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Inspection of an Underground Shollar Drinking Water Reservoir and Strengthening of a Design Taking into Account Square Ecology

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Abstract: Historic facts of design and construction of the region's first industrial tank for drinking water are given in article. For strengthening of a design use of carbon fiber tape and laminating superficial fittings on an epoxy basis was offered. Models of the walls strengthened by carbon fiber fittings were tested for tension and a bend. As a result of test linear deformations under loading are also defined necessary mechanical characteristics of composite material - the elasticity module, Poisson's coefficient, the tension resistance, a support angle of rotation during a bend. The tests are conducts in the experimental polygon of the Construction materials research institute.

Key words: drinking water reservoir, strengthening, carbon plastic, tension

1. Historical Information

Showing pride for each Azerbaijanian the first hydraulic engineering construction it has been designed and constructed according to all requirements of hydraulic construction of that time more than 100 years ago. And today this creation of an engineering thought serves people. Construction of this construction is connected with a name of two outstanding persons - the patron of the Azerbaijani people Hadji Zeynalabdin Tagiyev and the English scientist, the engineer hydraulic engineering of Sir William Heerlen Lindley (figure 1). The famous engineer in the memoirs wrote "... *only in Western Europe by me it has been designed and constructed in 35 cities of various water and sewer constructions. I never had such project difficult technically*".

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Figure 1. H.Z.Tagiev and Sir W.H.Lindley

In 1859 in Shemakha there is a destructive earthquake and the provincial center moves from Shemakha to Baku. At this time because of an oil boom in Baku a large number of the population moves. First of all there was a problem of providing the population of the city with drinking water. Shollar is the first built water canal of drinking water on Apsheron the peninsula. The project of the English engineer William Lindley has appeared at the beginning of 20 centuries. With direct support of the patron Hadji Zeynalabdin Tagiyev it constructions of already 100 years provides the population of Baku and Apsheron with drinking water. In 1889 after signing of the contract design of the drink water channel and an underground reservoir has begun. In 1911 construction in Baku has begun. In 1917 in Baku the line of drinking water Shollar has been started. On the project length of the water channel is 170 km. Construction Shollar of a water supply system has begun in 1903. The beginning of World War I has stretched construction terms. Even works have been suspended. Because of the compelled breaks in construction the population of Baku has got access to water only 14 years later only in 1917. In Soviet period 1928-1950 four more reservoirs in this territory have been constructed. Construction of a reservoir in Baku was a big event. This construction in the form of a sarcophagus the area 60×60 m and 6 m in depth entirely from concrete without use of reinforcement (Figure 2). It is courage of the English engineer! He has achieved that his concrete construction working for compression was capable to resist without destruction to flexural deformations. Operating since 1917 this construction on average has productivity of 1200-1300 liters of water a second. The site is chosen not incidentally. At that time it were suburbs of Baku. Considering strategic purpose of an object it has been chosen not far from military barracks and was constantly protected until recently. When that here a stone pit that has given confidence in stability of the basis.

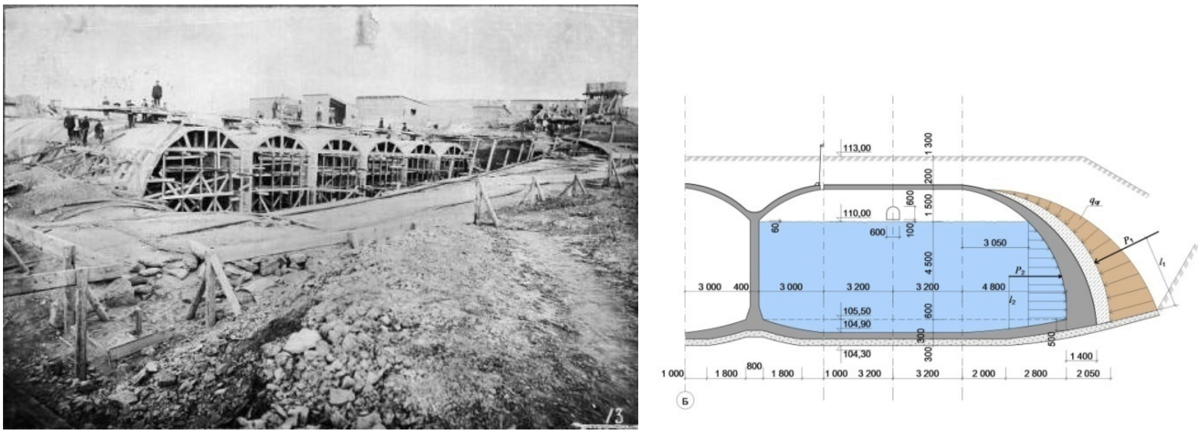

Figure 2. Construction and cross-section of structure

Studying old drawings of 1912 and visually surveying a construction the following shortcomings have been revealed:

• On the project soil thickness over a construction 0.6m, on the place changes in predelakh1.5-2.0m today. It is additional load of a construction. Besides everyday watering of plantings in a garden harms a construction. As the drainage system and a waterproofing aren't provided. It leads to a construction emergency;

• Internal plaster of a reservoir is destroyed. Chlorine and other chemical additives in water do harm to quality of concrete;

• The design of a reservoir transmits the top loading through concrete arches to cross walls of a construction. Traces of chalk and calcium on support of an arch testify to insufficiency of a waterproofing of a construction.

Multiple cracks on walls of a construction promoted introduction of water in thicknesses of concrete and to change quality of material of a construction (Figure 3). And it in turn does harm to stability of all design. Cracks in the basis at the bottom of a reservoir promote leak of drinking water under the base of a construction. It leads to an emergency of a construction and destruction of the general hydrological and hydro geological structure of the environment. Such leak of water within 100 years has led to weakening of the soil basis under a construction. The reservoir constructed by a row later in 1928 has other constructive scheme. Small caps reinforced concrete columns under the influence of vertical loading and constant humidity on the verge of total loss of stability and durability.

a *b*

Figure 3. Internal view of first - a (1911-1917) and second -b (1928-1932) reservoir structure.

The being nearby artificial lake has played the negative role in this case too (Figure 4).

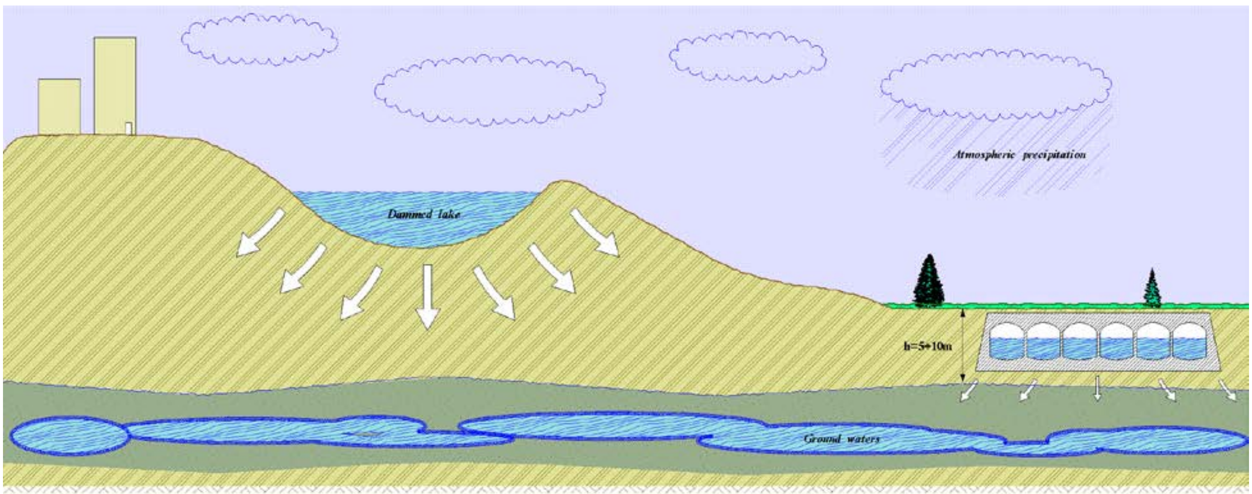

Figure 4. Lake above reservoir structure

Near a reservoir on a sublime part the artificial lake is located (figure 4). For years of water of this lake flow down to surrounding regions that specialists in water problems, a hydra of geologists and hydraulic engineering constructions don't remain unattended. Thus, waters from the lake connecting to the atmospheric precipitation and waters followed from a reservoir create at a depth 5-10m a sheet of water. In 100 years this water layer promoted a full ground liquefaction under a construction. It and so considered seismic active area the Apsheron region promotes accumulation of seismic energy in this environment. Because in weak and the liquefaction soil the speed of a seismic wave decreases and it promotes a congestion of seismic energy that can lead to destruction.

2. Inspection of a Design

After visual inspection in a reservoir nondestructive methods assessment and capture of cores from concrete have been conducted. Considering aggression of the environment in a construction the author has decided not to use metal reinforcement. During more than 100 years concrete has gained high durability. According to today's standards concrete corresponds to the class B30. Design of a construction in the form of a sarcophagus promoted not emergence of the tension loadings and a design completely worked for compression. Face walls of a construction have been designed at an angle 45^0 and it promoted an equilibration of soil pressure internal hydrostatic pressure. From outside wall of a construction of a reservoir have been protected 1.5m by a layer a clay waterproofing. During nondestructive control Schmidt's hammer test, ferroscan, georadar installation, the device for capture of a core from concrete walls have been used. Besides around a construction engineering-geological surveying works have been carried out. At a depth of 10 m holes have been drilled. At a depth of 3-7 m the water layer is found. It was confirmed also on schemes of the georadar (figure 5).

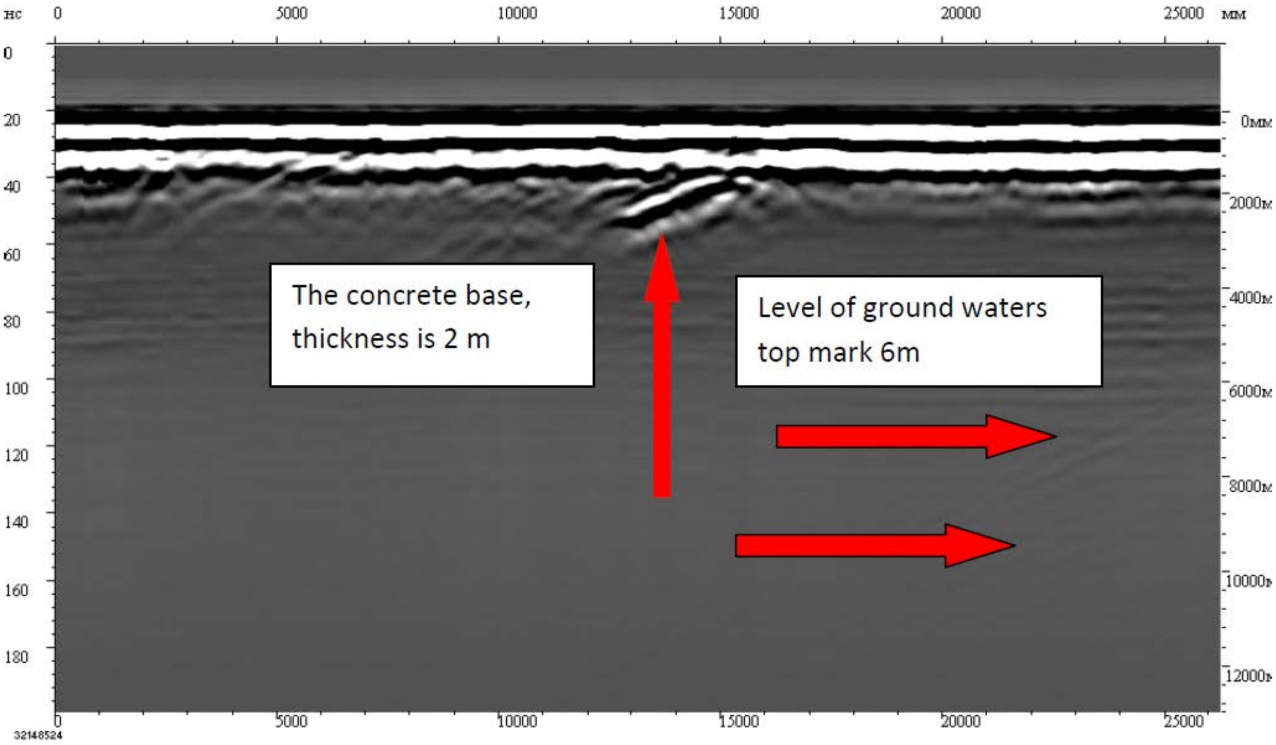

Figure 5. Georadar scheme

Later in the 1930-50th years construction of four more underground reservoirs has shown a serious hydro geological condition. Inspection of other four objects and the environment has confirmed accident rate of a situation.

3. Strengthening of a Design

For the analysis of the operating loads of a construction was the three-dimensional model of a construction is collected on the computer (Figure 6).

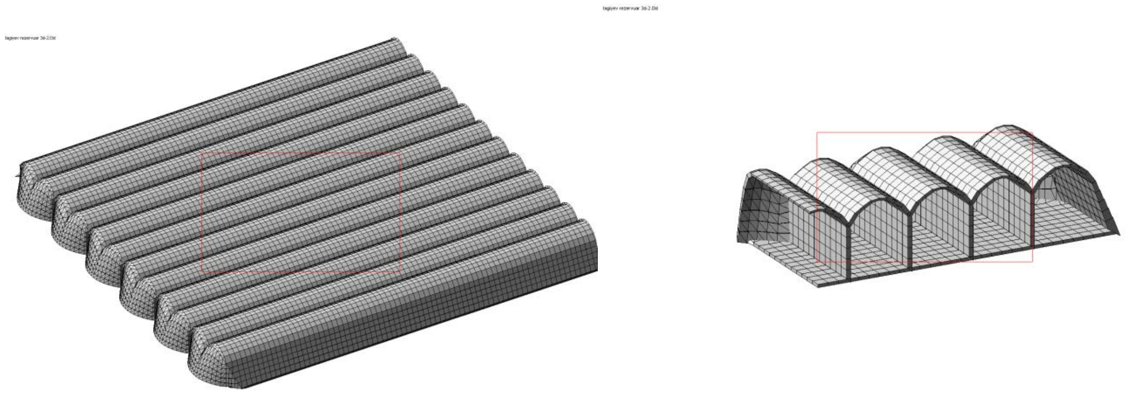

Figure 6. 3-D scheme of the reservoir structure

Vertical loading, horizontal seismic loading, temporary hydrostatic loading affect a design and other loadings have shown weak stability of average walls (thickness of 40 cm). To it the reason weak rigidity of these walls and lack of reinforcement with concrete (Figure 7).

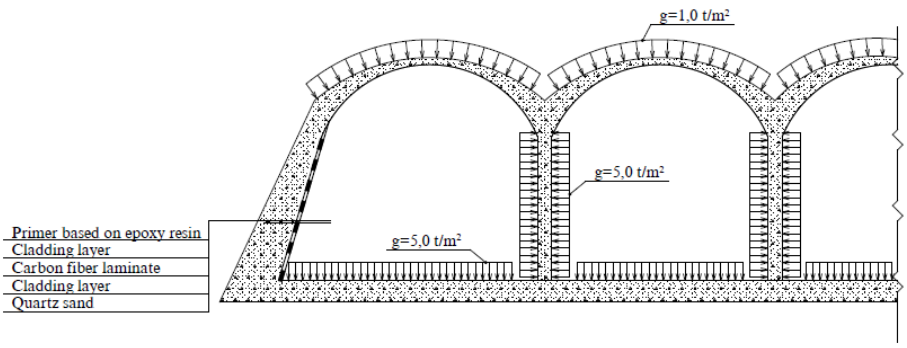

Figure 7. Cross-section of the structure with loading

From this point of view, that is for increase to resistance to tension and providing an internal waterproofing of a construction it has been decided to reinforce a construction completely external carbon fiber tape and laminating strips from within and then to cover shut-cup concrete.

4. Test of a Water Tightness

On the ground of institute tests of the samples protected by a carbon fiber tape on the water resistance (humidity), water tightness and frost resistance have been carried out. As carbon fiber material the material Magnal Laboratory for Concrete Research Institute (Belgium) was used. Epoxy of the CCS EP Grout brand. Tests were carried out on concrete cubes by the size 150×150×150 of mm and cylinders the mm size 150×150. The used concrete for samples corresponded to durability to the class B15, frost resistance of the class F300 and water tightness of the class W6.

Figure 8. Isolation and preparation of concrete samples with a carbon fiber holder to test.

Tests of water resistance of concrete were carried out on the basis of the state standard specification 12730.2-78 [6] Interstate standard. Humidity of samples (W_n) was calculated about an error to 0.1%: $W_n = \frac{m_b - m_c}{m_c} \times 100$. Here m_b - the mass of a sample before drying process., qr; m_c - the mass of a sample after drying, qr. Volume humidity of concrete (W_0) is calculated with a margin error to 0.1%: $W_0 = \frac{W_n \times \rho_0}{\rho_w}$. Here ρ_0 - concrete density; ρ_w - water density, ρ_w =1g/cm^3.

Samples of concrete are dried up to the temperature of 60^{0}C. Concrete samples before obtaining stable weight contain in a drying cabinet. After drying the stable weight of samples is defined. Average humidity of control concrete samples of $W_{ort}=2.7$ % is defined. Average humidity of samples with a carbon fiber holder has made $W_{ort}=0.3\%$. Here the difference of the relation of average strength to control samples makes 1.2%. Here the relation of average humidity will make. $n = \frac{W_{ort}^{k}}{W_{ort}^{kl}} = \frac{2.7\%}{0.3\%} = 9$. That is, water tightness of samples with a carbon fiber holder by 9 times are steadier usual samples. The water tightness of concrete samples was defined on the basis of the state standard specification 12730.5-84 [6] Interstate standard. For test concrete samples of a cylindrical form have been made. The sizes - diameter are 150 mm, height is 150 mm. Concrete samples of the class B15 (6 pieces) and concrete samples with a single-layer carbon fiber holder in the bottom of a sample (6 pieces). Sticker of samples it was made by epoxy from 1-1.5 cm release from edges. Tests of water tightness were carried out at the specially stand UVF-6/04 No. 195. Cylindrical samples were established in special nests. The free space was filled with paraffin for sealing. Water pressure in the device increased every 16 hours by 2 atm. Tests have begun with a pressure of 2 atm. The maximum pressure which was sustained by samples was 14 atm. On norms the indicator of water tightness corresponded to the class W14. At achievement of pressure of 16 atm. water tightness has been broken and test is suspended. Therefore water tightness of the samples protected below by a single-layer carbon fiber tape has been accepted the class W14. Durability on compression of the images which have passed on water tightness has yielded the following results: 21.5MPa; 15.0MPa; 16.0MPa; 17.2MPa; 19.7MPa; 16.8MPa. These results correspond to class B20 concrete.

5. Frost Resistance Study

The samples enveloped by a carbon fiber tape (cubes 150×150×150мм) were tested on frost resistance according to the state standard specification 10060.0-95 [5]. Interstate standard. Beforehand samples to keep in water of 1/3 in depth from sample height within 24 hours. The cycle of freezing and defrosting was selected by 25. One cycle makes: 4 hours samples to contain in the freezer (t = - 20^0C). Then 2 hours in water at a temperature (t = + 20^0C). After that samples are again placed in the freezer for 4 hours at a temperature (t = - 20^0C). Samples to contain 24 days in the freezer CONTROLS 10-D 1429 (fig. 17). In the freezer samples are frozen t = - 20^0C and are located in a trough at a temperature + 200C for defrosting. It is the camera volume $5m^3$ and samples in the camera were exposed 4 hours to freezing. Then 2 hours samples for typing of durability were left and prepared for test of durability for compression. Tests of durability for compression of samples after frost resistance test the following: 18.4; 17.5; 15.5; 13.1; 19.2; 11.5 MPa. Average durability is 15.9 MPa. Change of durability makes 10.2%. It corresponds to a class on frost resistance of F25. According to the standard the allowed frost resistance to 15%.

6. Tests of Mechanical Characteristics

For modeling of an average wall of a reservoir models by the size 1×0.25×0.1m have been made of class B10 concrete. For test of models on stretching and a bend previously samples became covered with brand epoxy *CCS EP Grout*. Both carbon fiber tapes and laminating strips were made at the Belgian institute *MAGNEL LABORATORY FOR CONCRETE RESEARCH* [4]. Tests were carried out in the proving ground of research and design institute after named S.A. Dadashev. The tension loading it was transferred by an interval 0.5tq (5kN). On model two electronic sensors for deformation measurement have been established. For composite material have been defined by these sensors relative lengthening ε_1 and relative narrowing ε_2 a sample. It has allowed to determine Poisson's coefficient for composite material $\mu = \frac{\varepsilon_1}{\varepsilon_2}$ (3.1). Knowing the destroying stretching loadingit is possible to define strength: $\sigma_B = \frac{P}{A}$ (3.2).

a) *b)*

Figure 9. Test of composite samples concrete + carbon fiber on tension (*a*) and a bend (*b*).

Results of test - the maximum stretching load changes in the range of 17-30 tq, Poisson's number 0.175-0.409, and strength on tension $\boldsymbol{\sigma_B = \frac{P}{A}}$, changes in an interval of 0.68-1.2 kN/cm^2. At test loading was transferred to a bend by an interval 1tq. After installation of a sample at the stand for distribution of vertical loading on width (*L/3* where *L*-span between supports) the plate by the size 30×30sm and 1 cm thick on the rolling supports has been established. This scheme is widely used for definition of the tension loading at a bending. During test the maximum deformation of a sample has been measured. For exact measurement electronic sensors have been placed in three points. In the middle of a sample to the maximum point of deformation a sensor I_1, and in two support I_2 and I_3. From here it is possible to define average deformation (V_k).

$$V_K = \Delta_1 - \frac{1}{2}(\Delta_2 + \Delta_3)\ .$$

Here Δ_1, Δ_2 and Δ_3 the measured indicators of deformations in support and in the middle of a sample.

7. Conclusion

1. Results of pilot studies have shown high crack resistance of the concrete samples strengthened by surface carbon fiber. Resistance to tension has increased at 8-10 times, and rigidity by 2-3 times. It has in turn increased stability of a construction twice;

2. The analysis of results allows to claim that strengthening of composite materials, reinforced concrete designs, stone constructions perhaps only on the basis of the executed pilot studies;

3. Carbon fiber tapes and laminates are preferable to strengthening of walls, columns for increase in crack resistance. Especially in reinforced concrete structures where it is necessary to increase the tension resistance;

4. In the solution of such complex engineering problems to be based on theoretical justifications not enough. It is necessary to conduct pilot model studies. It though is difficult, but only the correct way. Therefore the received results can be applied at restoration of not reinforced concrete underground reservoir constructed 100 years ago. That is to strengthen this construction by means of carbon fiber tapes and the laminate of strips;

5. Advantage of this method of strengthening without breaking structure of an element, by means of additional superficial elements to achieve strengthening of a design;

6. These pilot studies give the chance in similar engineering problems, during the strengthening and restoration of ancient constructions to apply these means of strengthening of a design to reduction of risk of seismic destruction;

7. This method of strengthening considered in article can be applied not only at restoration old constructions, but also modern underground constructions. Tests of control concrete samples and samples with a carbon fiber covering on water absorption, a water tightness and frost resistance have shown the following results: *a)* Water resistance of the concrete samples covered with a carbon fiber tape have water resistance in 9 times more; *b)* Water tightness of control concrete samples hasn't sustained pressure of 4 atm and on humidity corresponded to a class W2. The samples which are wrapped up by a carbon fiber holder were subject to pressure to 16 atm and on humidity corresponded to the class W14; *c)* On frost resistance samples with a carbon fiber holder can be carried to the class F25.

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