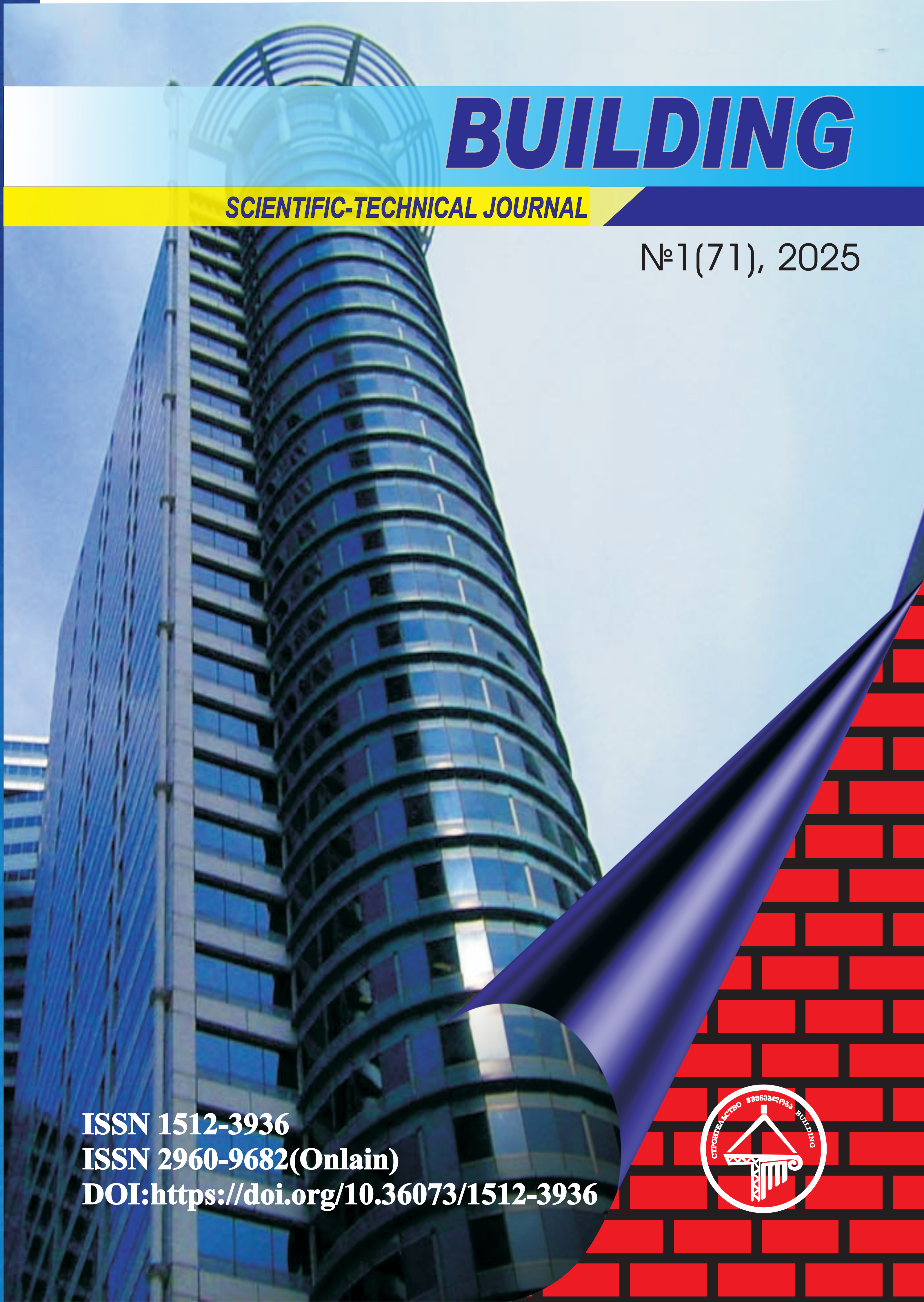

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Theoretical-experimental study of optimization of operational parameters of protective nets of aircraft power units

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Abstract. This scientific work discusses increasing the effectiveness of a bird-proof mesh for aircraft components (propeller, fan, compressor, etc.) by optimizing the mechanical, geometric, and aerodynamic parameters of its constituent cells.

Instead of steel wires, ropes made from high-strength composite fibers produced by world-renowned companies were selected for the protective net: Dyneema (DSM-Holland), Spectra-75 (Honeywell USA), Zylon (Toyobo MC Corporation, Japan), VECTAN (DuPont); Kevlar (DuPont). Taking into account the specific type of aircraft and its flight and operational conditions, the geometric parameters of the ropes of the cells constituting the protective net were specified (diameter, dimensions of the sides of the net cell, etc.). On a modernized tensioning machine UTM-M, the breaking strength limit of selected ropes was determined within the framework of extreme environmental operating temperature conditions of +60 -60 ^{0}C. A net was made from Dyneema fiber rope with the best characteristics and was tested on a dynamic stand at various bird weights and impact speeds.

Using a mathematical model and computer simulation programming created by scientists at the Scientific Research Center of the Georgian Aviation University, the conditions for the containment, fragmentation, and tearing of the net when birds hit a protective net were determined.

Key words: Aircraft, air intake device, fan, bird, protective net.

Introduction

The number of aircraft, and especially unmanned aerial vehicles, and consequently the number of flights performed by them, is increasing significantly every year in the world. The number of different species of birds is also increasing significantly, which significantly increases the likelihood of a collision between an aircraft and a bird.

In the publication of the International Civil Aviation Organization, "ICAO" Aviation Safety Network, which is based on data from 91 countries, there were 33,376 cases of damage to aircraft as a result of bird collisions in 2008-2015, of which 48.9% were caused by engines.

Fig. 1. Boeing-737 aircraft during a collision with a flock of birds

Collisions between aircraft and birds occur most frequently during takeoff and landing at relatively low altitudes of 150-300 m, accounting for 75% of cases. 20% of collisions occur at altitudes of 300-1500 m and only 5% above 1500 m [1], [2].

Currently, some helicopter engines are equipped with protective grid [3]. The use of protective nets has both positive and negative aspects: the positive aspect is that their use significantly reduces the risk of a single large mass of bird entering the engine, which could cause significant damage to its components. The downside is that if the net is designed solely to contain birds, the diameters of its constituent threads increase significantly, which in turn leads to a significant increase in the coverage coefficient of the engine air intake inlet and, consequently, aerodynamic drag.

Scientists and employees working in the aviation field of leading countries are actively involved in solving this problem.

Main part

One effective measure to solve the above problem is to use a protective mesh or mesh system in the front part of the engine air intake, the mesh of which has the smallest possible diameter and is made of modern high-strength composite fibers.

In this case, the flight speed of the aircraft and the outer diameter and, accordingly, the cross-sectional area of the air intake inlets are taken into account, as well as the weights and speeds of the birds involved in the collision with the engine. The cruising speeds of civil aviation aircraft are in the range of 800–1000 km/h, and their takeoff and landing speeds are within 250–280 km/h. As for helicopters and drones, their flight speeds are in the range of 150-300 km/h.

When manufacturing protective nets, the geometric and mechanical parameters of their constituent ropes must be determined to meet the following technical requirements:

a) The geometric dimensions of the protective mesh cell must ensure that small birds cannot enter the engine while at the same time having minimal aerodynamic resistance;

b) The material of the protective net must ensure that a bird that has crashed into the net is stopped or dismembered. In the rare case that the mesh breaks due to unforeseen reasons, the mesh fragments that enter the engine should not be able to damage its components.

Among the parameters determining the effectiveness of a protective net, the geometric parameters of the net cell and its constituent rope (diameter, length, and cell area) are important, over which the tension σ induced when a bird hits the net is distributed, both for its individual elements and for the net as a whole. It is also important to consider the importance of the air intake coverage coefficient with the mesh-fitting ropes, on which the aerodynamic drag and air flow rates of the engine significantly depend [7].

To determine the optimal physical parameters of the rope required for the production of a protective net, let's use the following method: let's say a bird with mass M_b and density ρ_b collides with an aircraft with a certain contact area S_f. In this case, we can imagine the bird as a cylindrical object with base area S_b and height H_b. When a bird with these parameters collides with the protective net of the air intake, the kinetic energy that is transferred to the impact surface is expressed by the formula.

$$E_{kin} = \rho_b V_b (V_{\chi o\mu} + V_b)2 /2 = \rho_b S_b H_b (V_{\chi o\mu} + V_b)2 /2 \quad (1)$$

Based on the laws of impulse constancy, it is easy to calculate the impact force of a bird of mass m_b and length l_b with the concept given in {5}. Table 1 presents the parameters of some birds and the forces of collision with aircraft.

Table 1

N	Bird name	Bird flight speed, km/h	Total collision speed km/h (m/s)	Poultry weight kg	Bird length cm	Impact force, N (kgf)
1	Quail	60	340(94,4)	0,1	18	4951 (556)
2	Seagull	50	330(91,7)	1,4	40-60	26508 (2867,2)

3	Wild duck	90	370(102,8)	1,0	58	18220 (2048)
4	Canadian goose	90	370(102,8)	6,8	55	124892 (14039)

As can be seen from the table, the range of direct impact force values of birds of various weights on an aircraft during takeoff or landing is approximately 500 – 14,000 kgf. It is necessary to determine what the strength of the rope and the net structure made from it should be in order to withstand the above-mentioned collision forces and not tear, i.e. to ensure the containment or dismemberment of the bird.

In the work [3], a hydrodynamic model of a bird is used and, as an example, the strength and diameter of the wire constituting a steel mesh are calculated that will withstand and not tear when hit by a 6.8 kg goose at a speed of 77.8 m/s (σ= 3846 MPa, d = 8 mm, mesh cell dimensions 20x20 mm). The above results are unsatisfactory, because if we use the calculation method of the data in Table 1, we will find that a steel wire mesh with a diameter of 8 mm will cause the aircraft engine to cover almost half of the air intake inlet, which is unacceptable. At the same time, it is important to consider the significant increase in the weight of the mesh when using steel material and the danger that can arise from steel fragments entering the engine's exhaust system. Therefore, it is necessary for the protective net to be made of smaller diameter and high-strength composite fiber ropes. For this purpose, the authors selected and analyzed the characteristics of various brands of modern high-strength composite fibers (see Table 2).

Table 2

N	MSP **fiber** name	Specific gravity [g/cm3]	Tensile strength σ [GPa]	Elongation modulus E [GPa]	Deg. Temp. [0C]	Humidity %
1	HMWPE-Dyneema, Spectra, Izanas)	0.97-1	C	120-180	147	0,01-0,05
2	Zylon	1.55-1.65	3-5.8	140-280	500-750	0.2-3.5
3	Kevlar	1.44-1.46	2.6-3.6	70-150	250-350	0.5-1
4	Vectran	1.38-1.45	2.8-3.5	110-180	300-400	0.3-0.8

It should be noted that the tensile strength of the above composite fibers and the ropes made from them differ significantly depending on the purpose of the specific brand of rope, therefore this difference must be taken into account when conducting theoretical and experimental work.

Ropes made of Kevlar, Vectran, Dyneema and Zylon fibers were purchased and their samples were tested for breaking on a modernized tensile machine UTM-M. The tests were carried out taking into account the extreme operating temperature conditions in the range of -60 ^{0}C to +60 ^{0}C, for which it was equipped with a Cryo-thermo camera. Table 3 presents the geometric parameters of the ropes made of these brands of fibers and the results of the tests for breaking.

Table 3

	MSB rope	Factory marking Φ [mm]	Actual cross-sectional area [mm^2]	Fg. [kg]	Tensile strength. [GPa]
1	Zylon	1.3	1.1	110	1.0
2	Spectra	1.3	1.69	153	1.1
3	Dyneema	1.4	0.96	91	1.0
4	Kevlar	1.6	1.26	96	0.8
5	Vectran	1.6	1.27	97	0.8

As can be seen from the table presented, threads (ropes) made of Zylon and Dyneema fibers are distinguished by the highest strength characteristics. However, it should be noted that threads (ropes) made of Zylon fibers are characterized by the ability to absorb water moisture in their surface layers (up to 3%), which creates the risk that during take-off and landing of an aircraft, when there is a sharp change in air temperature, the elements of the mesh made of Zylon may be damaged due to the formation of ice in its structural layers. For these reasons, preference was given to threads (ropes) made from Dyneema strands.

Dyneema fiber belongs to the family of ultra-high molecular weight polyethylene (UHMWPE) fibers (Dyneema – DSM, Netherlands), aka Spectra – Honeywell USA, aka Izanas – Toyobo Japan). As members of the thermoplastic polyethylene family, they are characterized by very long molecular chains that effectively transfer loads through polymer intermolecular interactions. It is characterized by high strength and lightness. It has high tensile strength and low density, high abrasion resistance and low elongation. It can handle rapid deformations under high loads. In addition, it is resistant to solar ultraviolet radiation and its moisture absorption is close to zero.

Based on experimental data on strength and the operating conditions of aircraft, ropes made from Dyneema fibers best meet the technical requirements for the production of protective nets.

Computer simulation modeling has been used to better assess the impact of bird strikes on protective nets [5], [6]. To calculate this task, the 2022 version of the Workbench program was used. This version includes the LS-DYNA module, which is designed to calculate collision and ballistic problems.

Fig. 2 shows images of the fragmentation of a simulated cylindrical body of a bird with a mass of 0.1 kg (d=40 mm; L=80 mm) in the mesh cells of a mesh made of Dyneema fiber yarns (d=1.4 mm. a x a 20 x 20 mm) during a collision at a speed of V=58.92 m/s. As a result, the impact force generated during the collision was determined to be 3492.3 N.

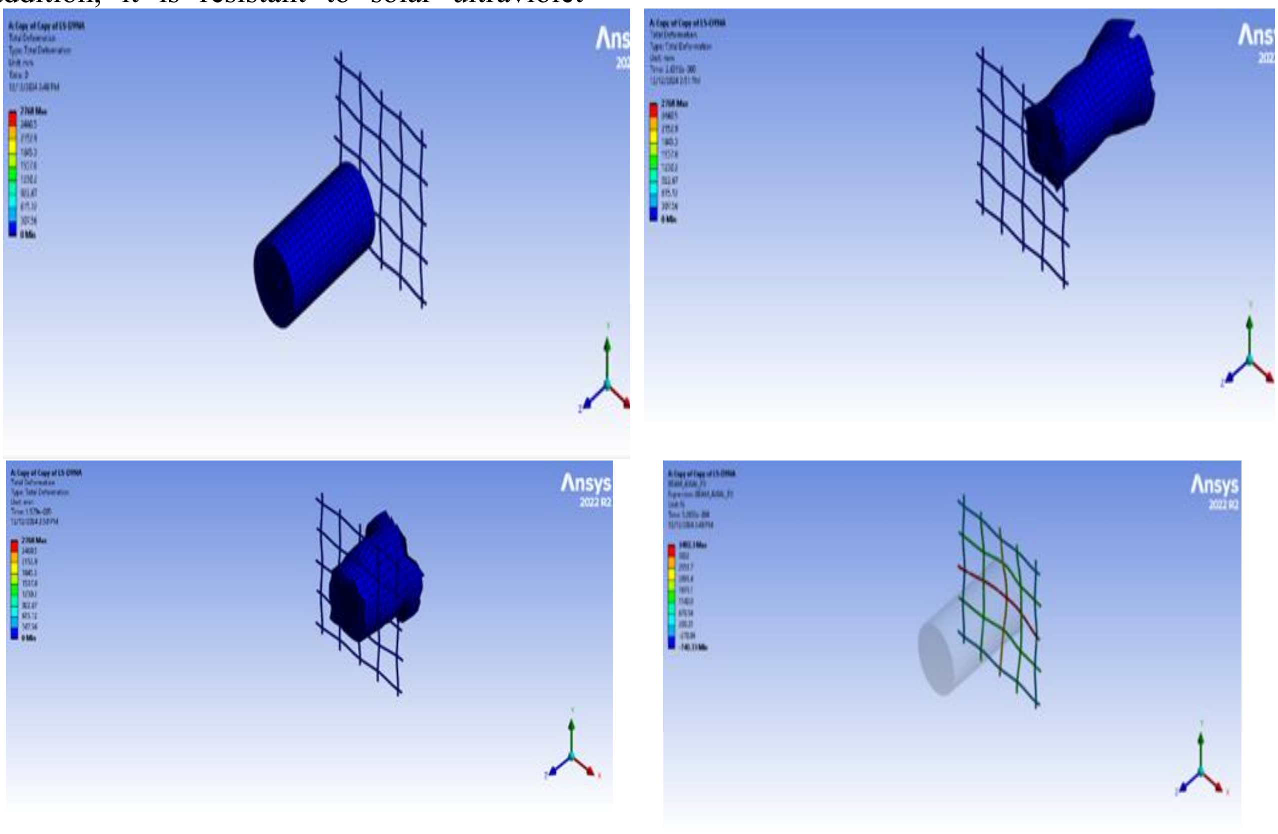

Fig. 2 Simulation of a bird hitting a net

A mesh with cell sizes of 20 x 20 mm was made from Dyneema ropes with a diameter of d = 1.3 mm, which was placed in a 100x100 mm metal frame and equipped with a special sensor device for dynamic tests (Fig. 3).

Fig. 3 Protective net with a strong frame after a bird hit it

The dynamic test stand consists of a pneumatic firing device and an electronic complex for measuring the speed of a simulated mass of a thrown bird. The test sample of the protective net was subjected to dynamic tests during bird strikes at various masses and speeds (Fig. 4).

Fig. 4 shows an experiment conducted on a dynamic stand, where a 0.1 kg bird model hit 20x20 mm mesh cells made of Dyneema fibers at a speed of V=58.92 m/s, generating a force impulse of 3788 N.

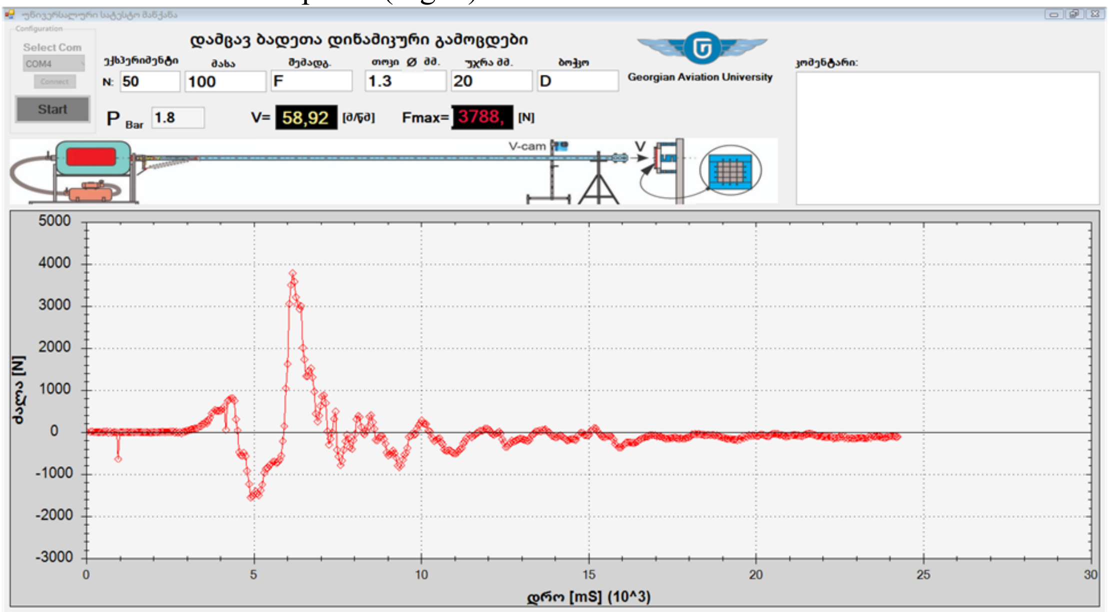

Fig. 4 Graph showing the impact force of a cylindrical bird (D = 0.04 m, L = 0.08 m) with a mass of M = 100 g hitting a 20x20 mm Dyneema fiber net.

Based on the initial data for this task, the magnitude of the impact force impulse was estimated in accordance with the model given in the literature [6]. In particular, using the values of the voltage induced in the mesh threads calculated by the energy method, which has the form:

$$\sigma = \frac{2 \cdot f_{lm} \cdot D}{\pi \cdot d \cdot sin\vartheta} \qquad (2)$$

where D is the diameter of the bird model, d is the diameter of the mesh thread, ϑ is the angle of deviation of the mesh thread from the plane of the mesh frame, which according to experimental data is $\vartheta \approx 11.5°$, and f_{lm} is the limiting value of the shear resistance force exerted on a thread with a unit longitudinal area [6], which is related to the limiting shear force by the ratio $F_{lm}=f_{lm} \cdot l \cdot d$, where l is the length of the mesh thread in contact with the bird, and d is the diameter of the thread. Based on new experimental data, the value of f_{lm} was specified and it is $f_{lm} = 15.71 \cdot 10^6 N/m^2$.

During the experiment, a cylinder representing a bird model encounters two intersecting ropes, which have a total of 8 suspension points on the net frame, with the end of each thread tilted from the plane at an angle ϑ. The magnitude of the impact impulse on the mesh frame, taking into account formula (2), will be:

$$F = 8 \cdot \sigma \cdot \frac{\pi \cdot d^2}{4} sin\vartheta = 4 \cdot f_{lm} \cdot D \cdot d = 3519 \text{ N} \quad (3)$$

The results obtained from the three approaches presented are quite close to each other.

Conclusion

This scientific work concerns the improvement of flight safety of aircraft by significantly reducing the damaging factors caused by birds hitting the working elements of their power units (engine, propeller, fan) through the use of protective nets.

Instead of the steel wires traditionally used for protective nets, threads based on high-strength composite fibers produced by world-renowned companies were selected: **Dyneema** (DSM-Holland), **Spectra-75** (Honeywell), **Zylon** (Toyobo MC Corporation, Japan), **VECTAN** (DuPont); **Kevlar** (DuPont).

Samples of yarns of this designation were subjected to tensile tests on a modernized UTM-M stretching machine, within the operating extreme temperature range of +60 -60 ^{0}C. Based on the results of strength tests and taking into account the specific requirements regarding the resistance of protective nets made of composite fibers to the action of ultraviolet radiation and their percentage of moisture content, the best characteristics were found for yarns made of Dyneema fibers.

A mesh with cells of 20x20 mm was made using a thread made of Dyneema fibers with a diameter of 1.3 mm. When using meshes of this size, the overlap coefficient of the CFM-56 air intake of the Boeing-737-is turbofan engine is 13%, and the TB3-117 turbofan engine of the Ми-8MTB helicopter is 14%.

Theoretical and computer simulation modeling of bird collisions with the net in the range of 100 g mass and velocities (V= 0 – 70 m/s) was conducted for a mesh with given parameters, as a result of which the conditions for bird retention, fragmentation, and mesh tearing on the net were determined.

To calculate the bird-net collision problem, the 2022 version of the Workbench program was used. This version includes the LS-DYNA module, which is designed to calculate collision and ballistic problems.

Experimental studies have shown that a net made of Dyneema ropes (with parameters: dimensions of the sides of the power frame 90 mm; drop=1.4 mm; lru = 20 mm) completely withstood the impact of a bird weighing 100 g with it at speeds (V= 50 – 70 m/s) and completely disintegrated it (10% of feathers and bone fragments remained on the front part of the net, and the remaining 90% was thrown out of the back part of the net in the form of small particles over a large area).

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An Experimental, Theoretical, and Numerical Investigation

Technical Passportization of Buildings and Seismic Resistance Assessment

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Abstract: The article discusses the issues of technical passportization of buildings and the assessment of their seismic resistance. Existing passportization methods are analyzed, the main objective of passportization and its results are discussed. A form for the building's passport card is proposed, and the procedure for filling out the passport card for both new buildings and buildings in operation is provided. It is recommended to use the vibration machine BUM-80 for assessing the seismic resistance of buildings, as it allows us to subject the building to conditions as close as possible to real earthquakes and to perform the identification of its computational model under various impact levels. The issue of the wide implementation of modern active and passive special constructions for protecting buildings from seismic impacts in seismic construction in Georgia is raised. The readiness of the National Association of Earthquake Engineering and Engineering Seismology of Georgia for conducting passportization of buildings in Tbilisi, assessing the seismic resistance of existing high-rise buildings, and determining the effectiveness of active seismic protection measures is emphasized.

1. Introduction

In seismic regions, building passportization is the first stage of ensuring the seismic reliability of existing construction objects at a necessary and economically reasonable level. It addresses issues of physical, moral, and seismic wear, seismic hazard changes, and the adaptation of design standards and construction improvements. The passportization of buildings and the assessment of seismic resistance is particularly important in Tbilisi and large self-governing cities in Georgia, where many buildings from the 19th and 20th centuries were built under changing seismic conditions and outdated seismic design standards. Based on building passportization, a passport document should be created, containing data on the building's technical condition, seismicity of the construction site, and its seismic resistance.

2. Main body of the paper

Many problems have accumulated in the housing stock of the Republic of Georgia. Numerous buildings are damaged or in an emergency state. There are also issues with other types of buildings. Unfortunately, some of these buildings are of high responsibility. For example, buildings where large numbers of people gather, or whose damage could lead to significant material losses or human casualties (stadiums, theaters, train stations, military facilities, hazardous materials storage, etc.).

In advanced countries, legislation mandates mandatory passportization for all buildings, which involves examining their technical condition, documenting it in the form of a passport, and controlling it periodically (every two or five years, depending on the category of the building). For instance, according to the building norms of our neighboring countries, the passportization process includes determining the dynamic parameters of the building, among other factors [1].

The main goal of building technical passportization is to extend their normal operational period. The primary objectives of building passportization in seismic zones are:

1. Identifying seismic hazards in buildings that require reinforcement, repurposing, or demolition (destruction), i.e., monitoring the technical condition of buildings.
2. Assessing the probable extent of damage to buildings under different levels of seismic impact.
3. Comparing the actual seismic resistance of buildings, i.e., determining whether specific measures have been implemented according to regulations and identifying any seismic resistance deficits.

A technical passport is a document that contains essential data required for the building's operation and is considered an informational reference document that reflects its actual condition [2].

This data helps reduce labor costs when calculating the scope of repair works for structural elements and calculating material-technical resources for building maintenance and repairs.

The initial materials for passportization are:

- Microzonation maps of populated areas, or if unavailable, seismic hazard zone maps according to the technical regulation "Seismic-resistant Construction" PN 01.01-09 [3].
- Engineering-geological and geomorphological maps of the area, as well as the results of engineering-geological investigations for construction sites.
- Project technical documentation, including design seismicity of buildings.
- Inspection reports for buildings that have previously been impacted by earthquakes.
- Technical documentation based on which the buildings were restored after an earthquake or another emergency situation.

Existing methods for passportization can be classified into three groups:

1. Expert evaluation methods.
2. Calculative-analytical methods.
3. Technical diagnostic methods.

Analysis shows that each method has both positive and negative aspects, and there is no unified, universally accepted standard method. Therefore, it is essential to conduct measurement work on buildings, visual and detailed (instrumental) inspections, identification of structures, and recalculation based on changes in seismic standards.

The investigation results determine the actual seismic resistance of the building and any seismic resistance deficit, which is reflected in the conclusion with relevant recommendations aimed at restoring the building's normal operational characteristics.

The result of conducting passportization is the monitoring and control of the condition of buildings, as well as the creation of a unified system for documenting the state of buildings in order to detect potential hazardous or emergency situations in a timely manner, and to cease the operation of dangerous buildings.

Passport cards are filled out:

- When designing buildings.
- During the preparation of reconstruction projects or when the purpose of a building changes.
- When the seismic situation changes (with the emergence of new information).

Thus, the methodological issue of technical passportization is reduced to a fundamental question: what criteria should be used when assessing the seismic resistance of buildings:

a) Expert evaluation, which reflects the degree of compliance of the building with construction standards and structural requirements.

b) Seismic resistance calculation or analytical assessment, which corresponds to the conditional seismic loads based on seismic-resistant construction norms and regulations.

c) The results of the technical diagnostics of the building.

Experience in investigating the effects of earthquakes shows that the primary material damage and social losses due to earthquakes are usually concentrated in a small number of more severely damaged buildings.

More complete information on damage is used when calculating seismic risk, where the reliability of the calculations depends not only on the selected seismic risk model but also on the completeness and reliability of the results of the buildings' passportization — one of the links in the seismic hazard-damage-passportization-seismic risk-methodological chain.

Therefore, it is advisable that in Georgia, passportization should apply to all buildings of state agencies and individual enterprises, regardless of ownership type, that are located in areas with seismicity of 7, 8, and 9 intensity. Conducting passportization facilitates the thorough examination of the technical condition of buildings and the determination of their actual seismic resistance level. It should be carried out by a specialized organization staffed by highly qualified specialists, who will be responsible for the accuracy of the data entered into the building's technical passport.

It is clear that after the passportization of an individual object, it will be determined whether the building needs to be demolished, repaired, or if no structural intervention is required from the standpoint of reconstruction, for which it is necessary to create a technical passport for the object.

A building's technical passport is considered an informational reference document that reflects its actual condition. It is a document containing essential data necessary for the operation of buildings, which helps reduce labor costs when calculating the scope of repair works for structural elements, and for calculating material-technical resources for building maintenance and repairs [3].

The technical passport includes information about the structural features of the building, design loads, dimensions, area, number of floors, construction date, foundation characteristics, wall thickness and materials, roofing, roof details, date of major repairs, etc. Additionally, this document is accompanied by floor plans and specifications of rooms.

Based on the materials of technical passportization, it is possible to create a passport card (form) in the format proposed below in this article, which should be accompanied by working materials (technical documentation, observation journals, seismic resistance assessment calculations and diagrams.).

For new buildings, the passport card is filled out during the design process by the design organization. For buildings already in operation, the card should be completed when the initial seismic resistance evaluation is carried out. Changes to the passport card are made during subsequent investigations of the buildings.

The passport card should also be filled out in the following cases:

- When developing a reconstruction project for buildings or when changing their intended use.
- When the seismic situation in the area changes (with the emergence of new information).

Passport Card

Building Name: -------------------

N	Building Passport Data	
1	Location Name (Region, City, Municipality, Street, Building Number)	
2	Seismicity of the Settled Area	
3	Building Purpose	
4	4.1 Type or Individual Project, Project Code, Design Organization	
	4.2 Building Class	
	4.3 Ecological Consequences of Collapse under Seismic Impact	
5	5.1 Type of Structure	

	5.2 Type of Foundation, Presence of Basement	
	5.3 Structural Particularities of the Building	
	5.4 Main Material of Load-Bearing and Enclosing Structures (Concrete Class, Steel Grade, Type of Masonry)	
6	Seismic Intensity of Building According to the Design	
7	Construction Organization, Years of Construction Start and Completion, Construction Quality	
8	8.1 Building Dimensions (Length, Width, Height), Presence of Balconies, Loggias	
	8.2 Number and Dimensions of Blocks Separated by Anti-Seismic Joints, Presence of Reinforcements	
	8.3 Number of Floors, Floor Height	
	8.4 Balance Value, Initial and Current at the Time of Investigation	
9	Volume-planning and Structural Particularities of the Building Affecting the Seismic Resistance	
10	10.1 Seismic Resistance Development Area (Flat, Sloped, Lowland, Elevated), Type of Filling (Bulk, Cut off)	
	10.2 Groundwater Level, Presence of Protective Measures against Water	
	10.3 Ground Category According to Seismic Properties	
	10.4 Other Geological Features of the Site	
11	Design Seismicity of the Site	
12	Evaluation of the Building's Technical Condition	
13	Conclusion on the Building's Seismic Resistance	
14	Recommendations for the Building's Further Operation	
15	Recommended Period for the Next Investigation	

Chairman of the Commission: --------------
Members of the Commission: ---------------
Passport card filling date ---------------------

It is noteworthy that continuous monitoring is required for bridges, viaducts, overpasses, towers, masts, and other similar structures, where one of the main tasks during inspections is to determine their dynamic parameters, which today are either not carried out at all or are mainly performed inadequately with outdated and imperfect methods.

In the second half of the last century, almost every new type of building structure, its model, fragment, or individual load-bearing structures were subject to natural-experimental testing under both static and dynamic loads. Based on the results of these experiments, the structural perfection of these buildings was achieved and incorporated into construction practice. In the 1980s and early 1990s, in the former Soviet Union, several dozen such experiments were conducted, which contributed to the structural perfection of various types of residential and public buildings. For example, large panel multi-apartment buildings, known as "Tukhareli" type (Tbilisi, Kutaisi), incomplete-frame large-panel multi-apartment buildings (Irkutsk), reinforced concrete residential buildings with an incomplete frame (Leninakani), large-panel multi-apartment buildings with solid concrete cores (Sochi), large-block multi-apartment buildings with cut limestone blocks (Feodosia), and multi-apartment buildings with prestressed reinforcement in construction conditions (Kutaisi, Ashgabat), large-panel multi-apartment building with detachable connections (Tbilisi)were tested.

Unfortunately, these processes have now been halted. However, as mentioned above, during the development of European standard national annexes [4] and the process of building passportization, it will be necessary to conduct natural-dynamic (including vibrational) testing to determine the dynamic characteristics of buildings and assess their real rigidity. Currently, these tests are performed with outdated Soviet-era equipment. The data recorded by these instruments cannot be directly or immediately processed by computers. Consequently, in addition to providing certain inaccuracies when determining specific parameters, the decryption of these records requires significant time and effort, ultimately affecting the quality and reliability of the research.

For conducting experimental natural-vibrational studies, which inherently include testing the seismic resistance (stability) of a building under real earthquake conditions up to 7-8 intensity, our association member, the company "Zniepi," has one of the world's most powerful vibrational machines, the BIM-80. This machine can generate harmonic (sinusoidal) vibrations in the frequency range from 0.5 to 20 Hz and apply an inertial load of up to 80 tons in the horizontal direction per one complete vibration cycle. Depending on the type and size of the building being tested, this allows us to simulate seismic loads equivalent to those of a 6-7 intensity earthquake and study the behavior of the building, its individual structures, and joints in the plastic stage (up to destruction, i.e., when the building's own vibration frequency decreases by 30% or more). This allows us to subject the building to conditions closely resembling a real earthquake, determine the full package of its dynamic parameters (including mode shapes), and identify its theoretical calculation model under various levels of impact (discretization). Using this vibrational machine, most of the above-mentioned residential buildings were tested both in quasi-static and plastic stages.

Considering the increased seismic risks worldwide, the introduction of modern special (active and passive) seismic protection structures in construction is particularly relevant. Much progress is being made in developed countries in this direction, and after each new earthquake, specialists are becoming increasingly convinced of their effectiveness. In Georgia, these structures have mainly been implemented in the construction of several bridges (Tbilisi, Heroes Square). Given the relevance of the issue, the use of this vibrational machine has made it possible to scientifically study modern seismic protection structures and systems, as well as to develop necessary recommendations (technical regulations) for practical use. Currently, our colleagues in neighboring republics are also actively engaged in this type of work.

It is noteworthy that the National Association of Earthquake Engineering and Engineering Seismology of Georgia is ready to participate in the process of buildings passportization in Tbilisi, the re-assessment and evaluation of the seismic resistance of existing high-rise buildings, and the testing of building fragments to determine the effectiveness of active seismic protection measures, under appropriate conditions.

3. Conclusion

Based on the analysis conducted, it is determined that the main objective of the technical passportization of buildings is to extend their normal operational lifespan and to stop the operation of buildings in emergency condition. In Georgia, passportization should be carried out for all buildings of public institutions and individual enterprises, regardless of ownership type, located in areas with seismic activity of 7, 8, and 9 intensity. A building passport form has been developed, which should be completed during the design process for new buildings by the design organization, and for buildings in operation, the card should be filled during the initial assessment of seismic resistance. Changes to the passport card should be made during subsequent investigations of the buildings. The passport card should also be filled out when developing reconstruction projects or changing the purpose of buildings, as well as when there are changes in the seismic situation of the area. The process of passportization and assessment of seismic resistance requires the implementation of natural-dynamic testing of buildings using the vibration machine BUM-80, which is available to the member company of the National Association of Earthquake Engineering and Engineering Seismology of Georgia, LLC “Znieps.” The scientific study of modern special active and passive constructions for protecting buildings from seismic impacts, the development of necessary recommendations, and their implementation in Georgia can be carried out using the aforementioned vibration machine.

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The Longest Constructions in the History of Mankind

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Anotation Construction is a complex and laborious process, as it requires the full implementation of a number of technological operations. In addition, it often takes no less time to draw up an architectural and structural project, which often changes during the construction process. Without a properly executed project, not a single significant object in the world has been built and will never be built. Therefore, the construction itself can last a very long time, but the main thing is the final result. It is only worth mentioning that the huge pyramids built in Egypt 45-46 centuries ago have survived to this day without serious damage and subsidence of the foundations. In addition, one can cite examples of many stone structures dating back to the Paleolithic era, which were earlier than them, whose structure has withstood millennia and retained its original condition. All this indicates that construction traditions have existed since time immemorial. There are great architects and builders whose names are remembered alongside saints, emperors, pharaohs, kings, and other great historical figures.

Key words: Duration, Beginning, End, Construction, History, Building, Century

1. Introduction

Many famous buildings in the world sometimes lasted several centuries, and maybe even a millennium. There were many reasons for such delays, but such long-term construction projects are finally completed, and most of them are masterpieces of world architecture and construction. In addition, there are many such buildings that lasted at least one or two centuries. We must definitely mention the Sagrada Familia, a Catholic cathedral in Barcelona, the construction of which began in 1882 and is still unfinished. This magnificent creation of the architect Antonio Gaudi attracts tourists from all over the world even during the construction process, but no one knows exactly when it will be completed. In the history of mankind, for the consideration of the longest construction projects, we have selected such objects that took four or more centuries to build. There were 8 of them in total. It is interesting that their names alone are enough to imagine the greatness that has been created by human hands. They prove that achieving the desired result is impossible without hard work, overcoming unprecedented obstacles, and striving for perfection.

2. Main part

Based on all available documentary materials, the longest period of construction was the Great Wall of China, which was rightfully included in the list of the New 7 Wonders of the World according to a general survey conducted in 2007. This defensive structure is the largest architectural monument, its length is 8851.9 km (according to some sources it was 21,196 km). Its construction began in the 3rd century BC and was completed in 1644 AD, that is, it lasted for 20 centuries. It is interesting that China was not a unified state at the time of construction. The kingdoms located in the north began to build separate sections of the wall to protect themselves from nomadic tribes, who were attracted by the wealth of Chinese cities and tried to plunder them. In the 20th century BC. In 246, Qin Shi Huang ended the centuries-old era of wars, unified the lands of China, formed the first centralized Chinese state, founded the Qin Dynasty, of which he himself became the ruler, and began the construction of a single wall. The grandeur of the construction is also evidenced by the fact that during the Qin Dynasty, up to 2 million people worked on it. The construction environment itself was extremely difficult, since the wall followed mountain ranges. In addition, it had to overcome both heights and very significant and deep valleys. However, this is precisely what caused the peculiar uniqueness of the structure. It is unusually naturally integrated into the landscape and forms a single whole with it. A large part of the wall was built mainly of rammed earth. Clay, pebbles and other materials that could be obtained on site were mixed in layers. Sun-dried bricks were also used. It is because of the construction materials that the wall is called in Chinese folk name - "Earth Dragon". Already during the Qin period, in some areas, stone slabs began to be used, which were laid in layers of compacted earth. The sections of the Great Wall of China that have survived to our time were built mainly by the Ming Dynasty, during which its construction was completed (1368-1644). By this period, the main building materials were already bricks and stone blocks, which made the structure more reliable. Interestingly, the Chinese used a mixture of glutinous rice porridge and calcium hydroxide to glue the stone blocks. The dimensions of the wall vary in different places. The height is on average 7.5 meters, with towers - 9 meters, width 5.5-6.5 meters, in general places more. Towers are an integral part of the wall. They were mainly built together with the wall, but there are also cases of later construction and they are narrower. Some, all towers are 200 meters apart, within reach of the arrows used to send messages. At a distance of 10 km, there are taller, signal towers. A bonfire was lit on their roofs to warn of an enemy invasion. During this longest and most difficult construction, due to harsh working conditions and epidemics, more than 1 million people died on the construction site, who, of course were buried there, and therefore the wall is also the longest cemetery in the world (Fig. 1).

Fig. 1. Great Wall of China

Many famous constructions in the world sometimes lasted several centuries, and maybe even a millennium. There were many reasons for such delays, but such long-term construction projects are finally completed, and most of them lasted more than a millennium, about 11 centuries. The construction of the Great Pyramid of Cholula in Mexico (3rd century BC - 8th century AD), which in the Aztec language means "mountain built by hand" and is located in the city of Cholula. The pyramid was dedicated to the "winged serpent", whose cult existed in these places until our era. The height of the ancient complex is 66 meters (the actual height compared to the existing ground surface is 55 m), but due to the large length of the sides of the base (450 X 450 m), it is considered the Guinness World Record holder as the largest pyramid in the world by volume. The volume of stones used for its construction is 4.45 million m3, according to some sources this figure does not exceed 3.3 million, but in any case it is much larger than the volume of the world's tallest pyramid, the Pyramid of Cheops.

Fig. 2. Choluli Hill

Fig. 3. Great Pyramid of Cholula

The pyramid has been almost completely covered with earth for centuries and is a large, well-greened hill. On top of the hill is a temple, which was built in later years and reconstructed many times. It is noteworthy that the existing road and stairs leading to it from the west side are preserved in many later paintings, which indicates that its surface was covered with earth very soon after the construction of the pyramid itself was completed. It is noteworthy that in the post-colonial period the pyramid was seriously damaged in connection with the construction of roads from the north and west sides (Fig. 2). As a result of research, it has been established that the pyramid consists of six rectangular structures of different sizes (decreasing in plan as the height of the pyramid increases) stacked on top of each other. It is noteworthy that only three of them have been studied so far. These structures were connected in height from all sides by stairs in the middle, which ultimately took the form of a pyramid (Fig. 3).

The city of Petra is one of the oldest cities on earth and is located in Jordan, 900 meters above sea level. This city is unique because the buildings are built of sandstone and many temples, houses and utility buildings are carved directly into the rock. The inhabitants of Petra were masters of working with stone. The name "Petra" itself means rock in Greek. Petra occupies a huge area (larger than Manhattan). It stretches for kilometers from the center. The main street, which was laid from west to east during Roman rule. On both sides of it there is a magnificent colonnade. The end of the street in the west led to the great temple, and in the east it ended with a triumphal arch. The monastery carved into the rock is a huge building about 50 meters wide and 45 meters high.

Fig. 4. Petra

The famous Al-Khazneh temple-mausoleum was built in the riverbed. For this, the riverbed was changed, a tunnel was made in the rock to transport water, and several dams were built, which was truly amazing for that time. Moreover, in a place where rainfall does not exceed 15 cm per year, channels were cut directly into the rock, and more than 200 reservoirs in the city were filled from all sources within a radius of 25 km. This solved the problem of water scarcity. It is precisely because of such engineering achievements that the city of Petra is named one of the New 7 Wonders of the World. Studies have confirmed that its construction began in 600 BC and was completed in 250 AD. Although its construction lasted 8.5 centuries, there is no other such magnificent creation in the history of mankind (Fig.4)..

The first stone of the foundation of the Gothic cathedral of Cologne in Germany was laid on May 15, 1248, and construction was completed in 1880, 632 years after it began. Upon completion, the cathedral, with its height (157 meters), became the tallest building in the world for four years. It still ranks third among the cathedrals in the world in height and is the most important architectural landmark in Germany in terms of the number of visitors. It lost the first place in height to the 169-meter monument to George Washington. The construction of the cathedral was carried out continuously, and during this time many masters of construction changed, each of whom perceived the final form of the building in his own way. In Germany, there is a legend about this, according to which the first architect of the Cologne Cathedral, Konrad von Gochstadten, sold his soul to the devil in order to develop an ingenious and unique project. The devil agreed, but on the condition that if the construction process was stopped, the building would immediately collapse. This is how tourists are still explained the ongoing restoration work in the temple. Interestingly, even in conditions of complete calm, there is always wind near the temple; the stream of Hari, as soon as it encounters resistance from the high spires of the temple, goes down. The temple is very impressive. Its length is 144 meters and its width is 86 meters. To allow more light into the temple, pilasters were erected, and a system of external buttresses and arches was used to support the weight of the arches by the walls. In addition, the arches had not a semicircular shape, but an arrow-like outline, which allowed the entire building to be evenly covered and the entire structure to be emphasized as if it were reaching heaven (Fig. 5).

Fig.5. Cologne Cathedral

St. Vitus Cathedral in Prague is a masterpiece of European Gothic and is an artistic and national-historical monument of the Czech Republic. Its architecture is a combination of Gothic, Renaissance and Baroque styles. The resulting beautiful cathedral was built in four stages for almost 600 years, from November 21, 1344 to the beginning of the 20 th century. Its construction, despite the 6th century construction, was incredibly expensive. The first architect, the Frenchman Matthias of Arras, died 8 years after the start of construction. Since 1352, his work was continued by the 23-year-old architect from Germany, Peter Parlerz, who introduced many useful innovations into the construction. He died in 1399, and his three sons took up the work, but the war of 1419 seriously damaged the cathedral under construction and the construction process was stopped for a long time. Despite several attempts, the work did not progress due to lack of funds. In 1541, it was in even worse condition due to a severe fire. In 1619, it came under artillery fire during the new war, and three years later the dome of the main tower was split in two by lightning. In 1844, the architect Josef Kraner presented a program for the completion of the temple, which mainly envisaged the reconstruction of the already built building, but only in 1861 was the Church Restoration Society created and in

1929, after 585 years, the construction was completed (Fig. 6). The length of the main part of the temple is 124 meters, the highest, the southern tower, is 96.5 meters high. On the west side, two 82-meter Neo-Gothic stone towers are erected. The three portals of the cathedral are richly decorated with sculptures, stone and bronze reliefs During the construction process, 10 architects were replaced, and many sculptors and artists of several generations participated and contributed to this work.

Fig. 6. St.Vitus Cathedral in Prague

Milan Cathedral (Italy) is the largest building in the world made of white marble. Its construction lasted from the end of the 14th century to the middle of the 20th century. To be exact, 579 years. It is very impressive in its size and the deliberate use of various architectural styles. It is the fourth largest Christian cathedral in the world. According to legend, in 1386, in a dream, the devil demanded that the architect Gianluca Galeazzo Visconti build a building decorated with numerous demonic images. Otherwise, he would be doomed to eternal torment. In accordance with the agreement with the church, he began to fulfill this task, but soon (1402) he died. The cathedral was built not in the name of the devil, but of the 3,400 sculptural compositions in its interior and exterior, 96 are demonic in nature. Construction, which began in 1388, was often stopped in order to make significant changes to the project. Therefore, the architecture of the cathedral does not belong to any one style, but is a kind of mixture of them with unadorned spires. The length of the cathedral is 158 meters, the height of the main spire is 106.5 meters. At the same time, the cathedral can accommodate 40,000 people. The main landmark of the cathedral is the golden statue of the patron saint of Milan located on the spire of the cathedral (Fig. 7).

Fig. 7. Milan Cathedral

Angkor Wat, a Hindu temple built in Cambodia in honor of the god Vishnu, is one of the largest cult buildings in the history of mankind. It occupies a huge area. It was built as a city-temple and is a three-tiered truncated pyramid with towers on top. Its total height reaches 65 meters and it is surrounded by a rectangular wall and an artificial reservoir measuring 1.5 X 1.3 km. It has only one entrance from the west. The path from the entrance tower to the temple is bordered by a parapet decorated with sculptures. Angkor Wat is an outstanding example of the fusion of architecture and sculpture. Of particular note are the bas-reliefs located on the galleries surrounding all three tiers of the temple (Fig. 8). The construction of the first buildings of the complex began in 802 AD and was completed in 1220, and the construction lasted 418 years. After its completion, the population soon abandoned the site for unknown reasons. The city, which had become a ruin, was almost merged with the jungle. Only at the end of the 16 th century was this forgotten city briefly mentioned by Portuguese missionaries, but efforts to restore it began 1981.

Fig. 8. Angkor Wat

Fig. 9. Chichen Itza

Chichen Itza, the cultural and political center of the Maya civilization, is a city with a large number of buildings of various purposes and sophisticated architectural styles on the Yucatan Peninsula in Mexico. One of the New 7 Wonders of the World, Chichen Itza is a vivid example of the realization of the capabilities of the Maya Indians as a people of a distinctive and highly developed ancient civilization. Scientists agree that construction began in 600 AD and was completed 400 years later. The total area of this massif is several square kilometers. The most famous building of the complex is the "Temple of Kukulkan", a 24-meter-high 9-step pyramid with wide stairs on all sides (Fig. 9). It was built to better see and hear the orator standing on it, and a number of acoustic features were carefully considered. .It is noteworthy that during the construction, the Mayan Indians did not use either the wheel or the live power of domestic animals. All buildings were built by human hands. In the 13th century, the city was plundered and raided by enemies. After that, the influence of the Mayan people gradually weakened, and soon, for a long time, this unique settlement was completely abandoned.
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Conclusion

1. Most of the world's most famous ancient constructions took from several tens of centuries to several millennia to complete. Despite the unlimited number of workers, the work was mainly hampered by an extremely high proportion of manual labor. A lot of time was spent refining the project, which often underwent significant changes during the construction process, and, most importantly, problems with financing almost always arise during grandiose constructions;

2. As a result of analyzing the longest constructions in the world, it can be said with certainty that the longest time, 20 centuries, was spent on the construction of the Great Wall of China. The Great Pyramid of Cholula in Mexico was built for 11 centuries. The construction of the city of Petra took 8.5 centuries. The cathedrals of Cologne, St. Vitus, and Milan were built around the 6th century, while the construction of the Angkor Wat (Cambodia) and Chichen Itza (Mexico) complexes continued for the 4th century.

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Climate Change and Urban development in Tbilisi: Challenges and Responses

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Abstract. Urbanization and climate change pose growing risks to global cities, with 70% of the world's population projected to live in urban areas by 2050. Tbilisi, Georgia's capital, faces environmental challenges like air pollution, heatwaves, flooding, and land instability, exacerbated by climate change and rapid growth. In response, the city has adopted several strategic plans, including the Tbilisi Land Use Master Plan, Green City Action Plan, and Resilience Strategy 2030, focusing on sustainable urban development, green infrastructure, and climate resilience. National reforms aligned with the EU framework support these initiatives. Moving forward, integrated planning, technical solutions, public participation, and improved communication are vital for building a safer, greener, and more resilient Tbilisi.

Key words: Urbanization; Climate Change Tbilisi; Sustainable Development; Urban Resilience; Green Infrastructure; Urban Planning; Disaster Risk Reduction;, EU-Georgia Association Agreement; Climate Adaptation; Public Participation; Urban Mobility; Environmental Policy; Heatwaves; Flooding.

1. Introduction

Cities are the global future with more population projected to reside in urban areas in the coming decades. By 2050, 70% of the world's population is expected to be living in urban areas.

Humanity faces a dangerous threat from urbanization and climate change, which converge to negatively impact quality of life and stability. Despite these threats, there are significant opportunities. Urban areas, though heavily impacted, can develop strategies for climate mitigation and adaptation. Cities can help address the need to adapt to climate change and mitigate its drivers, aiming to keep global temperature increases within 2 to 2.4°C above pre-industrial levels, as outlined in the UNFCCC.[1]

As Georgia's capital, Tbilisi has a long history that goes back over fifteen centuries. Thanks to its key location on the crossroad of the east and west, Tbilisi became an important cultural, political and economic center of the region, developing into a melting pot of oriental and western cultures, whist still maintaining its strong identity.

Tbilisi is a self-governing city with defined boundaries, symbols (e.g. flag and coat of arms) and assets, with an ambitious vision to become one of the leading smart, sustainable cities in the United Nations
Economic Commission for Europe (UNECE) region and beyond. It has registered an impressive progress in implementing the 2030 Agenda for Sustainable Development (2030 Agenda), capitalizing on the growth opportunities generated by the Association Agreement between Georgia and the European Union (EU).[2]

2. Urban Development in the Face of Climate Change

According to the most recent data, 59 percent of the country's population lives in urban areas, while Tbilisi accounts for 32 percent of Georgia's population.[3] Therefore, Tbilisi faces a number of serious environmental challenges, particularly in the area of urban development and transport. There is no denying that urbanization makes cities richer. Newcomers attracted by the opportunities that the city offers start businesses or join growing companies, which

[1] Cities and Climate Change: Global Report on Human Settlements, United Nations Human Settlements Programme (UN-Habitat), London * Washington, DC, 2011, 9-10

[2] Smart Sustainable Cities Profile – Tbilisi, Georgia, United Nations, United States of America, 2023, 1-2

[3] Population by regions and urban-rural settlement, National Statistics office of Georgia, 2020

fuels all sectors of the local economy[4]. Due to massive recent growth in these sectors, air pollution was the top environmental concern of Georgian citizens in a 2019 opinion poll.[5] Urban mobility infrastructure have led to overutilization of the existing urban transport systems and a strong increase in motorized individual traffic. The traffic management and transport modes of the city therefore need to be aligned with climate protection goals and to contribute to better living conditions for the population.[6]

Tbilisi's geographic location—a coastal city subject to flooding—is impacted by climate change. Extreme heat and drought have made this climate threat worse in recent decades. The number of days in which the heat index in Tbilisi reached unsafe levels increased by 14 when the temperature values from 1961–1985 were compared to 1986–2010. The maximum temperature of 40.6 °C was recorded in July 2021. The loss of green cover has been aggravating the urban heat island effect, with adverse consequences for biodiversity and human health (WBG and ADB, 2021).[7] Urban Heat Island effects amplify Tbilisi's heatwaves, impacting human health. Combined with climate change and future urban expansion, this will likely harm the service sector's productivity, affecting labor and increasing adaptation costs.[8]

Apart from the above mentioned impacts, Tbilisi is experiencing some key shocks, such as: Fooding, Seismic risk, Landslides and Ground instability**.**

In resilience terms, a shock is a sudden or acute event that threatens Tbilisi's immediate wellbeing. A shock could be an earthquake, infrastructure failure, an extreme weather event, or civil unrest.

During the industrialisation of the city, much of the industrial infrastructure was built into the ravines, which today have become unsafe areas, due to the risk of flooding. During the June 2015 floods, heavy rainfall in the Vere basin and its tributaries triggered large scale landslides and debris flows, putting two motorways out of use. Residential buildings and and Tbilisi Zoo located at the low elevations in the River Vere Gorge were significantly damaged or/and totally destroyed. Over 21 people were killed, and over 1000 people lost their homes or businesses.[9]

This terrible shock became a turning point for Tbilisi to join 100RC network in 2016, May. The aims of Resilient Tbilisi can only be achieved through local, national and international partnerships.

3. Governmental Responses and Strategies

Disaster risk reduction and climate change adaptation are crucial for city resilience. To reduce the "urban heat island" effect, attention has focused on urban management, sustainability, planning, and green infrastructure. Integrating these with metropolitan development requires a systems-oriented approach to risk assessments and planning, using current climate data and future projections. Effective multilevel governance and integration are essential, demanding significant governance capacity and financial resources. Efforts are aimed at sustainable development, with international and national policy frameworks, to create future cities that

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[4] Tbilisi: a Growing City with Growing Needs, Yaroslava Babych, Luc Leruth, 2020, available at <https://iset-pi.ge/en/blog/75-tbilisi-a-growing-city-with-growing-needs>

[5] Green City Action Plan for Tbilisi – A Mere Formality?, CEE Bankwatch Network, 2020, available at: <https://bankwatch.org/publication/green-city-action-plan-for-tbilisi-a-mere-formality>

[6] Sustainable urban mobility in Georgia (SUM Tbilisi) - Project implementation and accompanying measures Consultant, available at: <https://www.gopa-infra.de/projects/sustainable-urban-mobility-georgia-sum-tbilisi-project-implementation-and-accompanying>

[7] Smart Sustainable Cities Profile – Tbilisi, Georgia, United Nations, United States of America, 2023, 6

[8] Climate Risk Country Profile - Georgia, Asian development bank, World Bank Group, 2021, 2

[9] Resilient Tbilisi, A strategy for 2030, Tbilisi, Gegia, 2019, 13

are sustainable and improve quality of life.[10]

Cities have a vital role to play in the implementation and achievement of commitments within the international climate change framework. They also stand to benefit from the opportunities created by this framework for local responses to climate change.

While Tbilisi's local government manages spatial planning and urban development, key policies are set and implemented at the national level, aiming for inclusive growth addressing economic, social, and environmental sustainability. National reforms advanced in 2014 with Georgia's Association Agreement with the EU, integrating Georgia into the EU regional bloc through the Deep and Comprehensive Free Trade Area (DCFTA). The DCFTA requires Georgia's laws to align with EU standards, driving national legislative and institutional reforms across all sectors. Annex 2 summarizes urban-related policies and laws under the central Government's responsibility.[11] As of 2022, Georgia has harmonised over 50 per cent of the EU Regulations and Directives of direct relevance to urban development and has adopted most of the European harmonised standards.

The Ministry of Environmental Protection and Agriculture (MOEPA) handles environmental policy, climate change impact assessments, and climate strategies. In 2022, MOEPA implemented Georgia's 2030 Climate Change Strategy to reduce GHG emissions by at least 35% below 1990 levels by 2030. MOEPA also launched an online portal for publishing Environmental Impact Assessments (EIAs) and Strategic Environmental Assessments (SEAs), managed by the National Environment Agency, to improve transparency and public-private consultations, alongside efforts to enhance Georgia's environmental and hydrometeorological monitoring system.[12]

Tbilisi has an ambitious urban development agenda best expressed in the following city planning documents:

- Tbilisi Land Use Master Plan (2019) – defines legal zones and basic parameters for land use and specifies spatial-territorial requirements for environment protection and heritage preservation, as well as economic, transport and infrastructural development necessities and directions for the whole city. The Master Plan, in particular, lays out the following concepts which Tbilisi should strive for: a compact city, green city, well connected city and resilient city. The "green city" concept in the Master Plan refers to an integrated approach for the improvement of environmental and recreational conditions.[13]
- Green City Action Plan 2017-2030 – identifies priority measures for reducing CO2 emissions by around 450,000 tons per year and generating water savings of around 55 million m^3 per year[14]. In the area of urban transport, the action plan aims to reduce at least 85% of the current air pollution through the introduction of new compressed natural gas buses.[15]
- Tbilisi Resilience Strategy for 2030 (2019 edition) – aims at supporting the development of "a resilient and vibrant city, where residents are protected and safe, where there is access to opportunity and healthy natural environments and where we are empowered to plan ahead, ready respond to any challenge". Goal 8 of the strategy aims to develop Tbilisi's climate change strategy actions, as follows:
  - ✓ This goal supports two targets within the EU Georgia Association Agenda: • Start implementing new global agreement on Climate Change (Paris Agreement) • Ensure

[10] Interdependency between Climate Change and Urbanization, Pallavi Tiwari, Aditi Arora, Kavita Nagpal, 2023, available at: <https://www.researchgate.net/publication/373689845_Interdependency_between_Climate_Change_and_Urbanization>

[11] Smart Sustainable Cities Profile – Tbilisi, Georgia, United Nations, United States of America, 2023, 24

[12] For strategic documents on the 2030 Climate Change Strategy of Georgia, see https://mepa.gov.ge/En/ PublicInformation/32027.

[13] Green City Action Plan for Tbilisi – A Mere Formality?, CEE Bankwatch Network, 2020

[14] Smart Sustainable Cities Profile – Tbilisi, Georgia, United Nations, United States of America, 2023,17

[15] Green City Action Plan for Tbilisi – A Mere Formality?, CEE Bankwatch Network, 2020

public access to environmental information and public participation in decision-making. • Infrastructure Adaptation Climate Change Commitment[16]

- Sustainable Urban Mobility Plan (2019-2030)
- Tbilisi Transport Plan (2023-2043).[17]

4. Conclusion

Growing awareness of the link between urbanization and climate change has spurred national and international efforts to develop policies, goals, and guidelines to mitigate its adverse effects. Supporting Tbilisi in adapting to climate change necessitates collaboration across sectors like ecosystem management, biodiversity conservation, urban planning, energy efficiency, and infrastructure rehabilitation. These actions safeguard city infrastructure and ecosystems for the benefit of Tbilisi's residents in the long term.

With numerous plans under different national and international processes, it is important to have clear instruments for implementation and monitoring. Furthemore, in order to mitigate the impacts of climate change in urban planning and architecture, various technical solutions should be employed. These include green roof systems, ground drainage and rainwater harvesting systems, porous pavement systems, and other innovative approaches.

A step forward would be participatory planning, where public involvement in city development is essential for successful urban planning. Public participation ensures a balanced approach between the public and private sectors.

To sum up, the city should provide citizens with more substantial information about strategic documents, clearly communicating the need for climate action and adaptation, and how these efforts can improve quality of life. Effective communication between scientists, planners, managers, and the public is essential to make Tbilisi a "green city."

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Taking into account the decrease in concrete strength in reinforced concrete buildings during long-term operation when designing reconstruction and reinforcement works

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Abstract: The reasons for the decrease in the strength of concrete in reinforced concrete building structures during long-term operation are considered. The results of the study were taken into account in the VII GTU.The building (which was built in the 1960s) When developing the reconstruction and strengthening project for the structures.

Key words: Concrete strength, service life, actual strength, climatic conditions, design, reinforcement, beam.

Introduction

Three types of normative exploitation periods of buildings and structures are distinguished:

1. **Design period of exploitation.** This is the period that designers set when creating an object, based on design solutions, properties of building materials and expected operating conditionsThe validity period is:

- *For residential, public and industrial buildings - not less than 50 years.*
- For buildings with monolithic walls and floors l – more than 100 years.

2. **Actual operating time.** It depends on real operating conditions. For example, exposure to aggressive environments, frequent and sharp changes in temperature and humidity, improper maintenance of structures can significantly reduce the estimated service life.

3. **Remaining service life**. It is determined based on the results of a technical inspection of the building and determines the service life without major repairs or reconstruction. [1] .

The aim of the article is to analyze the change in the strength of concrete in buildings constructed from monolithic reinforced concrete, which have been in operation for a long time, and to use its results in the reconstruction of buildings.

It is known that the physical and mechanical properties of concrete, including strength, change over time. After pouring the structure, the increase in concrete strength under appropriate conditions occurs intensively in the initial period and then slows down.

Увеличение прочности бетона с течением времени можно приблизительно определить по логарифмической зависимости [2]:

$$R_n = R_{28} \frac{\lg n}{\lg 28}$$

Where:: R_n და R_{28} - concrete strength at the age of n and 28 days respectively, MPa;

n- Age of concrete, day and night

Table 1 shows average data on the increase in strength of Portland cement concrete over time.

Table 1. Increase in the strength of concrete made with Portland cement over time.

Concrete ages day and night.	Relative compressive strength R_{28}=1	Age of concrete in years	Relative compressive strength R_{28}=1
7	0,6-0,7	1	1,75
28	1,0	2	2,0
90	1,25	4-5	2,25
180	1,5		

During operation, over time, the actual strength of concrete will be significantly lower than the standard. Its strength (and therefore service life) depends on the operating conditionsThe main factors affecting the durability of concrete are: The main factors affecting the durability of concrete are:

- Chemical impact;
- Impact of mechanical loads;
- Quality of preparation and laying of concrete

mix. Failure to comply with technological standards may lead to the formation of defects that reduce the durability of the material;

• Human factor. Insufficient knowledge, inexperience and carelessness may lead to errors at various stages of construction.

In the case of long-term operation of buildings and structures, when the strength of concrete is significantly reduced due to the impact of the above-mentioned negative factors, which creates a threat to the further operation of the building (or its individual structural element), there is a need for reconstruction-reinforcement of the said structural elements (or the building as a whole). If the cost of reconstruction is significant, there is a need to dismantle the structure (or the entire building) and build a new one.

The above considerations were taken into account by the authors of the article when planning the work to strengthen and reconstruct the VII building of the Tbilisi State Technical University, built in he 1960s (see photo 1).

photo 1

Main Part

The VII building of the Tbilisi State Technical University is a 5-storey building with reinforced concrete longitudinal and transverse load-bearing walls and wooden interfloor ceilings, the load-bearing structure of which is monolithic reinforced concrete beams located across the building (see Fig. 1-4).

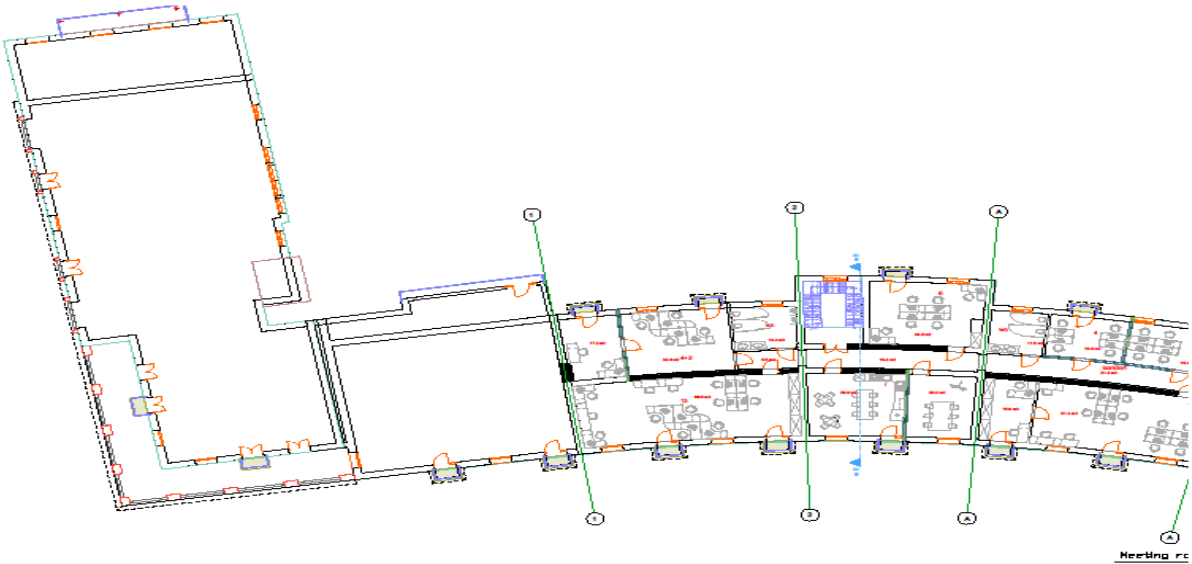


Fig. 1 Floor plan of the third floor

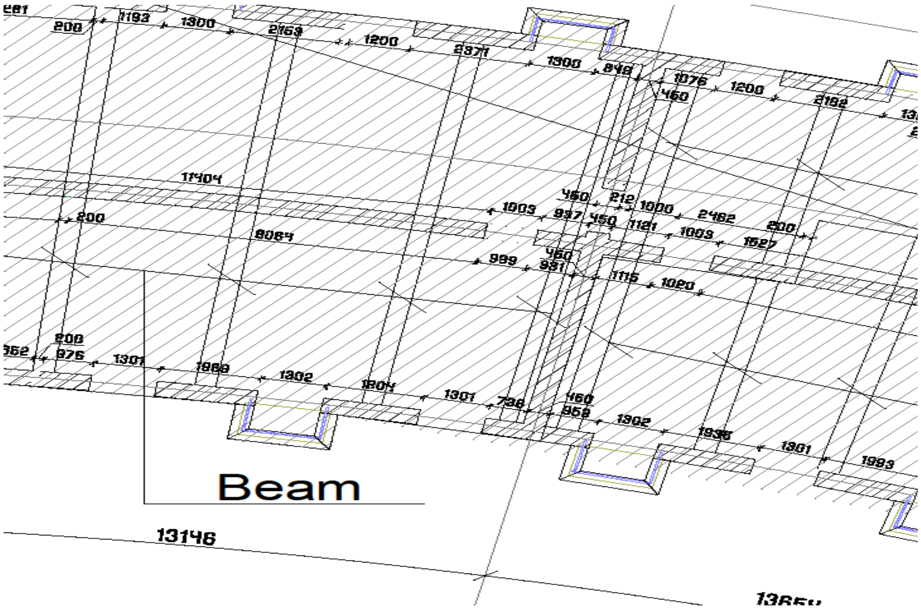


Fig. 2 Fragment of the plan showing the ridges

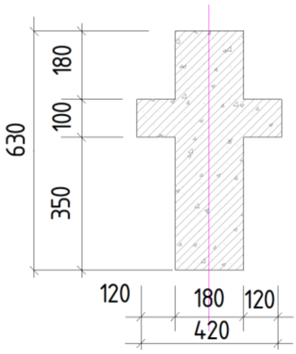


Fig. 3 beam section

Wooden floor installation scheme

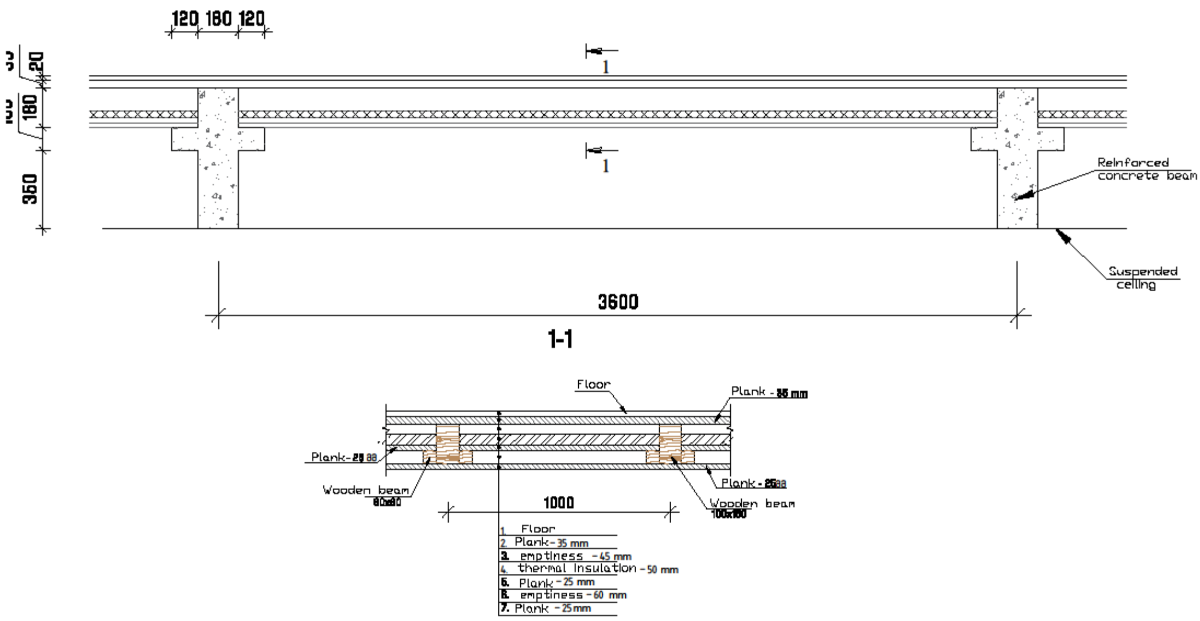


Fig. 4 Scheme of installation of new floor

Work on strengthening and restoring the building is expected to be carried out in accordance with the design project we have developed [3].

Due to the long-term operation of the building (about 70 years) as a result of the impact of the negative factors described in the introduction, the average strength of the concrete of its load-bearing walls (tuff rubble was used as a concrete filler) decreased to approximately 70 kg/cm2 (class B10), while the average strength of the concrete of the beams of the interfloor ceiling is 240 kg/cm2 (class B15).

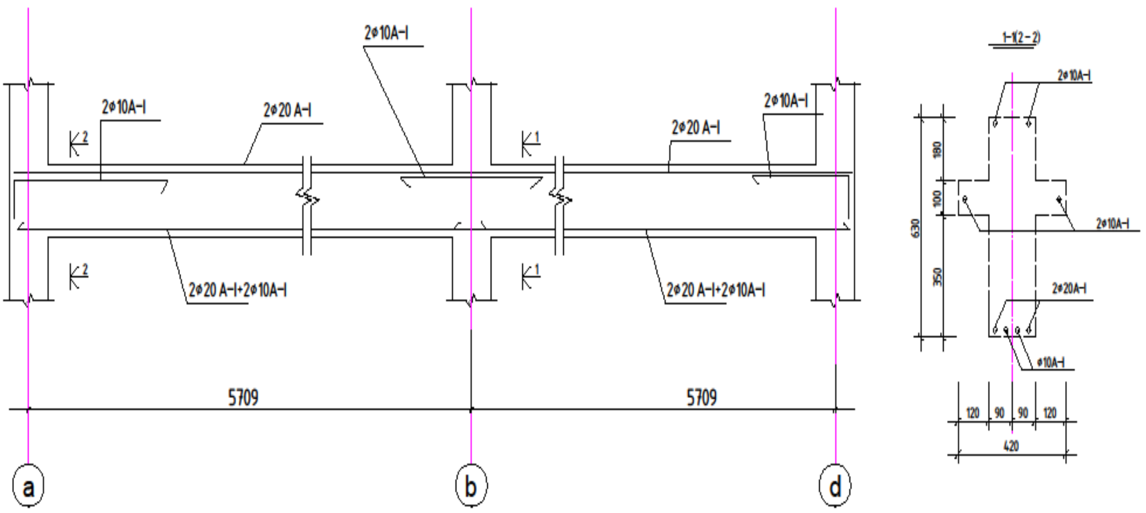


Fig. 5 Reinforcement of a two-span beam

The building has 2 types of beams: 2-span and 3-span. They are continuous beams

Note: Before starting work on strengthening the beams, it is obvious that the heavy wooden interfloor floors resting on them (which are damaged) must be dismantled, and after strengthening the beams, it is necessary to install light wooden interfloor floors.

The beams are reinforced with smooth reinforcement (due to the absence of periodic section reinforcement at that time). The reinforcement of the beams is shown in Figures 5 and 6

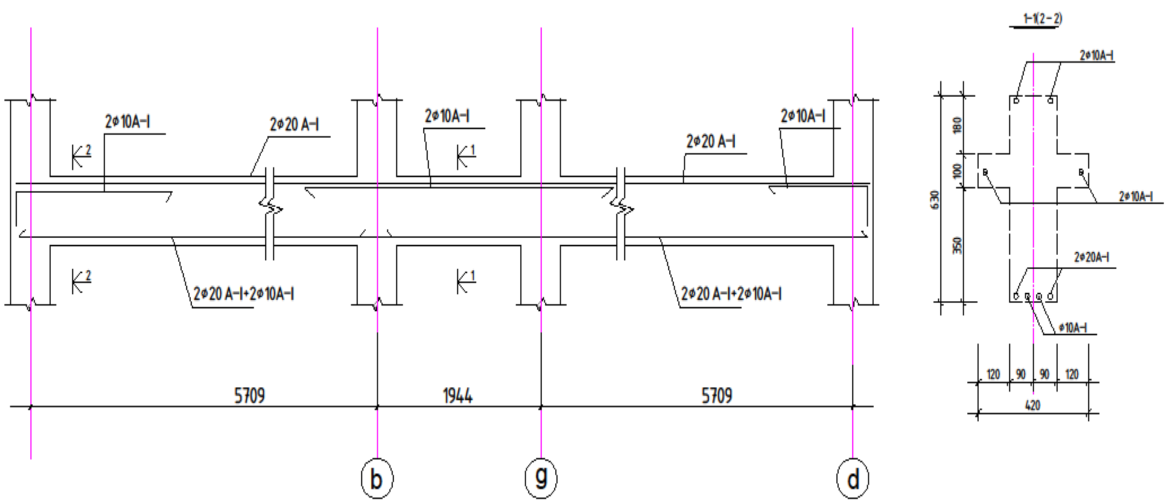


Fig. 6 Reinforcement of a three-span crossbar

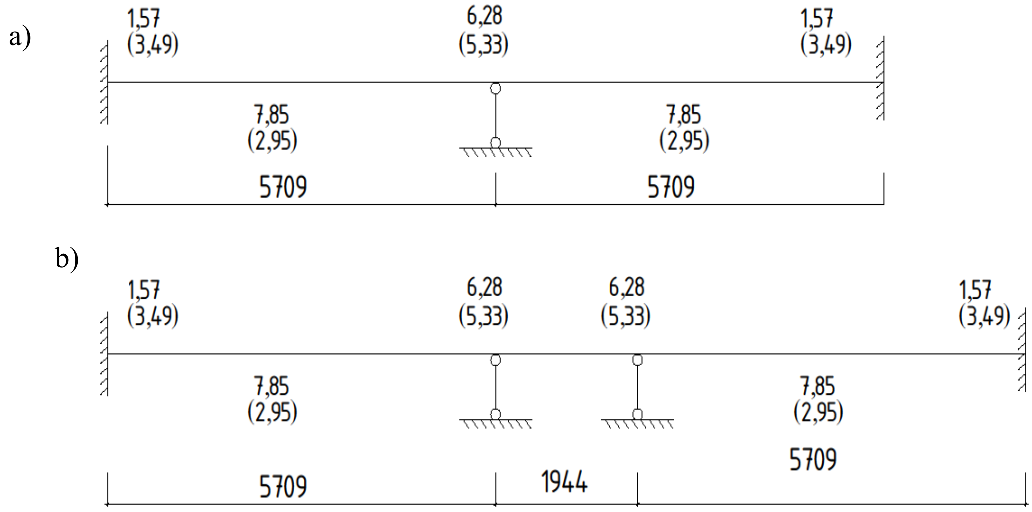


Fig. 7 shows a comparison of the required reinforcement of the beam cross-sections obtained by calculation with the existing reinforcement.

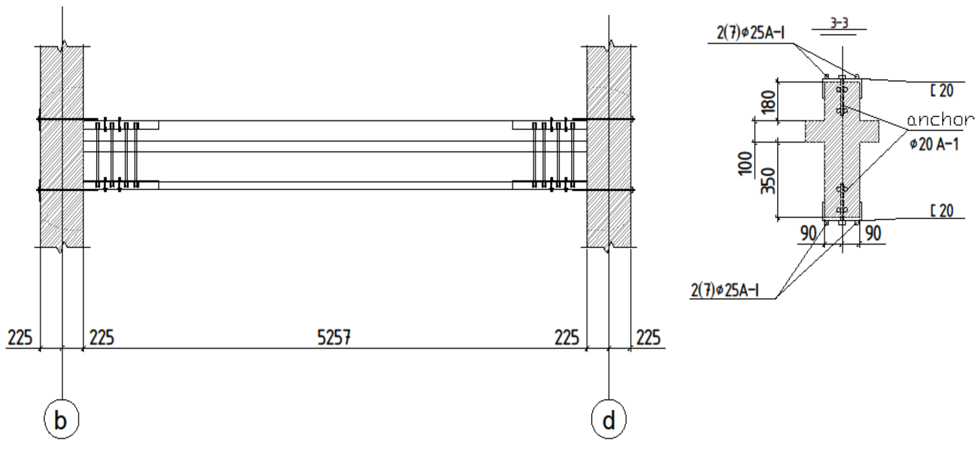
As a result of the computer spatial calculation of the building (obviously, taking into account the actual strength of the concrete of its walls and beams), the area of the obtained reinforcement (A500c) of the beams and its comparison with the existing one are shown in Fig. 7. a) Two-span beam; b) Three-span beam Note: The numbers without brackets reflect the existing reinforcement area of the beam sections, and those in brackets reflect the required area obtained as a result of the calculation.

It is evident from Figure 7 that the existing reinforcement of the beams is insufficient. (Moreover, it is also important to consider that in the future the strength of concrete will decrease even more). At the same time, the reinforcement in the beams corresponds to class A-I, while the required reinforcement obtained by calculation corresponds to class A 500.

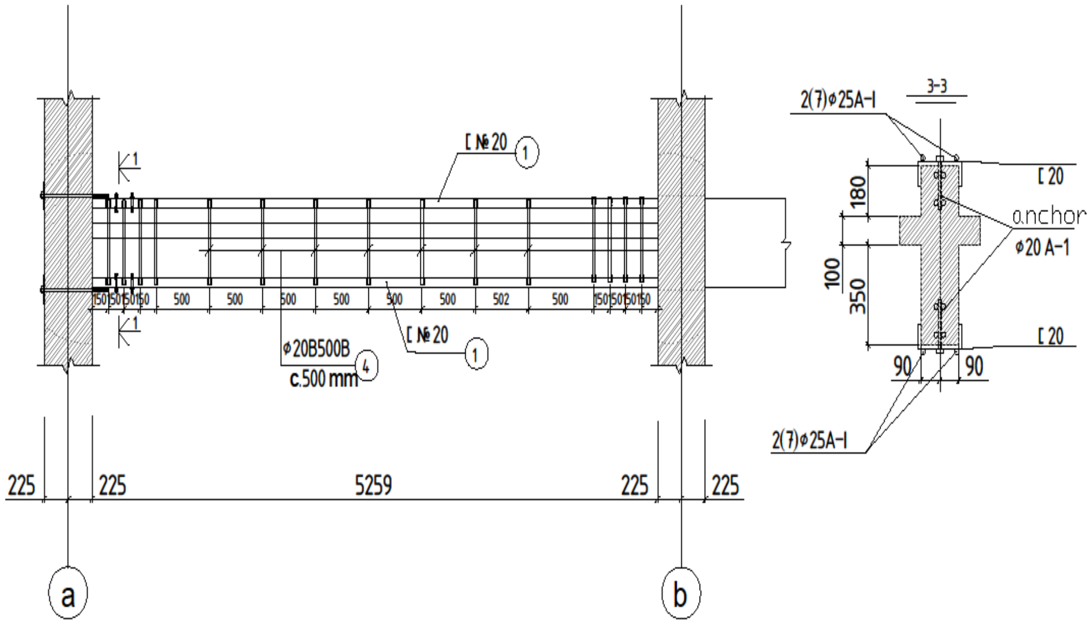
Because increasing the area of reinforcement of beams (both on supports and in the span) is impossible, and their dismantling and installation of new structures is unprofitable - for two reasons:

As a comparison of the actual and calculated reinforcement shows, reinforcement on the edge supports is usually insufficient. We will have two design solutions for reinforcing the beams:

1. Large financial costs are required;
2. The load on the lower part of the roof will increase due to the breakage of the rafter material. For the reasons stated above, it was decided to strengthen them with steel profiles.



Rice. 8. Reinforcement of beams in the support zone



Rice. 9 Reinforcement of beams along the entire length of the material

As a comparison of the actual and calculated reinforcement shows, reinforcement on the edge supports is usually insufficient. We will have two design solutions for reinforcing the beams:

1. Reinforcement of all beams of all floors in the support zone (except for the meeting room, where the useful load will be high);
2. Reinforcement of beams along the entire length (in the meeting room).

For design solutions for reinforcing beams, see Figures 8 and 9.

Conclusions

Upon expiration of the standard service life of buildings and structures, it is necessary to conduct an inspection of their technical condition, including spatial computer calculations taking into account the actual, changed (deteriorated) properties of materials. Based on the results obtained, a decision should be made:

• When the entire building is in a state of disrepair, it is obvious that it should be demolished and a new one built;

• If it is not the entire building, but its individual structural elements, that are in a state of emergency, they need to be reinforced in such a way that the safe operating life of the building (i.e. the remaining operating life) is increased for a considerable period of time.

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Asphalt Concrete Durability

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Abstract: In road construction, asphalt concrete pavement undergoes intense mechanical and physical impacts during operation, ultimately leading to its deterioration. The most characteristic factors include impact loads and wear caused by moving vehicles, water saturation of the material, the accompanying freeze-thaw cycles, and salt corrosion. The negative impact of these factors is intensified by the accumulated residual deformations in the material, caused by operational loads and uneven foundation settlement. Ultraviolet radiation from the sun and the action of atmospheric oxygen lead to the aging of the binder, manifested in an increase in its hardness.

Keywords: Asphalt concrete, hardness, plasticity, water saturation, water resistance, frost resistance, wear resistance, fire resistance, temperature factor, freeze-thaw cycle, aging.

Introduction

Static and repeated cyclic loads cause the accumulation of irreversible deformations in asphalt concrete, eventually reaching a critical threshold. In water-saturated and frozen asphalt concrete, additional internal deformations develop, which combine with external loads, accelerating the process of irreversible deformation and ultimately leading to material degradation.

Main part

The deterioration of asphalt concrete is visually manifested by the appearance of cracks on the surface, primarily around large aggregates, with the disintegration of particles and the loosening of the material.

Asphalt concrete is a porous material. Properly selected and carefully compacted asphalt concrete primarily contains closed (or conditionally closed) pores, the quantity of which increases as the size of the aggregate particles decreases. Without external load, these pores do not fill with water. However, if the wet surface experiences brief compression (from moving traffic), some of the water is expelled from the pores, and during the release of pressure, due to the material's elastic recovery, a vacuum is created in the pores, causing water to be drawn into them from the surface. As this process repeats multiple times, water significantly fills or completely fills the pores in the surface layer of the pavement. Since water is practically an incompressible liquid, under the influence of external loads, it is forced into the micro-pores formed in the contact zone between the aggregate and the bitumen, leading to the detachment of the bitumen layer from the aggregate particles.

The water absorbed in the micro-pores of the asphalt concrete structure causes adsorptive desorption, leading to the opening of micro-defects and a reduction in structural bonds. With repeated wetting and drying, these defects accumulate. The deterioration of water-saturated asphalt concrete deepens with the presence of clay impurities on the surface of the mineral aggregates. When the clay particles absorb moisture, they accelerate the process of bitumen detachment from the surface of the mineral grains.

When water freezes in the pores of asphalt concrete, which always occurs on the surface layer, the ice crystals formed from the frozen water exert pressure on the remaining liquid water in the closed pores, causing it to fill the pores. When the water saturation of the pores reaches a critical level (theoretically no less than 91%), subsequent freezing leads to dangerous tensile stresses, resulting in plastic (irreversible) deformations, with the volume of the pores increasing irreversibly. During thawing, the volume of ice decreases (by approximately 9%), and the pressure in the pores becomes lower than atmospheric pressure, causing a certain amount of water to be absorbed into the pores. With repeated freezing and thawing, the accumulated irreversible deformations reach a critical point, leading to the formation of initial micro-defects, which then accumulate and enlarge, eventually transforming into macro-defects. From the moment macro-defects caused by freezing appear, the deterioration of asphalt concrete increases progressively, as these defects also fill with water, becoming a source of internal stress.

The weakest point in asphalt concrete is the contact between the asphalt binder and the coarse aggregates. This is primarily due to the difference in the coefficients of thermal expansion between the stone materials and bitumen: the volumetric thermal expansion coefficient of stone materials averages around 1×10^{-5} °C, while for bitumen it is approximately 8×10^{-5} °C, meaning it is nearly one order of magnitude higher. As a result, during temperature changes, bitumen experiences much more deformation than the mineral aggregate. At positive temperatures, the generated thermal stresses relax quickly, and the "aggregate-bitumen" contact remains intact. However, at negative temperatures, when bitumen becomes elastic and brittle, the thermal stresses increase significantly due to reduced relaxation, leading to the detachment of bitumen from the aggregate particles. Water enters the formed cracks, which, upon freezing, expands, causing the bond between the large aggregate particles and the surrounding bitumen to break.

A key factor in the durability of asphalt concrete is the aging of bitumen, which manifests as an increase in viscosity, a loss of plasticity, and the appearance of brittleness, even at positive temperatures. The properties of bitumen change due to the effects of heat, solar radiation, and oxygen in the air. This results in the evaporation of lighter fractions, oxidation of hydrocarbons, the formation of free valence bonds, and their subsequent polymerization, leading to the creation of more viscous and rigid substances.

The stability of petroleum bitumen under the influence of air and solar radiation depends on the content of methane, naphthenic, and aromatic hydrocarbons. As the amount of oxygen-containing, nitrogenous, and sulfur compounds increases, the stability of bitumen decreases. Oxidation processes are intensified by an increase in the porosity of asphalt concrete, which allows better penetration of water and air.

Bitumen undergoes maximum oxidation and polymerization in the surface layer of asphalt concrete, which is also exposed to other detrimental influences such as mechanical stress, water saturation, freezing and thawing, and more. The impact of these processes decreases with depth, and at certain depths, it may not manifest at all. Depending on the quality of the asphalt concrete, bitumen aging can extend to a depth of 2 to 6 cm.

The aging process of bitumen is influenced by the mineral composition of the asphalt concrete. Adsorptive processes also change the group composition of bitumen and contribute to its structuring. The molecules of bitumen hydrocarbons become less mobile in the adsorptive layers compared to free bitumen, which reduces its reactivity. Regarding the loss of bitumen's plasticity, the increase in viscosity and brittleness worsens the properties of asphalt concrete. It becomes stiffer and less plastic.

Water saturation is characterized by the amount of water absorbed by a water-saturated asphalt concrete sample under a specified regime. Water saturation is determined on samples prepared in the laboratory or cut from the surface (core samples). For this purpose, cylindrical-shaped samples are used.

The determination of water saturation is carried out as follows: Asphalt concrete samples are initially weighed in air. Then, they are placed for 30 minutes in a water bath at a temperature of 20±2°C, where the sample should be covered by at least 20 mm of water. Afterward, the samples are weighed in water and placed again in a water bath at a temperature of 20±2°C. The water level above the samples should be no less than 3 cm.

The container with the samples is placed in a vacuum apparatus, where the pressure is no more than 2000 Pa (equivalent to 15 mm of water). This process lasts for 1 hour. Then, the pressure is gradually released to atmospheric pressure, and the samples are left in the chamber for an additional 30 minutes. Afterward, the samples should be removed, weighed in water, gently dried with a soft cloth, and weighed in air.

The water saturation W of the sample, in percentage, is calculated using the following formula:

$$W = \frac{m_3 - m}{m_2 - m_1} \cdot 100 \quad (1)$$

- m is the weight of the sample in air, gr.
- $m_1$is the weight of the sample after being immersed in water for 30 minutes and weighed in water, gr.
- m_2 is the same sample weighed in air, gr.
- m_3 is the weight of the water-saturated sample weighed in air gr.

This formula calculates the percentage of water saturation in the asphalt concrete sample.The water saturation value is taken as the arithmetic mean of the three samples rounded to the nearest tenth. Water saturation is standardized only for dense and high-density hot asphalt concrete mixtures (Table 1).

The normative requirements for water saturation. Table 1

Type and grade of asphalt concrete.	Volume water saturation, %.	
	For samples formed from the mixture.	For cores extracted from the finished pavement, not exceeding.
High density.	1...2,5	3,0
Dense type.		
A	2,0...5,0	5,0
B, C, D	1,5...4,0	4,5
E	1,0...4,0	4,0

For cold asphalt concrete mixtures, water saturation should be between 5% and 9% (by volume).

The magnitude of water saturation depends on the structure of the asphalt concrete. As the content of mineral aggregates increases, the volume of pores also increases, resulting in a higher number of open pores. This is confirmed by numerous data (Fig. 1).

In the figure:

Curve 1 represents the water saturation of the asphalt binder,

Curve 2 represents the water saturation of the asphalt mortar,

Curve 3 shows the water permeability of asphalt concrete after prolonged exposure to water.

The swelling of asphalt concrete is characterized by its hydrophilic properties and the degree of bitumen adhesion to the surface of mineral aggregates. Swelling is defined as the increase in the sample's volume after being saturated with water under vacuum. The determination of swelling is based on the data obtained during water saturation testing.

The swelling of asphalt concrete is determined in volumetric percentage:

Swelling

$$V = \frac{(m_3 - m_4) - (m_1 - m_2)}{m_1 - m_2} \cdot 100 \quad (2)$$

- m1 – the mass of the sample after being immersed in water for 30 minutes and weighed in air, grams;
- m2m_2m2 – the same sample weighed in water, grams;
- m3m_3m3 – the mass of the vacuum-saturated sample weighed in air, grams;
- m4m_4m4 – the same sample weighed in water, grams.The swelling value is taken as the arithmetic mean of three samples, rounded to the first decimal place.

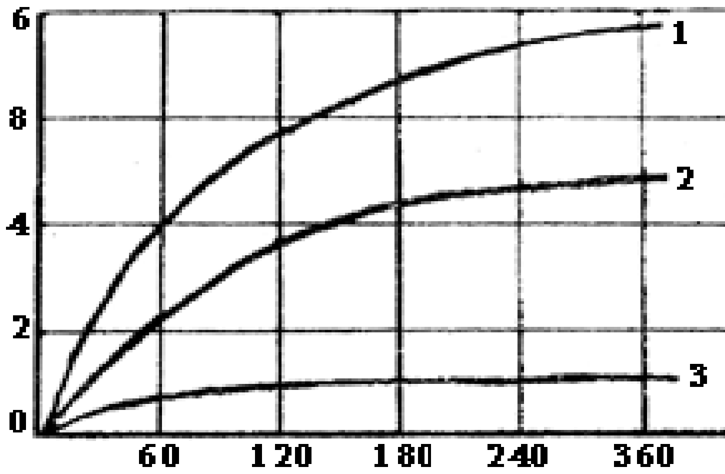

Fig. 1. Change in water saturation over time:
1 – Asphalt binder; 2 – Asphalt mortar; 3 – Asphalt concrete

The water resistance of asphalt concrete is determined by the water resistance coefficient, which indicates the extent to which its strength decreases after water saturation and characterizes the asphalt concrete's resistance to the destructive action of water.

The water resistance coefficient is determined for all types of hot and cold asphalt concrete mixtures, except for coarse-grained mixtures. There are two methods for determining water resistance.

The first method considers the reduction in sample strength due to water exposure under a vacuum. For this purpose, the same samples used for determining water saturation and swelling can be utilized.

The water resistance coefficient Kw is determined with an accuracy of one decimal place using the following formula:

$$K^w = \frac{R_k^w}{R_k^{20}} \quad (3)$$

Where: R_k^wThe compressive strength limit of the sample saturated with water under vacuum is in MPa;

R_k^{20}The same sample's compressive strength before water saturation at 20±2°C is in MPa.

The second method differs from the first in that the samples saturated under vacuum are transferred to water at a temperature of 20±2°C and left for 15 days. After this period, the samples are tested for compressive strength.

The results of the second method for testing water resistance are lower than those of the first method. Therefore, according to the requirements of the normative documentation, the determination of the water resistance of asphalt concrete must be carried out using both methods.

The frost resistance of asphalt concrete is determined by the reduction in compressive strength due to the effects of a defined freeze-thaw cycle. The method is as follows: Samples saturated with water under vacuum at a temperature of 20±2°C are frozen in a chamber at a temperature of -18±2°C for 4 hours. After this, the samples are transferred to a water bath at a temperature of +18±2°C, where they thaw for 4 hours. For the specified freeze-thaw cycles (5, 10, 15, 25, 50 cycles), the samples should be held for 2 hours in a water bath at a temperature of 20±2°C and then tested for compressive strength.

The reduction in compressive strength ΔR,% in percentage, is calculated using the following formula:

$$\Delta R = \frac{R_k^w - R_k^f}{R_k^w} 100 \qquad (4)$$

Where:

R_k^w is the average compressive strength after saturation in water at a temperature of 20±2°C, in MPa.

R_k^f is the compressive strength after the specified freeze-thaw cycles, in MPa.

The number of test cycles and the allowable reduction in compressive strength are specified in the project documentation, based on the actual climatic conditions and the intended use of the asphalt concrete.

Conclusion

During the operation of road pavements, the various factors acting on asphalt concrete, their combinations, and intensity complicate the unambiguous assessment of its durability. Therefore, indicators such as water absorption, water resistance, freeze-thaw resistance, wear resistance, and temperature factors can be used as specific criteria for assessing the durability of asphalt concrete. These factors provide valuable information on the material's ability to withstand environmental stresses and mechanical loads, contributing to a better understanding of its long-term performance and suitability for different road conditions.

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River Rioni and sediment management process of reservoir Rion Hpp

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Abstract. In 1927, construction of the Rioni Hydroelectric Power Plant began on the Rioni River near Kutaisi.The article discusses the construction processes of the Rioni hydroelectric dam and hydropower station, as well as the problems associated with it. The processes of sediment formation at the Rioni hydroelectric power station and the associated problems of hydroelectric power station operation are studied. The paper presents data from field observations and measurements during the process of dredging and flushing of the reservoir.

Key words: Low-threshold reinforced concrete dam, Output channel, sediment management of reservoir, Washing the reservoir.

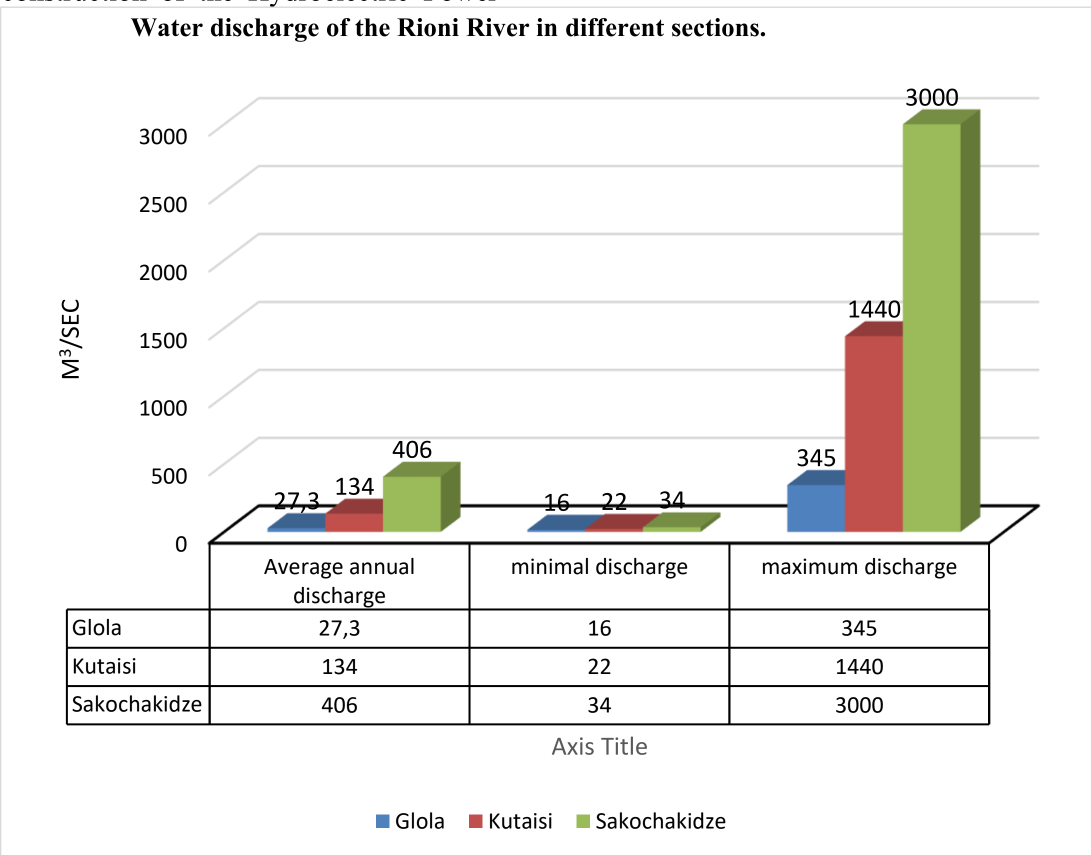
1. Introduction

The program for the construction of the Rion Hydroelectric Power Station was extremely difficult for Georgia at that time, but feasible, since Georgian engineers had the necessary education for the construction of the Hydroelectric Power Plant. Today, the Rioni Hydroelectric Power Plant is truly a unique structure in all respects. The Rioni Hydroelectric Power Station on the Rioni River is a well-designed and technically reliable station. The construction of this complex was carried out under very difficult and challenging conditions.

On September 30, 1933, the Rioni Hydroelectric Power Station provided our republic with its first electric power, and on July 30, 1934, all four hydroelectric generators of the Rioni Hydroelectric Power Station began operating at full capacity.

Main part

Rioni is a river in western Georgia. Length 327 km, river basin area 13400 km2. It has its source on the southern slope of the Caucasus on Mount Fasi, 2960 m above sea level. It flows into the Black Sea. Below Kutaisi the river enters the Colchis plain, forms a transverse channel, swells and forms islands. The Figure 1 shows the average annual discharge of the Rioni River.



	Average annual discharge	minimal discharge	maximum discharge
Glola	27,3	16	345
Kutaisi	134	22	1440
Sakochakidze	406	34	3000

Fig. 1 average annual discharge of the Rioni River.

The Figure 2 shows the water discharge of the Rioni river to seasonality of the year

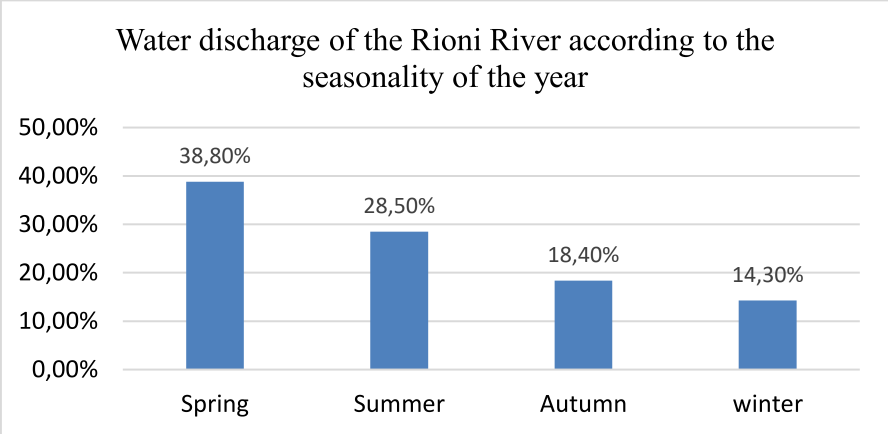


Fig. 2 discharge of the Rioni river to seasonality of the year

The Figure 3 shows the water discharge of the Rioni river to nutrient sources components.

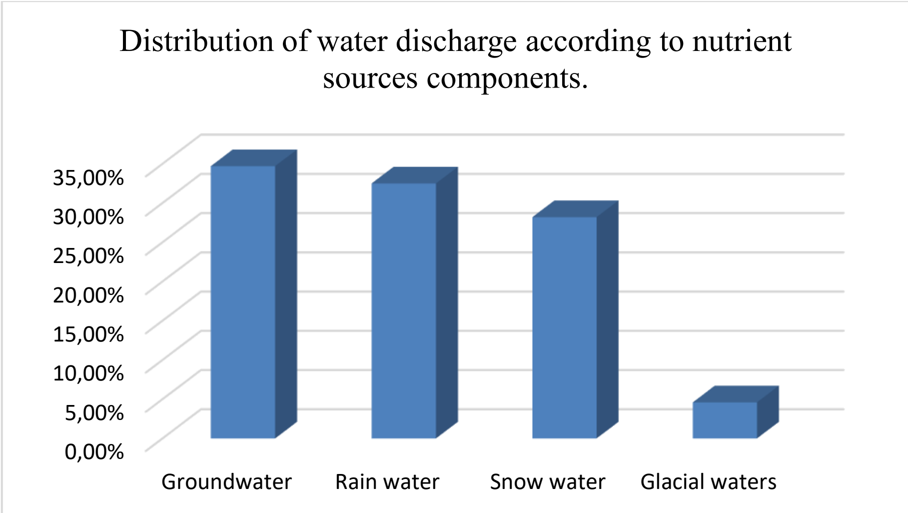


Fig. 3 Distribution of water discharge according to nutrient sources components.

Rioni annually discharges 12.9 km3 of water and a large amount of solid runoff into the Black Sea. The average annual amount of solid runoff increases from the source to the confluence: at the village of Ghebi it is 96 thousand tons, at Khidikar — 2.2 million tons, at the village of Namakhvani — 4.9 million tons, at Sakochakidze — 6.9 million tons.

In table 1 shows Rioni River bottom and floating sediment data for 1985.

Table 1.

№	Year of observation	water metering station of River Rioni	Catchment area, F km^2	transported material, thousand tons	The module of transported material, t/m^3
1	1985	Village Utsera	707	190	270
		City Oni	1060	310	1060
		Village Khidikari	2010	850	420
		Village Alpana	2830	910	320
		Village Namakhvani	3450	1900	550
		Village Sakochakidze	13300	4700	350
		City Poti Northern Branch	13400	6600	490
		City Poti Southern Branch	13400	-	-

		River Lajanuri Village Orbeli	231	91	390
		River Kvirila city Zestaponi	2490	600	240
		River Dzirula	1190	230	190

Rioni Hydroelectric Power Plant (Rioni HPP) is a hydroelectric power plant in Georgia, on the Rioni River, near the city of Kutaisi. It is part of the Rioni Hydroelectric Power Plant Cascade and is its fourth stage.
Structurally, it is a typical diversion hydroelectric power plant with a head reservoir and a non-pressure diversion. The hydraulic scheme is based on the diversion of part of the Rioni River flow into the lower reaches of its tributary, the Kvirila River.

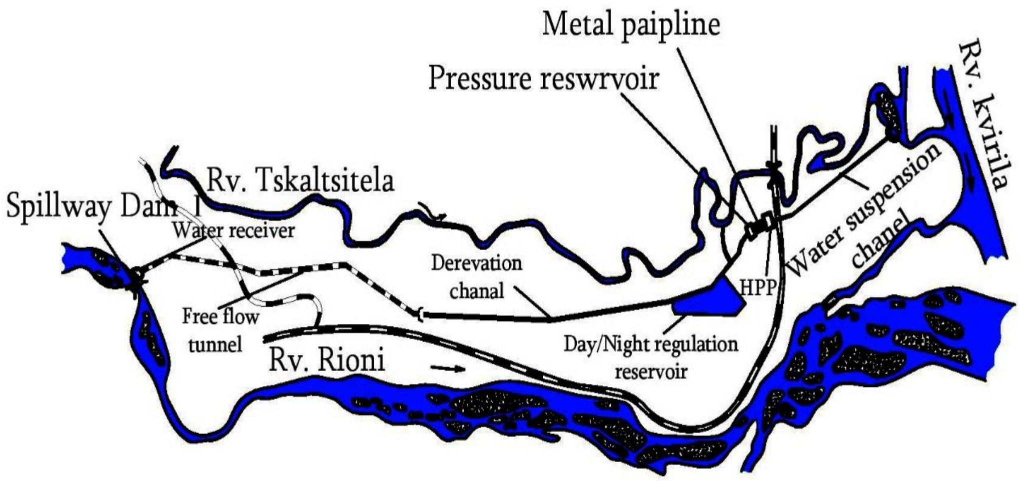


Fig. 4. Scheme of the hydropower node of the Rioni River of hydroelectric power station.

Embankment Water intake.
Diversion structure with a total length of approximately 9 km, including:
Gravity diversion tunnel with a length of 3927 m;
Diversion channel with a length of 5131 m.
Station node, including:
Pressure basin;
Four-thread pressure turbine water pipeline;
Hydropower plant building;
2.1 km long outlet channel into the Kvirila River;
35/110 kV switchgear.
Fig. 5. The upper reaches of the Rioni River are shown, which include: a concrete spillway dam with a siphon spillway, pontoon and flushing sluices, with a total length of 92.5 m. The dam is designed to pass 2600 m³/s of water and is equipped with four spillways, each 10.2 m wide, covered with flat gates. The siphon spillway has five main and one auxiliary spillways and is designed for a flow rate of up to 80 m³/s.

Fig. 5. Dam at the head node of the Rioni River

The dam creates a small reservoir with a total volume of 3 million m³ and a useful volume of 0.5 million m³.
Fig. 6 shows the Rioni River Reservoir during the repair and washing works. During the washing of the reservoir in 2024, an island (mesoform) is visible in the riverbed, which gradually decreases during the washing process and the volume of the reservoir increases and approaches the design data. As the volume of the reservoir increases, the water supply in the reservoir increases, which allows for the improvement of peak electric energy consumption.

Fig. 6. The reservoir of the Rioni River Hydroelectric Power Plant on August 21, 2024 at 12:19 am during maintenance and cleaning.

The capacity of the hydroelectric power plant is 48 megawatts, the average annual output is 317 million kWh. The hydroelectric power plant building is equipped with 4 hydropower units with vertical radial-axial turbines RO-VM-190 (the working diameter of the hydropower unit is 1.9 m), operating at a design head of 60 m (maximum pressure - 65.4 m), the maximum water flow in each turbine is 25 m^3/s. The turbines are driven by BB-7442-300 hydrogenerators, the capacity of which is 12 MW each.
Fig. 7. The lower reaches of the Rioni River Hydroelectric Power Plant reservoir dam are presented on August 20, 2024 at 11:56 am. The process of regulating the flow of floods and waterlogging in the Rioni River bed with artificial structures in order to ensure the protection of the population.

Fig. 7. The lower reaches of the Rioni River hydroelectric power station reservoir dam on August 20, 2024 at 11:56 a.m.

The Rioni Hydroelectric Power Station, with its technical and architectural design, represents a safe, environmentally friendly source of energy that provides the homeland and its people with the necessary energy. Today's living conditions are unimaginable without electricity.

3. Conclusion

1. The Rioni River is a mountain river characterized by abundant liquid and solid runoff, playing a special role in replenishing the Rioni hydroelectric power plants with sediment.
2. Despite the barriers (in the form of reservoirs) created by the stations on the Rioni River: Gumati I, Gumati II, the headwater dam of the Rioni HPP, the Somashveli headwater dam, the Vartsikhe Dam, the Vartsikhe Cascade, Vartsikhe I, Vartsikhe II, Vartsikhe III, and Vartsikhe IV, a large amount of sedimentary material continues to move to the Black Sea. The average annual amount of solid runoff of the Rioni at Sakochakidze is 6.9 million tons, and on average 7.0 million tons of solid sedimentary material enters the Black Sea.

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Aspects of Organization and Implementation of the having Historical-Cultural Monument's Status Buildings Reconstruction

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Abstract: In this article are considered main aspects of the organization and implementation of the having historical-cultural monument's status buildings reconstruction. The reconstruction of a monument refers to a number of measures to restore and strengthen the structure that are carried out using various architectural-structural solutions and technologies in order to adapt the building to modern socio-cultural conditions and nake it as close as possible to its original appearance, which it has completely or partially lost due to the influence of time or other negative force and ecological factors. The article analyzes the stages of the reconstruction of buildings with the status of a historical-cultural monument, taking into account general construction norms and legislative requirements when implementing such projects.

Keywords: reconstruction, buildings, cultural heritage, historical and cultural monuments, reconstruction experience.

1. Introduction

Historical and cultural monuments are recognized as the property of the nation, the world cultural heritage, as well as a means of immortalizing the cultural and engineering activities of that time people in which they were created. As a result of observing many historical buildings, the age of cities, their changes and development at different stages of history can be determined. Most of the architectural monuments created in the past are still used today, although often not at all for their original purpose. Basically, they serve the development of science, artistic and social culture, public education. However, over the long period of their existence, under the influence of various environmental factors, architectural monuments undergo significant changes and are significantly worn out. Often they not only lose their original appearance, but also have significant structural damage, or complete or partial collapse and experience complete decay. Therefore, reconstruction works of buildings and structures recognized as architectural monuments and cultural heritage objects are in great demand in modern city conditions [1, 2,3,4,5].

2. Basic part

In the international practice of reconstruction of historical centers, there is experience of chaotic mass demolition of historical buildings and construction of modern ones in their place. For example, in Brussels in the 1960s-1970s, under the pretext of building a "city of the future", entire quarters were built with futuristic-looking office buildings with glass facades. The lack of a unified plan and aesthetics in new construction led to the massive relocation of historical buildings, which was followed by their destruction over the decades. This practice was even called "Brusselization".

In modern Europe, the problem of preserving architectural monuments is taken very seriously and they try to preserve the appearance of the masterpiece as much as possible, while adapting it to modern needs.

In Georgia, historical and cultural monuments, that are buildings-monuments, old blocks, historical centers, represent the cultural heritage of the Georgian people that reflects the history of the country, architecture, painting, and cultural history.

Monuments would be defined as the most valuable category of real estate. Its peculiarity is, on the one hand, the increase in its value depending on the antiquity of the creation or historical event, and, on the other hand, the possibility of increasing this value as a result of constantly conducted historical-cultural research. In addition, the assessment should be carried out not only in terms of cultural significance, but also from the material value, which takes into account its financial representation (similar to the assessment conducted for museum and private collections), which allows to correctly determine its value, organize insurance of monuments, and determine penalties for caused damages.

Thus, the preservation of buildings-monuments is a technically difficult and complex task, which must be solved at a time when the volume of repair and restoration works has significantly increased, in a shortened timeframe, and in the absence of clear regulation of the composition, volume, and nature of the complex of engineering studies to be conducted on the building-monument, which is not provided for in the existing regulatory documentation for restoration and research works.

The development of a methodology for a complex approach to the assessment of historical and cultural monuments, leading to a set of specific methods, defines the goal of the work.

The theoretical and methodological basis of the research are the following methods: system analysis; hierarchy method; structural linguistics; expert assessment method; multifactor analysis; regression analysis. The reconstruction of architectural monuments is a very laborious process. It depends on many factors, laws, regulations and rules. Before starting work on the site, it is necessary to conduct a number of studies, including works on the architectural study of the monument and a cycle of engineering and technical studies. This is necessary so that the reconstructed object maximally repeats the appearance that was conceived by the architect when creating it. The materials are also very carefully selected so that after all the work is completed, the object does not resemble a "new building" [2,6].

The main stage in identifying problems in the reconstruction is an expert assessment of the condition of the object. At this stage, a comprehensive examination and technical examination of building structures are being carried out for the most accurate assessment of the condition. Work is also underway with archival materials and the city plan to reveal the historical appearance of the building, its significance and relevance in the life of the city. In parallel, a study of the cartogram of the quarter's development is being carried out to obtain information about the number of floors of the building, the construction materials used, the degree of moral and technical wear and tear.

Based on the information received, a detailed project for the reconstruction of the facility has been drawn up for its phased implementation in the future.

The main structural elements of any building are the foundation, walls and roofs.

Buildings and structures inevitably deteriorate over time from precipitation, temperature changes and solar radiation. Also, the development of housing and road infrastructure leads to an increase in the load on buildings. If a subway line or highway is being laid near an old house, the structural elements experience increased vibration and, when cracked, lose their bearing capacity. Such loads were not taken into account at the design stage of the construction, so now they need to be strengthened.

If the walls of the house are in satisfactory condition, it is advisable to replace the wooden floor with reinforced concrete. If the roof walls and foundation are severely damaged, it is necessary to strengthen and restore the old wooden structures or partially replace them with new ones.

When carrying out such work, the use of modern technologies along with the use of the latest composite materials is very relevant.

To compensate for the effects of natural wear and tear and to protect buildings from emerging negative factors, reinforcing mesh, shotcrete and waterproofing are used as reinforcement methods.

Steel and composite reinforcement are used for reinforcement, various rolled metal products - angles, channels, welded mesh. For reinforcement, additional elements are installed outside, creating an external reinforced belt, and are laid inside load-bearing structures - in walls, beams, ceilings.

The shotcrete method is a relatively recent invention compared to other construction technologies and today is one of the most effective and economical ways to strengthen brick, stone and concrete structures.

With the help of shotcrete, it is possible to quickly process large surfaces and concreting structures of any complexity, including in conditions of limited space. This is especially important when working with old buildings, the dimensions of which are not calculated for the dimensions of modern construction equipment.

The waterproofing method is relevant primarily for protecting the foundation, basement and low ground floor floors from contact with water. In such cases, anti-filtration waterproofing is used. Anti-corrosion waterproofing can also be used, which protects structures from moisture and other chemically aggressive substances that can provoke corrosion of concrete and reinforcement [3,7,8].

The long service life of cultural heritage monuments is partly due to the fact that, although the technologies and materials used were imperfect compared to modern ones, their foundations are usually very strong. However, the foundations of almost all historical buildings are significantly overloaded due to the ongoing construction or reconstruction of the building.

The beginning of the reconstruction of the foundation begins with a thorough analysis of the causes of its damage, because. The choice of the method of its restoration and strengthening depends on this. To eliminate the cracks in the foundation and strengthen the pile, cement mortar is injected into the existing cracks. Metal or reinforced concrete casings are also built to improve the bearing capacity of the foundation.

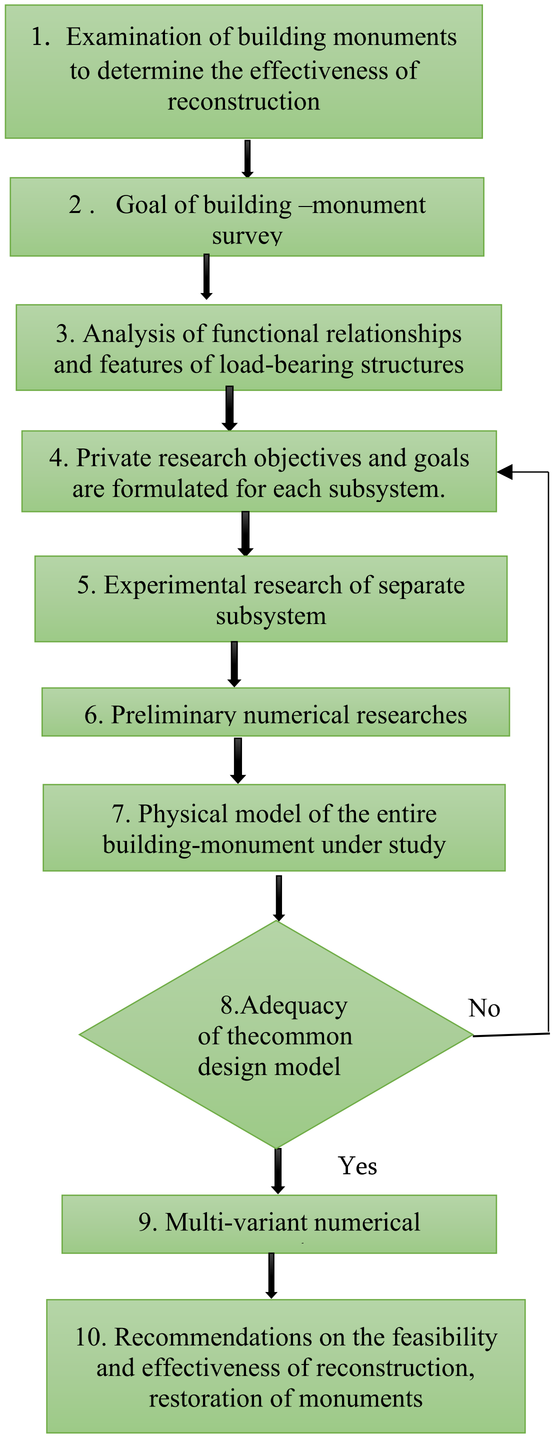

Fig. 1. Flowchart of the process for determining the effectiveness of reconstruction of building-monuments

To relieve excessive load on the foundation, metal belts are used to distribute it. Also, by installing supports or new slabs, you can change the structural scheme of the foundation if it is severely worn out.

Often, a reconstruction project involves the complete demolition of a dilapidated building or

monument.
A study of the construction of many monuments was carried out using the developed methodology. After compiling and calculating the calculation models of the study objects, the analysis of the calculation results was carried out, after which the calculation of the enhanced model and comparative analysis were carried out.

3. Conclusions

1. The structural solutions of existing historical and cultural monuments are analyzed, their classification is made (on the example of a cylindrical vault, a cross vault, a closed vault and closed arches), the architectural monument is presented as an element of a complex natural-technical system "monument-environment", which contains interconnected structural and architectural elements;
2. A block diagram of the hardware-computer diagnostics of the stressed-deformed state of a historical-cultural monument has been developed, which takes into account the methodology for studying the state of the monument, combining experimental and numerical methods;

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Hydraulic calculation of a water discharge system for protecting construction pits and foundations from flooding

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Abstract The groundwater level above the design pit bottom mark, together with surface runoff, create many negative conditions both during construction and operation. The article discusses the mechanism for protecting construction pits and foundations from flooding using irrigation systems. It is noted that when performing hydraulic calculations of irrigation systems, it is necessary to take into account the fact that surface runoff water carries a mass of solid particles. The calculation method takes into account the mass of these solid particles only from the point of view of abrasiveness. The work calculates the external pumping network and operating parameters of the hydrotransport system taking into account the characteristics of the selected pump based on data from regulatory, reference, advisory and scientific sources. (Q, H, N, η) Calculation formulas when working with hydraulic mixture.

Key words: construction pit, flooding, drainage system.

1. Introduction

Protection of pits and foundations from flooding (by surface and ground water) is one of the important factors in the organization of work, ensuring safe and uninterrupted working conditions during construction and positively influencing the subsequent operation of the facility. The groundwater level, located above the design mark of the pit bottom, together with surface runoff, create many negative conditions, both during construction and during operation. In particular, this complicates excavation work and can lead to flooding of construction equipment. Changes in the hydrological regime in urban areas often lead to the activation of such processes as deformation of the earth's surface, landslides, collapse of quarry slopes, flooding, etc. (Fig. 1). A rise in the groundwater level causes hydrostatic compaction of sand and softening of clay rocks. Penetration of capillary moisture into clay rocks leads to a decrease in their adhesion and strength. Foundations of buildings, represented by loams, clays and sands, as a result of dehydration change their physical and mechanical properties, lose strength, reduce the ability to resist movements and compression, are subject to swelling, significant deformations occur - uneven settlement of buildings and structures. Excessive moisture creates favorable conditions for the development of pathogenic microorganisms and other pests, which negatively affects the strength and durability of building materials.

Picture. 1

The protection of the construction cave from the crop is performed by four main methods [1-2]:

1. Superficial drain water flows to the mountain canal;

2. Open water;

3. Allowing (water);

4., Organizing an anti -filter curtain.

We will touch the protection of caves and foundations using water systems.

Please note that in the hydraulic calculation of waterproof systems, it is necessary to remember that the surface drop in water is introduced into the mass of solid particles from the water column, partial (relatively large particles) are removed in the sea bottom gallery, partly in this area. Currently, the content of solid particles is provided by the reporting methodology, only from the point of view of abrasiveness and the choice of low bases. As for the calculation of the external network of the pump, the content of solid particles in dried water is not provided.

Based on the data of regulatory, reference, recommendations and scientific sources, we will try to calculate the waterproof system when the contents of the solid mass in the dried - wound are accepted.

The movement of hydration losses calculated by the formula [2, 9].

$$\mathfrak{I}_{h.m.} = \lambda \frac{1}{D_{m.sh.}} \cdot \frac{V^2}{2g} \cdot \frac{\rho_{hn}}{\rho_w} \qquad (1)$$

Where: λ - Is a hydraulic coefficient of friction of the pipeline,V - The average flow rate in the pipeline (m/cm); g - The force of gravity is accelerated (m/s^2), $D_{I.d}$ - Inner diameter of the pipe.

$$\boldsymbol{\rho_{hn} = \rho_w + S(\rho_{sm} - \rho_w)} \quad (2)$$

The density of hydraulic mixture (kg/m^3), $\boldsymbol{\rho_{sm}}$ - The density of the sent solid material (kg/m^3), $\boldsymbol{\rho_w}$ - Water density (kg/m^3), While $\boldsymbol{S}$ - True volumetric consistency of hydraulic power.

The crisis speed of the hydromixture in the pipeline is calculated by the formula [7]:

$$\boldsymbol{V_{cs} = 8,3\sqrt[3]{D_{msh}} \cdot \sqrt[6]{S\psi_m}} \quad (3)$$

Where $\boldsymbol{\psi_m}$ - It is a coefficient of solid material (see table 1).

General pressure losses on hydrotarev are calculated by the formula [2, 4]

$$\boldsymbol{H_{tplh.} = (\mathcal{J}_{hn.1}L_1 + \mathcal{J}_{hn.2}L_2) + H_{tplh.+H_{g.}}} \quad (4)$$

Where K is the coefficient that takes into account the loss of pressure in the correct areas of the connection, $\boldsymbol{\mathcal{J}_{hn.1}}$ are losers of the absorbing pipeline; $\boldsymbol{\mathcal{J}_{hn.2}}$ losing pressure in the pipeline, L_1 - the length of the right area of the pipeline in this drainage unit (M); L_2 - the total length of the pipeline (m); $\boldsymbol{H_{tplh.}}$ - total Loss of Pressure, on Hidromixture in local barriers

$$\boldsymbol{H_g = \Delta Z \frac{\rho_{hn.}}{\rho_w}} \quad (5)$$

This is pressure to overcome the geodetic height. Here $\boldsymbol{\Delta Z}$ There is a difference between the minimum water level in the adjustable tank and geodetic characteristics of the axis in the field of hydration in the region.

The individual characteristics of ground pumps are determined by the plant using special exams on water and are given in the relevant catalogs and other reference literature.

Schedule 1

According to the fractions of materials Ψ Value of the coefficient

Material fraction, mm	0,05-0,10	0,10-0,25	0,25-0,5	0,5-1,0	1,0-2,0	2,0-3,0	3,0-5,0	5,0-10,0
ψ	0,02	0,20	0,40	0,80	1,5	1,8	1,9	2

When working with a hydraulic mixture, the characteristics change depending on the consistency and granulometric composition of the solid material being transported.

The pump characteristics also change due to intensive wear of the impeller and other parts.

The pressure created by a new pump when working with a hydraulic mixture can be calculated using the formula [5, 7]:

$$\boldsymbol{H_{tplh.n} = KH_{w.n}\left[1 + \frac{S}{\sqrt{\psi_m}}\right]} \quad (6)$$

And when working with a hydraulic mixture, the pressure developed by a partially or completely worn-out soil pump has the form [7]:

$$H_{hnwtg} = KH_{wtn}(1 - a_1^3 q^5)\left[1 + \frac{S}{\sqrt{\psi}}\right] \quad (7)$$

In images (6) and (7) is the consistency of the hydraulic mixture,k A dimensionless coefficient close to unity, a_1 - the experimental coefficient
q - The mass of solid transported by the pump, which must be determined directly on site based on statistical data.

To calculate the flow rate of the hydraulic mixture, we have the following expressions [3-7]:

$$\begin{cases} Q_{hnt.(max)n.} = Q_{wt.(max)n.}(1 - 1,65S)\,\frac{m^3}{min} \\ Q_{hnt.(max)n} = Q_{wt.(max)n}(1 - -a_1^3 q^5)\,\frac{m^3}{min} \end{cases}$$
(8)

The calculation of the soil pump MCC for a hydraulic mixture of consistency S is performed using the formula:

$$\eta_{hn.w.} = \eta_{w.n}(1 - 0,33S) \quad (9)$$

Where: η_{wn} - the efficiency factor of the ground pump when working on water, taken from the relevant catalogs. It is accepted that the MCC for worn pumps is taken in the same way as for new pumps. The conversion of power on the pump shaft from water to hydraulic mixture is carried out according to the formula [3-7]:

$$N_{hn.t.n} = N_{wtn}\frac{H_{wtn}}{H_{hntn}} \cdot \frac{\eta_{wn}}{\eta_{hn.n}} \quad (10)$$

The operating parameters (Q, H, N, η) of the hydrotransport system when working on a hydraulic mixture are determined based on the characteristics of the external network and the selected pump. The corresponding reserve size is calculated based on the number of selected simultaneously operating pumps, namely, if more than one pump is operating simultaneously, then a 50% reserve is taken, and in the case of one pump operating - 100% [8-9].

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Architectural and urban planning regulation of development for resort settlements in Georgia

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Abstract One of the main priorities of Georgia's economic development is the development of the resort and tourism industry to international standards.

Therefore it is a pressing issue for specialists to conduct a comprehensive study and analysis of the ways to develop and rationally use the country's resort and recreational resources, and to develop appropriate recommendations in order to regulate the flow of vacationers and determine the permissible loads on the landscape so that the equilibrium and ecological balance of the country's unique resort and recreational landscapes is maintained [1].

When addressing this issue it is important to consider the main feature of Georgian resorts - most of them are located in small and medium-sized settlements.

Considering that large touristic resorts and hotel complexes require developed consumer-economic infrastructure, the construction of complexes of this scale represents a risk of losing the historically formed spatial-architectural appearance, landscape, scale, and individuality of small and medium-sized resort settlements.

In addition, as research has shown, pristine, authentic, untouched, exotic environments are currently more popular among vacationers and tourists around the world.

Key words: resort, development, environment, house-hotel, block, floor.

Introduction

In Georgia private housing stock has traditionally been used to accommodate vacationers in small and medium-sized resort settlements. In recent years, a number of Georgian resorts (Kobuleti, Ureki, Bakuriani, Borjomi, etc.) have been intensively renovating private housing stock. Old houses are being extended, built, reconstructed and adapted. New private house-hotels (so-called "Guest houses") and frequently multi-storey hotel complexes are also being built.

Currently this process is carried out arbitrarily and chaotically, reflecting only the interests of the private owners or investors. Specialists (ecologists, economists, demographers, sociologists, architects, urban planners) are not involved in this process, which is why it can become more extensive and lead to irreversible negative consequences in terms of disruption of the ecological balance and urban planning.

Main Part

The study and analysis of the current situation shows that the use of private housing stock in resorts has future prospects. This circumstance determines the need for fundamental changes in the tourism industry. Based on the study of existing literary sources in this field and the research conducted by us, the main parameters necessary for the formation of the typology of residential houses and hotels were determined. [2]

In particular, based on urban planning specifics, the types of nomenclature and architectural and urban planning requirements for their use were determined. The project concept, recommendations, proposals and instructions were developed, which can be reflected in the normative base in the future.

Based on the conducted studies, the construction of low-rise (1-4 story) house-hotels was deemed appropriate in small and medium-sized resort settlements of Georgia, in terms of regulating the use of existing resort and recreational resources, enhancing resort and tourist services, maintaining ecological balance, and preserving resort and recreational landscapes.[3]

For use in small and medium-sized resort developments in Georgia, based on the rational amount of stories, volume, spatial-planning structure, apartment types, homestead plot areas, resort-vertical zoning and urban planning parameters, we have developed a common nomenclature of low-rise house-hotel types. Four main types of house-hotels are recommended:

1. **Homestead type**
2. **Blocked type**
3. **Terraced type**
4. **Combined type**

Each type is characterized by a special spatial-volumetric solution and architectural-planning structure.

Homestead type - detached residential building with a developed volume-planning structure. It usually has a homestead plot of 600-1200 sq.m.

Blocked type - consists of two or more blocks. Its constituent element is a block apartment or block section, which contains several apartments arranged horizontally or vertically. The blocking of these elements, depending on specific conditions, may be carried out in a single row, in two rows or in terraces. A block-type house may have a small area of homestead land (60-500 sq.m.) or be without a land plot.

Terraced type - consists of two or more 2-4-story block sections arranged in a terraced manner. Their use is recommended in regions with difficult terrain and allows for regulation of the density of development.

Combined type - consists of combining different story units (block-apartment and/or block-section) into one structure, the planning solution of which can be done with sectional, corridor and gallery systems. It is important that any type recommended by us should be selected based on the urban planning conditions of a specific settlement and ensure the appropriate modernity of the relevant zones.

For the construction of the above-mentioned types of home-hotels, it is advisable to use three main territorial groups:

1. **Undeveloped territory of a resort settlement;**
2. **Low-density developed area of a resort settlement;**
3. **Undeveloped area outside the resort settlement.**

Territorial groups, in turn, are divided into territorial zones and for their development it is recommended to use one or several types of home-hotels.

1. **Undeveloped territory of a resort settlement -** the following territorial zones are recommended for use in these areas:

- **Territorial zone surrounding the resort settlement -** this zone includes the reserve, new and developing areas within the resort settlement. The following are recommended for construction in this zone:

-*Homestead type*- the area of a homestead plot of land is determined in accordance with specific urban planning conditions within the range of 600-1200 sq.m.

-*Blocked type*- the area of a homestead plot of land is determined in accordance with specific urban planning conditions within the range of 60-600 sq.m.

-**Territorial zone with little potential for construction in a resort settlement-** this zone includes areas within the resort settlement that are not suitable for high-rise construction due to difficult terrain, steep slopes, or relatively weak soil. The following are recommended for construction in this zone:

-*Blocked type*- the area of a homestead plot without a homestead plot or with a homestead plot is determined in accordance with specific urban planning conditions within the range of 60-600 sq.m.

-***Terraced type-*** the area of a homestead plot without a homestead plot or with a homestead plot is determined in accordance with specific urban planning conditions within the range of 100-400 sq.m.

-***Combined type-*** the area of a homestead plot without a homestead plot or with a homestead plot is determined within 60-100 sq.m. in accordance with specific urban planning conditions.

2. **Low-density developed area of a resort settlement -** the following territorial zones are recommended for use in these areas::

-**Existing homestead development zone** - this zone includes existing homestead development, where construction is possible on vacant plots. The following are recommended for construction in this zone:

-***Homestead type-*** the area of a homestead plot of land is determined in accordance with specific urban planning conditions within the range of 600-1200 sq.m.

-***Blocked type***- the area of a homestead plot of land is determined in accordance with specific urban planning conditions within the range of 60-600 sq.m.

-**Development zone with preservation of land fund (development reconstruction with partial or complete replacement of old buildings)** - this zone includes the central area of the resort settlement and its surrounding areas, where it is necessary to replace old buildings. The following are recommended for construction in the zone:

-***Homestead type-*** by maintaining the area of the existing homestead land plot.

-***Blocked type***- by maintaining the area of the existing homestead land plot.

-**Development zone without homestead land -** this zone includes areas with difficult terrain and little land. The following are recommended for construction in the zone:

-***Terraced type-*** without a homestead plot of land.

-***Combined type-*** with semi-open or closed interior terraces or atriums.

Undeveloped area outside the resort settlement - the following territorial zones are recommended for use in these areas:

- **A zone suitable for new resort development with a resort climate or unique landscape;**
- **Zone allocated for the development of an existing resort settlement.**

In these zones it is recommended to use various types of houses defined by the nomenclature developed by us (Fig. 1), the selection of which and the determination of the areas of homestead plots will be carried out taking into account specific conditions. In these territorial zones it is recommended to establish small-scale resort settlements, the so-called "resort villages" common in Europe.

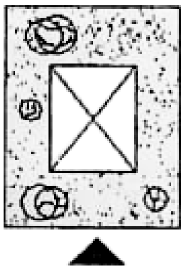
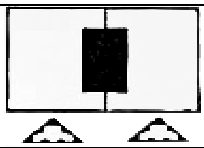
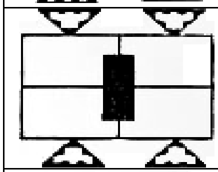
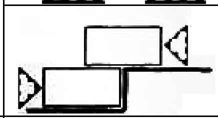
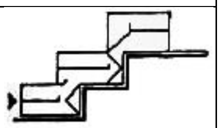
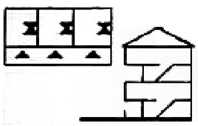
Conclusions

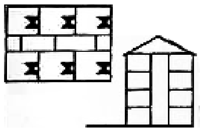
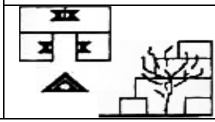
Thus we can conclude that in order to achieve architectural and spatial unity of the development of selected zones in resort settlements and the effectiveness of social services, construction should be carried out in a complex manner, in the form of urban planning units with developed infrastructure. This method allows for a rational solution of engineering and communication networks and street systems.

It is also necessary to maintain the character, scale, unified nature and visual perception of the historically formed development, urban planning and landscape accents of the environment.

New development should also ensure compliance with basic normative requirements. In addition, along with rational spatial planning, it is important to focus on creating an interesting architectural appearance of buildings and their harmonious combination with the environment. The main goal of these requirements is to create a unique and individual look for resort settlements, preserve unique landscapes, and ensure the ecological balance of the environment.

General nomenclature of types of low-rise residential buildings-hotels (Fig. 1)

House type		Number of floors	Volume elements		Apartment type	Approximate area of homestead land plot in m2	Terms of Use					
							Resort areas				Settlement type	
			Name	Scheme			Lowland zone	Lowland zone	Mid-mountain zone	High mountain zone	Small	Medium
Homestead	One-family house with large homestead plot	3-6	House		3-6 rooms	600-1200	•	•			•	
	1-2 apartments with medium homestead plot					400-600	•	•	•		•	•
	1-2 apartments with small homestead plots					300-400	•	•	•	•		•
Blocked	Single-row blocking	3-6	Block - apartment		3-6 rooms	400-600	•	•	•		•	•
	Two-line blocking					200-400	•	•	•		•	•
	Terraced blocking					60- 200 or without a plot of land		•	•	•	•	•
Terraced	Terraced blocking of apartment blocks	3-4	Block - apartment		3-6 rooms	100-400 or without a plot of land			•	•	•	•
	Terraced Blocking Block - Sections		Block - Section						•	•	•	•
Combined	Multi-apartment gallery-blocking	3-6	Block - Section		3-6 rooms	60-100 or without a plot of land	•	•	•			•

	Multi-apartment Corridor-blocking						•	•	•			•
	Multi-apartment with sectional blocking and atrium						•	•	•			•

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Analysis of the stress state of a pressure tunnel considering nonlinear deformation of the rock massif

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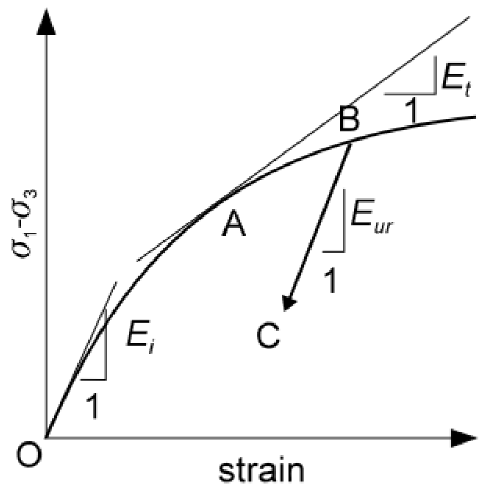
Abstract The presented study is based on the calculation of the "tunnel-surrounding massif", a unified system taking into account the nonlinear operation of the surrounding massif, where a hyperbolic model of rock material is used. Numerical calculations were carried out on the example of the Aspindza HPP diversion tunnel.
The Aspindza HPP hydro node (on the Mtkvari River) includes a diversion tunnel, the operation of which is envisaged in the pressure mode and, together with the equalization reservoir, partially receives a hydraulic shock, taking into account which the pressure from inside the tunnel reaches 25 m.
It was accepted that the nonlinearity of the material has a significant impact on the construction and operational stress states of the tunnel. In particular, the influence of nonlinearity reduces extreme stresses in the construction and, accordingly, reveals strength reserves, which allows for optimization of reinforced concrete construction.
The horizontal tensile stresses identified by nonlinear calculations in the tunnel bottom cross-section were significantly reduced compared to linear calculations, and when taking into account the phased nature of the tunnel construction (compared to the sudden construction scheme), the tensile stresses were completely eliminated.
The paper presents some results of the calculation of the derivation tunnel for the construction and operation periods, taking into account the nonlinear operation of the surrounding massif.

INTRODUCTION

The nonlinear behavior of a material is represented using a hyperbolic model (Duncan and Chang, 1980). In the hyperbolic E-B constitutive model, the bulk modulus (B) is assumed to be constant, while the elastic modulus (E) changes according to a hyperbolic function under loading (Fig. 2.1 1).
The theoretical formulation is based on the analysis of the shape of the "stress-strain" curve, as well as the volumetric response of the material (O-A-B). At the time of failure of the



material (in accordance with the condition of constancy of the bulk modulus), the increase in the volume strain tends to zero, which is consistent with the concept of a critical state.
Fig. 1. Nonlinear stress-strain curve.
The E-B hyperbolic model also allows for the determination of the loading-unloading modulus.
The "stress-strain" response at any loading-unloading instant (B-C) is the deformation modulus (stiffness response) with respect to the initial state (O), which is controlled by the ratio of the specified initial elastic modulus to Poisson's ratio.
The deformation modulus at any point on the nonlinear stress-strain curve can be expressed as the tangent of the tangent. It is defined from the instantaneous elastic modulus by the

condition:

$$E_t = \left[1 - \frac{R_f \ (\sigma_1 - \sigma_3)(1 - \sin\phi)}{2c(\cos\phi) + 2\sigma_3 \sin\phi} \right]^2 E_i$$

Where,
Ei - initial shear modulus,
Et - shear modulus,
φ - soil friction angle,
c - specific friction;
σ1 - maximum shear stress;
σ3 - minimum shear stress;.
C and ϕ are strength parameters; σ_1 and σ_3 are principal stresses; and R_f is the failure parameter, which is determined by the formula:

$$R_f = \frac{(\sigma_1 - \sigma_3)_f}{(\sigma_1 - \sigma_3)_{ult}}$$

The material strength condition is presented as follows:

$$\frac{(\sigma_1 - \sigma_3)_f}{2} - \frac{(\sigma_1 + \sigma_3)_f}{2} \sin\phi \geq R_f c \cos\phi$$

The presented conditions allow the assessment of the material's stress state and strength reserves.
The surrounding massif of the Aspindza tunnel is mainly represented by sandstones. Therefore, calculations were carried out using the CNI method (according to the generalized Hawk-Brown criterion) with the obtained stress-strain curve - obtained for limestones and sandstones.

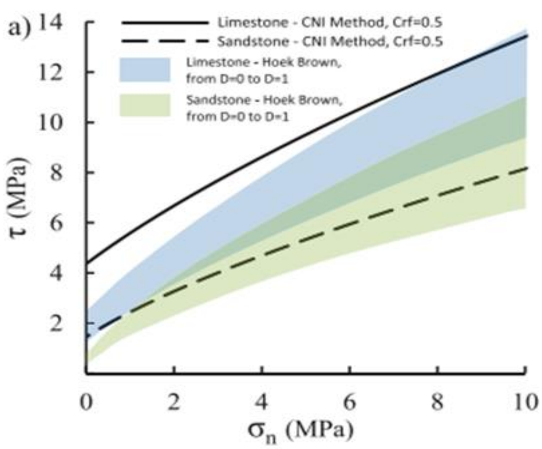


Fig. 2. Stress-strain curve for limestones and sandstones.

➢ **Calculation under the conditions of a sudden and construction phase construction scheme**

The calculation results provided a complete picture of the stressed state of the repair. In this regard, the contact area of the foundation slab and the walls of the repair is important, which is a stress concentration zone (Fig. 3).
- Horizontal normal stresses in the contact zone are tensile and under the conditions of the "sudden construction scheme" reached the values:
-1700 kPa, -1200 kPa, linear and nonlinear, respectively.
When taking into account the construction phase, tensile stresses in the mentioned zone were practically eliminated when taking into account the nonlinearity.
- Vertical normal stresses in the contact zone, during both linear and nonlinear deformation of the material, when taking into account the construction phase, the stress concentration is increased, although compressive stresses are maintained (Fig. 3)

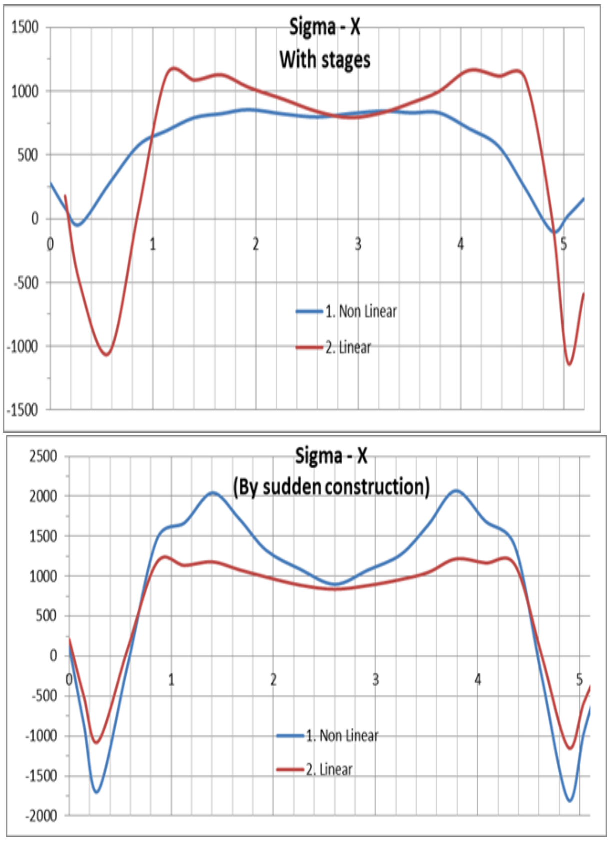


Fig. 3 Distribution of horizontal normal stresses at

the contact section of the tunnel lining base (construction status): taking into account the construction phase and sudden construction schemes.

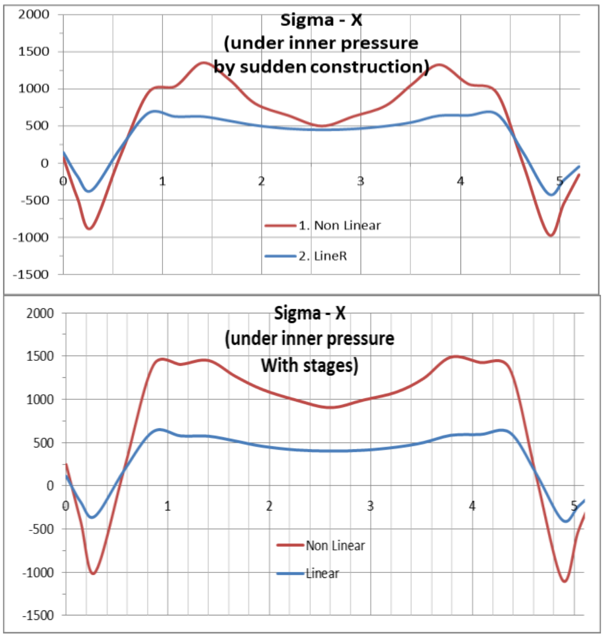
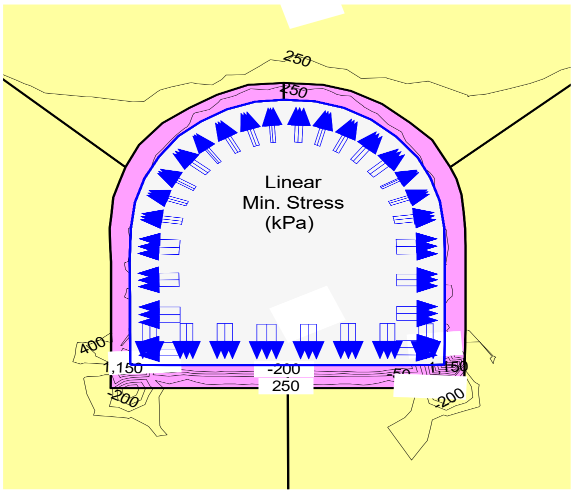


Fig. 4. Distribution of horizontal normal stresses at the contact section of the tunnel lining (operational condition - under inner pressure) taking into account the onstruction phase and sudden construction schemes.

Under the action of the inner pressure of the tunnel the tensile stresses in the wall and bottom slab contact are reduced (compared to an empty tunnel) and reach up to 1000 kPa (Fig. 4).

A general picture of the distribution of the main stresses is given in the drawings (Fig. 4,5).



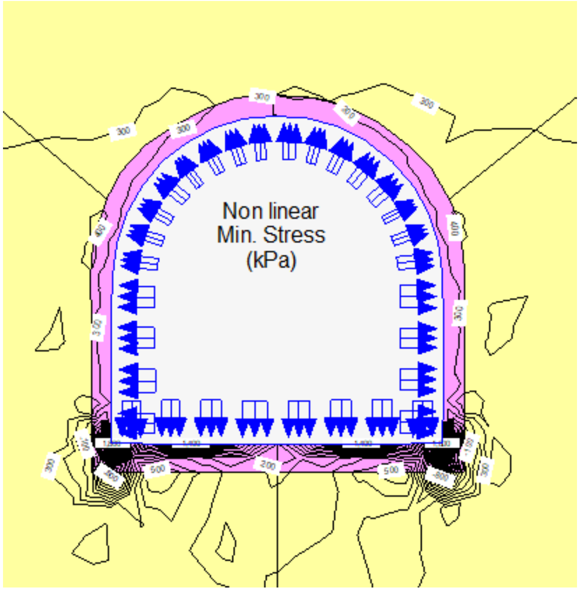


Fig. 5. Distribution of minimum principal stresses in tunnel lining taking into account nonlinear behavior of the material (by sudden construction scheme and operational condition).

Due to the nonlinearity of the surrounding massif, the value of the tensile stresses at the slab of the lining increased (from -200 kPa to -1400 kPa), however, as a result of taking into account the phased nature of the construction, these stresses decreased sharply (to -100 kPa).

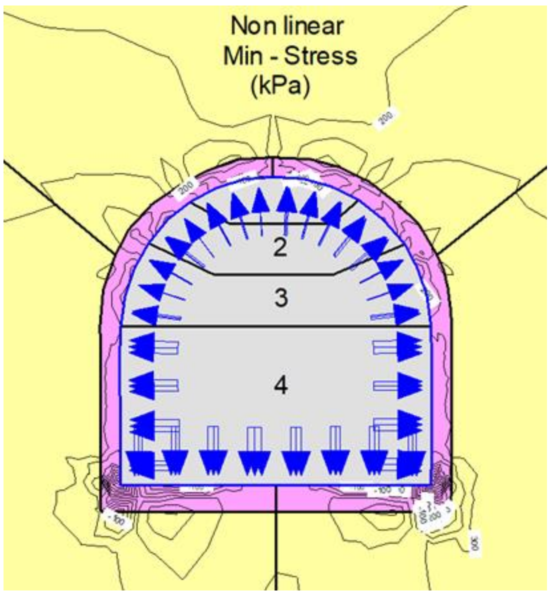


Fig. 6. Distribution of minimum principal stresses in tunnel construction taking into

account material nonlinearity and construction technology (operational condition).

Conclusion

1. The nonlinear behavior of the surrounding massif has a significant impact on the stress states of the tunnel lining, both during construction and during operation. In particular, the nonlinearity of the massif significantly refines the joint operation of the system tunnel-massif. As a result of the distribution of loads under the influence of nonlinearity, the concentration of stresses in individual areas of the lining increases (along with tensile stresses).
2. When taking into account the construction technology and the nonlinearity of the massif, the stress state of the lining improves and, accordingly, strength reserves are revealed, which allows for the optimization of reinforced concrete lining.

The horizontal tensile stresses identified by the nonlinear calculation in the tunnel bottom slab were significantly reduced compared to the linear ones, and when taking into account the phased construction of the tunnel (compared to the sudden construction scheme), the tensile stresses were completely eliminated.

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Determining the rational thickness of a prefabricated dome made of a finite number of spherical shells

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Abstract The problem of calculating a prefabricated dome, the thickness of which is selected in such a way that the maximum deflection is equal to a predetermined value, is considered.
The geometry of the structures and the nature of the acting load determine the involvement of the mathematical apparatus of constructing discontinuous integrals of differential equations in solving the problem.
An algorithm for solving the problem is constructed, including two nested iterative processes.
The problem is solved both for a prefabricated dome and for a corresponding round slab.
A specific example shows the efficiency in terms of material savings of using flat prefabricated domes, compared to flat slabs
Keywords: cylindrical shell, optimal designs, iterative process, internal pressure, elasticity.

INTRODUCTION

Circular plates and gently sloping domes are widely used as roof and ceiling structures for industrial and civil buildings. Usually, the calculation of such structures is of a verification nature. For given geometric dimensions, mechanical properties of the structure material and the load acting on it, the stress-strain state of the structure is determined. Then, the extent to which this state satisfies the operational conditions of the structure is checked.

Often, the shape and dimensions of structures are established based on technological, aerodynamic or aesthetic considerations. In such cases, it is natural to look for ways that are different from the classical ones, ensuring compliance with the predetermined conditions of rigidity or strength.

In the work [1], a method of "parametric" optimal design is proposed, according to which the function determines the shape of structures is given with an accuracy of up to n unknown parameters. These parameters are determined from the conditions of strength, rigidity, stability, etc.

Later, the idea of that method was used to design circular plates [2], stretched-curved annular disks [3] and closed cylindrical shells [4]. In these works, the law of variation of the thickness of structures was a problem with an accuracy of two unknown parameters, which were determined from the conditions of rigidity and strength. Namely: the maximum displacement had to be equal to a predetermined value and plastic deformation was formed in the fibers with the maximum stress along the thickness.

In this work, a prefabricated flat dome composed of a finite number of spherical shells is considered, which is subjected along with a uniform load, to the action of concentrated transverse forces distributed along parallels and bending moments. The thickness of the shell is determined in such a way that the maximum deflection is equal to a predetermined value.

Then, the same problem is solved for a round plate, and in a specific example, by comparing the results, it is shown what advantage, in terms of material savings, a prefabricated flat dome has in relation to the corresponding plate.

1. Prefabricated shallow dome

Let us consider the structure of a dome, which is a shallow shell composed of spherical parts with different radii of curvature. The structure is subject to both a uniformly distributed load of intensity q and concentrated forces and moments acting along the circular boundaries of adjacent structural elements.

Let us select the thickness of the dome in such a way that the rigidity condition is obviously satisfied. Namely, the maximum deflection of the structures must be equal to a predetermined value .

The equilibrium equation of a shallow spherical shell, written in displacements, is known to have the form [5]**:**

$$\left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}\right)\left(\frac{d^2w}{dr^2}+\frac{1}{r}\frac{dw}{dr}\right)+\frac{Eh}{R^2S}w=\frac{q}{D}, \qquad (1)$$

where w- is the deflection of the shell, E- is Young's modulus, $D=\dfrac{Eh^3}{12(1-\nu^2)}$ the cylindrical bending rigidity, h- is the thickness, and R- is a piecewise constant radius, which takes the following values: and . $R=R_1$ $(0\le r\le r_1)$ и $R=R_{k+1}$ $(r_k\le r\le r_{k+1},\ k=1,2,\ldots,n)$.

Let us move on to a dimensionless quantity $\eta=r/b$ and give equation (1) the following form:

$$\frac{d^2\varphi}{d\eta^2}-\frac{1}{\eta}\frac{d\varphi}{d\eta}-\frac{\varphi}{\eta^2}=\frac{Qb^2}{D}, \qquad (2)$$

Where

$$\varphi=-\frac{dw}{bd\eta},$$

$$Q=\frac{\sum_{k=1}^{n}Q_k\eta_k}{\eta}+\frac{b}{\eta}\int_0^{\eta}\left(q-\frac{Eh}{R^2}w\right)\eta d\eta,$$

a Q_k denotes a vertical load uniformly distributed along the parallels: . $\eta=\eta_k$.

The boundary conditions are as follows:

$\varphi=0$ at $\eta=0$ and $w=0$ $\varphi=0$, at . $\eta=1$

Let us analyze the desired function and its derivatives.

Due to the flatness of the structures, the function w- can be considered continuous. As for the angle of rotation φ, its continuity is ensured by the rigidity of the connection of the individual parts to each other. Bending moments and transverse forces acting along parallels , an abrupt change in φ' and φ'' . The piecewise constant nature of the change in radius R- is the cause of the abrupt change in $\varphi^{(3)}$.

Let us construct a solution to equation (2).

For this purpose, we will represent the desired function φ in the form of the Maclaurin formula, generalized by Sh.E. Mikeladze [6]:

$$\varphi=\varphi(o)+\varphi'(o)\eta+\sum_{k=1}^{n}\delta_k(\eta-\eta_k)+\int_0^{\eta}(\eta-t)\varphi''(t)dt, \qquad (3)$$

Where

δ_k denotes the jump of functions $\varphi'(\eta)$ at points $\eta=\eta_k$.

For $\varphi'(\eta)$ we have:

$$\varphi'(\eta)=\varphi'(o)+\sum_{k=1}^{n}\delta_k+\int_0^{\eta}\varphi''(t)dt. \qquad (4)$$

As a result of substituting φ and φ' into (2), we obtain the Volterra integral equation of the second kind:

$$\varphi''(\eta) = F(\eta) - \int_0^\eta \frac{t}{\eta^2}\varphi''(t)dt,$$

Where

$$F(\eta) = -\frac{Qb^2}{D} - \frac{\sum_{k=1}^{n}\delta_k\eta_k}{\eta^2}. \qquad (5)$$

The resolvent of the resulting integral equation has the form:

$$. \ \Gamma(\eta,t) = \frac{t^2}{\eta^3}$$

As for the solution, it will be written as follows: .

$$\varphi''(\eta) = F(\eta) - \int_0^\eta \frac{t}{\eta^3}F(t)dt.$$

Having φ'', we can determine φ' and φ, and based on the dependence , $\varphi = -\frac{dw}{bd\eta}$ – the deflection -w:

$$W = w(o) - b\int_0^\eta \varphi d\eta. \qquad (6)$$

The constants w =0, φ = 0 and are determined from the boundary conditions.

We have::

$$\varphi(o) = 0,$$

$$\varphi'(o) = -\sum_{k=1}^{n}\delta_k(1-\eta_k) - \int_0^1 (1-t)\varphi''(t)dt,$$

$$w(o) = b\int_0^1 \varphi d\eta.$$

As for the jumps δ_k, they are known quantities:

$$\delta_k = \frac{M_k}{D},$$

where M_k are the values of the moments acting along the parallels $\eta = \eta_k$.

Note that the right-hand side of equation (2) and, consequently, all relations following from it contain -w as an unknown function, for the determination of which the method of successive approximations is used.

The rational thickness is found by the method of simple iteration according to the formula [7]:

$$h_{i+1} = h_1 + æ[w(o) - w_0].$$

$$(æ = 1-m), \ m = 1, 2, 3 \ldots$$

Thus, the presented algorithm for determining the rational thickness includes two nested iterative processes, which is very convenient for calculation on a digital computer.

2. Circular plate

Let us consider a circular plate that is subject to the same loads as the gently sloping dome.

Let us determine the displacement of the plate from concentrated bending moments. For this purpose, we can use the relations that were given for the dome. Indeed, assuming in (5) $Q = 0$,we obtain formulas describing the deformed state of a circular plate subject to moments distributed along the circumferences.

Let us consider in detail the case when the load acts only along one circumference $\eta = \eta_1$ and give the corresponding relations.

We will have:

$$\varphi(\eta) = \varphi(o) + \varphi'(o)\eta +$$

$$\delta_1\left(\frac{\eta_1\eta^3}{6} - \frac{\eta_1^2\eta^2}{2} + \frac{\eta_1^3\eta}{2} - \eta_1\ln\eta_1 - \frac{\eta_1^4}{6}\right).$$

Satisfying the boundary conditions: $\varphi(o) = \varphi(1) = 0$, we obtain:

$$\varphi'(o) + \delta_1\left(\frac{\eta_1}{6} - \frac{\eta_1^2}{2} + \frac{\eta_1^3}{2} + \eta_1\ln\eta_1 - \frac{\eta_1^4}{6}\right).$$

For the deflection w based on (6) we have:

$$w = w(o) - \frac{b\varphi'(o)^2}{2} - b\delta_1\left[\frac{\eta_1\eta^4}{24} - \frac{\eta_1^2\eta^3}{6} + \frac{\eta_1^3\eta^2}{6} - \right.$$

$$\left. -\eta_1(\eta\ln\eta - \eta) + \eta_1\eta\ln\eta_1 - \frac{\eta_1^4\eta}{6} + \frac{\eta_1^5}{24} - \eta_1^2\right].$$

From the condition w[I] = 0, we obtain:

$$w(o)=\frac{b\varphi'(o)}{2}-b\delta_1$$
$$\left(\frac{25}{24}\eta_1-\frac{7}{6}\eta_1^2+\frac{\eta_1^3}{4}-\frac{\eta_1^4}{6}+\frac{\eta_1^5}{24}+\eta_1\ln\eta_1\right).$$

As for the expressions for displacements from distributed - q and concentrated Q_1 transverse loads, we have for them [8]:

$$w=\frac{qb^2}{64D}(1-\eta^2)+$$
$$\frac{pb^2}{8\pi D}\left[\left(\eta_1^2+\eta^2\right)\ln\eta_1+\frac{(1+\eta^2)(1-\eta_1^2)}{2}\right].$$

At the center of the plate, the deflection from all loads must be equal to a predetermined value w_0:

$$w(o)=\frac{b\varphi'(o)}{2}-b\delta_1$$
$$\left(\frac{25}{24}\eta_1-\frac{7}{6}\eta_1^2+\frac{\eta_1^3}{4}-\frac{\eta_1^4}{6}+\frac{\eta_1^5}{24}+\eta_1\ln\eta_1\right)+$$
$$+\frac{qb^2}{64D}+$$
$$\frac{pb^2}{8\pi D}\left(\eta_1^2\ln\eta_1+\frac{1-\eta_1^2}{2}\right).$$

By specifying specific values: b, η_1 , E, , q and Q_1, we can determine the thickness of the structures that ensures compliance with the predetermined rigidity condition.

3. Numerical results and conclusions

Let us consider a specific structure in the form of a prefabricated dome composed of two spherical parts. Let us assume that q = 500 kg/m^2, Q_1= 200 kg/m, M_1 = 100 kgm/m, η_1= 0.5, w_0 = 1•10–4 m, R_1 = 20 m, R_2 = 10 m, b = 2 m, E = 1•1010 kg/m^2, æ = 10, v = 0.

For the numerical implementation of the task, a program was compiled for calculation on a digital computer.

The thickness corresponding to the specified rigidity condition turned out to be equal to 0.055 m.

For a flat plate, the thickness is 0.104 m.

Analysis of the obtained results allows us to conclude that even with an insignificant lifting arrow (of the order of the thickness), the rigidity of the prefabricated dome is significantly greater than the rigidity of the plate. And when it is necessary to design a structure with a predetermined rigidity condition, a flat prefabricated dome provides significant savings in material. In the case under consideration, the thickness of the slab exceeds ≈1.9 times the thickness of the dome.

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Determination of internal forces in sections of curved arcuate rod at its deformation

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Abstract. The article discusses the calculation of the strength of a prestressed curved rod in the form of a round arch by the method of displacement. Such arches are used in building structures and in various machine units, and need to be comprehensively studied by methods of resistance of materials. This problem is a fundamental problem of building mechanics of machines and various building stationary structures.
Keywords: rod, curvature, displacement, force, bending moment.

Introduction

Some parts of various building structures and some machine units are under the influence of forces applied from interaction with various adjacent parts. These forces cause the stress-strain state of these parts.

As is known in order to increase the strength of machine-building and building structures, some of their parts are given a curvilinear shape, which significantly increases their rigidity and carrying capacity. In addition, the use of such parts makes it possible to create these structures as light as possible, and to produce less material consumption during their manufacture.

Main part

A circular arch of constant cross-section, which at point D has a rigid fastening, is a statically detectable elastic system. After pre-stretching its end point B and fixing it to the fixed post C, the curved element becomes pre-stressed and it will already be statically indeterminate twice.

The curved rod of circular shape is stretched by Δ_x along the axis Ox and is connected to the fixed hinge C. It is necessary to find the bending moment, transverse force and longitudinal force in an arbitrary section of the rod.

The problem is statically indeterminate, based on this, to determine the value of the X_1 and X_2, it is necessary to draw up two equations of displacement of the end of the rod, i.e. Canonical elastic curvilinear rod deformation equations.

$$\left.\begin{aligned}\Delta_{F1} + \delta_{11}X_1 + \delta_{12}X_2 = \Delta_x \\ \Delta_{F2} + \delta_{21}X_1 + \delta_{22}X_2 = 0\end{aligned}\right\} \quad (1)$$

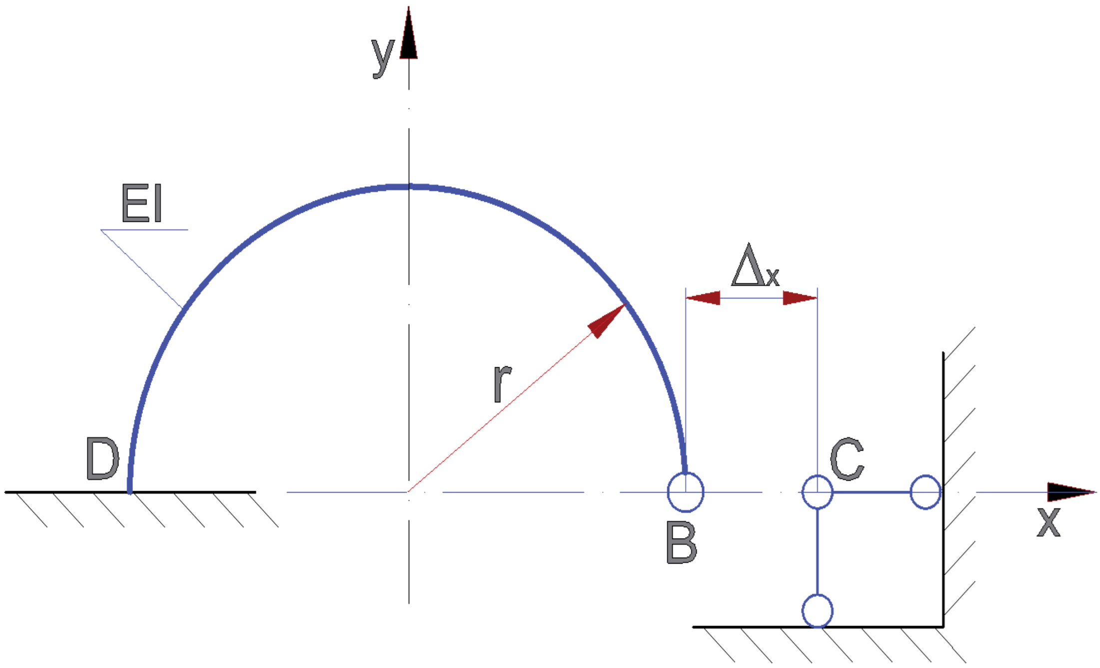

Fig. 1

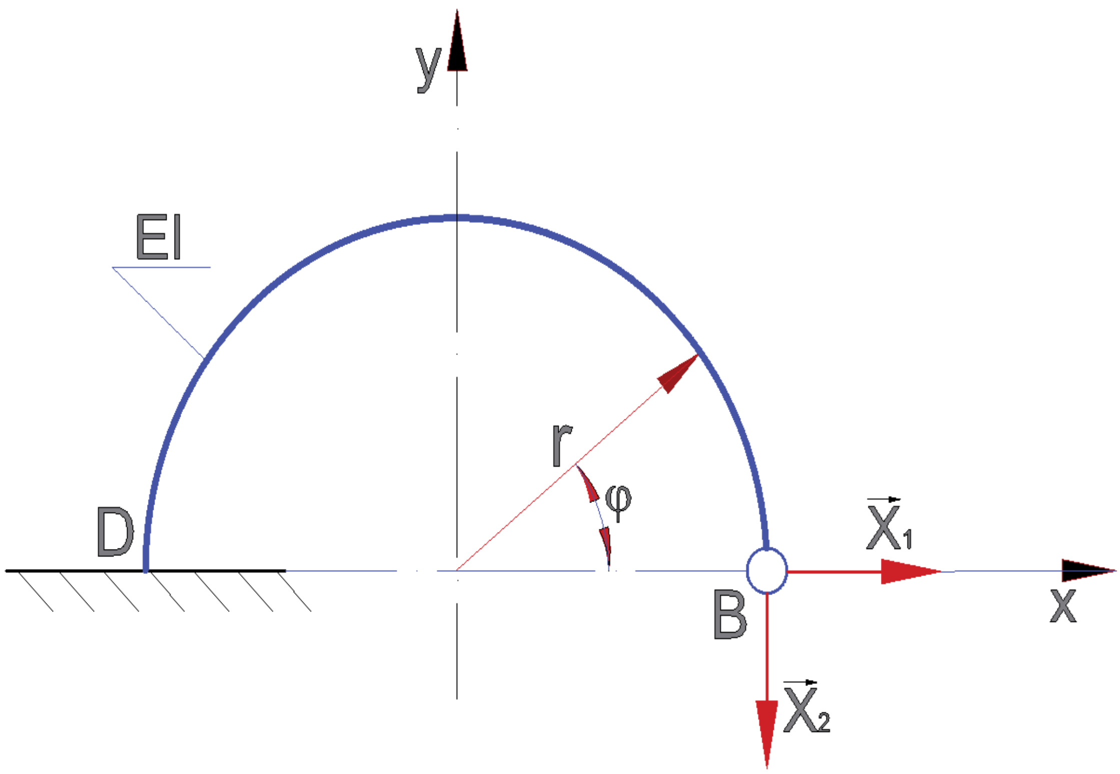

Fig. 2

Given that:

$$M_F = 0, \quad M_1 = r \cdot sin\varphi, \quad M_2 = -r \cdot (1 - cos\varphi), \qquad (2)$$

We find:

$$\Delta_{F1} = \Delta_{F1} = 0, \quad (3)$$

Based on this, the coefficients in the system of canonical equations are determined by the following expressions:

$$\delta_{11} = \int_0^{\pi} \frac{(r \cdot sin\varphi)^2 \cdot r}{EI} d\varphi = \frac{\pi r^3}{2EI} \quad (4)$$

$$\delta_{22} = \int_0^{\pi} \frac{r^3 (1-cos\varphi)^2}{EI} d\varphi = \frac{3\pi r^3}{2EI}, \quad (5)$$

$$\delta_{12} = \delta_{21} = -\int_0^{\pi} \frac{r^3 \cdot sin\varphi \cdot (1-cos\varphi)^2}{EI} d\varphi = -\frac{2r^3}{EI}, \quad (6)$$

After substituting the obtained values of these coefficients into the system of canonical equations, we obtain expressions that determine the values of unknown forces acting at the end of the arch:

$$X_1 = \frac{6\pi EI}{3\pi^2 - 16} \cdot \frac{\Delta_x}{r^3}, \quad (7)$$

$$X_2 = \frac{8EI}{3\pi^2 - 16} \cdot \frac{\Delta_x}{r^3}, \quad (8)$$

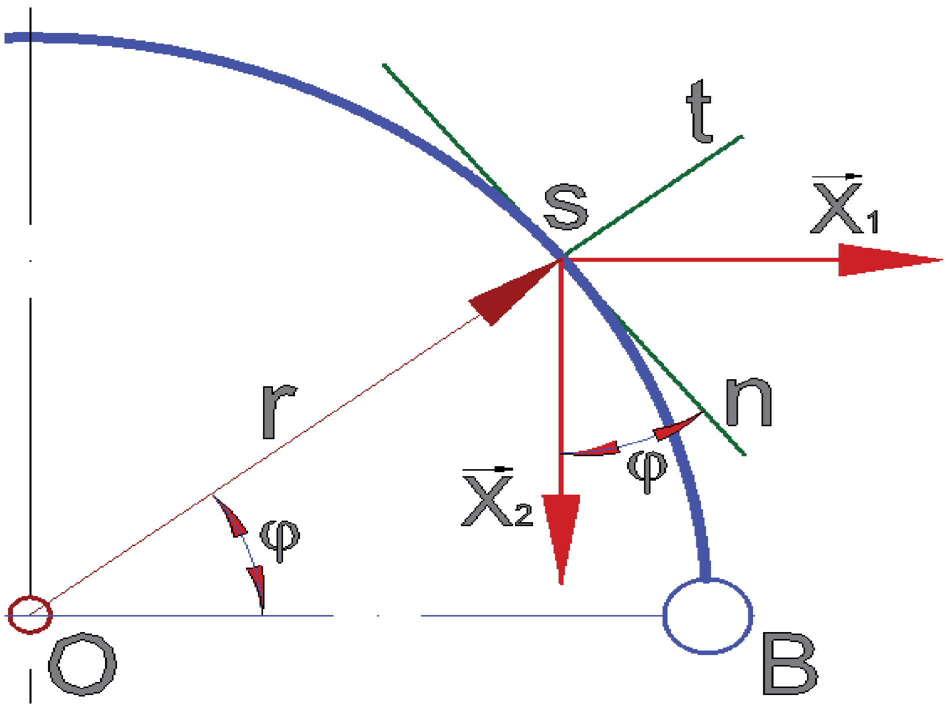

Fig. 3

Knowing the values of these forces, you can determine the internal forces in any section of the arch (Fig. 3).

The bending moment in any section of the arch will be:

$$M = X_1 \cdot r \cdot sin\varphi - X_2 \cdot r(1 - cos\varphi) = \frac{6\pi EI}{3\pi^2 - 16} \cdot \frac{\Delta_x}{r^3} \cdot r \cdot sin\varphi - \frac{8EI}{3\pi^2 - 16} \cdot \frac{\Delta_x}{r^3} \cdot r \cdot (1 - cos\varphi) = \frac{2EI}{3\pi^2 - 16} \cdot \frac{\Delta_x}{r^2} \cdot [3\pi \cdot sin\varphi - 4 \cdot (1 - cos\varphi)] \quad (9)$$

The transverse force in any section of the arch is given by:

$$Q = X_1 \cdot cos\varphi - X_2 \cdot sin\varphi = \\ = \frac{6\pi EI}{3\pi^2-16} \cdot \frac{\Delta_x}{r^3} \cdot cos\varphi - \frac{8EI}{3\pi^2-16} \cdot \frac{\Delta_x}{r^3} \cdot sin\varphi = \\ = \frac{2EI}{3\pi^2-16} \cdot \frac{\Delta_x}{r^3} \cdot [3\pi \cdot cos\varphi - 4 \cdot sin\varphi] \quad (10)$$

The longitudinal force in any section of the arch will be:

$$N = X_1 \cdot sin\varphi + X_2 \cdot cos\varphi = \\ = \frac{6\pi EI}{3\pi^2-16} \cdot \frac{\Delta_x}{r^3} \cdot sin\varphi + \frac{8EI}{3\pi^2-16} \cdot \frac{\Delta_x}{r^3} \cdot cos\varphi = \\ = \frac{2EI}{3\pi^2-16} \cdot \frac{\Delta_x}{r^3} \cdot [3\pi \cdot sin\varphi + 4 \cdot cos\varphi] \quad (11)$$

Conclusion

Some machine installations and building structures contain curved parts that work in conditions of force interaction with other parts of the structure. Such interactions can create deformations of these elements, which in turn can cause the occurrence of additional normal and tangential stresses, which can exceed the permissible values, and this can cause the part to collapse and disable the entire unit. Calculations for the strength and rigidity of such parts are an urgent task of modern mechanics and one of the solutions to this problem is shown in this work.

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Principles of Artistic Design for Pediatric Medical Facilities Based on Survey Results

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Abstract The article discusses the importance of color in medical facilities. Modern architects, in collaboration with psychologists, carefully and thoughtfully make color-related decisions, a practice that is well-established abroad. However, in our local context, this aspect receives considerably less attention.

In foreign practice, especially in the planning of pediatric medical spaces, the needs of children are taken into account. Calm colors and lighting are selected to help children adapt to the environment and gain their trust during an already challenging psycho-emotional period.

Our research aimed to determine the significance of interior design for patients who have to spend a certain amount of time in a clinic. To achieve this, we identified several target groups and conducted surveys at the Tbilisi State Children's Infectious Disease Clinic, involving patients, their parents, and medical staff. Additionally, research was carried out on social networks among parents of young children. Following these efforts, interviews with child psychologists proved to be particularly interesting and noteworthy.

The research confirmed that environmental factors significantly influence the mood and emotions of both patients and their guardians, as well as the productivity and attitude of medical staff. A well-designed interior and carefully chosen colors can help build children's trust and minimize their anxiety.

Keywords: medical facility, design, color solutions, color psychology, pediatric clinics.

Introduction:

Color and lighting are among the most essential components in architecture and design. They are closely tied to the psychology of perception and aesthetics. In general, the color palette for projects is selected based on various factors such as the purpose of the object, its geographical location, culture, religion, and many others.

Our goal is to provide recommendations for the proper planning of pediatric medical facilities, with a focus on the appropriate design of their interiors, particularly emphasizing color and lighting. The main objective is to develop recommendations in this field that will form the basis for the development of so-called project standards and regulations, as there is currently a lack of such documents at the national level. It will assist architects in designing not only clinics equipped with modern technologies and in line with the latest standards but also clinics that simultaneously create a comfortable, "familiar" environment for patients. This will make the examination and treatment periods less stressful for both children and parents, helping to prevent additional feelings of fear for the ill children.

Main Body:

Our research on pediatric medical facilities was based on a variety of activities surrounding this topic. We reviewed both international and local literature, examined the practices of leading countries abroad, and analyzed the current situation both outside our borders and within our own country. To achieve the objectives of the research, one of the methods we selected was a survey-based study. In line with the goal, the content and number of survey questions were determined, target groups were selected, and it was decided to conduct the research in two directions: at the Children's Infection Hospital of Tbilisi, involving both patients and their parents, as well as doctors. Surveys were also conducted with parents of young children on social media platforms. After all of this, interviews with pediatric psychologists, in particular, proved to be especially interesting and noteworthy.

A total of 150 respondents were surveyed in both directions. Of these, 50 were from the Children's Infection Hospital — 20 were staff members, and 30 were parents of patients. The remaining 100 respondents were surveyed via social media platforms.

It was essential to understand the perspectives of both sides — the patients and their parents, regarding the type of clinic in which they would like to receive services, as well as the medical staff, in terms of what kind of working environment would allow them to feel comfortable and perform at their best.

The research object was the Children's Infection Hospital located on Simon Chikovani Street. With its location, territory, recreational area, and buildings, it stands out from others due to its potential. However, it undoubtedly requires reconstruction to meet modern standards and create a more comfortable and positive environment for children. Just like in the case of this particular clinic, the general survey also revealed that the majority of parents and doctors prefer a simple interior in light colors, decorated with colorful designs and painted with beloved cartoon characters or animals for children. They request more greenery and natural materials.

Based on the conducted survey interviews, we can say that the environment is a very important factor for parents when choosing a clinic. We asked them to name a children's clinic in Tbilisi that they preferred over others. The most frequently mentioned was the 'American Clinic,' which is a new, modern hospital tailored to current standards, where patients feel comfortable and hopeful.

Overall, the survey conducted in both directions revealed that the coloristic design of children's medical facilities in Tbilisi largely needs to be reconsidered.

The above-mentioned survey was not sufficiently informative for us; it was more general in nature. Therefore, interviews were planned and conducted with psychologists in the relevant field. These meetings turned out to be extremely interesting and informative for us. We prepared a few key questions and asked the child psychologists to share their opinions on these topics. The discussion was about both general child psychology and the recommendations provided specifically for medical institutions. Topics included how children feel calm in certain environments, which colors can reduce their anxiety and minimize stress, how to make them feel in a cozy and homely atmosphere, and so on.

About ten psychologists participated in the interviews, including: PhDs in psychology, psychotherapists, university professors, and founders of rehabilitation centers. The majority of them spoke about calm, pastel, and neutral colors. As a result of a comprehensive analysis of the interviews with the psychologists, it was revealed that for a child, it is essential to create a familiar environment; they should have associations with home, school, kindergarten, and playgrounds. When entering the clinic's territory, even the yard should be properly arranged. When a patient has to spend several days in the clinic, they should not be restricted from going outside. The child should be able to use the hospital's yard, which will be adapted for any type of child. They should be given the opportunity to use swings, play in the sand, or simply walk in the greenery.

Primarily, when entering clinics, we encounter a stressful environment right from the first step— the registration area, where people in white coats sit, filling out the patient's history and then directing them to a specific doctor. Registrars are not doctors, and they can replace the white coat with a colorful uniform, which will not add stress to children as soon as they enter the clinic. In addition, it is possible to set up a play corner in the lobbies, where the child will have the opportunity to entertain themselves and shift their attention to playing while the parent completes the registration and waits for their turn.

Also, based on the psychologists' survey, we can conclude that it is better to use pastel colors in the vestibule, corridors, and waiting rooms. The main color recommended is blue, as it is associated with calmness, does not tire the eyes, and does not overstimulate. In the case of corridors, the main color can be complemented with applications, cartoon characters, installations, numbers, letters, and shapes, which, when observed by the child, will shift their primary focus and reduce their anxiety about the upcoming procedures and pain.

It is desirable to have bright lighting, plain walls, and some accent in the procedure rooms. Dominantly, an application can be placed in a specific corner of the room, or there can be a screen, through which, during a specific procedure, the child will have an object of interest, and their attention will be focused on a single point.

We can confidently incorporate maximum imagination in the case of patient rooms, where the patient spends the most time during their stay at the clinic. The spaces should not be exhausting, monotonous, or boring, while also not being overloaded to avoid tiring or overstimulating the child. In addition to wall tones, it is advisable to introduce color through lighting, for example, a soft, calming lavender shade. Natural lighting should be maximized, utilizing skylights and as much sunlight as possible through windows. Children should always feel connected to nature, as this helps improve their mood and contributes to physical recovery, a fact supported by numerous scientific studies. The rooms can include small play areas, and the use of screens may also be considered, as watching cartoons helps pass the time and provides emotional uplift. In some cases, the use of red elements in the interior is acceptable. Although red is considered aggressive and is associated with anger and fire, children still like it, as it represents the color of love for them and their psyche processes it well. Often, children choose red among the primary color palette. This, of course, does not mean painting the walls red, but red accents on the walls will be pleasant for toddlers. Additionally, pink has a calming aura, alleviates chronic fatigue and tension, and is considered a color of relationships and friendship.

The design of doors leading to different rooms is very important. Ideally, every space should be engaging and appealing for children. If the door is glazed or has a window, children should be able to see what's happening behind it. This will prevent them from feeling anxious or scared and help them understand that they are not entering a dangerous space when they go through the door.

It is essential for clinics to have play and social rooms where children, who are allowed to interact with others, can meet, play, draw, sculpt, and spend time pleasantly with their peers. This not only enhances their social skills but also positively impacts their psychological and emotional well-being.

When talking about children, it is crucial to consider all of them, especially in medical environments. There are both typical and atypical development children, and any of them can become ill, including children with special needs, such as those with autism spectrum disorders, ADHD syndrome, and others. In any case, these children require specialized attention, a comfortable and cozy environment tailored to their needs, so as not to cause irritation and to help maintain the balance of their psychological state.

A very interesting and extensive interview took place with Dr. Sofo Tsignadze, a psychologist with a medical center that specializes in children with behavioral disorders. Ms. Sofo spoke in detail about the needs of children with atypical development, the creation of the right environment for them, and the correct psychological approaches. What we discussed above is largely applicable to all developmental children, with a few exceptions. For example, if a child enters a vestibule and is immediately greeted by bright lighting and music, in most cases, this music could be a soundtrack from a cartoon or a piece of children's repertoire, which would surely appeal to the child and create a good mood. However, if we consider children with spectrum disorders, the music should be selected more carefully. It should be children's music, but played at a very low volume and be as calm as possible. Loud sounds and a colorful environment may irritate the child to the point where the parent cannot calm them down and may not even be able to get to the doctor's office.

In the vestibule, corridors, and common areas, designed in neutral, pastel, and calm colors, children with autism spectrum disorders will feel safe and comfortable. As for the patient rooms, separate spaces could be created for them, featuring cozy lighting, plain walls, and minimal decoration, to avoid the psychological irritation caused by bright colors and active lighting, and to create a peaceful atmosphere.

We discussed the red color, which, as mentioned, is highly favored by children with typical development. However, for children with anxiety disorders, it can be psychologically damaging. For instance, a bright red drawing of a ladybug on the wall might be an appealing, vibrant element for a typical child, but it may cause agitation for a child with a disorder. Therefore, we can use red in any case, but it should be calm, not loud, pastel, and soft. The same applies to sunny shades, yellow, and orange tones.

Based on the overall analysis, we can conclude that the principles of inclusive design (Marzia Morena, 2011) should be considered in every clinic. An environment tailored for both typical and children with special needs is necessary. As mentioned, infectious diseases can affect anyone, including patients with cerebral palsy. Therefore, every detail must be taken into account for all types of children. There should be ramps, special elevators, properly arranged restrooms and rooms, and the color design should also be considered for all types of patients.

Interviews, along with international experience, have revealed the advisability of using chromotherapy in clinics (alternative medicine that helps doctors and psychologists manage patients' emotions and maintain balance through colors) (Viana, 2020). Color therapy belongs to the supplementary medical system; it is a well-established method and is often used in today's practice. It is one of the oldest practices, gradually gaining interest as an active and effective science. Using electromagnetic radiation, chromotherapy activates specific points in our bodies and has been found to alleviate various diseases.

In his book "Chromotherapy, The Power of Colors" (Valnet, 2014), Christian Valnet explains chromotherapy, discussing the significance of colors and the profound impact they can have. He examines each color individually and talks about their positive and negative attributes.

An interesting article on this topic is "Chromotherapy - A Useful Tool for Managing Anxiety in Children" (Aparna Jai Krishna, Jyothsna V. Setty, 2024). The authors conducted a study in a pediatric dental clinic, obtaining parental consent, and observing over a period of six months. They demonstrated the significant impact colors can have on children's psychology. Dental clinics often cause anxiety in both children and adults. They fear the instruments, and the smells from the clinic can become deeply ingrained in their minds, leading to stress during future visits. The researchers turned to chromotherapy, using colors that children love in the interior design. They also provided pink and blue glasses for the children. As a result, they observed less stress and minimal anxiety, with heart rates often within normal ranges, and received positive feedback after the visits.

Chromotherapy can be integrated into the treatment process of any clinic, helping children overcome anxiety.

Our survey results, along with interviews with psychologists, have shown how important not only the patient's but also their companion's (parent's, guardian's) psycho-emotional state is when entering a clinic. Our opinion is supported by the work of the Italian researcher Elena Commodari, published in 2010, (Commodari, 2010), where the psychological state of parents and guardians is discussed. Hospitalization of children is a highly stressful event for parents, and the emotional stability of adults, their expressed level of anxiety, and restraint play a significant role in the child's mental state. The researcher discusses the importance of properly created environments in hospitals, noting that the longer the stay in the clinic, the more difficult it becomes for the parents' mental health. To address this, she highlights the importance of recreational, educational, and entertaining spaces within the clinic, where children can spend their time pleasantly, while adults have the opportunity to relax. When they see their calm children, their anxiety levels decrease as well. Generally, there could be a school-like space on the clinic's premises for adolescents, where children will feel like they are in a familiar environment. Additionally, there could be "teachers," or tutors, who will assist them with various tasks and, most importantly, help redirect their attention from pain to something pleasant.

Reducing stress in the guardians of hospitalized children will contribute to more effective treatment planning and help children perceive their illness more lightly. As a recommendation, we believe it would be beneficial if hospitals provided children the opportunity to complete homework, prepare lessons, and this should apply to all children, including those confined to their beds, so that they feel life continues in its usual rhythm. They should feel they have responsibilities and cannot stop or waste time.

The results of our surveys are supported by an article published in 2001 by a group of American psychologists, architects, and doctors (SANDRA WHITEHOUSE; JAMES W. VARNI, MICHAEL SEID; CLARE COOPER-MARCUS; MARY JANE ENSBERG; JENIFER R. JACOBS; ROBYN S. MEHLENBECK), which discusses the importance of the artistic design of a hospital environment for a child's psyche. The article cites as an example the children's hospital in San Diego, which features a well-equipped inner courtyard. The study was conducted to determine whether the idea of creating a garden in a hospital was justified in reducing stress and increasing customer satisfaction. According to the research results, the garden brought numerous benefits, being perceived not only as a therapeutic space but also as a relaxing public area. The children's hospital in San Diego, with its courtyard and interior design, is a great example of how a pediatric clinic should be. The vestibule is spacious, with a dominant use of blue and white colors on the walls. The reception area features accents of blue and orange, and an aquarium is mounted on the wall. The cafeteria is designed in cheerful colors. Each patient room has a window in the entrance door, allowing children to see what’s happening beyond the wall. This detail emerged as an important component during the interviews we conducted with psychologists. The design of the patient rooms is thoughtfully executed, with each room featuring a decorative wall depicting themes like space, animals, and other imaginative visuals. The atmosphere of this hospital has a positive impact on children's psychology, and both patients and their parents consistently mention experiencing less anxiety during stressful days. This is attributed to the overall environment of the clinic and the quality of service provided.

Healthcare professionals have come to the conclusion that the artistic and aesthetic environment of a hospital can influence the patient's mood, reduce stress caused by illness, and that determining stress levels in both patients and their family members is crucial during the treatment process.

The conclusion drawn from our survey and in-person interviews, confirming that the artistic design of both the exterior and interior of pediatric medical facilities plays a significant role in the rapid recovery of patients, is supported by a 2023 study on environmental experiences in pediatric healthcare, published in the United States (Clarissa Yu, Mi Wong, Juliana Gigna, Meaghan Walker, Timothy Ross, 2023). The researchers conducted surveys in clinics to explore stressful environments and ways to alleviate them. Architecture and interior design elements, such as walls, ceilings, floors, windows, colors, decor, and furniture, can all contribute to reducing stress. All of these factors influence the psyche and can impact anxiety levels. Reducing anxiety can speed up the recovery process. It is also important to consider the preferences of children, who often appreciate the use of blue and green colors in the interior, as these colors create a calm, trustworthy, and stable environment. The study also emphasizes the creation of a comfortable environment for guardians. In the surveys, guardians actively criticized the conditions for guardians, stating that they should be able to relax, eat, and take showers in the patient’s room. This is because, in many cases, they spend several days with their children. Disorganized spaces negatively affect their emotional state, further complicating their psychological well-being and making it almost impossible to maintain emotional balance. A rested and calm guardian is, first and foremost, essential for the patients.

In 2024 and 2025, the Architecture Week was held in Tbilisi, where professors from the Polytechnic University of Milan were invited. They conducted lectures on healthy architecture, discussing the modern standards of hospital design and the necessity of incorporating greenery and natural environments into clinics. Stefano Copollo, the head of the Faculty of Architecture at the Polytechnic University of Milan and a full professor in architecture, gives public lectures and workshops worldwide on hospital design.

In the process of understanding the principles of artistic design for children's healthcare facilities, we found a noteworthy article published in 2021 by Prof. Stefano Copollo and his co-authors (Monica Botta, M.Arch, Anna Lisa D’Aniello, and Stefano Capolongo, PhD, M.Arch). The article discusses the importance of nature, particularly after the COVID pandemic, and how even a brief pause in nature can help reduce stress in individuals. Considering environmental factors, stress, routine life, polluted environments, and the accelerated pace of life, general mental health is currently in a rather challenging state. A study was conducted based on surveys of medical personnel to understand how contact with nature could help balance their emotions. The COVID pandemic caused significant disruptions in people's daily lives, which, in turn, affected their mood, especially during the lockdown period. It became clear how calmly people adapted to staying at home when they had their own yard, terraces, or balconies, even if just small green spots with plants. During the study, several hospitals had therapeutic gardens in their designs, open and green spaces that were specifically created for therapeutic purposes, benefiting not only the patients but also their families and staff.

Our survey results analysis also shows the significant importance of the connection to nature in the artistic design process of children's medical institutions. Even a short break in green spaces has a strong impact on the psycho-emotional well-being of hospital staff, emphasizing the importance of green spaces in hospital architecture. Even a brief break in nature can aid in the regeneration of users, especially when health issues are accompanied by mental health challenges.

We have discussed the issues regarding the arrangement of hospitals in Tbilisi. In several currently operating clinics, their design has been somewhat considered, and the interiors are less standardized and monotonous. However, even in these cases, the requirements that would satisfy both the patients and the medical staff have not been fully met. As for the direction of children's hospitals, the situation here is much more challenging. It is true that some pediatric clinics, such as "Tsitsishvili Hospital," leave an overall positive impression. The facility is newly renovated, and the interior features details designed for children. A children's play area is arranged at the entrance, and there are also entertainment corners in the doctor's offices, where patients can enjoy themselves and shift their attention to other elements. Most pediatric hospitals in Tbilisi do not take into account the psycho-emotional impact of the environment, and there is no consideration for an overall color scheme. For example, the children's infectious disease hospital selected for our survey falls short of all standards. Its medical inventory is outdated and incompatible with modern times, and both the interior and exterior spaces are in need of repair. Significant changes are required from a color perspective, and both the equipment and furniture need to be replaced. The yard should also be organized, with the potential for proper development, making it a central focus of the clinic's improvement.

Conclusion

Based on the analysis of surveys from children, parents, doctors, and psychologists, it was determined that one of the decisive factors in the treatment process is the environmental conditions. When planning new clinics or during the restoration and rehabilitation of existing ones, we must consider not only high-standard equipment and tools but also pay significant ttention to the proper arrangement of the interior. This includes creating designated recreational spaces for children, incorporating natural elements through materials and landscaping, and ensuring the use of a proper color scheme. This means employing non-tiring, pastel, and calm colors, along with the introduction of soothing lighting. By considering all of these factors, we will achieve the well-being of children, maintain their psycho-emotional balance, reduce anxiety and fear regarding doctors and procedures, which in turn will ensure the satisfaction of the parents.

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Challenges of the Urban Environment and Their Impact on the Quality of Life of Children with Autism Spectrum Disorder

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Abstract The urban environment plays a critical role in shaping the quality of life for children with Autism Spectrum Disorder (ASD). While urban planning often addresses physical disabilities, the specific needs of children with ASD are frequently overlooked. Children with ASD are particularly sensitive to sensory stimuli, making thoughtful urban design essential for reducing stressors and improving their overall well-being. This article explores how urban environments impact children with ASD, highlighting challenges such as noise and sensory overload, intense visual stimuli, lack of safe spaces, limited access to inclusive play and educational spaces, and the importance of personal zones. Additionally, the article discusses the positive aspects and opportunities presented by green spaces, acoustic comfort, and inclusive design, offering recommendations for urban planning that accommodates the needs of children with ASD. The study emphasizes the necessity of sensory-friendly spaces, noise reduction, and inclusive recreational and transport systems to enhance social integration and improve the quality of life for children with ASD. Effective urban planning that incorporates these factors can foster a supportive, inclusive, and accommodating environment for children with ASD.

Key Words: Urban environment, Autism Spectrum Disorder (ASD), sensory overload, noise reduction, visual stimuli, inclusive design, green spaces, urban planning, sensory-friendly spaces, play spaces, educational spaces, personal zones, spatial organization, social integration, environmental design.

Introduction

In contemporary society, the urban environment plays a pivotal role in shaping the quality of life for individuals. While significant attention is often given to addressing the physical needs of people with disabilities in the design and construction of buildings and infrastructure - such as providing ramps for accessibility, audible signals at traffic lights, Braille on elevator buttons, and accessible restrooms - the specific needs of children with Autism Spectrum Disorder (ASD) are frequently overlooked. These children exhibit heightened sensitivity to sensory stimuli, which makes thoughtful urban planning essential to mitigate potential stressors and enhance their overall well-being. Urban spaces, if not carefully designed, may inadvertently present challenges that hinder the development and daily functioning of children with ASD.

This article examines the various ways in which the urban environment influences the lives of children with ASD, identifies existing challenges, and offers recommendations for improving urban planning to better accommodate their needs.

Main Part / Main Body Challenges of the Urban Environment for Children with ASD

Noise and Sensory Overload

Urban environments are frequently marked by elevated noise levels, including those generated by traffic, construction activities, crowded public spaces, and pervasive advertising sounds. For children with ASD, such auditory stimuli can lead to sensory overload, exacerbating stress and discomfort. The heightened sensitivity to sound commonly experienced by individuals with ASD makes them particularly vulnerable to the negative effects of urban noise, potentially resulting in anxiety, behavioral disruptions, and challenges in processing and responding to their surroundings. This sensory overload can significantly impact their ability to engage in daily activities and limit their participation in community life.

Intense Visual Stimulation

Urban environments often feature intense visual stimuli, including bright lighting, dynamic advertisements, and vibrant, contrasting colors. For children with ASD, such stimuli can become overwhelming, leading to difficulties with spatial orientation and concentration. The heightened sensitivity to visual input that characterizes many individuals with ASD may cause challenges in processing these sensory cues, resulting in distractions or disorientation. This sensory overload can interfere with their ability to navigate and interact with their surroundings, further impacting their overall quality of life and participation in urban spaces.

Lack of Safe and Quiet Areas

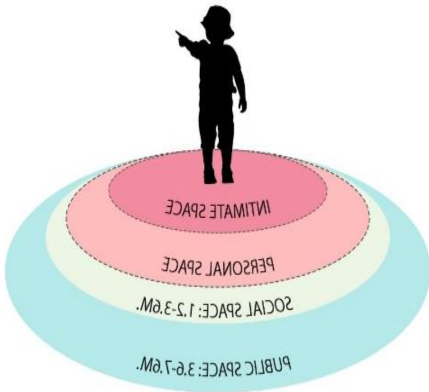
Children with Autism Spectrum Disorder (ASD) often require a safe, structured, and predictable environment to support their emotional regulation and daily functioning. The dynamic and unpredictable nature of urban spaces—characterized by noise, crowds, and constant change—can exacerbate anxiety and stress in these children. The absence of designated safe and quiet areas within urban environments can significantly hinder their ability to process and respond to stimuli in a calm and controlled manner. Without such spaces, children with ASD may face increased difficulty in communication, social interaction, and overall participation in everyday activities, further impacting their quality of life.

Limited Access to Play and Educational Spaces

Playgrounds and public spaces are frequently designed without considering the specific needs of children on the autism spectrum, which can pose significant barriers to their socialization and active recreation. The lack of inclusive design in these spaces often limits opportunities for children with ASD to engage in meaningful play, interact with peers, and develop essential social and cognitive skills. Inadequate access to such spaces can hinder their ability to participate in recreational activities that are crucial for their development, thereby restricting their overall engagement with their environment and limiting their quality of life.

Personal Zones

According to the 2016 publication Designing for Autism Spectrum Disorders (USA), individuals experience several distinct spatial zones in relation to their proximity to others. The closest zone is the intimate zone, followed by the personal space, which typically ranges from approximately 1.2 meters to 3.6 meters. Beyond this lies the social zone, which extends from about 3.6 meters to 7.6 meters. Finally, the public zone encompasses distances greater than 7.6 meters. These spatial zones play a crucial role in how individuals with ASD perceive and interact with their environment, as they may have heightened sensitivity to the invasion of personal space, making the design of spaces that respect these boundaries particularly important.



Personal space is an individualized concept, varying from person to person. However, children with Autism ASD, particularly those with heightened tactile sensitivity, may require additional space around them to feel comfortable. Conversely, children with diminished proprioceptive sensitivity may struggle to perceive the location of their body in space, leading them to avoid engaging in physical play and preferring to observe others instead. Furthermore, children with ASD often experience difficulty in interpreting social distances, which can result in challenges during social interactions and communication. In light of these considerations, it is essential that the environments in which children with ASD live, including their homes, educational institutions, therapy centers, and recreational spaces, be designed with greater attention to their spatial needs. These spaces should be free from unnecessary barriers or clutter, ensuring that children have ample room to navigate and interact comfortably. Urban planning should prioritize the inclusion of open, natural environments and well-lit spaces, as well as the integration of isolated green areas and quiet zones, to foster a supportive and accommodating environment for children with ASD.

Positive Aspects and Opportunities

Green Areas and Natural Environments Research has demonstrated that exposure to natural environments and green spaces can significantly reduce stress and enhance concentration. Integrating more parks and green areas into urban settings can provide children with ASD with calm, restorative environments that support their emotional well-being and cognitive development. The presence of such spaces fosters a sense of tranquility and connection to nature, which is particularly beneficial for children who experience sensory overload in more urbanized settings.

Acoustic Comfort and Low Noise Levels Effective urban zoning and the careful selection of building materials can play a pivotal role in reducing noise levels within cities. By strategically planning these elements, it is possible to create quieter environments that promote acoustic comfort. For children with ASD, who are often highly sensitive to auditory stimuli, a reduction in environmental noise can significantly contribute to a calmer, more supportive atmosphere. This approach not only benefits children on the autism spectrum but also enhances the overall livability of urban spaces.

Inclusive Play and Educational Spaces

In the context of urban planning, the design and development of playgrounds and educational spaces tailored to the specific needs of children with ASD are essential for fostering their social development and enhancing their daily living skills. By creating inclusive environments that consider the sensory, cognitive, and social needs of children with ASD, urban spaces can provide opportunities for meaningful engagement, interaction, and skill-building, thereby promoting their overall development and integration into the community.

Recommendations for Urban Planning

Sensory-Friendly Urban Spaces: Urban infrastructure should incorporate sensory-friendly zones, including sensory gardens and quiet relaxation areas, to provide environments that cater to the sensory sensitivities of children with ASD. These spaces can help mitigate sensory overload and offer refuge for children who may find typical urban settings overwhelming.

Noise Reduction: Implementing noise control measures in public spaces is essential to create a calm and supportive environment for children with ASD. The use of sound-absorbing materials and effective zoning can significantly reduce auditory stimuli, contributing to a quieter, more comfortable urban atmosphere.

Inclusive Play and Recreation Spaces: Parks and recreational areas should be designed with the specific needs of children on the autism spectrum in mind. These spaces should provide a safe, engaging, and accessible environment that supports both social interaction and sensory regulation, promoting the development of critical social and recreational skills.

Adapting Public Transport: Public transportation systems should be adapted to accommodate children with ASD by introducing quiet zones and simplifying informational signage. Such measures would reduce anxiety and confusion, ensuring a more inclusive and accessible travel experience for children on the autism spectrum.

Conclusion

International best practices emphasize that living and therapeutic environments for children with ASD should be situated in natural settings, removed from excessive noise and the hustle of dense urban areas. Providing children with greater opportunities to engage with nature and participate in outdoor play is essential for their development and well-being. Additionally, greater attention should be paid to the cognitive and sensory aspects of environmental design when constructing

residential spaces. Creating environments that are sensitive to the needs of children with ASD will ensure greater comfort and accessibility for all individuals.
The urban environment plays a significant role in shaping the experiences of children with ASD. In urban planning, it is crucial to consider the sensory sensitivities of these children by minimizing noise and visual overload while developing safe, structured, and predictable spaces. Inclusive urban planning policies and architectural solutions will facilitate the social integration of children with ASD, thereby enhancing their quality of life and fostering a more supportive and inclusive society.

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The impact of the state of drinking water supply networks on the quality of water intended for consumption

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Abstract The suitability of drinking water for drinking depends not only on the source and purification system, but also on the quality of the water supply facilities. In fact, the quality of drinking water is significantly deteriorating due to the dilapidated state and lack of maintenance of drinking water supply networks. Most of the drinking water supply networks in different cities are aging. Despite the efforts made by the company responsible for the purification and distribution of water to make the water suitable for drinking, the water in consumers' taps is often colored, has an unpleasant taste and settles after collection. As a result, people are concerned about the suitability of tap water for drinking, and some turn to alternative sources of drinking water of unknown quality. In order to determine the factors responsible for the deterioration of the color and taste of water, as well as the most affected areas of the network, diagnostics of the network equipment were carried out. Water samples taken from the network were analyzed for color and turbidity. Diagnostics showed that most of the equipment (suction cups, valves, drains and fire hydrants) are outdated and irregularly maintained. The analyses show that water is more colored in cast iron and PVC pipes than in asbestos-cement pipes. The color values in the network vary from 0 to 27 UVC for asbestos-cement pipes, from 15 to 56 UCV for ductile iron pipes and from 11 to 102 UCV for PVC pipes. On the other hand, the turbidity values vary from 8.02 to 3.32 NTU for ductile iron pipes, from 8.51 to 16.98 NTU for asbestos-cement pipes and from 0.9 to 6.98 NTU for PVC pipes. Old cast iron pipes release iron ions when in contact with water, which deteriorates their color. Old cast iron pipes release iron ions into the water, which deteriorates its color. High color values observed near drains are believed to be due to irregular network maintenance. In fact, after network maintenance, a decrease in turbidity of 2% to 73% is observed, while for color, this figure varies from 5% to 72%. In short, network aging and irregular maintenance contribute significantly to the deterioration of water quality.

Keywords: Pipe, Water Supply Network, Drinking Water.

1. Introduction

Water is a natural resource essential for life and sustainable socio-economic development. The quality of water to meet different needs varies from one use to another. Water quality can be degraded by anthropogenic activities such as the use of fertilizers, phytosanitary products, chemicals and assimilated products and industrial effluents. Thus, this deterioration in drinking water quality can affect human health. In addition, the aging and lack of maintenance of drinking water supply networks does not come without consequences for the quality of tap water, while optimal management of drinking water supply networks requires supplying consumers with water that meets potability and quality standards, at a lower cost and without interruption in service. The phenomenon of obsolescence has affected most drinking water networks. In fact, these networks usually exist from the year they were put into operation and rarely undergo a regular renewal program, except in cases of pipe bursts. This can lead to the spread of faults in the network and have a negative impact on the health of consumers. Network faults usually manifest themselves in leaks, breaks, changes in water colour, pressure drops and hydraulic power in the network. Despite the efforts of the company responsible for water treatment and distribution to make the water suitable for drinking, the water in consumers' taps is often coloured, has an unpleasant taste and settles after collection in a container. Consumers of drinking water in the community are afraid of the colour and taste of tap water, so much so that some of the population turns to alternative sources of water, the quality of which for direct consumption is still unknown. To address these issues, this study was initiated to determine the impact of the water supply network on the quality of drinking water. The study will be conducted in two stages. First, a physical diagnostics of the network equipment will be carried out. Secondly, and finally, an analysis of the color and turbidity of water samples taken from the network was carried out.

1.1. Field Equipment

Equipment used in the field included: a Garmin etrex 10 handheld GPS navigator for determining geographic coordinates; a camera for taking photographs; survey sheets for conducting surveys; 1 liter (L) bottles for collecting water samples in the network; a cooler for storing water samples; a beaker for collecting water samples and glass tubes for on-site analysis.

1.2. Laboratory Equipment

The following equipment was used in the laboratory: HACH 2100Q nephelometer for measuring turbidity in water samples taken from the network; HACH DR 1900 spectrophotometer for measuring color of water samples taken from the network. PAleontological STatistics (PAST) 3.20, Autocad 2017 and ArcGIS 10.4.1 were used for data processing.

2. Main part

2.1 Physical diagnostics of the network

The physical diagnostics of various objects of the drinking water supply network included a detailed visual assessment of the condition, operation and performance of the equipment used for the transportation and distribution of drinking water. This includes tanks, pumping stations, pipes, valves, meters, water purification devices.

In addition, during the physical diagnostics, the geographic coordinates of various network equipment were collected to create a database.

2.2 Sampling

The samples were then collected in 1-liter plastic bottles and stored in a cooler with ice. Samples were taken from various types of materials that made up the entire network, as well as from fire hydrants and outlets before and after maintenance work.

3 Results

3.1 Physical diagnostics

3.1.1 Diagnostics of suckers

All drinking water networks consist of pipes that transport water from the source to the consumer's tap. During this process, air pockets can form and remain in the pipes. The main function of the suction cup in the drinking water network is to continuously pump out air pockets that have entered the pipes. Physical diagnostics of the suction cups not only identified all the suction cups in the drinking water network, but also checked their physical operating condition.

Diagnostics show that 67% of air valves in the network are in good condition (BE), 28% are in faulty condition and 5% are in poor condition.

3.1.2. Fire Hydrant Diagnosis

The diagnostic results show that 37% of fire hydrants are faulty, 32% are located in high pressure zones, 21% are in low pressure zones and 10% are not serviced because they are located in areas that are difficult to access by the network.

3.1.3. Drain Diagnostics

The diagnostics showed that: 56% of drains are treated and in good condition, 13% of drains are inaccessible, 5% of drains are located in low pressure areas, 2% are faulty.

3.2 Qualitative Diagnosis

The qualitative diagnostics of water samples taken from the Daloa drinking water network mainly concerns two parameters that cause concern to the population, such as colour and turbidity.

3.2.1 Turbidity

In the water supply network, which is mainly composed of cast iron pipes, the recorded turbidity values are in line with the World Health Organization (WHO) guideline values, except for places such as the traditional treatment plant, compact plant.

In the distribution network:

• Turbidity values recorded on cast iron pipes do not exceed WHO recommended values;

• High turbidity values observed at the reservoir are due to mixing of waters, and at Radio Tkhrato due to the fact that this point is located close to the discharge.

• For asbestos-cement pipes, the recorded values do not correspond to WHO recommended values.

3.3 Water Supply System Maintenance

Maintaining a drinking water network involves regularly cleaning pipes and other network equipment. Maintaining a drinking water network helps ensure water availability and provides consumers with better quality water. It minimizes service interruptions and contamination risks, and ensures that hydrants and fire hydrants are working properly.

4 Discussion

Physical diagnostics show that the Daloa water network includes some faulty equipment, which prevents maintenance work from being carried out at certain points in the network. The lack of maintenance is the source of sludge accumulation in the network, which is a potential source of discoloration and increased turbidity in the water network.

A common feature observed between the water from the treatment plant and the water passing through the supply pipes is high levels of color and turbidity. In fact, a malfunction of some pneumatic valves that discharge the settled flakes from the settling tank may lead to their re-suspension and clogging of the filters. Consequently, a deterioration in the quality of the water at the inlet to the network due to a decrease in the performance of the filtration system will be a consequence of the observed malfunctions. Secondly, failure to pump out will contribute to the accumulation of sludge in the water supply network. In addition, the continuous discharge of sludge into the water supply network along its entire length and the physical and chemical reactions that can occur between the connecting parts of the pipes (cast iron or steel) contribute to an increase in the color and turbidity of the water.

The main cause of water quality deterioration in metal pipes such as cast iron is pipe corrosion. In fact, corrosion reactions cause metal ions to be released into the water, which causes iron ions to precipitate, which can puncture the walls of ferrous pipes, causing scale formation (reduction in diameter). In addition, problems with red water, metallic taste, and increased concentrations of dissolved metals are all consequences of pipe corrosion.

Asbestos cement pipes are not subject to corrosion problems; this is a significant advantage over cast iron metal pipes. However, when in contact with water, the material (asbestos cement) releases calcium hydroxide $Ca(OH)2$, which is said to have a carcinogenic effect on the health of consumers. This is reflected in high turbidity values and low color values. This can lead to increased alkalinity, calcium content and the release of magnesium, silicon and hydroxide from asbestos (Mg3Si2O5(OH)4). However, near pumping stations, the accumulation of sludge in the pipes increases the color and turbidity of the water.

PVC pipes are not as susceptible to corrosion as asbestos-cement pipes. The increase in turbidity and color in PVC pipes can be explained by the lack of purging in the network and the transit of water from one type of material to another. In PVC pipes, corrosion of cast iron or steel fittings and the transit of water from cast iron to PVC pipes increase the color and turbidity of the water, as well as the concentration of iron ions. The increase in organoleptic indicators can then become a source of taste development in the network.

In the water supply network, the high turbidity values are thought to be due to the accumulation of dirt after a long period of residence on the site. The discrepancy between the turbidity values of the cast iron pipes and those observed in the water supply network may be due to the fact that the water supply network is quite new, while the distribution network, which is quite old, may be affected by corrosion of the pipes.

5. Conclusion

In this study, we analyzed the factors that degrade the physical and organoleptic characteristics of the drinking water supply network in a community. Samples were analyzed for two physicochemical parameters: turbidity and color. The results showed that color and turbidity did not meet the 2017 WHO guideline values for either the supply or distribution network. After network maintenance, the reduction rate for turbidity ranged from 2% to 73%, while for color, the rate ranged from 5% to 72%. Lack of network maintenance leads to sludge accumulation in the network and is one of the main causes of color changes, taste and sediment in consumer tap water. It appears that color and turbidity are the determining factors for water quality deterioration in the drinking water supply network.

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High-Strength Concrete Composition Design: Current Trends

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Abstract A rational proportioning of the main components of high-strength concrete—cement, aggregates, water, and additives—has been determined, ensuring minimal cement consumption while maintaining optimal technical and technological performance characteristics required for concrete mix design. The concrete composition has been selected using an analytical-experimental method, optimizing the preparation of mixtures within permissible limits. The following factors must be considered: concrete strength at compression (class), ease of placement, compaction coefficient (Kg > 0.98), cement activity, actual and overall porosity, granulometric composition of sand and gravel, as well as the type and quantity of modifiers.

Key words: Concrete, hyperplasticizer, microfiller, granulometry, dispersion, aggregate, fine-grained, cement stone, modifier.

Introduction.

High-strength concrete (80-150 MPa) is achieved through the combined use of high-activity cements, calcined and finely ground sand, coarse aggregates with strengths exceeding 120-150 MPa, plasticizing chemical modifiers, and various micro- and ultradispersed additives (such as silica fume, metakaolin, fly ash, limestone powder, microquartz, etc.). The water-cement ratio (w/c) in such concretes is relatively low, typically in the range of 0.3-0.35 or even lower. High-strength concretes are characterized by increased density, durability, and resistance to atmospheric and other aggressive influences. A key feature of high-strength concrete technology is the ability to achieve higher-grade concrete using cement of a given grade. This is not only accomplished by using materials with enhanced properties but also by designing a concrete structure where the performance characteristics of its

components are effectively optimized.

the main part

The modern requirements for the design of high-strength concrete structures involve meeting the following conditions:

1. Incorporation of hyperplasticizers in the concrete mix, which allows for a reduction in the water-cement ratio, significantly increasing the strength of the concrete.
2. Optimization of aggregate consumption, ensuring a granulometric composition that closely aligns with the ideal distribution—from micron-sized fine particles (such as microfillers) to coarse aggregates measuring several centimeters. This approach enhances the efficiency of mineral fillers, reducing the amount of coarse aggregates. Research indicates that the maximum aggregate size should not exceed 20 mm. The optimal granulometry of aggregates and dispersed materials ensures the formation of a dense, strong structure, where fine particles fill the voids between coarser grains.

High-strength concrete exhibits superior physical and mechanical properties. Its low porosity minimizes the penetration of aggressive substances into its Matrix.

Currently, ultra-high-strength concretes (120-150 MPa) are divided into two categories: fine-grained (maximum aggregate size up to 16 mm) and ultra-fine-grained (maximum aggregate size up to 0.5 mm). In both cases, the use of microfillers and finely ground mineral additives is recommended. To improve compressive strength and crack resistance, metallic, synthetic, or polymer fibers are used. The properties of high-strength concrete are significantly influenced by the structure of the cement paste. The main factors affecting cement paste properties are the crystalline phase structure and porosity.

The accurate calculation and selection of concrete mix proportions ensure a rational balance between cement, aggregates, water, and additives, leading to minimal cement consumption while maintaining the necessary technical and technological characteristics. Concrete mix designs are selected using analytical-experimental methods within feasible composition limits. The following factors must be considered: concrete compressive strength (class), workability of the concrete mix, compaction coefficient (Kg > 0.98), cement activity, actual and total porosity, granulometric composition of sand and gravel, type and quantity of modifiers, etc. (pic. 1).

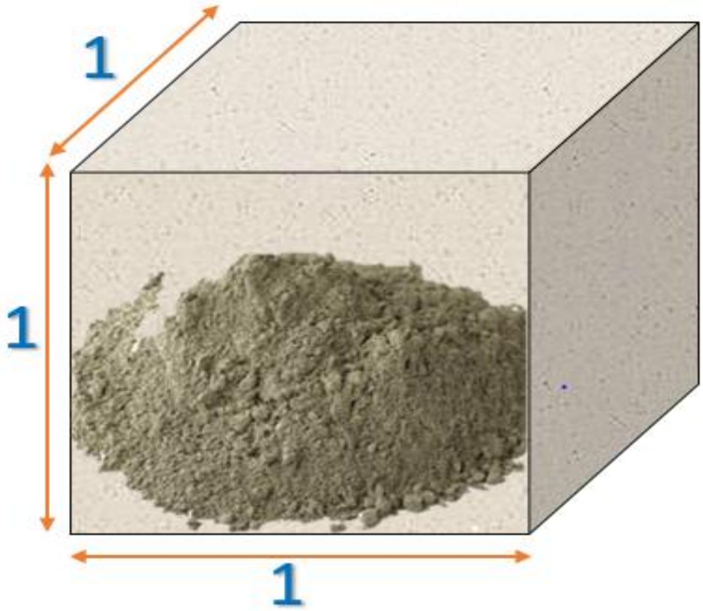


Fig. 1. The water-cement ratio (w/c) is estimated using the formula:

$$w/c = 0.43Rc / (Rb - 0.215Rc)$$

where Rc is the cement grade or activity (MPa), and Rb is the target concrete strength (MPa).

To determine the water demand per cubic meter of concrete, experimental data based on known bulk density and maximum aggregate size is used.

Cement consumption is calculated using the formula:

$$c = w / (w/c)$$

The feasibility of achieving high-strength concrete with a specific cement type is determined based on experimental results. For 1 m³ of concrete, cement consumption should not exceed 550-600 kg.

Mix proportions are determined using the absolute volume method, ensuring that the total absolute volume of all materials equals 1000 liters.

Optimal aggregate proportions are selected based on the following principles:

1. The highest overall strength of the mix is achieved by properly balancing fine and coarse sand fractions.
2. The highest overall strength of the mix is achieved by properly balancing fine and coarse gravel fractions.
3. The optimal sand-to-gravel ratio is determined to ensure the best workability while maintaining cement and water consumption within acceptable limits.

If the designed mix does not meet the project requirements, adjustments are made by increasing or decreasing the cement content,

which subsequently affects the w/c ratio.
The optimal amount of sand and gravel in 1 m^3 of concrete is calculated using the formulas:
R = (s + g) / (1 + r), and S = (s + g)-g;
The final mix proportions are tested through laboratory trial batches, ensuring that the calculated w/c ratio is maintained. Bulk density remains unchanged, and only water and cement adjustments are made when necessary.
Each batch of concrete is used to prepare a set of control specimens for quality assessment. The number of specimens per batch is determined according to the specific requirements of the construction technology being utilized. These specimens are subjected to rigorous compressive strength testing after a curing period of 28 days. The results from these tests are used to develop graphs that illustrate the relationship between compressive strength and the water-cement ratio, providing valuable insights for optimizing mix design. Currently, achieving concrete strengths exceeding 100 MPa remains a significant challenge due to material limitations. Despite advancements in mix design methods and the availability of high-quality materials, the primary obstacle is the crushing strength of granite aggregates. Granite originates from natural rock formations with an average compressive strength of approximately 180 MPa. However, during the crushing process, microcracks inevitably form within the aggregate particles. These microcracks substantially reduce the effective strength of the aggregates to around 90-100 MPa, limiting the potential strength of the concrete. Efforts to enhance concrete performance have led to the incorporation of chemical modifiers, which can improve the strength of the cement matrix up to 120 MPa. While these additives strengthen the binding material, the reduced strength of the aggregates remains a critical limiting factor. Without stronger aggregates, further increases in concrete strength are difficult to achieve. To overcome this issue, research is needed to explore alternative aggregates with higher crushing strength or to develop advanced processing techniques that minimize microcracking. Additionally, innovations in nanotechnology and supplementary cementitious materials could help optimize the structural integrity of high-strength concrete. Until such advancements are realized, the maximum achievable concrete strength will continue to be constrained by the inherent properties of available aggregates.

Fig. 2 . Granite gravel

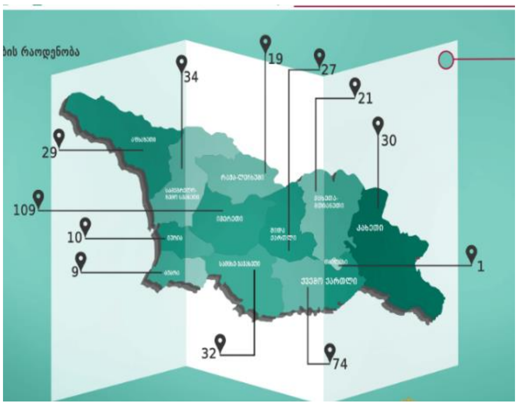
In the process of selecting the composition of high-strength concrete, some of our colleagues opted for maximizing the consumption of cement and modifiers while minimizing the amount of fine aggregates. As a result, the obtained concrete primarily relied on the durable cement matrix, while the coarse aggregate functioned merely as a casing. The composition of this type of concrete is reflected in Table 1.

Table 1: Concrete Mix Composition (kg/m³)

Cement (kg)	Modifier MB10-01 (kg)	Sand (kg)	Gravel (kg)	Water (kg)	Hyperplasticizer (kg)	Slump (cm)	w/c Ratio	Concrete Density (kg/m³)	Concrete Strength (MPa)
550	110	697	902	152	2	20	0.28	2413	102.9
550	110	660	930	164	4	27	0.3	2436	98.7
550	110	650	950	135	-	19	0.25	2421	92.5

The compressive strength of gravel is a critical factor influencing the overall performance and durability of concrete. It is widely recommended that the compressive strength of gravel should be at least 1.5 times greater than that of the concrete it is used in. This ensures the structural integrity and longevity of concrete structures. However, in our opinion, for specific types of concrete, the strength of the gravel should at the very least match the compressive strength of the concrete itself. When the aggregate strength aligns with or exceeds that of the concrete, it enhances bonding, reduces the risk of failure, and improves the long-term durability of the structure.

Georgia possesses significant reserves of both crushed and natural rock quarries, making it a valuable source of high-quality aggregates for concrete production. These abundant reserves provide a reliable raw material base for manufacturing high-strength concrete, which is essential for constructing durable and resilient infrastructure. The availability of strong aggregates enables engineers to design and build structures that can withstand heavy loads and harsh environmental conditions while maintaining structural stability over time. In addition to its structural benefits, using



locally sourced gravel offers economic and environmental advantages. By utilizing

Fig. 3 . Mineral resources of Georgia

domestic aggregate resources, construction costs related to material transportation are significantly reduced. This not only makes concrete production more cost-effective but also contributes to sustainable construction practices by minimizing carbon emissions associated with long-distance transportation. Locally available, high-quality gravel ensures that infrastructure projects maintain high performance while being economically and environmentally responsible.

The role of aggregate strength in achieving high-performance concrete is especially critical in large-scale projects and load-bearing structures, such as bridges, high-rise buildings, and industrial facilities. The mechanical properties of gravel directly impact the compressive strength and durability of the concrete mix. By optimizing the selection of high-strength gravel, construction professionals can ensure that concrete structures meet modern engineering standards and remain resilient for years to come.

Given Georgia’s rich quarry resources, the country has the potential to continue developing high-performance concrete for a wide range of construction applications. Careful selection of strong aggregates is essential to maximizing the structural efficiency of concrete. As construction demands increase, the use of high-quality gravel will remain a key factor in ensuring the durability, strength, and sustainability of infrastructure projects.

Conclusion.
Currently, the existing methods for designing high-strength concrete and the quality of available raw materials do not allow for the production of concrete with a compressive strength exceeding 100 MPa. One of the main limitations is the quality of the coarse aggregate used in concrete mixtures. Most coarse aggregates are derived from crushed river ballast, which, while containing some high-strength fragments, also includes particles with relatively low compressive strength. These weaker particles reduce the overall structural integrity of the concrete, preventing the achievement of ultra-high-strength compositions. To produce concrete with a compressive strength of 150 MPa, monomineral crushed rock aggregates from igneous formations such as granite, diorite, and gabbro are required. These rocks possess compressive strengths of up to 250 MPa, making them suitable for high-performance concrete. Additionally, the incorporation of chemical modifiers can enhance the strength of the cement matrix, potentially increasing it to 150 MPa. However, despite improvements in cement matrix strength, the limiting factor remains the low strength of coarse aggregates derived from river ballast. The presence of weaker particles in river ballast significantly impacts the structural performance of concrete, making it difficult to achieve ultra-high compressive strengths in practical applications. To overcome this limitation, alternative aggregates with higher crushing strengths need to be explored. The use of carefully selected, high-strength aggregates could enable the production of stronger, more durable concrete. Further research is essential to identify new aggregate sources and processing techniques that minimize microcracking and enhance aggregate strength. Until then, the development of ultra-high-strength concrete remains constrained by the limitations of available coarse aggregates, making advancements in material selection crucial for future high-performance concrete applications.

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Construction of highways in Georgia

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Abstract: The specific geographical position, political condition in the region and the high-through transit flows across Georgia witness about urgency and necessity of the rapid and efficient development of the country's road network. When roads are built tourists in Georgia will become more, cargo turnover will also grow, in which there will be still - beautiful girls, and investors will be even more Volga, and all this will contribute to the improvement of the situation in the country, including political.

Keywords: Silk Road, Rikoti Pass, Kvesheti-Kobi section, East-West Highway, South-North Highway

Introduction

As for Georgia, considering its geopolitical and geographical position, it represents the axis of the ancient Silk Road (the Great Silk Road). Taking into consideration all these factors and current situation in the region, it is possible to argue that Georgia is the only safe road for carrying cargos between Europe and Asia and vice versa.

Besides the present circumstances in the region (i.e. the situation of conflict that persists on the soil of Ukraine) there is the factor based also on the fact that it is the shortest and, therefore economically most advantageous for the countries that utilize this corridor, the Georgia route.

Basic part

It is important to emphasize that Georgia's land corridor is not only the place for rapid and cheap transit, but also pipelines, the air and subsoil communication networks and etc. Growth of cargo turnover has a direct positive impact on the country's economic development; foreign investment is growing, new jobs are being created, and the standard of living of the Georgian population is rising. The nation has added another role in politics in the region.

The nation's infrastructure is becoming even more reliable and in-demand. Prompt expressway building and reconditioning in Georgia has been and is a must. The hardest part of the East-West Highway is the Rikoti Pass; the hardest part of the South-North Highway is the Kvesheti-Kobi section. Both segments are geographically challenging areas. The plan will include bridges, tunnels, overpasses, parks and roads. Both sections are being constructed at present. Construction is progressing although not without challenges, with some stretches already operational and others readied for business. So soon enough, Georgia will have shiny expressways in both directions (to all its neighboring countries). The high material cost unattainable by the country budget during these phases is paid by many international donors (a gesture we are extremely grateful for).

Fig. 1. South-North Connecting Highway

On the Kvesheti-Kobi road, it is planned to construct a 2-lane asphalt-concrete - 22.7 km. road, 6 bridges and 5 tunnels, including one 9 km tunnel. The tunnel will start near the village of Tskeres and end near the village of Kobi, the tunnel will pass under the Jvari Pass. The construction of the Kvesheti-Kobi road is divided into 2 lots.

The Kvesheti-Kobi section is part of the North-South corridor of transit importance. The road passes through a difficult geographical route and is characterized by heavy snowfall in the winter. In winter, due to avalanche danger and difficult meteorological conditions, road traffic is often closed, and transit traffic is hampered. The new road and 9 km tunnel will solve the existing problems. Transit traffic will be possible at any time of the year without any obstacles.

The 9-km Kvesheti-Kobi tunnel will be 15 meters wide, which is quite rare, not only in Transcaucasia but worldwide.

500 m arch bridge will be built on the Kvesheti-Kobi road, the arch of which will be an unprecedented 300 m long.

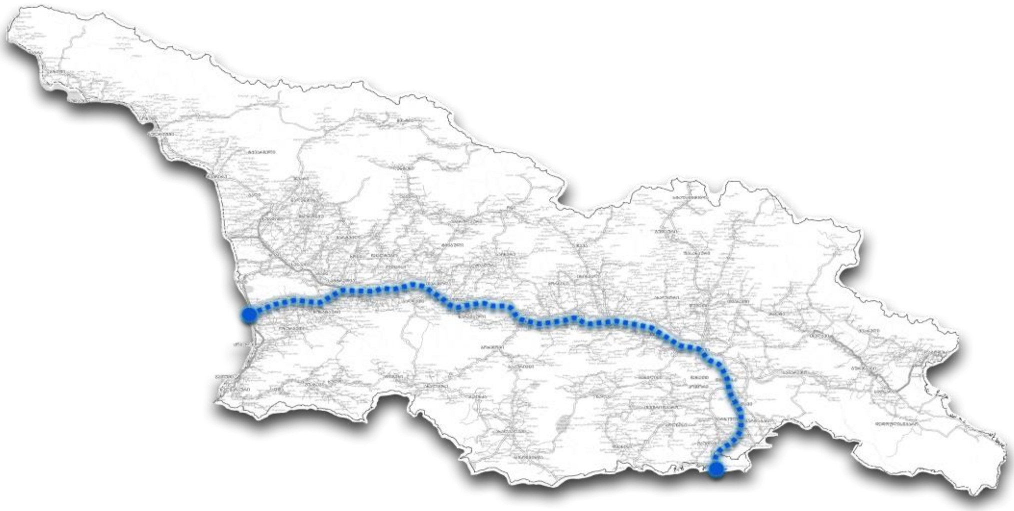

Fig. 2. East-West Connecting Highway, Sections 1

On the Rikoti Pass, a total of 51.6 km of road construction is underway (part of which has been completed and put into operation), which includes 96 bridges and 53 tunnels. The modernization of the Rikoti Pass section is of paramount importance in terms of the development of the country's road network and its compliance with modern standards. Ultimately, the Rikoti Pass road will reduce the distance of the East-West corridor by 30 km, and the travel time from Tsiteli Khidi to Sarpa will be halved. It is worth noting that the current project is extremely difficult from an engineering point of view, given the geographical location of the highway.

The remaining sections of the East-West Highway are also actively being developed, both in terms of the construction process and the preparation of design documentation.

60% (261 km) of the East-West Highway is already open to traffic. Construction work continues on 81 km of the highway.

Fig. 3. East-West Connecting Highway, Sections 2

The Kakheti route connects the capital of Georgia with the eastern region of the country, Kakheti. This route is important both from a tourist and trade-economic perspective.

At this stage, work is actively underway on several sections of the 85-km Kakheti highway, and various sections have already been put into operation.

Conclusions

The construction and design challenges provide some positive factors as, on completion of the event, the country will have numerous construction companies and engineers trained from all streams.

The country's economic development will increase road, tourism, transit and more all the people living in the country become the source of strength to the population of the country.

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Determination of the normative price and market value of land plots, methodology, and comparability in the current situation. Land plot valuation based on the example of Georgia

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Abstract. The document describes the methodology for the normative and market determination of non-agricultural land plots in Georgia, including the legal framework, legislative registration and valuation practices. The normative order on the state technical regulation of the economy, approved by the Ministry of Economy and Finance of Georgia on January 25, 1999 (№6-№18) and based on the base rate of land tax (0.24 GEL/m²), macro-location and zonal indices and adjustment coefficients, which is 20. This price is intended as the initial cost of the necessary material for the privatization or auction of state land. Depending on the administrative status, economic, infrastructure and geographical parameters, the zone is divided into central, intermediate and peripheral zones.

Market value, a draft law, which was determined by a private independent or Levan Samkharauli-named National Bureau of Forensic Expertise, an analysis of the previous year's accounting analogues. It uses various operations: sale, mortgage, insurance contracts, taking into account the balance sheet, etc. The assessment is determined by the location of the land, lighting capabilities, infrastructure, rights and restrictions, ecological condition and other characteristics.

The definition of agricultural land, which contains information on product yield, cultivation costs and market prices, is also considered.

The document is based on the current legislation, practical methods of assessment of state bodies and analysis.

Key words:
Normative Price, Macrolocation Index (I MG), Real Estate Market, Non-Agricultural Land, Agricultural Land, Yield / Agricultural Productivity.

A land plot is part of the land's surface and sub-surface territory, with fixed boundaries, area (square footage, code), location, legal status, and the legal restrictions defined by laws, which are registered and reflected in the state unified registry of real estate.

There is a distinction between determining the normative price of land and determining the market value of land; these are two different values defined for a territory.

The normative price of the land is defined by the methodology established by legislation, which depends on the land tax, and the normative land price is set based on market value once a year, no later than February of each year, by the representative bodies of the relevant local self-government units – city councils. On the other hand, the market value of land is determined by a private expert, and in many cases, it is established by the National Bureau of Forensic Expertise named after Levan Samkharauli.

How is the normative price of land determined?

On January 25, 1999, an order No. 6-18 issued jointly by the Minister of Economics of Georgia and the Minister of Finance of Georgia approved the methodology for determining the normative price of non-agricultural land for cities (districts) of Georgia, the macro-location indices of territories, and zoning.

This methodology includes the following:

- The normative price of non-agricultural land is used as the starting price during the privatization process or public auction for state land.
- One of the criteria for determining the normative land price is the base rate of the land tax defined by Article 6 of the Georgian Tax Code – "Land Tax," which is set at 0.24 GEL per square meter for non-agricultural land, along with a regulatory coefficient set by the representative body of the district or city, which is at least 20.

The price of land or the annual rent is determined by the governing body of the district or city based on the land price or rent set during the previous auction or competition, and it should not be lower than the normative price or rent.

The macro-location indices of cities and districts in Georgia are determined based on the socio-economic and natural characteristics of settlements according to the following parameters:

- Population size
- Administrative status
- Economic and functional profile
- Elevation above sea level
- Availability of transportation infrastructure
- Position in the settlement system

In cities and districts, zoning is done based on the following parameters:

- Engineering infrastructure
- Transportation infrastructure
- Social infrastructure
- Urban amenities
- Natural and ecological conditions
- Prestige

Zoning and Indexing System

1. The macro-location index (I MG) for cities and districts with more than 10,000 inhabitants is determined based on a system of six parameters:
   - Population size
   - Administrative status
   - Economic and functional profile
   - Elevation above sea level
   - Availability of transportation infrastructure
   - Position in the settlement system
2. Zoning in cities with more than 50,000 inhabitants is done in two stages, where three main zones are initially identified: central, intermediate, and peripheral. On the second stage, sub-zones (territorial structural units) are identified in the main zones.
3. In cities with populations between 10,000 and 50,000, zoning is done in a single stage, dividing the territory into three zones: central, intermediate, and peripheral.

Method for Determining Normative Land Price

The normative price of non-agricultural land or the annual rent (or lease) for 1 square meter of land is calculated using the following formula:

C N = I MG × I TL × C × K

Where:

- **C N** is the normative price per square meter of non-agricultural land.
- **I MG** is the macro-location index of the respective city or district.
- **I TL** is the local territorial index determined by the local authorities based on zoning.

- **C** is the base rate for land tax under the Georgian Tax Code (0.24 GEL per square meter).
- **K** is the coefficient defined by the local governing body.

For urban centers with fewer than 10,000 inhabitants, the normative price for non-agricultural land is 50% of the price for the respective city’s intermediate zone.

For ares between settlements, the normativeprice is 25% lower than the price for the respective urban center’s intermediate zone.

The land normative price regulatory coefficient, the minimum amount of which is 20 and 2, respectively.

The characteristic of the land plot is that it does not lose its utility characteristics over time. While the value of buildings and structures gradually decreases over time due to accumulated depreciation, the land plot maintains its value.

The market value of the land plot is primarily evaluated for subsequent operations such as:

- Investment of the land plot in the legal entity’s charter capital;
- Sale of the land plot;
- Insurance of the land plot (the value of the insurance contract depends on the land plot's value);
- Accounting in the organization’s financial records (although depreciation is not recorded for the land plot, as it does not lose its utility characteristics over time, market changes affect the land plot's value, necessitating its revaluation);
- Transfer of the land plot to accredited management;
- Mortgaging of the land plot (banks and credit organizations issue loans by mortgaging the land plot based on the report of an independent evaluator), and other cases.

Several factors influence the value of a land plot during its evaluation, including:

- Property rights and restrictions;
- Intended and operational purpose;
- Construction criteria;
- Dimensions of the land plot;
- Location, position, and slope;
- Availability of transportation hubs;
- Other factors influencing value.

Specific Features of Land Plot Evaluation:

The evaluation of non-agricultural land plots (in cities, villages, and other settlements) is based on the following data:

- Market data analysis of buying and selling transactions;
- Information about prices of real estate objects available for sale (including undeveloped plots);
- Information about engineering and transportation infrastructure;
- Information about social and residential service facilities;
- Environmental condition;
- Information about historical and architectural-aesthetic value of the landscape;
- Landscape and recreational value of the territory.

When evaluating vacant land plots, one of the most important factors is evaluating them at their highest value based on the principle of their best and most efficient use.

The determination of the price of agricultural land is based on the productivity of the main agricultural products, as well as the productivity of meadows, pastures, and perennial crops. It also takes into account the structure of arable lands, the market prices of agricultural products, and necessary costs for

cultivating these crops.
The methodology presented in the conclusion of the Levan Samkharauli National Forensic Bureau is as follows:

Market Value Definition:
"Market value is the monetary amount at which property would change hands between a willing buyer and a willing seller as of the valuation date, in an open and competitive market, after proper marketing, where both parties act knowledgeably and without compulsion."
The market value of real estate is derived from the interaction of demand and supply for identical (or similar, in the absence of identical) properties in the relevant market during the specified period. The real estate market is considered to be the trading space that is defined by the buyer's/seller's ability to sell/purchase property within the nearest area of Georgia without significant costs.
For the purposes of this evaluation, the appraiser used the market (sales comparison) approach, which involves the direct comparison of the subject property with data of similar properties that have been sold or are available for sale.

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Building settlement study considering ground conditions

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Abstract: The study of building settlement taking into account ground conditions is discussed. Various models of settlement calculation are discussed and in order to bring the calculation model as close as possible to the real model, the calculation results are compared with the values of real building settlements. It is established that in order to bring the results closer to the real one, it is recommended to calculate the building and the ground as a single spatial structure.
Key words: Elastic foundation, subgrade coefficient, building settlement, spatial model, ground conditions

Introduction

The construction of modern buildings and structures, the economy of construction, and industrialization depend greatly on both the correct determination of soil conditions and the correct selection of the geometric dimensions and materials of the foundations [1], [2]. The foundation, as an intermediate link and connecting the building to the ground, which takes on the loads transmitted from the building, must operate without overstressing and transfer these loads to the ground in such a way as to ensure the stability, rigidity, and strength of the building.

Main Part

Foundations resting on the ground are considered as a slab or a beam on a flexible base. When calculating on a flexible base, it is important to correctly determine the so-called sag coefficient. To determine the subgrade coefficients, the values of the averaged deformation modulus E and Poisson's ratio are used, which are determined by formulas 1 and 2 of Appendix 2 to SNiP 2.02.01-83* [4].

$$E_{gr}=\frac{\sum_{i=1}^{n}\frac{\sigma_{zp,i}h_i}{E_i}}{W}; \quad (1) \qquad \mu_{gr}=\frac{\sum_{i=1}^{n}\lambda_{1,i}h_i}{H_C}; \quad (2)$$

The software complex "LIRA SAPR" uses three methods for determining the subgrade coefficient:

The first method: according to the first method subgrade coefficient is calculated according to the Poisson's ratio and flexibility module of average importance.

Subgrade reaction is calculated with the following formula: $C_1=\frac{E_{zp}}{H_C(1-2m_{zp}^2)}$ (3).

The second method: subgrade reaction is calculated by this method by using the Winkler foundation: $C_1=\frac{q}{S}$ (4), where $q=\frac{P}{\eta b^2}$ is the average pressure on the foundation bottom. b – Minimal size of the foundation; η - ratio of the maximal side of the foundation with the minimal one; S – foundation closure;

The third method: for determining the subgrade reaction in the third method one uses formula of the first method (3). Difference among these methods is that for determining the module of the average deformation of ground one uses the coefficient correcting the module of the average deformation of ground. This coefficient is changed $u_1=1$ from the benchmark of the foundation bottom $u_1=12$ up to H_C limit of the active zone (before finishing the compressed zone).

$u=\frac{11z^2}{H_C{}^2}+1$ (4). C_2 - Subgrade reaction for all three methods is calculated by one common formula: $C_2=\frac{C_1H_c{}^2(1-2m_{zp})}{6(1-m_{zp})}$ (5).

Determining the subgrade reaction in the used computer

Furthermore, it is assumed that the additional vertical stresses at depth are uniformly distributed, then we obtain the following expression:

$$E_{\Gamma P_3} = \frac{H_C}{\sum_{i=1}^{n} \frac{h_i}{u_i E_i}}$$

The third method is experimental in nature and is based on engineering experience, namely that the modulus of elasticity increases with soil depth.

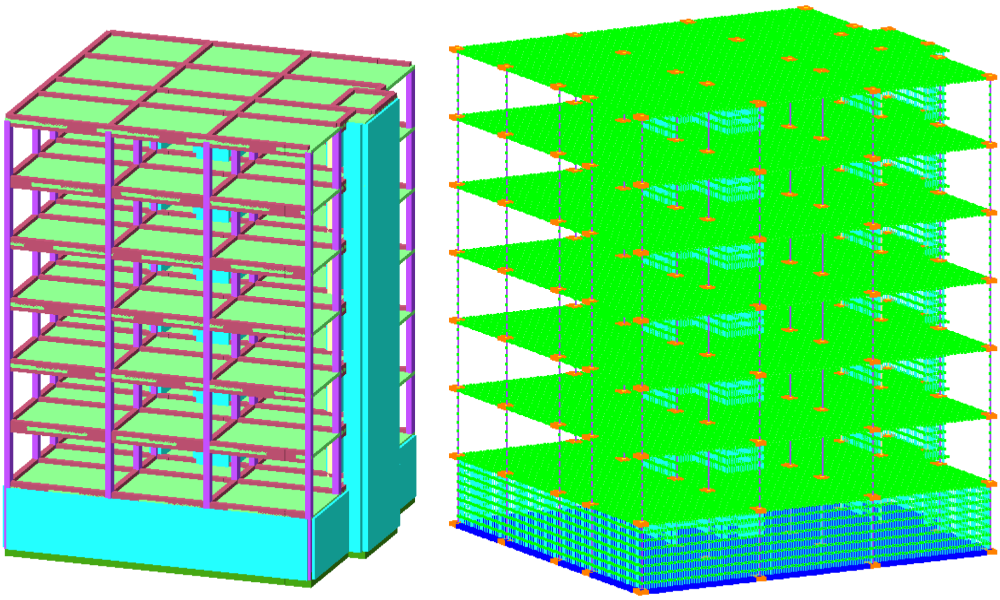


Fig. 1 Computational spatial model of the educational building

In order to study the influence of the foundation calculation model on the building settlement, an 8-storey frame building under construction (Fig. 1) was selected. The building is rectangular in plan with maximum dimensions in axes of 16.00X22.00 m. The foundations are based on hard plastic brown (dpQIV) clays. After concreting the foundation slab, 5 points were marked on it (see Fig. 2), at which observations were made with a level.

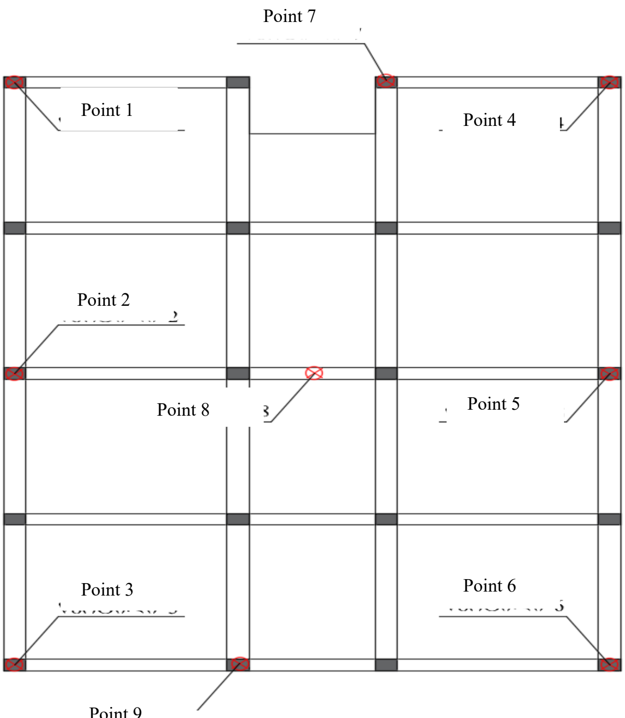


Fig. 2. Scheme of placement of survey points on the foundation

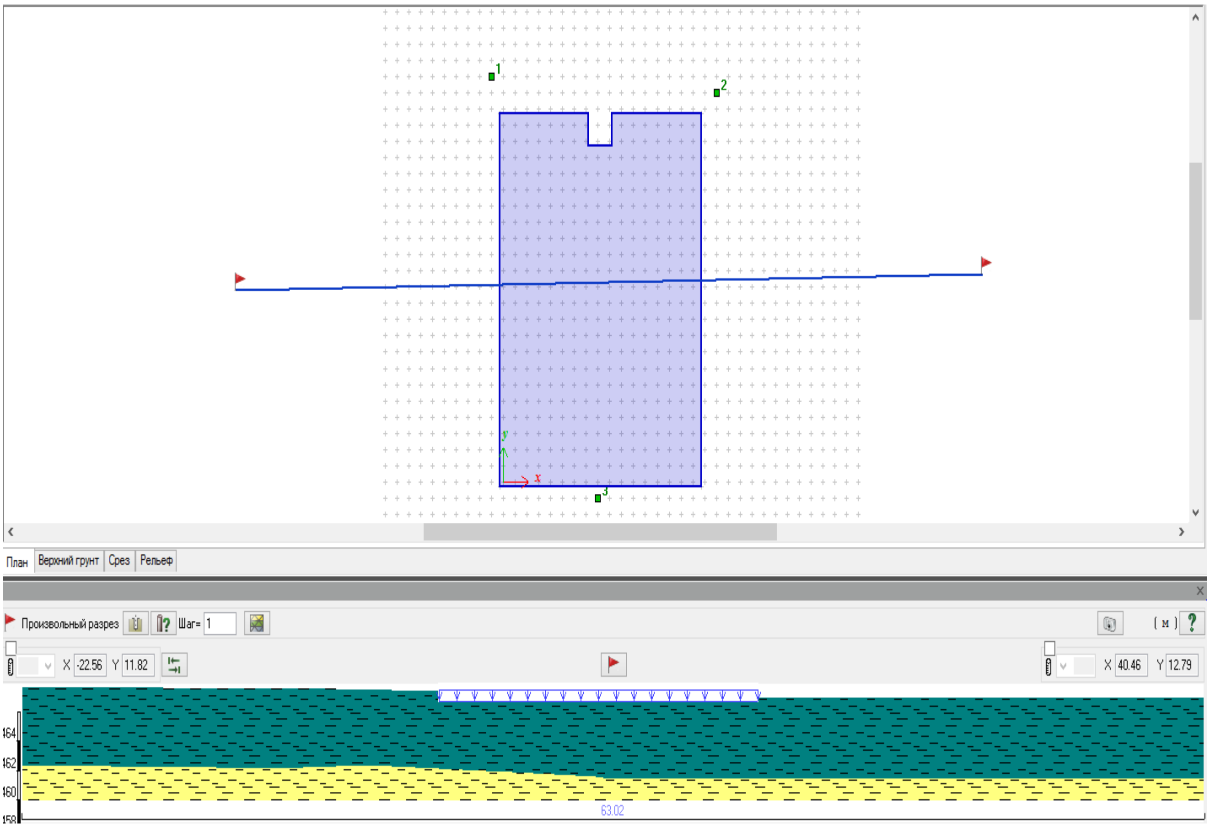


Fig. 3 Well layout plan in the 3D soil calculation model

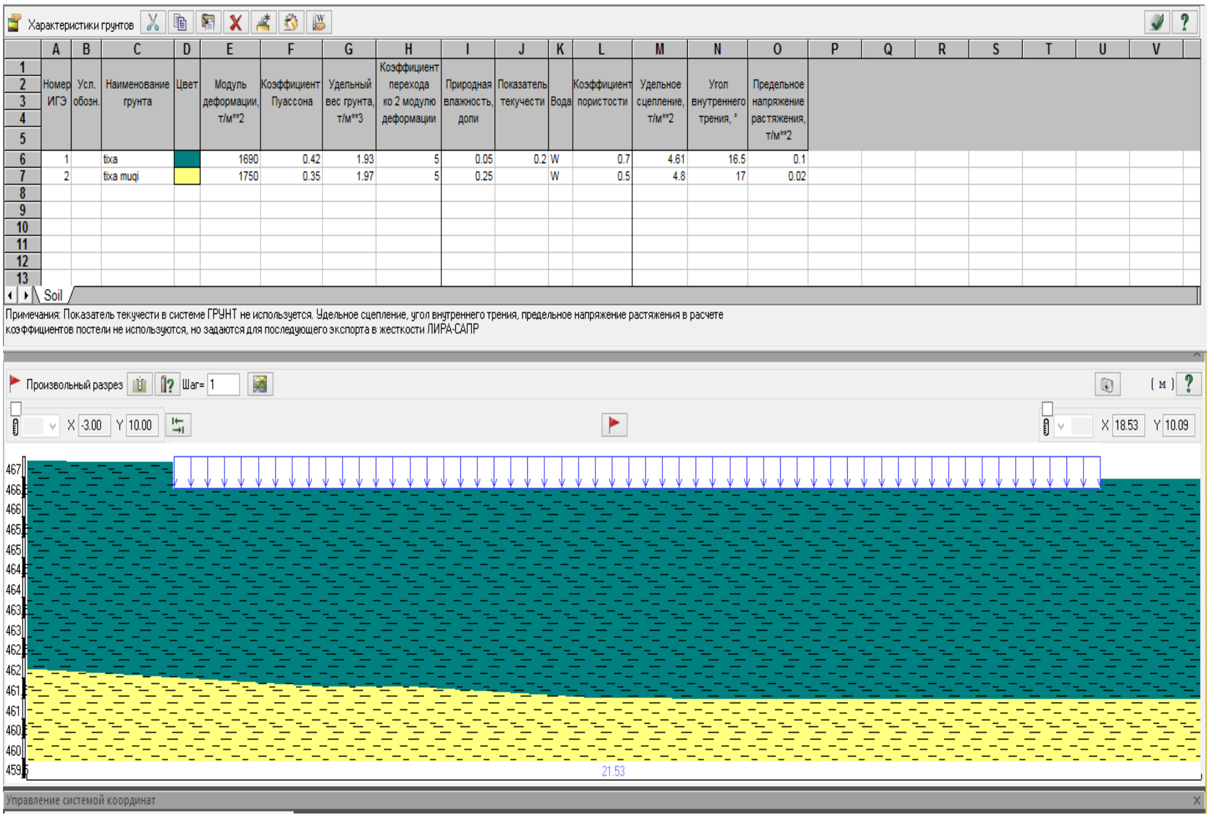
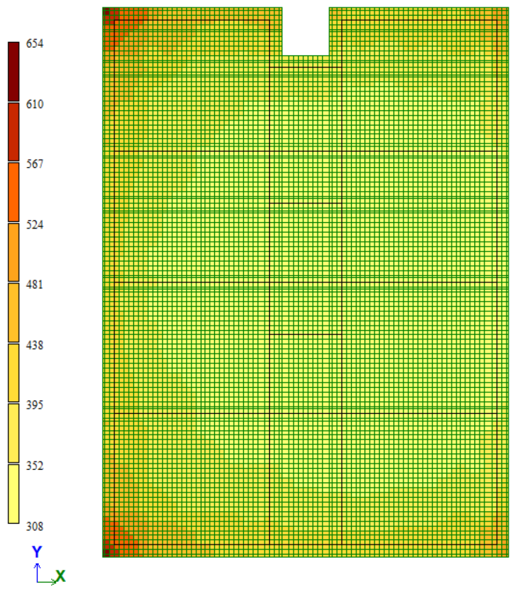
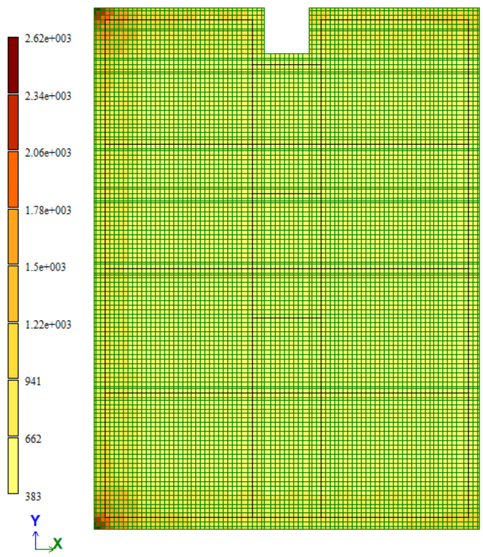


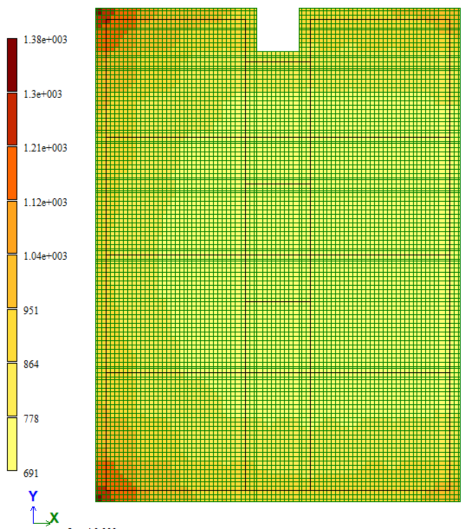
Fig. 4 Load on the base (in the cut)



Subgrade coefficient C1 I method



Subgrade coefficient C1 II method



Subgrade coefficient C1 III method

Fig. 5 Mosaic of the calculated C1 coefficient

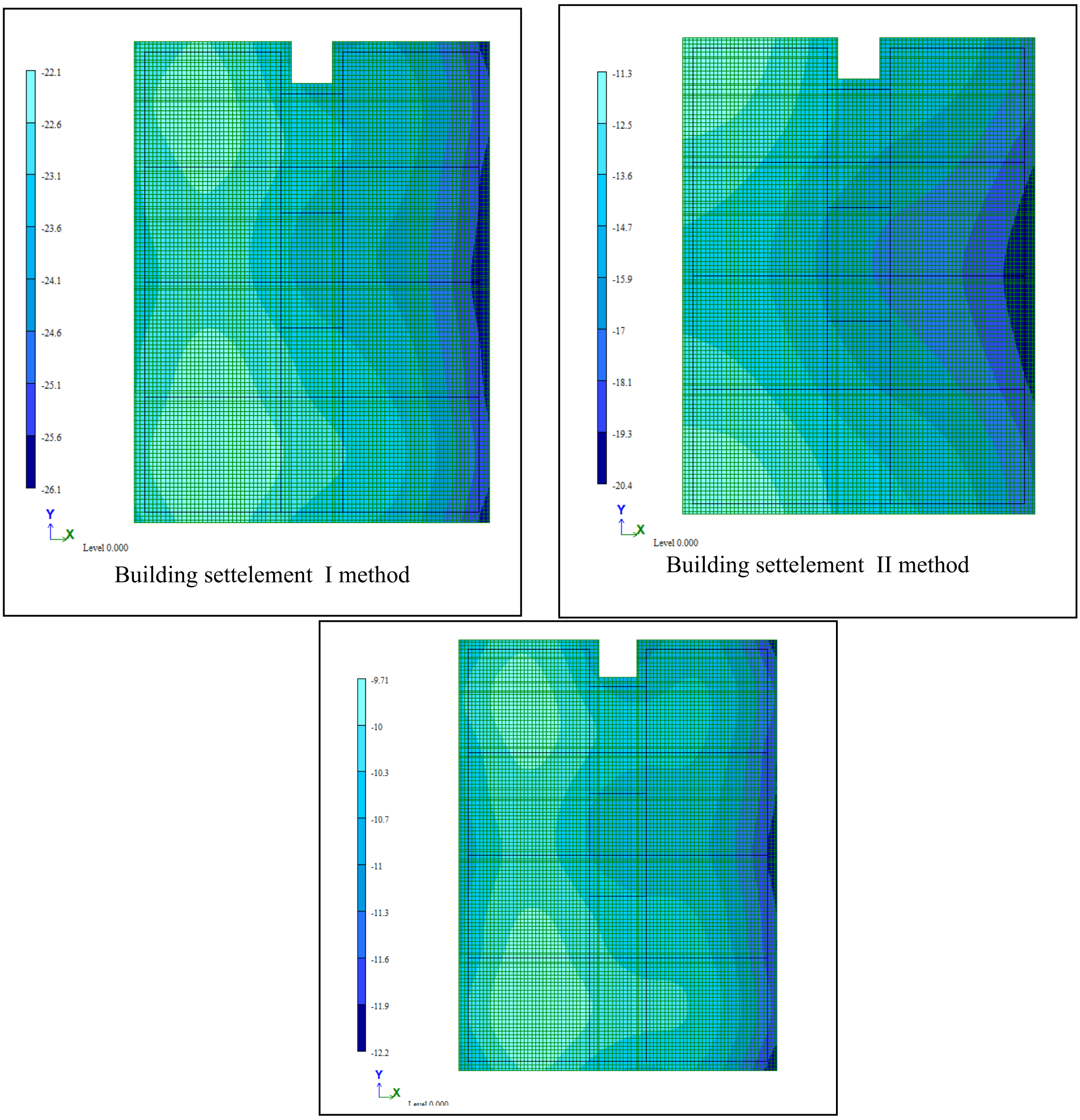
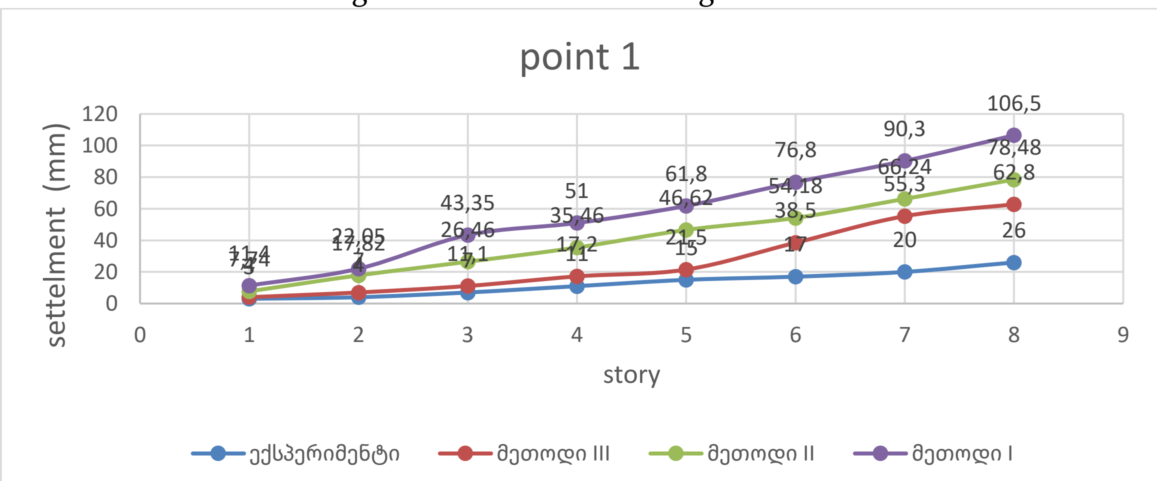


Fig. 6 Calculation of building settelement



Experiment III method II method I method

Fig. 3. Graphical relationship between theoretical and experimental data

Conclusions

1. Ground conditions, and their correct consideration in calculations, have a significant impact on the stressed-deformed state of a building.
2. The third method [3], [5] of the methods for determining the coefficient of subgade implemented in the software complex " "LIRA SAPR" is closest to the experimental data.
3. The results obtained by the experimental and method III are close to each other up to the fifth floor (35%), the differences increase as the load increases further.

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Hydraulic comparison of stepped and Chute spillways

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Abstract. The thesis presents the comparison of the hydraulic calculation of stepped spillway and chute spillway. The issue becomes even more relevant when, must be resolved, how will be type of spillway, which will conduct discharge water from upstream to downstream. The paper discusses the hydraulic characteristics of two different spillway structures. The results of theoretical calculations clearly show the flow heights at different sections. Calculations were carried out using formulas proposed by various authors.
Key words: Chute spillway, stepped spillway, channel,

1. introduction

A spillway is a structure used to provide the controlled release of water downstream from a dam or levee, typically into the riverbed of the dammed river itself. Spillways ensure that water does not damage parts of the structure not designed to convey water. Water normally flows over a spillway only during flood periods, when the reservoir has reached its capacity and water continues entering faster than it can be released. Today are many type of spillway, but in the article is discussed only two type of spillway, first is stepped spillway and second chute spillway.

A stepped spillway is a spillway with steps on the spillway chute to assist in the dissipation of the kinetic energy of the descending water. This eliminates or reduces the need for an additional energy dissipator, such as a body of water, at the end of the spillway downstream.

Chute spillway is an open channel like structure, which is constructed on steep slope of the gully face with a suitable inlet and outlet. The major part of the drop in water surface takes place in a channel.

2. Main parts.

The first time calculate the stepped spillway and create water level surface. The results of the theoretical calculation are important for determining of water level surface.

There are presented boundary conditions for the hydraulic calculation of spillway structures.

The width of the stepped spillway of rectangular section b=8.5 m.

Water discharge Q=95 m^3/sec

The average width of the leading trapezoidal channel B=9.97 m.

Normal depth of water in the channel $h_0 = 1.47$ m.

Upstream Z=489.00 m

Downstream Z=466.5 m

Number of steps of spillway n=6

The height of the well d=2 m

Determine the height of the well for the given depth.

$$P = \frac{Z_{upst} - Z_{dst}}{n} + d = 5.75 \qquad (1)$$

Calculate the depth in the narrowed section of the stream

Determine the depth h_c by the selection method. Chart 1

$$y = (p + H_0)h_c^2 - h_c^3 \qquad (2)$$

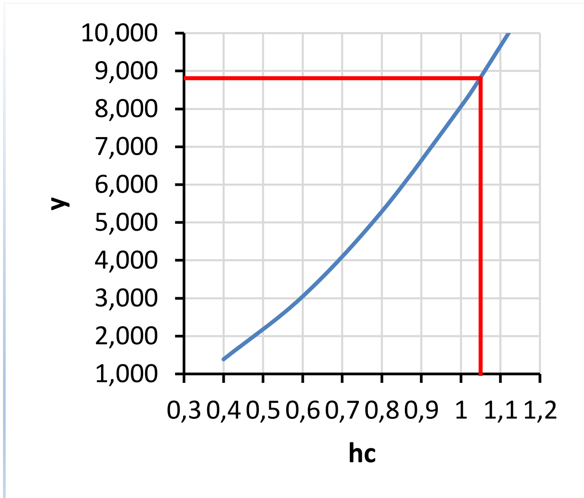

Chart 1

The depth of marriage is equal

$$h_c^c = 0{,}5h_c\left[\sqrt{1+\frac{8}{gh_c}\left(\frac{q}{h_c}\right)^2}-1\right] = 4.93 \quad (3)$$

Pressure on the waterline threshold (at the end of the step)

$$H_0 = \left(\frac{q}{M}\right)^{\frac{2}{3}} \quad (4)$$

Depth of water in the first well

$$H = H_0 - \frac{v^2}{2g} \quad (5)$$

The depth of the well

$$d = h_c^c - H \quad (6)$$

The depth of the water in the well

$$t = d_1 + H \quad (7)$$

Stock factor of Well depth

$$\frac{t}{h_c^c} \quad (8)$$

The second and subsequent steps are calculated as follows $H_0 = 3.31$; $H_0/p = 0.58$; $h_c = 1{,}05$; $t =$ Average speed at the threshold $v = q/H = 3.67$

The length of the drop is calculated by 8 formula

$$l = v\sqrt{\frac{2y}{g} + 0.8 \cdot 2.5(1.9h_c^c - h_c)} = 21.3$$

For hydraulic comparison, it is necessary to carry out a hydraulic calculation of a rectangular cross section of chute spillway and construct a circle of the free surface of the water flow.

The width of the base of the rectangular cross-section of chute b=8.5 m

Water discharge Q=95 m3/sec

Normal depth of water in the cannel $h_0 = 1.47$ m.

Upstream Z=489.00 m

Downstream Z=466.5 m

The length of the chute L=123.19

Slope i=0.203

Basic calculation formula:

$$\frac{il}{h_0} = \eta_2 - \eta_1 - (1-\bar{J})[\varphi(\eta_2) - \varphi(\eta_1)] \quad (10)$$

Let's make the calculation in the form of a table:

Table 1

hi	b	ω	χ	R	i	n	C	Q	η_1	η_2
	$h_0 = 0.48$				$i = 0.203$	$x = 2.5$				
3,53		30,005	15,56	1,928			101,42	1904,02	7,37	4,60
2,2		18,7	12,9	1,450			96,71	981,07	4,60	3,76
1,8		15,3	12,1	1,264			94,53	732,80	3,76	2,09
1		8,5	10,5	0,810			87,76	302,41	2,09	1,46
0,7	8,5	5,95	9,9	0,601	0,203	0,011	83,51	173,56	1,46	1,27
0,61		5,185	9,72	0,533			81,87	139,69	1,27	1,23
0,59		5,015	9,68	0,518			81,47	132,50	1,23	

continue of table 1

$h_{avg.}$	$\chi_{avg.}$	$\omega_{avg.}$	$R_{avg.}$	$C_{avg.}$	$J_{avg.}$	$\varphi(\eta_1)$	$\varphi(\eta_2)$	L	ΣL
2,865	14,23	24,3525	1,69	99,07	102,0456	0,038	0,07	1,07	**1,07**
2	12,5	17	1,36	95,62	108,2315	0,07	0,081	2,78	**3,86**

1,4	11,3	11,9	1,04	91,15	108,7823	0,081	0,253	39,78	**43,64**
0,85	10,2	7,22	0,71	85,64	106,3817	0,253	0,45	47,48	**91,12**
0,305	4,86	2,59	0,27	40,93	51,01277	0,45	0,618	19,82	**110,94**
0,6	9,70	5,1	0,53	81,67	101,74	0,618	0,67	12,26	**123,1 9**

Based on the calculation results, a free water surface for spillways was created. Fig. 1

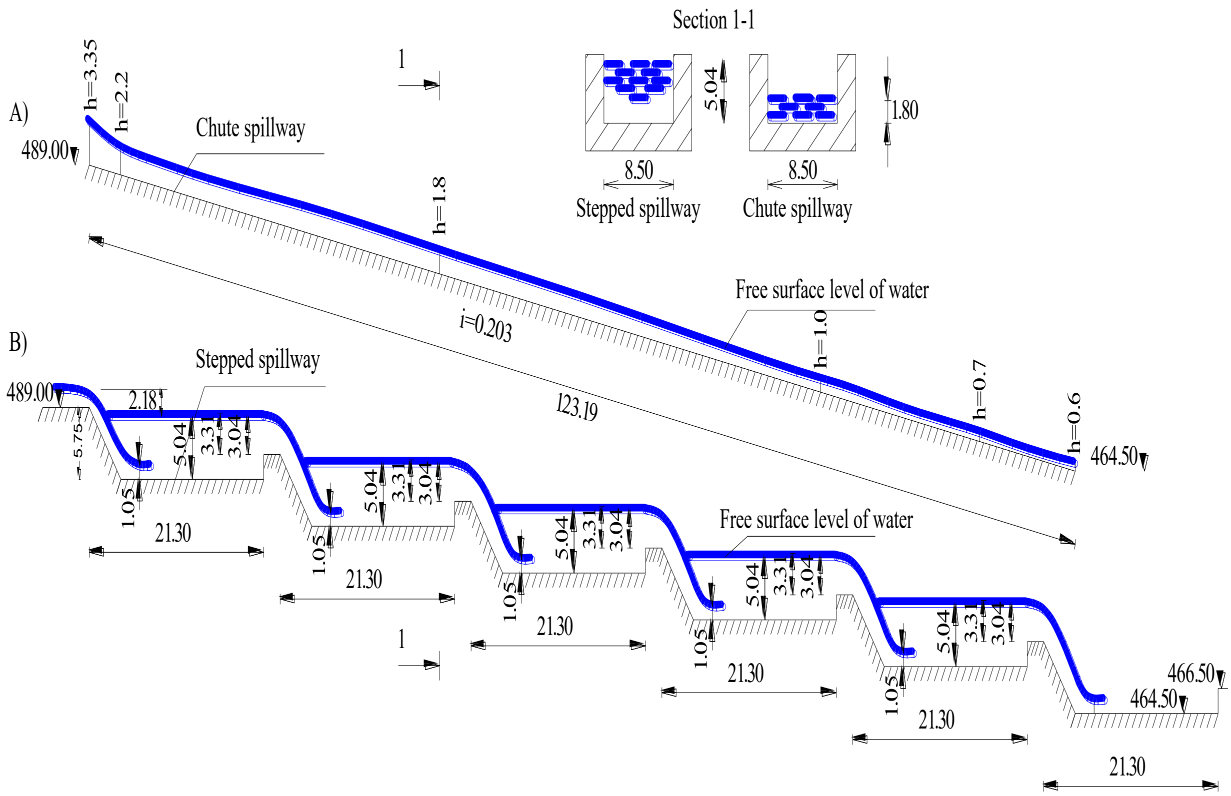

Fig. 1 longitude section of the stepped and chute spillways
A) chute spillway B) stepped spillway

3. conclusion

Analyzing and comparing the results of the theoretical calculations, shows water level of surface in stepped is higher than water level in the chute spillway, for the same boundary conditions. At the same times, it should be noted that in some cases construction of a stepped spillway is justified, because the stepped spillway does not need an additional exit well, extinguishing well of water stream.

$$\frac{2a'}{g}\left(\frac{Q}{b}\right)^2\frac{1}{r_1h_1^c}+r_1(h_1^c)^2 = \frac{2a'}{g}\left(\frac{Q}{b}\right)^2\frac{1}{r_1h_1^c}+r_2(h_c^2)^2 - \beta\frac{(h_1^c)^2h_1^ch_2^c+(h_2^c)^2}{3}l_{II} \qquad (11)$$

Under the conditions of the given task, using formula 11, determine the height of the flow in the exit section for chute spillway and construct the dependence curve of $\boldsymbol{h_2^c}$ and **Q(h)**.

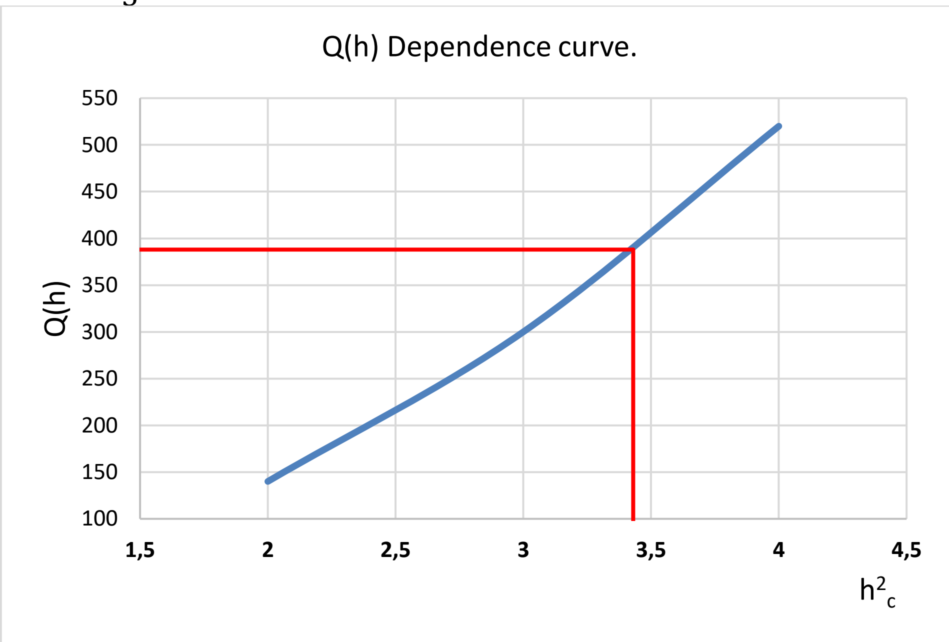

Chart 2

sing formula 11, the height of the flow in the exit section was determined, which is equal to 3.44 meters.

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Trends in the development of energy-efficient construction

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Abstract Energy-efficient construction plays an important role in reducing energy consumption and greenhouse gas emissions. Human activity significantly increases the global problems caused by climate change. Modern energy-efficient and energy-saving technologies and materials used in the construction sector significantly contribute to reducing the effects of global warming. The article discusses the measures to be taken to solve the above problems facing the construction industry.

Keywords: energy-efficient construction, renewable energies and energy-efficient technologies, carbon footprint, greenhouse gases, green buildings, passive and active buildings.

Introduction:

Implementation of the priority direction of socio-economic development - construction of modern housing at an affordable price, presents the construction industry with the task of developing new energy-efficient technologies in construction

The most pressing issue facing humanity today is "global warming," which is manifested in climate change. "Global warming" has often become a motivator for various environmental movements. The world is asking the question: can humans slow down climate change by taking certain measures?

1. The construction sector and climate change

The development of renewable energies and energy-efficient technologies is an indispensable response to the pressing environmental, economic and social challenges facing the world's population. It is a necessary condition for mitigating climate change and conserving biodiversity, as well as ensuring human well-being and quality of life.

The Earth has been an urban planet for decades, with 2008 being the last year in history when the majority of the world's population lived in rural areas, and since 2009 we have been living on an urban planet. By 2050, 68% of the nearly 10 billion people on Earth will be city dwellers. This means that many of us will be surrounded by urban infrastructure – buildings and structures. By 2060, the area of buildings is expected to double, meaning construction will also increase. New construction and renovation of existing buildings will affect the economic performance of every country, as well as climate change anywhere in the world.

Climate change is a global emergency that transcends national borders. This challenge requires coordinated solutions at all levels and international cooperation to help countries transition to a low-carbon economy.

Impacts and problems

The first problem we face when talking about the climate impact of the construction industry is that it is difficult to measure this impact. Construction is a long, complex process that involves many activities, from mining to waste disposal. Typically, the carbon footprint of construction is "packaged" in indicators for individual industries - energy, cement production, steel, etc.

However, even with this approach, it is

clear that the overall carbon footprint of the industry is huge, as it involves many resource- and energy-intensive processes. Cement production alone accounts for 7% of global greenhouse gas emissions. Cement, steel, aluminum, and glass all require high temperatures, which means a lot of energy. Energy generation for steel production accounts for more than 7-9% of energy emissions, and about half of the steel is used in construction. 35% of all energy generation and 38% of energy emissions are related to the construction and operation of buildings. In addition, many energy industries can only operate on hydrocarbon sources.

Buildings typically have a lifespan of decades, and the products of each stage determine to some extent the carbon footprint of the next stage. For example, high-quality building materials can improve energy efficiency and reduce emissions during operation.

2. Solutions and Innovations

The World Green Building Council defines the types of greenhouse gas emissions in construction:

- Emissions from the extraction, production, and transportation of materials and resources account for approximately 11% of global emissions and are typically not considered construction emissions.
- Primary emissions are associated with the construction phase. These emissions are the most difficult to reduce. They will account for approximately 50% of the industry's carbon footprint in the coming decades.
- Direct operational emissions are the most obvious part of a city's carbon footprint, with the greatest potential for reduction. They include emissions from energy production for building operations. They can account for up to 40% of a city's carbon footprint.
- Embedded operational emissions from materials and processes required to maintain the building throughout its life cycle.
- End-of-cycle emissions from transportation, disposal and recycling of construction waste.

As a reminder, the EU Green Deal is a new initiative of the European Union, its goal is to make Europe the first carbon-neutral continent by 2050. The interim target is to reduce greenhouse gas emissions by 55% by 2030 compared to 1990.

In addition to climate change, buildings and structures are subject to environmental impacts, and these impacts will increase. This is especially true for areas with special conditions - permafrost zones, coastal zones, areas with a high risk of flooding. As conditions change, the approach to building comfort and the structure of energy consumption change. Although traditionally in central and northern countries most of the energy is spent on heating, in the future the same buildings may need additional cooling during hot periods.

We need to build much more efficiently than we do now: with fewer resources and energy, but at the same time more resistant to external influences, more comfortable and convenient.

Experience shows that the most effective results can be achieved by combining measures to reduce emissions and adapt to new conditions. Increasing energy efficiency is today the most important and realistic way to quickly reduce emissions.

Today, there are a number of classifications of building energy efficiency, one of the most common - BER (Building Energy Rating) - is used in the European Union countries. Its characteristics take into account energy consumption and losses and their determining factors - insulation, use of natural energy, etc.

Low-energy houses are usually called passive houses; houses that not only consume but also produce energy (for example, through renewable energy installations) are called active houses. From 2021, all new buildings in the European Union must comply with the passive house standard.

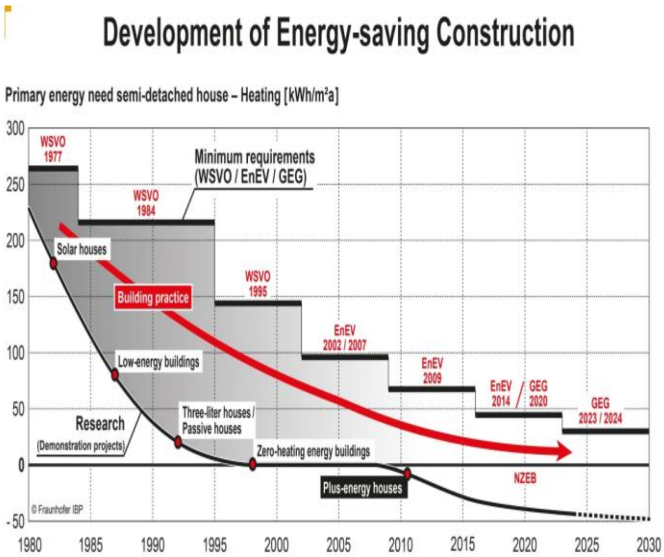

Fig. 1 Reducing energy consumption using the example of Germany.

Construction is one of the industries that is always growing. There is always a demand for residential, office, recreational and other spaces, and the supply is not slow. In just 6 years (2013 - 2019), the turnover of the construction industry has increased from 4.6 billion GEL to 8.3 billion.

The number of construction projects, whether residential or commercial, is increasing every year throughout Georgia.

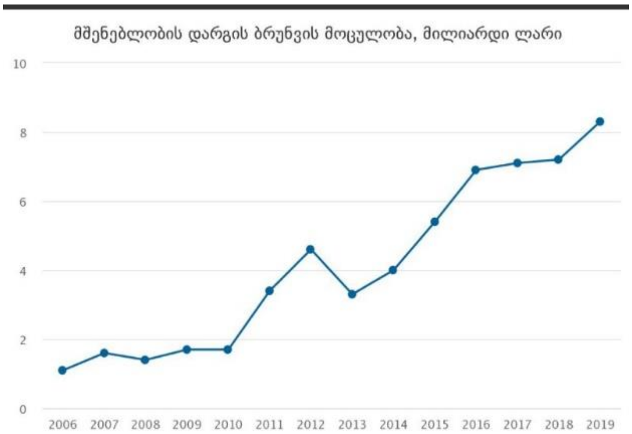

Fig. 2 Development of the construction sector in Georgia.

Over time, the field has evolved, and with it, the demands for building quality have changed. As awareness has grown, various components have been added to the definition of building quality. Today, we can say with certainty that an essential component of the quality of a modern building is its energy efficiency.

Before discussing the energy efficiency of buildings, it is important to understand two main principles of energy efficiency:

1. Get the same thing using less energy
2. Get more with the same energy.

These two principles directly serve to improve the quality of human life, which (1) is felt immediately: whether it is cost savings or optimal use of resources, and (2) has a benefit that is very important in the long term: environmental protection and awareness.

61% of heat in a building is lost through its roof, walls and windows. Buildings are responsible for 39% of the world's total CO_2, of which 28% comes from the operation of the building, i.e. its heating, cooling and lighting.

In the world, more and more attention is paid to buildings, the principles of their construction and dismantling, the materials used and construction techniques. The variety of international and local certificates confirms that modern standards always take into account the impact of a building on the environment, not only during the period of its commissioning, but also from the stage of site selection and design. The new goal of the standards is to reduce CO_2 emissions.

Energy efficiency of buildings is also gaining relevance in Georgia. In early 2020, the Georgian Parliament adopted a law on energy efficiency. According to it, all new buildings in Georgia must meet certain standards within a few years. It is also gratifying that the law applies not only to physical construction, but also to the design of the building. This means that the energy efficiency component will be taken into account from the very beginning.

According to the NDC:

- Georgia makes an unconditional commitment to reduce national greenhouse gas emissions by 35% by 2030 compared to 1990 levels (≈45 Mt CO2 eq.). This target does not include the land use, land use change and forestry (LULUCF) sector. This means that in 2030, total national emissions, excluding LULUCF, should not exceed 29.25 Mt CO2 eq.
- With international support, Georgia commits to reducing its national greenhouse gas emissions by 50-57% (to 22.5-19.35 Mt CO2 eq.) by 2030 compared to 1990 levels, if global emissions are to be limited to a 2˚C or 1.5˚C scenario[5].

In the case of Georgia, the reform of the energy sector is defined by the Association Agreement with the European Union and the Protocol on Georgia's Accession to the Treaty establishing the Energy Community. The legal basis for the reform of Georgia's energy sector is created by transposing European directives into national legislation.

Nowadays, everything we do requires energy, and as time goes by, the demand for it increases. Given that the world still receives energy from exhaustible sources, it is important to use it correctly and wisely. The world is actively working on creating new technologies for energy security that will make it possible to use renewable energy sources. One way to solve this problem is to use energy efficiently.

Conclusion:

The consumer properties of residential and public construction are constantly changing, taking into account the accumulated experience and economic capabilities of the country," - "The creation of comfortable and environmentally friendly buildings that will meet the needs of modern consumers involves a number of problems, many of which require careful analysis and study." It is their solution that will allow us to build energy-efficient comfortable buildings with relatively small capital investments, thereby creating the prospect of large savings in the future.

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Projects of Incredibly High Skyscrapers and Their Implementation Possibilities

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Annotation People have been obsessed with the idea of building skyscrapers since time immemorial. Everyone is well-known for the mythical story of the Tower of Babel, which is the best example of the existence of such a desire of people and their striving for its implementation. If at that time people were interested in building a building as high as heaven only in order to get closer to the gods, then this was replaced by other considerations. First of all, this is the accommodation of as many people as possible in a small area. Despite the centuries-old experience of construction, the possibility of constructing such buildings structurally arose only at the end of the 19th century in the form of arranging metal frames. After the construction of many skyscrapers in different parts of the world, construction technology has improved and the use of reinforced concrete along with steel has made it possible to build super-tall buildings. Although many such projects have been implemented, there are still incredibly tall skyscraper projects that belong to the realm of fantasy and need to be evaluated for their feasibility.

Key words: Skyscraper, Project, Building. Foundation, Structure, Concrete, Steel

Introduction

The number of cities and the population in the world are growing rapidly. Compared to past centuries, this process is currently more accelerated and requires the most optimal use of existing urban areas. The main solution is still the construction of skyscrapers, but due to the ever-increasing needs. The number of projects for buildings 1 kilometer high and higher is increasing. Their development is associated with high costs and, if not implemented, seriously harms the customer. Despite this, there are many unrealized projects for incredibly high skyscrapers (height 2.0 - 4.0 km), which can be used in the future. This is not surprising, because many projects, thanks to their authors, are geniuses and are far ahead of their time. A vivid example of this is the project of Antonio Gaudi's 360-meter-high hotel "Attraction" in New York in 1908, when a 200-meter building had not yet been built anywhere in the world. The project was presented in the form of drawings, but it is one of the most important examples of architectural Azov. The central part of the complex is a building in the shape of a pointed parabolic arch, surrounded by several similar elongated domed buildings. On the lower floor there is a large hall with six-level spaces erected above it, since the use of the word floor does not accurately reflect the grandeur of the project. The second, highest level, has a wide arched roof similar to a temple. It was intended for a theater, lecture and exhibition halls. The third and fourth levels were devoted to galleries, above which it was planned to arrange a passage into a large spherical storage room with a viewing platform for 30 people. The hotel project turned out to be very difficult from a technological point of view, the arrangement of very large arched structures on the upper levels was of particular difficulty. Because of this, the project was forgotten for a long time. It was first proposed almost 65 years later, but the twin towers of the World Trade Center had already been built on that site in 1972. A second version was considered as a replacement for the towers destroyed on September 11, 2001. A new version was proposed on January 23, 2003, but was later abandoned (Fig. 1).

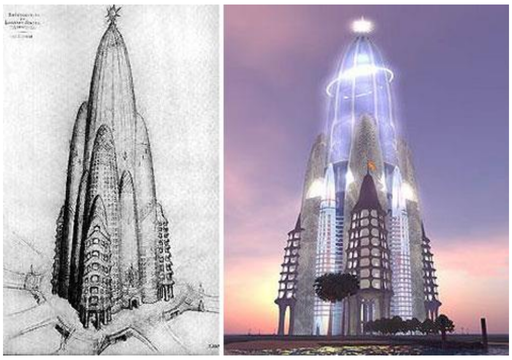

Fig. 1. Gaudi's project

1. Main part

Japan has always tried and is trying to solve the problem of overpopulation practically and profitably. Despite the country's location in a very seismically active zone, the main emphasis has always been on building buildings that are as capacious and comfortable for people as possible. Based on this approach, in 1966-1969, by order of one of the Japanese companies, the first project of the world's tallest skyscraper, 4000 meters high, was developed by Nikitin and Travush, the chief designer of one of the world's unique projects at that time, the Ostankino television tower in Moscow. The name of the skyscraper is known as "The Nikitin-Travush Tower". It was a four-tiered conical metal lattice structure. The height of each tier was 1000 meters. The foundation of the skyscraper with a diameter of 800 m was a 100 m high prestressed reinforced concrete cylinder, which was part of the first tier. The structure was calculated taking into account the most extreme effects of hurricanes and earthquakes in Japan. It was supposed to be a residential building for 500,000 people, with all the engineering communications projects worked out perfectly (Fig. 2). The world-famous Japanese architect Kenzo Tange was also ready to start developing the architectural project, but the first difficulties arose when Soviet specialists were sent to Tokyo, since they were supposed to work mainly there. Then the Japanese side, interested in the implementation of the project, could not resolve other organizational issues and first demanded a reduction in the height of the tower to 2 km, and then to 550 meters. This led to a complete cessation of cooperation, and no one was interested in the project for a long time. owever, in the 1990s, its elements were used in the development of the X-Seed 4000 project.

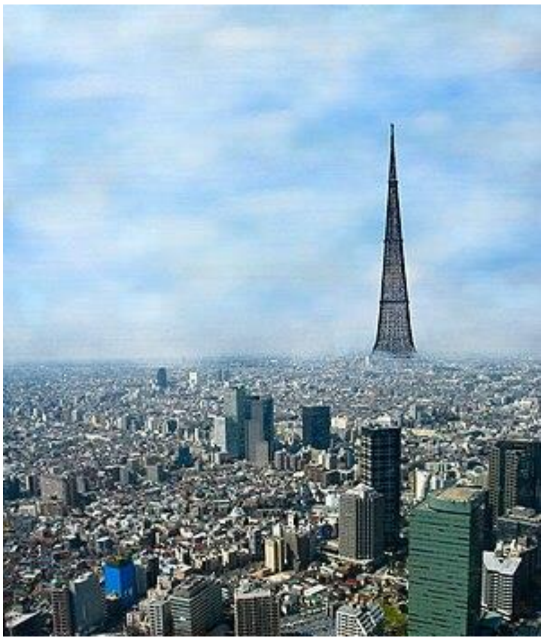

Fig. 2. „The Nikitin-Travush Tower"

X-Seed 4000 is one of the hypothetical projects of the tallest and largest building in the world. Its height is 4000 meters above the ground and 800 floors. Thanks to the base with an area of 6 km^2, the structure can be built on the sea. In its configuration, it resembles, but is higher than the highest mountain in Japan, Mount Fuji, whose height above sea level is 3776.24 meters (the highest point in Japan). The skyscraper-city is designed for 700,000 to 1 million inhabitants. The project was developed by the Japanese company Tasai Corporation in 1995 as a building of the future in Tokyo. Where an ultra-modern lifestyle should be combined with nature. Unlike conventional skyscrapers, the X-Seed 4000 will protect its residents from pressure differences and changes in natural conditions. Throughout the entire height of the building. Its design provides for the use of solar energy to provide the building with energy and maintain a microclimate. The main problem for the implementation of the project was its location in the "Pacific Ring of Fire" region - the world's most powerful volcanic activity zone, which makes the occurrence of earthquakes and tsunamis very dangerous. The elevators are designed for 200 people and take 30 minutes to the highest point. In addition to apartments and offices, the building will include entertainment and shopping centers, parks, and forests. Its construction, according to current calculations, should be completed in 8 years from the start. No one has been working on the project for a long time, but its estimated cost is growing every year and, according to recent estimates, has exceeded 1.5 trillion dollars (Fig. 3).

Fig. 3. **X-Seed 4000**

In Japan, against the backdrop of such interest in the tallest housing, the Chinese-American architect Eugene Tsui designed one of the tallest buildings of the future in 1991, the 500-story "Ultima Tower", with a height of 3218 meters. It is designed to accommodate 1 million people and is aimed at relieving overly dense settlements. The concept of Ultima arose as a result of studying the development of San Francisco. It turned out that there are very few green areas in this large city, and in the conditions of the unstoppable growth of the megalopolis, one of the best solutions is to build vertical structures. The idea is based on the construction of nests by African termites, or an order of insects. The height of the "towers" created by these microscopic creatures sometimes reaches 15 meters. They have great strength, easily resist strong winds. .The structure has passages and tunnels cut inside, which provide natural ventilation and keep cool even on hot days. The architect's goal was to turn San Francisco into a benchmark for "natural living", which should become a role model for humanity. Eco-architecture was an important direction for this author, and he has also implemented several interesting small-scale projects. The implementation of the "Ultima Tower" project has been widely discussed for a long time, but the final decision has not yet been made, because it is too grandiose and ambitious. Nevertheless, the project is unusually unique, because it is designed as a closed ecosystem where the entire city should be located. The structure of the tower consists of many floors, each of which has its own ecosystem, reservoirs and landscape. The diameter of its base is almost two kilometers, or more precisely 1828.8 meters. The internal area of the building is incredibly large - 140 km2, which far exceeds the entire territory of some countries. Lakes and waterfalls are provided at the base. According to the laws of physics, they should cool the upper levels of the building. Natural air conditioning ensures the preservation of oxygen and its increase in the building. To ensure sunlight, giant mirrors are placed in the central part, which reflect the rays coming from the aerodynamic windows. The architect was a great propagandist of the use of renewable materials, and this is evident in the use of recycled raw materials as building materials. In addition, the secondary use system involves the purification of all wastewater and its use for watering the gardens inside the building. The use of solar panels and wind generators. Also, due to the shape of the skyscraper, the electrical energy generated at the expense of the difference in atmospheric pressure at its base and top should be completely allocated to the building's power supply. The building will have its own internal "mini-ecosystem". To reach the top, new types of elevators need only 10 minutes, which is already realistic. A new protection system for conical reinforced concrete walls with double spiral reinforcement has also been designed to protect against ground shaking. As the population on Earth grows and climate change continues, such a building becomes more and more necessary to ensure a normal life for people, and this well-thought-out project can be implemented in just a few decades (Fig. 4).

Fig. 4. "Ultima Tower"

After the completion of the Burj Khalifa in Dubai in 2010, there was talk of a new fantastic project, “The Dubai City Tower”, which would be 2.4 km high with a slightly smaller diameter base. This idea, like many others, seemed at first to be impractical and unrealistic, although experts immediately said that there were no technical obstacles to this project. The only problem was economic efficiency. Many believed that building a 600-meter tower would be more profitable than building one of these skyscrapers. Some also noted that it would be more difficult to operate than to build. In addition to the residential part, the building is planned to house a hotel, offices, shopping, sports and tourist centers, and green spaces.

Fig.5. „ The Dubai City Tower“

In fact, this project involves the construction of a vertical city, consisting of six interconnected, inclined towers made of steel and reinforced concrete, which, with different colored glazing, were to become the most distinctive and largest building in the world. Three such towers are built clockwise, and three in the opposite direction, which leaves an extraordinary impression and should become a symbol for Dubai similar to the Eiffel Tower. The towers are connected after every 100 floors, that is, a total of 400 such connections are formed. People are not supposed to be transported to the floors by elevators, but by special trains moving at a speed of 200 km/h. Inside the building, all conditions for people to stay and relax are created. According to the report, the skyscraper itself should generate the colossal amount of electricity that the skyscraper should consume using wind turbines and solar panels. Despite all the difficulties, financiers appeared, whose main goal was to build the most grandiose building in the world, but considerable time passed in refining the structural part of the project, then the pandemic period followed, and the project, which was already ready for implementation, unfortunately stalled and is no longer being discussed (Fig. 5).

„The Shimizu Mega-City Pyramid" is an idea proposed by the Shimizu Corporation to create a pyramid-shaped artificial city in Tokyo Bay, Japan. The building will house shopping and business centers, parks, squares and everything else that a person needs for a full life. The project aims to solve one of Tokyo's major problems related to the lack of living space. The building is designed for 1 million residents. The pyramid, which is 2,004 meters high and has a base of approximately 2.0 X 2.0 km, is so massive that today's existing building materials cannot withstand its weight and its implementation is impossible in the near future. The idea and design are based on the use of future super-strong carbon nanotubes and graphene-based lightweight materials that have already been discovered and research is underway. The construction was scheduled to begin in 2030, and completion is expected by 2110, but all this is still at the level of an idea. It will become the tallest building in the history of mankind, if no higher project has been implemented before. For the 15th year in a row, the Burj Khalifa in Dubai, with its 828 meters high, has not lost the title. The huge pyramid structure consists of five rows of trusses. Among them, the first row houses pyramid-like dwellings, each of which is the size of the Great Pyramid of Giza. The foundation of the entire building will be formed by 36 piers made of special concrete. Because the seismically active Pacific Ring of Fire runs through Japan, the pyramid's outer structure will be an open network of megastructures that will help the carbon nanotube supports withstand the effects of strong winds, earthquakes, and tsunamis that affect the pyramid. The trusses will be covered with photovoltaic film to convert sunlight into electricity and power the city. Robotic systems are planned to play a significant role in both construction and building maintenance. Transportation within the city will be provided by accelerated walkways, inclined elevators, and a personal rapid transit system, where automated poles will move between the trusses. Residential and office space will be provided by twenty-four or more 30-story skyscrapers, which will be suspended from above by nanotube cables and, together with the pyramids below, will create a system of development (Fig. 6).

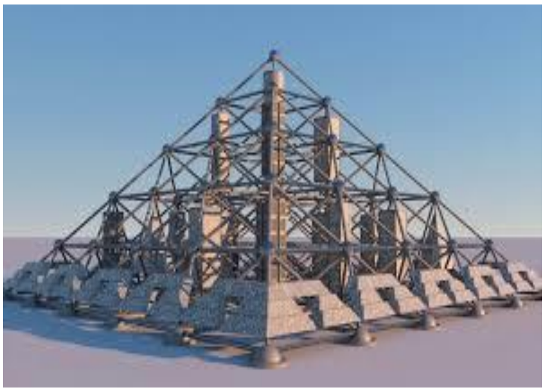

Fig. 6. "The Shimizu Mega-City Pyramid"

"Rise Tower" is a skyscraper project planned for Riyadh, the capital of Saudi Arabia, which will become the world's tallest building upon completion. It is 2,000 meters tall, 1,180 meters taller than the Burj Khalifa. The building has 678 floors. The project, developed by the famous design company Foster & Company, was first announced in December 2022, when the Public Investment Fund of Saudi Arabia announced its decision to build the world's tallest skyscraper on an area of 18 square kilometers in Riyadh. The construction process will use the latest engineering and construction technologies, ultra-strong concrete and high-strength steel reinforcement. The main structural element is a central reinforced concrete core. Its outer steel frame is a high-strength structure that reduces mass and increases flexibility during wind and earthquakes. The shape of the building is also such that the impact of wind is minimized. A giant damper will be placed at the top of the building, which will reduce the vibration during strong winds or earthquakes. Flexible joints will be built into the structure, which will also reduce the impact of earthquakes. The foundation should be one of the deepest and strongest in the world, with 80-100 meter long bored piles, which rest on the rock layer and eliminate soil movement. The "concrete slab" will be built with high-strength concrete several meters thick. (Fig. 7).

Fig. 7. "Rise Tower"

Conclusion

1. The implementation of the currently existing projects for the construction of incredibly high skyscrapers is still impossible due to the mass of the buildings and the technological difficulties of construction. Nevertheless, in the very near future, with the practical application of new ultra-light and ultra-strong building materials that have already been almost completely researched, there is a great opportunity to realize each such project;

2. Despite the existence of numerous unfulfilled skyscraper projects, the development of which is associated with high costs, all of them play a major role in creating a more interesting and even more incredible project. One of the best examples of this is the X-Seed 4000, a grandiose project created in Japan using elements of a previously developed project, which will probably be implemented in the future.

3. The Shimizu Mega-City Pyramid project, which is currently under development, is particularly interesting, but its idea and constructional solution depend entirely on the use of lightweight materials based on future super-strong carbon nanotubes and graphene. These materials have already been discovered and their research has been actively underway for several years. Hopefully, with the start of mass production of these materials, the project will also begin to be implemented, and another wonder of the world will be added.

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Durability of asphalt concrete

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Abstract: In road construction asphalt concrete pavement undergoes intense mechanical and physical impacts during its operation, which ultimately leads to its breakdown. The most common impacts are load impacts and wear and tear from moving vehicles, water soaking of the material with its accompanying alternating freeze-thaw cycle, and salt corrosion. The negative impact of these factors is enhanced by the residual deformations accumulated in the material, which are caused by operational loads and uneven settlement of the base. The aging of the binder, which is expressed in an increase in its hardness, occurs due to the ultraviolet radiation from the sun and oxygen in the air.

Keywords: asphalt concrete, hardness, plasticity, water saturation, water resistance, frost resistance, wear resistance, durability, temperature factor, freeze-thaw, aging.

Introduction

Static and multiple repetitive loads in asphalt concrete cause the accumulation of reversible deformations, which eventually reach a critical level. In water-soaked and frozen asphalt concrete, additional internal deformations arise, which, combined with external loads, accelerate the processes of reversible deformations and, as a result, the collapse of the material.

Main body

The collapse of asphalt concrete is externally manifested by the appearance of cracks on the surface of the pavement, primarily around large aggregates, with the loosening of grains and the loosening of the material..

Asphalt concrete is a porous material. Asphalt concrete, selected according to the need and carefully compacted, contains mainly closed (conditionally closed) pores, the number of which increases with a decrease in the thickness of the filler grains. Without external load, these pores are not filled with water. However, if the wet pavement is subjected to short-term compression (from moving vehicles), some water is squeezed out of the pores, and when unloaded, due to elastic recovery of the shape, a vacuum is created in them, and water is absorbed from the surface of the pavement into the pores. As a result of repeated repetition of this process, water significantly or completely fills the pores in the surface layer of the pavement. Since water is a practically incompressible liquid, then under the influence of external load it is squeezed into the micropores formed in the contact zone of the filler and bitumen, causing the bitumen layer to separate from the filler grains.

Water soaked into the micropores of the asphalt concrete structure causes adsorption leaching, which leads to the opening of microdefects and a decrease in structural bonds. These defects accumulate by repeated wetting and drying process. The decomposition of water-soaked asphalt concrete is aggravated by clay impurities on the surface of the mineral filler. Clay particles, being soaked when wet, accelerate the process of bitumen peeling from the surface of the mineral grains.

During the freezing of water in the pores of asphalt concrete, which always occurs on the surface of the pavement, the frozen water crystals moisten (press) the still unfrozen water in the closed pores and it is filled with water. At the limit saturation of the pores with water (theoretically not less than 91%), subsequent freezing causes dangerous tensile stresses and the resulting plastic (reversible) deformations (at the same time, the volume of the pores increases reversibly). During thawing, the volume of ice decreases (about 9%), and the pressure in the pores becomes less than atmospheric, resulting water absorption into them. In the process of multiple freezing and thawing, the accumulated reversible deformations reach a critical value and microdefects appear initially, which then accumulate and merge, turning into macrodefects. From the moment of the appearance of macrodefects of frost-induced cracking, the cracking of asphalt concrete increases like an avalanche, because these defects are also filled with water and become a source of internal stress.

The weakest point in asphalt concrete is the contact of the asphalt binder with large aggregates. This is mainly due to the difference in the coefficients of thermal expansion of stone materials and bitumen: the temperature coefficient of volumetric expansion of stone materials is on average 1×15^{-5} °C, while that of bitumen is about 8×15^{-5} °C. Ie. almost an order of magnitude more. Because of this, bitumen undergoes much greater deformations than mineral grains when the temperature changes. The thermal stresses, that arise at positive temperatures, are quickly relaxed and the “grain-bitumen” contact is not broken. However, at negative temperatures, when the bitumen becomes ductile and rigid, due to the small relaxation, the thermal stresses increase significantly, which leads to the removal of bitumen from the filler grains. Water enters the formed cracks; The water swells when frozen, and the adhesion of large filler grains to the surrounding bitumen is broken.

An essential factor in the durability of asphalt concrete is the aging of bitumen, which is manifested in increasing viscosity, loss of plasticity and the appearance of hardness, even at positive temperatures. The properties of bitumen change under the influence of heat, solar radiation and oxygen in the air. At the same time, light fractions evaporate and carbon oxidates, with the formation of free valent bonds and their subsequent polymerization, which leads to the formation of even more viscous and rigid substances.

The stability of petroleum bitumen to the effects of air and solar radiation depends on the content of methane, naphthenic and aromatic hydrocarbons in it. With an increase in the amount of oxygen-containing, nitrogenous and sulfur compounds, the stability of bitumen decreases. Oxidation processes are intensified by increasing the porosity of asphalt concrete, i.e. due to better penetration of water and air.

Oxidation and polymerization are maximally experienced by bitumen in the surface layer of asphalt concrete, which also receives other harmful impacts: mechanical loading, water soaking, freezing and thawing, etc. The impact of these processes decreases with the depth of the coating and may not be manifested at all at a certain depth. Depending on the quality of asphalt concrete, bitumen aging extends to a depth of 2 to 6 cm.

The aging process of bitumen is influenced by the mineral composition of asphalt concrete. Adsorption processes also change the group composition of bitumen and its structuring. Hydrocarbon molecules of bitumen in the adsorption layers become less mobile than in free bitumen, which reduces its reactive properties. Due to the loss of plasticity of bitumen, the properties of asphalt concrete deteriorate with an increase in viscosity and hardness. It becomes more rigid and less plastic.

Water saturation is characterized by the amount of water absorbed by a sample of asphalt concrete saturated with water at the required regime. Water saturation is determined on samples (cores) made in the laboratory or cut from the pavement. Cylindrical samples are used for this.

Water saturation is determined as follows: Asphalt concrete samples are initially weighed in air. Then they are placed in a water vessel with a temperature of 20±2 °C for 30 minutes, where the sample must be covered with water with a thickness of at least 20 mm. After that, the samples are weighed in water and placed again in water with a temperature of 20±2 °C. The water level on the samples must be at least 3 cm.

The vessel with the samples is placed in a vacuum apparatus, where the pressure is not more than 2000 Pa (15 mm of mercury water), for an hour. Then the pressure is reduced to atmospheric and the samples are kept in it for another 30 min. After that, the samples must be removed, weighed in water, dried with a soft cloth and weighed in air.

The water saturation of the sample W, % is calculated by the formula:

$$W = \frac{m_3 - m}{m_2 - m_1} \cdot 100 \qquad (1)$$

Where m – is the mass of the sample weighed in air; m_1 – is the mass of the sample kept in water for 30 min and weighed in water; m_2 – is the same, weighed in air; m_3 – is the mass of the sample soaked in water, weighed in air.

The water saturation value is taken as the arithmetic mean of three samples rounded to the nearest tenth.

Water saturation is standardized only for dense and high-density hot asphalt concrete mixtures (Table 1).

Standard requirements for water saturation — Table 1

Type and volume of asphalt concrete	Water saturation, %	
	For samples formed from the mixture	For cores removed from the finished pavement, no more than
High density	1...2,5	3,0
Dense type		
A	2,0...5,0	5,0
B, C, D	1,5...4,0	4,5
E	1,0...4,0	4,0

For cold asphalt concrete mixtures, water saturation should be from 5 to 9% (by volume). The degree of water saturation depends on the structure of asphalt concrete. With an increase in the content of mineral grains, the volume of pores increases, the number of open pores becomes greater. This is confirmed by numerous data (Fig. 1). In the figure, curve 1 shows the water saturation of the asphalt binder, curve 2 - the asphalt mixture, curve 3 shows the water saturation of asphalt concrete after a long stay in water.

The shrinkage of asphalt concrete is characterized by its hydrophilic properties and a certain degree of adhesion of bitumen to the surface of mineral grains. Swelling is defined as the increase in the volume of the sample after its saturation with water in a vacuum. The data determined during its water saturation are used to determine the shrinkage.

The shrinkage of asphalt concrete is determined by volume percentage:

$$g = \frac{(m_3 - m_4) - (m_1 - m_2)}{m_1 - m_2} \cdot 100 \qquad (2)$$

where m_1 is the mass of the sample, which was soaked in water for 30 minutes and weighed in air; m_2 – mass of the same sample, weighed in water; m_3 – mass of the sample saturated in vacuum, weighed in air; m_4 – mass of the same sample, weighed in water.

The arithmetic mean value of three samples, rounded to the first decimal place, is taken as the magnitude of the shrinkage.

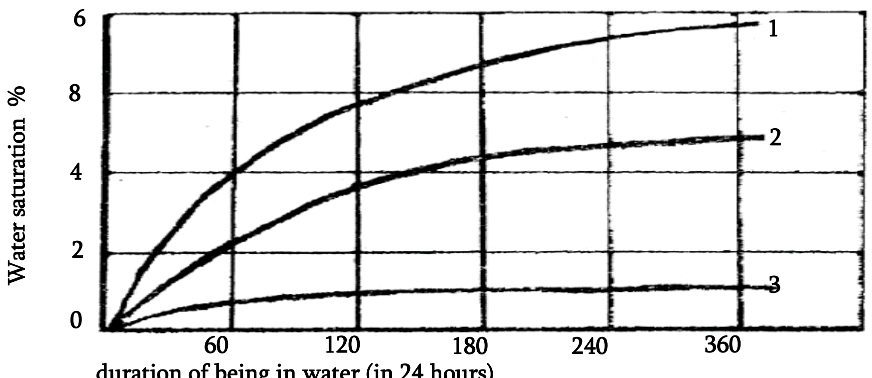

Fig. 1. Change in water saturation over time:
1 - asphalt binder; 2 - asphalt mixture; 3 - asphalt concrete

The water resistance of asphalt concrete is determined by the water resistance coefficient, which shows how many times its strength has decreased after saturation with water and characterizes the resistance of asphalt concrete to the destructive action of water. The water resistance coefficient is determined for all types of hot and cold asphalt concrete mixtures, except for coarse-grained ones. There are two methods for determining water resistance.

The first method takes into account the decrease in strength of samples as a result of exposure to water in a vacuum. For this purpose, samples on which water saturation and shrinkage have been determined can be used.

The water resistance coefficient $K_{\text{წ}}$ is determined with an accuracy of one tenth by the following formula:

$$K_{\text{წ}} = \frac{R_{\text{კ}}^{\text{წ}}}{R_{\text{კ}}^{20}}, \qquad (3)$$

where $R_{\text{კ}}^{\text{წ}}$ – is the compressive strength of a sample soaked in water in a vacuum, mgPa; $R_{\text{კ}}^{20}$ – the same, before soaking in water at 20±2°C, mgPa.

The second method differs from the first in that the samples soaked in a vacuum are transferred to water at a temperature of 20±2°C and left for 15 days, after which they are tested for compression.

Water resistance is determined according to the test results by the formula:

$$K_{\text{წყ}} = \frac{R_{\text{კ}}^{\text{კწ}}}{R_{\text{კ}}^{20}}, \qquad (4)$$

where $K_{\text{კ}}^{\text{წყ}}$ – is the strength limit of the sample at a temperature of 20±2°C after soaking in water for 15 days, mgPa; $R_{\text{კ}}^{20}$ – is the strength limit of the sample not soaked in water at a temperature of 20±2°C.

The results of the second method of testing for water resistance are of a smaller magnitude than the first method. Therefore, according to the requirements of normative documentation, the determination of the water resistance of asphalt concrete is established by both methods.

The frost resistance of asphalt concrete is determined by the decrease in compressive strength as a result of the effect of the established freeze-thaw cycle on it. The essence of the method is as follows. Samples soaked in vacuum at a temperature of 20±2°C are frozen in a chamber at a temperature of minus 18±2°C for 4 hours. After that, it is transferred to a water bath with a temperature of plus 18±2°C, where it thaws for 4 hours. Samples of the specified freeze-thaw cycles (5, 10, 15, 25, 50) must be kept for 2 hours in a water bath with a temperature of 20±2°C and tested for compression.

The reduction in compression strength ΔR, %, is calculated by the formula:

$$\Delta R = \frac{R_{\text{კ}}^{\text{წ}} - R_{\text{კ}}^{\text{ბ}}}{R_{\text{კ}}^{\text{წ}}} \cdot 100, \qquad (5)$$

where $R_{\text{კ}}^{\text{წ}}$ – is the arithmetic mean value of the compression strength after saturation with water at a temperature of 20±2°C, mgPa; $R_{\text{კ}}^{\text{ბ}}$ – the same, after the specified freeze-thaw cycle, mgPa.

The number of test cycles and the permissible decrease in strength are established in the design documentation, depending on the actual climatic conditions and the purpose of the asphalt concrete.

Conclusion

Many factors affecting asphalt concrete during the operation of the road surface, the combination of their differences and intensity make it difficult to unambiguously assess its durability. Therefore, the indicators like water saturation, water resistance, frost resistance, wear resistance, temperature factors can be used as specific criteria for the durability of asphalt concrete.

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Reviving Abandoned Suburban Settlements: Urban and Architectural Approaches to Seasonal Housing

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Abstract. The revival of abandoned suburban and seasonal settlements has become increasingly relevant in response to rapid urbanization and the growing need for nature-based living spaces. Historically significant for recreation and relaxation, these settlements are being reimagined through sustainable urban and architectural planning. Key principles include functional zoning, ecological building practices, modular and adaptable housing systems, and the integration of natural elements. Global examples, particularly from Scandinavian countries like Sweden, demonstrate successful models that combine environmental sensitivity with quality of life improvements. This study explores these approaches and highlights their potential for restoring suburban spaces as sustainable, inclusive, and community-oriented environments.

Key words: *Revival of suburban settlements; Abandoned villages; Seasonal settlements; Urbanization impact; Urban-rural dynamics; Sustainable development; Ecological architecture; Energy-efficient buildings; Restorative tourism; Community-based planning; Georgia's suburban history; Eco-friendly housing concepts.*

The revival of abandoned suburban settlements is an interesting and relevant topic, especially today, when many villages or settlements have disappeared or have been degraded due to urbanization. Suburban settlements have traditionally been of great value both for urban dwellers and for all conditions related to nature, relaxation and improvement of the quality of life. A seasonal settlement is a place that is used mainly during a certain season, usually summer or spring, when climatic conditions support closeness to nature and the environment.

Introduction

The revival of abandoned suburban settlements is a growing and compelling topic in today's world, particularly as many villages and settlements face decline or disappear due to the pressures of urbanization. These suburban areas, once vital hubs for relaxation, recreation, and connection with nature, have traditionally offered a retreat from the hustle and bustle of urban life. However, with changing societal dynamics, there is an increasing recognition of their potential for rejuvenation. Seasonal housing, in particular, offers a unique solution, providing spaces that cater to short-term needs, like recreation and relaxation, during specific seasons. This text explores the urban and architectural approaches to reviving these suburban settlements, focusing on their historical context, the design principles necessary for their sustainable growth, and the lessons drawn from successful global models. By blending ecological sensitivity, modular systems, and functional zoning, these settlements can be transformed into thriving, sustainable communities that offer both a connection to nature and a high quality of life.

1. The Needs of Settlement Planning: The main goal of seasonal suburban settlements is to cater to short-term needs such as recreation, nature, and free time. The planning of housing types, infrastructure, and spaces are planned for active or controlled use during the summer period.

Functional Characteristics: The needs of such settlements include living spaces where people can spend time in peace and comfort. This includes both permanent structures (in addition to modular and adaptable housing) and temporary housing.

Natural Environment: Another important aspect of suburban settlements is their proximity to nature. In such places, the population often maximizes the use of agriculture and nature — gathering natural products, engaging in entertainment, walking, or engaging in sports activities.[18]

2. History of Suburban Settlements

Suburban settlements, as a concept, mainly developed in the late 19th century and early 20th centuries. This period was marked by urbanization and industrial growth, when living conditions in cities became more complicated, and people felt the need to spend time outside the city.

The Primary Type: The creation of suburban settlements mainly occurred by entrepreneurs, intellectuals, and representatives of prestigious mechanisms, often by building houses in suburban areas or remote villages.

Tourism and Recreation: As society grew economically, resorts, recreational areas, and suburban settlements proliferated in virtually every country. In Europe, for example, the concept became particularly popular in Norway, Sweden, and Germany, where suburban settlements became large gathering places during the summer season.

Development in Georgia:

In Georgia, suburban settlements have played an important role since the late 19th century, especially in the regions surrounding large cities. Part of the urban population spent their summers in country houses, which introduced a different model of rural and suburban life.

In this historical context, such settlements were initially characterized primarily by ethnic and social status, but today they are widespread and it is clear that they have new functions and social roles.

The Next Phase: In the 20th century, suburban settlements underwent changes, with a greater focus on architectural details, infrastructure, and the opening of these spaces to a wider population. This meant opening up these spaces not only to the elite, but also to a broader population, including tourists.

The Current Situation: Today, the importance of suburban settlements has grown even more, as urbanization and the tension of city life make people return more often to nature and seek places to relax.[19]

3. Urban Principles of Settlements

The planning of suburban settlements should be based on functional zoning, which allows the settlement to combine different functions, such as residential, commercial and recreational areas. This means that the settlement should have spaces not only for living, but also for various social and economic activities.

Residential Zone: Residential houses should be designed in such a way that the local population and guests can enjoy a peaceful environment and proximity to nature. These houses should be comfortable and their layout should encourage the creation of better community spaces.

Commercial Zone: The commercial areas of suburban settlements create opportunities for small businesses, such as shops, small markets, pharmacies and other service facilities, which help the local economy and tourism.

Relaxation and Entertainment Areas: The settlement area must include parks, walking trails, sports fields, and other spaces where people can relax and engage in leisure activities.

Improved Infrastructure: In architectural and urban planning, it is important that the infrastructure is improved and as conducive as possible to providing comfortable living conditions.

Infrastructure Facilities: Reliable roads, water and electricity systems, sanitary and purification facilities must be planned to ensure comfort and stability in living conditions.

Trade and Service Spaces: The combination of commercial and residential areas must be arranged so that the population has easy access to necessary services and can live in comfortable conditions.

Inclusive Design: The infrastructure must take into account the needs of all age and social groups (including those with special needs) to ensure that everyone has maximum access to the settlement.

[18] https://worldgbc.org/

[19] https://www.archdaily.com/

4. Seasonality and Modular Systems

Seasonal settlement refers to a settlement that functions only for a certain period of time, such as during the summer or spring seasons. Therefore, it is necessary to implement modular systems that can be easily adapted based on the season.

Mobile Structures: For such settlements, the best solution may be mobile homes that can be easily moved, adapted and quickly changed according to the season. This could include mobile camps or affordable housing systems that can be expanded or relocated.

General Adaptation: The settlement can create infrastructure that accommodates enough space to adapt to different types of activities seasonally (for example, sports areas in the summer and relaxation areas in the fall).

5. Architectural Principles

Ecological Buildings: One of the main principles related to suburban settlements' architecture is ecology. Buildings should not only be energy-efficient but also environmentally friendly.

- **Natural Materials:** The use of natural materials for suburban houses, such as wood, stone, glass, and other eco-friendly building materials, is not only aesthetically pleasing but also has a lesser environmental impact.
- **Energy Efficiency:** It is necessary to use solar energy, install solar panels, and recycle water. These approaches not only contribute to environmental protection but also significantly reduce the resources required for living.
- **Energy-Efficient Planning:** Buildings should be designed to make the most of natural resources (sunlight, natural ventilation, and weak water recycling) to minimize the use of electricity and water.[20]

Local Design and "Micro-Houses": The architecture of suburban houses should be oriented towards compatibility with nature and the local culture.

- **Local Architecture:** The design should be appropriate for local traditions and styles. This could involve elements like roofs, facades, balconies, and terraces that reflect local architectural traditions and blend more easily with the natural environment.
- **Micro-Houses:** Micro-houses, or small homes, are often used in suburban settlements because they offer functional and efficient use of small spaces. Such houses often include solar panels, plant borders, integrated living spaces, and compact designs.

Integration of Natural Elements: The harmonious integration of nature and architecture must be included in any design to ensure that locals and tourists can stay as close to nature as possible.

- **Large Windows and Open Spaces:** Large windows in homes allow residents to fully enjoy the beauty of nature. The same applies to terraces and open balconies, which are prioritized in suburban houses.
- **Parks and Landscape Planning:** It is essential to combine park and landscape engineering to create a pleasant environment. For example, designing the natural landscape with trees and plants helps create a more comfortable and sustainable environment in the settlement.
- **Natural Elements:** Gardens, water streams, reservoirs, and other natural features depend on seasonal conditions and offer additional benefits.

These architectural approaches provide not only visual comfort but also help users stay in closer contact with nature.

6. Practical Examples and Successful Models

Global Experience: Several countries around

[20] https://unhabitat.org/

the world stand out for their successful models of seasonal settlements that effectively use places near nature, innovative architectural and urban approaches, and ensure maximum comfort, ecology, and sustainability. Such models are often developed by Scandinavian countries, such as Sweden, Norway, and Finland.

Sweden: Sweden is one of the first countries to actively use seasonal settlements as restorative tourism and relaxation spaces. Many of these settlements are located in beautiful natural landscapes and near lakes, which support local and international tourism.[21]

- **Ammerån-Hosjö:** One of the popular locations in Sweden, which has been revived as a seasonal settlement. The homes built in this area are architecturally innovative and ecologically sustainable, welcoming tourists during peak summer months for local relaxation. The buildings are made from ecological materials such as wood, stone, and glass, harmonizing well with nature.
- **Eco-Houses in Sweden:** Sweden is distinguished by modern ecological house models that are designed based on energy efficiency and sustainability principles. Many residential complexes in Sweden use solar energy and water recycling to reduce environmental impact and increase sustainability.

Conclusion:

Suburban settlements, as seasonal spaces, combine the use of functional zoning and ecological approaches to ensure high-quality living conditions close to nature. The urban and architectural principles of the settlement, such as modular systems, the use of ecological materials, functional zoning, and the integration of natural elements, contribute to comfortable and sustainable living. The global experience, such as in Sweden, Norway, and Finland, shows that these types of settlements thrive when local resources and ecological approaches are correctly utilized. Models from Sweden and Norway demonstrate that such settlements not only play a social and economic role but also help maintain harmonious relationships with nature and promote sustainable development.

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Calculation of Coefficient of Subgrade Reaction with Different Norms

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Abstract The paper discusses the model of the interaction of the building and the soil (foundation) under static loads and their joint work determines the stressed-deformed state of the structure. The calculation was carried out using the computer software complex "LIRA SAPR 2024", which is based on the finite element method. The calculation was carried out with the building stiffness varying (the thickness of the foundation slab varies), and various methods of calculation for a flexible foundation were also used. The results obtained were analyzed. In the examples considered in the paper, various construction numbers and rules ("SP22.13330.2011/2016", "SP 50-101-2004", "DBN B.2.1-10:2009", "SNIP 2.02.01.-83"). The calculation was carried out using the computer software complex "LIRA SAPR 2024", which is based on the finite element method "FEM".

Key words: Coefficient of Subgrade Reaction, Elastic foundation.

Introduction

The types of soil have a significant impact on the stressed-deformed state of a building. Correctly defined and maximally approximated accurate modeling of the influence of the interaction of the foundation and soil allows us to make the building more reliable and more economical. Due to the fact that the soil is heterogeneous, anisotropic, and determining its physical and mechanical properties is a difficult task, taking into account these reasons, it is not possible to accurately describe the real state of the soil and the superstructure, taking into account the interaction of the superstructure on the stressed-deformed state of the building, using current methods. The paper discusses three different methods for calculating coefficient of subgrade reaction and their impact on vertical deformations of the foundation (beams) taking into account various construction standards ("SP22.13330.2011/2016", "SP 50-101-2004", "DBN B.2.1-10:2009", "SNIP 2.02.01.-83").

Modeling

Calculation using the linearly deformable half-space method

The software complex "LIRA SAPR" uses three methods for determining the subgrade coefficient:

The first method: according to the first method subgrade coefficient is calculated according to the Poisson's ratio and flexibility module of average importance.

Subgrade reaction is calculated with the following formula:

$$C_1 = \frac{E_{zp}}{H_C(1-2m_{zp}^2)} \quad (1).$$

The second method: subgrade reaction is calculated by this method by using the Winkler foundation:

$$C_1 = \frac{q}{S} \quad (2),$$

where $q = \dfrac{P}{\eta b^2}$ is the average pressure on the foundation bottom. b – Minimal size of the foundation; η - ratio of the maximal side of the foundation with the minimal one; S – foundation closure;

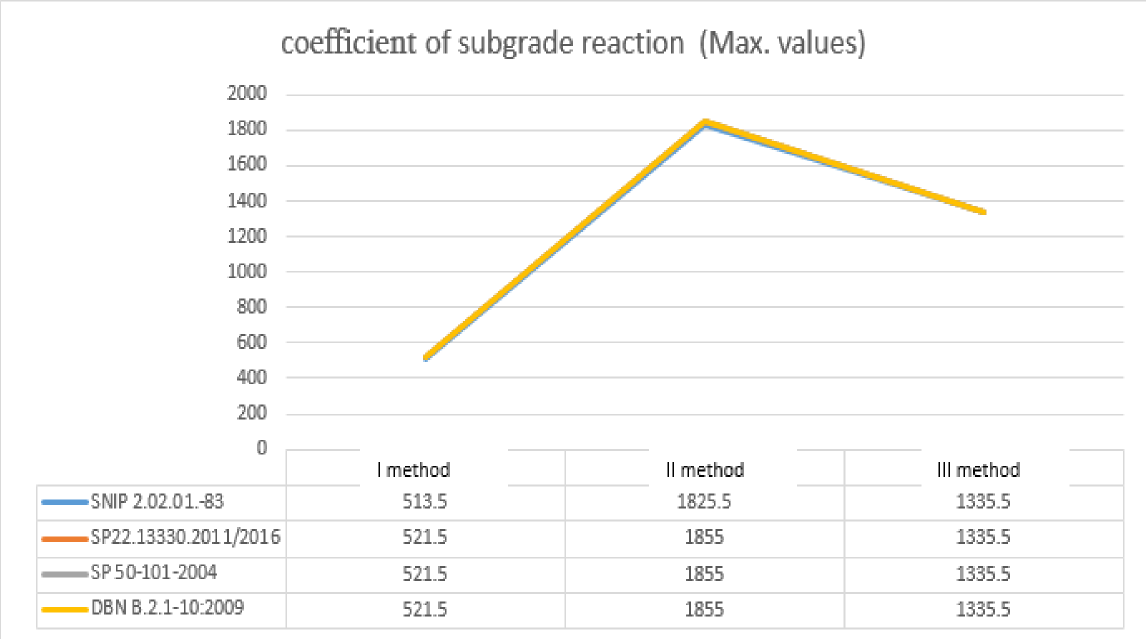
The third method: for determining the subgrade reaction in the third method one uses formula of the first method (3). Difference among these methods is that for determining the module of the average deformation of ground one uses the coefficient correcting the module of the average deformation of ground. This coefficient is changed $u_1 = 1$ from the benchmark of the foundation bottom $u_1 = 12$ up to H_C limit of the active zone (before finishing the compressed zone).

$u = \frac{11z^2}{H_C^{\ 2}} + 1$ (3). C_2 - Subgrade reaction for all three methods is calculated by one common formula:

$$C_2 = \frac{C_1 H_c^{\ 2}(1-2m_{zp})}{6(1-m_{zp})} \quad (4).$$

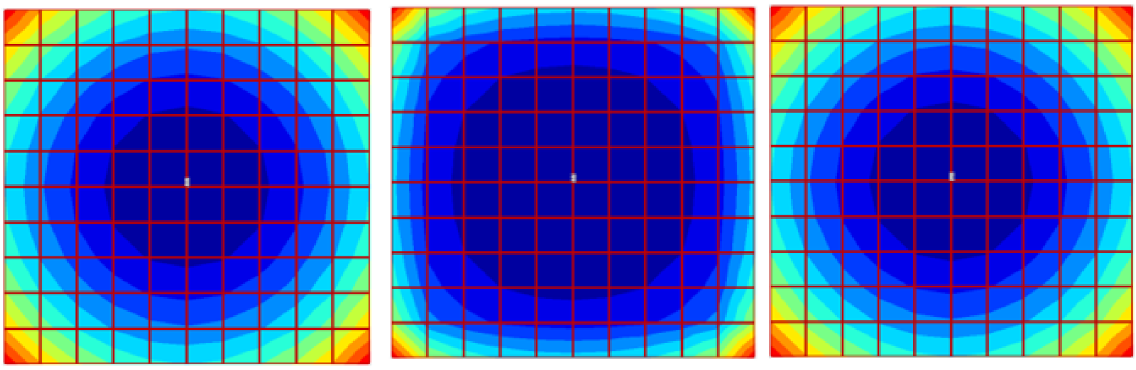
In the used computer program, coefficient of subgrade reaction is carried out in two variants: the averaged method and according to the soil modeling. In both cases, the calculation is carried out using all three methods of coefficient of subgrade reaction mentioned above. In our case, the soil model variant is used, since it more accurately reflects the interaction of the grout and the foundation in different situations, since each finite element has a different coefficient of subgrade reaction. The modulus of elasticity of the concrete of the foundation slab Ef=3000000 t/m2, the volumetric weight of reinforced concrete 2.5 t/m2, the size of the foundation slab AXB=5X5 m. The load on the foundation slab is 50 t/m2. The modulus of elasticity of the soil Es=3000 t/m2, the volumetric weight of the soil 2.0 t/m2, Poisson's ratio 0.3

		coefficient of subgrade reaction C1, t/m2				Settelment (mm)		
		method 1	method 2	method 3		method 1	method 2	method 3
SNIP 2.02.01.-83	Min.	466	900	1211		18	18	7
	Max.	561	2751	1460		55	55	29
SP22.13330.2011/2016	Min.	473	915	1211		17	17	7.7
	Max.	570	2795	1460		54	54	29.7
SP 50-101-2004	Min.	473	915	1211		17.8	17.8	7.74
	Max.	570	2795	1460		54.6	54.6	29.76
DBN B.2.1-10:2009	Min.	473	915	1211		17.88	17.88	7.74
	Max.	570	2795	1460		54.61	54.61	29.76



	I method	II method	III method
SNIP 2.02.01.-83	513.5	1825.5	1335.5
SP22.13330.2011/2016	521.5	1855	1335.5
SP 50-101-2004	521.5	1855	1335.5
DBN B.2.1-10:2009	521.5	1855	1335.5

Grafic #1-Coefficient of subgrade reaction

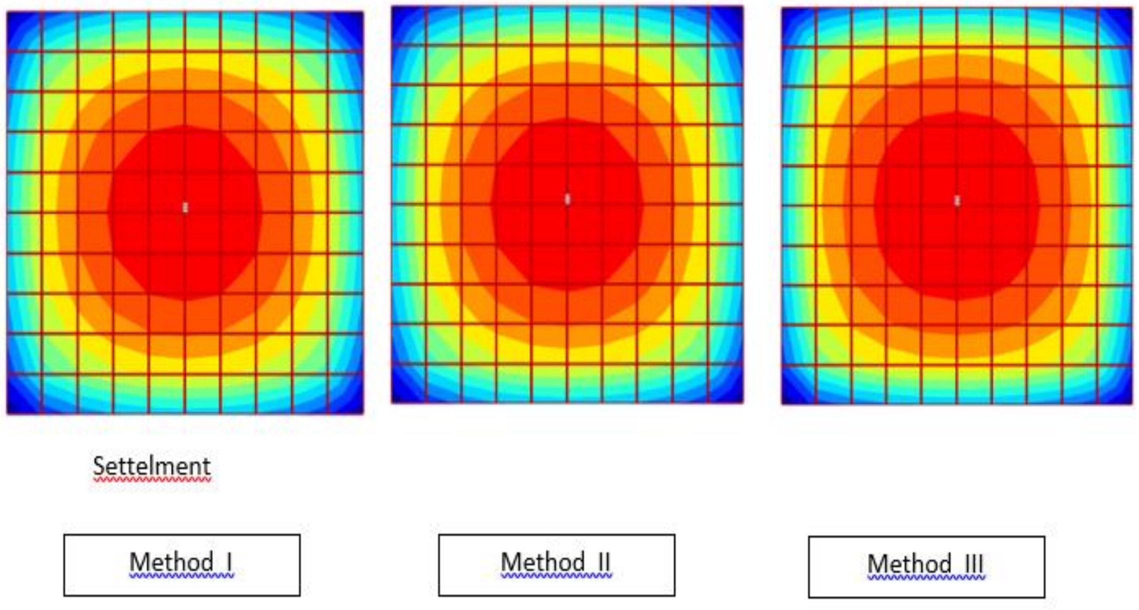


Coefficient of subgrade reaction

Method I

Method II

Method III



Conclusions

In all three methods, an increase in the stiffness of the building (the thickness of the foundation slab) leads to an increase in the stresses, while the stresses in both the foundation slab and the columns are different. In the case of the first method, an increase in the thickness of the foundation slab leads to a decrease in the stresses, both in the foundation and in the columns, while in the

second and third methods, the bending moments in the foundation slab increase, and in the columns, like the first, decrease.

As the calculation shows, the values of the sag coefficients calculated by different methods differ from each other by approximately 30-50%.

According to the norms given in the calculation program used, the difference in winning coefficients is insignificant.

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Design of pressure tunnel with consideration of construction sequence influence

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Abstract The paper presents a study of the stress state of the "tunnel-surrounding massif" unified system taking into account the technological scheme of tunnel construction.

During tunnel construction, during the staged development of the ground, there will be a gradual development of mining loads on the existing tunnel lining. Unlike the sudden construction scheme, such a scheme is close to the correct assessment of the loads developed on the lining and, accordingly, the calculation of the lining structure.

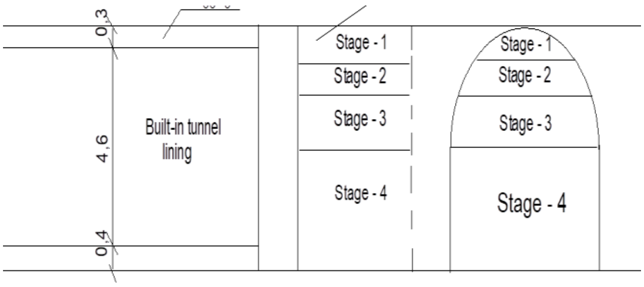
On the basis of the numerical calculation carried out for the design solution of the Aspindza HPP pressure tunnel, the stress state parameters reflecting the joint operation of the "tunnel-surrounding massif" system were obtained, taking into account the differentiated influence of the construction technology (sudden construction and staged construction). In particular, the vertical normal stresses in the lining cross-section increased insignificantly, while the horizontal normal stresses decreased by 25%. In the cross-section of the foundation, the compressive stresses increased in the construction state (up to 20%), while in the operational state, the compressive stresses decreased (up to 30%).

INTRODUCTION

In general, tunnels are calculated using the "sudden construction scheme" - within the framework of superposition. In reality, the tunnel is constructed in stages along its longitudinal axis, which deviates from the superposition approach.

During the tunneling process, as the ground is gradually worked out, there will be a gradual development of mining loads on the existing tunnel lining. Unlike the sudden construction scheme, such a scheme is closer to the correct assessment of the loads developed on the lining and, accordingly, to the calculation of the lining structure.

The study of the joint operation of the tunnel surrounding the array system, taking into account the construction stages, was carried out in 4 main stages (processing zones 6, 7, 8, 9 are given in the drawing (Fig. 1).



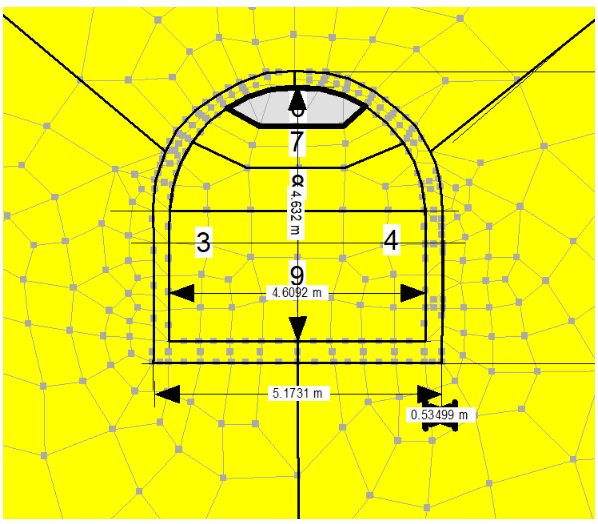


Fig. 1 Scheme of the phased construction of the tunnel.Fig. 2 Calculation scheme of the "Tunnel

Surrounding Array" system. Stages of tunnel development.

During the calculation, in accordance with the presented calculation scheme, at each stage of the array processing in accordance with the tunnel construction stages, the corresponding elements of the excavated area are removed from the calculation scheme. As a result, at each stage of the calculation, the stresses are redistributed from the removed elements to neighboring elements.

- Calculation of the stress state of the tunnel construction

Taking into account the construction stages

As a result of the calculation, the results of the stress state of the tunnel construction were obtained for all stages of construction and are given in the drawings below.

- Tunnel crown section (1-1)

σy - The distribution of stresses in the vertical section of the intact massif was reflected in the epigraph with a linear regularity. At each subsequent stage of massif processing, there is a decrease in loads at the crown section of archt.

During tunneling, the stresses σx in the direction of the cross-section of the clit (vertical cross-section direction) gradually increase and reach their maximum value when the tunnel is completely finished. This indicates the appearance of the arch effect.

The regularity of the stress distribution was clearly evident in the section of the repair cleft. During the stage-by-stage processing of the tunnel, the compressive horizontal normal stresses gradually decrease, and during the complete processing of the tunnel section, they transition into tensile stresses.

- Toe and wall sections (2-2, 3-3) of tunnel

During the staged processing of the tunnel, the distribution of stresses at the heel and wall intersections develops according to the following regularity (fig. 2):

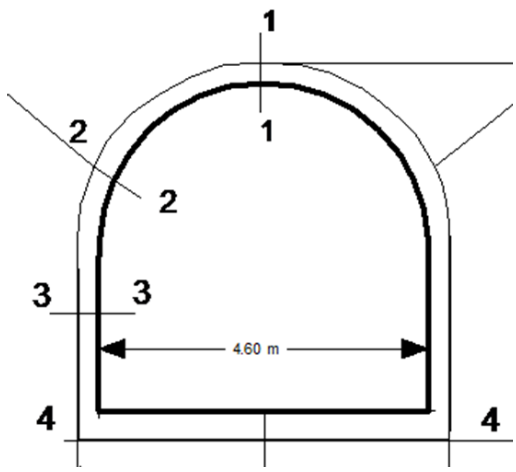


Fig. 3. Sections under consideration for tunnel construction.

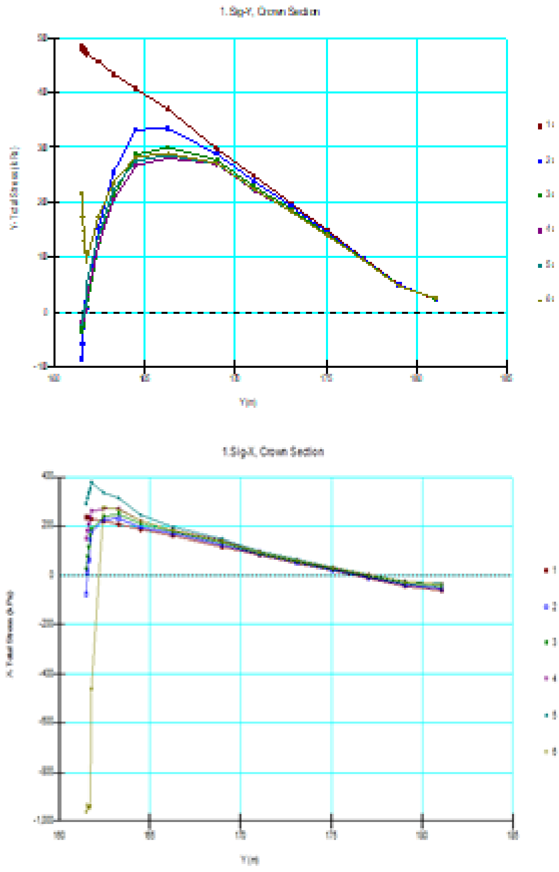


Fig. 4. Distribution of the normal stresses in the vertical cross-section of the tunnel.

a. vertical normal stresses;
b. horizontal normal stresses

– The vertical normal stresses σ_y in the direction of the array's construction gradually increase, and at the heel intersection the stresses reach their maximum. Under the action of hydrostatic pressure, tensile stresses appear in the structure, the maximum value of which at the heel intersection reaches -68 kPa.

– During tunneling, the stresses σ_x in the direction of the cross-section of the clit (vertical cross-section) gradually increase and reach their maximum value during the complete tunneling (Fig. 2.2.4 2).

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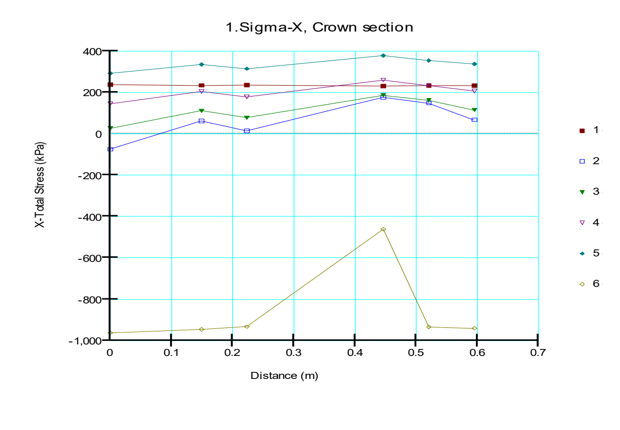


Fig. 5. Distribution of horizontal normal (σ_x) stresses in the arch crown section

– Distribution of vertical normal stresses in the vertical cross-section of the clit of the tunnel. σx Distribution of horizontal normal stresses in the cross-section of the repair arch. c). This indicates the occurrence of the arch effect.

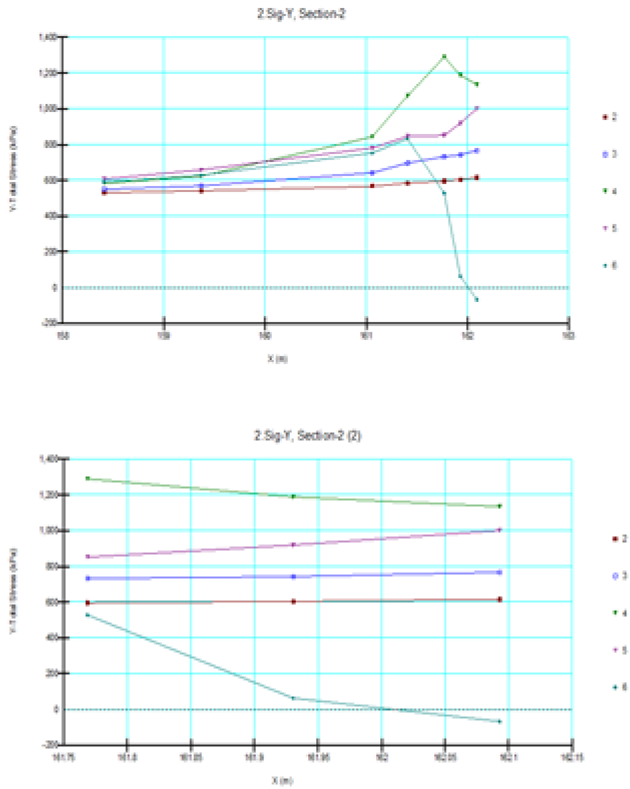
➢ Tunnel arch heel and wall sections (2-2, 3-3)

During the gradual development of a tunnel, the stress distribution at the heel and wall intersections develops according to the following regularity (fig. 3,4):

– σy vertical normal stresses occur with a gradual increase in the fibers. Obviously, the stresses reach their maximum value at the heel section. Under the action of hydrostatic pressure, tensile stresses appear in the structure, the maximum value of which at the heel section reaches -68 kPa.

– The distribution of horizontal normal stresses σx in the massif is increasing, and on the contrary, it decreases along the repair section.

– As a result of the pressure from inside the tunnel, the stresses in the section decrease,



which is reflected in the values of the stresses σx and σy.

Fig. 6. Distribution of vertical normal stresses in the vertical cross-section of the tunnel

➢ Tunnel base section (4 - 4)

The gradual processing of the tunnel was also reflected in the contact section of the tunnel lining and the base (Fig. 2.2.4 6 σ_xhorizontal and σ_y vertical normal stresses distribution at the contact section of the tunnel lining and the base,. In particular,

The distribution of σx horizontal normal stresses is mainly of an increasing nature, and during the complete processing of the tunnel section, on the contrary, the stresses decrease in the central part, and towards the heel sections, the stresses increase.

The distribution of σy vertical normal stresses during the gradual processing of the tunnel has a decreasing nature and reaches a minimum value (0.32 kPa) during the complete processing of the tunnel section, while towards the heel sections, the stresses increase and reach a maximum value (958 kPa).

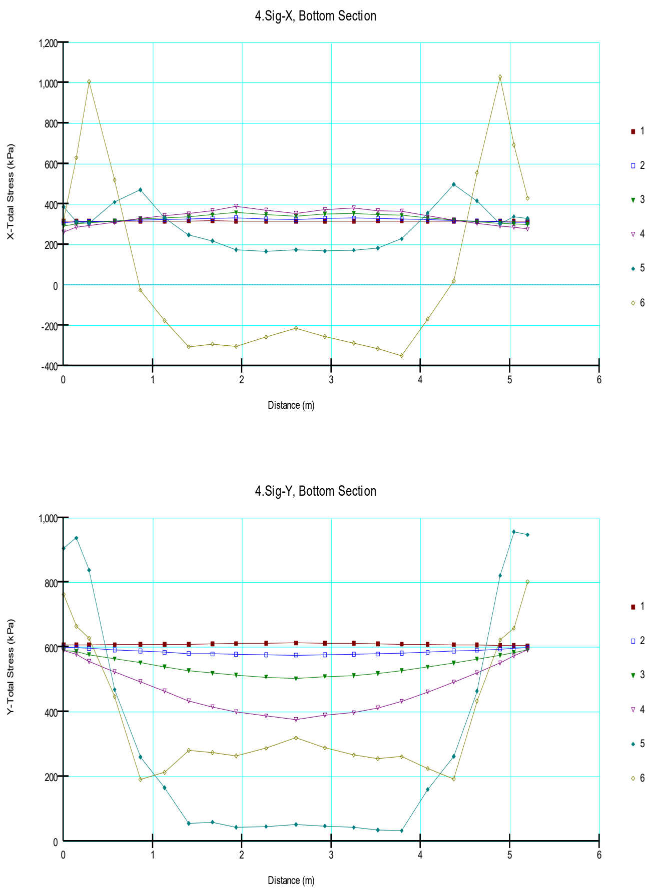


Fig. 7 Distribution of σx horizontal and σy vertical normal stresses at the contact section of the tunnel lining and base.

The contact section of the lining and the base under the action of internal pressure At the intersection: σx, the tensile horizontal normal stresses increase significantly and reach -350 kPa, while towards the heel intersections, on the contrary, the compressive stresses increase and reach 100 kPa.

Below is an analysis of the stress state of the tunnel lining (based on the results of the principal stresses) taking into account the construction stages in the empty state and as a result of the action of internal pressure (fig. .

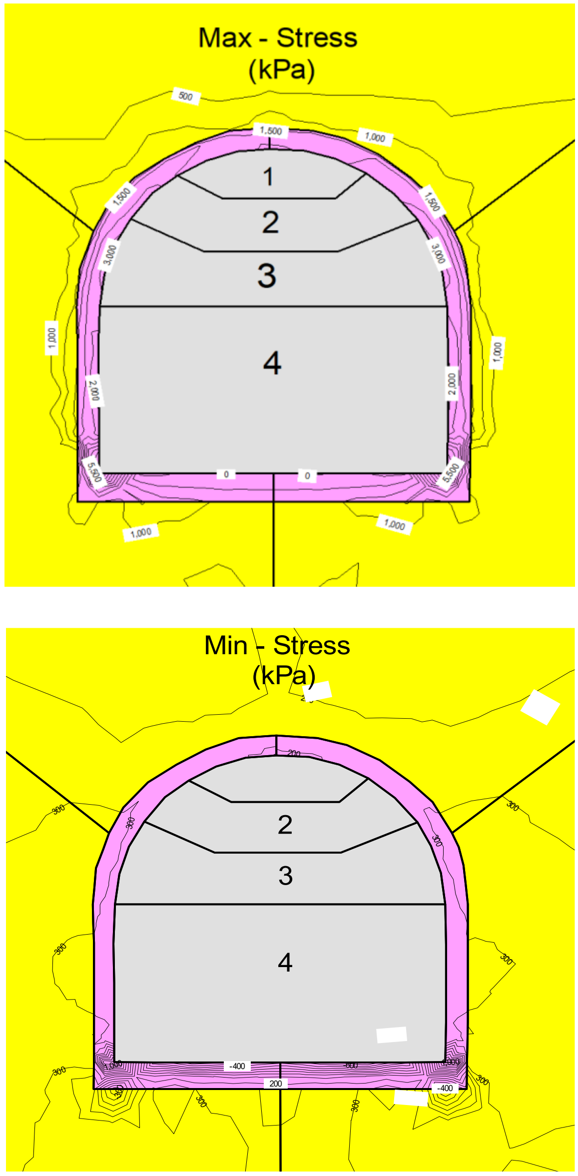


Fig. 8. Distribution of maximum and minimum principal stresses in tunnel lining after completion of construction (empty tunnel).

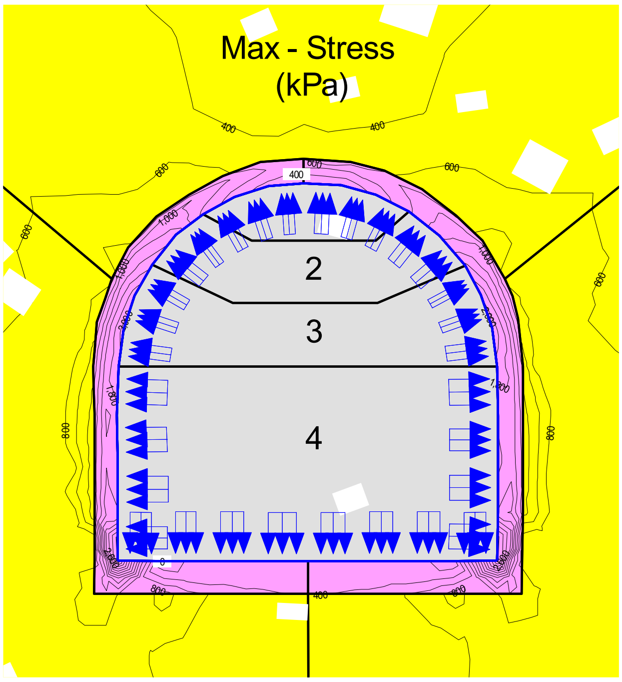


Fig. 9 Distribution of maximum principal stresses in tunnel construction (operational condition).

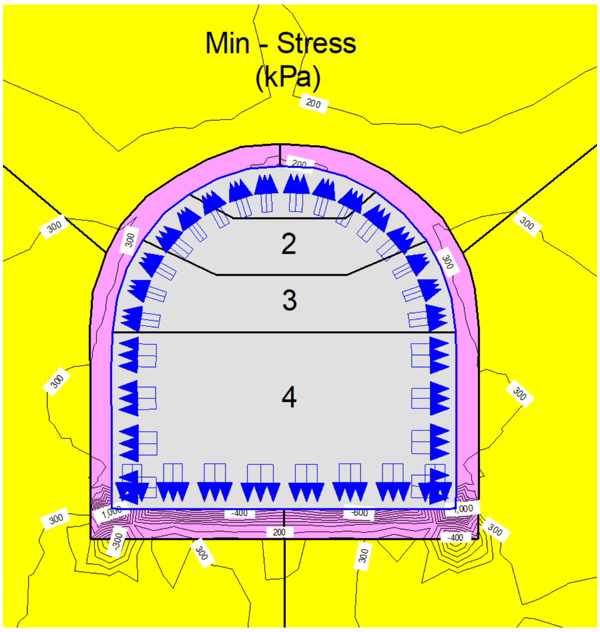


Fig. 10 Distribution of minimum principal stresses in tunnel construction (operational condition).

hBased on numerical calculations, the parameters of the stress state reflecting the joint operation of the "tunnel array" system were obtained, taking into account the differentiated influence of the construction technology (sudden construction and gradual construction).

– During the construction of the tunnel, the gradual processing of the soil was regularly reflected in the nature of the distribution of stresses in the structure and the surrounding area. The zone of collapse of the rock soil (vertical mining pressure) was specified according to the vertical normal stresses (σy) developed at the tunnel cleft section.
– The vertical load acting on the arch, during the gradual processing of the tunnel (compared to the sudden tunnel construction scheme), decreased insignificantly (up to 4%), while the stresses in the horizontal direction increased up to 8%.
– In crown section of tunnel, the vertical normal stresses increased by 5%, and the horizontal normal stresses decreased by 25%.
– In the bottom section of tunnel, the compressive stresses increased in the construction state (up to 20%), while in the operational state, the compressive stresses decreased (up to 30%);

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