Performance evaluation of the effectiveness of the use of core drivers in the construction of base plates

D Yu Chunyuk and S M Selviyan
Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

Abstract. This article is an example of the calculation of a foundation monolithic slab using void formers during the construction of an apartment complex consisting of three buildings located on one stylobation. In this example, we consider several options for calculating multi-hollow foundation slabs in order to determine the most cost-effective design. At the same time, a multi-hollow foundation slab should have the same rigidity and load-bearing capacity as usual.

1. Introduction

Currently, slab foundations are widely used in construction, since they allow reducing the load on the soil and are less time-consuming compared to other types of foundations. But a significant drawback of this foundation is the large consumption of materials and "excess" concrete in the neutral zone of the structure. Therefore, the main task in the design of foundation slabs is the ability to reduce the volume of concrete and reinforcement as much as possible, while ensuring sufficient structural rigidity and its bearing capacity.

One of the ways to solve this problem may be to exclude concrete and reinforcement structures from the neutral zone by including void formers. The dimensions and geometry of the void formers are selected based on the dimensions of the slab, its thickness and technological and structural requirements. A void formers can be made of the following materials: plastic, foam plastic, cardboard, plywood, foam concrete.

The shape of the holders is varied: oval or round cylinders, spherical and ellipsoidal, as well as prismatic.

This work is aimed at analyzing the optimal cross-section of structures, the location and size of pore former in the fundamental slab in order to achieve material consumption.

2. Description of the complex

The apartment complex consists of 3 high-rise buildings located on the common stylobate, which has two underground levels.

Complex dimensions: 74.3 x 171.2 m
The dimensions of the buildings: building 1 - 23.2 x 51.3 m, building 2 - 23.2 x 59.4 m, building 3 - 23.2 x 49.8 m.

Number of floors in each building: lower mark 0.000 - 3 floors, above ground - 34 floors and 1 technical floor.

The height of the buildings of the complex with the inclusion of the upper technical floors is 105.9 m.

2.1. Engineering-geological conditions of the pad

The geology of the field is represented by the following sediments: topsoil, modern modern floodplain alluvial deposits, Upper Quaternary deposits of the floodplain terraces of the Moscow River and Upper Jurassic rocks.

Modern floodplain alluvial deposits are mainly represented by small and medium sized sands, less often coarse and gravelly. The settlement thickness is 1.3–22.7 m.

The Upper Quaternary deposits of the floodplain terrace are represented mainly by sands from dusty to medium size of medium density and dense, moist and saturated with water. Settlement thickness from 1.4 to 24.9 m

The deposits of the Jurassic system underlying the Quaternary stratum are represented mainly by loams and clays of a refractory and semi-solid consistency. The thickness of the layer ranges from 0.25 to 16.8 m.

The main mechanical characteristics according to triaxial tests lie within the following limits:

Modern alluvial floodplain deposits:
E = 29-36 MPa; \( \varphi = 35-39 \, ^\circ \); C = 1-2 kPa; \( \nu = 0.3 \); \( \gamma = 1.5 - 1.77 \, g / cm^3 \)

Upper Quaternary alluvial deposits:
E = 25-40 MPa; \( \varphi = 31-38 \, ^\circ \); C = 1-3 kPa; \( \nu = 0.29 \); \( \gamma = 1.88 \, g / cm^3 \)

Deposits of the Jurassic system:
E = 16-25 MPa; \( \varphi = 35-39 \, ^\circ \); C = 1-2 kPa; \( \nu = 0.33 \); \( \gamma = 2.71 \, g / cm^3 \)

2.2. Features of constructive solutions

Load carrying structure - monolithic reinforced concrete braced frame, consisting of load-bearing walls, pylons and flat floor slabs.

The foundation is monolithic slabs with a thickness of 1 to 1.5 m.

Interfloor overlappings - monolithic 220, 300 mm thick.

The stylobate cover plates are flat with capitals 350 mm thick. The size of capitals in the plan is 3.0 x 3.0 m.

The outer walls of the basement are monolithic reinforced concrete 300 mm thick.

Bearing frame material:
- concrete of strength class B35, waterproof W6, frost resistance F 50.
- fittings of class A500S (GOST R 52544 - 2006) and A240 (GOST 5781 - 82).
We considered 4 variations for the foundation slab, 3 of which were designed using hollow formers of various sizes. The following dimensions of liners and slab structures were used.

**Table 1.** Characteristics of hollow core slab

| №  | Slab element          | Dimensions     |
|----|-----------------------|----------------|
| 1  | Slab thickness        | 1000 mm        |
| 2  | Height of voids       | 500 mm         |
|    | Void length           | 7200 mm        |
|    | Void width            | 7200 mm        |
|    | Thickness of top flange | 250 mm        |
|    | Thickness of bottom flange | 250 mm    |
|    | Thickness of the wall between voids | 1200 mm |
| 3  | Height of voids       | 500 mm         |
|    | Void length           | 3300 mm        |
|    | Void width            | 3300 mm        |
|    | Thickness of top flange | 250 mm        |
|    | Thickness of bottom flange | 250 mm    |
|    | Thickness of the wall between voids on the main axes | 1200 mm |
|    | between the main axes | 600 mm        |
| 4  | Height of voids       | 500 mm         |
|    | Void length           | 1350 mm        |
|    | Void width            | 1350 mm        |
|    | Thickness of top flange | 250 mm        |
|    | Thickness of bottom flange | 250 mm    |
|    | Thickness of the wall between voids on the main axes | 1200 mm |
|    | between the main axes | 600 mm        |
3. Calculation

The calculation of 4 variations for the foundation slab was carried out in the SCAD Office computing complex (version 21.1). Bed ratios were determined in the CROSS program. To do this, in this program, the base soils were set and the calculation scheme from SCAD ++ was imported. Further, in the CROSS program, a calculation was made and coefficient of soil reaction for each finite element were determined. Then these coefficients were imported into SCAD ++ and the whole scheme was calculated.

The slab itself, the pylons and walls of the stylobation of the lower floor were modeled, and the load from the entire building was already assigned to them.

The main task was to compare the precipitation, plot of moments and the percentage of reinforcement in the two options for the design of plates.

3.1. The calculation of the monolithic slab. Variation 1

![Figure 2. Calculation scheme](image1)

![Figure 3. Plots of displacement along the Z axis](image2)

![Figure 4. Plot of Moments Mx](image3)

![Figure 5. Plot of moments My](image4)
3.2. Calculation of hollow-core foundation slab. Variation 2

Figure 6. Calculation scheme

Figure 7. Plot of Z Movements

Figure 8. Plot of Moments Mx

Figure 9. Plot of Moments My

3.3. Calculation of hollow-core foundation slab. Variation 3

Figure 10. Calculation scheme

Figure 11. Plot of Z Movements
Figure 12. Plot of Moments Mx

Figure 13. Plot of Moments My

3.4. Calculation of hollow-core foundation slab. Variation 4

Figure 14. Calculation scheme

Figure 15. Plot of Z Movements

Figure 16. Plot of Moments Mx

Figure 17. Plot of Moments My

The results of calculations are shown in table 2.
Table 2. Results of calculations

| Characteristics          | Monolithic slab Variation 1 | Hollow-core monolithic slab. Variation 2 | Hollow-core monolithic slab. Variation 3 | Hollow-core monolithic slab. Variation 4 |
|--------------------------|----------------------------|------------------------------------------|------------------------------------------|------------------------------------------|
| Z-axe motion             | Max – 69.62 mm Min – 54.08 mm | Max – 137.34 mm Min – 38.18 mm | Max – 109.03 mm Min – 68.12 mm | Max – 109.08 mm Min – 71.97 mm |
| Epure Mx                 | Max – 150.39 T*m/m Min – 156.22 T*m/m | Max – 165.37 T*m/m Min – 174.04 T*m/m | Max – 131.3 T*m/m Min – 129.65 T*m/m | Max – 130.59 T*m/m Min – 129.17 T*m/m |
| Epure My                 | Max – 158.18 T*m/m Min – 116.55 T*m/m | Max – 78.31 T*m/m Min – 70.84 T*m/m | Max – 146.08 T*m/m Min – 151.25 T*m/m | Max – 112.35 T*m/m Min – 119.77 T*m/m |
| Concrete volume          | 3499 m$^3$                  | 2307 m$^3$                              | 2497 m$^3$                              | 2828 m$^3$                              |
| Reinforcement percentage | 0.866 %                     | 1.12 %                                  | 0.97 %                                  | 0.81 %                                  |
| Rebar Weight             | 238 t                       | 308 t                                   | 265 t                                   | 223 t                                   |

4. Conclusion

In this work, we performed a comparative analysis of the location of the hollow formers in the foundation slab. A calculation was made of 4 variations for the foundation slab with a change in the number of void formers:

Variation 1 - a monolithic slab 1 m thick. There are no hollow formers.

Variation 2 - a monolithic slab with a total section height of 1 m. Void formers with dimensions of 7200x7200x500 mm are located one at a time between the axes of the columns. The total number of void formers is 46 pcs.

Variation 3 - a monolithic slab with a total cross-sectional height of 1 m. Void formers with dimensions of 3300x3300x500 mm are located in four pieces between the axes of the columns. The total number of hollow formers - 184 pcs.

Variation 4 - a monolithic slab with a total cross-sectional height of 1 m. Void formers with dimensions of 1350x1350x500 mm are located in 16 pieces between the axes of the columns. The total number of void formers is 736 pcs.

After analyzing the above options, we concluded that the most optimal is a foundation plate with hollow core formers with dimensions of 1350x1350x500 mm (Variation 4). In this case concrete savings were 19.2%, reinforcement- 6.3%. When calculating the cost indicators, the savings will be 14.4%.

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