina. It was used in a specific building: in the Commercial Center, while the rest of surrounding buildings such as: housing and administration are being built in classical system (slabs of reinforced concrete). To elaborate the advantages of this system we took a case study-a conceptual design of a hotel which is supposed to be built in the center of Pristina. This project was intended to be built in a classical system and the classical construction was replaced with Cobiax system. Various attempts were made in the past in order to reduce the weight of concrete slabs without reducing the flexural strength of the slab. Reducing the own weight in this way would reduce deflections and make larger span lengths achievable. Idea- \*The essence of structural design is the appropriate usage of material. Unnecessary weight is created by materials that are not significantly contributing to a structure's stability.\* A bird can fly because its bones are made of a hard shell with struts placed inside. The bone's weight is optimized and at the same time the bone is stable. Cobiax slabs differ in three ways from traditional solid flat plate slabs ;  
\*Reduce dead load due to the concrete displacement of the void formers. The bending moments and column reactions are reduced consequently  
\*Reduced stiffness of the slab due to the presence of the void formers. The deflection of the slab is influenced consequently.

\*Reduced shear capacity of the slab due to the presence of the void formers. This requires the identification of the slab areas with too high shear in which the void formers mustn't be placed.



The Cobiax slab is dimensioned with the methods used for traditional flat slabs and compatible with any concrete design code.

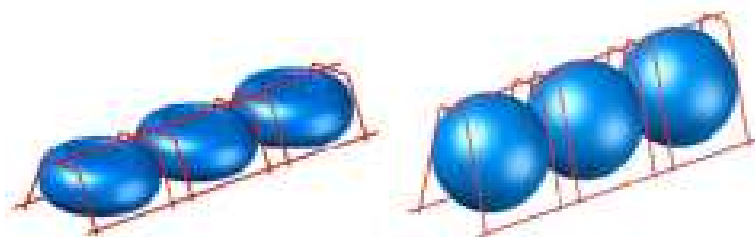


**Fig 1** The appearance of cobiax slab surface and the solid area.

*Source: Personal photo courtesy*

### 1.1. Typology of Products

There are two types of Cobiax cage modules, the “Slim- Line” and “Echo- line”;



#### **Slim Line**

\* Void former height 100 to 220 mm

\*Slab depths 20 to 35 (+) cm

#### **Echo- Line**

\*Void former height 225 to 450 mm

\*Slab depths 35 to 60 (+) cm

Void formers, positioned between the bottom and top reinforcement layers - displaced concrete. They are used when the distance between the columns is large ie., when we have strain in which case concrete works more in pressure (98%) and less in traction. (cobiax Engineering; 2010).

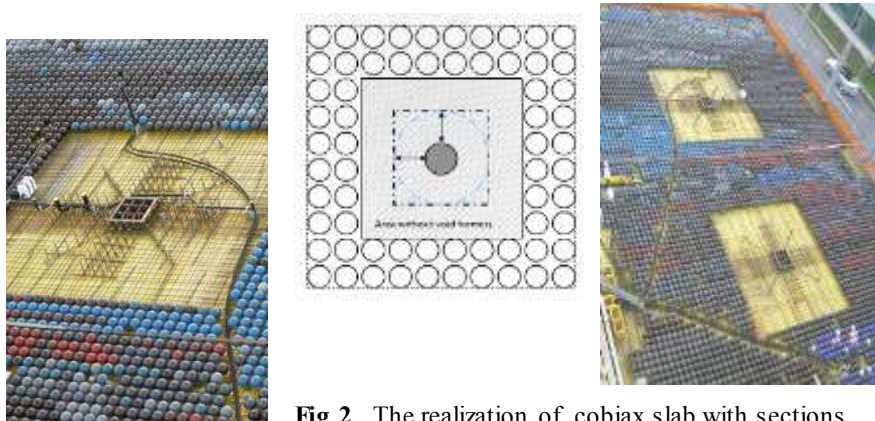
It should be mentioned some points regarding this system;

a) Bending – The bending strength of Cobiax slabs was investigated in laboratory tests using various slab depths and void former sizes. The bending behaviour has been proved to be comparable with the one of solid slabs.

b) Stiffness – The void formers in Cobiax slab reduce its stiffness compared with solid flat slabs.

c) Shear – According to current standards, calculation of the shear strength for traditional one – way spanning hollow core slabs is based on the smallest available web width of a hollow cross section. With such criteria used for two-way spanning voided slabs, the resulting shear strength for Cobiax flat slab would only be about 10 % of the shear strength of a solid flat slab with same thickness.

d) Punching – Due to shear force limitations areas with high shear force concentration such as around columns heads are to be executed without Cobiaxcage modules. The critical perimeters that are relevant for the punching shear design are located within these solid areas. The punching shear considerations in these areas are therefore as for solid flat slabs. It is recommended to explicitly verify that the determining perimeter for punching is located inside the solid zone as shown on below drawing. Should this not be the case, the solid zone has to be increased accordingly. The reduced dead weight of the Cobiax flat slab decreases the column reactions and allows optimizing the necessary amount of punching reinforcement.



**Fig 2** The realization of cobiax slab with sections

Source: *Engineering Manual - Cobiax*

e) Fire protection – Fire tests in specialized laboratories with Cobiax slab specimens have shown that above parameter and criteria can be applied with no limitation to Cobiax flat slabs and that they can withstand fire in the same way as solid flat slabs. The current fire rating of Cobiax slabs stands for 180 minutes issued by the German Authorities (report P-SAC 02/III – 187 done by MFPA)

f) Acoustic Insulation – Acoustic Insulation tests were conducted on Cobiax slabs with specimens in specialized laboratories as well as in completed buildings. The aim was to evaluate the acoustic insulation capacities of Cobiax slabs compared to solid flat slabs and to define an appropriate acoustic insulation rating method. Interpretation of these acoustic insulation measurements show that for a Cobiax slab the same acoustic insulation evaluation methods can be used as per solid flat slab.

g) Various technical issues – Compared to a solid slab of same thickness, Cobiax slab has an improved vibration performance. Cobiax flat slabs have higher natural frequencies for common practice live loads compared to solid slabs due to their reduced dead load.

## 1.2. Execution

Cobiax slab can be executed in traditional in-situ concrete or in combination with semi-precast elements.

### In-situ concrete

Application of concrete slabs in site, is done through placements of void forms in between lower and upper steel reinforcement. First are placed 1.frames, 2. distance holders 3. reinforcement nets, 4.void formers, 5.concreting



**Fig 3** Realization of the slab in workplace

Source: Personal photo courtesy

1.cables for strain

1.frames, 2. distance holders,

3.reinforcement , 4.void forms,

5.reinforcement

### Combination with semi-precasted elements

In this case void forms are placed in factory in a prefabricated slab and together are brought instantly into a construction site. In both cases void forms are placed in between lower and upper steel reinforcement.



**Fig 4** Application of prefabricated slabs in site

Source: Cobiax Technologies

The advantage of this system is noted on the possibility of establishing installations on mid-floor slab construction, in which case we can remove any sphere without causing any constructive problem.

It is notably a suitable system for seismic countries. Concentrated masses are reduced without losing construction stiffness, and loads in foundations are reduced significantly by 15 %



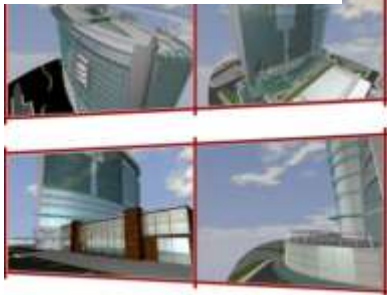
**Fig 5** Installation within a slab construction

*Source: Personal photo courtesy*



## 2 Methodology

### 2.1. Case Studies



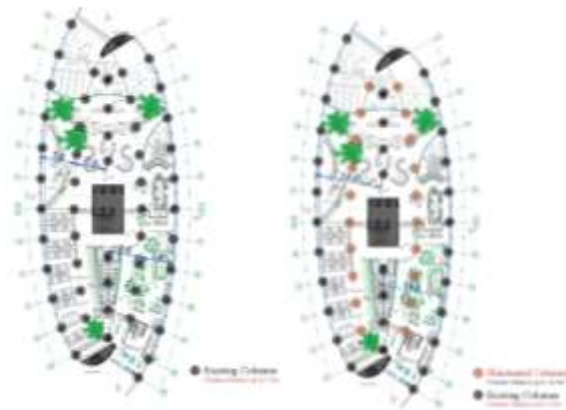
**Fig 6** Several views of the building

**Fig 7** Location

of the building in site

*Source: ©Ertan Sylejmani*

As a case study a conceptual hotel design was chosen. This building has 3 floors underground, a ground floor and 16 floors with a total height varying from 46,5 to 50,2 meters. This building is designed in a location chosen at the very center of the city of Prishtina known as Center 1. The reason why we have chosen this building as a case study is because during the design phase, the interior columns could create functional problems. These types of columns were not possible to be eliminated since the building was intended to be built by using a classical construction system. However, the application of void forms has enabled us to eliminate a considerable number of columns, the elimination of launching beams all in all, as well as reducing the floor-floor height.



**Fig 8** Typical floor layout

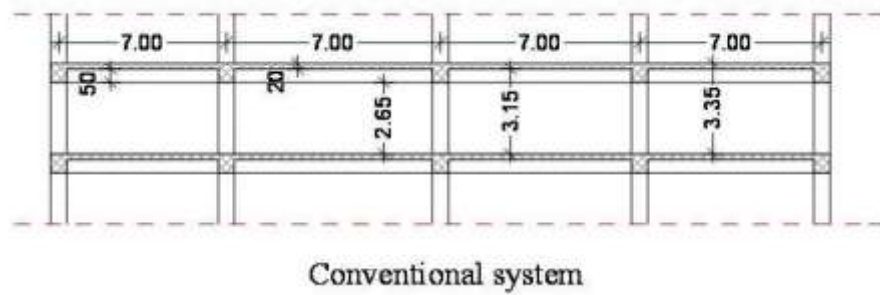


**Fig 9** A view of building construction

*Source: ©Ertan Sylejmani*

## **2.2. Comparisons**

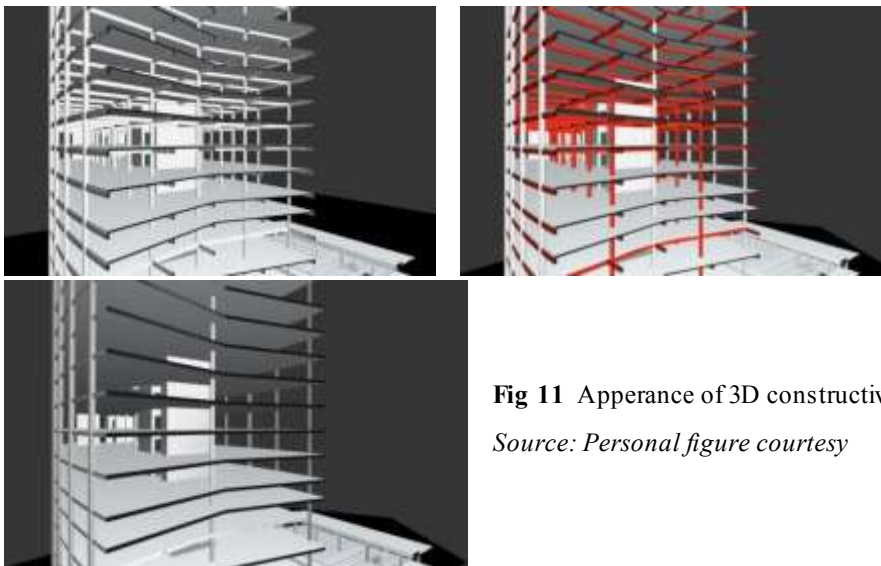
Knowing that with the application of void forms, the distance between the columns can go up to 20 m, we have decided to eliminate the selected columns highlighted in colour red, to achieve higher commodity and functionality.



**Fig 10** Plan-comparison before and after

Source: ©Ertan Sylejmani

- a) Existing layout- where the distance between the columns was 7m
- b) Layout with columns that will be eliminated, where the distance between the columns will be 14m

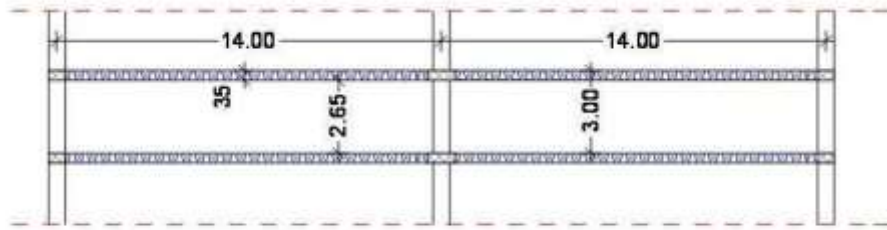


**Fig 11** Apperance of 3D constructive system

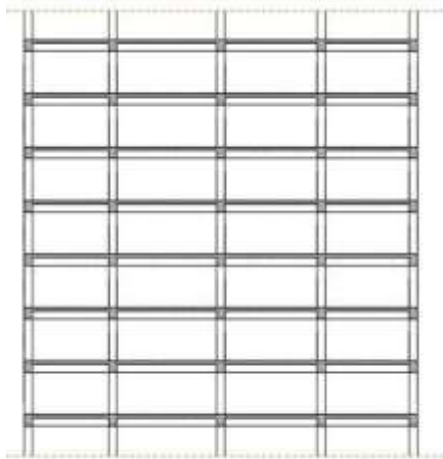
Source: Personal figure courtesy

By replacing a solid slab with an agile type of slab (cobiax) as shown in the Figure nr. 12 results: in the elimination of the columns by producing new neat spaces and by eliminating launching beams floor-floor height is reduced. In an architectural aspect , it facilitates architects with great opportunities in floor flexibility and the execution of the building is easier.

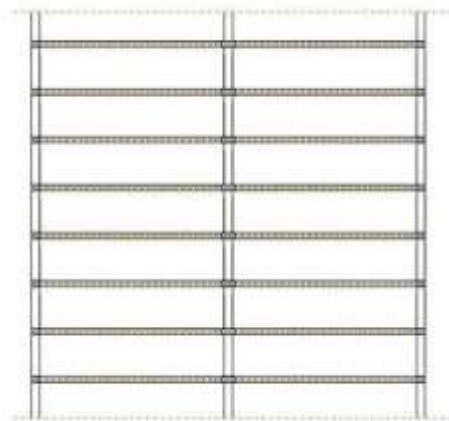




Optimized with Void formers



Conventional system

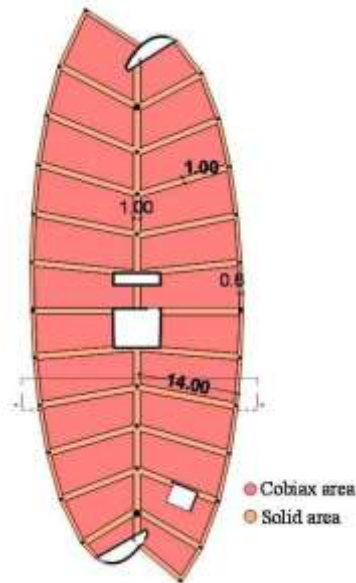


Optimized with Void formers

**Fig 12** Apperance in section of the object

*Source: Personal figure courtesy*

### 2.3. Calculations



**Fig 13** Layout where the surface from reinforced concrete is seen and the extension of void formers

Source: Personal photo courtesy

In the conceptual design the entire surface of slabs is with reinforced concrete with a 20cm height.

$$\begin{aligned}
 S &= a \times b \dots && (m^2) \\
 V_{\text{slab}} &= S_s \times h_s \dots && (m^3) \\
 V_{\text{columns}} &= S_c \times h_c \dots && (m^3) \\
 V_{\text{issued beams}} &= S_{ib} \times h_{ib} \dots && (m^3) \\
 V_{\text{foundation}} &= S_f \times h_f = \dots && (m^3) \\
 V_{\text{total}} &= V_s + V_c + V_{ib} + V_f = \dots && (m^3)
 \end{aligned}$$

For our project we have chosen the following; Void former height – 220 mm  
 Void former horizontal diameter – 315 mm, and slab thickness from 350 mm, when dead load reduction per m<sup>2</sup> is 2.80 kN/m<sup>2</sup>, concrete displacement per m<sup>2</sup> is 0.112 m<sup>3</sup>  
 Number of void formers per m<sup>2</sup> is 8.16  
 Width of the hidden beams is acquired 100 cm, the inner and the perimetric 60 cm (according to calculations), there are times when it is realized with sector as shown in Figure 2

$$\begin{aligned}
 V_{\text{slab(cobiax)}} &= S_s \times h_s \times 0.888 \dots (m^3) \\
 V_{\text{hidden beams}} &= S_{hb} \times h_{hb} \dots (m^3) \\
 V_{\text{columns}} &= S_c + h_c \dots (m^3) \\
 V_{\text{foundation}} &= S_f \times h_f = \dots (m^3) \\
 V_{\text{total}} &= V_s + V_{hb} + V_c + V_f = \dots (m^3)
 \end{aligned}$$

0.888 – amount of concrete slab of mid-floor

0.112 – amount of cobiax spheres

**Table 1** - Main parameter of Cobiax cage modules

Slab depth	[mm]	200	225	250	275	300	325	350	400	450	500	550	600
		↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Recommended Cobiax cage module type	[-]	CBCM-S-100	CBCM-S-120	CBCM-S-140	CBCM-S-160	CBCM-S-180	CBCM-S-200	CBCM-S-220	CBCM-E-270	CBCM-E-315	CBCM-E-360	CBCM-E-405	CBCM-E-450
Dead load reduction* per m <sup>3</sup>	[kN/m <sup>3</sup> ]	-1.40	-1.64	-1.88	-2.10	-2.32	-2.56	-2.80	-2.86	-3.34	-3.82	-4.29	-4.77
Stiffness correction factor	[-]	0.92	0.92	0.92	0.92	0.91	0.91	0.91	0.92	0.91	0.90	0.90	0.89
Shear reduction factor	[-]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.55	0.55	0.55	0.55	0.55
Cage module support height	[mm]	110	130	150	170	190	210	230	275	320	366	411	457
Void former height	[mm]	100	120	140	160	180	200	220	270	315	360	405	450
Void former horizontal diameter	[mm]	315	315	315	315	315	315	315	270	315	360	405	450
Spacing between void formers	[mm]	35	35	35	35	35	35	35	30	35	40	45	50
Void former centre line spacing	[mm]	350	350	350	350	350	350	350	300	350	400	450	500
Number of void formers per m <sup>2</sup>	[-]	8.16	8.16	8.16	8.16	8.16	8.16	8.16	11.11	8.16	6.25	4.94	4.00
Concrete displacement per m <sup>3</sup>	[m <sup>3</sup> /m <sup>3</sup> ]	0.056	0.066	0.075	0.084	0.093	0.102	0.112	0.114	0.134	0.153	0.172	0.191
Void formers per cage module**	[-]	7	7	7	7	7	7	7	8	7	6	5	5
Equivalent area per cage module	[m <sup>2</sup> ]	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.72	0.86	0.96	1.01	1.25

Source: (Engineering Manual Issue 2010)

### 3 Results and Discussion

Slab surface is;  $S=2\ 073.13\ m^2$

$h_s=20\ cm$

$V_{slab.} = 2\ 073.13 \times 0.2 = 414.62\ m^3$

$V_{columns} = 41.11\ m^3$

$V_{issude\ beams} = 84\ m^3$

$V_{foundation} = 3\ 768.83\ m^3\ hf = 1.6\ m$

$V_{p,sh,t} = 539.62\ m^3 \times 18\ floors = 9\ 713.16\ m^3$

$V_{total} = 13\ 481.99\ m^3\ concrete$

Concrete is selected with C25/30 class

Solid area;  $S = 424.94\ m^2$

Cobiax area;  $S=1648.19\ m^2$

$h_p=35\ cm$

$V_{slab} = 1648.19 \times 0.35 = 576.86 \times 0.888(\text{void formers}) = 512.25\ m^3$

$V_{hidden\ beams} = 424.94 \times 0.35 = 148.72\ m^3$

$V_{columns} = 21.79\ m^3$

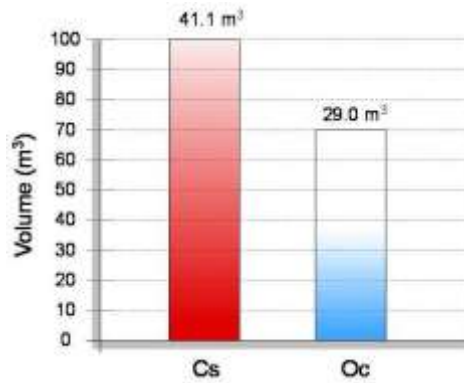
$V_{foundation} = 2\ 753.4\ m^3\ hf = 1.2\ m$

$V_{s,c,b} = 689.72\ m^3 \times 18\ floors = 12\ 289.68\ m^3$

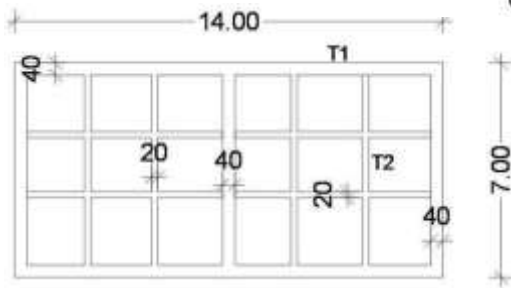
$V_{total} = 15\ 043.08\ m^3\ concrete$

Concrete is selected with C40/50 class, which affects the reduction of cross-cutting elements and contributes to a greater construction life length.

Static spaces  $l_x 14$  and  $l_y 7$  formers could be realized but this is more difficult to height would go to 1.4 and this floor-floor height impose us suspended column dimensions from slab height will be 10 cm, height would rise to hf. 160 hf. 120 cm.



m beside by using void also with ribbed system, be realized. The beam 1.0 m and as a result of would rise and would ceiling, it would increase 30 x 60, to 40 x 80 cm, while the foundation cm, while previously was



Beam 1- 40 – 140 cm

Beam 2 - 20 – 100 cm

$$2073.13 : 98 = 21.15$$

$$V_{\text{issued beam}} = 35.27 \times 21.15$$

$$V_{\text{slab}} = 207.313 \text{ m}^3$$

$$V_{\text{columns}} = 36.64 \text{ m}^3$$

$$V_{\text{issued beams}} = 745.96 \text{ m}^3$$

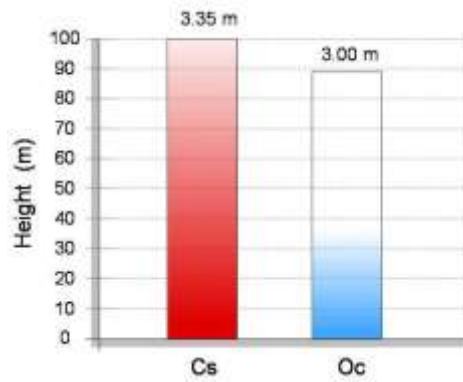
**Fig 14** The amount

*Source: Personal*

**Cs** - conventional

**Oc** - optimized with

In the conceptual  
columns was initially  
forms has reduced it  
number of columns



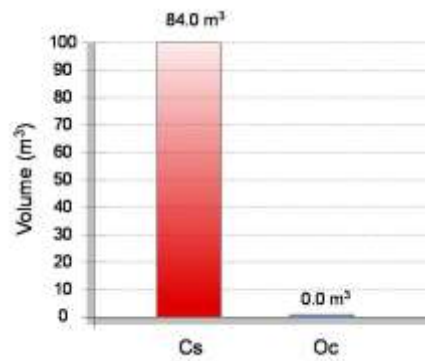
of concrete in slabs

*figure courtesy*

system

Cobiax

design the number of the  
52, in which case the use of void  
to 32, that means that the  
is reduced by 40%



**Fig 15** The amount of concrete in launching beams

*Source: Personal figure courtesy*

**Cs** - conventional system

**Oc** - optimized with Cobiax

By the diagram we notice that we don't have beams

**Fig 16** Comparison of floor height with two chosen construction system

*Source: Personal figure courtesy*

**Cs** - conventional system

**Oc** - optimized with Cobiax

The height of the building will be reduce by 11%

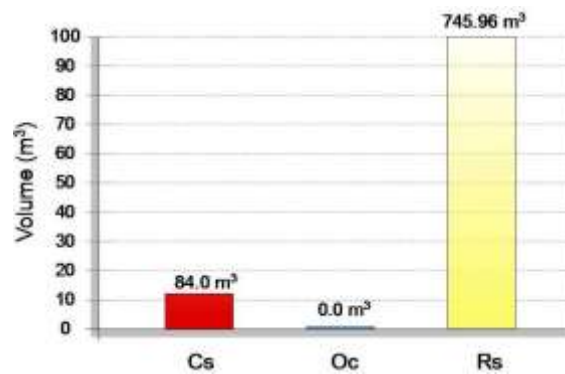
**Fig 17** Concrete construction

*Source: Personal*

**Cs** - conventional

**Oc** - optimized

**Rs**- ribbed system

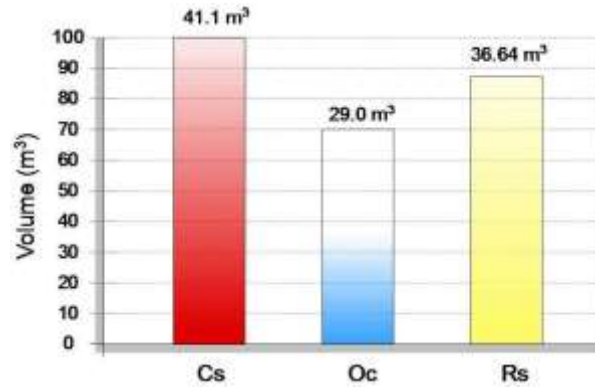


volume amount in three systems

*figure courtesy*

system

with Cobiax



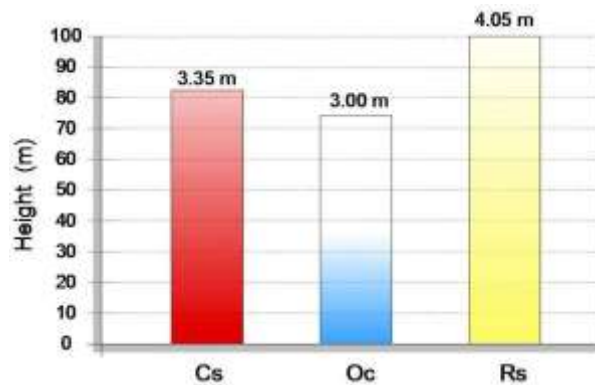
**Fig 18** Diagram of issued beams -concrete amount

Source: Personal figure courtesy

Cs - conventional system

Oc - optimized with Cobiax

Rs- ribbed system



**Fig 19** Overview of floor height in three construction systems

Source: Personal figure courtesy

Cs - conventional system

Oc - optimized with Cobiax

Rs- ribbed system

## 4 Conclusions

From these tests we can conclude that the application of void forms enables distances between columns up to 20 meters and by this we achieve 40% reduction of original planned columns with classical system of construction. It should be noted that these void spheres are manufactured using recycled materials. It contributes also in a shorter period of implementation, reduces cross-cuttings of vertical elements, achieving lower floor heights. By achieving lower floor heights, suspended ceilings are not required

resulting in lower foundation height as well. It contributes also in achieving a more affordable building costs, by reducing cubic meter volume of concrete from the local price of 200 euros to 130 euros.

In designing inner spaces, gypsum card boards could be applied, and they play a feasible role.

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