Condition diagnostics of the Stadium “Rođeni” in Mostar

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Abstract. The paper presents a diagnosis of the condition of the stadium FK Velež "Rođeni" in Mostar, which was built in period 2006–2008 and represents an important facility for the citizens of Mostar. The steps in diagnosing the condition of an existing structure are explained, including a collection of existing documentation, an inspection of the structure, test and calculations, and assessment and decision on further action. Drawings of the stadium were given, visual inspection of the stadium was performed and calculations of the current and future layout of the structure. The calculations were performed in software Tower 8 and with respect to European norms EN0, EN1, EN2, EN3 and EN8. A visual inspection revealed a large number of damages to the stadium, which were classified into specific groups. The mechanisms of destruction and classification were performed using EN 1504.

1. Introduction
Football club Velež Mostar is a professional football club based in Mostar. The club has a history of being one of the most successful clubs from Bosnia and Herzegovina.

The location of the club stadium is in the northeastern part of the city, in the suburb of Vrapčići. The stadium, at its current stage of development, can accommodate up to 7,000 fans. Lack of funds and the slow process of the country’s recovery from the war, as well as the complicated political environment in the city and the country as a whole, have affected the scale and pace of stadium development. Velež returned to the top of Bosnian football after being promoted to the Premier League of Bosnia and Herzegovina in 2006. This return was accompanied by the construction of a large north and a smaller east grandstand. In 2008, a large west stand was built, which was followed by additional works and extensions between 2017 and 2018. In 2019, the roof for the west stand was completed. The construction of a large east stand is in progress [1].

1.1. Existing condition
The stadium is located on the site of Mostar at an altitude of N.V. 76 m. The stadium is oriented east-west with its longer axis. The field is surrounded by a grandstand on the north and west, while on the south side of the field there is a prefabricated grandstand for visiting fans.

The west stand consists of a ground floor, first floor and auditorium, 14 m wide and 70 m long, and is connected by a concrete and metal structure. Metal pillars are continued on concrete pillars, where a canopy is hung on them by the braces. The slope of the canopy is i = 10% (Figure 1.a).
The north grandstand consists of a ground floor and an auditorium and is not covered. The construction consists of three parts that are separated by dilatation 5-7 cm wide. The length of one segment is 35 m and the width is 12.50 m. The total length of the northern stadium, which is the connection between the concrete and masonry structures, is 106.20 m (Figure 1.b).

**Figure 1.** Current condition of the west and north stands of the "Rođeni" stadium

1.2. *New designed condition*

In order to achieve stability and durability of the structure in accordance with the importance and tradition of the club, and the relationship with the category of fans with mobility difficulties, a proposal was made to improve the existing condition through redesign of the west and north stands (Figure 2 and Figure 3).

**Figure 2.** New designed condition of the west and north stands of the stadium "Rođeni"

Necessary interventions to ensure the stability and durability of the structure or increase the energy efficiency of the building are:

- Installation of the thermal facade on the external facades of the west and north stands,
- Collect the water that remains in the access parts around the stadium with drainage pipes in the tank,
- Installation of mini windmills whose energy would be used to power the display or lighting,
- Landscaping a new garage.
2. Condition diagnostics of the west and north stand

The main goal of diagnostics of the condition of structures is to give answers to the questions in which condition the structure is observed, based on measurements and research. It is necessary to determine the critical elements of the structure, since the overall condition of the building dictates the condition of its weakest part. The diagnostic sequence for existing buildings can be divided into several steps: collecting or reconstructing existing documentation, inspecting the building, testing and calculations, evaluating and deciding on next steps.

Within the condition diagnostics of the west and north stands of the stadium "Rođeni", following the steps of diagnostics of the existing facilities, it was done:

1. Drawings of the west and north stands
2. Overview of stands
3. Static calculation
4. Evaluation and decision on further action

2.1. Architectural drawings

A preliminary review of the west and north stands was approached first. After that, we made the architectural drawings. The geometry of the stands and the cross-sectional were taken. The stands were measured manually, without scaffolding, with the help of a meter, a ribbon and a laser distance meter. The result of the survey are architectural drawings of the existing condition of the building (Figure 4 and Figure 5), which contain:

- situation
- layouts
- cross and longitudinal section
- external and internal facades
2.2. Damage categorization according to EN 1504
After that we made the architectural drawings, we started a detailed review of the existing condition, and all identified damages were noticed and inscribed. During the detailed visual inspection of the structure, special attention was paid to: the appearance and differences in the color of the structure surface, the appearance of cracks, their size and arrangement, signs of material degradation on the structure surface, deformations on the structure, and places of leakage or water retention on wet surfaces. A drawing of the existing condition together with damage identification and mapping is the starting point for the next step, the analysis of damage occurrence.

The mechanisms and influences on the deterioration of structures are numerous and very different. The basic question with such damaged structural parts of the structure is can, and for how long, this structural element still performs its (designed) load-bearing task. In summary, the main damage was due to poor design (design phase), poor construction technology and poor material quality (construction phase), subsequent overload of the structure (exploitation phase, but also design), and due to various atmospheric and chemical influences [2].

The categorization of damage on the west and north stands was performed according to the European standard EN 1504 (Figure 6 a and b). The following terms were used to describe the occurrence of damage:
• Damage - physical disruption or change in the condition of the structure or its components due to external actions or influences
• Degradation - a decline in the condition, quality or functionality of a material that most often results in damage
• Deterioration - the process of deterioration or weakening of quality, value, characteristics and other materials and which can result in a progressive reduction of the ability of the structure or its parts to serve its purpose
• Deficiency (structure or components) - Defects occur due to a defect in performance or design or a defect in material and may result in inadequate structural capacity, premature deterioration or aesthetic appearance
• Weathering - any chemical or mechanical process by which a material exposed to atmospheric influences undergoes changes in its character and weakens or loses quality
• Crack - complete or partial cracking of concrete in two or more parts caused by cracking or fracture
• Separation (spall, flake, detachment) of parts of the material due to certain reasons (influence of weather, pressure, etc.)
• Delamination - separation of a certain part of the surface layer but at a certain depth due to a crack below the surface
• Scaling - peeling or intermittent separation of surface pieces of concrete or mortar

![Figure 6](image_url)

Figure 6. Drawings of one part of the damages on the west and north stands

2.3. Static calculation
Structural calculation refers to the design of critical points on the structure and the calculation of the entire system with realistic parameters, determined through the inspection and testing of the structure. The design model on which the design of the structure is performed must adequately show the behaviour of the structure, the resistance of its parts and the load on the structure in accordance with the actual condition of the existing structure. We used Tower 8 software package in the calculation of the west and north stands, and static analysis of the complete construction of the existing and new designed condition.

Static calculation has proven that the existing and new designed condition satisfies the limit state of bearing capacity and the limit state of usability according to European norms.
2.4 Proposed reparation measures

The process of condition diagnostics ends with an answer to the question of what steps should be taken and how to treat structures in the future. Recommendations for short-term and long-term activities should be made.

After the analysis of the occurrence of damage as well as the analysis of individual elements of the structure, we prepared an intervention proposal, based on the findings of the analysis. A damage catalog was made with all the damage and the necessary interventions to repair them. Table 1 shows a part of the damage catalog, with proposals for remedial measures.

For the correct classification of damage and selection of the appropriate method of repair, it is necessary to adjust the diagnosis, design, product selection and repair work to the individual condition of the facility, with the necessary expertise among all people involved in the process. Consequently, only if a systematic assessment clearly identifies the structure of the material, we can select adequate principles and methods of remediation. Also, it is important to assess the further development of the condition of the structure in order to select the optimal time for protection or repair measures. The new European standard EN 1504 provides a systematic approach to the principles and methods of repair and protection of structures, including the selection of appropriate products, and quality control. This approach provides an optimal basis for understanding and designing repairing works.
Table 1. Damage catalog and repair methods

| Type of damage | Figure | Detailed description of the damage | Possible cause of damage | Rehabilitation proposal |
|----------------|--------|-----------------------------------|--------------------------|-------------------------|
| Crack / deformation (damage) | ![Figure](image1.png) | Separation at the site of dilatation on the north stand. It causes further deterioration of water into the expansion layers. | Incorrect installation and execution | - Filling with waterproofing foams  
- Putting a waterproofing layer with fibers  
- Applying a new layer of plaster (final layer - facade plaster) |
| Separation (separating two or more parts along a certain line or more) | ![Figure](image2.png) | | |
| Degradation | | Change of the original color of the wall of the west stand. | - Incorrect execution.  
- Unfinished waterproofing.  
- Cracks at the joints of the panels and on the entire panel | |
| Moisture area Water / moisture penetration at the dilatation site | ![Figure](image3.png) | | |
| Efflorescence | | Color change and appearance of deposits on the pillar below the north stand. | Appearance of salts | - Treatment with anti-mold additives  
- Waterproofing on the upper part of the stand  
- Salt rinsing  
- Setting up protective layer of mortar |
3. Conclusion
This paper presents the diagnostics of the west and north stands of the stadium "Rođenii" and explains the principle of diagnosis which consists of: collecting existing documentation and drawings, visual inspection of the stands, the necessary static calculations and finally evaluations and decisions on further action and maintenance of the stands. Some variants of the new designed solution are given to improve the energy efficiency of the west and north stands.

Static calculations have shown that damage to the stands does not significantly affect the load-bearing capacity of the entire structure. A catalog of all damages has been made with the necessary interventions and guidelines for better and more purposeful maintenance of the stands.

References
[1] https://fkvelez.ba/
[2] Raupach M and Büttner T 2014 Concrete Repair to EN 1504

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