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THE ASSESSMENT OF THE CONCRETE STRUCTURE STADIUM "SJEVERNI LOGOR" IN MOSTAR

Abstract

The paper presents the assessment of the stadium "Sjeverni logor" in Mostar, through the necessary steps in diagnosing the state of the existing structure: collection of existing documentation, inspection of the structure, testing and analysis, and assessment and decision on further action. Drawings of the stadium were made with defined damage and test points with non-destructive methods.

Destruction and classification mechanisms are performed according to EN1504. The non-destructive methods used during the examination are the rebound hammer and ultrasonic pulse velocity. At the end of this paper, the results and assessment of the condition are given, and the appropriate methods of sanctions are proposed, in accordance with EN1504.

Keywords: mechanisms of destruction, non-destructive methods, methods of rehabilitation

ДИЈАГНОСТИКА СТАЊА БЕТОНСКЕ КОНСТРУКЦИЈЕ СТАДИОНА "СЈЕВЕРНИ ЛОГОР" У МОСТАРУ

Сажетак

У раду је приказана дијагноза стања стадиона "Сјеверни логор" у Мостару, кроз неопходне кораке у дијагностицирању стања постојеће конструкције: прикупљање постојеће документације, преглед конструкције, испитивање и анализе, те процјену и одлуку о даљњем поступању. Израђени су цртежи стадиона са дефинисаним оштећенима и мјестима испитивања са недеструктивним методама.

Механизми уништавања и класификације изведени су према EN1504. Неразорне методе које су кориштене приликом испитивања су склерометар и ултразвук. На крају овог рада дати су резултати и оцјена стања, те су предложене одговарајуће методе санције, у складу са EN1504.

Кључне ријечи: механизми разарања, неразорне методе, методе санације

1. INTRODUCTION

The assessment of the construction [1] aims to provide an answer to the question of the state of the construction on the basis of measurements and research. The diagnostic procedure includes:

- Determining the current state of the entire structure and especially its individual elements
- Determining the remaining level of load capacity, usability or other essential property of the structure

The request to determine the condition of the structure can arise for several reasons, such as:

- the need for planning and designing maintenance works,
- the conversion or adaptation of the building is foreseen,
- the development of technology requires higher usage loads.

In this paper assessment based on visual inspection and in-situ tests for concrete structure stadium "Sjeverni logor" in Mostar is presented. After the inspection and conducted tests, rehabilitation measures are proposed in accordance with EN 1504.

2. THE STADIUM "SJEVERNI LOGOR" IN MOSTAR

The "Sjeverni logor" stadium is located within the USRC "Midhat Hujdur Hujka" in the Sjeverni logor in Mostar. The building has three entrances, one each on the north, east and west sides. The stadium together with the stands was built in 1996. The aerial view is presented in figure 1.



Figure 1. Aerial view of the stadium structure

It is a reinforced concrete construction, where the foundations, columns and the upper two floors of the stands are built by concreting on site, with the pillars and upper floors of the stands being monolithically connected, while the remaining floors of the stands are prefabricated concrete elements.

Due to the fact that the documentation was not adequately archived and given to the team that was working on the diagnosis of the condition of the sinking object, the dimensions and characteristics of the section were defined by visual inspection and measurements. The dimensions of the base of the building are 43.2 m x 58.5 m. The total height of the stands is 5.1 m.

The columns have a rectangular cross-section with dimensions of 60x30 cm. The total number of columns is 34. The stands consist of beams with cross-section dimensions of 100x50 cm.

The columns, together with the "stairs" and foundations, form a framework structure on which the beams rest. The connection between the monolithic and prefabricated beams is made with a layer of concrete 10 cm thick. The beams overlap each other at a width of 20 cm, and the other 80 cm rest on the "stairs". The static system of the stands is a continuous beam. On the south and west side, it is a continuous beam with 8 spans 4.50 m long, while the beams on the west and east side are spread over 5 spans of 4.70 m with an overhang up to half of the span of the opening for the entrance to the building, length 2.15 m.

3. VISUAL INSPECTION

For structures whose condition needs to be determined at some point in their existence, i.e. after they have been in use for some time, the simplest way to collect data on the structure is to study the design and construction documentation, as well as reports on previous inspections and maintenance. Of course, data should be corrected prior the usage.

Data on the original design and calculation of the structure, as well as plans of the built state, are not usually available, as is the case with this structure. In this case, a visual inspection of the structure is used to determine the dimensions of the section, the geometry of the structure, the parameters that describe the properties of the materials from which certain structural elements are made, according to the methods of diagnosing the state of the structure [2].

A visual inspection of the structure determines damage to individual structural elements, their causes, spread, and the impact on the load-bearing capacity and usability of that element and the structure as a whole. In addition, the possible existence of excessive deformations, rotations or vibrations is controlled. It is important that the inspections are aimed at evaluating the decisive factors of the safety and usability of structures, and at observing and evaluating all phenomena and changes that may lead to disruption of the specified parameters [2].

The assessment for existing buildings can be divided into following steps [3, 4]:

- Collection or reconstruction of blueprints
- Collection or reconstruction of calculations
- Building inspection
- Investigations and monitoring
- Calculations
- Evaluation and decision on further action.

A visual inspection of the structure determines damage to individual elements and their extent.

During the visual inspection of the construction, special attention was paid to [5]:

- geometry and cross-section dimensions
- appearance and differences in the color of the construction surface
- appearance of cracks, their size and arrangement
- signs of material degradation on the surface of the structure.

On the existing structure of the "Sjeverni logor" stadium, the following damages were observed during visual inspections:

- Damage caused by moisture
- Degradation
- Segregation
- Appearance of vegetation
- Corrosion of reinforcement
- Cracks
- Deterioration

Some of the observed damages are shown in the figure 2.

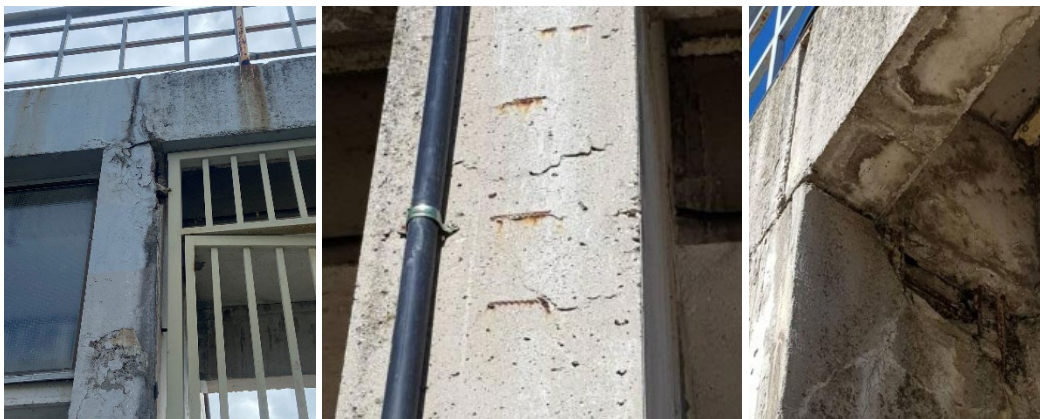


Figure 2. Examples of damages on construction (from left: cracks on column, corrosion, concrete separation)

After the visual inspection, new blueprints of existing condition were created, due to lack of original blueprints. On these blueprints, all observed damages were defined (figure 3). Also, visual inspection provided data on damages on construction and points of in-situ tests.

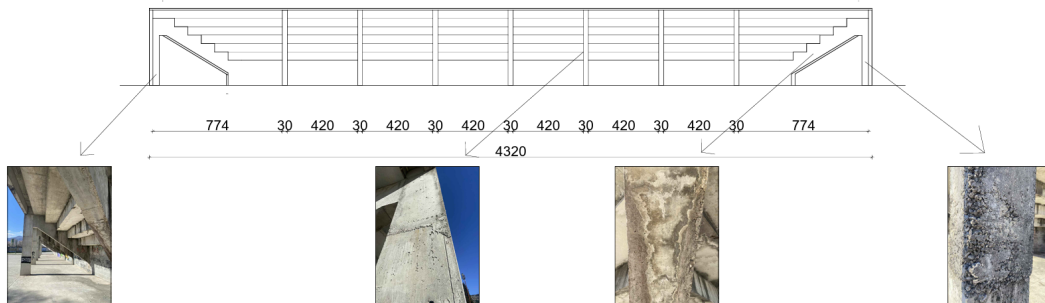


Figure 3. Example of damages defined on blueprints

4. IN-SITU TESTS RESULTS

The outer side of the stadium structure was tested with non-destructive in-situ tests. Compressive strength was measured with digital rebound hammer. Concrete quality was measured by ultrasonic pulse velocity (UPV) test.

Tests were conducted on 10 columns and 10 beams. Of these, there are two pillars each in the western and northern tribunes and three pillars each in the southern and eastern tribunes. The points are given in figure 4.

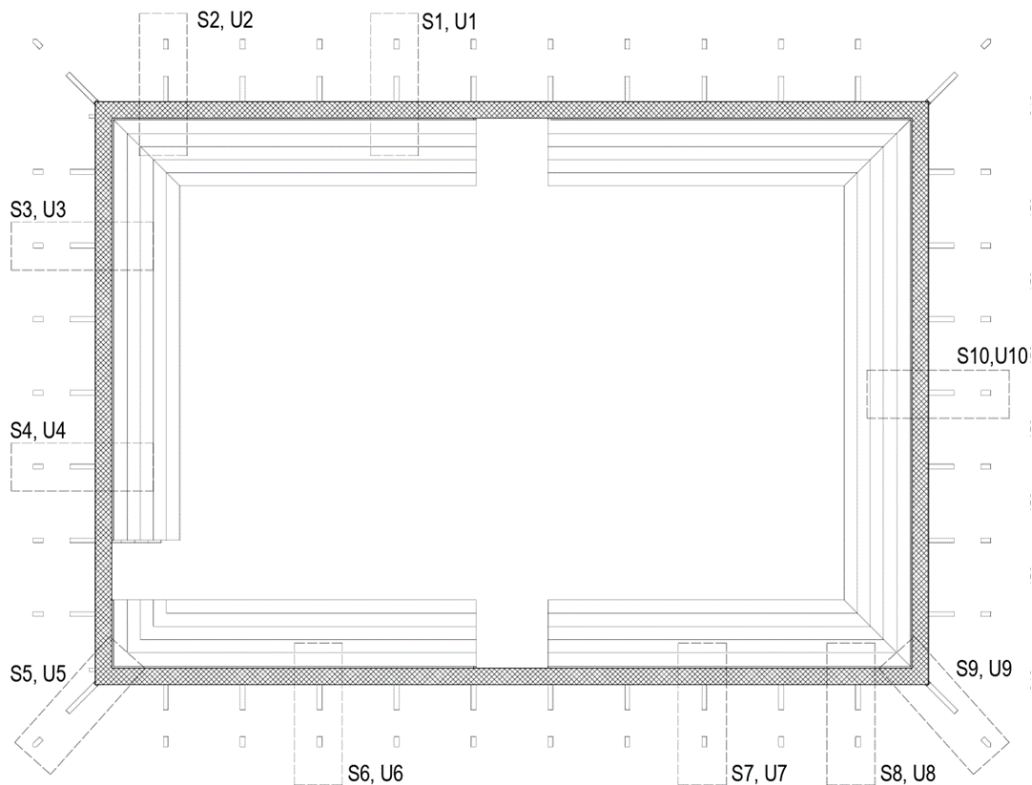


Figure 4. Selected columns and beams for in-situ tests

The rebound hammer is a method used to determine the characteristic compressive strength. The test was conducted at a total of 20 locations, with a maximum of 5 shots per test location. As a result, the mean value of the readings at the test site is taken, adjusted to take into account the direction of the rebound hammer test and the rebound hammer index is expressed as a whole number. If more than 20% of the reading differs from the mean value by more than 6 index units, the entire test spot should be discarded.

Table 1 shows the results of sclerometer measurements on the beams and columns of the stadium.

Table 1. Average in-situ tested compressive strength (MPa)

Location	Column	Beam
S1	40,36	62,76
S2	51,40	65,68
S3	56,50	54,84
S4	54,24	67,56
S5	65,05	61,08
S6	47,92	57,40
S7	56,98	52,10
S8	43,16	59,10
S9	73,60	48,71
S10	48,56	51,68
Average	53,78	58,09



Figure 5. Compressive strength tests

The UPV test is one of the non-destructive testing methods that is widely used due to the great adaptability, sensitivity and reliability of the results that can be achieved. The UPV test was applied in the same places where the sclerometer was used, i.e., on 10 columns and 10 beams. Regarding the accessibility of the test sites, a direct test method was used on all columns and beams (figure 6). The velocity of the ultrasonic pulse in a material depends on the density and elasticity of that material. If the ultrasonic pulse encounters an inhomogeneity in the material, given the size and shape of the inhomogeneity, the ultrasonic pulse will bounce off the inhomogeneity while the remaining part of the ultrasonic energy will continue to propagate to the back of the object's surface. Ultrasonic testing of components and structures is based on the propagation of an ultrasonic pulse through the material, during which the ultrasonic pulse is subject to all the laws of propagation of sound waves.

Elastic properties such as Young's modulus of elasticity E , shear modulus G and Poisson's ratio μ can be estimated and calculated by measuring the UPV using longitudinal and/or transverse waves. The dynamic modulus of elasticity was determined empirically (1) based on the measured ultrasonic pulse velocity [6]. To calculate the dynamic modulus of elasticity, the values of Poisson's coefficient $\mu=0.20$, and the density of concrete $\rho=2400\text{ kg/m}^3$ were assumed.

$$E_d = v^2 \rho \frac{(1+\mu)(1-2\mu)}{(1-\mu)} \quad (1)$$

v – velocity (km/s)

ρ – density of concrete (kg/m³)

μ – Poisson's coefficient

Table 2 shows the results of in-situ UPV measurements.

Table 2. Average in-situ test results for pulse velocity and E_d

Location	Test	Column	Beam
S1	v (km/s)	4,20	3,41
	E_d (MPa)	38026,3	25103,3
S2	v (km/s)	4,48	2,65
	E_d (MPa)	43305,9	15170,6
S3	v (km/s)	3,68	3,89
	E_d (MPa)	29267,2	32703,0
S4	v (km/s)	4,07	2,38
	E_d (MPa)	35693,0	12225,5
S5	v (km/s)	4,20	3,41
	E_d (MPa)	38026,3	25046,3
S6	v (km/s)	4,28	4,40
	E_d (MPa)	39560,4	41795,3
S7	v (km/s)	4,32	3,55
	E_d (MPa)	40246,4	27290,5
S8	v (km/s)	4,35	4,26
	E_d (MPa)	40831,8	39112,7
S9	v (km/s)	4,38	3,55
	E_d (MPa)	41430,0	27290,5
S10	v (km/s)	4,17	4,48
	E_d (MPa)	37604,4	43435,4

Based on the standard EN 12504-4, it is concluded that the concrete is mostly medium to good quality ($v=3,0 - 4,5$), due to average measuring values range about 4,00 km/s.

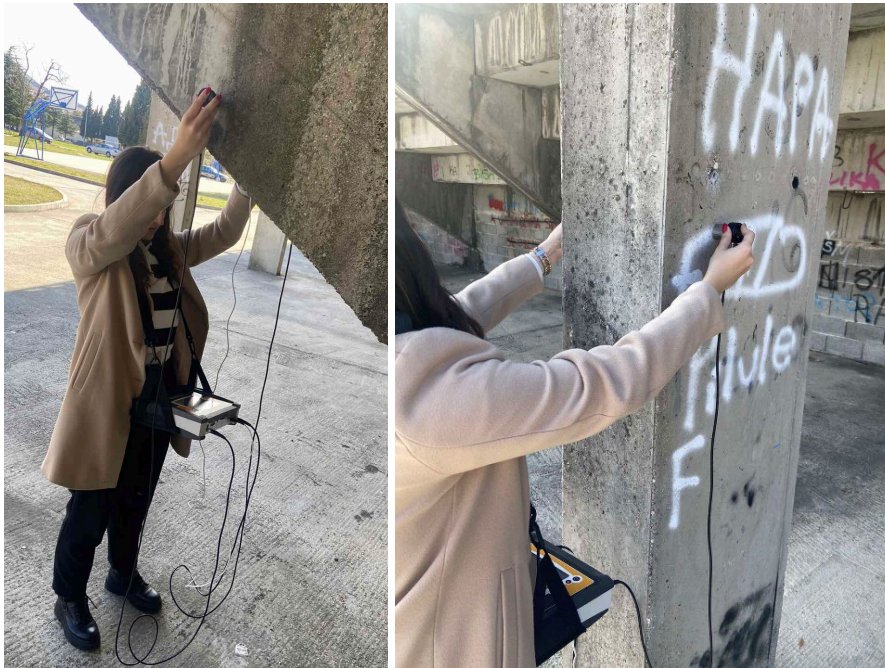


Figure 6. Ultrasonic pulse velocity test

5. REHABILITATION

After the inspection of the "Sjeverni Logor" stadium and after the rebound hammer and UPV tests, it can be concluded that the general condition of the structure is satisfactory. Damage caused by mechanical, physical and chemical action does not affect the load-bearing capacity of the structure. But it is necessary to carry out certain repairs in order to extend the useful life of the structure. Regular maintenance is also necessary, in order to reduce the occurrence of new damages. Based on the proposed remedial measures according to EN1504, and in accordance with the categorization of damage mechanisms for the concrete construction of the stands of the "Sjeverni Logor" stadium, the following remedial measures are proposed [7]:

- Manual application of mortar

It represents an established method of local repair of damage in concrete and is most often used for the repair of smaller areas. Mortars are specified in EN 1504-3. The goal of this method is to replace poor quality concrete with new mortar or concrete.

- Modifying elements

In places where the column has cracked due to the horizontal movement of the beam, it is more economical to replace part of the structure. In such cases, it is necessary to ensure the adequate bearing capacity of the structure and the distribution of the load by means of appropriate systems for gluing or tying.

- Hydrophobic impregnation

The entry of water, including dissolved harmful substances, can be prevented by hydrophobic impregnation of concrete. In this way, significant cracks are repaired and closed.

- Impregnating

Impregnation aims to fill the pores of the concrete surface to prevent any transport of liquids or gases through the concrete surface. In addition to filling the concrete pores, a thin film of impregnation material is often additionally placed on the surface of the concrete. The result is sometimes called pore blocking.

- Surface sealing of cracks

It is done to prevent the penetration of aggressive substances into the concrete. This method is used for individual cracks or exceptional displacements of cracks that cannot be covered with coatings.

- Coatings

Surface coatings improve the surface of concrete, which becomes more resistant to certain external factors or behaves better under their influence. Small surface cracks with a displacement of up to

0.3 mm can be safely repaired and then filled. Their movement is adapted to the use of flexible coatings for bridging cracks, which are resistant to water and carbonization.

- Increasing coverage by adding mortar or concrete

This method is mostly related to the corrosion of reinforcement. If the reinforcement is not sufficiently covered with concrete, adding cement mortar or concrete reduces the aggressive effect of chemicals.

- Replacement of contaminated or carbonized concrete

This method is the traditional standard for repairing reinforced concrete. By removing the damaged concrete and re-covering the rebar, the steel is once again protected by an alkaline coating.

6. CONCLUSION

Assessment of condition of the "Sjeverni Logor" stadium in Mostar requires the necessary steps, namely: collection of existing documentation, inspection of the structure, examination and analysis of the obtained data, and assessment and decision on further action. The first step in the preliminary inspection of the construction was the measurement of the construction and the drafting of the existing state. Based on a visual inspection, the mechanisms of destruction of the structure, their causes, the spread of damage, and their effect on the structure were established. All observed damages are entered in detail in the construction database, with defined causes and proposed remedial measures according to EN 1504.

As part of the assessment, in-situ tests were performed using non-destructive methods: rebound hammer and ultrasonic pulse velocity. Nowadays, non-destructive methods of testing materials and structural elements are increasingly used in construction, for quality control, but also for determining the constancy of properties. The advantage of non-destructive methods is that tests can be repeated in different periods on the same test sample or place, and the results are collected for the purpose of monitoring changes in properties. Testing, with a rebound hammer and UPV, was performed on 10 columns and 10 beams. With the use of a sclerometer, it was concluded that the compressive strengths of concrete at all test locations are satisfactory. When testing with the UPV method, it was concluded that the concrete is of mostly medium to good quality. This paper presents tables of the results of these tests and their analysis.

Although the mentioned destruction mechanisms do not affect the load-bearing capacity of the structure, it is necessary to repair the damage, and appropriate methods of repair are proposed, according to EN1504. Regular maintenance and repair can extend the life of the structure.

LITERATURE

- [1] M. Šahinagić – Isović, M. Čeček "Reconstruction of the Municipal Court, National Monument Building in Mostar", *Proceedings of the 1st International Conference on Construction Materials for Sustainable Future*, Zadar, Croatia, 19 - 21 April 2017, pp. 718 – 723.
- [2] E. Zlomušica, M. Šahinagić – Isović, N. Ademović, *Elementi održivosti okolinskih infrastrukturnih sistema*, Dzemal Bijedić University of Mostar, 2020.
- [3] M. Šahinagić-Isović, M. Čeček, M. Kukrica, "Diagnostics of the condition of the Tabija Tower in Mostar", e-Zbornik *Electronic collection of papers of the Faculty of Civil Engineering*, Special Issue, 2023., Vol. 13, <https://doi.org/10.47960/2232-9080.2023.SI.13.129>
- [4] A. Šarančić-Logo, M. Čeček, M. Šahinagić-Isović "Assessment of masonry structure "Radnički dom" in Mostar", *IOP Conference Series Materials Science and Engineering* 1208(1). DOI: 10.1088/1757-899X/1208/1/012044
- [5] J. Džino, F. Trešnjo, M. Šahinagić-Isović, "Condition diagnostics of the stadium "Rođeni" in Mostar", *IOP Conference Series Materials Science and Engineering* 1208(1). DOI 10.1088/1757-899X/1208/1/012041
- [6] EN 12504-4:2021 - Testing concrete in structures-Determination of ultrasonic pulse velocity
- [7] M. Raupach and T. Büttner, *Concrete Repair to EN 1504, Diagnosis, Design, Principles and Practice*, CRC Press, 2019.