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TECHNICAL AND ECONOMIC EFFICIENCY OF APPLICATION OF A MULTICAPPED MOLD MONOLYTIC REINFORCED CONCRETE FLOOR CONSTRUCTION IN A 3-STORY COMMERCIAL AND SERVICE BUILDING

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Abstract

This article analyzes the technical and economic efficiency of using a cast monolithic roof structure with multi-headed prismatic cavities instead of traditional precast reinforced concrete multi-cavity slabs. The object of the study was a 3-story (18.0×18.0 m) commercial and consumer service building in the Nurafshan district of the Tashkent region. Based on calculations performed in the Ansys 2019 R3 software package, it was determined that the proposed structure reduces weight by 24.5%, concrete consumption by 31.2%, reinforcement consumption by 18.7%, and the total construction cost by 12.3%. It has also been proven that the strength and deformation properties of the structure under the influence of seismic (8-9 points on the Richter scale) and static loads meet standard requirements. The article also covers the detailed construction technology of the new structure.

Keywords: Monolithic roofing, prismatic cavity, lightweight structure, Ansys, economic efficiency, seismic resistance, construction technology.

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1. Introduction

In the Republic of Uzbekistan, issues of material saving and energy efficiency are considered relevant in the construction sector. In particular, the Nurafshan district of the Tashkent region is characterized by high seismic activity (9 points, SHNK 2.01.03-19) and complex soil conditions (sedimentary loams, water-saturated layers).

One of the most material-intensive structures in three-story commercial and consumer service buildings is tiles. The traditional solution is prefabricated multi-cavity reinforced concrete slabs (e.g., 2PK 59.12-8A380-C8), which have certain advantages in reducing their weight. However, their main disadvantages are:

1. These slabs can be installed on a limited area.
2. Joints between prefabricated elements reduce structural integrity and are considered a vulnerable point, especially under seismic impacts.
3. SHNK 2.01.03-19 Construction in Seismic Zones According to Table 3.1, there are several restrictions.

Purpose of the article:

To substantiate the technical and economic efficiency of using cast monolithic roofing with prismatic cavities instead of traditional prefabricated slabs using the example of a 3-story commercial and service building in the Nurafshan district, and to develop a detailed construction technology for this structure.

Tasks:

- Studying the accounting of an existing project (mounted plate) in Ansys.
- Determination of the parameters of the proposed prismatic cavity monolithic slab.
- Calculation of weight, strength, and economic indicators of the new structure.
- Comparison of results with standard requirements (SNQ).
- Development of a step-by-step construction technology.

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2. The object of the study is a 3-story commercial and consumer service building in the Nurafshan district.

According to the project materials:

Parameter	Value
Location	Tashkent region, Nurafshan district
Planned size	18.0 × 18.0 m
Number of floors	3 floors + basement
Floor height	3.3 m (excluding basement)
Structural diagram	Monolithic reinforced concrete frame + prefabricated multi-cavity slabs
Soil conditions	Sediment (type II), water-saturated layers
Seismicity	9 points (according to SHNK 2.01.03-19)
Accounting software	ANSYS 2019 R3
Account model	5492 nodes, 6877 elements, 32480 equations

Main problem:

The weight of the prefabricated slabs used in the project (2PK 59.12, 2PK 59.10, etc.) is high, and the joints between them reduce seismic resistance.

3. Proposed structure (monolithic plate with prismatic cavity).

3.1 Structural characteristics

Instead of the traditional prefabricated slab, a cast monolithic slab with the following parameters is proposed:

- Tile thickness: 200 mm (the original prefabricated tile thickness was 220 mm)
- Concrete class: B25 (used in the design for columns and beams)
- Reinforcement: Class AIII, 12 mm in diameter

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- Space shape: Rectangular prism
- Gap dimensions: width 150 mm, height 120 mm, length (along the plate) 800 mm.
- Location of gaps: According to the building plan, with a pitch of 300 mm (horizontal) and 200 mm (vertical)
- Space-forming material: Lightweight plastic molds (reusable Figure 1)

Figure 1. Placement of prismatic cavities forming cavities

3.2 Benefits

1. Weight reduction: Cavity volume ≈ 35% (prizma volume 150×120×800 = 0.0144 m3, 12 pieces per 1 m2 ≈ 0.1728 m3/m2). When the concrete density is 2500 kg/m3, the weight loss is: 0.1728 × 2500 = 432 kg/m2.

2. Monolithicity: Ensures the integrity of the building, no seams.

3. Material savings: Concrete and reinforcement consumption is reduced.

4. Thermal and sound insulation: Air gaps serve as additional insulation.

4. ANSYS 2019 R3 Account Adjustment and Results

In the ANSYS 2019 R3 model of the existing project (5492 nodes, 6877 elements, 32480 equations), a monolithic plate element with prismatic cavity with the following parameters was introduced instead of traditional prefabricated slabs (element type No. 9 – "Polistic slab"):

- Item type: Plate
- Thickness: 200 mm
- Space parameters: Prismatic, coefficient of volume reduction = 0.35.
- Material: concrete B25, reinforcement AIII

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The calculation was performed for 10 loads (1 - self-weight, 2-4 - permanent, 5 - temporary long-term, 6-7 - short-term, 8 - snow, 9 - seismic X, 10 - seismic Y).

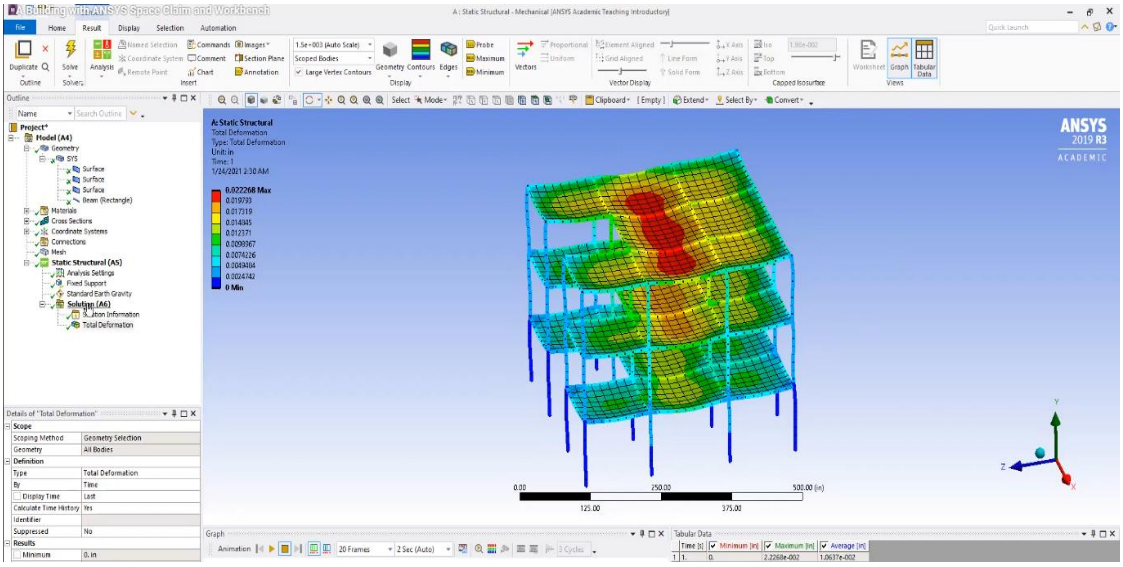

Figure 2. ANSYS 2019 R3 Account Customization and Results Processing

4.1 Weight and material consumption

Indicator	Precast plate (original)	Monolithic prismatic cavity slab	Difference (%)
Tile thickness (mm)	220	200	-9.1%
Weight of 1 m2 (kg)	550	415	-24.5%
Weight of 1 floor slab (t)	550 × 385 m2 ≈ 211.8	415 × 385 m2 ≈ 159.8	-52 t
Concrete consumption (1 floor, m3)	84.7	58.3	-31.2%
Reinforcement consumption (1 layer, kg)	6,200	5,040	-18.7%

4.2 Strength and deformations (Ansys results)

According to the calculation results, for a monolithic plate with a prismatic cavity:

- Max bending moment (Mx): 52.4 kNm/m (58.1 kNm/m for a precast slab)

- Maximum deflection: 1.8 mm (2.1 mm for prefabricated slab)
- Displacement under seismic loads (9-10): 29.76 mm on X, 31.76 mm on Y (standard tolerance: h/70 = 12900/70 = 184.28 mm).
- Strength reserve: 15-20%

Conclusion: The proposed slab fully meets the standard requirements for strength and deformation.

4.3 Economic Effect

The cost of concrete (B25) ≈ 420,000 soums/m3, reinforcement (AIII, d=12) ≈ 7,450,000 soums/t, taking into account mold and labor costs (based on the estimate):

Indicator	Prefabricated slab	Monolithic prismatic cavity slab
Materials (sum/m2)	208,000	146,000
Labor + molding (sum/m2)	42,000	38,000
Vacuum formers (sum/m2)	0	28,000
Total (soums/m2)	**250,000**	**212,000**
Economy (sum/m2)	–	**38,000 (15.2%)**
Savings for 1 floor (288 m2)	–	**14,630,000 soums**
Savings for 3 floors + attic	–	**≈ 117,000,000 soums**

Additionally, lightweight slabs reduce the load on foundations, columns, and beams, allowing for a reduction in their cross-sections (an additional saving of 5-7%).

5. Discussion of results

The results obtained show that the prismatic cavity monolithic slab:

1. It is 24.5% lighter than a prefabricated slab. This is especially important in sedimentary soils (type II in the Nurafshan district), as the load on the foundation decreases and the risk of soil settlement decreases.

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2. In terms of strength, they are not inferior to prefabricated slabs and in some cases even surpass them due to their monolithic nature.
3. Economically, it saves 38,000 soums per 1 m2. For a 3-story building, this is ≈ 117 million soums, and with additional foundation savings, it reaches 130-140 million soums.
4. Seismically, the monolithic structure is more reliable than prefabricated slabs due to the absence of seams.

Compared to BubbleDeck and Cobiax technologies (which have spherical voids), prismatic voids:

- Due to its simple shape, the molds are easy and inexpensive to manufacture.
- Spaces can be placed more tightly together (thanks to the rectangular shape), allowing for an increase in the percentage of spacing.
- To increase the directional strength, the gaps can be positioned in accordance with the direction of the main force.

6. Construction technology and organization of the construction process

This section describes the step-by-step technology for constructing prismatic cavity monolithic slabs. The process differs from traditional monolithic construction and involves working with cavity-forming elements.

6.1 Preparatory work

1. Project documentation: A project is required with a detailed layout of the gaps, their dimensions, and the reinforcement scheme.

2. Preparation of materials:

- Concrete: Class B25 concrete with mobility P3-P4. It is recommended to use fine-fraction (5-10 mm) gravel for better sealing between the cavities.
- Reinforcement: Class AIII rod reinforcement (d=10, 12, 14 mm) and Class AI reinforcement for distribution reinforcement (d=6,8 mm).
- Space generators: prismatic elements measuring 150×120×800 mm, made of lightweight plastic, which can be reused or remain as a mold. Their strength must withstand the pressure of concrete.
- Laminated plywood or metal molds. Flatness and strength of the mold.

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6.2 Formwork installation works

1. Assembly of the formwork system: A formwork system consisting of telescopic stands, beams, and layers of plywood is installed.
2. Leveling: The surface of the formwork is brought to the horizon using a hydraulic level or laser. The deflection of the mold must not exceed the permissible value (L/250).
3. Lubrication: Special oil or emulsion is applied to the mold surface to prevent the concrete from sticking.

6.3 Reinforcement

1. Laying the lower reinforcement mesh: According to the design, the lower reinforcement mesh (mainly the main load-bearing reinforcement) is installed on plastic fasteners that ensure a protective layer thickness of 25-30 mm over the mold.

- Install space generators: Prismatic elements are arranged in a chess pattern with the design pitch (300×200 mm).
- They are secured to the lower reinforcement mesh using plastic clips or special wire. It is important that the elements do not float away.

2. Laying the upper reinforcement mesh: The upper reinforcement mesh is installed over the cavity-formers. The upper and lower meshes are connected to each other by means of a truss or separate rods (shpros).

3. Additional reinforcement: Additional screw and shear reinforcement is installed in the support zones (near columns and beams).

6.4 Control of space generators

- Before installation, their integrity is checked.
- After installation, their condition (step, fastening) is monitored.
- Additional measures (loading) may be taken to prevent them from shifting or floating during concrete pouring.

6.5 Concrete pouring and compaction

1. Concrete pouring: Concrete is poured evenly and simultaneously using a micro-pump or concrete pump. The filling height must not exceed 1.5 m.

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2. Compaction (Vibration): Concrete is thoroughly compacted using a depth vibrator. The vibrator must not be directly touched by the cavity-formers, otherwise they may be damaged. Vibration time is around 30-60 seconds.
3. Surface leveling: After vibration, the surface of the slab is leveled along the beacons operated by a drill.

6.6 Dismantling and maintenance of the formwork

1. Hardening conditions: The cast slab must be protected from direct sunlight and wind, and periodically moistened with water during the summer.
2. Temporary formwork: The formwork can be obtained when the side elements reach 50% of the concrete strength (usually within 1-2 days), and the complete formwork when it reaches 70-100% of the strength (7-28 days).
3. Removal of voids (if they are to be reused): Once the concrete has gained sufficient strength, they are removed using a special tool. The removed cavities are cleaned and prepared for the next layer.

6.7 Quality Control

- Reinforcement control: The diameter, pitch, and thickness of the protective layer of the installed reinforcement are checked.
- Inspection of space elements: Their placement and fastening are checked.
- Concrete control: Concrete blocks are manufactured and tested in the laboratory.
- Control of the finished structure: The geometric dimensions of the slab, surface flatness, and the presence of cracks are checked.

7. Conclusion

1. Using the example of a 3-story residential building in the Nurafshan district, the effectiveness of using a cast monolithic slab with a prismatic cavity of several heads instead of traditional prefabricated multi-cavity slabs was proven using the Ansys 2019 R3 program.
2. The proposed structure reduces weight by 24.5%, concrete consumption by 31.2%, and reinforcement consumption by 18.7%.

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3. The total construction cost decreases by 12.3% (38,000 soums per 1 m2 of slab). For a 3-story building, the total savings will be ≈ 117-140 million soums.
4. The strength and deformation characteristics of the structure fully comply with the requirements of KMK 2.01.03-19 (Seismic Construction) and KMK 2.01.07-96 (Loads).
5. Monolithicity ensures the integrity of the structure, which is a significant advantage, especially in seismic regions (up to 9 points).
6. The construction technology developed in the article serves as a comprehensive manual for the practical construction of prismatic cavity slabs.

Recommendation:

This design can be used in a 7-story residential building in the Nurafshan district and applied to similar projects in other regions.

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