THE IMPORTANCE OF HISTORICAL STAGES OF CONSTRUCTION WITHIN THE CONTEXT OF SUSTAINABLE URBAN DEVELOPMENT OF HADRUT CITY

Preservation of Artsakh's architectural heritage and the issues of use have acquired a special significance today. The historical stages of the construction of the city of Hadrut in Artsakh, and, as a result of their analysis, their impact on the further sustainable development of the city have been revealed. There are 5 main stages: formation, late Middle Ages, from the 19th century to the first half of the 20th century, Soviet and independence periods. Suggestions are given on the territorial development of the city.

Keywords: urban development stages, historical stages of construction, sustainable development, architecture of residential buildings, Hadrut city, cities of Artsakh.

Introduction

The historical development of the city is the most important part in the context of the creation and sustainable development of the city. Many cities in Artsakh do not have a development strategy or conception, which can lead to the wrong choice of area for modern construction. The study of the existing historical settlements and the problems of their construction is of great importance for solving the problems of the territorial development of Artsakh. During the Soviet period, Azerbaijan pursued a policy of concealing and destroying the Armenian historical and cultural heritage in Artsakh. This approach has had a negative impact on the spatial development of the cities. In recent decades, the relatively slow urban development of Artsakh has contributed to the preservation of the architectural heritage of historic Armenian cities, as well as to the holistic historical and cultural architectural image of the region up to the present day. The problem of preserving and using this valuable heritage has acquired special significance today.

The problem of preserving and using the historical construction of Hadrut is hindered by its lack of knowledge. It should be noted that unique complete samples of the Armenian national habitat have been preserved in Hadrut, which are a vivid example of the process of historical change of habitat. The study of dwellings provides an opportunity to study the types of social life, the formation of rural communities, their origins, traditional rules of behaviors and communication skills. During the study of the habitats, the fact of the fragmentation of their types and the ways of the process of transformation are of interest. There are examples of housing construction and habitats not far from each other, the principles of development and substantiation of which are not easy to understand. Moreover, the possible architectural relationships with neighboring countries, such as Iran and Russia, the influence of which within the normal range lasts for decades, have not been studied.

Before the 44-day war, a new wave of construction had begun in Hadrut city of Artsakh, but there was no plan to preserve the city's identity. The modernization process did not take into account the historical and cultural heritage and the architectural plan of the city. This led to a number of urban-architectural planning problems. Although I. Davitbekov wrote about the city of Hadrut in his work “The village Hadrut” in 1887, nevertheless there is no work revealing the historical development of the city and its overall.

In the 1980s, Manvel Sargsyan implemented measurements of settlements with his own financial resources. Arthur Mkrtchyan's contribution to the collection of information on the foundation and development of the city is also invaluable. However, in Hadrut, the structures of historical and architectural value are being destroyed: in particular, houses built at the end of the 19th century, which are not protected by the local self-government bodies, have been forgotten.
Materials and Methods

Materials and methods of the research are based on the study of archival, historical and literary materials and on the author’s situational observations and analysis.

Results and Discussion

In order to understand the stages of territorial development of Hadrut city, it is necessary to analyze the stages of city formation, historical development, external influences and other factors.

The period from the approximate formation of Hadrut to the present day can be divided into five stages, which include generalized historical events and the process of architectural planning development intertwined with the latter, as well as the constructions specific to each period.

First References and Formation. 14th-16th centuries

The earliest reference on Hadrut known to us dates back to 1428. In that year, in the "Chgnavori qar" desert near the historical city of Yeghegis, the center of the historical Vayots Dzor, a gospel manuscript was copied. The gospel was penned by Yeghia, who, as it could be seen from the memoir, was originally from Hadrut.

The manuscript was written "իթվիս Հայ ոց ՊՀԷ" [1] which corresponds, as it has already been mentioned, to the year of 1428, that is, about 560 years ago. However, if we take into account that Father Yeghia wrote the manuscript in mature age, and he is from Hadrut only by origin, it would mean that the fact that Hadrut is not less than 600 years old is a historically documented fact. However, it is natural that the first reference does not mean that it immediately followed the establishment of the settlement. Newer or older references may be found in those unknown sources. There is evidence that during the construction the remains of the pagan period and khachkars (cross-stones) were found in Hadrut. Unfortunately, they have not been studied at all.

According to the aforementioned information by Arthur Mkrtchyan, one can claim that the village of Hadrut was formed before the 15th century. However, very few architectural structures, mainly the ruins of castles and churches, have been preserved from this period. It is noteworthy that the fragments of dozens of monuments found during field observations refer to both pagan and early Christianity periods as well as the Middle Ages. According to the description of Hadrut in Sh. Mkrtchyan's book "Historical and Architectural Monuments of Nagorno Karabakh", five main buildings that had been typical to Hadrut are highlighted, Hin Hangstaran, Ghalin Band, Tschakhach Ghalay, Vnesa Ghalay, Spitak Khach Monastery.

The Hin Hangstaran, is now partially preserved and is located in the western part of the village. Tombstones without records indicate their pagan origin. According to Sh. Mkrtchyan, only two tombstones were found, on which a cross was engraved. The latter also mentioned that in the 19th century these tombs were called "Krapashht hangstaran" (Idolater’s cemetery) among the people.

The Ghalin Band, with towers, which is not preserved now.

In the northeastern part of the village is the Ghalin Band (entrance to fortress) castle with towers, which is not preserved now.

About 1.5 km away from the previous one, on the slope of a small hill, there are the ruins of another fortress called "Tstsakhach Ghalay". Once there was a great need for water in this fortress. This is evidenced by the fact that water from the village of Shaghakh (Saren-Shen) was brought artificially by the inhabitants of that time, as evidenced by the remnants of clay pipes, which here are called "Tyungi". The tomb of the owner of this castle Velijan, is located near the Church of White Cross. The tombstone was laid by Velijan’s son Khumar in 1527 [2].

To the northwest of the village, on a high forested "Vnesa-mountain", there is another ancient fortress called "Vnesa Ghalay". This means that it belonged to the owner of that time Vanes (Hovhanness). Only the half-ruined church and the walls of the former building remained now.

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2 Ibid.
Spitak Khach Monastery is located a few hundred meters south of Hadrut, near a village called Vank, which is now part of the city of Hadrut. The village has been given that name probably because it is close to the monastery. And the monastery complex has existed since the 14th century [3]. The exact date of the construction of the church is unknown. However, it should be assumed that it was built in the 14th century at the latest, since it contains many traces of the 14th century. For example, the inscription of the cross under the north arch inside the temple: “Ես Սիրաւք կանգնեցի զխաչս հաւր իմոյ Խութլափի թվ (1333)” [4].

These 5 architectural structures date back to the same period, 13th-16th centuries, they surround Hadrut, but only the Spitak Khach Monastery has been preserved. Another reference on Hadrut is found in another manuscript of the Gospel written about 150 years ago from the previous one, which is now kept in the manuscript repository of the Zmamar Monastery near Jerusalem. This manuscript was already copied in Hadrut by Hieromonk Abraham in 1584.

The manuscript already proves that in the 16th century Hadrut was a famous settlement, the center of writing, that is, there was some famous building here, probably it was the church in the old cemetery, which can be supposed to have been a writing center.

This conclusion is confirmed by the fact that other manuscripts written in the villages of Tyak-Taghaser are known from the 16th-17th centuries. It is natural that these villages, being located very close to each other, were in close contact.

Based on this information, the outline of Hadrut of that period is presented, including a number of constructions that were described in the work "The village Hadrut" written by I. Davitbekov in 1887 (Fig. 1).

Fig. 1. Hadrut outline in the 16th century according to historical sources and location of castles

Late Middle Ages. 17th-18th centuries

There is no complete information about the architecture of Hadrut in the 17th-18th centuries, but various famous people visited Hadrut and referred to the fact that the village was developed compared to the

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5 Ibid.
6 Ibid.
surrounding villages. The aforementioned information indicates that already in the 18th century Hadrut was a well-known settlement and was famous outside Artsakh.

St. Harutyun Church is located in the historically formed part of Hadrut – in the circle of old buildings. According to some sources, it is a large and durable structure, the roof of which is covered with polished semicircular stone slabs.

This church was built in 1621. Polished stones and cross-stones belonging to the ancient monastery, which are typical to the 12th-14th centuries are used inside the walls [2].

Ancient Hadrut was surrounded by a number of defensive fortress-castles. In the north-east, the traces of the old fortress named "Berdi mutq" have been preserved, separate parts of walls and towers of "Ttsakhach" fortress in the south, "Vnesaberd" in the north, "Tisoraberd" in the southeast have also been preserved. Hadrut, along with the province, has been repeatedly destroyed by Persians, Arabs, Seljuk Turks, Tatar-Mongols and Ottoman Turks, but has always been rebuilt. This is evidenced by the lithographs of Spitakakhach Monastery, Shakhkakh, Shinategh, Anapat, St. Harutyun, St. Astvatsatsin, Grigor the Illuminator, Amenaprkich, St. Grigor monasteries and churches (9th-17th centuries) and many other monuments in Hadrut and the surrounding villages [2].

The conducted researches allow to restore the outline of Hadrut in the 17th-18th centuries (Fig. 2).

![Fig. 2. Hadrut outline in 17th-18th centuries](image)

The period from the 19th century to the first half of the 20th century

The 19th century was especially conducive to the prosperity of Hadrut, after the unification of Eastern Armenia with Russia, when the population of the barracks quadrupled over several decades.

In the past, Hadrut was not so different from surrounding villages, but since the establishment of the military unit, some residents were able to earn much money by delivering various supplies for the headquarters.
Such residents began to build one-storey and two-storey houses with tin roofs to the best of their abilities. But the houses of the ordinary people were built under a conical roof leaning on wooden pillars. The pillars were arranged very close to each other, so that from a distance it seemed to be a common wall, and the conical openings for light and smoke penetration were also visible. The surrounding forest, stones, sand and clay, as well as a small amount of fired brick were a source of construction materials. The forest is located 10-15 km west of Hadrut, and the other materials were obtained directly from Hadrut [5,6].

On the whole, there was only one street in the village, that started from the headquarters (military unit) and before reaching the middle of the village, it was narrowed, not allowing to pass with a carriage. The remaining streets were narrow alleys paved with tiles.

Thus, although Hadrut was not a provincial center, it played an important administrative role in the life of the province. This circumstance made a great contribution to the development of the settlement. And it is not accidental that in 1880 a telegraph office was opened in Hadrut, and in 1885 a pharmacy and a four-bed patient reception center, which served the entire province of Jabrayil.

The cultural life of the settlement is marked by the fact that in 1879 an Armenian parish school was opened in Hadrut, and two years later also a Russian two-class school.

Later, in 1912, due to the efforts of the teacher of the Armenian school in Hadrut S. Nazaryan, a branch of the Armenian Benevolent Society of Caucasus was created, one of the first actions of which was the opening of a library-reading hall. The economic life of Hadrut was becoming more active. A silk factory was established in 1877 (Fig. 3).

The settlement was gradually becoming bigger and the population was growing. If in 1823 the population in Hadrut was only 229 people, then at the beginning of the 20th century it had increased tenfold reaching 2,300. Along with the administrative, economic and cultural development and growth of Hadrut, the settlement and life of the inhabitants were improving. In 1819, the St. Harutyun church of the village was

Fig. 3. Hadrut outline according to the construction carried out from the 19th century to the first half of the 20th century
renovated - a dome was installed on it\(^7\). In 1900 a spring was built, in 1908 a two-span bridge was built on the river passing by the settlement near Khor Aghbyur, the central street was tiled, buildings of Armenian and Russian schools and administrative buildings were constructed. Residents began to build one-storey and two-storey town-like houses, furnishing them with European furniture.

The available materials allow us to claim that at the beginning of the 19\(^{th}\) and 20\(^{th}\) centuries, Hadrut was one of the most famous settlements in Artsakh after the city of Shushi (Fig. 3). In the 19\(^{th}\) century, Hadrut was constructed on a regular planned basis. The old part of the settlement is still visible today. From the lower part of the regional center to the upper cemetery, on both sides of the street, valuable one- or two-storey balcony houses and shops of folk architecture are preserved. According to the formed list, their number reaches about 300 [2].

**Soviet period. 20\(^{th}\) century**

In 1918, the people of Hadrut showed strong resistance to Turkish forces attacking Zangezur. After the Sovietization, Hadrut was forcibly incorporated into the Azerbaijani SSR, and deprived of the possibility of its development. Almost all industrial enterprises were closed, hundreds of hectares of fertile mulberry orchards were cut down or uprooted, and a number of buildings were demolished.

Later, a number of buildings were built in Soviet times. These include the House of Culture, built in 1980, the Cinema in 1971, the Winery in 1960, the Editorial building in 1950 and the Museum building in 1930 (Fig. 4).

![Fig. 4. Hadrut Outline during the Soviet era](image)

**Independence period. 1990 – today**

Thanks to the Karabakh movement of 1988, the population of Hadrut experienced a national revival. Residents of the city fought together with the Armenians of Artsakh for their freedom. Indeed, over the past

\(^7\) List of monuments. http://www.monuments.nkr.am/
Nersesyan N.A., et al

30 years, some buildings that do not fit into the urban landscape have been constructed, but the city has entered a new stage of development (Fig. 5).

Due to the 2020 war, the city of Hadrut was handed over to the Republic of Azerbaijan, as a result of which the Artsakh Republic lost its territorial integrity, as well as the possibility for the further study of the architecture for an indefinite period of time.

**Fig. 5. Hadrut Outline after independence**

**Conclusion**

As a result of the research and analysis, five main stages of urban development are distinguished together with the existing architectural monuments belonging to each of them:

- First references and formation: 14\(^{th}\)-16\(^{th}\) centuries
- Late Middle Ages: 17\(^{th}\)-18\(^{th}\) centuries
- The period from the 19\(^{th}\) century to the first half of the 20\(^{th}\) century
- Soviet period. 20\(^{th}\) century
- Independence period. 1990 - today

The architecture of this ancient settlement, which has a great historical value has not received due attention, and currently systematic research is hampered by the destruction caused by the war and the occupation of the territory by Azerbaijan.

However, in case of solving geopolitical problems, taking into account the above-mentioned circumstances, all further construction works should be relocated to another area, in order not to damage and interrupt the panorama of the old city by modern construction (Fig. 6).

It is proposed to expand the city to the south-east and north-west, where it is possible to develop the city without damaging the panorama of the old district. Analysis of the historical stages of Hadrut construction makes it possible to make a correct and justified choice of territories for further development of Artsakh cities through such methods and study [7].
Fig. 6. Proposal for further development of Hadrut outline

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STIFFNESS OF POST-TENSIONED GIRDERLESS FLOORS WITH DIFFERENT COLUMN GRIDS

The paper considers models of monolithic flat floor slabs with five spans in both directions. The cell sizes are 6×6m, 6×9m, and 6×12m. The calculation method is based on the application of temperature load and rope modeling of rod elements. It is shown that post-stressing should be used for slab side lengths over 7 m, as the installation of pre-stressed reinforcement for shorter lengths is less feasible and causes high economic costs.

Keywords: reinforced concrete slab, stiffness, deflection, column grid, post-tension.

Introduction

When designing structures with a prestressed system without adhesion to concrete, it should be taken into account that prestressed reinforcement does not transfer forces to the concrete over the entire length, but only at the anchor points at the ends of the structure, as well as at the bends in the ropes. Accordingly, the prestress must be assumed in the calculation as external forces applied to the structure. The forces formed at rope bends depend primarily on the rope geometry and the forces in it.

Works [1-8] are devoted to studies of girderless structures with prestressed reinforcement.

The calculation of prestressed elements in deformations (stiffness) is carried out according to the normative document1. The compression force $N_p$ is determined by taking into account all losses and $\gamma_{sp} = 0.9$. Deflections are calculated by considering the strength of concrete at different stages of loading, including the transfer of compression forces.

The deflections of reinforced concrete elements are calculated under the condition:

$$ f \leq f_{ult}, $$

where $f$ is the deflection of the reinforced concrete element from the external load,

$f_{ult}$ is the value of the maximum permissible deflection of a reinforced concrete element.

For bendable elements of a constant cross-section, along the length of the element without cracks, the deflections are determined by the general rules of structural mechanics using the stiffness of the cross-sections determined by the formula:

$$ D = E_{b1} \cdot I_{red}, $$

where $E_{b1}$ is the deformation modulus of compressed concrete, determined according to the load duration and taking into account the presence or absence of cracks,

$I_{red}$ is the moment of inertia of the given cross-section in relation to its center of gravity, determined taking into account the presence or absence of cracks.

Materials and methods

The calculation method is based on the temperature load application and the modeling of ropes with rod elements [9].
The modeling of the reinforcement of the central cell structure is carried out using a rod element in LIRA SAPR. The cross-section of the rod element is similar to the area of prestressed reinforcement in the floor slab as well as to the computer synthesis [10].

In this paper, models of flat floor slabs with five spans in both directions are investigated. The cell sizes are 6×6m, 6×9m and 6×12m, with the thickness of h = 0.3m (Fig.1). The size of the finite elements is 0.3×0.3m.

**Fig. 1. Scheme of a monolithic floor with rope-mounted reinforcement of the central cell**

**Main characteristics of construction materials**

Concrete class B30. Post-tensioned reinforcement in form of ropes (monostrends): K7O \( (R_{sp,n} = 1860 \cdot 10^3 \text{kN/m}^2, E_{sp} = 1.95 \cdot 10^5 \text{MPa}, d = 15.7 \text{mm}, Asp = 1.54 \text{cm}^2) \). For calculation 5, 7 and 9 ropes are taken.

A uniformly distributed load \( q = 5 \text{kN/m}^2 \) is applied to the slab.

The reinforcement of the central cell is modeled by the rod elements in the structure, the section of which is similar to the prestressed reinforcement area in the element. To simulate prestressing in the reinforcement, a temperature load is applied to it, which is calculated according to the formula:

\[
\Delta t = \frac{\varepsilon_0}{\alpha},
\]

where \( \varepsilon_0 = \frac{\sigma_0}{E_p}, \)

\( E_p \) is the modulus of elasticity of the prestressed reinforcement,

\( \sigma_0 \) is the controlled tension of the prestressed reinforcement,

\( \alpha \) is the expansion coefficient of the reinforcing steel.

The deflections will be considered at characteristic points of the cell (Fig. 2).

**Fig. 2. Characteristic points of the central cell: \( f \) - deflection in the center of the cell, \( f_a \) - deflection in the center of the smaller side of the cell, \( f_b \) - deflection in the center of the larger side of the cell**
The prestress, calculated by the formula (3), is equal:

\[ \varepsilon_0 = \frac{0.7 \cdot 1860}{1.95 \cdot 10^5} = 667 \cdot 10^{-5}. \]

\[ \Delta t = \frac{667 \cdot 10^{-5}}{0.000012} = 556 \, ^{\circ}C. \]

The reinforcement of the structure’s central cell was modeled using a rod element in LIRA SAPR 9 (Fig. 3). A 6x6m slab cell with 5 ropes along the contour is modeled using flat (floor slab) and volumetric (columns) elements. The size of the finite element is 0.3x0.3m.

The floor slab is defined as a plate with a thickness of 300mm. The section of the column is 600x600mm.

Fig. 3. Calculation scheme for a 6x6m central cell with 5 ropes

The results of the calculation are shown in Figures 4 and 5.

Fig. 4. Travel along the Z axis of the entire slab with 6x6m cells and a central cell reinforced with 5 ropes
Results

Based on the calculations carried out for the central cells 6x6, 6x9 and 6x12m with different numbers (5, 7, 9) of ropes, the deflection values were obtained, which are summarized in Table 1.

Table. Deflections of central cells with different numbers of ropes

<table>
<thead>
<tr>
<th>Cell, m</th>
<th>Deflections (5 ropes), mm</th>
<th>Deflections (7 ropes), mm</th>
<th>Deflections (9 ropes), mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>a×b</td>
<td>f₁</td>
<td>fₐ₁</td>
<td>fₚ₁</td>
</tr>
<tr>
<td>6×6</td>
<td>2.84</td>
<td>2.52</td>
<td>2.52</td>
</tr>
<tr>
<td>6×9</td>
<td>14.4</td>
<td>5.03</td>
<td>14.8</td>
</tr>
<tr>
<td>6×12</td>
<td>44.9</td>
<td>5.7</td>
<td>46</td>
</tr>
</tbody>
</table>

Table 1 shows that for a 6×6m square cell, with an increase of prestressing ropes from 5 to 7, the deflection in the center decreases from 2.84 to 1.81mm (1.57 times or 36.3%), and for 5 to 9 ropes - from 2.84 to 0.936 (3.03 times or 67%), in the center of "a" and "b" sides with an increase of the ropes from 5 to 7, the deflection decreases from 2.52 to 1.88mm (1.34 times or 25.4%) and for 5 to 9 ropes - from 2.52 to 1.43 (1.75 times or 43%).

For a 6×9m rectangular cell, with an increase of prestressing ropes from 5 to 7, the deflection in the center decreases from 14.4 to 13mm (1.1 times or 9.7%), and for 5 to 9 ropes - from 14.4 to 11.7 (1.23 times or 18.8%), in the center of the short side "a" with an increase of the ropes from 5 to 7, the deflection decreases from 5.03 to 3.99 mm (1.26 times or 20.7%), and for 5 to 9 ropes - from 5.03 to 3.52 (1.43 times or 30%), with an increase of the ropes from 5 to 7 in the center of long side "b", the deflection decreases from 14.8 to 13.7mm (1.08 times or 7.4%) and for 5 to 9 ropes - from 14.8 to 12.7 (1.17 times or 14.2%).

For a 6×12m rectangular cell, with an increase of prestressing ropes from 5 to 7, the deflection in the center decreases from 44.9 to 42.1mm (1.07 times or 6.2%), and for 5 to 9 ropes - from 44.9 to 39.6 (1.13 times or 11.8%), in the center of the short side "a" with an increase of the ropes from 5 to 7, the deflection decreases from 5.7 to 4.95mm (1.15 times or 13.2%), and for 5 to 9 ropes - from 5.7 to 4.29 (1.33 times or 24.7%), in the center of long side "b" with an increase of the ropes from 5 to 7, the deflection decreases from 46 to 43.6mm (1.06 times or by 5.2%), and for 5 to 9 ropes - from 46 to 41.5 (1.11 times or by 9.8%).
Tamrazyan A.G., et al

The results show that with an increase of the long side of the slab cell from 5 to 7 m, the effect on the deflection of the installation along the contour of a larger number of ropes is reduced significantly. For example, for the center of the cell, the effect on the deflection of installing 9 ropes compared to 5 ropes is reduced from 67% to 11.8%, for the short side "a" - from 43.3% to 24.7%, for the long side "b," - from 43.3% to 9.8%.

Conclusion

1. Prestressing is recommended to apply when the side of the slab is longer, than 7 m, since with a shorter side length, the installation of prestressing reinforcement is less expedient and entails high economic costs.

2. The use of post-tensioned ropes on the shorter side of a rectangular cell is unreasonable since the deflection on the short side meets the normative value even before the prestressed reinforcement is introduced into the model.

3. It is expedient to install more ropes for longer cells. For example, according to the calculation, it is not reasonable to install less than 7 ropes for a 6×9 m cell, and it is expedient to install 9 ropes or more for a 6×12 m cell. However, the use of 9 or more ropes can create large flexures at the base of the column, which would require additional reinforcement and strength testing of the compressed concrete.

4. With an increase of the long side of the slab cell from 6 to 12 m, the effect on the deflection of the installation along the contour of larger number of ropes decreases significantly: for the center of the cell, it reduced from 67% to 11.8%, for the short side "a" - from 43.3% to 24.7%, for the long side "b" - from 43.3% to 9.8%. This indicates that for cells with sides of 7 m or more, it is more expedient to use a average number of ropes but with a higher prestressing force to reduce the financial cost of their installation.

5. The method of modeling prestressed ropes using rod reinforcement with the application of a temperature load is simple, accurate, and easy to use.

References


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