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GEODETIC MONITORING OF THE ARMENIAN NUCLEAR POWER PLANT MAJOR STRUCTURES VERTICAL DISPLACEMENTS

The geodetic monitoring of deformations is an integral part of the system of technical control over the operation of buildings and engineering structures. The technology of geodetic control over settling of structures and their foundations consists of three main processes:

1. The design of control includes: selection of objects, geometric parameters, the development of methods of control, designing survey markers, leveling schemes, the calculation precision of leveling, purpose and methods of measuring the settling, development of methods of processing the results of measurements and forms of reporting documentation.
2. The carrying out monitoring of deformations at the site includes: fabrication and installation of survey markers, personnel training, equipment and devices, development of safety regulations; taking measurements.
3. The processing and analysis of measurement includes: checking and processing documentation, adjustment, calculating the settling and deformation; interpretation of the results [1].

The Armenian Nuclear Power Plant was built during the Soviet era in the Armenian Soviet Socialist Republic, near the town of Metsamor. It consists of two power units with WWER-440 (Water-moderated Water-cooled Energetic Reactor). [1] The information about the Armenian NPP units is presented in Table 1.

TABLE 1

The information about the Armenian NPP units

Power block	Reactor types	Power		The date of the beginning of construction	Commissioning	Closing
		Net [MW]	Gross [MW]			
Armenian-1	WWER-440/270	376	408	01.07.1969	06.10.1977	25.02.1989
Armenian-2	WWER-440/270	375	408	01.07.1975	03.05.1980	2016 (planned)

In Figure 1 are shown the quantitative data of some nuclear power plants that use the WWER-440 as well.

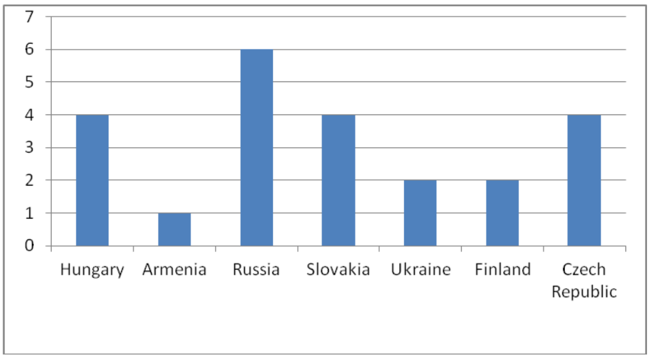

Fig. 1. Number of power units with WWER-440

The heat capacity of the Armenian nuclear power plant is 1375 MW per unit and the power capacity - 440 MW.

On December 7, 1988 at 11:41 local time the Spitak Earthquake occurred in the northern region of Armenia, measuring more than 7 points (MSK-64) and taking at least 25,000 lives. During the earthquake the nuclear power plant equipment as well as the buildings and structures withstood the severe shock. The plant was designed for an earthquake of 9.5 on the Richter scale, which provided the durability of buildings and structures and hydraulic shock absorbers, which in case of an earthquake rigidly connected with the seismic foundation (monolithic slab) and equipment, not allowing the latter to move under the influence of shocks and inertia forces. However, the Council of Ministers of the USSR and the Council of Ministers of the Armenian SSR made the decision to stop the Armenian Nuclear Power Plant due to the high risk of its operation work in a seismically unstable area and the likelihood of aftershocks. Prior to this stop ANPP developed 48,446 million kWh of electricity. After stopping the ANPP unit № 1 became worthless. The equipment of NNP units was partially dismantled and sold.

However, in the future, taking into consideration the power economy situation, the blockade of transport communications and the lack of domestic energy resources, on April 7, 1993 the Government of the independent Republic of Armenia issued the decision: “On the beginning of rehabilitation and start of operation of the second unit of the Armenian Nuclear Power Plant.” On November 5, 1995 the 2nd unit of ANPP was launched, it had been closed down for six and a half years.

The ANPP produces an average of 30÷40% of the electricity produced in Armenia nowadays. According to experts, the station can safely operate until 2016 [2]. Geodetic observations of settlings of nuclear facilities of Armenian Power Station were started in 1976. The base height survey network of nuclear power plant consists of five contiguous polygons of 1st class leveling (Fig. 2), covering all structures being under observation. The total number of the established settling marks on structures of nuclear power plant is 289 pieces. To monitor the stability of reference height and deep benchmarks in 1975 on firm ground was laid a bloc of benchmarks, consisting of three benchmarks K-1, K-2 and K-3. In 1993 the benchmark K-3 was destroyed, therefore to carry out further observations two initial benchmarks K-1 and K-2 were used. Changes in their height marks from the beginning of the observations (1975) occurred within the accuracy of their determination (+0.6 mm), that's why they could serve as a solid basis for further verification of the stability of the supporting height survey network.

Due to the fact that the base height network compared with the previous period of observation cycles performed in 1993 and 2002-2003 has undergone significant changes, some benchmarks were also destroyed, a new program has been drawn up to observe the initial benchmarks which ensured the accuracy of observing settling marks on structures.

The reference marks of base height network and observed marks on structures are defined with precision leveling of the 1st class. The leveling was done in both forward and reverse direction with precision leveling instrument NA-3003 of a Swiss company "Leica" with allowable mean quadratic error at the station no more than $m_{cm} = 0.13\,\text{mm}$ [3].

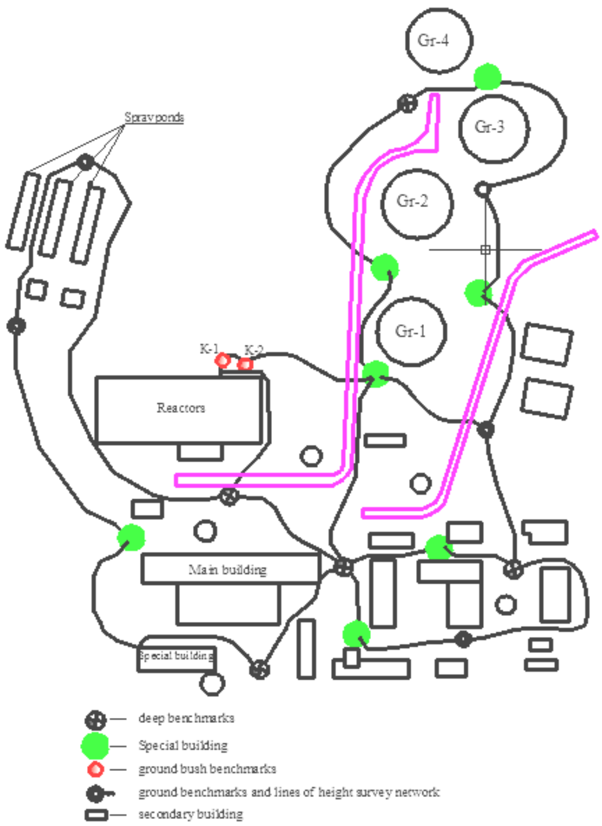

Fig. 2. The scheme of structures and height network of ANPP

The error in determining of settling reference benchmarks of base height network in relation to the bloc of ground reference benchmarks does not exceed ±0.60 mm, and for marks on the structures of 1st class, as we know, is ±1,0 mm.

Observations of the deep benchmarks have been conducted since 1981. Over the past 6 years, the deep benchmark number 6 gave the settling of 1.1 mm and 3.4 mm. The rest of the deep benchmarks have changed their position within the height accuracy of settling, i.e. elevation of these benchmarks is stable [4].

The results of observations of ground benchmarks have shown that, despite the fact that the ground benchmark number 33 from the beginning of the observations made in the settling of 17.2 mm, in the last 18 years the vertical displacement of this benchmark is not observed (total -0.6 mm).

Observations of settling of load-bearing columns of the main building of nuclear power plant have been carried out from March 1981. Prior to that, observations were carried out for the marks placed on the outside wall of the main building with tufa lining, so the change in height of the provisions of these marks reflected the deformation of tufa lining, not the state of bases of walls of the main building.

From 1981 to December 2002 there were 26 cycles of observations, of which 25 - up to November 1993.

From December 1981 to November 2009, for 28 years, the settling marks of the outer walls of the main corps have changed their position with height from -3.2 mm to +3.5 mm, and supporting columns - to 8.9 mm. The main part of the settlings was observed during the first phase of observations, that is, until 1993 [4].

Settling marks set on the outside tufa lining walls of a special corps, in the period from March 1977 to November 2009, gave the settling from 3.8 mm to 9.1 mm. The main part of the settling falls on the period before 1993 (-3.6 … -8.0 mm).

Over the last 18 years on the settling marks in the walls of special building were seen settlings from 0.4 to 2.4 mm.

To obtain reliable data were carried out two cycles of measurings one after another. Later on, before November 1988, were annually held two measurings and extra one - after the earthquake in December 1988.

Only on the first stage of the research 12 repeated measurements were carried out , the following measurement cycle was conducted in December 1993.

According to the results of 13 cycles of measurements made prior to December of 1993, settling marks on the walls of the turbogenerator corps are from -3.1 mm to -8.3 mm, and on the first phase of observations, i.e. from the beginning of observations till November of 1988 they made up to 1÷2 mm, the major settlings occurred prior to the year of 1993. This is due to the fact that during the previous cycles of measurment there was a strong vibration of the site, where the level was set, despite the fact that under the tripod legs of leveling a felt litter was spread in order to reduce the influence of vibration [5].

The last cycle of observations was carried out in December of 2009. In the period between cycles of measurements, i. e.during the period of 7 years settling marks on the walls of turbo-generator corps gave heaves:

- on the walls of the turbogenerator № 1 -3.0 … -7.2 mm;

- on the walls of the turbogenerator № 2 -3.0 … -6.2 mm;
- on the walls of the turbogenerator № 3 -3.0 … -7.6 mm;
- on the walls of the turbogenerator № 4 -0.7 … -2.4 mm.

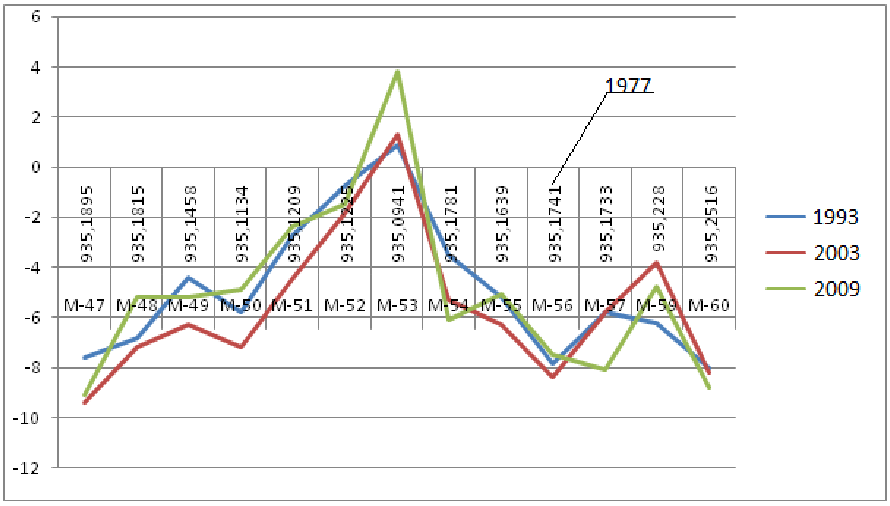

Fig. 3. Observation chart of settling marks outside the walls of special building

However, taking into consideration the long period between cycles (18 years), we can conclude that after 1993, on the walls of turbo-generator corps no settling is observed, and a slight growth in their size on the walls of the turbogenerators № 1, № 2 and № 3 should be considered as a consequence of vibration of the site.

The observations of the vertical displacements of the marks in the walls of the hardware department began on June 24, 1986, during the operation of the reactors at the suggestion of plant management. The following 2 cycles of observations were carried out during the shutdown of reactors on September 26 and 29, 1986 for getting the most reliable information and the possibility of their use in the future as a source for the following cycles. The following measurements were carried out during the operation of the reactors, except from the last cycle of observation, which was also implemented in the hardware department at the time of shutting down of the reactor [4].

Analyzing the results of the first monitoring period (1986-1993), it can be concluded that settlings of installed marks in the hardware department walls are within the accuracy of their determination. However, these same marks over the past 10 years have given relatively less settling than on the first stage of the research, i.e. from +0.8 mm to -2.4 mm, with the exception of mark M-515, which gave a settling of 16.8 mm. Taking into consideration that the indicated regime in the research has been broken (instead of 5 years, research has been carried out 10 years later), it is impossible to determine during what period of time this setttling has taken place.

From December 1993 to December 2002 was performed the monitoring of settling marks on the walls of cooling towers. For 10 years, the three marks of tower N1 has given settlings -2.2 mm, -11.7 mm and -15.2 mm, respectively. The remaining settling marks in the same period have changed their height position within the accuracy of their determination. Installed at the site of location of the above mentioned marks the deep benchmark number 2 in the same period changed its height position accordingly from -4.8 mm to -42.6 mm [4]. Such sizes of the displacements, possibly, could be obtained due to the fact that in this area, you may have a water filtration.

In the program of observations in 2009 were also included observations of settlings of 8 marks on the walls of the storage of spent nuclear fuel and 4 marks in the pump house. As in previous cycles, these settling marks were not included in the program of observations, so the obtained height will be the initial one. Settling marks on these structures will be determined during subsequent cycles of observation.

On the proposal of the Armenian nuclear power plant management, supervision over tower structures, including the vent pipe and 4 towers began in December 1984. Prior to December 1993 were conducted 11 cycles of observation. According to the results of previous observations, the deviation of the planned tower structures including the vent pipe (-8.9 cm) was within acceptable tolerance [5].

Thus, as a result of geodetic monitoring of the settlings of structures of NPP in Armenia the following conclusion can be drawn.

1. With regard to the criteria of structures stability within 1 mm (per year), all the deep benchmarks are in stable condition, but, taking into consideration the systematic settling of the deep benchmark number 2 from the beginning of the observations, we can assume that the settling of this benchmark continues.
2. The results of observations of ground benchmarks have shown that, despite the fact that the ground benchmark number 33 from the beginning of the observation made settling of -17.2 mm, over the past 18 years the settling of this benchmark is not observed (in all -0.6 mm).
3. Foundation walls of the main building of nuclear power plant are in a stable condition.
4. Basically, the settlings in structures occurred in the first stage of observations - till 1993. After that, things have stabilized, although in some structures still there is a slight settling and displacement, among them - the main corps, turbogenerator number 1, 2 and 3, the hardware department and the cooling tower number 1.
5. Based on the results of the observations of the last cycle, we recommend observing the displacements of nuclear power plant to produce in terms of guidance, that is, with an interval of 5 years. This will allow to get the full impact of the condition of structures in Armenian NPP.

References

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Abstract

Geodetic monitoring is an integral part of the technical control system over operation of works, building structures, constructions and process equipment of industrial enterprises and civil facilities. One of the most important factors of failure-free operation of nuclear power plants is the proper organization and implementation of measures for the technical operation of its buildings, structures and equipment. The problem of increasing the reliability and service life of structures of nuclear power plants is an urgent economic task, as the efficiency of its solutions arising from measures to prevent failures and accidents is beyond any doubt.

The paper on the basis of geodetic measurements processing presents material on one of the most important types of geodetic monintoring - control over settling of foundations of the main structures of the nuclear power plant in the Republic of Armenia.

Monitoring geodezyjny głównych pionowych przemieszczeń konstrukcji ormiańskiej elektrowni jądrowej

Streszczenie

Monitoring geodezyjny jest integralną częścią systemu kontroli technicznej w trakcie prowadzenia robót budowlanych oraz eksploatacji konstrukcji i urządzeń procesowych przedsiębiorstw przemysłowych i obiektów cywilnych. Jednym z najważniejszych czynników bezawaryjnej eksploatacji elektrowni jądrowych jest właściwa organizacja i realizacja działań w zakresie eksploatacji technicznej budynków, budowli i urządzeń. Problem zwiększenia niezawodności i żywotności konstrukcji elektrowni jądrowych jest pilnym zadaniem gospodarczym, tak jak wydajność rozwiązań wynikających ze środków zapobiegania awariom i wypadkom nie ulega wątpliwości. W pracy, na podstawie opracowanych pomiarów geodezyjnych, przedstawiono materiały dotyczące najważniejszego monitoringu geodezyjnego - kontroli osiadania fundamentów głównych konstrukcji elektrowni jądrowej w Republice Armenii.