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A technological solution for strengthening the foundations of Old Tbilisi buildings without changing the original look

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Abstract: The article discusses the history of the city of Tbilisi. The historical architectural buildings of old Tbilisi preserve the city's cultural heritage and preserves an important part of the unique cultural heritage of the city for the future generations. To preserve the self-sufficiency of old Tbilisi and the appearance of its old buildings, the technology of strengthening their foundations is considered. The most common methods are used, namely: strengthening the foundation with the use of drill-injection joints, anchor and suspension joint.

Keywords: architectural buildings, technology, foundation construction, strengthening

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Introduction

Tbilisi is one of the oldest cities in the world. It was the capital of Iberia and is mentioned in ancient Georgian and foreign literature. The first settlement in Tbilisi appeared in the 4th century, and in the middle of the 5th century the King of Kartli, Vakhtang Gorgasali started to cultivate the city. His successor Dachi declared Tbilisi the capital of the Kingdom of Kartli. Tbilisi consisted of three cities – Tiflisi (Tbilisi), Kala and Isani. The city is divided into two parts by the river Mtkvari. The town of "Kala" was surrounded by a fortress and included the right bank of the

river. The upper square of the "Kala" Fortress included the royal residence, palaces, churches, theological schools, baths and an observatory. On the south slope there was a garden of royal palaces. The northern slope was occupied by monastic complexes, which are referred to as castle churches. Tsavkisi river waterfalls flowed down the northern slopes and there were suitable conditions for sailing boats to the river Mtkvari.

It is interesting to look at the old urban planning of the city and how old Tbilisi developed. In the 5th century the centre of the city was considered to be the so called "Kldisubani", the upper part of the fortress (Gorgasali) square to Lower Bethlehem, and the surrounding area of Mukhrantubani, King Square. Later, in the 19th century, the city centre was moved to Sololaki.

Historical records and archaeological excavations allow us to determine the boundaries of early medieval Tbilisi, its districts and partly its urban appearance. A place was chosen for the city in the strait of the Mtkvari, and the road leading to this narrow place was controlled on one side by the Salalak ridge and on the other by the Metekhi plateau. Zeda-tsikhe, a small fortress, can be found on the ridge of Salalak and also Narikala, "Narin-Kala", which means a small fortress in Arabic. Tbilisi itself, originated right at the confluence of the Tsavkistskali River and the Mtkvari, around the hot springs of sulfur, in present day Abanotubani. In the time of Vakhtang Gorgasali, there was a wall from the upper fortress to the river along the left bank of the Tsavkistskali, to the Mtkvari. The remnants of this wall are still preserved near the Pentecostal Church in Abanotubani. The ruins of a Roman-type bath were found there, dating to A.D.Y. By the 2nd century, the fortress "Sadilego" was built on the left bank of the river Mtkvari, on the Metekhi plateau, behind which there was a cemetery called Sogdebili (Sogdia was a functioning fortress in the middle of the IX century. From the XI century this part of Tbilisi is referred to as Isani) (Milashvili et al., 2017).

1. Selected valuable architectural objects of Old Tbilisi

The historical part of Old Tbilisi includes the districts and settlements that were called "Tbilissi" until 1936. Old Tbilisi includes the following districts: Abanotubani – Kharpukhi (or Tbilisi, later Seidabad), Kala, Isan – Avlabari, Sololaki, Mtatsminda, Vere, Ortachala, Chugureti, Didube, Nadzaladevi. This part of Tbilisi has been referred to as Isani for centuries.

In old Tbilisi you can find most of the sights of Tbilisi and, consequently, this is the main tourist attraction. This area is distinguished by Abanotubani – the sulfur baths that are still operating today. Also, there can be found churches and museums, and Sharden Street, where located are popular restaurants, open-air cafes and bars, nightclubs, galleries and much more. Another major charm of Old Tbilisi is the architecture – old shopping streets, wooden carved houses and balconies.

Old Tbilisi has been a candidate for UNESCO World Heritage Sites since 2007.

The city of Tbilisi belongs to the chronological group of the ancient cities of Georgia, which originated in the pre-feudal era and their development was consistent

with the development of the feudal era itself. At the same time, Tbilisi is specific in the sense that it was built from the beginning as a capital city and remained so throughout its history (Milashvili et al., 2017).

According to graphic sketches, Tbilisi has been famous since the middle of the 17th century. A panorama of the city in 1671 was painted by the traveling painter Grelo with the French traveler Jean Chardinhe, and followed by a sketch a belonging to Claude Aubrey, a companion of the French traveler and botanist Joseph Tournefort in 1701. The earliest appearance of Tbilisi can only be imagined from historical written sources and archeological excavations.

As known, old Tbilisi was formed over centuries and thus has common urban-building features characteristic of the cities built in the middle Ages.

Comparing the plan of the historical Tbilisi "Kalaubani", partly "Isani", with the medieval cities of other countries, similarities were revealed: in the density of the population, in the abundance and narrowness of the street networks, in the presence of regular and irregular cultivation, in the similarity of the religious buildings. At the same time, their distinctive features, including the artistic-compositional merits of the space, were clearly revealed (Fig. 1).

There were many foreign architects or engineers in Tbilisi in the 19th century, whose contribution to the development of the city's architecture is truly invaluable. The buildings built by European architects are scattered in the adjacent quarters along the main arteries on both banks of the Mtkvari – on the right, Shota Rustaveli (formerly Golovin) and on the left, Davit Agmashenebeli (formerly Mikhailov, later G. Plekhanov).

Fig. 1. View of Kalaubani of Old Tbilisi before reconstruction (*own photo*)

Today's buildings in "Kalaubani" are built on the foundations of old buildings, basements or underground floors. Because of this, the urban planning structure

largely replicates the urban planning structure of the late feudal era. The main feature of this structure is the network of streets in Kalaubani and Isani, which in most cases are identical to the earlier period.

What is peculiar about Tbilisi's urban planning structure and what is its consequences? As known, old Tbilisi was formed over centuries and thus it has common urban-building features and characteristics of cities formed in the Middle Ages.

The Old Tbilisi area, despite its impressive architecture, has changed significantly, as the density of the capital-city-wide Tbilisi urban structure has been altered due to the construction of the Metekhi Bridge in the 1950s. Unjustifiably, the Abo Bridge and a "donkey bridge" from the "Maedani" side were sacrificed for the construction of a new bridge and the development of the right bank of the Mtkvari in this area. Today, it is necessary to renovate the architectural space of this zone in the way that will allow us to identify the planning potential identified as a result of adapting the historic development plan to the modern development plan. The renovation program of Old Tbilisi from the very beginning envisaged the housing and infrastructural development of the most famous and tourist-friendly areas of Tbilisi through the joint efforts of the state, the population, the builders and the banking sector (Ezugbaia et al., 2018; Qvaraia, 2017).

One particular area of development was Ioane Petritsi Street Square, which was bound along one axis by the whole urban structure with its openings on Zion, Mamadaviti, and along the main axis by Sachino-Metekhi. It should also be noted that in the area of Rike, in addition to the bridge area, there was a market for goods, boxwood and hay.

When maintaining the identity of Old Tbilisi along with the development of the city, the most important issues are: How the city keeps its distinguishing features, how not to lose its charm and how it manages to be constantly interesting?

Tbilisi certainly has a special spirit, which can be found everywhere you walk in the old quarter – on the old balconies of old houses, narrow streets and yards. A very important part is the topography of the city, i.e. the ridges, lowlands, and hills on which the city of Tbilisi was built.

Today, many tourists visit Georgia. Their admiration does not go unnoticed – they enjoy the nature of Georgia, its villages and cities, they appreciate and love our capital Tbilisi with its old neighbourhoods, streets and alleys, Italian yards and architectural monuments, which are all certainly interesting for them (Milashvili et al., 2017).

2. The need to protect the architectural monuments of Old Tbilisi

Despite so much destruction and so much loss, there is still much to be saved.

It is necessary to maintain the contour of Old Tbilisi. It is unacceptable to demolish old houses because of negligence. There are houses where it is no longer possible to restore them and they need to be dismantled immediately. City transportation routes need to be completely changed and are changing, new drainage systems are being installed, which is important. The historical entrances have been restored, and

in the process of restoration, the paintings and historical inscriptions found on the entrances and facades have also been restored. In the particular, damaged yards, and glass windows were restored and the yards were improved. New grills were made on the houses. Fifty-seven historical buildings have been restored to their original form, of which thirty-eight are cultural heritage sites. The buildings were structurally strengthened, the facades of the buildings and the historical ornaments on them were restored to their original appearance. Old balconies, doors or gates have also been completely restored (Figs. 2 and 3).

Fig. 2. View of Abanotubani of Old Tbilisi after reconstruction (*own photo*)

Fig. 3. View Bread Square of the Old Tbilisi after reconstruction (*own photo*)

It is necessary to preserve an important part of the unique cultural heritage for future generations, we must preserve old Tbilisi perfectly, so as not to lose its uniqueness, because, as researchers say: "This will be a serious loss not for Tbilisi, but for the international community as a whole". This was recognised back in 2000, when UNESCO stated that Old Tbilisi is special and unique and that it is necessary to protect it. The restoration of the district should include the restoration of the historical urban plan that the site had. The main reasons for damage and deformation of building structures can be considered: The antiquity of the building, the wear of its construction materials, factors related to the foundations due to uneven ground, and in earlier periods, movement of foundations due to intense dehydration. The upper parts of the buildings show certain types of deformations, which manifest themselves as sloping cracks in the walls and deformation of doorways and windows all without the presence of seismic events.

3. Proposed solution to strengthen the foundations of historic buildings

The main construction material of the buildings in the old districts of Tbilisi is red brick. Walls are transversely and longitudinally located in the building, and their thickness varies from 250-800 mm. Brick walls can also be found which are over 800 mm thick. The foundations of the buildings are in most cases of the ribbon type, which is mainly arranged in rubble masonry, without armature. Floor and attic roofs are made of wood, and are made with double and multi-sided sloping sides, stairs are of wooden or metal anvils (Ezugbaia et al., 2018).

In most cases, the buildings need strengthening of the foundations, which looks like a dish-shaped foundation (inside the building), with pile foundations (Qvaraia, 2017; Javakhishvili, 2008).

The work is carried out on the basis of the existing construction norms and rules in Georgia. There are many ways to strengthen foundations. Rill-injection and pole-pile foundations, anchor pile foundations and also foundations of the hanging pile. Strengthening is mostly effective these days, because we know that reconstruction--reinforcement work is carried out in limited conditions of the work space and it does not require additional work. In particular: arranging the ramp needed to dismantle the foundation panels, part of the foundation pole and remove the soil (Fig. 4).

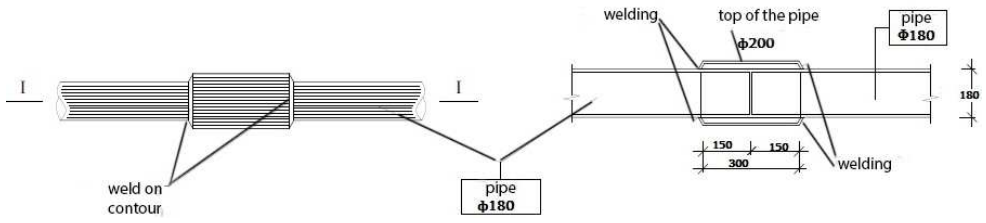

Fig. 4. Reinforcement of drill-injection pile foundations by means of injection pipe sections (*own study*)

Drill-injection and pole-pile foundations, anchor pile foundations and also foundations of the hanging pile are used both inside the basement and outside the building and also in open deep trenches. Its arrangement in the basement floor area is as follows: The height of the basement floor should be not less than 2.00 meters, if this is the case, then this height will be achieved by digging out additional soil (Qvaraia, 2017; Javakhishvili, 2008; Chincharauli, 2018).

The work is mainly done with the following machines: ЭОТНС-VS and НКР-100. The estimated diameters of the drill is taken to be 75; 105; 130; 160 mm; up to 200 mm. This drill is preferred because it is compact and can move freely even under limiting conditions. Drilling is carried out by cutting 1.00-1.50 meter sections, and not more than 2 meter sections: In order not to break the walls of the well, it is necessary to drill it with a drill that has a diameter of more than 30-40 mm, possibly in stages due to the passage through of lithologically different layers. Cement (sulfate-resistant Portland Cement B35) concrete solution should be applied, after further drilling, 12-24 hours before the cement solution is poured into the well, a tampon (so-called stopper) and the solution is supplied at a pressure of 0.2-0.9 atmospheres to 4 atmospheres, only after which the secondary drilling takes place. The tampon in addition to the cement solution may be made of ordinary rubber (Javakhishvili, 2008).

The pole-pile foundation solution for injection oriented expenditure after hardening (with a pressure up to 0.2-0.6 atmospheres, in some cases 2-4 atmospheres) must be not less than 1.25 well volume for dense soils; not more than 2.5 volumes for highly compacted soils (turbulence produces up to 4-6 atmospheres); average volume for compacted soils of 1.9 volume (compression pressure value should be within 4 atmospheres). In clay soils, in the absence of groundwater, in most cases the well should be treated without reinforcing its walls, unless other solutions are available. In sandy, as well as loamy soils, which are located below groundwater, drilling of wells should be performed with a drilling rig, using inventory perimeter pipes. If such a device is not available, the walls of the well should be fixed with a solution of clay, excessively pressurized water, or using a solution of cement (mortar) of a certain consistency w/c = 1/2.

Once the well is ready, a reinforcement frame with longitudinal rods diameter 3Φ20A500C, or 3Φ18A500C, 3Φ22A500C will be installed in it, which are welded to each other, with the installation of a special stem Φ = 20 mm (Fig. 5).

Fig. 5. The developing fixator (*own study*)

The frame also has side fixators. The frames are made in sections and welded to each other (by adding welding lengths) the armature of the last section the length will be 1.0 m longer so that they can be further used to embed the beams in the structures of dish-shaped foundation or in the perimeter girder.

After installation of the reinforcement frame, cement mortar will be poured into the well using sulphate-resistant Portland cement (B 35). The well is filled with a little pressure using the supply tube, arranging a tampon on top of it. Concrete is delivered (0.2-0.6 atm) under pressure (Fig. 6).

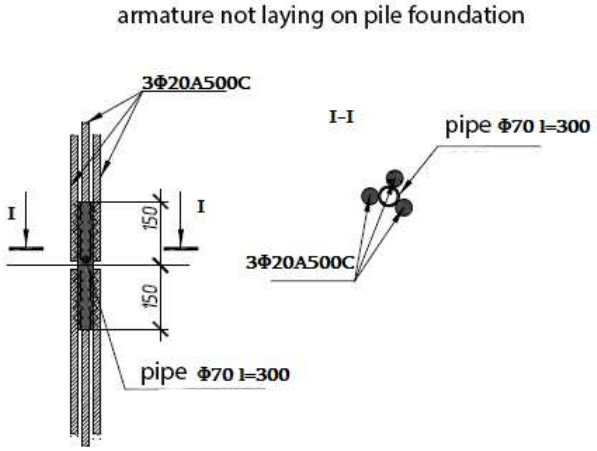

Fig. 6. Drill-injection pile foundation construction drilling the well is further done by dropping the reinforcement into the well and filling it with cement mortar (solution) (*own study*)

Control pile foundations (1 piece for every 20 pile foundations). After implementation, make corrections in the draft field arrangement project based on the relevant conclusion-recommendations, which are developed by a team of engineers, geologists and builders, by making a sketch drawing of the construction solution, according to which the pile foundations field will be corrected, because during the drilling process unforeseen circumstances are expected to occur, such as: existence of different types of formations in the base-soils: conglomerates, empty space, grooves (Kavernes), underground sources, etc. The presence of old unconditioned structures on the sides of the building is also not ruled out (Ezugbaia et al., 2018).

There are many cases during the arrangement of pile foundations, when borehole drilling takes place in a loose soil environment – a layer of naturally occurring sand-gravel, or a conglomerate with brittle cemented limestone and cobblestones or an artificial base with a sand-gravel pad. Then it is advisable to use a perimeter pipe to a certain depth, which is dropped into the well at a pressure of 2-4 meters on average. If such rock is deeply located beyond its length, we have to pour and drill concrete many times. If the rocky top soils reaches to a certain depth we will have to pour in concrete several times.

Conclusions

After the restoration and renovation of Tbilisi, the goal was achieved – the appearance of Tbilisi has been so far drastically preserved. Although many things have changed, many things are still to be changed. However, one thing is certain – Old Tbilisi still attracts visitors because it has not lost the identity that is so necessary for the city's own residents.

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