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# Features of determining the concrete structures strength at dangerous production objects by means of non-destructive control

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# Features of determining the concrete structures strength at dangerous production objects by means of non-destructive control

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**Abstract.** The article deals with the assessment of reinforced concrete structures of a hazardous production facility, namely, the localizing facility of a nuclear power plant during the construction. The analysis of the methods applicability for determining the strength of concrete for this type of structures.

## Introduction

Technical facilities, during the operation of which, under appropriate circumstances, damage to humans and the environment can be caused, are the hazardous production facilities (HPF). These facilities certainly include nuclear power facilities (NPF): structures and complexes with nuclear reactors; structures and complexes with industrial, experimental and research nuclear reactors, critical and subcritical nuclear stands, structures and complexes with industrial, experimental and research nuclear reactors, critical and subcritical nuclear stands; structures, complexes, landfills, installations and devices with nuclear charges for use in both peaceful and military purposes and other containing nuclear materials; structures, complexes for the production, use, processing, transportation of nuclear fuel and nuclear materials.

The main objective of ensuring safety during the operation of nuclear facilities is the adoption of effective measures aimed at preventing severe emergencies. The most important function in case of unfavorable development of events is to consider the localization and retention of radioactive substances within the zone of the accident localization. Evaluation of such reinforced concrete structures is carried out in order to determine their current technical condition under the implemented operating conditions, the devices parameters ensuring their safe operation and environmental protection [1, 2, 3].

## Materials and Methods

During the construction of the localizing facilities (LF), the examination is carried out by implementing instrumental control according to the approved program. The strength of concrete, the thickness of the protective layer of a reinforcement structure and the parameters of cracks are determined by non-destructive testing [4, 5, 6, 7]. The geometric parameters of the LF are determined after the installation of a circular crane on the crane runway. The ellipticity of the track to the installation of the LF dome facing, after the installation of the dome, during the running-in of the crane and during its testing [8, 9] is estimated. According to the Federal norms and rules in the field of industrial safety “The main requirements for conducting non-destructive testing of technical devices, buildings and structures at hazardous production facilities” methods, technologies, volumes, consistency and means of non-destructive testing should be selected based on the conditions for obtaining reliable results and applying the most effective methods for detecting unacceptable deviations (defects, inconsistencies) in each case.

In the course of the visual inspection of the shell, visible defects and deformations of the building structures of LF are revealed; that can reduce the bearing capacity and durability, in particular the presence of horizontal and vertical cracks; sites with large sinks, large-pore concrete; places with poor compaction of concrete; areas with corrosion of bare reinforcement. As an example, we will present some results of one LF field observations during the construction period before the prestressing of the structure. As a result of the cylindrical and domed parts visual inspection, the following were found: areas with poor-quality compaction of concrete and areas with surface shells (Figure 1); cracks (depth 20-60 mm, opening size 0.1-0.2 mm), formed as a result of concrete shrinkage, the location of which is random in nature (Figure 2).

a)

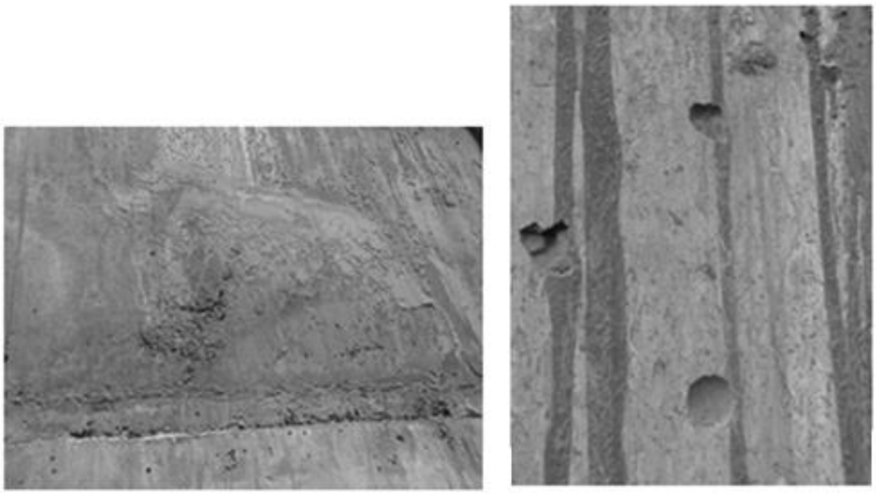

**Figure 1.** Areas with poor compaction of concrete with surface shells

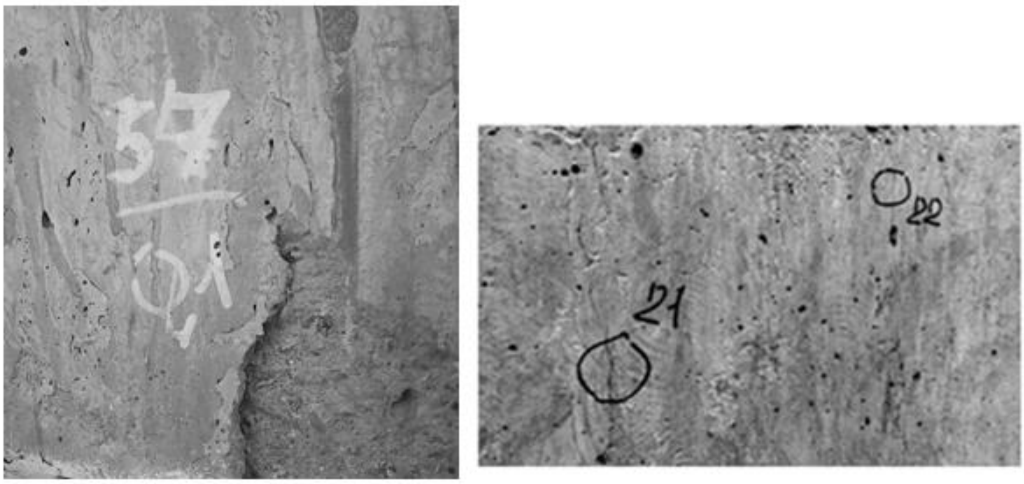


**Figure 2.** Cracks on the LF surface

Determining the strength of the concrete of the LF design was made difficult by the requirement to conduct a study without any damage to the surface, i.e. by the indirect methods of non-destructive testing. However, these methods are characterized by a large error in the results of measuring the

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strength of which are promoted by various factors, which include surface treatment; microcracks, pores, cavities, delamination at the measurement site; coarse aggregate inclusions; presence of reinforcement at the measurement site; defrosting, oiling or wetting the surface layer.

**Results**

To determine the concrete strength in the structure, a calibration relationship between the strength of concrete and an indirect characteristic of strength is pre-established [5]. The methods of plastic deformation, elastic rebound or shock impulse during the inspection of structures, concrete with parameters different from the material by which the calibration dependence was determined, can only be used with the specification of this dependence, which implies testing concrete with destructive methods. Also, according to the set of rules [7], the determination of the concrete strength is performed by non-destructive methods in accordance with the standard [5], and without building a calibration dependence can be performed only by the direct methods of control, implying local damage to structures (tearing, peeling with chipping, rib splitting) and on testing selected samples by the destructive methods. Thus, it is impossible to apply indirect methods of monitoring the strength of concrete without calibration dependence, and its construction is impossible without the use of the destructive methods. In order to develop a methodology for determining the strength of a concrete LF structure, as well as to assess the applicability of a particular method, the preliminary studies were conducted.

**Discussion**

Control samples testing allows to assess the concrete mix quality, but not the strength of the structure concrete itself. This is caused by the impossibility to provide identical conditions for curing for concrete in the structure and concrete cubes of the samples. Thus, concrete for the longline (datum No.1), according to the test protocol of the samples for strength in laboratory conditions, had an average strength value of 58.0 MPa or 592 kg / cm$^2$ (with a required strength of 51.3 MPa), and for the samples of this the same concrete on the site (Figure 3) the average value was 56.8 MPa and this is for the summer period. At the same time, the strength of the investigated concrete has a high heterogeneity with a variation coefficient of 13.5%. The smallest measurement error is characterized by the ultrasonic method, and the scatter of measurement results by the shock-pulse method is maximum (coefficient of variation is 31.2%).

To increase the reliability of the results, it was decided to use two indirect non-destructive methods for determining the strength properties of concrete: the impact-impulsive (“Beton Pro CONDTROL” device) and the ultrasonic (UK1401 device).


**Figure 3.** Control sample

The final results were determined in accordance with the methodology for establishing, adjusting and estimating the parameters of the calibration dependencies [4, 5]. The strength of concrete was determined by four hooks on the outside of the construction on each storey. On each bay at the appropriate storey, available control areas were selected, at which the strength was determined at five points. The final result was taken as the average of the ten values obtained. Before each measurement point, before performing measurements, the external surface of the LF was cleaned from the concrete influx and leveled off from local roughness. After the measurements, the controlled point on the surface of the construction was marked by staining and its number was signed. Table 1 shows some results of determining the strength of concrete by storeys and bays on the LF cylindrical part, which were then used in calculations of the stress-strain state of the construction.

**Table 1.** The final results of protective sheath cylindrical part strength measurements on the construction's outer surface (MPa)

| Storey | Bay no. | The points studied | | | | | Average acc. to the bay | Samples tested in the laboratory of the supplier company |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | |
| Datum no.2 | 1 | 43.8 | 62.9 | 55.3 | 44.1 | 52.7 | 51.8 | 52.2 |
| | 2 | 51.1 | 52.7 | 54.0 | 57.0 | 49.4 | 52.8 | 52.5 |
| | 3 | 51.2 | 60.1 | 54.4 | 53.2 | 54.9 | 54.8 | 52.7 |
| | 4 | 50.3 | 49.5 | 57.7 | 52.4 | 53.6 | 52.7 | 53.9 |
| Datum no.3 | 1 | 46.7 | 42.2 | 38.6 | 55.3 | 41.0 | 44.8 | 60.5 |
| | 2 | 43.2 | 42.6 | 40.1 | 41.6 | 62.9 | 46.1 | 55.5 |
| | 3 | 48.8 | 59.3 | 42.0 | 42.1 | 51.4 | 48.7 | 55.8 |
| | 4 | 62.4 | 45.2 | 42.9 | 60.9 | 61.8 | 54.6 | 54.7 |
| Datum no.4 | 1 | 46.2 | 45.3 | 40.1 | 48.4 | 54.0 | 46.8 | 56.3 |
| | 2 | 40.4 | 45.8 | 32.8 | 45.9 | 43.4 | 41.7 | 56.2 |
| | 3 | 33.3 | 59.0 | 56.5 | 45.0 | 30.4 | 44.8 | 56.3 |
| | 4 | 38.1 | 46.2 | 45.8 | 38.7 | 40.4 | 41.8 | 56.3 |

## Summary

As a result, it can be concluded that in order to obtain complete and reliable information about the elements parameters of the object under study, achieved in the process of implementing the design decisions during the LF construction and installation of the lifting and transport facilities of the reactor compartment, to avoid discrepancies, as well as guaranteed performance of work on instrumental control in the required amount, it is necessary to develop a package of the universal standard programs [10]. In addition, it is necessary to organize monitoring of the LF condition on the horizon of the crane cantilevers from its outer side, in order to conduct a comprehensive diagnosis of the zone cracking and assess its technical condition.

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