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**CLIENT:** European Union Delegation to Moldova through its operational contractor UNDP

# Technical Expertise and develop Detailed Technical Design for CONSERVATION AND RESTORATION WORKS OF BENDER FORTRESS (Phase I)

## DETAILED TECHNICAL DESIGN

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# 1 Background information

In 2019 the UNDP Moldova launched the fifth phase of the European Union Confidence Building Measures Programme (EU-CBM V), funded by the European Union and implemented by the UNDP Moldova.
UNDP announced the tender RFP No.: 19/01915 "REQUEST FOR PROPOSAL - Conduct Technical Expertise and develop Detailed Technical Design for conservation/restoration works of Bender Fortress Phase I" won by the Author of this report, Studio Berlucchi srl.

The Detailed Technical Design has the purpose, based on the previous Technical Expertise and Preliminary Project, to describe and determine the works to be carried out during the construction site.

During the Technical Expertise, the critical issues encountered were numerous; they were listed and ordered by priority. That list is a guideline for future interventions on the whole Citadel and Lower Fortress. Technical expertise report was registered at Moldovan authorities for constructions on 7th of May with number 008/07.05.2020 by Expert nr.095 Mr. Victor Toporet.

The Preliminary Project has developed, in a more detailed way, only the interventions identified as priority for the fortress and included in the lot of works falling within the scope of the funding allocated by EU CMB Programme V. It was approved, on the basis of the minutes of the meeting of National Council of Historical Monuments nr. 14 of July ,8$^{th}$ 2020, by Ministry of Education and Research of the Republic of Moldova nr.05/2-09 of July, 10$^{th}$ 2020.

These interventions address the main structural problems and propose technical solutions to them main structural problems present in the fortress, as well as the enhancement of unused parts of the fortress (especially in the citadel), the solutions for material conservation problems, the definition of guidelines for future interventions on the fortress and the resolution of the main architectural criticalities for the safe use of the monument by visitors.
Through Detailed Technical Design level, these interventions are fully designed and described in order to launch the tender to select the executing company and implement the first lot of restoration and consolidation works.
The compartments involved are architecture and structure.

This report includes:

- the evaluations related to the results of the surveys conducted on material, building techniques and components, and on their degradation and structural instability phenomena
- Technical specifications of the execution of conservation treatments, of the products to be used, of the structural intervention

The report includes diagrams, constructions details and any graphic material that is useful for clarifying the descriptive contents of the state of conservation and of the indications for the interventions.

# 2 Principles and requirements

## 2.1 Guiding principles adopted for the project

The guiding principles adopted for the project refer to the international standards recognized in the field of restoration.

There are numerous Treaties and Conventions recognized and ratified at international level such as

- the Convention on the Protection of the World's Cultural and Natural Heritage (Paris, 1972)
- the European Convention for the Protection of Archaeological Heritage (London, 1969)
- the Convention for the Protection of the Architectural Heritage of Europe (Granada, 1985)
- Principles for the preservation of historic timber structures (1999)

But the key document for international contemporary restoration is definitely the "International Charter for the Conservation and Restoration of Monuments and Sites" (The Venice Charter 1964) adopted by ICOMOS in 1965.

This Charter inspired all the treatises and subsequent operational guidelines about Cultural Heritage; this project was guided above all by:

- the ICOMOS Charter "Principles for the analysis, conservation and structural restoration of architectural heritage" adopted by ICOMOS in 2003
- the ICOMOS "European Quality Principles for EU-founded interventions with potential impact upon Cultural Heritage" published in 2019

We should underline in particular:

- The multidisciplinary approach[1] adopted in all phases of our work, that was conducted step by step as in medicine[2] (anamnesis, diagnosis, therapy, controls): the research for data and information, the individuation of the causes of damage and decay, the choice of the remedial measures and the indication of control measures to verify the efficiency of the interventions.
- The deep knowledge acquired[3] in order to **submit project proposals based on detailed studies to determine the characteristics and values of the Fortress, its state of conservation, needs and opportunities and risks**[4]
- That **the basis[5] for conservation and reinforcement measures were both safety evaluation** (e.g. consolidation of masonries and towers, substitution of railings) **and an understanding of the significance of the monument** (e.g. the importance, on Bender fortress, of being able to walk the path patrol or to visit the top of the towers to see the landscape and the Dniester river)
- **The choice between "traditional" and "innovative" techniques[6] was weighed up on a case-by-case basis** (e.g. the choice to cover towers with traditional wooden floors, or the choice to design a new cor-ten railing). In general we proposed interventions that aim **to respect historical values**, **techniques and materials** (without proposing shapes that never existed or choosing industrial

[1] ICOMOS Charter 2003, Principles-General Criteria 1.1
[2] ICOMOS Charter 2003, Principles-General Criteria 1.6
[3] ICOMOS Charter 2003, Principles-Researches and diagnosis 2.1-2.9
[4] ICOMOS European Quality Principles 2019, Ensuring quality interventions on Cultural Heritage - 3.3 Design
[5] ICOMOS Charter 2003, Principles-Remedial measures and controls 3.3
[6] ICOMOS Charter 2003, Principles-Remedial measures and controls 3.7

materials not suitable for conservation) **without limiting future interventions where there is not the possibility to make "reversible" choices**.

- That it is important to ensure the **distinguishability of the intervention**; this is possible using materials with a slightly different color than the historical ones, without causing a patchwork effect on the wall surface. For this reason, it will be important to make samples in the early stages of the construction site to be approved by the works manager and the restoration consultants.

The contents of the Detailed Technical Design of Bender Fortress (Citadel and Lower Fortress), were fixed also according to Moldovan legislation on constructions listed in our ToR and below:

- Government Decision (HG) n.73 of 31/01/2014
- NCM A07 02-2012 4802
- CP A 08.06:2014
- CP A 08.05:2015

## 2.2 Requirements

- Qualification, certification and experience in the field of Restoration of Cultural Heritage of the Contractor and its subcontractors and workers

**The fortress of Bender is a monument of great historical and artistic importance. For this reason, the restoration and consolidation works must not be entrusted to generic construction companies.**

It will be necessary to select a Contractor Company that can demonstrate and prove a deep experience in the field of Restoration works on Cultural Heritage.

Therefore, **the Contractor Company must have at least UNI EN ISO 9001-2015 Certification, in particular for EA Sector 28-35**: *Design and Execution of Work of restoration, preservation, analysis of cultural objects, works and furniture surfaces decorating, Architectural heritage, historic and artistic interest, protected or not. Designing and making surveys of Cultural Heritage and for the restoration.*

**The Contractor Company and any subcontractors or any partners in Joint Venture must demonstrate their experience in the field of restoration of Cultural Heritage**, in particular for stone surfaces, consolidation of masonry and wooden structures, through:

- Detailed Curriculum Vitae of work experience
- Certificates of "Proper execution of works" issued by the client of previous work experience
- Any certifications and qualifications obtained (e.g. certification of attendance of restoration schools, qualification of restorer of cultural heritage, registration to official lists, etc.) by public institutions and universities of the country of origin or internationally recognized bodies in the field of Restoration of Cultural Heritage

Before work begins, the Contractor Company must provide UNDP with all certifications listed above (both its own and any subcontractors or any partners).

**No executing company and no operator shall have access to the site without having obtained authorization from UNDP.**

- Restoration processes, products and materials

**The company must always carry out the works and apply all the products following the instructions contained in the product technical data sheets.**

**All materials and products (through their technical data sheet) must be submitted, from the Contractor to the work manager of UNDP and restoration supervisor, for approval.**

2.2.1.1 Biocide

The choice of the most suitable product will be done directly on site through the execution of tests. At least two different broad-spectrum quaternary concentrated liquid ammonium salts biocide must be tested (e.g. PREVENTOL® RI 80 by ANTICHITA' BELSITO srl, or BIO C by CIR Chimica Italiana Restauri, or another type with same technical characteristics and performances).

2.2.1.2 Consolidation products

The choice of the most suitable product will have to be done directly on site through the execution of tests. At least three products must be tested:

- AMMONIUM OXALATE: Water-soluble salt for the consolidation of limestone and stone surfaces to be applied in solution from 2 to 5% with cellulose pulp consolidating pack method (e.g. Ammonium Oxalate by Sinopia sas Turin – Italy - or another type with same technical characteristics and performances).
- ETHIL SILICATE: ready-to-use liquid product based on silicic acid ethyl esters in alcoholic solvent (e.g. Consolidante ETS of MAPEI S.p.A. or another type with same technical characteristics and performances).
- NANO LIME: calcium hydroxide nanoparticles dispersed in alcohol (e.g. NANORESTORE PLUS OF University of Florence or another type with same technical characteristics and performances).

2.2.1.3 Mortars

**All mortars must be cement-free Natural Hydraulic Lime mortars.**

**In general:**

- **it is strictly forbidden to use any other type of mortar, above all it is strictly forbidden to use cementitious materials or materials based on cement or with small traces of cement**
- **structural mortars must be NHL 5, other mortars (for plasters, groutings, injections etc.) must be NHL 3.5**

Use of premixed mortars is recommended, please notice that they must be compatible with the stone support. The choice of the most suitable product will have to be done directly on site through the execution of tests.

For **STRUCTURAL WORKS**, in particular **INJECTIONS:**

- Micro-cracks nucleus consolidation:
    - superfluous grout, volumetrically stable, packed with: fillerized hydraulic binder superfluid, salt resistant, free from cement, composed of lime and Eco-Pozzolana, ultrafine natural sands and special additives (e.g. Mape-Antique I of MAPEI S.p.A. or another type with same technical characteristics and performances). Injections must be executed until refusal, from bottom to top, with mechanical or electronic pumps.
    - hyperfluid geo-mortar with high water retention based on pure natural lime NHL 3.5 and geo-binding (type Geocalce FL Antisismica of Kerakoll Spa)
- Nucleus void filling:
    - pourable mortar for masonries, of fluid consistency, resistant to salts, free from cement, composed of natural hydraulic lime and Eco-Pozzolana, fine natural sands, special additives and microfibers, with very low emission of volatile organic substances (EMICODE EC1 R Plus)

(e.g. Mape-Antique Colabile type of MAPEI S.p.A. or another type with same technical characteristics and performances). For thickness over 4 cm, the mortar must be added with aggregates from 30 to 50% on the weight of the product, of appropriate grain size (e.g. limestone gravel 3-5 or 6-10)

For **STRUCTURAL WORKS**, in particular **INSTALLATION LAYERS:**

- premixed mortar for masonries, based on natural hydraulic lime (NHL 5) and inorganic reactive compounds, sand natural and special additives with very low volatile organic emissions (EMICODE EC1 R Plus) (e.g. type Mapewall Muratura Grosso of Mapei S.p.A. or another type with same technical characteristics and performances)
- high-pozzolanic reinforced fiber mortar based on natural hydraulic lime NHL 5, graded sand, synthetic fibers and additives (e.g. type MALTA STRUTTURALE NHL 712 by Fassa Bortolo or another type with same technical characteristics and performances)

For **STRUCTURAL WORKS**, in particular **INSTALLATION OF METAL ELEMENTS:**

- high performance bi-component epoxy resin (e.g. Kimitech EPOXY CTR ST3-0719 type by KIMIA S.p.A. or Epojet by MAPEI S.p.A. or another type with same technical characteristics and performances)

For **STRUCTURAL WORKS**, in particular **NEW FOUNDATIONS IN REINFORCED CONCRETE:**

- concrete shall comply with the requirements set out in CP H.04.04.2018 standard "*Betoane și mortare. Beton. Specificație, performanță, producție și conformitate*", table S.1 and S.2 Annex S. The clear concrete cover for foundations shall be at least 4,5 cm thick. The concrete shall be characterized by the following values:
  - concrete class C30 (or concrete mark M400 according to GOST 26633, table S.1 from CP H.04.04-2018)
  - consistency class S3 (according to CP H.04.04.2018 table 4)
  - exposure class XC1 (according to CP H.04.04.2018 table 1)

  Some controls shall be carried out on the concrete of the new foundations. These controls consist in the casting of n. 6 cubes of concrete of side 15 cm, casted using the same mix of the realized foundations. The six samples shall be subjected, within 28 days of the casting, to compression tests by a certified laboratory.

For **RESTORATION WORKS** like grouting and reparation of joints:

- premixed mortar for masonries, salt-resistant, cement-free premixed mortar composed of natural hydraulic lime and Eco-Pozzolana, natural sands, special additives and microfibers (type Mape-Antique Allettamento by MAPEI S.p.A. or another type with same technical characteristics and performances)
- mortar for masonries, based on natural hydraulic lime – NHL 3.5 according to EN 459-1, ground fine calcareous sand, inorganic coloured earth, free of organic components (type RÖFIX 952 or another type with same technical characteristics and performances)
- mortar with of pure natural hydraulic lime NHL 3.5 and mineral binders, extra-fine natural pozzolana and inert siliceous sand and dolomitic limestone in particle size curve 0 - 1.4 mm (type Biocalce® Pietra by Kerakoll or another type with same technical characteristics and performances)

2.2.1.4 Cleaning system

Tangential sandblasting (e.g. JOS or IBIX system) must be carefully tested, it'll be necessary to define:

- the correct pressure (e.g. different pressure level 0.2 ÷ 4 bar)
- the correct aggregate
    - o calcium carbonate (e.g. CarbonArt by IBIX)
    - o garnet sand
    - o natural aggregates and other (e.g. corn cobs, IBIXART by IBIX, etc.)

2.2.1.5 Aggregates for mortars

All mortar aggregates should be siliceous (sand, grits and gravel).

## 2.3 Services and tests to be performed by the contractor before beginning of the works

At the beginning of the implementation phase and after installing the scaffolding, the contractor must:

- **CARRY OUT SOME CHEMICAL AND PETROGRAPHIC ANALYSIS ON MORTARS AND STONES** in order to define the composition of the original materials and define the most compatible restoration materials (mortars, stones, plasters ecc).

  **Mortar and stones investigations** must comply at least with the CEN/TC 346 – Conservation of Cultural Heritage, following:

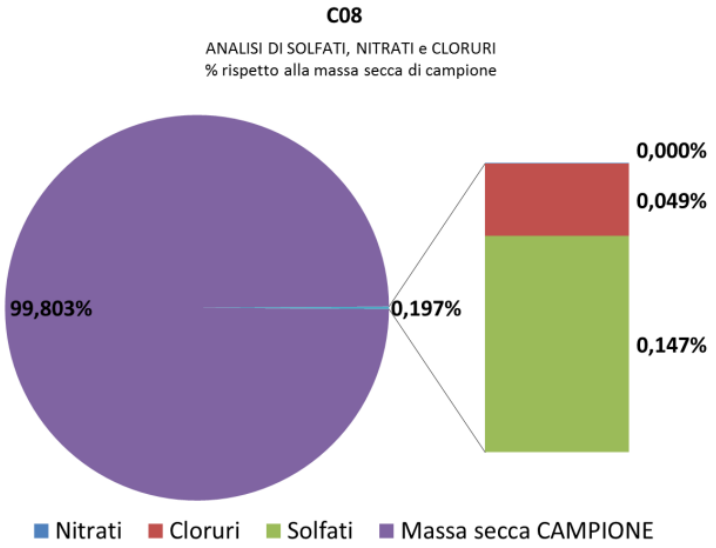
  - EN 17187:2020 - Conservation of Cultural Heritage - Characterization of mortars used in cultural heritage
  - EN 15898:2019- Conservation of cultural heritage - Main general terms and definitions
  - EN 16515:2015 - Conservation of Cultural Heritage - Guidelines to characterize natural stone used in cultural heritage
  - EN 16455:2014 - Conservation of cultural heritage - Extraction and determination of soluble salts in natural stone and related materials used in and from cultural heritage
  - EN 16085:2012 – Conservation of Cultural property - Methodology for sampling from materials of cultural property - General rules

  The execution of the investigations must follow these steps:
  - submission to the works manager of an **investigation plan** specifying where and how many samples will be taken
  - approval of the plan by the construction manager and the work supervisor
  - execution of samples and laboratory analyzes
  - delivery of the final report with the results of the analyzes and updating of the location of the samples, correlated with graphic and photographic documentation

  Three types of analysis that must be carry out on samples:

  - Quantitative determination of salts (sulphates, nitrates and chloride) – **at least 10 samples**

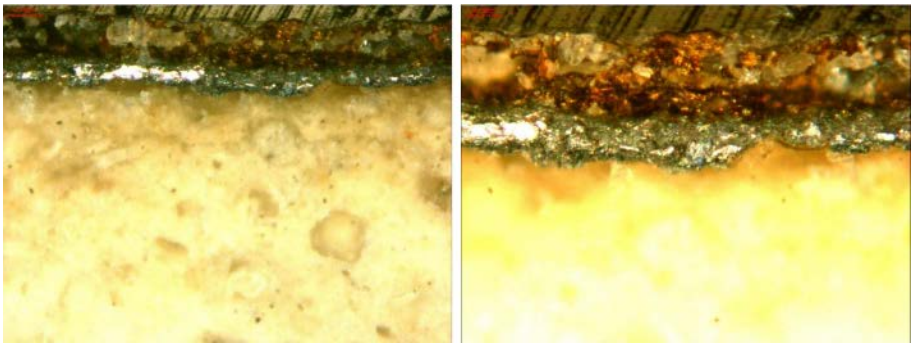
The extraction method should be used for the determination of soluble salts in order to evaluate the state of conservation of stone materials. Soluble salts can be present both as natural constituents of the stone and as products of its degradation, or derive from materials used in restoration interventions, from pollution or from the capillary rise through the walls; they can react and trigger chemical phenomena that can cause the stone to deteriorate.
For the qualitative and quantitative analysis of soluble salts, the photometric method should be used, in order to determine the percentage by weight with respect to the initial sample for each individual ionic species (sulphates, nitrates and chlorides). For the extraction of the salts from the samples under examination (about 100mg taken from the sample after drying in a stove at 60 ° C for 24 hours, grinding in an agate mortar and sieving on the sieve 0.100mm) double distilled water (100ml) should be used with slow stirring for 2 hours. The suspension should be filtered (black band filter) and measured by means of an ion chromatograph. The results of the analysis should be expressed as a percentage by mass with respect to the initial mass of the dried sample.




*% by mass of the ions with respect to the initial dry mass of the sample*

- Optical microscope analysis on glossy section (for the stratigraphic / morphological analysis of the sample) – **at least 10 samples**

  The analysis is carried out on micro-samples of material after creating a shiny section. The sample is first incorporated in transparent resin, then cut with a precision panel saw and then mirror polished with a lapping machine on abrasive paper with gradually decreasing grain size. The surface is then analyzed by means of a stereoscopic optical microscope with video camera suitably calibrated at magnifications varying between 28X and 1000X depending on the stratigraphy to be observed. The images do not show spherical deformation and are calibrated both as regards the color and the geometry; in this way it is possible to measure, for example, the thickness of pictorial layers or the dimensions of granules of material or pores. Through a special image analysis software it is possible to vectorize the images and then produce statistical processing regarding the parameters measured in a semi-automatic way (e.g. distributions porosimetric, granulometric curves, etc)

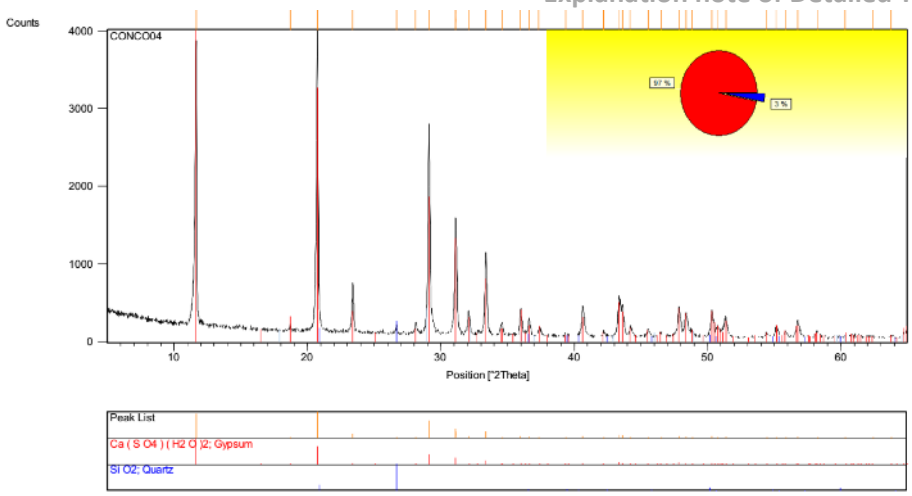


*Morphological and microstratigraphic analysis on shiny section with optical microscope*

- Characterization of the material using XRD - X-ray diffraction (for the chemical / physical analysis of the mortar) - **at least 10 samples**

  The characterization of the material by diffractometry should be performed on a sample properly ground with an agate mortar and prepared for analysis according to the method of powders.

  The X-ray diffractometry allows you to perform a qualitative characterization of the material (identification of the crystalline phases) and, through a specific calibration procedure, it is possible to perform a quantitative analysis. Spectrum analysis also allows you to determine the size of the crystallites and their possible deformations.




*Chemical / physical analysis with X-ray diffraction (XRD)*

Once the composition of the mortars and stones has been identified, it will be possible to define the most compatible restoration materials.

- **VERIFY AND UPDATE THE MAPS OF THE DECAY** - The maps, although based on orthophotoplans (1:50) produced from a drone survey, must be updated and checked. The in-depth visual investigation can only be carried out with scaffolding installed, with the possibility of observing and analyzing surfaces closely. This service must be performed by a professional with the qualification of Restorer of Cultural Heritage equipped with official accreditations and certifications.

- **PERFORMANCE TESTS ON ALL RESTORATION MATERIALS AND PROCEDURES**- all products for restoration and processes must be tested by the contractor and approved by work management from UNDP. The tests must be conducted at least for:

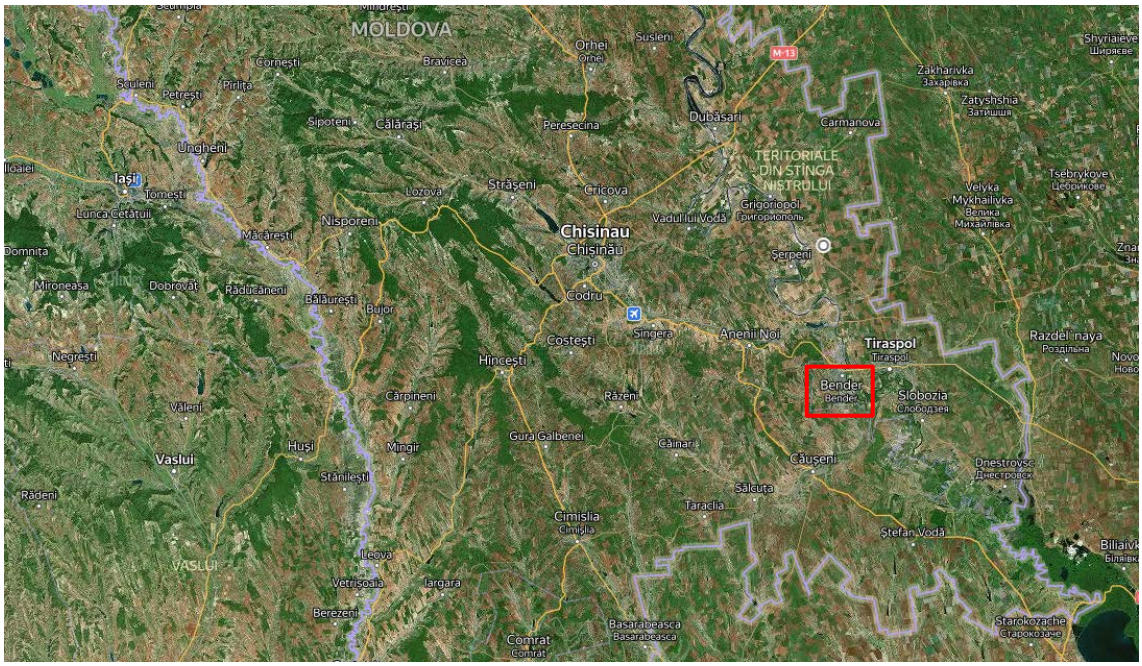
    - Cleaning techniques
        - Biocide
        - Consolidation products (at least ammonium oxalate, ethil silicate and nano-lime)
        - Restoration mortars and glues. At least:

- Structural
    - injections (for micro-cracks nucleus consolidation, for nucleus void filling)
    - for installation layers
    - for installation of metal elements
- For restoration (grouting and reparation of joints)

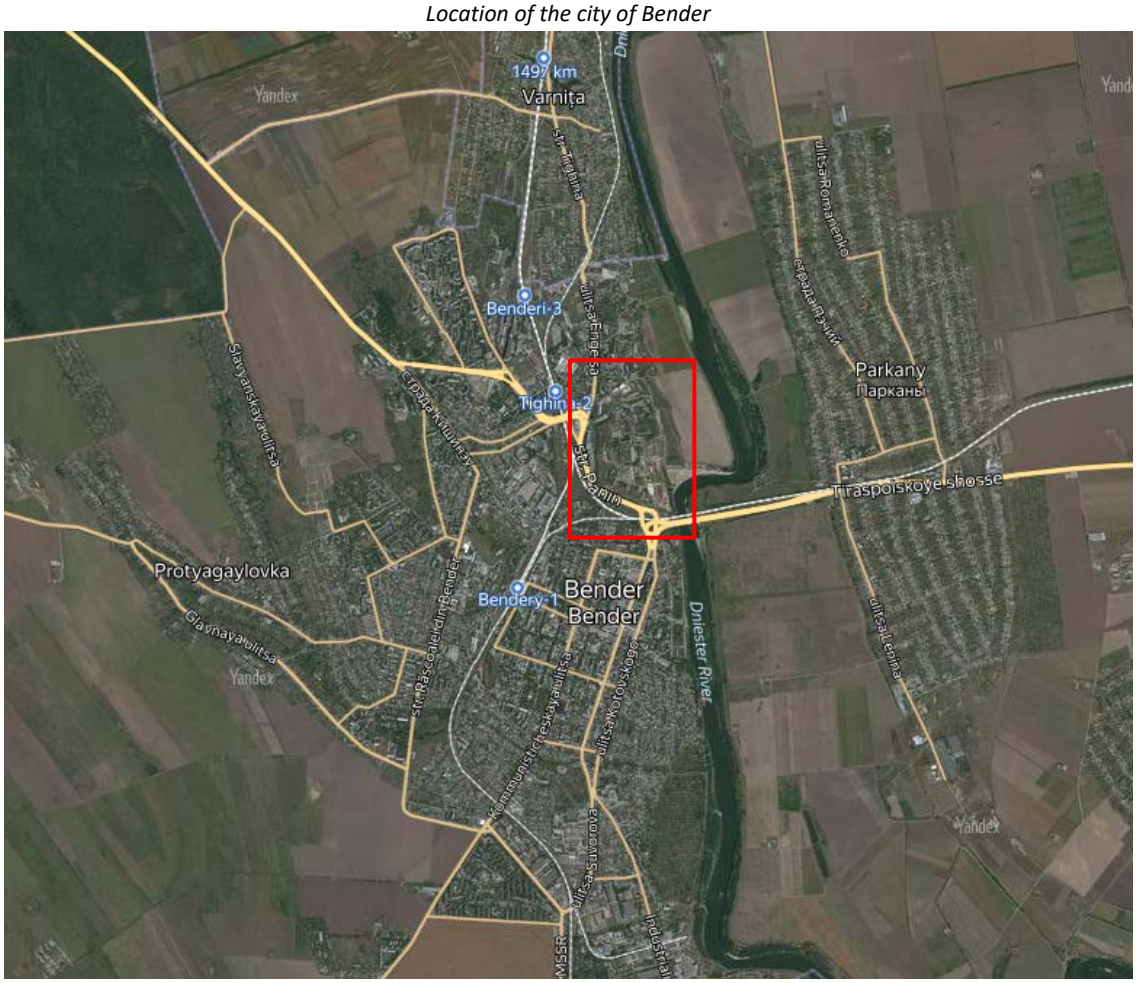
Once the scaffolding will be installed, during the construction site, the contractor must complete the BIM model by adding all the information relating to the materials, the stratigraphy, the degradation phenomena etc. After works the contractor must add to the BIM model all the information relating to the materials, the stratigraphy of all elements (masonries, floors and roofs etc.) and the interventions performed etc. At the end of the intervention, the model must be enriched with information on the intervention as carried out (all information “as-built”).

# 3 Initial data, general data and nomenclature

The fortress of Bender is located on a slightly elevated position, in the north of the center of Bender/ Tighina a city near the Dniester river, in south-east Moldova.

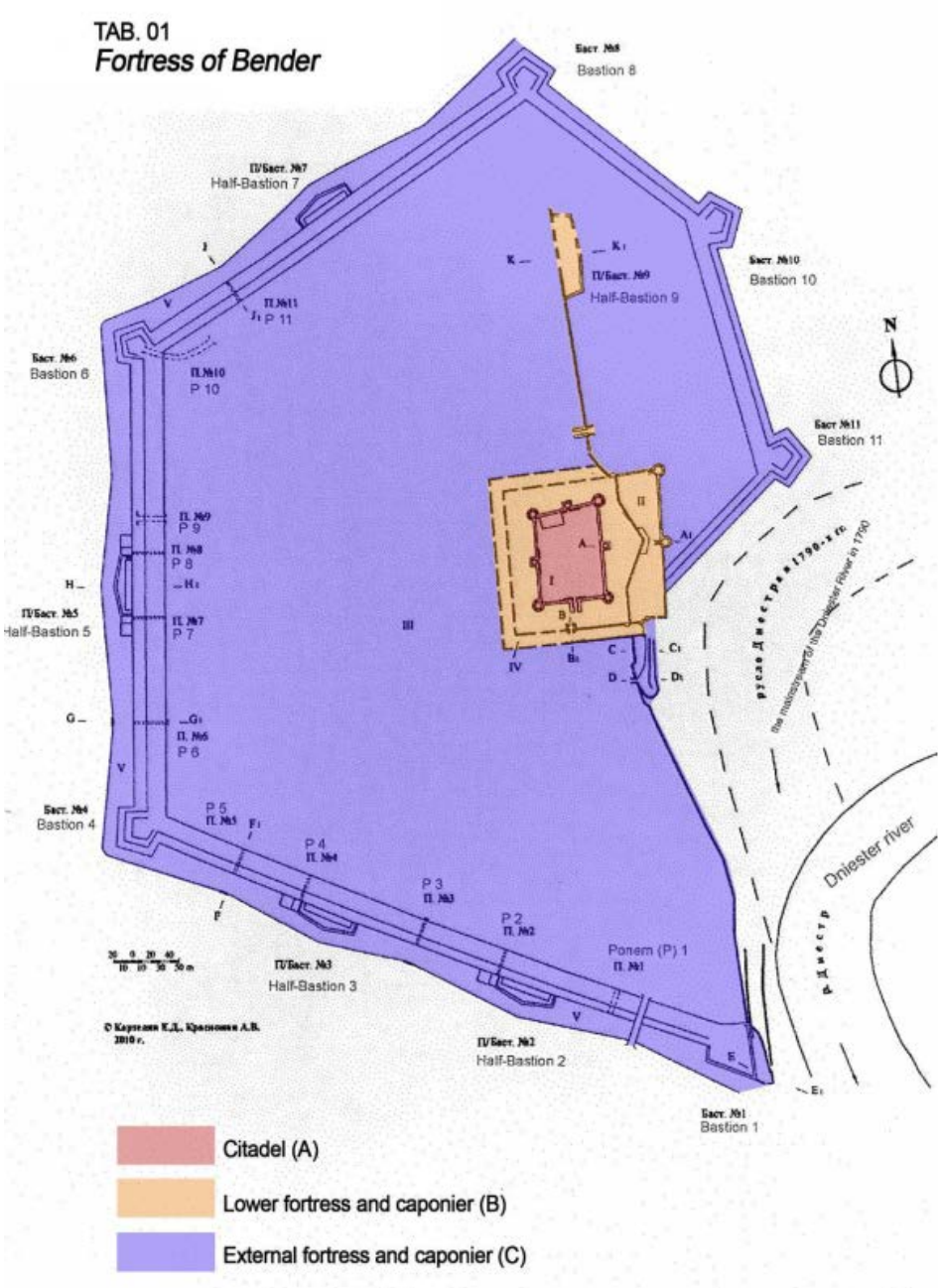



*Location of the city of Bender*



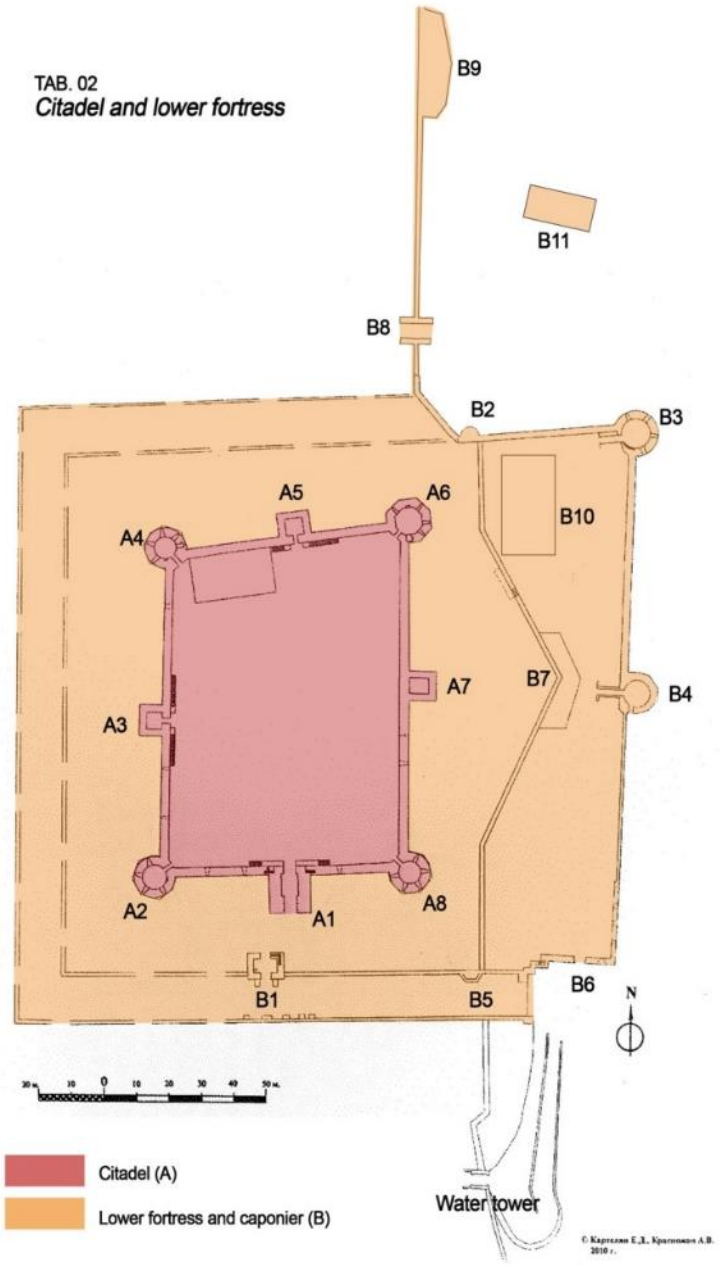

*Location of the Fortress into the city of Bender*

It is substantially composed of three main parts: the Citadel, the Lower Fortress and the outer Fortress.




The fortified complex is located in a peripheral area characterized by the presence of partially disused industrial buildings and by a military settlement within the outer boundaries of the fortress.

For a clear identification of the portions of the Fortress, please refer to the nomenclature shown in the following diagram.


TAB. 02
Citadel and lower fortress
B9
B11
B8
B2
B3
A5
A6
A4
B10
A7
B7
B4
A3
A2
A1
A8
B1
B5
B6
N
Citadel (A)
Lower fortress and caponier (B)
Water tower

# 4 Description and evaluations of the actual state of the Citadel and Lower Fortress

The diagnostic campaign, carried out through different types of investigations, allowed to define the main characteristics of the elements that form the Citadel and the Lower Fortress.

Archaeological tests, seismic analysis of the terrain, tomography, georadar and penetrometric tests were carried out. The collected data were crossed with the historical information found in the archives and in the specific bibliography.

All the elements (soil, foundations, walls, etc.) of the Bender fortress are the result of the numerous changes that have occurred over time due to natural disasters, to invasions (with destruction and reconstruction) and to new buildings for new needs to which the monument was subjected.

This chapter includes the evaluation related to the results of the surveys conducted on material, building techniques and components on their decay and structural instability phenomena.

## 4.1 Survey to define geometrical characteristic and to create a database of the Fortress

The design professional team carried out a survey that provides for the coordinated use of various techniques and instruments: drone, laser scanner, point cloud and true view.

**All the services were carried on with the aim of producing a unique work base, useful also and above all for future interventions to be carried out on the fortress, through 3D modeling with Revit, an Autodesk software for architectural, structural and restoration design.**

First, a geodesic micro-mesh was designed on the internal and external area of the complex, and then a denser micro-network was created in connection with the previously established mesh so that the materialized vertices allow the geo-referencing of all Plano-Altimetric, 3D Laser and Drone survey activities. Then it was conducted the 3D Laser Scanner survey. The sights were positioned for geo-referencing scans to the topographic micro-network; the scans acquired the HDR color data associated with the point cloud; all point clouds have a density of scans such as to define the elements for a 1:50 scale return of plants, elevations and sections. To obtain the best resolution and best color rendering in the return of the orthophoto of the prospects, the photogrammetric survey was associated with the scans.

Then we conducted a photogrammetric survey from the ground and with drone for the generation of orthophoto of elevations and facades, but also for the aerial view of the Citadel and Lower fortress.

Geometrical survey drawings for individual elements were also produced.

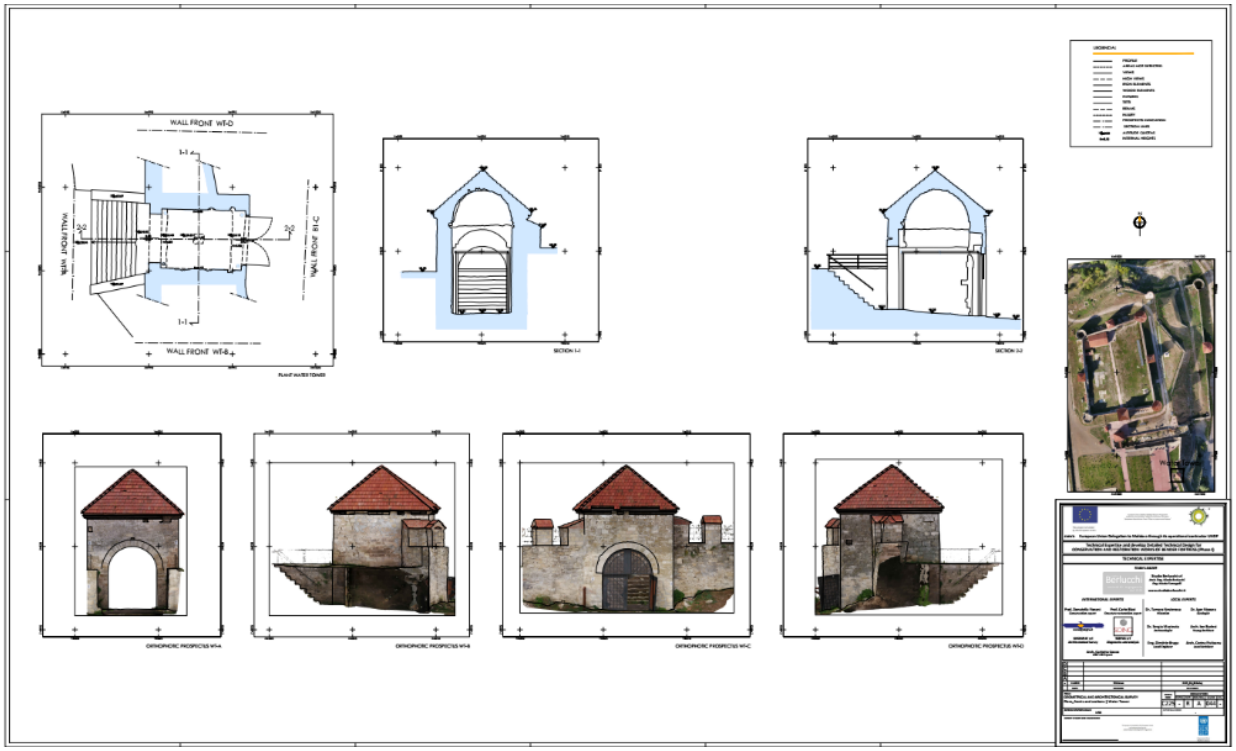
Below are some explanatory images.

*Aerial views of the citadel and the low fortress by drone*

*Views of the point clouds of the fortress*

*Point clouds and Photogrammetry together*

*Example of ortophoto*

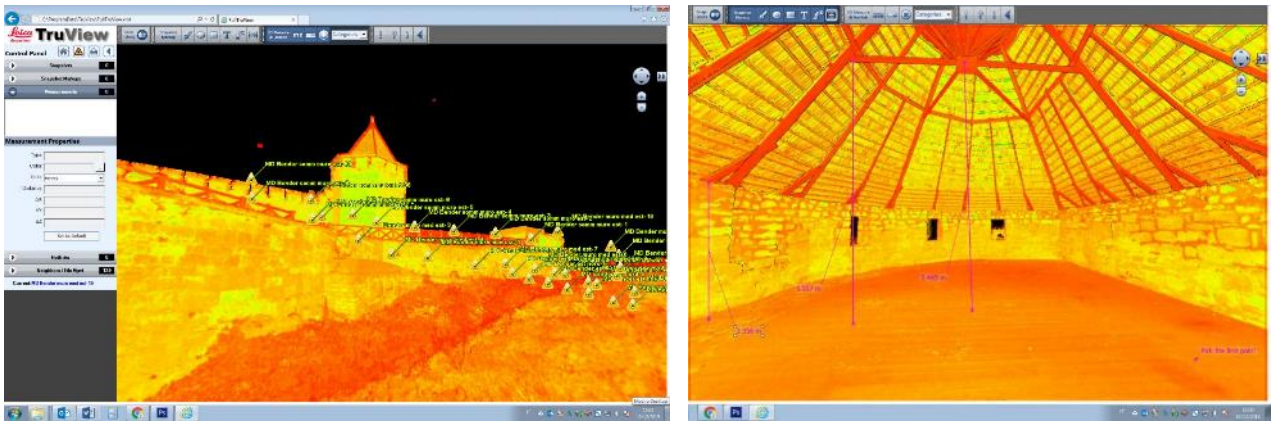



*Example of detailed geometrical and architectonical survey*

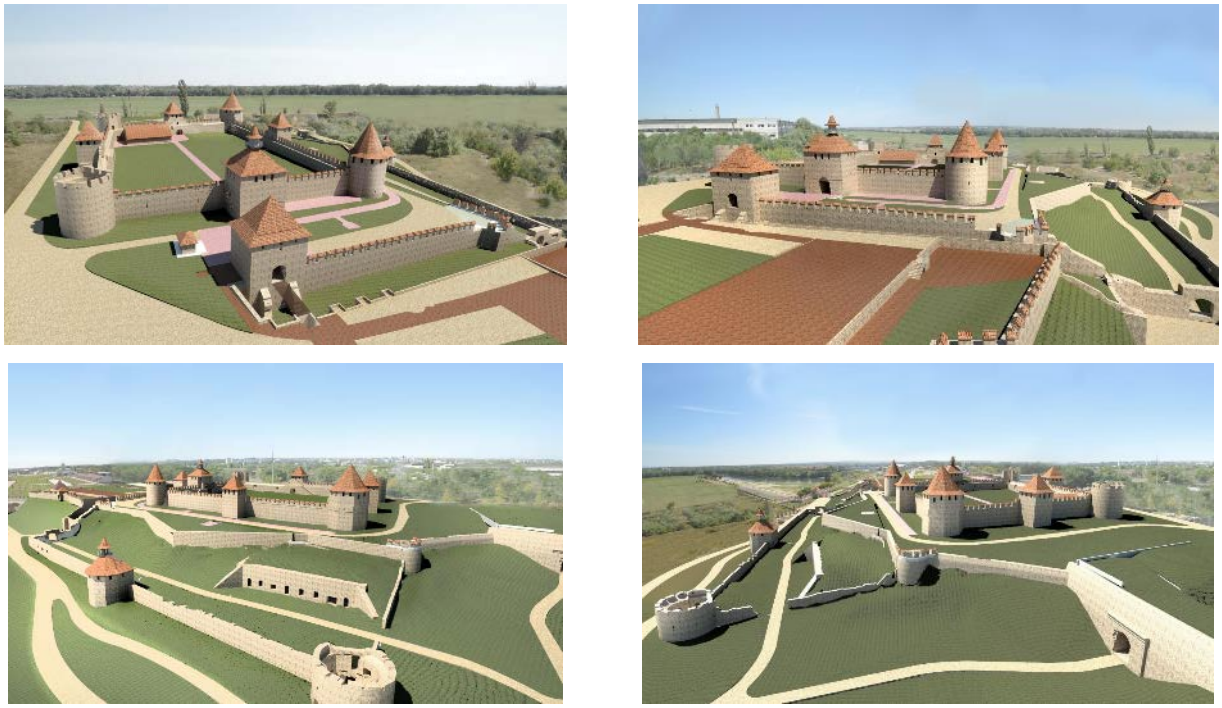
The results of this campaign produced two of the most innovative tools for cultural heritage, in particular for the future planning of interventions on the Bender Fortress:

1. the TRUE VIEW, i.e. the possibility of querying the point cloud of the laser scanner survey to check detailed situations at any time
2. the 3D MODEL for BIM design, built through 3D modeling in Revit, starting from the import of the point cloud. This will allow you to have at any time all the plants and all the sections necessary for any type of work to be carried out on the fortress.

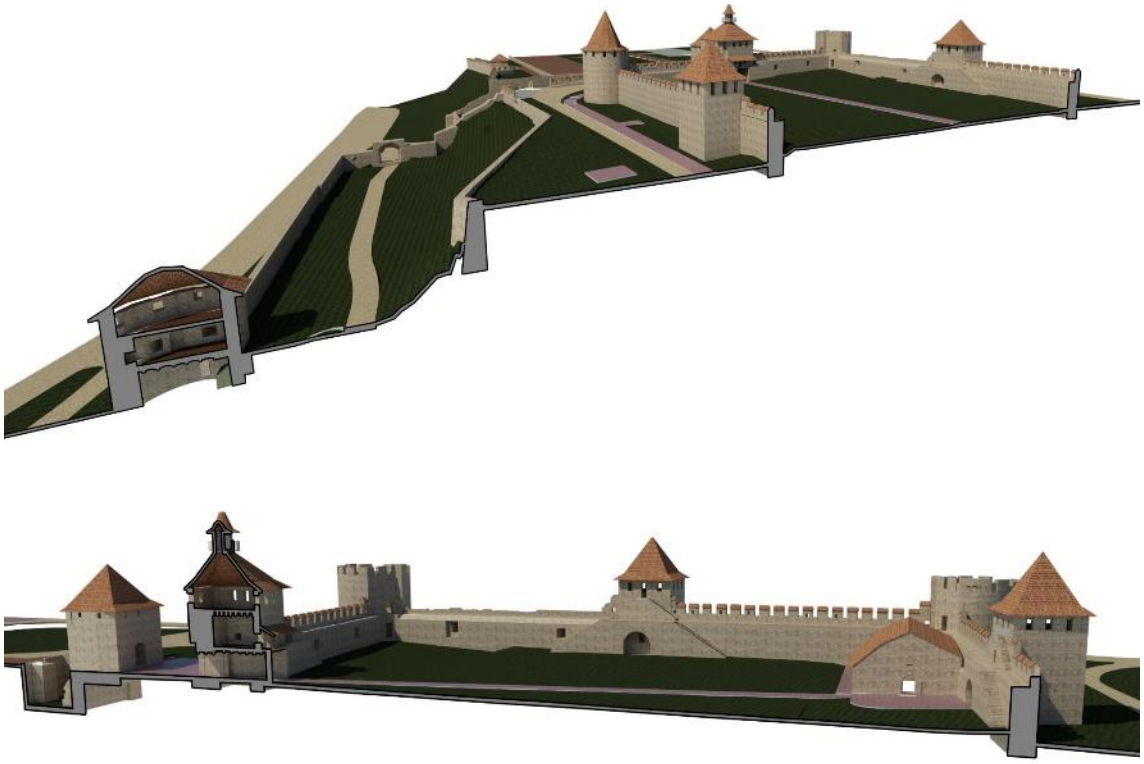
Below are some explanatory images.




*True view with commands for querying the point cloud*



*3d model views of the fortress*



*Perspective sections of the 3d model of the fortress*

The result of this survey is the availability of precise graphic representations of the actual geometric forms of the monuments (including possible deformations, discontinuities and cracks as a basis for registering all information about materials, construction techniques, decay phenomena etc.) anywhere in the fortress, anytime. It's a geometric and architectural database of the fortress that allows to avoid the preparation of a new survey at every intervention to be performed (even if only for maintenance). If kept constantly updated with the new intervention steps, at each new construction site it will already contain all the information relating to the previous project.

## 4.2 Construction techniques and main issues: Foundations and ground

From ground and foundations point of view, the three different situations identified can be localized in the three main portions of the fortress: the Citadel, the Rampart B7 and the Lower Fortress.

The investigations on the **Citadel**, in particular on the A5 and A6 towers, highlighted the foundation plan at about 2.80 m from the current level. The archaeological excavations confirmed the presence of landfill to that depth, also providing an interesting detail on the construction technique of the foundation above, which appears to have different masonry texture and different mortars. Historians and archaeologists should explore the hypothesis of the presence of a pre-existing fortress.

The electromagnetic (EM) investigations indicate the presence, in the subsoil of the Citadel, of metal objects, attributable to the bases of the benches or reinforced concrete blocks and to the large drainage channel in reinforced concrete present on the Rampart B7.

The 2D and 3D tomographic investigations revealed a stratigraphy of the terrain in the West-East direction which presents a strong anomaly at the **Rampart B7**, due to a carryover of the soil. This situation was

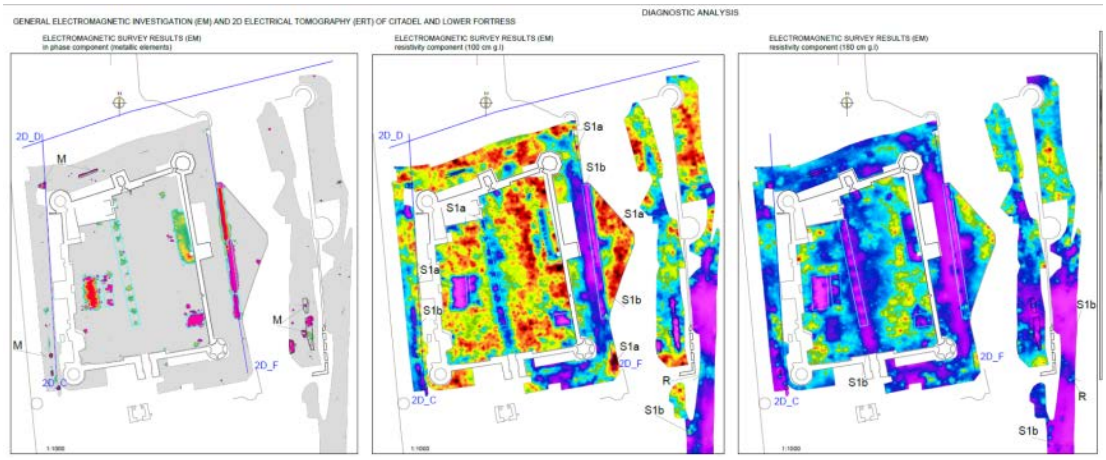
confirmed also by the archaeological excavations, which highlighted how the foundations of the Rampart are at a depth of 1.5 m from the current level of the low boundary, but resting on inconsistent soil. Rampart B7 is essentially a 12 meters high artificial bastion. Historical research has further confirmed the anthropic construction of this bastion.

The Citadel was build on the morphological terrace rim. Later, in order to build the new bastion to the east, it was founded lower over the rim, and the area between the citadel walls and the new bastion slope was replenished with landfill. The historical maps preceding the new rampart confirm this view, showing the citadel located on edge of a slope. As specified in our historical research this rampart

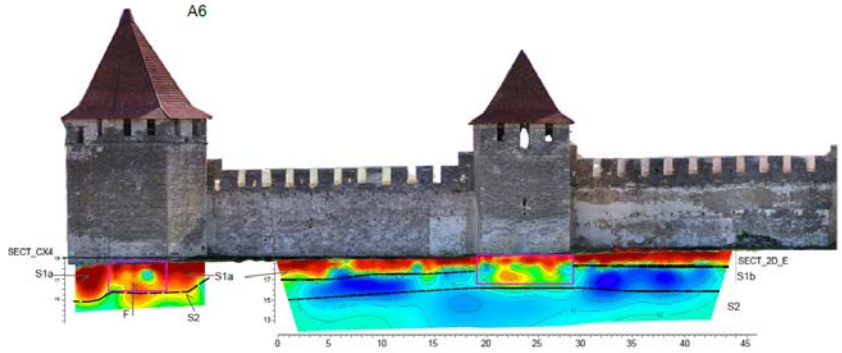
"can be related to the works of adaptation and strengthened of the fortress made by the architect Hasan Ağa and the French engineer Francois Kauffer in the last decade of 18th century (1791-94)".

According to tomographic sections the **Lower Fortress** has about 2 m deep foundation from ground level which lie on alluvial deposits. The incoherence of the soil is confirmed also by drilling tests.

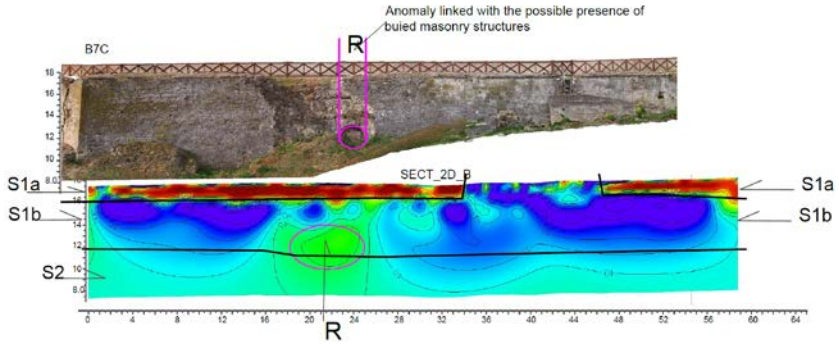
**The research allows concluding that the natural looseness of the soil and the presence of large volumes of landfill modified several times, can be considered the main causes of foundation subsidence that the fortress seems to show in various areas.**




*Geophisical investigations - Plans*




*Geophisical investigations and foundation levels*



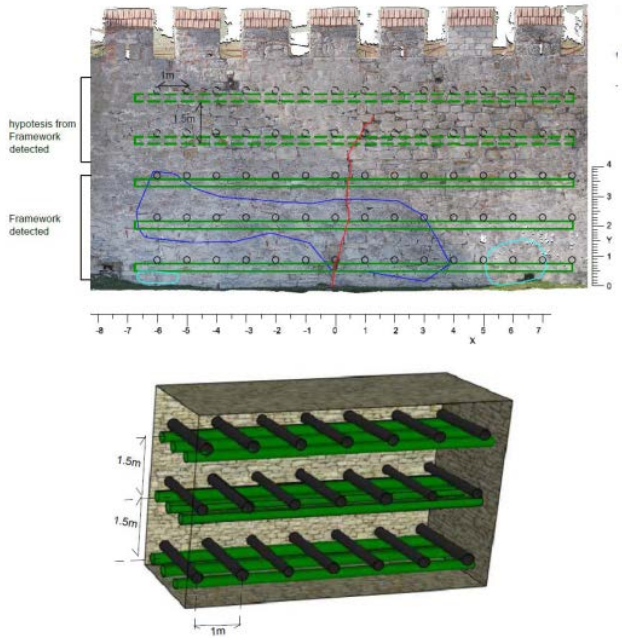

*Geophisical investigations and foundation levels*

*Archaeological excavations on Citadel and rampart B7*

## 4.3 Construction techniques and main issues: Fronts, elevations and masonries

Thanks to historical research and to GPR and videoendoscopy survey it was possible to define reliably the **construction technique of masonries**.

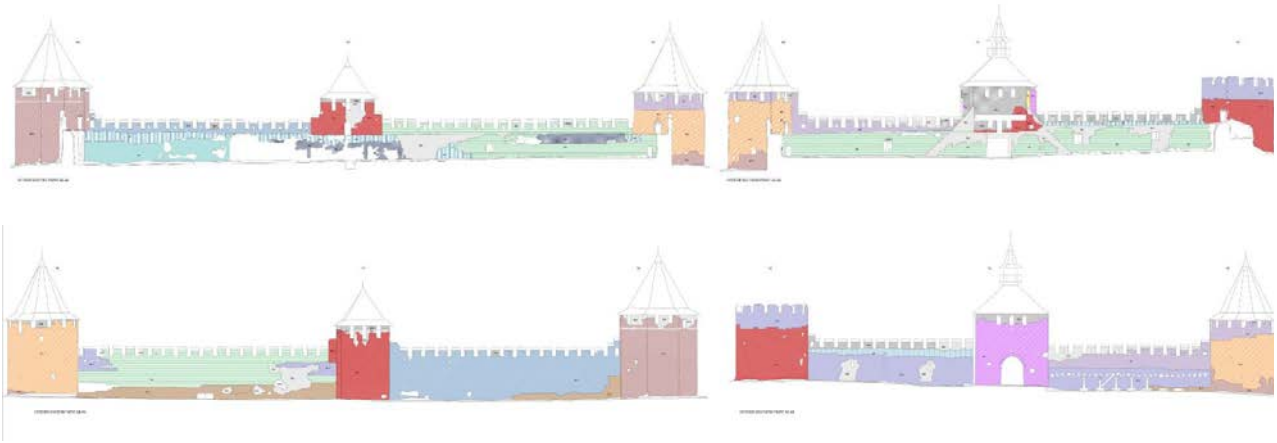
The system can be related to the Turkish building tradition, it is formed by a two stone faces connected with a nucleus composed with stones, mortar and a timber system of reinforcing, made by a “net” of wooden beams.




We have identified 26 different **masonry types**, including the last interventions of reconstruction. All of these masonry types use the local limestone, a well carved and resisting stone available not far from the site; often

the same stones have been reused for the later reconstructions. The traditional mortar with sand and lime, used for centuries, has been recently replace by cement.

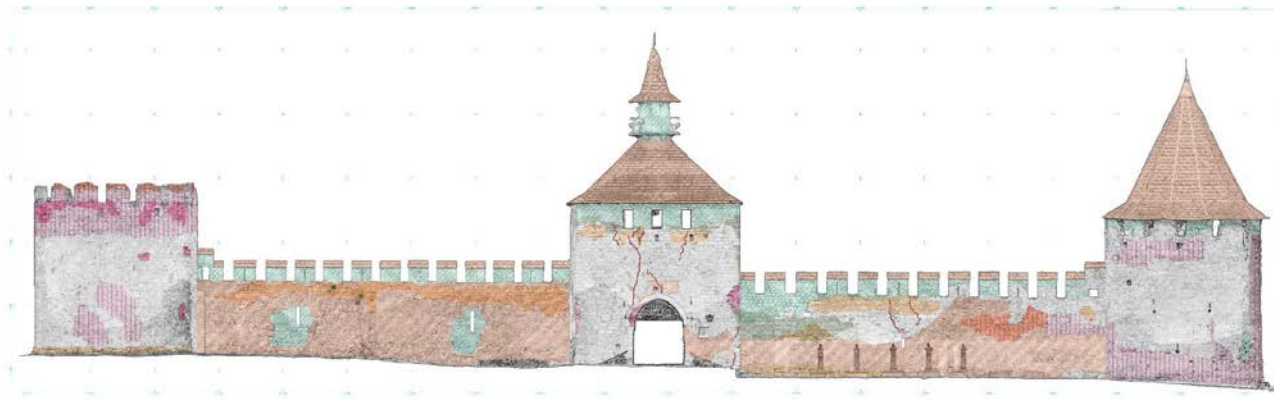
Then we've defined the stratification succession of these masonry types form 1538 to our days in 9 phases.



The walls show several problems from the conservative point of view, these problems derive from a **combination of the weaknesses due to the construction technique (for their own features and for the heterogeneity deriving from the many reconstructions), the recent history of abandonment and the atmospheric agents connected with the environmental climatic conditions of the Bender area**.

In the portions of masonries where the investigations were carried out and where stratification is visible, **the wooden structure inserted in the walls has been totally lost**. It is very probable that this decay phenomenon is extended to all the masonries. This can be a significant structural weakness for the masonries, which have a nucleus interrupted by horizontal levels (about every 1,50 meters in height) of empty space and broken material.

The presence of these voids and sometime the different building phases of the two wall facing of the same wall combined with the harsh climatic conditions of the Bender area, have favoured some **decay phenomena** currently visible on the masonries at different stages of progression (and properly mapped into the drawings named "Decay phenomena and cracks mapping").



*Stone surface mapping*

These phenomena concern above all the **wall facing of masonries**.



The first stage of decay is the **loss of mortar joints**, usually caused by the washing away of rainwater, freeze-thaw cycles and erosion of atmospheric agents.

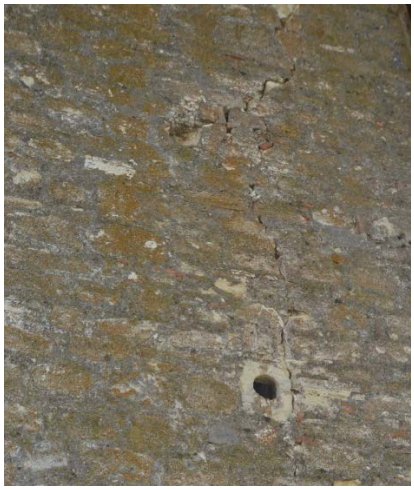
The infiltrations and the progress of the decay phenomena of the mortars often cause the **loss of single stones** or even the **swelling and the collapse of portions of the walls**. Even the presence of shrubby vegetation, especially when very rooted, can cause the detachment of stones.

These decay phenomena combined with the effects of the subsidence of the soil, increase the structural weaknesses which are revealed in the form of cracks (more or less deep) up to considerable detachments and collapses of the wall facing.

**Therefore, the priority must be to secure, from a structural point of view, the citadel and the lower fortress, in order to allow visitor's safe use. In this phase the structural works will be concentrated on Tower A6, Tower B3 and Water Tower (please see Structural chapters and Structural Project drawings). Securing works will involve also the masonries of the Citadel.**



Another very frequent decay phenomenon in monuments that, like the fortress of Bender, "live" substantially outdoors and in symbiosis with the surrounding context is the **biological patina** and **shrubby vegetation**.



The biological patina present on the walls of the fortress of Bender does not appear particularly aggressive. Surely, it will be necessary to remove it and to clean very well at least the surfaces where other works will be carried out in order to provide suitable supports to receive consolidation, grouting, reintegrations, etc.

The weed vegetation seems to be concentrated in the areas less frequented by visitors and at the collapses of the low fortress, as well as along the existing drainage channel.

Surely, it will be necessary to remove it and to clean very well at least the surfaces where other works will be carried out in order to provide suitable supports to receive consolidation, grouting, reintegration, etc.

## 4.4 Incompatibility of recent interventions

We identified some recent interventions that we should take into consideration to define the state of conservation of the fortress:

- Cementitious patches
- Cement plaster
- New roofs with metal structure and “Marseillais-type” tiles

The first two issues refer to the **incompatibility of the material used in the repairs** from a **chemical-physical point of view**.

It is important to underline that the use of cement in plasters and mortars can be very harmful to original stones in geographical areas subject to freeze-thaw cycles such as Bender, because of its high saline component and its different thermal expansion compared to the existing stone and mortar. This can cause fragmentation, detachments and collapses of stones. It is also important to underline that these phenomena often occur in combination with each other and their evolution is faster where the decay has already started.

The third issue refers to the **incompatibility of restoration solutions from the historical and cultural point of view**.

Marseillais-type tiles are not a local or traditional material. It is an industrial product that has no history in the Bender fortress. The use of this material returns an image of the fortress that never existed.

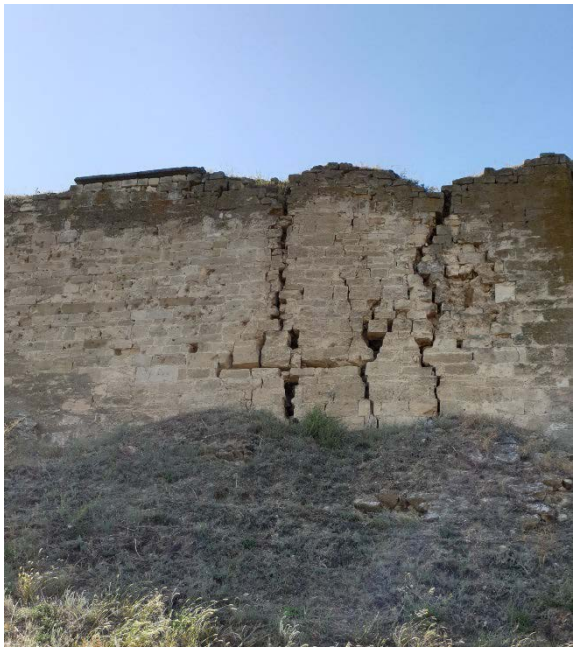
**In this phase this issue will be addressed on Tower A6, Tower A3, Tower A2 and Tower A4 (please see also Architecture chapters, Structural chapters and Project drawings). Restoration works will involve also all battlements of the Citadel.**

## 4.5 Issues in the safe use of the monument

In the use of a monument so exposed to atmospheric agents and to the rigidity of the climate, the problems in ensuring the safety of visitors are always numerous.

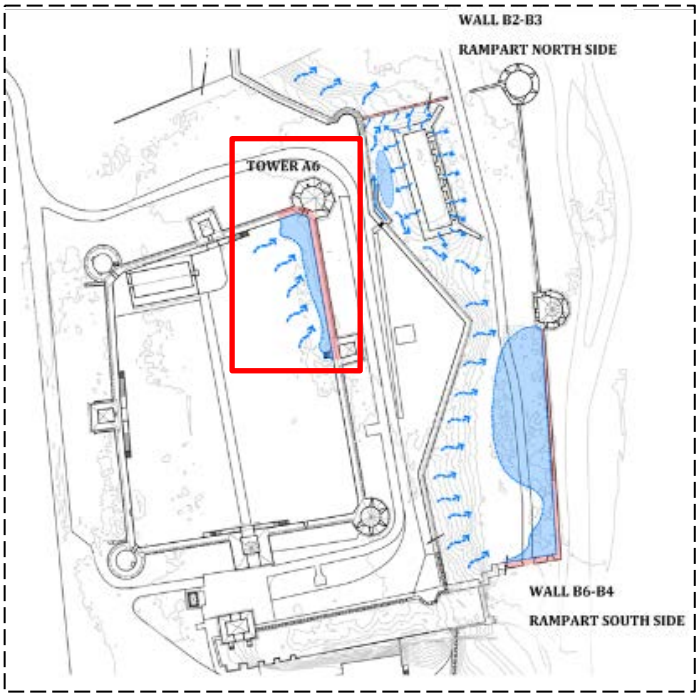
The problems we believe we need to solve primarily are:

- the **deviation of the visitors' path** away from the Rampart B7 (seriously compromised from a structural point of view), for which no interventions are foreseen in this lot of works because structural monitoring of at least one year is currently underway



The arrangement of the patrol path and all the parapets to avoid falls from a height

## 4.6 Problems in the drainage of rainwater




The drainage of water in the citadel is the main critical issue regarding the drainage of surface water.

The studies on the slopes of the land have shown a stagnation at the A6 tower.

This stagnation could be one of the triggering factors and in any case contributes to aggravate the structural problems of subsidence of this portion of the fortress.

Action is required to limit the accumulation of water at the A6 tower.

# 5 Summary of the interventions planned and designed in this phase

The interventions listed in this chapter are those considered to be a priority for the safety of the main structural problems and, consequently, for the safe use of the fortress by visitors.

The interventions listed here are fully described in the following chapters

ARCHITECTURAL AND RESTORATION INTERVENTIONS

- Restoration and completion of towers A2, A3 and A4 and walls between them (guideline for future restoration interventions)
    - Walkways, stairs and patrol path
        - Arrangement and repair of walkways and stairs over the curtains
        - Installation of new railings/fences made in Cor-ten all over the walkways and stairs
    - Battlements
        - Replacement of Marseillais-type tiles with terracotta flat tiles
        - Reconstruction of the masonry battlements
    - Stone surfaces
        - Complete restoration of internal and external stone surfaces
        - Cleaning, consolidation, saving of collapses, removal of dangerous recent interventions
    - Roofs
        - New roofs on towers A2 and A4 (wooden structure and tiles)
        - Substitution of roofs on towers A3 and A6 (from metal structure and Marseillais-type tiles to wooden structure and wooden tiles)
- Recent interventions
    - Rebuilt previously existing elements:
        - new battlements – replacement of Marseillais-type tiles and glazing with highly diluted natural hydraulic lime mortars
        - new stairs and masonries- glazing with highly diluted natural hydraulic lime mortars
    - Built elements that probably never existed:
        - closure of the inner side of the middle towers – visual mitigation through limewashing
- Securing and repair of stone façades
- Rampart B7: securing interventions for visitor's accessibility
- Patrol path, walkways, stairs and railings
    - arrangement and repair of walkways and stairs over the curtains
    - installation of new railings/fences made in Cor-ten all over the walkways and stairs
- Drainage system
    - Ground modelling
    - Restoration and maintenance of existing channels
    - New connections between channels

STRUCTURAL INTERVENTIONS

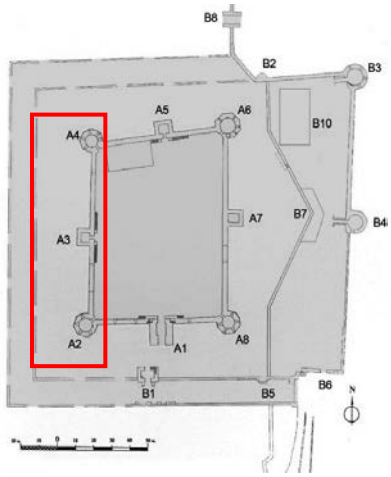
- the reinforcement of masonry of the Citadel with spread injections and artificial bondstones in a specific test area in order to carry out a pilot project;
- reinforcement of Tower A6 with two orders of tie-rods on the existing wooden decks;
- reinforcement of Water Tower with two couples of metal tie-rods and a new foundation curb made in reinforced concrete;

- Reinforcement of Tower B3 with an external joint grouting with stainless steel strands Ø6 mm inserted inside eight mortar joints;
- New roofs for towers A2, A3, A4 and A6 consisting of a primary and secondary structure in solid wood covered with wooden shingles.

# 6 Architectural and restoration works

The critical issues encountered are numerous and will have to be resolved in several intervention lots. The interventions listed in this chapter are those considered a priority for the conservation of the monument and for the safe use of the fortress by visitors.

## 6.1 Restoration and completion of towers A2, A3 and A4 and walls between them (guideline for future restoration interventions)




This is an area where reconstruction works have been carried out with techniques that are not fully compatible with the monument (reinforced concrete beams, cement mortars, roofs with Marseillais-type tiles etc.). These works, however, do not involve the whole area but only the roof of the A3 tower and the masonry between the A3 and A4 towers; much of the historical structure is still fully visible.

For this reason we believe that it can be a "sample area" where restoration interventions must be carried out according to international standards, to define the **methodological guidelines for future interventions overall Citadel and on the low fortress**.

**Integrations of walls and volumes has to consider the different building periods, avoiding to flatten the image of the fortress to an ideal and unreal status that never existed.**

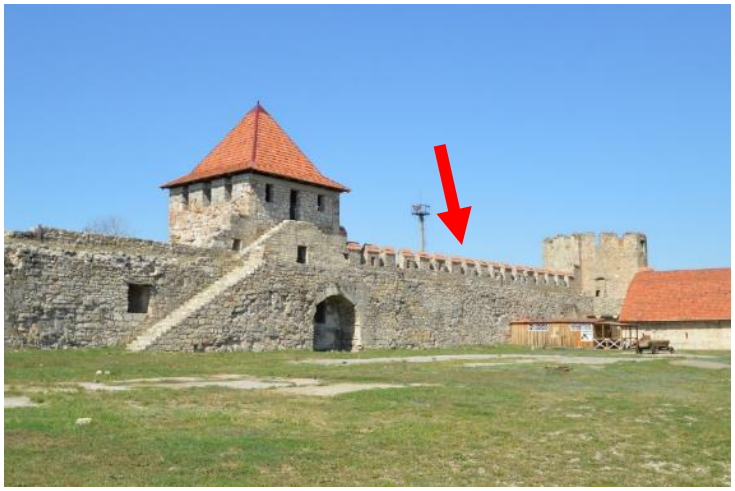
Among the possible methodological choices we choose to restore all elements preserved, carrying out restoration works to slow decay phenomena on materials and to reconstruct the elements that can give the visitor a historically correct image of the monument and a fully usable monument.

Some recent interventions on the fortress have not followed accepted restoration principles even if generically inspired by formerly accepted principles of “identical restoration” (restoration à l’identique). Our aim is not to forcefully intervene on the monument with an idea of restoration that does not take into account the cultural context. **We think that in the case of Bender's Fortress it is necessary to clarify the concept of compatibility.** Indeed, **we have chosen to guide the local vision of the restoration towards a greater compatibility of the materials with the historical architecture, and towards a greater historical compatibility and reliability of the interventions**. The action, in this area, is based on a multidisciplinary approach and consists of different interventions on the elements of architecture: walkways, stairs and patrol path, battlements, stone surfaces, roofs, recent interventions.

### *6.1.1 Walkways, stairs and patrol path*

**Synthesis of the intervention:**

- **arrangement and repair of walkways and stairs over the curtains**
- **installation of new railings/fences all over the walkways and stairs**

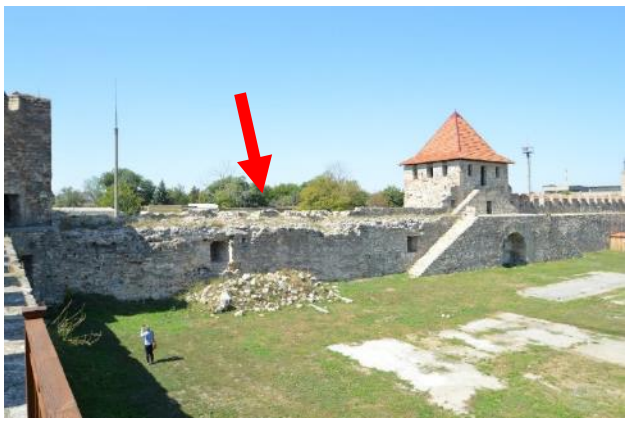


The existing recent stairs and patrol path on walls between towers A3 and A4 must be carefully cleaned by removing first of all vegetation and then deposits.

In the presence of vegetation or biological patina, it must be used a **biocide** based on quaternary salts ammonium, broad spectrum, which does not form films or chromatic alterations on stone surfaces.

After application and after the period for the action of the product (based on the technical data sheet), it will be possible to proceed with the removal and cleaning of the residues by dry removal with brushes. If necessary, a second application cycle must be carried out, in the same way and with the same timing. The cleaning can be done manually with brushes, brooms and vacuum cleaner. The unstable stones will be fixed again using (non-cementitious) mortars after cleaning and preparing the laying surface. If missing, the stones will be replaced by new ones. The missing joints should be carefully cleaned and grouted.

On walls between towers A2 and A3 the patrol path is now ruined, with lacks at the upper part of the masonry; restoration and rearrangement are here particularly necessary. This intervention must **follow the contemporary architectonical restoration principles, in particular: distinguishability, reversibility (at least potential) of the intervention and material compatibility**.



All surface deposits and weeds must be cleaned**, taking care that the top of the historical masonry still preserved is not damaged during the intervention**. Therefore, it might be necessary to stabilise moving stones with preliminary application of mortar. The restoration of the stone surfaces must follow the

indications of the specific chapter below. **The reconstruction of the patrol route resumes the shapes of the adjacent portions remained intact and guarantees the aesthetic continuity of walkways, and it must be distinguishable from the historical masonry on which it rests.** This may occur, for example, using stones of different sizes from the original, or using natural hydraulic mortars (without cement) of a slightly different colour than the original ones.

To allow the conservation of the historical parts of the monument **it will be necessary to use materials compatible with the existing ones both from the physical and material point of view, both from the historical point of view**. For this reason, **the replacement and the installation of new stone elements must take place with the same type of limestone present in the fortress**.

**All mortars must be based on natural hydraulic lime and cement-free. It is strictly forbidden to use cement mortar** due to the high saline component of cement the different rigidity and thermal expansion compared to the existing stone and mortar. These characteristics of cement mortar can be very harmful to original stones, especially in geographical areas subject to significant freeze-thaw cycles such as Bender. For more information about the sequence of processes, please refer to the mapping of the restoration interventions of the stone surfaces.

N**ew railings** will be installed to ensure the safe use of visitors (avoiding dangerous situations such as the one in the photo).

This intervention has a particularly incisive aesthetic impact on the image of the fortress and must be conducted in a unified way throughout the Citadel.

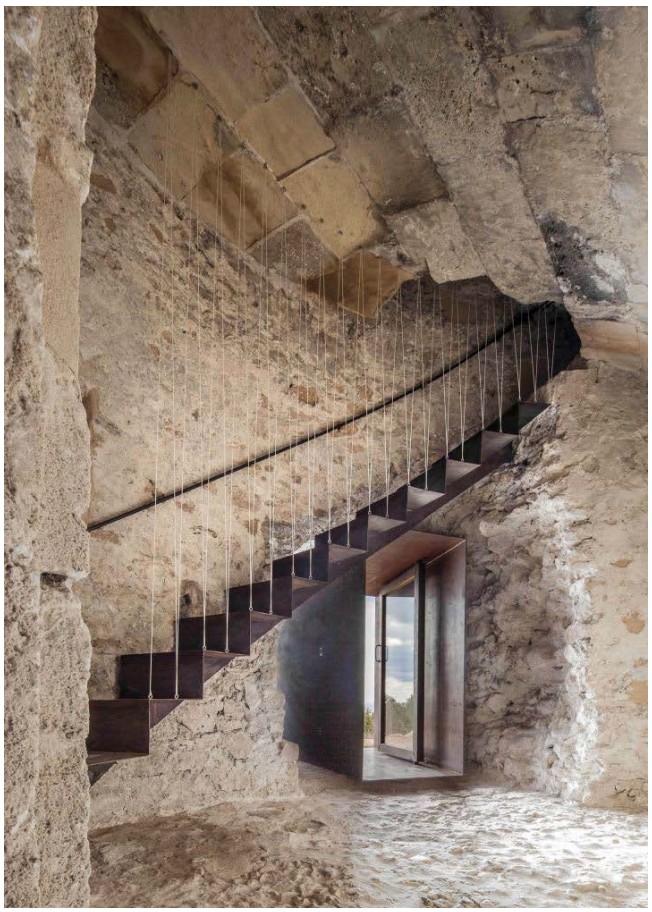
The railings will be installed directly on the patrol path. It will consist of vertical supports in Cor-ten iron with a top rail with a rectangular section and perforated Cor-ten panels according to the detailed drawings. The insertion of the metal mesh is important to guarantee the safety standards for visitors.

The Cor-ten is one of the most used materials in the restoration of outdoor monuments because it combines good performances with a pleasant aesthetics that make it particularly compatible with historic buildings.

The use of a contemporary material allows a perfect distinguishability of the intervention. Please find below some examples.

*Capo Falcone Tower, Sardinia, Italy*

*Tirolo Castle, Bolzano,. Italy*



*"Pi des Català" Tower, Formentera, Spain*

*Historical iron mine, Almeria, Spain*

Exposure to the natural elements can damage Cor-ten steel with consequent rust dipping; therefore it will be important to periodically apply a protective treatment with two-component aliphatic polyurethane paint for Cor-Ten steel (e.g. bz-COR Poliuretanica SAT-EX by OXIDACIÓN VIDMETAL, S.L or another type with same technical characteristics and performances).

The installation should be done with the following steps:

- uninstall all existing railings
- perforation of the masonry at a constant pitch of 1,20 m at the depth of about 50 cm
- fixing a threaded rod (at least 60 cm long) to the vertical supports with 3 hexagonal screws
- insertion of vertical support and bar in the holes and fixing them with epoxy resin
- installation of perforated panels welded to perimeter frames by hexagonal screws and spacer rings
- installation of handrail connected to vertical support by hexagonal screw

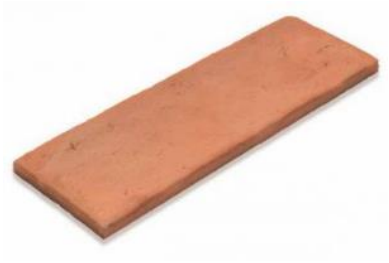
**In any case, before performing any perforation, the drilling points must be marked in advance on the patrol path, to submit them to the approval of the works manager and the client. If possible, re-use existing holes, possibly increasing their depth (if necessary) up to 50 cm.**

*6.1.2 Battlements*

**Synthesis of the intervention:**

- **Replacement of Marseillais-type tiles with terracotta flat tiles**
- **Reconstruction of the masonry battlements**

**The guidelines for the re-integration of the battlements are based on the observation of the few historical portions preserved**. As can be seen in the following images, **the battlements historically did not culminate with Marseillais-type tiles (a late 19th century industrial material) but with terracotta flat tiles**. Recent reconstructions have provided an image of these elements (and of the fortress) which is not reflected in history. We therefore believe that **the approach to restoration must take into consideration the historical materials with which the fortress was built and the image that the use of these materials generated**.




As summarized in the previous image, the battlements recently rebuilt between the A3 and A4 towers will be modified by

- replacing the “Marseillais”-type tiles with terracotta flat tiles, if there are no original tiles under the industrial one
- removing of the “Marseillais”-type tiles and restoring terracotta flat tiles, if original tiles are preserved under the industrial one.

The new battlements that will be rebuilt between towers A2 and A3 will also culminate in terracotta flat tiles.

On the battlements where the historical tiles are preserved, they will be restored and possibly integrated where missing. On the battlements where the Marseillais-type tiles are superimposed on the original tiles, they must be gently removed with their bedding mortar, taking care not to damage the historical materials. Then the historical tiles below can be restored and possibly reintegrated, where missing.

The restoration must always be done by professional restorers and certified restoration company and by using cement-free natural hydraulic mortars.

### *6.1.3 Stone surfaces*

**Synthesis of the intervention:**

- **Complete restoration of internal and external stone surfaces**
- **Cleaning, consolidation, saving of collapses, removal of dangerous recent interventions**

**The restoration of the stone surfaces must be done by professional restorers and certified restoration company**. The restoration will aim at resolving the alterations and stopping the progress of deterioration. Most of the surface alterations derive from exposure to atmospheric agents and the cycles of freezing and thawing to which mortars and stone are subjected. To this natural degradation are added the anthropic alterations of graffiti and interventions performed with materials not perfectly compatible with historical materials. The need for continuous maintenance in the elimination of weed vegetation is also evident.

**The interventions described below refer to the legend of the alterations of stone surfaces of the degradation maps, where the processes are listed in order of execution.**

The images below refer to the state of conservation of masonry between towers A2 and A3 internal side. They show well the masonry collapses, the weed vegetation, the partial absence of wall facing and the extensive deterioration of the patrol path.

The images below refers to state of conservation of masonry between towers A2 and A3 external side.






The images below refers to state of conservation of masonry between towers A3 and A4 internal side.




The images below refers to state of conservation of masonry between towers A3 and A4 external side.




All surface deposits and weeds must be cleaned, taking care that the top of the historical masonry still preserved is not damaged. The restoration of the stone surfaces must follow the indications of the specific chapter below. The reconstruction of the patrol route propose the same shapes of the adjacent portions remained intact and guarantees the aesthetic continuity of walkways, and it must be distinguishable from the historical masonry on which it rests. This may occur, for example, using stones of different sizes from the original, or using natural hydraulic mortars (without cement) of a slightly different color than the original ones.

To allow the conservation of the historical parts of the monument it will be necessary to use materials that are compatible with the existing ones for both their physic and historical features. For this reason, the replacement and the installation of new stone elements must take place with the same type of limestone used in the fortress.

All mortars must be natural hydraulic cement-free. It is strictly forbidden to use cement mortar due to the high saline component of cement and the different thermal expansion compared to the existing stone and mortar. These two characteristics of cement mortar can be very harmful to original stones in geographical areas subject to freeze-thaw cycles such as Bender.

For more information about the sequence of processes, please refer also to the mapping of the restoration interventions of the stone surfaces.

### *6.1.4 Roofs*

**Synthesis of the intervention:**

- **New roofs on towers A2 and A4 (wooden structure and tiles)**
- **Substitution of roofs on towers A3 and A6 (from metal structure and Marseillais-type tiles to wooden structure and wooden tiles)**

**The guidelines for the reconstruction of the roofs are based on the study of the historical data available (that indicates wooden structures and shingles) and on the observation of fortresses similar to Bender. Towers A2 and A4**, currently without roofs, will be equipped with new roofs made with a wooden structure and a covering made of wooden tiles. The shape of these new roofs will be similar to that of the other towers of the fortress and the construction methods used, although modern, will be compatible with the historical ones which can be found in similar fortresses located along the Dniester river.

The tower roofs of these buildings could provide a useful reference for the design of the new roofs for towers A2 and A4 of Bender Fortress. In the pictures below some examples are shown.

*Soroca fortress roofs: wooden structures consisting of a warp of beams covered with wooden tiles*

For Bender fortress, we have opted for a smaller projection of the external gutter, similar to that of the existing roofs and to other fortresses. The roof will be pitched-roof with double inclination of the flap both on polygonal towers and on circular towers. The same observation will be made for all the other roofs of the towers, to ensure greater compatibility of recent interventions with the historical nature of the monument. It's forbidden to use materials such as reinforced concrete, cement mortars, industrial tiles (Marseillais-type) and methodologically unjustified metal structures.

In this intervention lot, we will **replace the roofs of tower A3 and tower A6**, the whole interventions phases of which are fully described in structural chapters, currently built with metal structures and "Marseillais"-type tiles, materials historically never existed in the fortress of Bender.

The new roofs, as in towers A2 and A4, will be built with a wooden structure covered with wooden shingles.
These roofs will be reference for future works of revision of the other roofs, actually covered by fake contemporary tiles (Marseillais-type).

*Akkerman Fortress also known as Moncastro (Ukraine)*

*Aerial view of the fortress with the proposal of insertion of new wooden roofs for the towers*

### *6.1.5 Recent interventions*

**Synthesis of the intervention:**

- **Rebuilt previously existing elements:**
  - **new battlements – replacement of "Marseillais"-type tiles and limewashing with highly diluted natural hydraulic lime mortars**
  - **new stairs and masonries- limewashing with highly diluted natural hydraulic lime mortars**
- **Built elements that probably never existed:**
  - **closure of the inner side of the middle towers - highlight through a plaster layer**

Our proposal envisages a different treatment of **recent interventions** based on the historical role of each element. In particular, we distinguish to elements of two types: **previously existing elements** and **built elements that probably never existed in the period in which the fortress was mainly used for defense.**

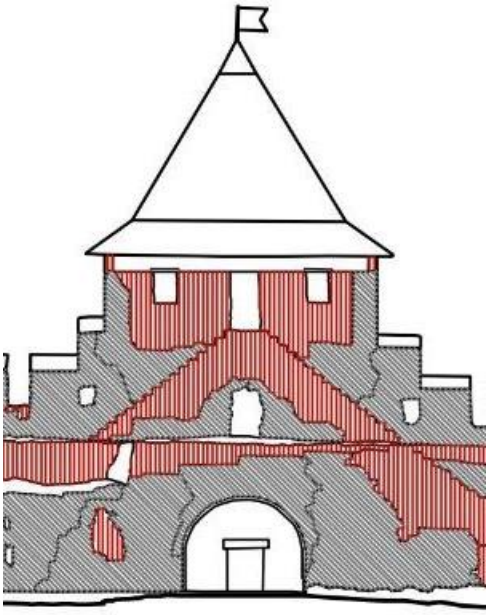
In the **first category,** we include the new battlements, the new roofs, the new stairs which, although previously existing, have recently been rebuilt with materials that are not compatible with the monument both from the historical point of view and from the point of view of restoration.

Since these are clearly distinguishable elements, substantial and sometimes invasive reconstructions, their replacement at this stage could cause greater damage to the monument. The choice is therefore to tackle with the main architectural criticalities that can be solved with a minimal impact on the monument.

The roof of the A3 tower will be replaced as already described above in this report, the "Marseillais"-type tiles of the battlements will be removed, the new battlements will be built with compatible mortars. Recent interventions made with cement mortars that cannot be removed without damaging the structure, such as the new battlements and the new stairs, can be visually mitigated by applying thin layers with highly diluted natural hydraulic lime mortars.

In the case of the **built elements that were added in more recent phases**, we particularly include the closure of the inner side of the middle towers, such as the A3 tower, with new masonry in the 19$^{th}$ century. In addition, it is impossible to remove this element without risk of damage to the historic walls; therefore, we have decided to mitigate the visual impact of this recent transformation through the disposition of a layer of plaster, composed by natural hydraulic mortar filled with local sand and small pebbles, as shown in the following images. **It is important to underline that the interventions in this chapter aim to solve critical issues caused by recent incompatible works. This type of works should never again be performed on the fortress, we refer in particular to the construction of elements that never existed and to the use of incompatible materials such as reinforced concrete.**

*Tower A3: current situation*



*Recent interventions in red*

*Project proposal*

## 6.2 General and operational indications for the restoration of masonries

The restoration will begin with the **REMOVAL OF THE BIOLOGICAL PATINA AND SHRUBBY VEGETATION**.

This process does not necessarily have to involve all surfaces without distinction; it should be carried out specifically where afterwards it will be necessary to work on the reintegration of missing parts and on the consolidation and safety of the masonry. The removal should be done by using a biocide based on quaternary salts ammonium, broad spectrum, which does not form films or chromatic alterations on stone surfaces. Once the products have been laid, it will be necessary to wait a few days (according to the product data sheet) for them to take effect and eliminate the organisms. The processing residues and all coherent and incoherent deposits should be removed by dry cleaning with brushes and the help of vacuum cleaner. The operation must not damage the stone surfaces.

All the stone surfaces will be cleaned[7] by **LOW PRESSURE TANGENTIAL SANDBLASTING** (like Jos or IBIX system). This system is an innovative low-pressure rotating vortex cleaning process used in the monumental sector to remove smog, graffiti, limescale, algae, moss, deposits on masonry and old plaster layers pulverized. This technology perfectly fits on Bender Fortress where dry sandblasting and hydro sandblasting could be too aggressive methodologies for its soft limestone. The vortex, created by rotation energy, distributes the inert granules (and possibly the drops of water) on helical trajectories projecting them on the dirty surface, adapting perfectly to it. The inert particles, sliding over the surface to be clean, should clean in a homogeneous way without producing micro-cracks and modifications on the surfaces.

The abrasives must be softer than the stone to be clean. The aggregate must be chemically neutral and non-metallic, free of toxic substances, non-carcinogenic and must not release free silica. Furthermore, it must not contain impurities or contaminants, must not be radioactive and must be free of salts.

Cleaning with tangential sandblasting must be tested on small portions of the stone surface and submitted for approval by the construction manager. Various combinations of pressure regulation and various types of aggregates must be tested. Once the approval of the works management has been obtained, the surfaces can be cleaned. **It is strictly forbidden to use industrial high-pressure sand blasting.**

Removal of coherent surface deposits, encrustations, concretions, altered fixatives should be done through the **application of or consolidating pack method** soaked in an inorganic salts or ammonium carbonate saturated solution; the deposits solubilized will be cleaned through brushes, scalpels and specils.

**MORTAR JOINT LEAKAGE** can be stopped through:

1. the cleaning of all joints and the removal of all coherent and incoherent deposits by careful manual cleaning with brushes and vacuum cleaner (in addition to the sandblasting mentioned above)
2. if the surrounding stones are subject to
    - pulverization: they can be consolidated by means of ethyl silicate/ammonium oxalate applied by spray or brush or consolidating pack method
    - flaking, micro-cracks and small detachments: adhesion can be guaranteed through injections of lime fluid mortar

[7] specific guidelines on restoration techniques can be found in the "Preliminary brief for the conservation and enhancement of Bender fortress (Thighina)" - chapter 3.2.2 "Cleaning":
«The cleaning treatment is to be limited to allow for the correct execution of the joint-filling and pointing and of the consolidation interventions. Such cleanings must be limited to the removal of the incoherent deposits and of the dust produced by the pre-existing mortars and the stone material of the ashlars during the decohesion phase and are to be carried out with non-abrasive brushes and water (without salts). It will be important that the surface of the stone ashlar blocks is not scraped thus removing the patina, that is to say, this surface layer bearing the traces of the finishing and of the interaction with the environment»

3. styling and grouting[8] of the joints with new lime mortar

**LOSS OF ORIGINAL SURFACE** leading to smoothed shapes can be stopped through

1. the cleaning of all surfaces and the removal of all coherent and incoherent deposits by careful manual cleaning with brushes and vacuum cleaner (in addition to the sandblasting mentioned above)
2. if the stones are subject to
    - pulverization: they can be consolidated by means of ethyl silicate/ammonium oxalate applied by spray or brush or consolidating pack method
    - flaking, micro-cracks and small detachments: adhesion can be guaranteed through injections of lime fluid mortar

The **FRAGMENTATION AND BREAKAGE OF THE STONE MATERIAL** can be stopped by

1. the cleaning of all surfaces and the removal of all coherent and incoherent deposits by careful manual cleaning with brushes and vacuum cleaner (in addition to the sandblasting mentioned above)
2. if the surrounding stones are subject to
    - pulverization: they can be consolidated by means of ethyl silicate/ammonium oxalate applied by spray or brush or consolidating pack method
    - flaking, micro-cracks and small detachments: adhesion can be guaranteed through injections of lime fluid mortar
3. Reintegrating of the wall facing with limestone elements with antiquing treatment: reconstruction of portions of lost or unrecoverable masonry walls, carried out after consolidation of the residual mortars with subsequent localized reconstruction of the missing part with the use of materials and techniques compatible with the original ones and adequate bonding to the core behind

It is possible that the nucleus of the masonry is damaged. It will be necessary to ensure that it is suitable for receiving the new wall facing. It will be necessary to:

a) carefully clean the core with the same cleaning procedures as the wall facing
b) consolidate the nucleus
    - with ethyl silicate applied by spray or brush where pulverization phenomenon is evident
    - with injection of fluid lime mortar where micro-cracks are evident
c) reintegrate the lost core portions by filling with natural hydraulic lime mortars free of salts and with appropriate aggregate/ binder/ water ratio and aggregate grain-size curve similar to the existing one

The reintegration of the masonry walls should take place with recovery stones from the ruined parts of the monument.

[8] specific guidelines on restoration techniques can be found in the "Preliminary brief for the conservation and enhancement of Bender fortress (Thighina)" - - chapter 3.2.3 "Filling and sealing":
« Each sealing and filling operation of the joints aims at limiting the penetration of water and moisture into the joints between the stones in he walls, in order to reduce the potential activation of related degradation phenomena. Furthermore, it is a preparatory activity for the possible consolidation of plasters, sealing the perimeters during the separation phase before. the subsequent injections. The choice of the mortar for injections must be carefully weighed and diversified in line with the characteristics of the existing mortars in each masonry wall or even portions of the walls. In this regard, reference should be made to […] the abacus of masonry types. In general, mortars based on binders without salt (natural aerated or hydraulic lime) are to be used with alluvial aggregates consistent with the granulometry and the petrographic characteristics of the historic mortars in place whenever possible (e.g. if the original mortar proves to be poorly prepared with evident shortcomings in the granulometric curve, it is not appropriate to reproduce a weak mortar). The injection of mortar to fill profoundly degraded joints of the wall side must be preceded by an adequate cleaning and must be carried out in such a way as to respect the legibility of the wall texture, i.e., the edges of the stone elements forming the wall should not be covered with mortar but must be left visible. A sufficient number of samples are to be prepared to evaluate the shade, the depth and the most suitable styling technique for the single masonry wall. […]»

**DECAY OF STONE** collects all decay phenomena listed before. Therefore, the interventions are:

1. the cleaning all stone surface and the removal of all coherent and incoherent deposits by careful manual cleaning with brushes and vacuum cleaner (in addition to the sandblasting mentioned above)
2. if the surrounding stones are subject to
    - pulverization: they can be consolidated by means of ethyl silicate/ammonium oxalate applied by spray or brush or consolidating pack method
    - flaking, micro-cracks and small detachments: adhesion can be guaranteed through injections of lime fluid mortar
3. if the stones are missing or completely detached, they must be replaced with stones of the same type and size.
4. styling and grouting of the joints with new lime mortar

It is possible that the nucleus of the masonry is damaged. It will be necessary to ensure that it is suitable for receiving the new wall facing. It will be necessary to:

d) carefully clean the core with the same cleaning procedures as the wall facing
e) consolidate the nucleus
    - with ethyl silicate/ammonium oxalate applied by spray or brush or consolidating pack method where pulverization phenomenon is evident
    - with injection of fluid lime mortar where micro-cracks are evident
f) reintegrate the lost core portions by filling with natural hydraulic lime mortars free of salts and with appropriate aggregate/ binder/ water ratio and aggregate grain-size curve similar to the existing one

The reintegration of the masonry walls should take place with recovery stones from the ruined parts of the monument.

Then it will be necessary the **REMOVAL OF GRAFFITI** from the surfaces, with formulation based on solvents and surfactants, it disintegrates the coloring oxides of the sprays and markers, applied several times by spray or brush, with final water sponge. Graffiti were found above all in lower fortress (not included in this lot of works) but there's the possibility to find some in not detectable areas of external A4-A2 elevation and in combination with old plaster layers pulverized (A4-A6 external elevation).

**All mortars must be hydraulic cement-free and based on natural hydraulic lime mortar. It's strictly forbidden to use cement mortar** due to the high saline component and the different thermal expansion compared to the existing stone and mortar. These two characteristics of cement mortar can be very harmful to original stones in geographical areas subject to freeze-thaw cycles such as Bender.

This is the reason why it is highly recommended the **REMOVAL OF ALL RECENT CEMENTITIOUS PATCHES**, replacing them with new joints and grouts in lime mortar, after careful cleaning and consolidation with ethyl silicate/ammonium oxalate if and where necessary.

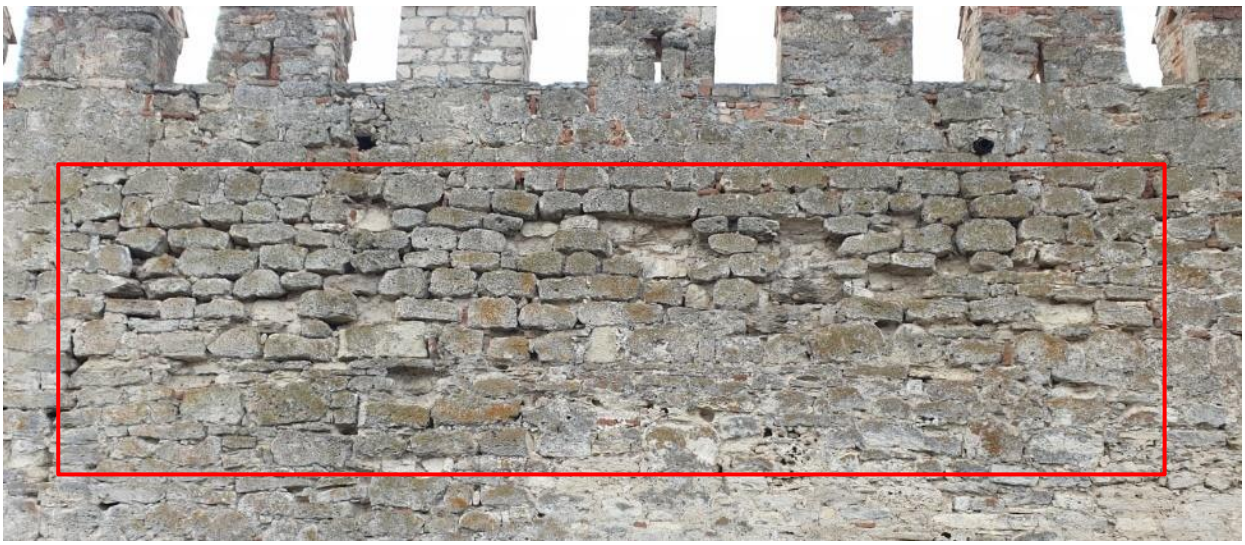
The layers of cement plaster should also be removed and the underlying surfaces carefully cleaned with brushes and - if necessary - consolidated with impregnated ethyl silicate/ammonium oxalate.

## 6.3 Interventions for other areas of the fortress

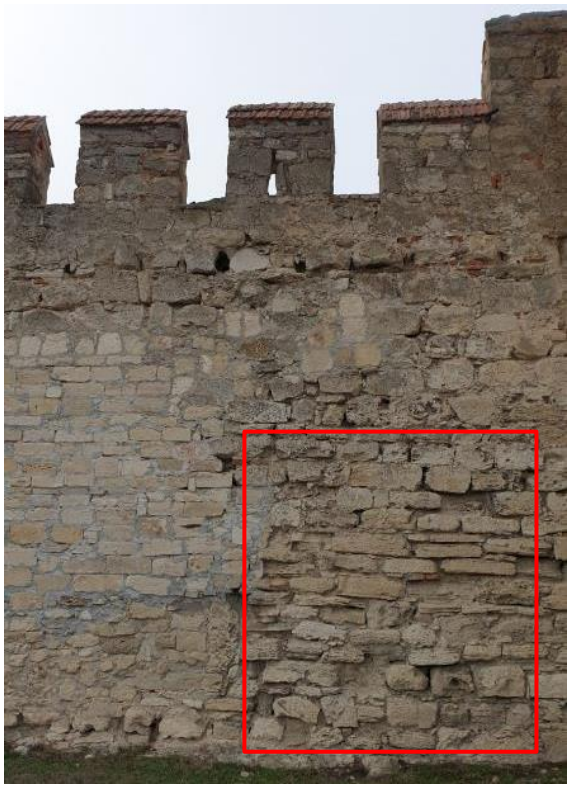
### *6.3.1 Securing and repair of stone façades*

The images below describe a situation of widespread deterioration both on the external and internal walls of the citadel. Generally, these degradation phenomena start with the loss of mortar joints and become more and more serious with the loss of some stone blocks up to entire portions of the walls.

In this case, there could be a further motivation: the loss of the timber frame inside the walls and the presence of these large voids has probably weakened the core of the masonry facilitating the degradation and the detachment of the facing stone.



*Local loss of mortar joints and loss of some stones*



*Loss of joints, degradation of stone facing, loss of stones*

*Collapse and local loss of the stone face at the voids left by the lost wooden net*

This situation must be made safe for two reasons: to allow visitors to enjoy the fortress safely and to preserve the fortress by stopping stopping or at least slowing down its degradation.

The proposed intervention consists of the securing and repair the stone facing where missing, with the insertion of new stone blocks appropriately coated to better integrate with the existing blocks.

**It is essential to specify that the materials used to make the walls safe must be compatible with historical materials.**

**It is strictly forbidden to use cement-based materials or with cement parts.** The high saline content of cement and its very different expansion coefficient compared to historic walls and mortars could cause more damage instead of solving problems. The new stones must be limestone similar to the existing one (or even salvaged stones); the mortars must be based on natural hydraulic lime and free of cement.

The surface to be treated must be cleaned of all deposits (both loose and adherent) and biological organisms in order to guarantee a surface suitable for taking restoration materials. If and only where necessary, existing materials (mortars, core, and stones) should be consolidated by mortar injections or impregnation with ethyl silicate.

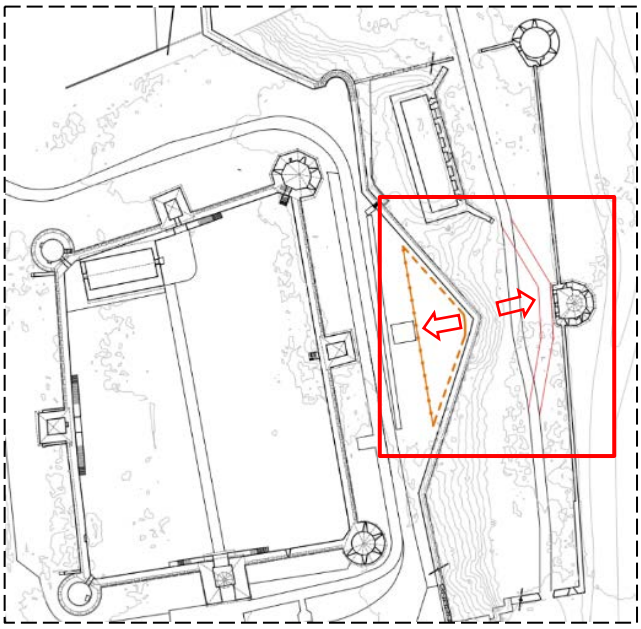
The unstable stones must be stabilized with new mortars; the missing ones must be replaced with stones similar to the existing one.

In Rampart B7, the situation appears rather serious and structural monitoring of at least 13 months is required to understand the behavior over time of the deep lesions and lack of facing present on the masonry, before defining the correct interventions.

Therefore, in this phase we only intervene on the weaknesses of the walls of the citadel and lower fortress and we will secure the visit route facing the Bastion B7 (as explained in the following paragraph) pending the results deriving from the structural monitoring.

### *6.3.2 Rampart B7: securing interventions for visitor's accessibility*

The aim of the proposed intervention in the present works-lot is to secure the visit routes pending evaluation for a more decisive intervention on the Rampart B7.



Structural reinforcement for the rampart B7 is a priority, but it will be necessary at least 13 months of structural topographic monitoring on it to properly define the appropriate interventions.

Once the monitoring campaign will be finished, we recommend reinforcement interventions on masonry. For this reason, the visit routes will need to be temporarily further distanced from the bastion.

To allow for a safe visit, the fence pat will be removed from the edge of the escarpment; under the bastion, the path will be moved away from the lower limit of the bastion.

Please see the image alongside.

### *6.3.3 Patrol path, walkways, stairs and railings*

**Synthesis of the intervention:**

- **arrangement and repair of walkways and stairs over the curtains**
- **installation of new railings/fences all over the walkways and stairs**

*Actual situation of walkways*

The intervention described in previous paragraph 6.1.1 must be extended to the entire patrol walkway.

As visible from the photos, the whole walkway requires general maintenance: removing vegetation and deposits, fixing of moving stones, replacement of missing stones, refill of missing joints.

*A child can fall through the mesh of the railing*

From the point of view of visitor safety, we can find two situations:

- railings of different types, all unsuitable for guaranteeing safety at altitude
- the absence of railings



All routes at height must be equipped with a railing that protects against falls.

The mesh must therefore be composed of elements close enough to prevent the passage of people, that can fall and injure themselves, and the passage of objects, that can fall and injure any passersby.

Where they already exist, all railings will be replaced, where they are absent, they will be added.

The railings will be installed directly on the patrol path.

*Project proposal*

### *6.3.4 Drainage system*

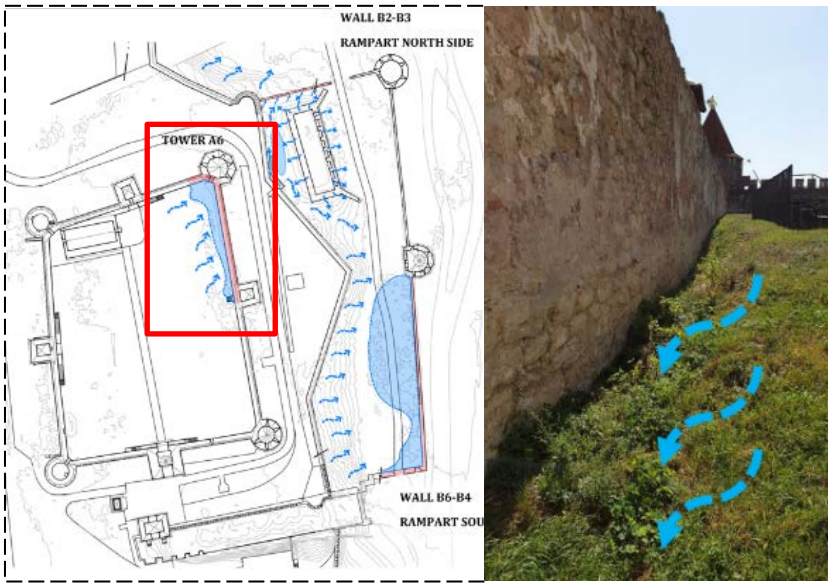
**Synthesis of the intervention:**

- **Ground modelling (earthworks)**
- **Restoration and maintenance of existing channels**
- **New connections between channels**

The drainage of water in the citadel is the main critical issue regarding the water drainage.

The studies on the slopes of the land have shown a stagnation at the A6 tower. This stagnation could be one of the triggering factors and in any case contributes to aggravate the structural problems of subsidence of this portion of the fortress.

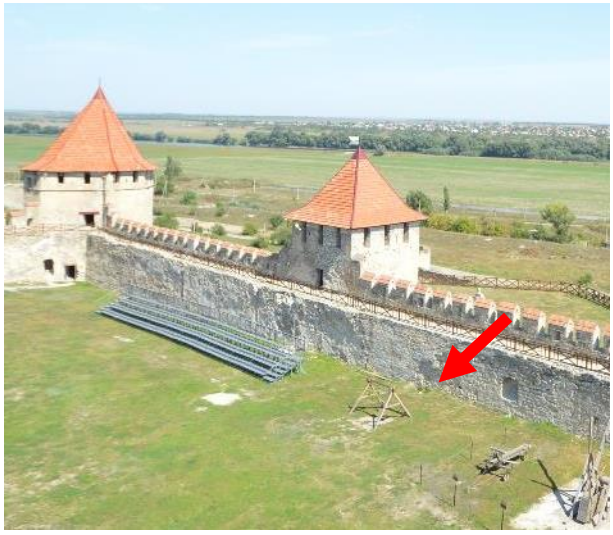
Action is required to limit the accumulation of water at the A6 tower.

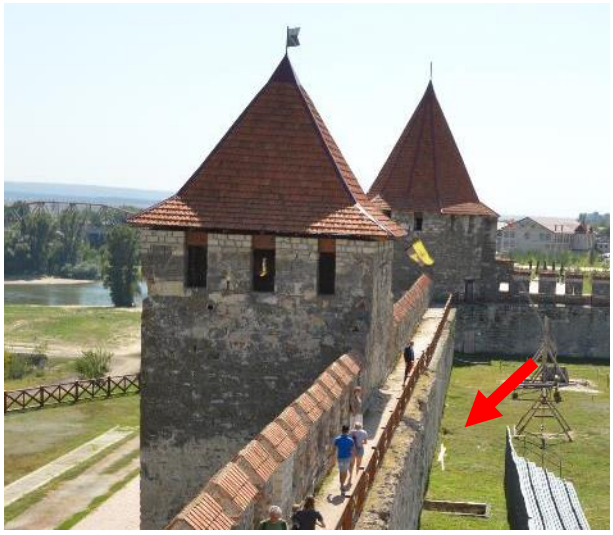


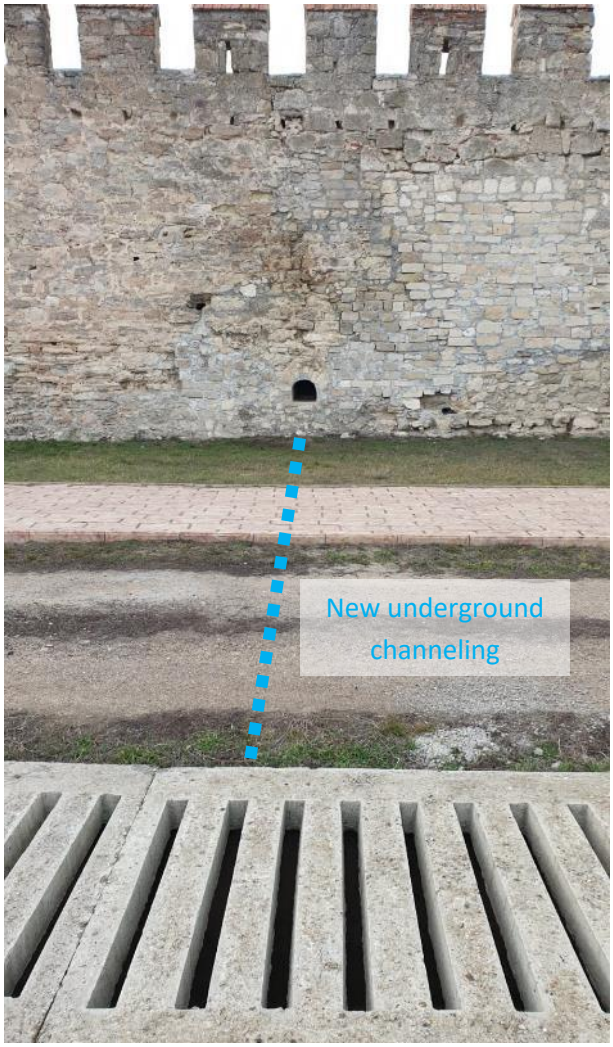

The ground will be remodeled to drain correctly water by inverting the inclination and it should be inserted, for the entrance to tower A6, a stone staircase similar to that existing for the entrance to tower A7. In this way the stagnation should be avoided.

In the citadel there will be two collection channels that will convey the water to the outside (see detailed drawings). For this purpose, it will be restored and maintained the canalization currently present that crosses the masonry between towers A7 and A8. It will be necessary to clean it well from all the weeds and deposits.

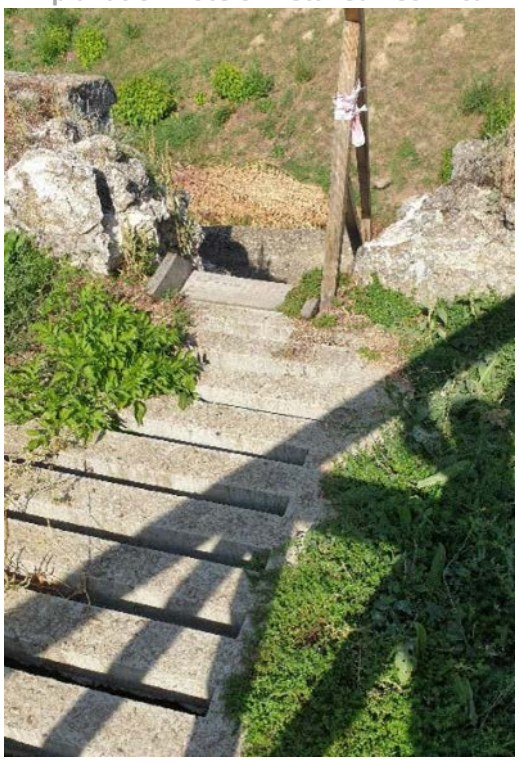
On the external side it will be possible to install a grid with a canalization to be connected to the large existing drainage.








The existing large concrete channel must be emptied and cleaned of all the vegetation and dirt that have blocked it from the beginning on rampart to the end (wall B2-B3).



It is important to provide for continuous maintenance of these canals, especially at the junction points, in the wells and where there are height jumps to ensure correct operation and to avoid damage to the rest of the fortress. In particular, the jump canalisation between the rampart and the low fortress must be cleaned and restored. In fact the construction of the staircase without the preparation of mortar cushions to protect the walls caused collapses and damage to the historical masonry.

The ramp bed for water drainage must also be cleaned and maintained. In fact, much of its path is infested with plants and vegetation that prevent the flow of water and can cause stagnation.

# 7 Structural interventions

This section of the report aims to illustrate the verifications concerning the executive project of structural consolidation for Bender Fortress. Specifically, the proposed interventions will concern:

- the reinforcement of the masonry of the Citadel with spread injections and artificial steel bondstones in a specific test area in order to carry out a pilot project;
- the reinforcement of Tower A6 with two orders of tie-rods on the existing wooden decks;
- the reinforcement of Water Tower with two couples of metal tie-rods and a new foundation curb made in reinforced concrete;
- the reinforcement of Tower B3 with an external joint grouting with stainless steel strands Ø6 mm inserted inside eight mortar joints;
- the construction of new roofs for towers A2, A4 and A6 consisting of a primary and secondary structure in solid wood covered with wooden shingles.

Below is a list of the project drawings referred to in the following paragraphs:

- reinforcement of masonry: **C226_PES_001**;
- reinforcement of Tower A6: **C226_PES_002**;
- reinforcement of Water Tower: **C226_PES_003**;
- reinforcement of Tower B3: **C226_PES_004**;
- new roofs for towers A2, A4 and A6: **C226_PEA_002a-b-c**;
- new railings: **C226_PEA_003**.

The last two drawings are part of the architectural project but they have also been deepened in this part of the report with regard to the structural verification of the wooden structure and railings.

Attached to this report are the analyses carried out by the Moldovan Engineer Evgheni Cutia, which shall be considered as integral part and main reference for the calculations carried out in the following paragraphs. In his report *"Comparative analysis between Eurocode 8 and SNIP II-7-81*"* an important comparison has been made between Moldovan seismic legislation and that provided for by Eurocodes, in order to verify the compatibility of the proposed structural project with the Moldovan standards.
Below is a list of the other reports drafted by Eng. Cutia which were referred to in the following paragraphs:

- reinforcement of Tower A6: *"Structural analysis of Tower A6 according to SNIP II-7-81*"*;
- reinforcement of Water Tower: *"Structural analysis of Water Tower according to SNIP II-7-81*"*;
- reinforcement of Tower B3: *"Structural analysis of Tower B3 according to SNIP II-7-81*"*;
- new roofs for towers A2, A4 and A6: *"Explanation note for new roof structure"*.

## 7.1 Reference standards

- Eurocode 8. Design of structures for earthquake resistance
- SNiP II-7-81* - Construction in seismic regions

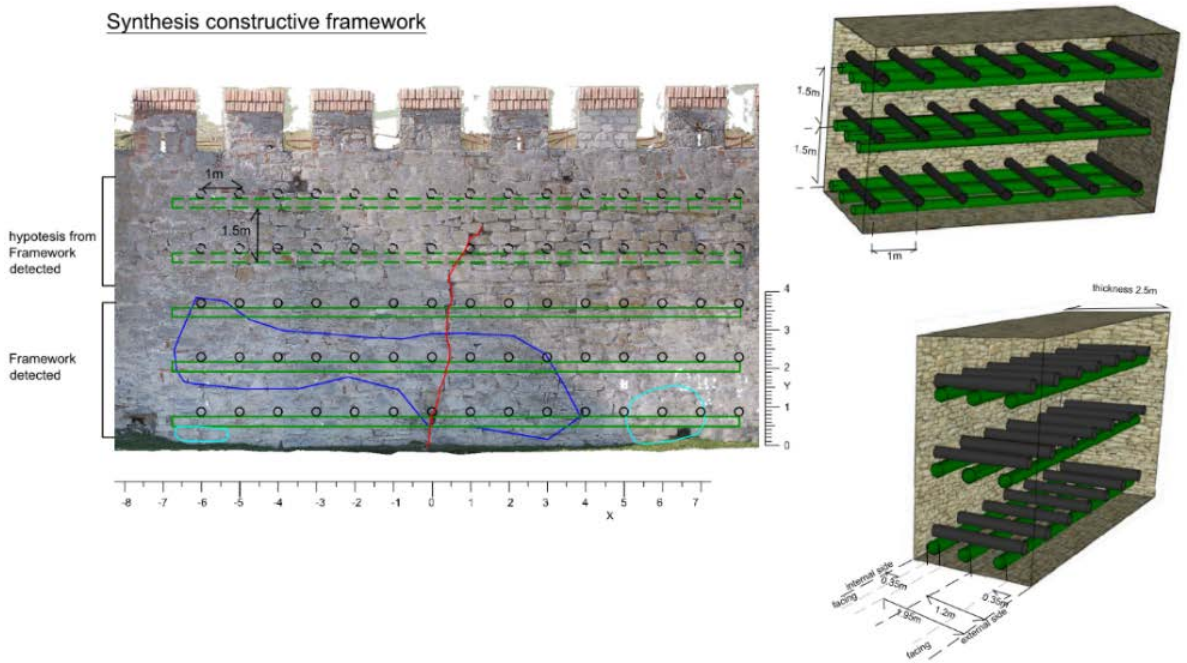
More specific standard references will be provided in the design drawings for structural material requirements.

## 7.2 Masonry reinforcement

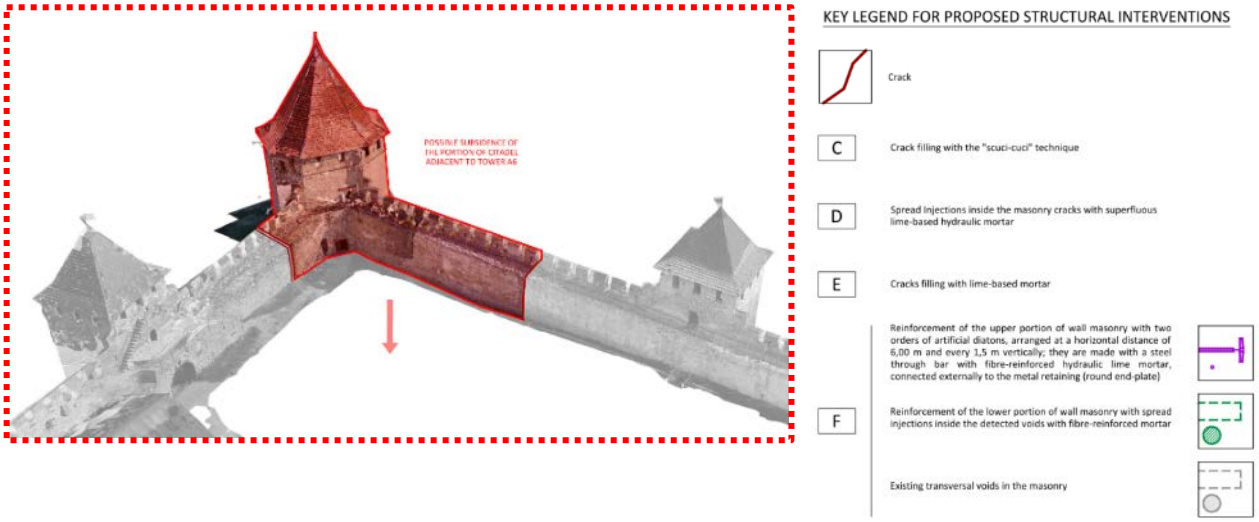
For masonry reinforcement a series of interventions has been foreseen, which will be carried out in a testing area between towers A6 and A7 (found in the successive images) in order to start a pilot project that in the future could be extended to all walls. The pilot project will serve as a local verification to test the global validity of this intervention.

The objective of these interventions which have been planned is to reinforce the masonry both from a static and seismic point of view. The foot of the wall, which mainly provides a static contribution, will be reinforced with spread injections inside the detected voids with fibre-reinforced mortar.

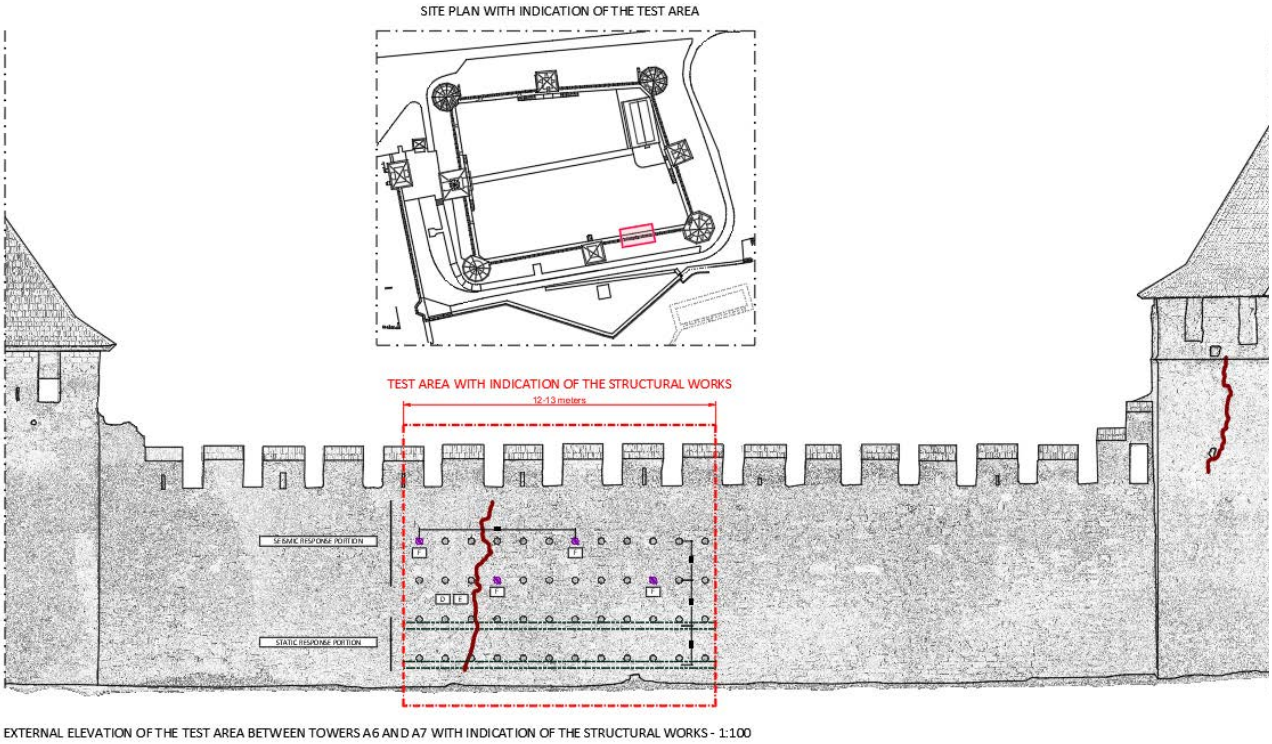
The upper part, which mainly provides a seismic contribution, will be reinforced by the insertion of artificial bondstones, made with a steel through bar inserted with fibre-reinforced natural hydraulic lime mortar, connected externally to the metal retaining.




The structural reinforcement proposals of the masonry exploit the ancient constructive framework consisting of wooden elements that are now missing and have been replaced by longitudinal and transversal voids.




Interpretation of the damage mechanism of the portion of the citadel adjacent to Tower A6, probably consisting of a ground subsidence.



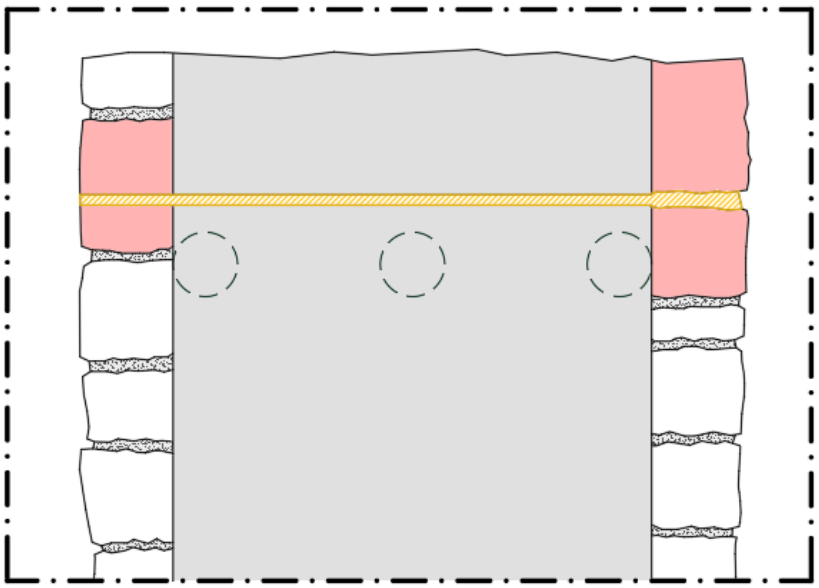

Elevation of the wall between towers A6 and A7 with proposal of the test areas where structural interventions could be done.

In the following paragraph the operating sequences for the realization of the proposed interventions will be illustrated.

### *7.2.1 Operating sequences*

This paragraph illustrates the operating sequences for the realization of the artificial bondstones in the upper part of the masonry and the spread injections inside the detected voids with fibre-reinforced mortar in the lower one.

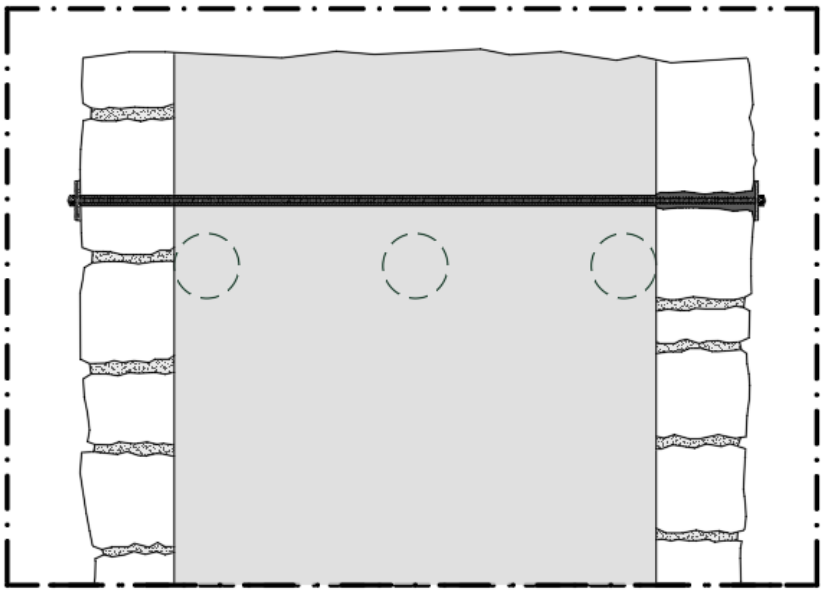
The following four picture shows the operating sequences for the artificial steel bondstones.



Existent masonry with longitudinal and transversal voids.

**PHASE I:** perforation of the wall for all its thickness with a hole diameter of 4-5 cm, with temporary local removal of the stone facing at the point of realization of the hole.

**PHASE II:** insertion of the stainless steel through bar with injection of fibre-reinforced natural hydraulic lime mortar (M3).

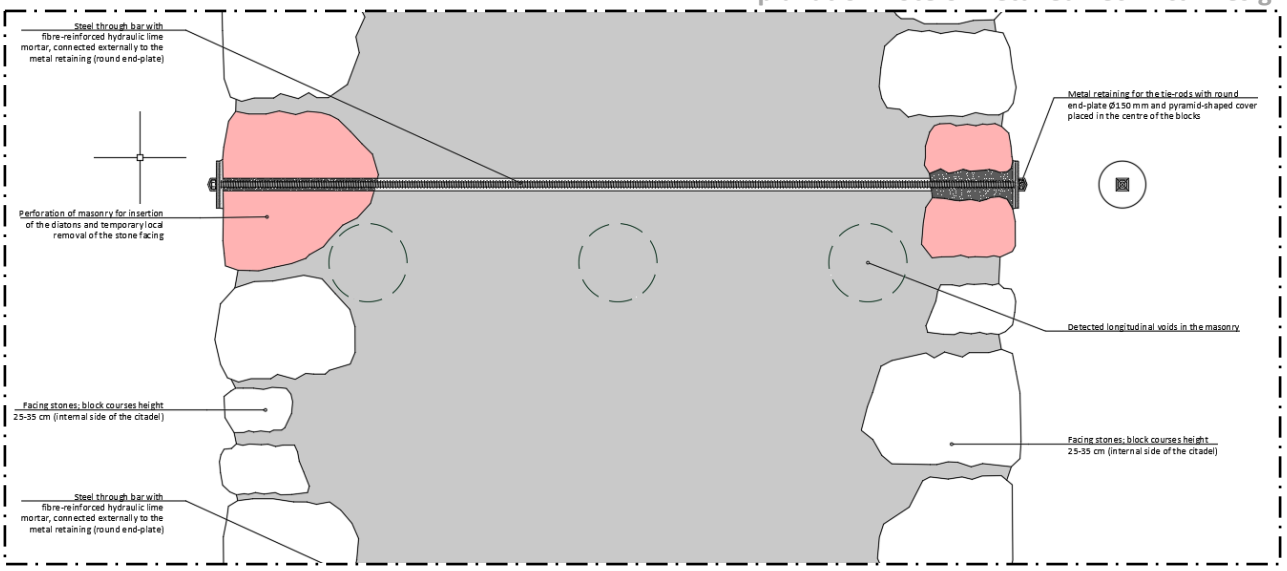


**PHASE III: i**nsertion of the stainless-steel retaining for the artificial bondstones consisting of a round end-plate Ø150 mm and pyramid-shaped cover placed in the center of the blocks.

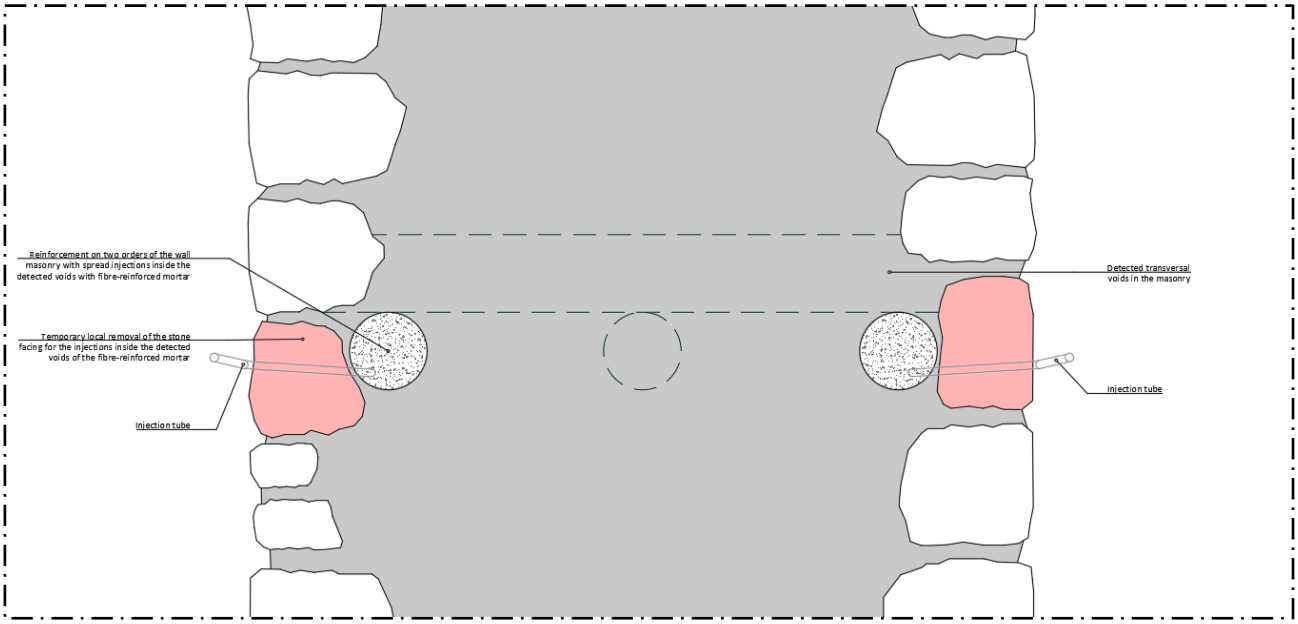
The operating sequences for the spread injections are instead:

- temporary local removal of a stone for the injections, at one end of the test area;
- insertion of the injection tube and pumping of the fibre-reinforced mortar for filling the core voids until refusal;
- removal of the injection tube and repositioning of the removed stone with lime-based mortar;
- temporary local removal of the next stone at a distance of 2,50/3,00 m from the first one and pumping of the fibre-reinforced mortar for filling the core voids, in the same direction of the first injection;
- removal of the injection tube and repositioning of the removed stone with lime-based mortar.

These operations should be repeated at both voids levels until all the extension of the test area is covered. In the following pictures the detail sections of an artificial bondstone and spread injections are shown as result of the operating sequences which have been explained.




Detail section of an artificial diaton and its retaining system in the upper part of the test area




Detail section of the spread injections for longitudinal voids in the lower part of the test area

## 7.3 Reinforcement of Tower A6

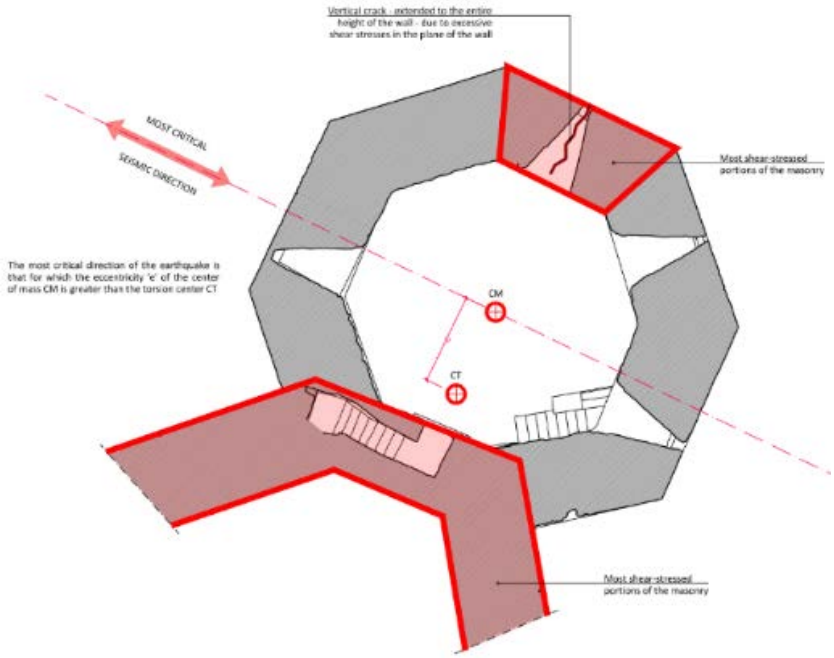
The polygonal Tower B3 is located at the northeast corner of the Citadel and it's characterized by three levels of wooden decks laid on a steel primary structure. The proposed intervention aims to prevent any possible kinematical motion of overturning and shear failure of portions of the perimeter wall due to seismic actions, as shown in the following picture.

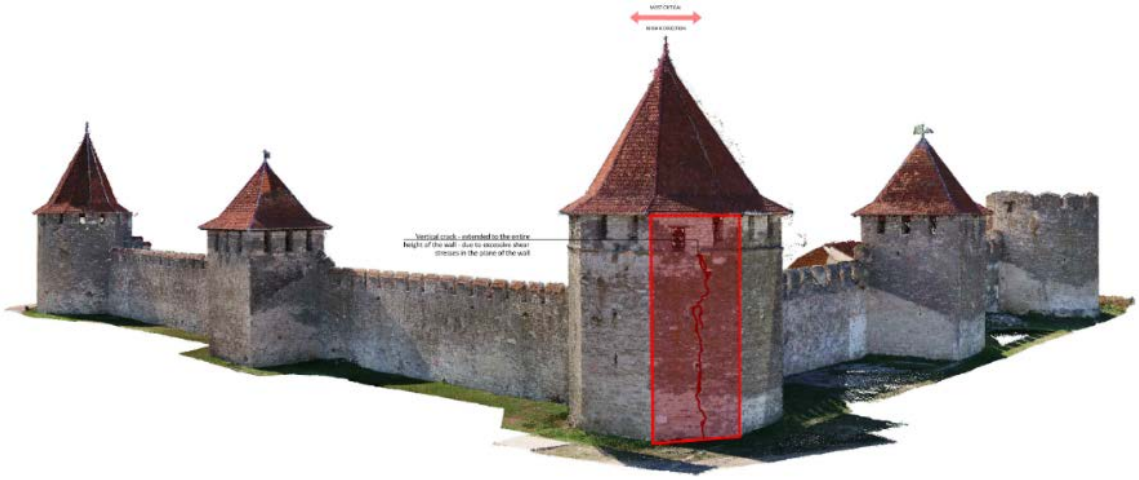
Reinforcement interventions are necessary to statically consolidate the tower after the manifestation of very large vertical cracks in the center of some walls of the tower, due to the typical lesions affecting lean structures such as towers and bell towers.
The following page shows the seismic analysis carried put for the identification of interventions.

The following pictures show the analysis which have been carried out for the identification of interventions.

The seismic analysis of the structure shows that the most critical direction of the earthquake is that for which the eccentricity 'e' of the centre of mass CM to the torsion center CT is highest.

The following plans, elevations and sections show the interventions which have been designed in order to improve the seismic behaviour of the tower.



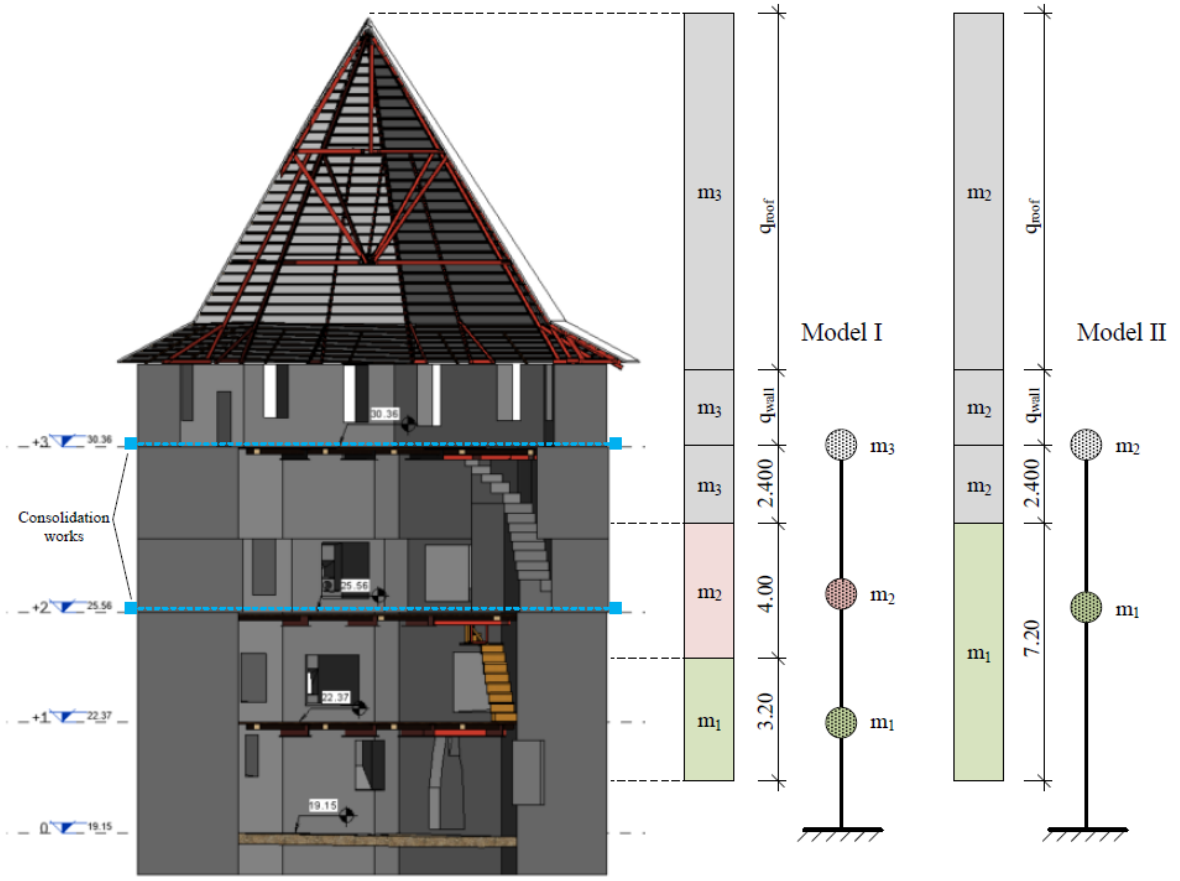


Vertical crack - extended to the entire height of the wall - due to excessive shear stresses in the plane of the wall in the most critical direction of the earthquake

This kind of seismic instability is typical of tall buildings such as bell towers. In the case of Tower A6, the intervention will be carried out at the level of the last two decks to ensure that they are able to strengthen the box behaviour of the structure and prevent the reciprocal sliding of the portions of masonry with shear failure. From a static point of view, however, the tower doesn't show any sign of failure.
The proposed intervention consists of eight metal tie-rods - four for each level - laid on the existent wooden decks and covered with a new one. These tie-rods consist of a metal plate 40 x 10 mm for what concerns the surface in contact with the floors and of a stainless steel through bar with circular section for what concerns the masonry section; each tie-rod ends with a metal retaining, in direct contact with the wall. Every executive indication is reported in the structural design drawing.

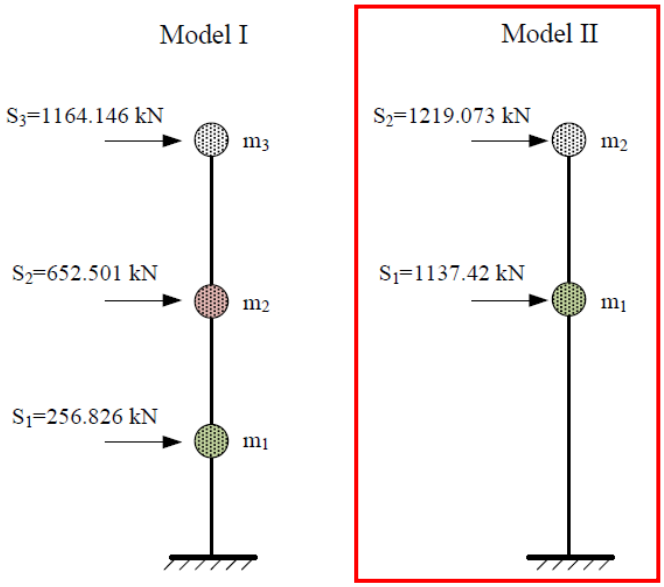
### *7.3.1 Sizing of tie-rods*

For the evaluation of the maximum value of pulling action to which the tie-rods can be subjected, the analysis carried out by Eng. Cutia shall be taken as important reference. The tower has been modelled and analysed as cantilever, two models with three or two degrees of freedom has been compared and consist of three or two masses arranged at different elevations, as shown in the following picture.




The analysed model of Tower A6

The seismic forces associated to each individual mass considering both the first and the second models are shown in the following diagram. From the results, it's possible to observe that seismic force from design model I at mass $m_1$ is significantly lower than seismic force from other two points. This suggests that this point could be omitted in favour of the design model II.




The seismic forces for Tower A6

The reinforcing system will be positioned indicatively at the height of the two masses, as it can be deduced also from the drawings of the structural design. The section of the tie-rods will be verified at the most stressed portion of the tower, i.e. that with mass $m_2$, placed at the highest level.
As stated in Eng. Cutia's report, the seismic force $S_2$ to which the mass $m_2$ is subjected results 1219,073 kN. Considering that in case of seismic action the portion of mass of competence for each tie-rods corresponds to about an eighth of the total mass $m_2$, the pulling action P to which the single tie-rod would be subjected results:

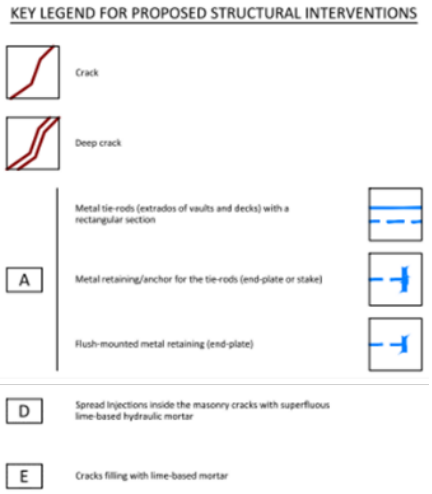
$P = S_2 / 8 = 1219{,}073\ kN / 8 = 152{,}38\ kN$

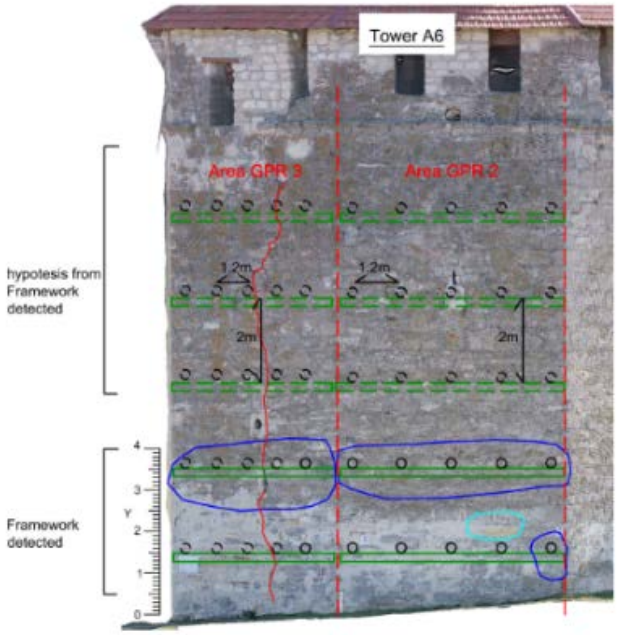
The minimum required area for each strand is:

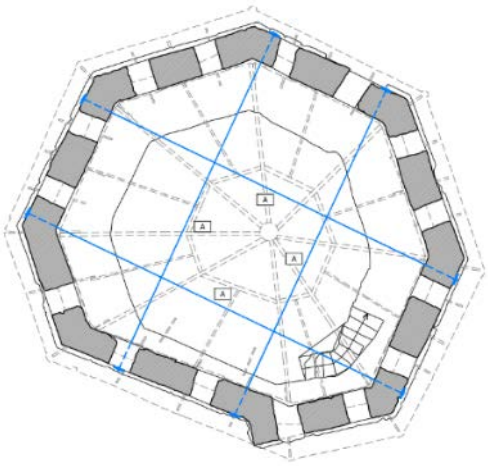
$A_{min.} = P / (2 \cdot \gamma_C \cdot R_y) = 152{,}38\ kN / (2 \cdot 1 \cdot 240\ N/mm^2) = 317{,}47\ mm^2$

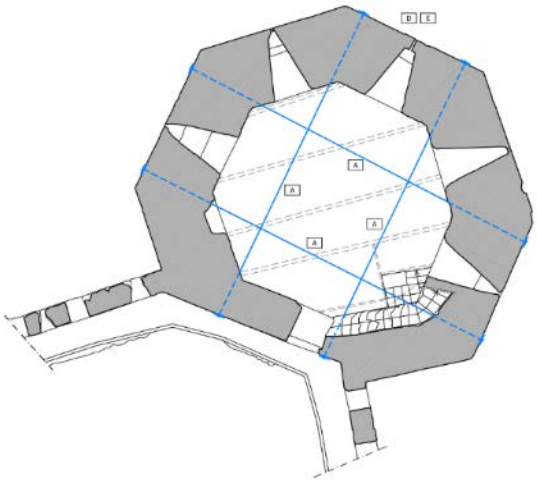
where $R_y = 240\ MPa = 240\ N/mm^2$ is yield strength for steel class C245 according to GOST 27772-88, reported in Eng. Cutia's report. The nominal area of each metal plate is 400 $mm^2$ (a rectangular section of 40x10 mm), for this reason the section assumed is verified for the containment of seismic forces. Each plate will be welded to a through stainless steel bar Ø20 mm (with a section area of 317 $mm^2$) with two welding seams of 120 cm.

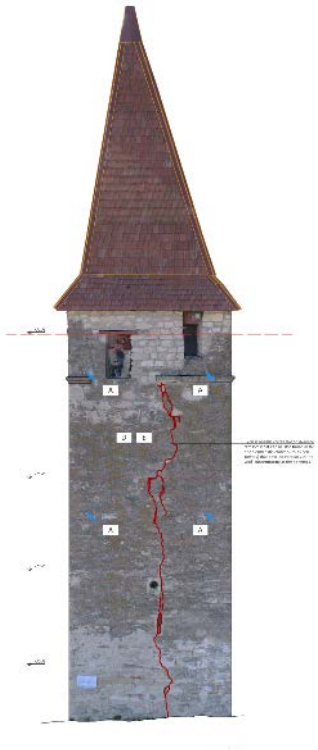
The following images summarize the interventions planned for the tower.

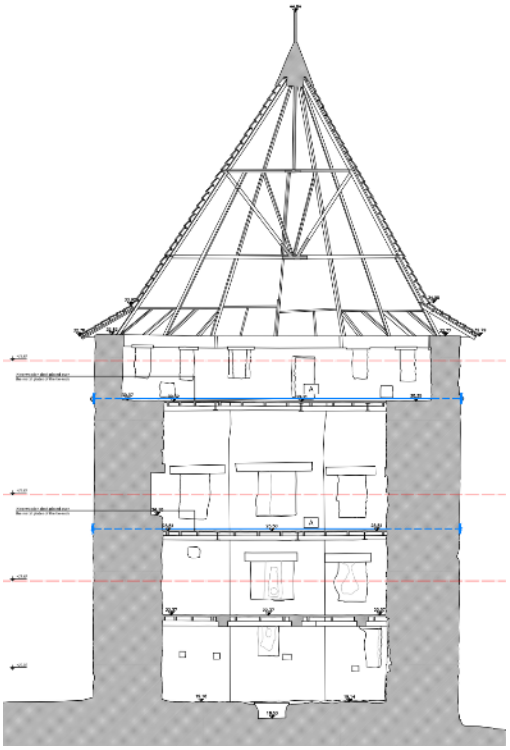








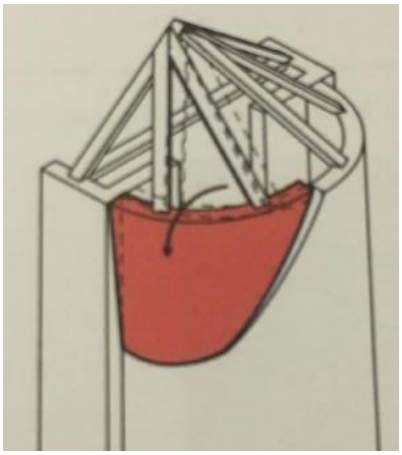


Elevation of the north-eastern facade of the tower with indication of the structural works

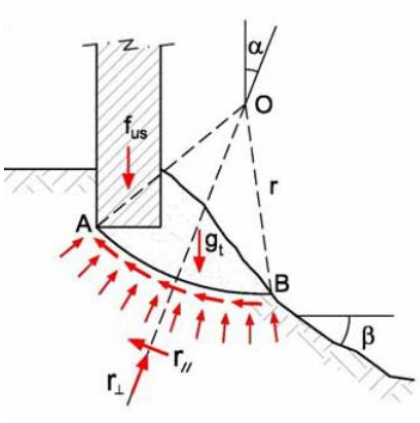
Vertical section of the tower with indication of the structural works

## 7.4 Reinforcement of Water Tower

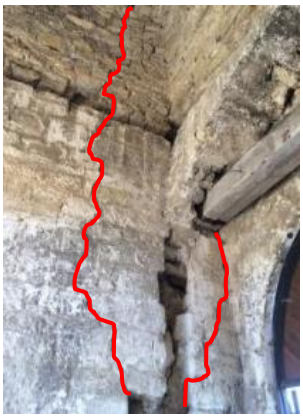
The Water Tower has a serious cracking that involves the inner pavilion vault for all its thickness; this crack extends also to the walls below and in particular involves two orthogonal walls to the eastern facade.
It has been assumed that such disruptions are caused by a combined action given by an excessive thrust of the vault at its bottom level and by a failure of the foundation of the prospectus due to a slip downstream of a portion of ground.
The interventions which have been planned consist of four tie-rods placed at the base of the vault to limit the movement of the wall at the top, and a foundation cordon that limits the lowering of the wall and the sliding downstream.
For the dimensioning of the structural interventions reference was made to the structural analysis carried out by Eng. Cutia, which is attached to this report and can be taken as reference for load analysis and specific calculations.
The evaluation of the interventions and their extent was based on the study of the vault thrust also in seismic conditions and on the analysis of the bearing capacity of the soil, which could be one of the causes of the collapse in progress.



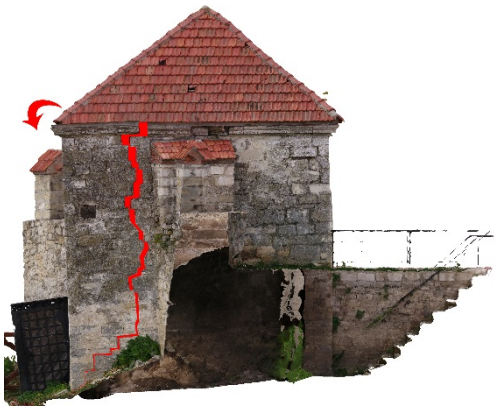
+




Masonry cracks show the activation of a kinematic mechanisms due to the thrust of the vaults combined with a ground subsidence.



1)



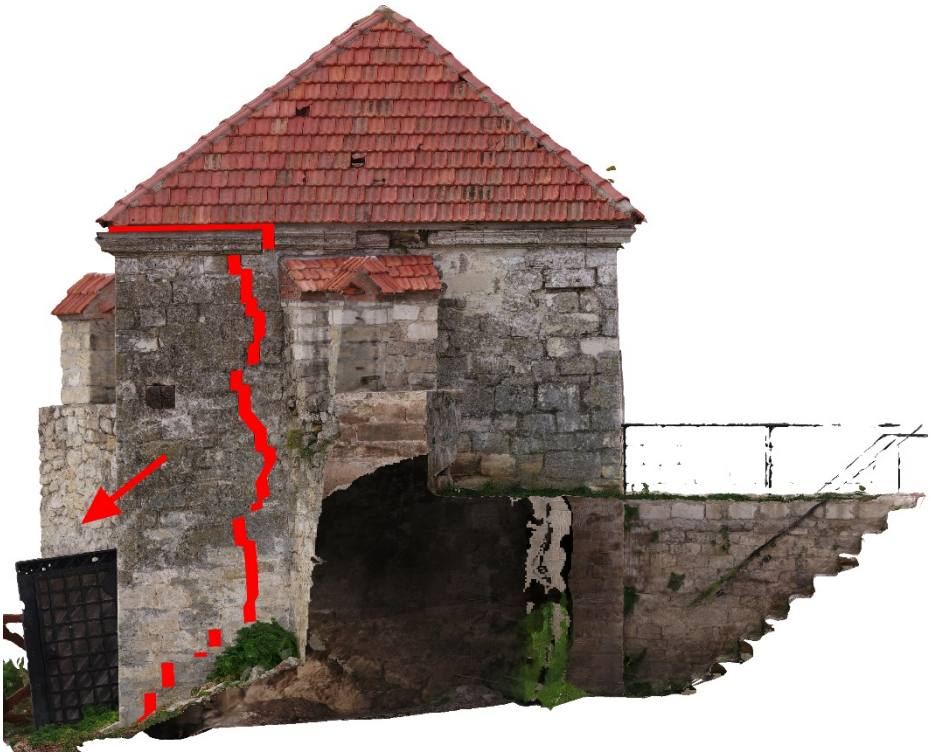
Out-of-plane rotation of the facade due to the thrust of the pavilion vault

+

2)

Rotation at the foot of the wall due to ground subsidence

3)



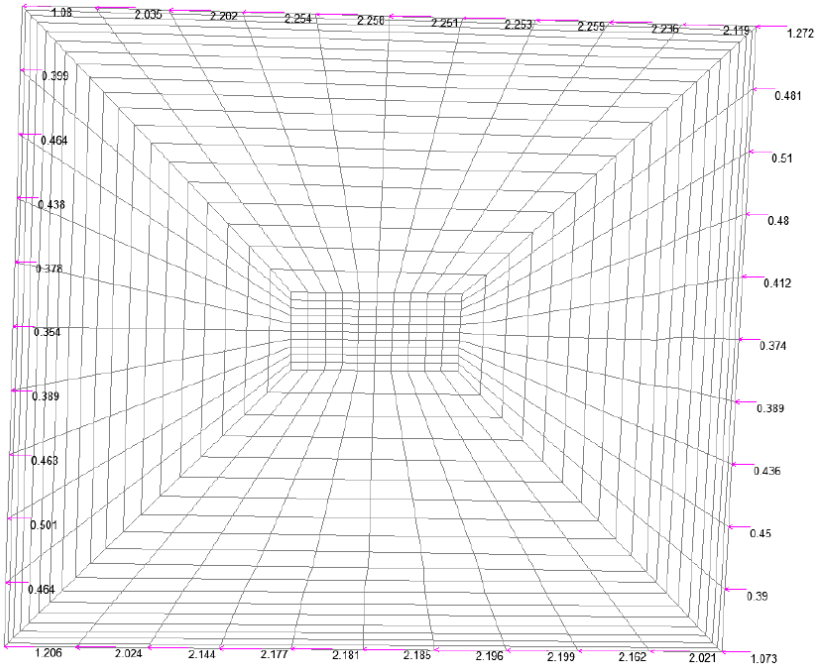
Masonry cracks could be linked to a combination of two main structural failures: the rotation of the façade due to the thrust of the vault (1) and a ground subsidence (2). The result is a shift of the wall in the direction of the ground slope (3).

### *7.4.1 Calculation of the static thrust of the pavilion vault*

For the evaluation of static thrust of the pavilion vault a calculation model has been adopted. The following table shows the external loads system applied to the vault, according to the analysis carried out by Eng. Cutia.

| Description | Unit | Normative value | Safety coefficient $\gamma_f$ | Design value | Note |
|---|---|---|---|---|---|
| PERMANENT LOAD | | | | | |
| Timber purlins ($b\ x\ h\ =\ 50\ x\ 120\ cm$) | $kN/m$ | 0.03 | 1.3 | 0.038 | NCM F.03.02-2005 |
| Roofs tile | $kN/m^2$ | 0.5 | 1.3 | 0.637 | СНиП 2.01.07-85, tab. 2 |
| VARIABLE LOAD | | | | | |
| Snow Load | $kN/m^2$ | 0.5 | 1.4 | 0.5 | СНиП 2.01.07-85 |

The analysis which has been carried out show that the horizontal component of the thrust of the vault has a maximum value of 2,259 kN per half meter of masonry. Applied on the longest side of the vault (about 5,00 m) the total load on the wall is 22,60 kN.




The horizontal actions on the perimetral walls of the vault

As the vault is fissured and therefore is no longer able to properly transmit its weight on the perimeter walls, some structural interventions have been planned to prevent possible out-of-plane tipping mechanisms in static conditions. The same interventions could achieve the same positive effect in seismic conditions, so they will be dimensioned to provide this additional contribution as well.
Two couples of tie-rods are proposed for the inhibition of out-of-plane tipping mechanism due to the thrust of the vault and to seismic loads; for this reason, they have been dimensioned to achieve this result.
The following paragraph provides the verification and sizing of the tie-rods.

### *7.4.2 Sizing and verification of the tie-rods*

Two pairs of tie rods have been designed to contain both the push of the vault and to inhibit any kinematics of seismic nature that could cause the loss of the box behaviour (overturning off the plane of portions of wall). For this reason, the metal profiles of the tie-rods have been chosen in order to be strong enough to absorb both these types of stress.
Considering that the maximum value of thrust of the vault is 22,60 kN, the pulling action each couple of tie-rod shall be subjected to is:

T = P / 2 = 22,60 kN / 2 = 11,30 kN

Considering that the tie rods shall also be able to absorb seismic forces, the maximum allowable value for each of them has been kept high enough to perform this function as well. The value which has been calculated with the assumed steel profiles (24,8 kN) is shown in the following table.

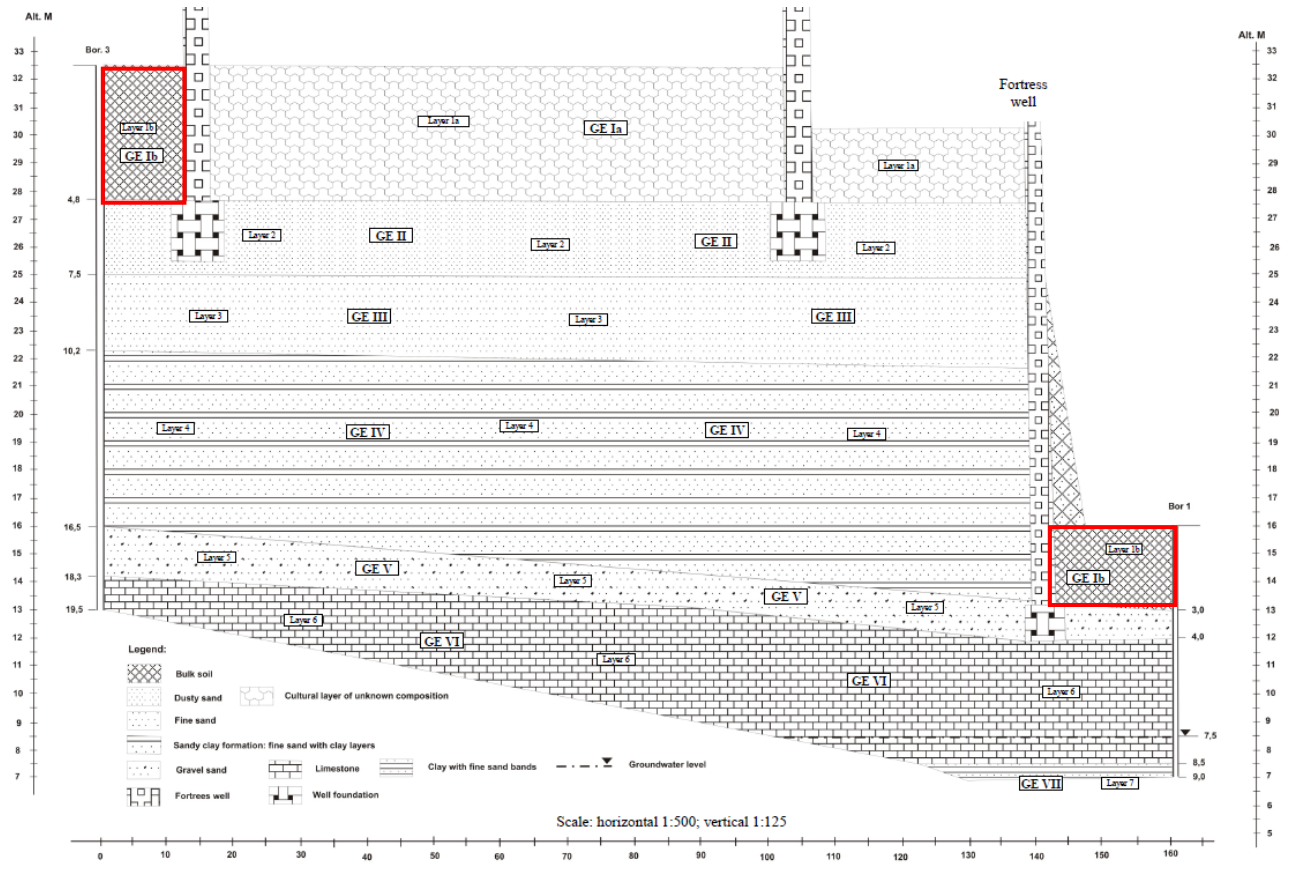
| DETERMINAZIONE DEL TIRO DELLA CATENA | | |
|---|---|---|
| CARETTERISTICHE GEOMETRICHE | Area della sezione trasversale del tirante $A_S$ [mm$^2$] | 201,1 |
| | Altezza della piastra di ancoraggio del tirante a [cm] | 25,0 |
| | Larghezza della piastra di ancoraggio del tirante b [cm] | 25,0 |
| | Spessore della parete su cui è ancorato il tirante t [cm] | 100,0 |
| | Angolo di attrito della muratura β [°] | 45,0 |
| | Area della zona di contatto della muratura con la piastra di ancoraggio del tirante $A_1$ [cm$^2$] | 625,0 |
| | Distanza del bordo della piastra dal più prossimo lato libero della parete su cui è ancorata [m] | 0,9 |
| | Area di ripartizione delle azioni di compressione $A_2$ [cm$^2$] | 718,2 |
| | $\sqrt{(A_2/A_1)} \leq 2$ | 1,1 |
| | Percentuale del contributo del taglio sulle facce laterali per il calcolo di $T_2$ [%] | 100,0% |
| PARAMETRI MECCANICI | Fattore di confidenza $F_C$ | 1,35 |
| | Coefficiente parziale di sicurezza sulla resistenza a compressione della muratura $\gamma_M$ | 3,00 |
| | Resistenza di calcolo dei tiranti $f_{d,S}$ [N/mm$^2$] | 190,00 |
| | Resistenza media a compressione della muratura $f_m$ [N/cm$^2$] | 150,00 |
| | Resistenza media a taglio della muratura $\tau_0$ [N/cm$^2$] | 2,50 |
| | Tensione di calcolo a compresione della muratura $f_{d,M}$ [N/cm$^2$] | 37,04 |
| | Resistenza di calcolo a taglio della muratura $f_{v\,d,M}$ [N/cm$^2$] | 0,62 |
| TIRO DELLA CATENA | Resistenza dei tiranti allo sneravamento $T_1$ [kN] | 38,2 |
| | Resistenza al punzonamento della muratura nelle zone di ancoraggio $T_2$ [kN] | 30,9 |
| | Resistenza alla pressione di contatto sulla muratura $T_3$ [kN] | 24,8 |
| | Massimo tiro esplicabile dalla catena T [kN] | **24,8** |

The two couples of tie-rods (two tie-rods will be inserted in the perpendicular direction) will be made of steel S275 ($f_{d,s}$ = 190 N/mm$^2$) with rectangular section of 40x10 mm ($A_S$ = 400 mm$^2$) or circular section consisting of a ϕ16 bar ($A_S$ = 201,10 mm$^2$), arranged according to structural design drawings.
They will be bound to the walls with round end-plates with a diameter of 25 cm, made of S275 steel and protected with a round cover made of Corten/burnished steel.
With a maximum pull T of 24,80 kN, the maximum bending moment to which the round end-plate is subjected (given by the distributed load that is generated at the interface with the masonry, equal to T / $A_P$, where $A_P$ is the area of the plate) is $M_{MAX}$ = 0,99 kN. Considering a 250x20 mm section of the plate, the following stress value is obtained: $\sigma_{S,d} = M_{MAX} / W = M_{MAX} / [(b \cdot h^2) / 6]$ = 0,99 kNm / [0,25 m · (0,02 m$^2$) / 6] = 59,22 N/mm$^2$ < $f_{d,s}$ = 190 N/mm$^2$. For this reason, the proposed solution is verified.

### *7.4.3 Sizing of the new foundation curb*

On the basis of the vulnerability analysis which has been carried out and the geological report drawn up by the geologist Dr. Igor Nicoara it was possible to determine how much the bearing capacity of the soil has a negative influence on the ongoing structural failure of the Water Tower.
The following image shows a section of the ground between two boreholes made for the geological surveys at the upper Citadel. It is possible to notice that the surface layer of soil outside the walls – classified as *Layer Ib* – is formed by "Technogenic soil bulk soil loam mixed with construction waste" with a thickness between 3,00 and 4,80 m.

v




This soil may well be compared to that which is located outside the Water Tower because it is a type of soil very recurrent on the external side of many walls of the fortress and involves almost everywhere the first meters of depth. Due to its very incoherent nature, this soil has been attributed a bearing capacity value of 100 kPa, as shown in the following table.

**Table of normative and calculated values of soil characteristics of Geotechnical Elements (layers) in natural conditions.**

| Geotechnical Element (layer) | Soil clasification | Normative value | | | | | | | | | Calculated values | | | | | | Soil resistance value, Ro, kPa | Uniaxial compression strength, kPa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | on deformation | | | on bearing capacity | | | | |
| | | Soil density, g/cm3 | Dry soil density, g/cm3 | Humidity | Plasticity Index | Fluidity Index | Porosity coeficient | Soil deformation modulus, MPa | Cohezion, kPa | Efective angle of friction, grade | Soil density, g/cm3 | Cohezion, kPa | Efective angle of friction, grade | Soil density, g/cm3 | Cohezion, kPa | Efective angle of friction, grade | | |
| Ia | Bulk soil (layer 1a) | | | | | | | | | | | | | | | | 150 - 450* | |
| Ib | Bulk soil (layer 1b) | 1,60 | 1,45 | 0,10 | | | 0,850 | 12 | 2 | 24 | 1,59 | 2 | 23 | 1,58 | 1 | 22 | 100** | |
| II | Dusty sand (layer 2) | 1,75 | 1,64 | 0,07 | | | 0,623 | 18 | 5 | 30 | 1,79 | 4 | 29 | 1,72 | 3 | 28 | 200 | |
| III | Fine sand (layer 3) | 1,80 | 1,70 | 0,06 | | | 0,578 | 28 | 4 | 32 | 1,79 | 3 | 31 | 1,78 | 2 | 30 | 250 | |
| IV | Sandy clay formation (layer 4) | 1,90 | 1,65 | 0,15 | 0,13 | < 0 | 0,624 | 22 | 31 | 24 | 1,89 | 30 | 23 | 1,88 | 29 | 22 | 250 | |
| V | Gravel sand (layer 5) | 1,95 | 1,81 | 0,08 | | | 0,480 | 45 | 2 | 40 | 1,94 | 2 | 39 | 1,93 | 1 | 38 | 500 | |
| VI | Limestone (layer 6) | 2,25 | | | | | | | | | | | | | | | 600*** | 450*** |
| VII | Clay (layer 7) | 2,00 | 1,64 | 0,22 | 0,22 | 0,00 | 0,665 | 24 | 60 | 20 | 1,99 | 58 | 19 | 1,98 | 56 | 18 | 450 | |

Note: Normative and calculated values of GE (soil layers) are presented by the laboratory test results, regional geological studies from the past and by tables 1, 2, 3 from anex 1 of SNIP 2.02.01-83 to take into consideration point 2.16 of the SNIP * value from table 1 annex 3 of SNIP 2.02.01-83 ** value from table 5 annex 3 of SNIP 2.02.01-83 *** regional tables forpontian limestone in water saturated conditions

Considering the loads transmitted to the ground by the proper weight of the masonry, the vault and the roof, the distributed load over the facade wall (which is 1 m thick and 2,70 m long) results:

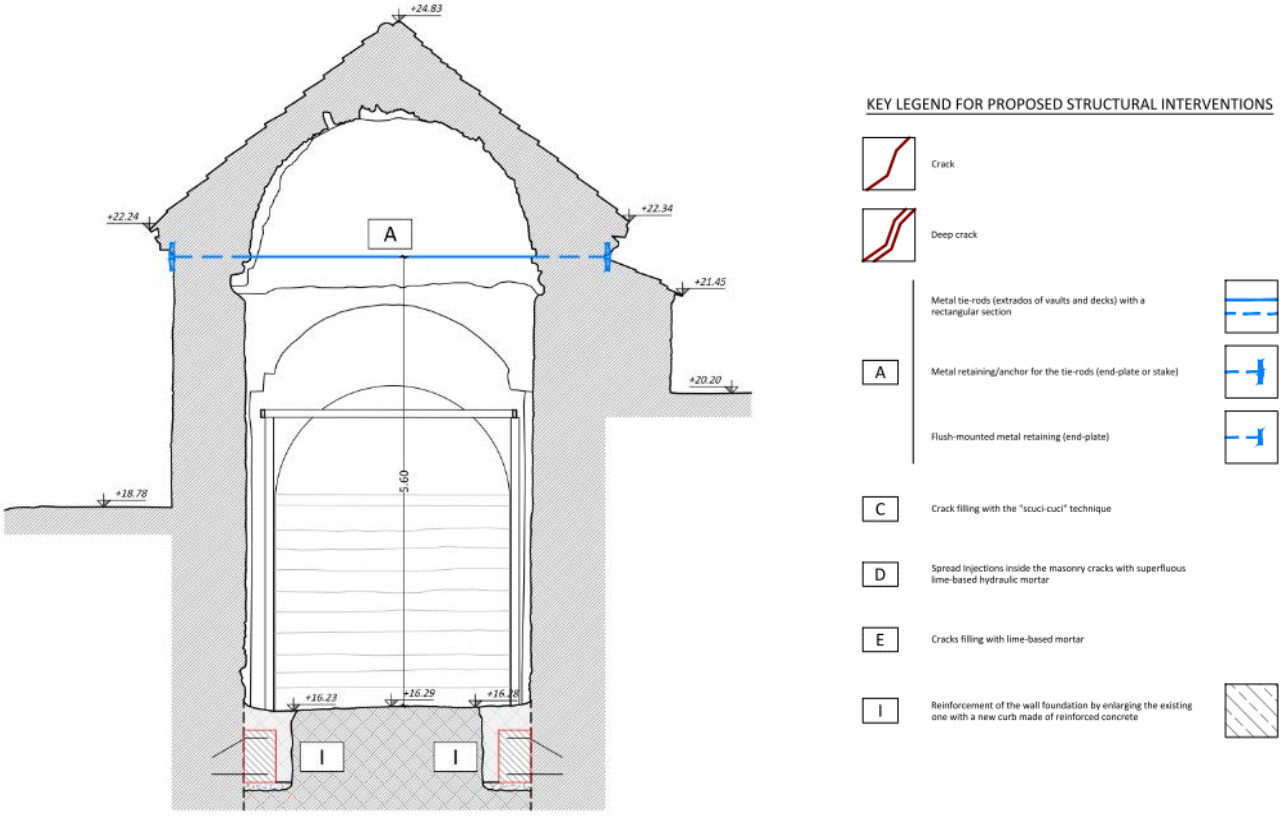
$F_{tot.} = [(P_{MASONRY} + P_{VAULT} + P_{ROOF}) / (1\ m \cdot 2{,}80\ m)] = [420\ kN / (1\ m \cdot 2{,}80\ m)] \simeq 150\ kN$

The value obtain is higher than 100 kPa, so a reinforcement intervention is needed in order to obtain a bigger foundation footprint on the ground thus decreasing the efforts transmitted to it. The minimum width of a foundation single strip to obtain a maximum effort of 100 kPa results:

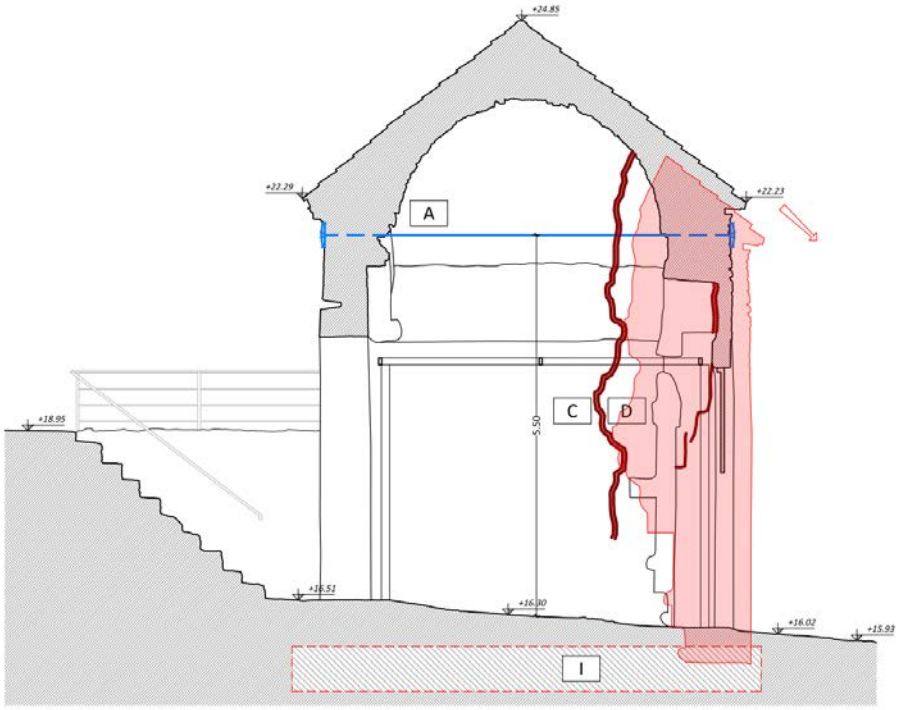
$s_{min.} = [(P_{MASONRY} + P_{VAULT} + P_{ROOF}) / (100\ kPa \cdot 2{,}80\ m)] = [420\ kN / (1\ m \cdot 2{,}80\ m)] \simeq 1{,}50\ m$

For this reason, an extension of the foundation is proposed by casting a reinforced concrete curb realized according to the requirements of structural project drawings. The minimum section will be 50 cm wide and 65 cm high, connected to the existing masonry by means of stainless-steel bars able to transmit the shear stresses between the concrete and the masonry. For what concerns the concrete reinforcing steel, there will be 3+2+3 Ø16 longitudinal bars and the stirrups Ø8 will be put every 25 cm; connectors between the concrete and the existent masonry will have a step of 25 cm as well.

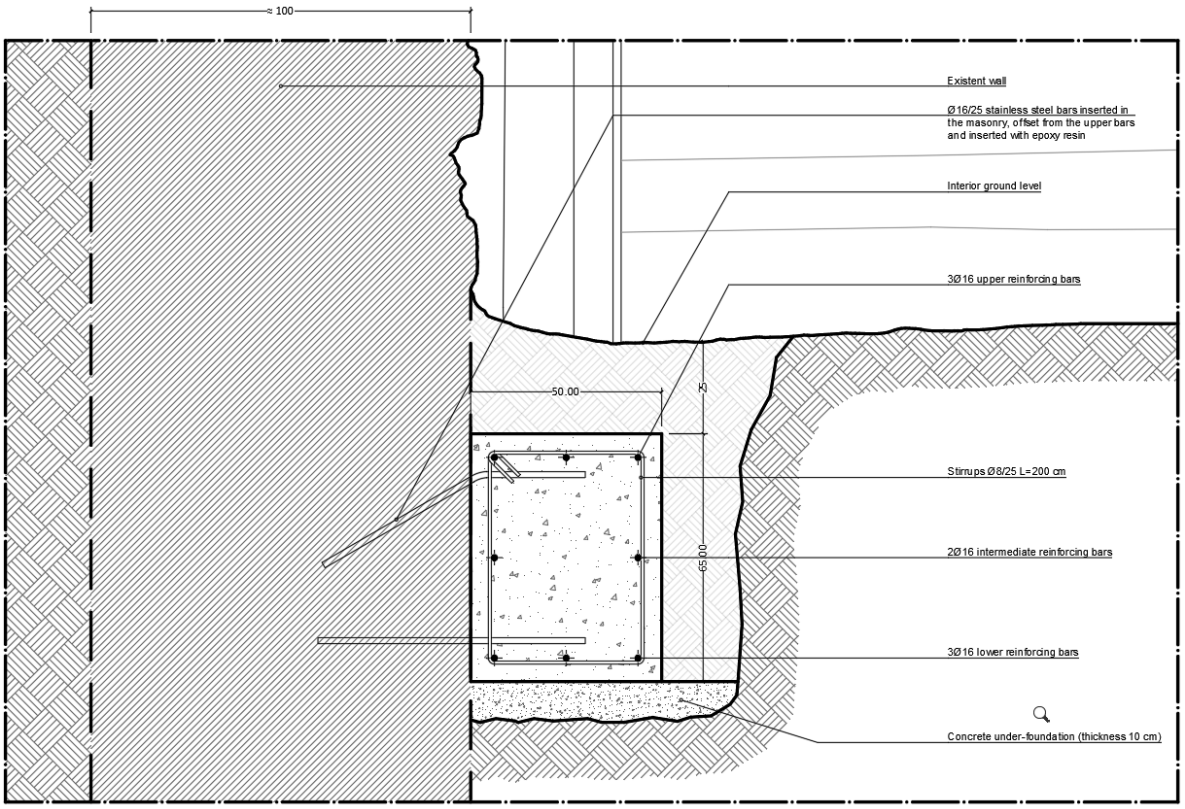
The following images summarize the interventions planned for the tower, with regard to foundations and vault reinforcements. The second image shows the damage scheme that the interventions have the aim of avoiding; the following construction details show the dimensions of the planned additional foundations and the requirements for the concrete reinforcing steel.



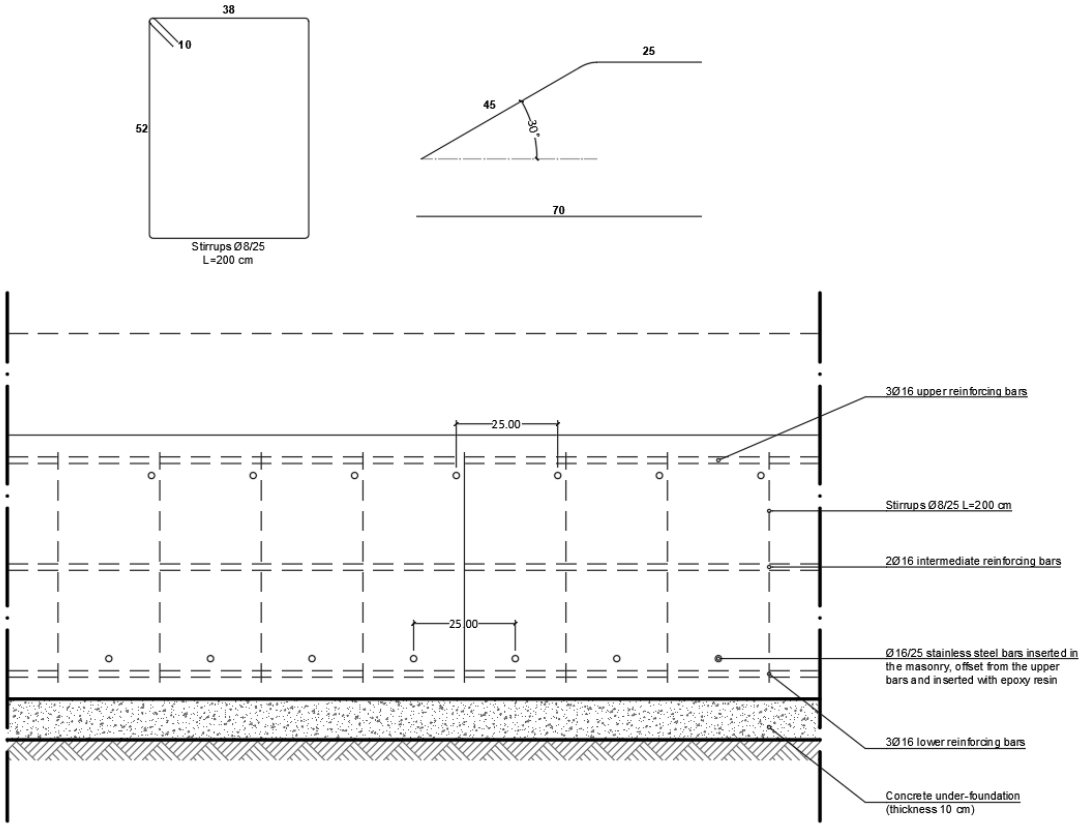

1-1 vertical section of the Water tower with indication of the structural works



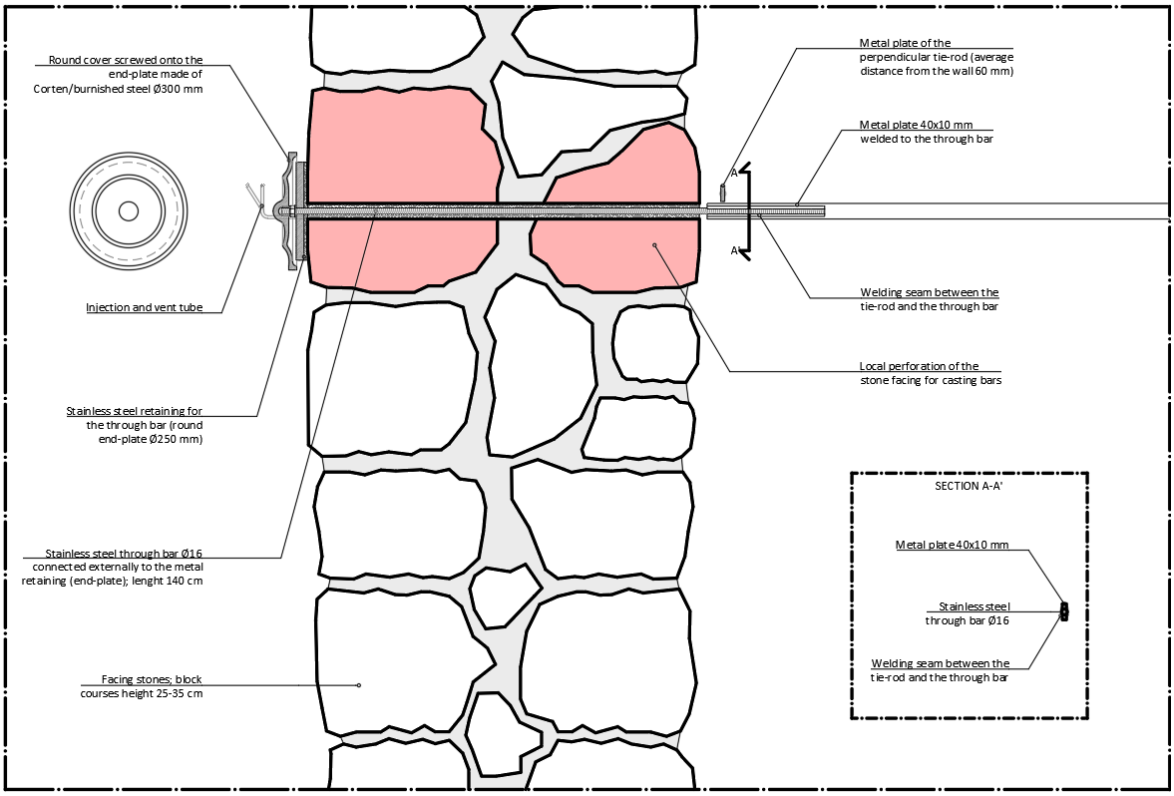

2-2 vertical section of the Water tower with indication of the structural works




The new curb made in reinforced concrete



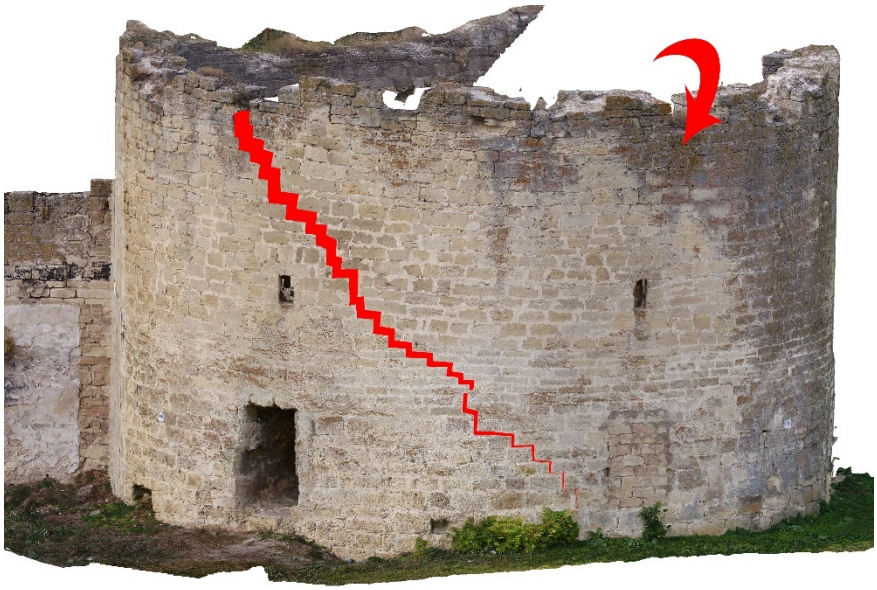

Lateral view of the curb




The new metal tie-rod and the round-plate with its cover

## 7.5 Reinforcement of Tower B3

The circular tower B3 is located at the northeast corner of the lower fortress and it's characterized by the total absence of deck inside. The proposed intervention aims to prevent any possible kinematical motion of overturning of portions of the perimeter wall due to seismic actions, as shown in the following picture.

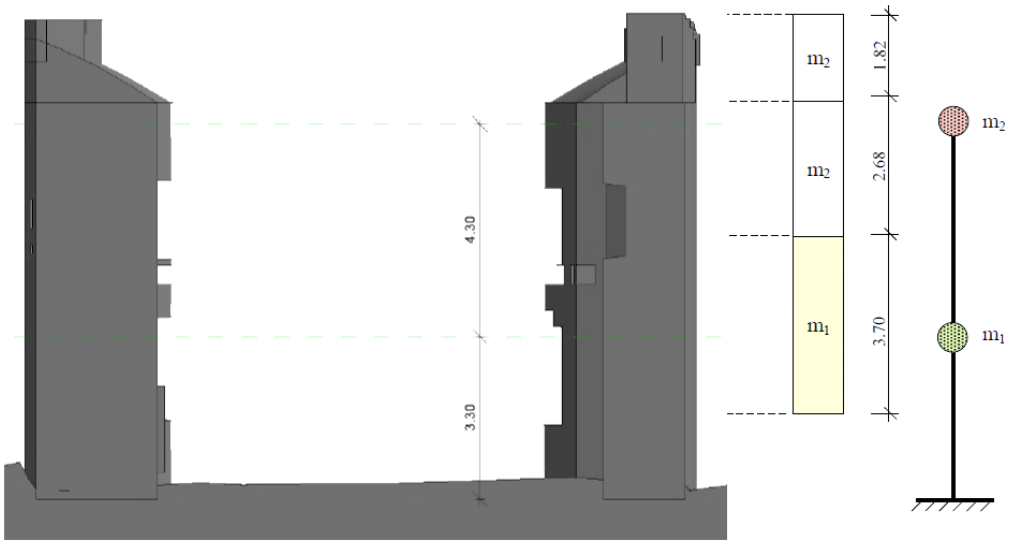


Typical kinematical motion of a portion of masonry in case of circular buildings such as Tower B3

This kind of seismic instability is typical of buildings with circular geometry such as towers or church apses. In the case of Tower B3, the intervention will be preventive, because currently the masonry does not show signs of damage but the lack of decks and consequently of a box behaviour can be considered as a vulnerability factor. From a static point of view, however, the tower doesn't show any sign of failure.
The proposed intervention consists of an external joint grouting with stainless steel strands Ø6 mm inserted - after partial sharpening - inside eight mortar joints in two main portions (upper and intermediate parts, approximately 3,00 m and 7,00 m above the external ground level) with ring connectors to keep the strands in place. Six steel strands for each joint are provided, for a total of 24 elements. Subsequent restoration of joints with mortar-based refills is needed. The mutual distance between a row of strands and the next one will correspond to the height of a course of stone blocks, an average of 25 cm. The strands will be arranged in such a way as to adapt to the irregular development of the joints, for this reason they will not have to be pre-tensioned and will thus act as a passive reinforcement system.
The anchoring system of the strands will be made with stainless steel bars anchored to the masonry for a depth of 1,50 m with mortar based on natural hydraulic lime. Two rows of strands (corresponding to two mortar joints) will be connected to each of these anchors.
Every executive indication is reported in the structural design drawing.

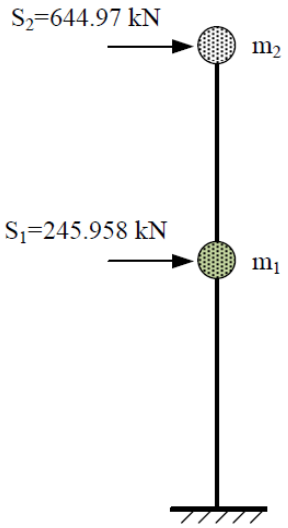
### *7.5.1 Sizing of the strand system*

For the evaluation of the maximum value of pulling action to which the strands can be subjected, the analysis carried out by Eng. Cutia can be an important reference. The tower has been modeled and analysed as cantilever, with two masses ($m_1$ and $m_2$) arranged at different elevations, as shown in the following picture.




The analysed model of Tower B3

The seismic forces associated to each individual mass considering both the first and the second way of vibrating are shown in the following diagram.




The seismic forces for Tower B3

The reinforcing system will be positioned indicatively at the height of the two masses, as it can be deduced also from the drawings of the structural design. The number and size of the strands will be verified at the most stressed portion of the tower, i.e. that with mass $m_2$, placed at the highest level.
As reported in Eng. Cutia's report, the seismic force $S_2$ to which the mass $m_2$ is subjected results 644,97 kN. Considering that in case of seismic action the detachable portion would correspond to about half of the mass $m_2$ (as can be seen in the first picture of this paragraph) and that both sides of the external hoop (diametrically opposite) would activate, the total number of strands to be involved would be 48 (six strands for each of the four joints on two sides of the tower) and the pulling action P to which the single strands would be subjected turns is:

$P = 0,5 \cdot S_2 / (4 \cdot 6 \cdot 2) = 6,72$ kN = 6720 N

The minimum required area for each strand is:

$A_{min.} = P / (\gamma_C \cdot R_y) = 6720\ N / (1 \cdot 240\ N/mm^2) = 28\ mm^2$

where $R_y = 240\ MPa = 240\ N/mm^2$ is yield strength for steel class C245 according to GOST 27772-88, reported in Eng. Cutia's report. The nominal area of each strands Ø6 mm is 28,27 $mm^2$, for this reason the size and the number of the strands assumed are verified for the containment of seismic forces.
The anchoring system consists of stainless-steel bars M16 with eyebolt, thimble and clamps for locking the strand, anchored to the masonry with mortar based on natural hydraulic lime, with a length of 150 cm. Considering that each anchor retaining bar is connected to 6+6 strands, the pulling action to which each bar is subjected is:

$T = 12 \cdot P = 12 \cdot 6720\ N = 80{,}64\ kN$

The pulling action that causes the collapse of the connection results instead:

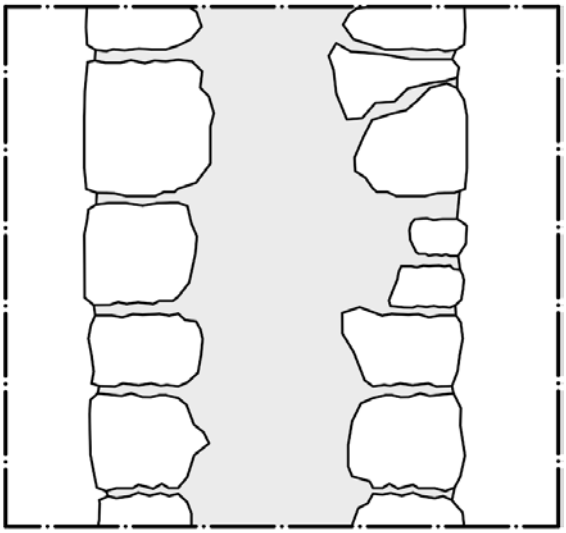
$F_{SU} = \tau_{bu} \cdot \pi \cdot \phi_s \cdot l_B = 2\ N/mm^2 \cdot 3{,}14 \cdot 16\ mm \cdot 1500\ mm = 150{,}80\ kN > T$

where $\tau_{bu}$ is a minimum value of tensile strength provided by the masonry, $\phi_s$ is the assumed diameter of the bar and $l_B$ is its assumed length. For this reason, the size of the anchoring system is verified.

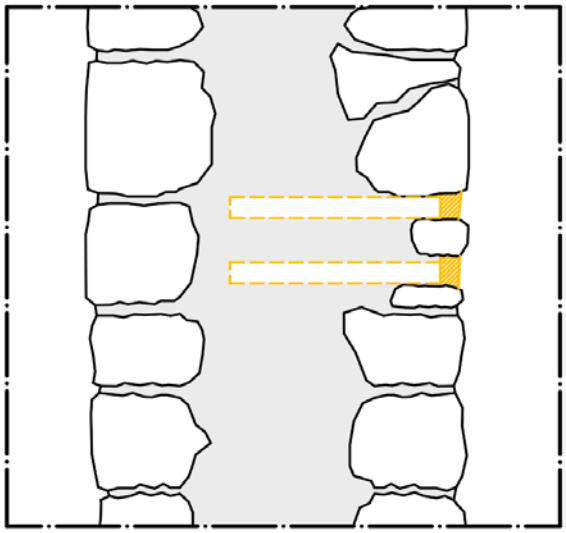
### *7.5.2 Operating sequences*

This paragraph illustrates the operating sequences for the realization of the external joint grouting on two different levels of the external side of the tower.

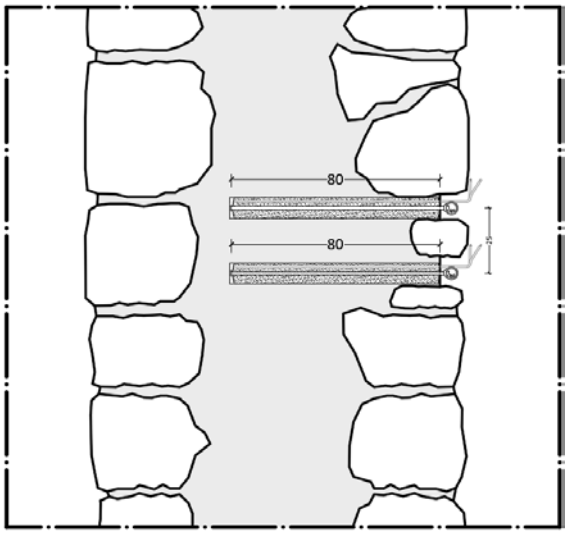
More specifically, the following four picture shows the operating sequences for the transverse ring connectors that connect the strands to the wall. The interval between these elements will have a minimum value of 3,35 m and a maximum one of 5,00 m.



Existent masonry.



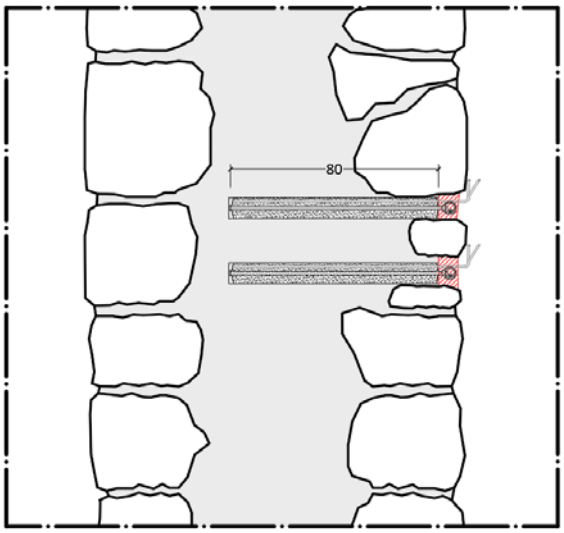
**PHASE I:** partial sharpening of the mortar joint for a dept of 5-6 cm and perforation of the wall with a hole diameter of 8 cm and depth 80 cm.




**PHASE II:** insertion of transverse ring connectors consisting of stainless-steel bars M16 anchored to the masonry, for a lenght of 80 cm, with mortar based on hydraulic lime (M3) with a minimum compressive strength of 12 Mpa. Minimum step 3,35 m; maximum step 5,00 m.

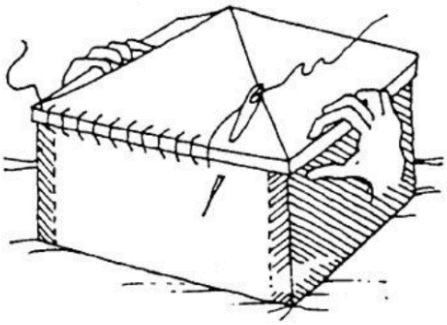
The bar, before being inserted in the masonry, must be inserted in a fabric sock open at the external end to allow the insertion of the injection tube for the mortar.

The six stainless steel strands are passed through the connector to maintain their position.

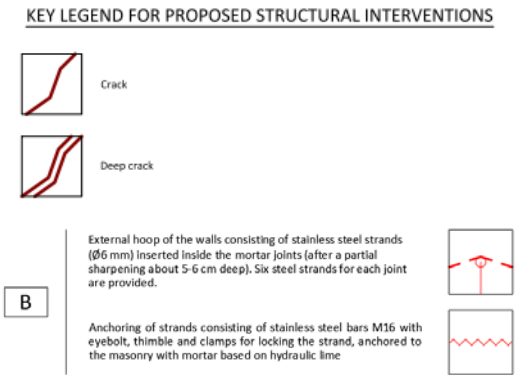


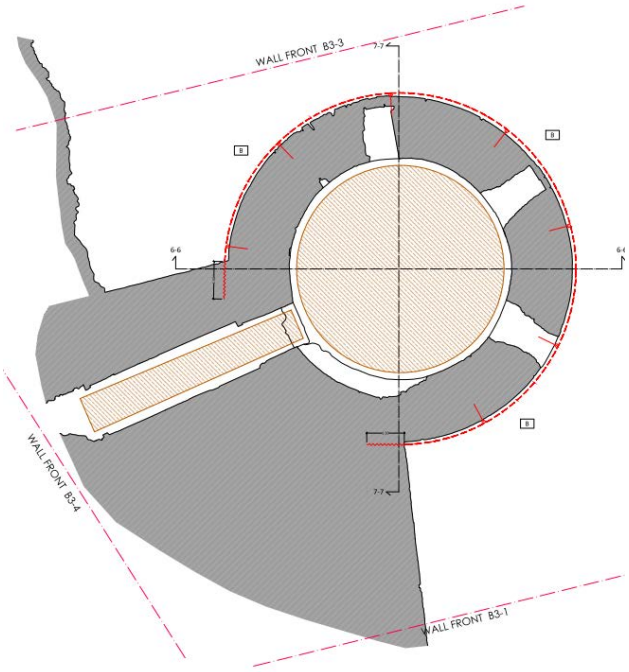

**PHASE III:** restoration of the mortar joint to cover the strands.

The following images summarize the interventions planned for the tower; the construction details show the arrangement and the number of the strands for each mortar joint and their connections with the existent masonry, even in in particular places such as the upper corner of the tower (see *Detail 2*).

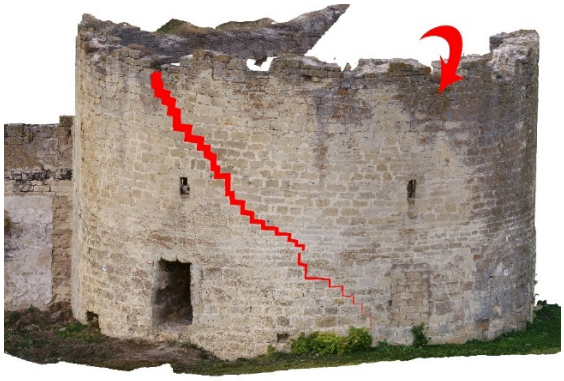


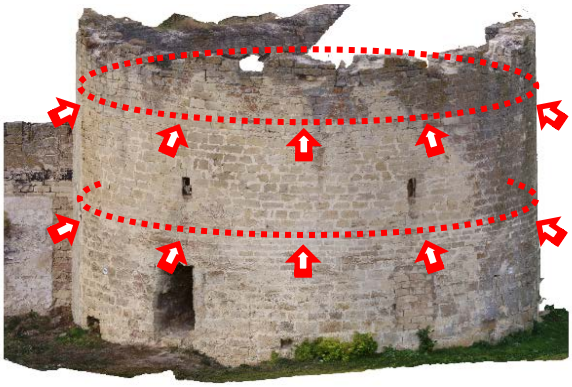
Circular walls are not loaded by the decks (which now are absent) but are similarly vulnerable because of the lack of the box-like effect.



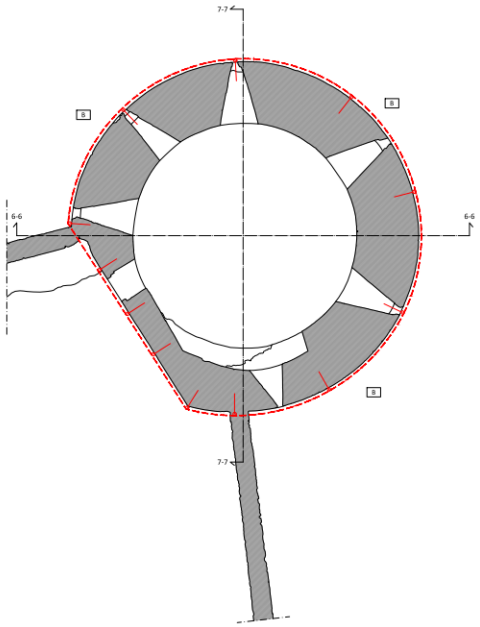

Plan Q3.40 with indication of the structural works





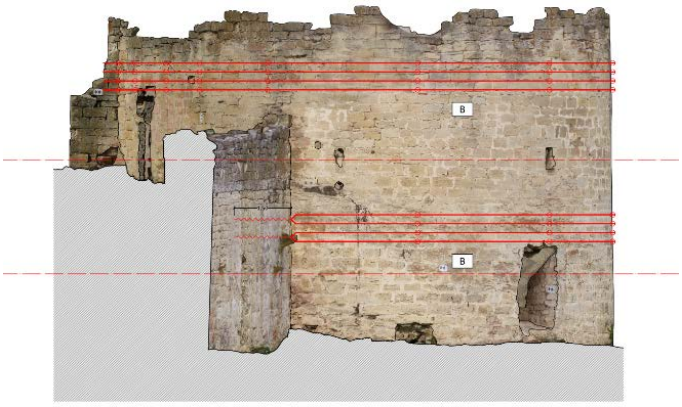
The intervention consists of an external hoop of the masonry with stainless steel strands inserted inside the mortar joints (after partial sharpening) and ring connectors to keep the strands in place. Subsequent restoration of joints with mortar-based refills is needed.

Anchoring system of the strands will be made with stainless steel bars anchored to the masonry with mortar based on hydraulic lime.

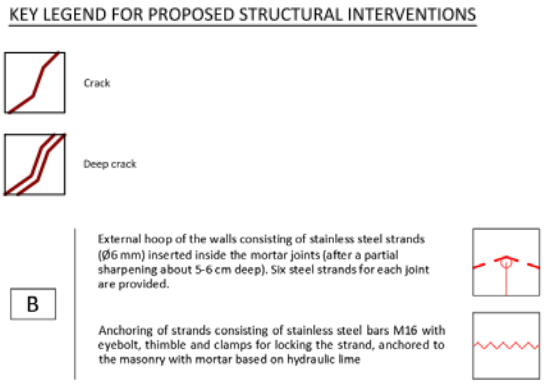


Plan Q6.40 with indication of the structural works

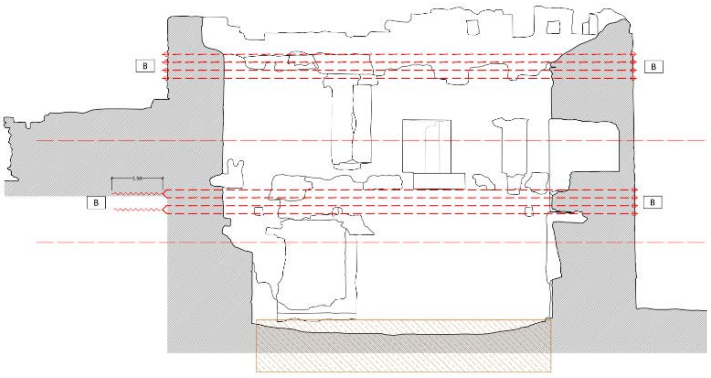
The steel strands inserted inside the mortar joints and the joints after the proposed intervention.



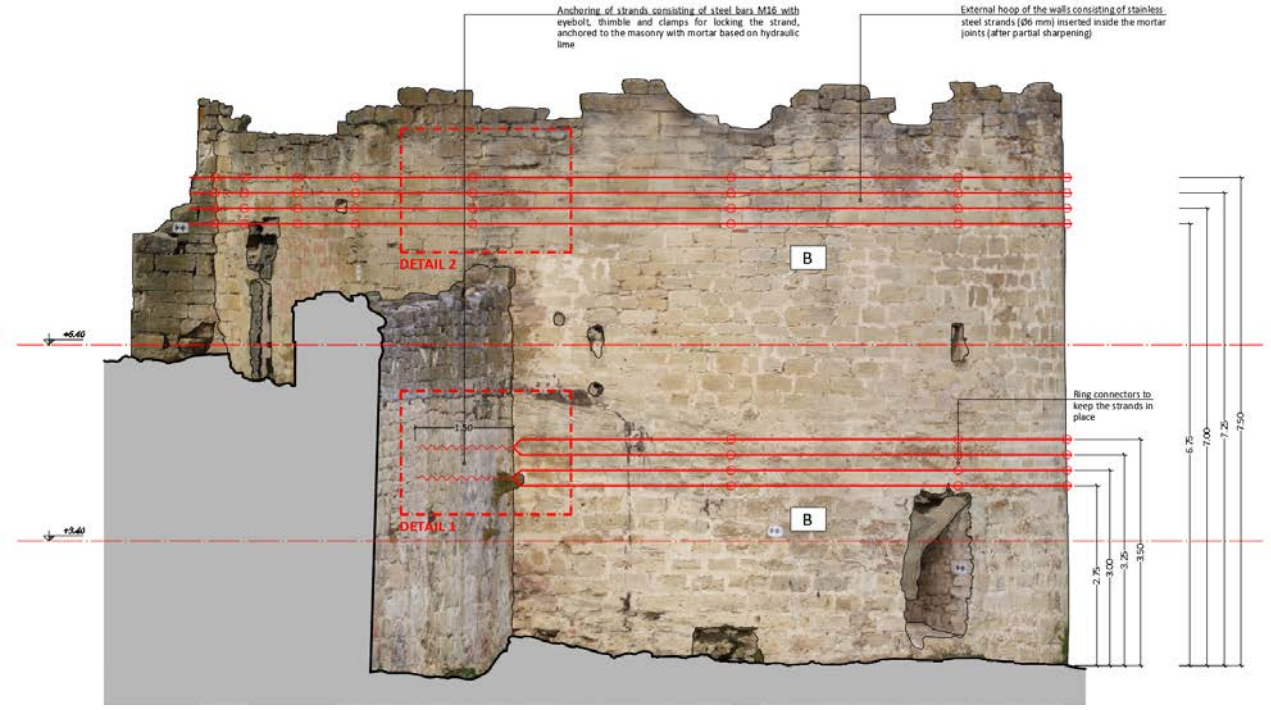
Detail of the anchoring system of the strands



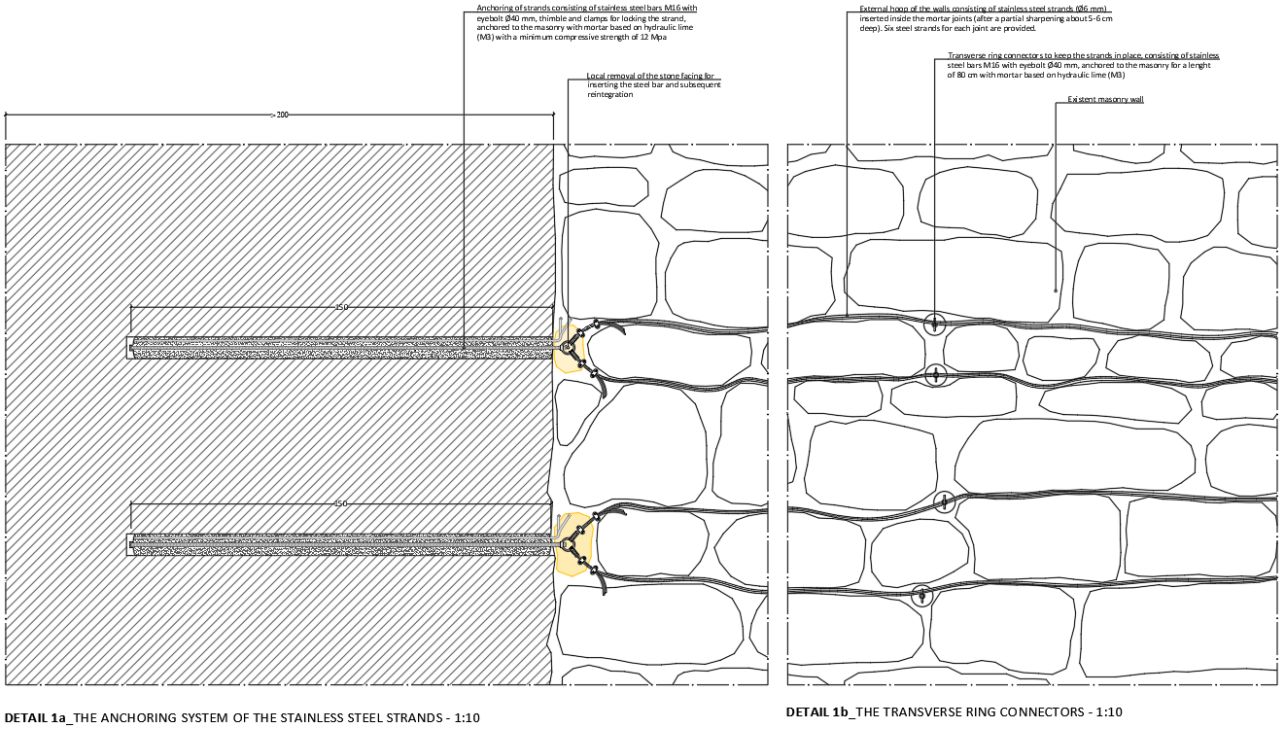

Southern elevation with indication of the structural works




Vertical section with indication of the structural works



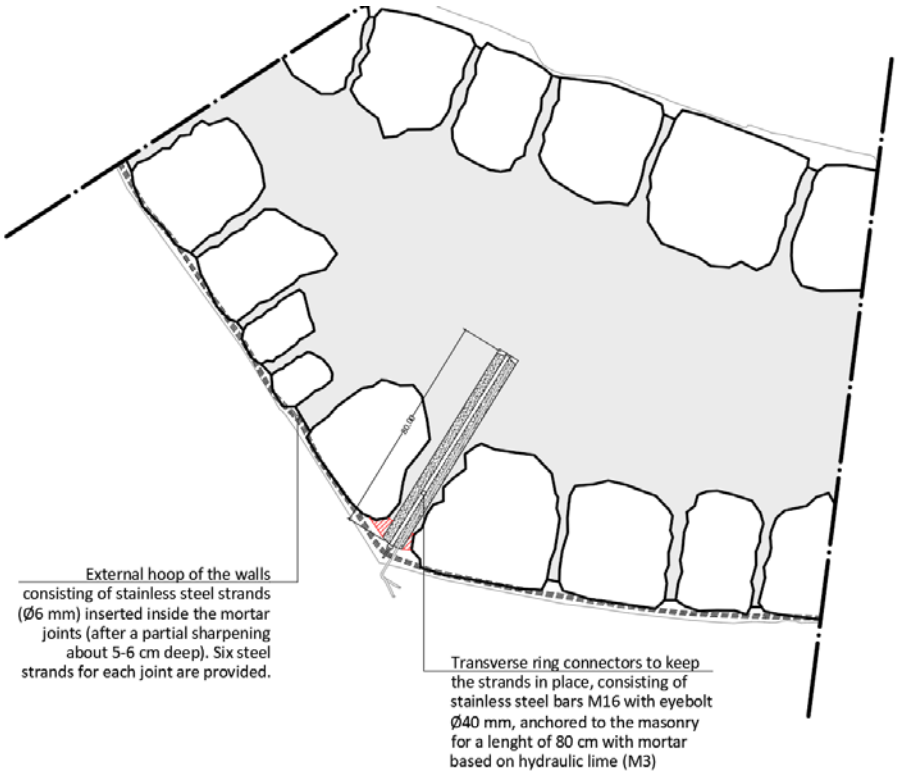

The southern elevation of Tower B3 with indication of the structural works. Detail 1 and Detail 2 are indicated




**DETAIL 1a**_THE ANCHORING SYSTEM OF THE STAINLESS STEEL STRANDS - 1:10

**DETAIL 1b**_THE TRANSVERSE RING CONNECTORS - 1:10

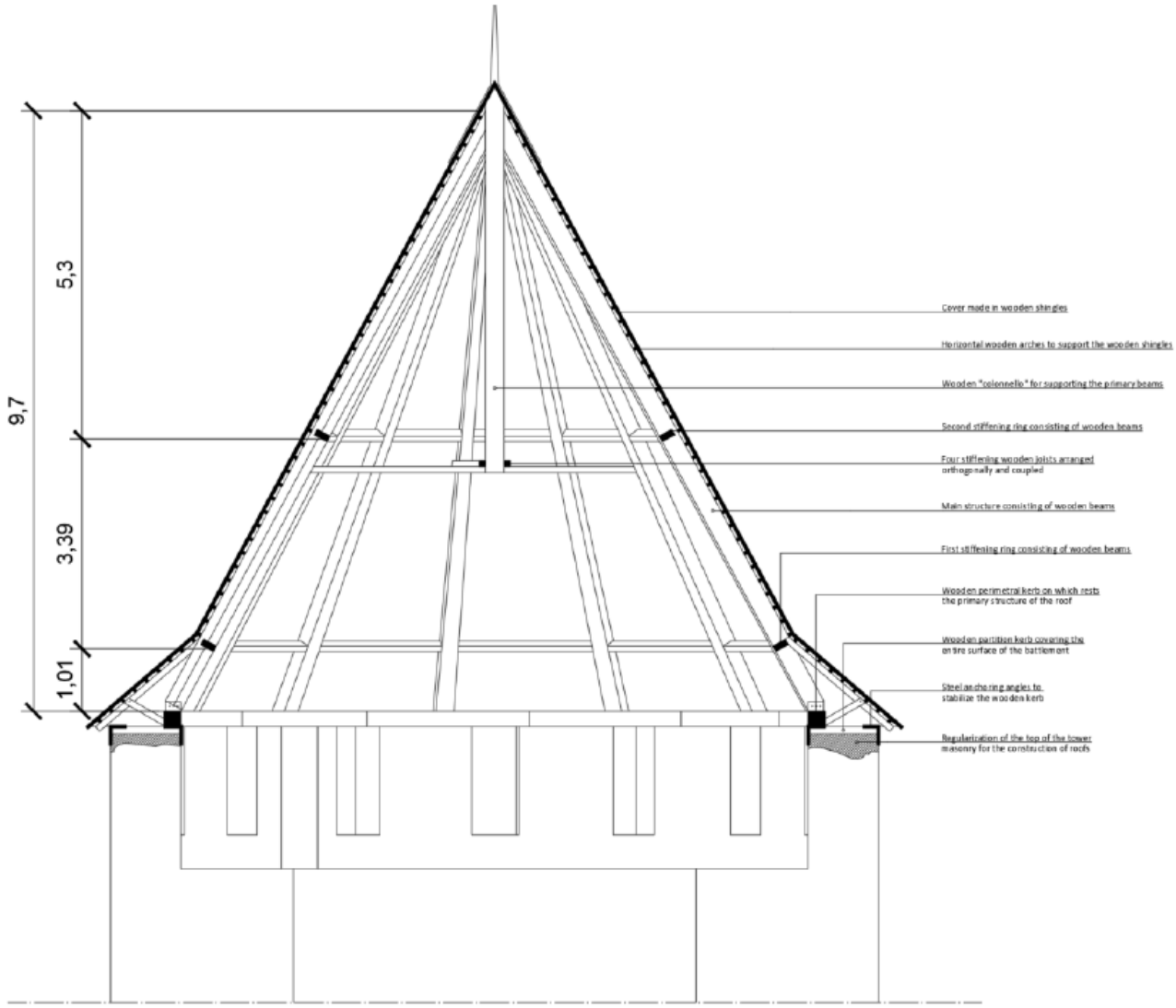
**Detail 1:** anchoring system of the stinless-steel strand (on the left) and the transverse ring connectors (on the right)




**Detail 2:** the transverse ring connectors

## 7.6 New roofs for towers A2, A4 and A6

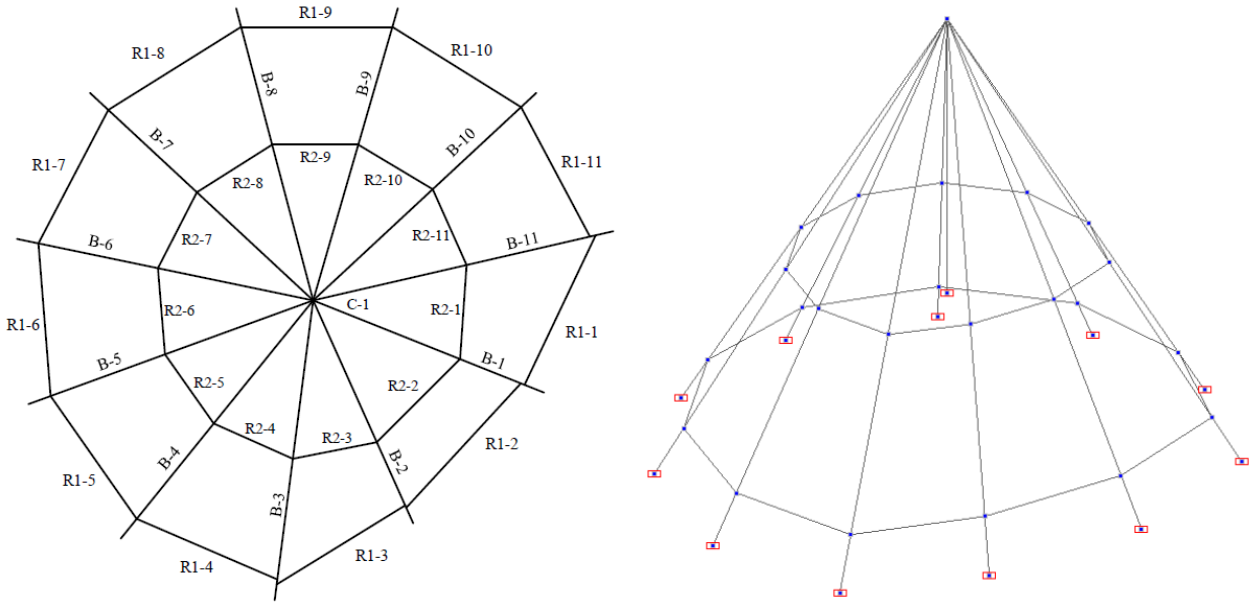
The new roof will be made of timber beams with two stiffening rings around it and covered with wooden shingles. The structure will consist of a primary warping with wooden beams 30x30 cm, two stiffening rings with wooden beams 25x10 cm, a wooden axial beam Ø30 cm and a secondary warping with horizontal wooden arches 5x5 cm (to support the wooden shingles) connected to the main beams. The whole structure insists on a wooden perimetral kerb formed by wooden beams 25x25 cm bound punctually to the underlying masonry after an appropriate regularization of the top masonry. A scheme of the structure can be section in the following section of the roof.
Every executive indication about materials and connections is reported in the structural design drawing.




Typological section of a new roof

In the next picture the indication of the element which have been verified is shown. With regard to the verification of each element, please refer to the calculations reported in Eng. Cutia report, in which it can be deduced that the structural resistance and stability of all structure it-self is ensured.
The analysis was carried out with regard to a kind of roof which can be used both for Towers A2 and A4 (circular plan) and for Tower A6 (polygonal plan), since they all have similar dimensions.

The relative structural analyses, therefore, can be considered ensured and sufficiently exhaustive also for Tower A3 (with a square plan) which is smaller than the others and shows less burdensome load configurations.




Plan and axonometric view of roof structure with indication of the single wooden beams which have been verified

## 7.7 New railings

As already specified in paragraph 7.3.3., railings will be installed directly on the patrol path and they will consist of vertical supports in CORTEN steel with box profile of 50x50 mm positioned at a mutual distance of 1,20 m, a top rail with a rectangular section and perforated panels according to the architectural design drawings. The steel box profile will be inserted in the masonry with epoxy resin for a depth of 20 cm; the steel bar Ø16, inserted inside it, will descend in depth for another 40 cm.
In this paragraph the overturning verification of the railings pillars is reported, the verification has been carried out considering a horizontal linear load applied to their top.

Although Moldavian regulations does not prescribe any kind of load on the railings (only some prevision of the dimensions are provided, especially their height), it might be reasonable that they should withstand a horizontal load of approximately 100 kgf/m, whereas the walkways where railings will be installed are places open to the public and therefore they should be able to accommodate many visitors at a time.
Considering a linear load f of 100 kgf/m, with a wheelbase i of 1,20 m between the pillars, the resulting punctual load P on the single pillar is:

$P = 2 \cdot [(f \cdot i) / 2] = 2 \cdot 100 \text{ kgf/m} \cdot 1{,}20 \text{ m} \cdot 0{,}50 = 120 \text{ kgf} = 1{,}20 \text{ kN}$

This value refers to the load that each pillar receives from two adjacent wheelbase; for this reason, in the formula it has been doubled. Considering the height h of railings (1,10 m) the stress moment at the base of the pillars is:

$M = P \cdot h = 1{,}20 \text{ kN} \cdot 1{,}10\text{m} = 1{,}32 \text{ kNm}$

The resistant section consists of a box steel profile of 50x50 mm, with a thickness s of 3 mm. The resistance module W of this profile is:

$W = [(H^4 – h^4) / 6 \cdot H] = [(50 \text{ mm})^4 – (44 \text{ mm})^4 / 6 \cdot 50 \text{ mm}] = 8339{,}68 \text{ mm}^3$

where H is the external side of the section and $h = H – 2 \cdot s$.
The bending stress is therefore:

$\sigma = M / W = 1{,}32 \text{ kNm} / 8339{,}68 \text{ mm}^3 = 1{,}32 \cdot 10^6 \text{ Nmm} / 8339{,}68 \text{ mm}^3 = 158{,}28 \text{ MPa}$

In order to ensure that the calculated value of effort is compatible with the steel used, it is required to use a CORTEN steel with chemical and mechanical characteristics similar to that of category S235JOW provided by EN 10025-5 standard, in accordance with the requirements provided by the structural design drawings.

# 8 Safety plan

## 8.1 Type of fencing of the territory

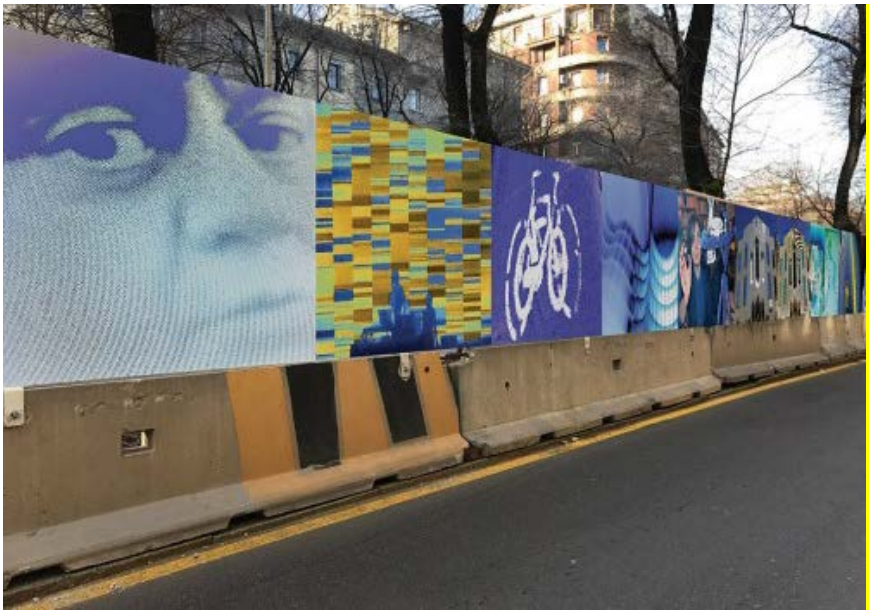
Fencing of construction site should be made of OSB panels or similar material, if necessary supported by concrete bases.

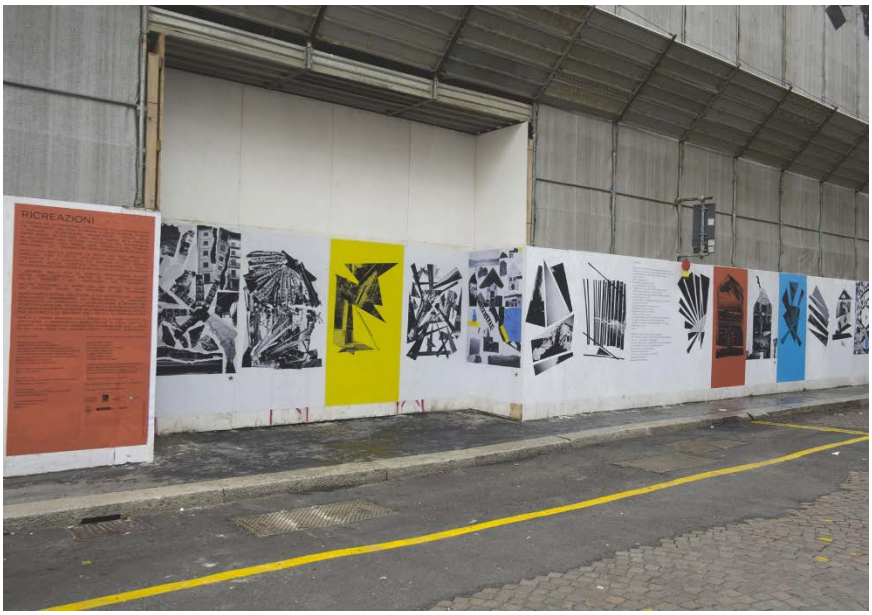
The panels will have to have informative function of the yard in progress through two modalities:

- provide transparent windows in some areas of the panels in order to allow visitors to see the work in progress
- provide contents for the communication of the history of the fortress and of the restoration project

The contents will be shared by the contractor with the work supervisor and approved by UNDP.

Some examples are provided below.



## 8.2 Basic principles regarding the organization of construction works and safety

### *8.2.1* Introduction

The objective is to develop a site organizational project for project "*Technical Expertise and develop Detailed Technical Design for conservation/restoration works of Bender Fortress*". The main objective of this project is the organization of the site and the management of the funds allocated for this purpose. In this sense, it is necessary to adopt rational solutions that will satisfy different requirements and other conditions that could appear in some situations along with saving of founds and resources.

The organization of the site, on each new location, is imposed by the action of the peculiarities of the production process and technologies in constructions. In this explanation note are selected and described the main works that will be performed during restauration of Bender Fortress. Along with the site organization plan, the detailed description of work stuff units and storages is provided. In addition to this the Gantt chart of work is shown.

Works are divided in four major phases:

I. First phase – at this phase the structural rehabilitation works of lower part of the fortress, i.e. Tower B3 is made.

II. Second phase – At the same time with first phase, the structural rehabilitation and architectural interventions at Water Towers are made.

III. The third phase is concentrated at citadel level where the structural reinforcement of wall A6-A7 and structural interventions at tower A6 are made. These works are followed with architectural interventions of wall and towers and finished with drainage system.

IV. The last phase of rehabilitation works represents extension of third phase. At this point only architectural interventions are made for walls and towers A4-A2-A8. Also, the handrails and perforated railings are installed to ensure security of visitors.

### *8.2.2* Solutions of technological sequence and methods of execution of works

**1. Restauration and completion of towers masonry and walls between them**

a. Removal of biological patina by application of biocide on surfaces.

b. Removal of shrubby vegetation by application of biocide.

c. Tangential sandblasting (with JOS or IBIX type system) operating with compressed air, with adjustable operating pressure, variable nozzle mounted on pen or gun.

d. Consolidation of structural cracks with preventive sealing of sublevel lesions with hydraulic lime mortar and aggregates, with insertion of the pipes necessary for injections and subsequent infiltration in depth of pre-mixed hydraulic mortars carried out gradually proceeding from the bottom to the top until saturation of the continuity solutions; including final grouting with finishing lime mortars.

e. Reparation of gaps affecting the core wall, carried out through integration with materials similar to the original ones.

f. Resumption of the drawing-up of the crack through the scrapping of the old cement mortars, then grouting with lime mortar and suitable aggregates.

g. Reconstruction of the joints through the stripping of old mortars (if irrecoverable) with the burden of protection of the sections where conservative intervention is possible, grouting of the connections with lime mortar and adequate aggregates, including the charges related to the essays for the composition mortars suitable for coloring and granulometry, surface

processing, cleaning of any residues from the surrounding surfaces, excluding the restoration of the cohesion of the preserved mortars, with a layer of depth with hydraulic mortar and any filling material (for a leveling layer); to be assessed on the actual treated surface: - medium-sized limestone or tophaceous face.

h. Filling lacuna affecting the walls, carried out through integration with materials similar to the original ones; including charges relating to the supply of the material to be integrated.

i. Surface reconstruction with "scuci-cuci" technique of wall facing of solid brick, stone or mixed masonry. Including: the mortar corresponding, if necessary, to the characteristics of the original one; new or recovered bricks or stones; the immorsature between new and old courses; the grouting and styling of the joints; the demolition of the damaged parts; the stacking of the rubble within the construction site, their loading and transport to storage, recovery or landfill plants; temporary works of protection, internal work plans. Excluding external scaffolding and disposal charges.

j. Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones), vertical and horizontal, in environments of any size, with mortar based on special hydraulic binders and aggregates selected and controlled in rational grain size distribution.

**2. Recent interventions**

a. Rebuild existing elements.

**3. Drainage system**

a. Cleaning and restoration of concrete drain channel.

b. Unreinforced excavation for pipes and manifolds.

c. Supply and installation of precast concrete channels, with built-in longitudinal slope.

**4. Masonry wall reinforcement**

a. Perforation of the wall for all its thickness with a hole diameter of 4-5 cm, with temporary local removal of the stone facing at the point of realization of the hole.

b. Insertion of the stainless steel through bar Ø16 mm with injection of fibre-reinforced hydraulic lime mortar (M3).

c. Application of the stainless steel retaining for the diatons consisting of a round end-plate Ø150 mm and pyramid-shaped cover placed in the center of the blocks.

**5. Reinforcement of Water Tower**

a. Partial excavation of foundation.

b. Execution of RC beams.

c. Perforations on solid brick, stone or mixed masonry performed with suitable equipment.

d. Iron worked for tie-rods, hoops, ties, wall keys, turnbuckles, clamps, plates, bands and similar elements, on site.

e. Injections in perforations already prepared, performed with hydraulic fluid mortar without cement with any anti-shrinkage additives with the use of a suitable low pressure injection system.

f.

6. **Reinforcement of Tower B3**
    a. Partial sharpening of the mortar joint for a dept of 5-6 cm and perforation of the wall with a hole diameter of 8 cm and depth 80 cm.
    b. Insertion of transverse ring connectors consisting of stainless steel bars M16anchored to the masonry, for a length of 80 cm, with mortar based on hydraulic lime (M3) with a minimum compressive strength of 12 MPa.
    c. Restoration of the mortar joint to cover the strands.
7. **Reinforcement of Tower A6**
    a. Perforations on solid brick, stone or mixed masonry performed with suitable equipment.
    b. Iron worked for tie-rods, hoops, ties, wall keys, turnbuckles, clamps, plates, bands and similar elements, on site.
    c. Injections in perforations already prepared, performed with hydraulic fluid mortar without cement with any anti-shrinkage additives with the use of a suitable low-pressure injection system.
8. **New roof for towers A2, A3, A4, A6**
    a. Installing new roofs on towers A2 and A4.
    b. Removing the old roof structure from tower A3 and A6.
    c. Installing new wooden roof structure on tower A3 and A6.

### *8.2.3* Work volumes

*Tabel 1 Estimated amount of work*

| Nr. | Works | U.M. | Volume | Reference | Time frame | | Labor | | Team |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Man/h | Machine/h | Man/h | Machine/h | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8.0 | 9 | 10 |
| 1 | Instalation of scaffolding (extern Tower A1) | m2 | 403 | CB14A | 0.75 | - | 302.3 | - | 1 skilled worker |
| 2 | Instalation of scaffolding (extern Tower A2) | m2 | 525 | CB14A | 0.75 | - | 393.8 | - | 1 skilled worker |
| 3 | Instalation of scaffolding (extern Tower A3) | m2 | 276 | CB14A | 0.75 | - | 207.0 | - | 1 skilled worker |
| 4 | Instalation of scaffolding (extern Tower A4) | m2 | 462 | CB14A | 0.75 | - | 346.5 | - | 1 skilled worker |
| 5 | Instalation of scaffolding (extern Tower A5) | m2 | 312 | CB14A | 0.75 | - | 234.0 | - | 1 skilled worker |
| 6 | Instalation of scaffolding (extern Tower A6) | m2 | 434 | CB14A | 0.75 | - | 325.5 | - | 1 skilled worker |
| 7 | Instalation of scaffolding (extern Tower A7) | m2 | 325 | CB14A | 0.75 | - | 243.8 | - | 1 skilled worker |
| 8 | Instalation of scaffolding (extern Tower A8) | m2 | 336 | CB14A | 0.75 | - | 252.0 | - | 1 skilled worker |
| 9 | Instalation of scaffolding (extern Tower B3) | m2 | 320 | CB14A | 0.75 | - | 240.0 | - | 1 skilled worker |
| 10 | Instalation of scaffolding (extern Woter Tower) | m2 | 70 | CB14A | 0.75 | - | 52.5 | - | 1 skilled worker |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11 | Instalation of scaffolding (extern wall A1-A2) | m2 | 232 | CB14A | 0.75 | - | 174.0 | - | 1 skilled worker |
| 12 | Instalation of scaffolding (extern wall A2-A3) | m2 | 296 | CB14A | 0.75 | - | 222.0 | - | 1 skilled worker |
| 13 | Instalation of scaffolding (extern wall A3-A4) | m2 | 320 | CB14A | 0.75 | - | 240.0 | - | 1 skilled worker |
| 14 | Instalation of scaffolding (extern wall A4-A5) | m2 | 200 | CB14A | 0.75 | - | 150.0 | - | 1 skilled worker |
| 15 | Instalation of scaffolding (extern wall A5-A6) | m2 | 200 | CB14A | 0.75 | - | 150.0 | - | 1 skilled worker |
| 16 | Instalation of scaffolding (extern wall A6-A7) | m2 | 480 | CB14A | 0.75 | - | 360.0 | - | 1 skilled worker |
| 17 | Instalation of scaffolding (extern wall A7-A8) | m2 | 540 | CB14A | 0.75 | - | 405.0 | - | 1 skilled worker |
| 18 | Instalation of scaffolding (intern Tower A1) | m2 | 96 | CB14A | 0.75 | - | 72.0 | - | 1 skilled worker |
| 19 | Instalation of scaffolding (intern Tower A2) | m2 | 79 | CB14A | 0.75 | - | 59.3 | - | 1 skilled worker |
| 20 | Instalation of scaffolding (intern Tower A3) | m2 | 72 | CB14A | 0.75 | - | 54.0 | - | 1 skilled worker |
| 21 | Instalation of scaffolding (intern Tower A4) | m2 | 82 | CB14A | 0.75 | - | 61.5 | - | 1 skilled worker |
| 22 | Instalation of scaffolding (intern Tower A5) | m2 | 96 | CB14A | 0.75 | - | 72.0 | - | 1 skilled worker |
| 23 | Instalation of scaffolding (intern Tower A6) | m2 | 82 | CB14A | 0.75 | - | 61.5 | - | 1 skilled worker |
| 24 | Instalation of scaffolding (intern Tower A7) | m2 | 72 | CB14A | 0.75 | - | 54.0 | - | 1 skilled worker |
| 25 | Instalation of scaffolding (intern Tower A8) | m2 | 82 | CB14A | 0.75 | - | 61.5 | - | 1 skilled worker |
| 26 | Instalation of scaffolding (intern Tower B3) | m2 | 40 | CB14A | 0.75 | - | 30.0 | - | 1 skilled worker |
| 27 | Instalation of scaffolding (intern Woter Tower) | m2 | 72 | CB14A | 0.75 | - | 54.0 | - | 1 skilled worker |
| 28 | Instalation of scaffolding (intern wall A8-A2) | m2 | 360 | CB14A | 0.75 | - | 270.0 | - | 1 skilled worker |
| 29 | Instalation of scaffolding (intern wall A2-A4) | m2 | 528 | CB14A | 0.75 | - | 396.0 | - | 1 skilled worker |
| 30 | Instalation of scaffolding (intern wall A5-A6) | m2 | 228 | CB14A | 0.75 | - | 171.0 | - | 1 skilled worker |
| 31 | Instalation of scaffolding (intern wall A6-A8) | m2 | 495 | CB14A | 0.75 | - | 371.3 | - | 1 skilled worker |
| 32 | Instalation of scaffolding (intern wall A4-A5) | m2 | 234 | CB14A | 0.75 | - | 175.5 | - | 1 skilled worker |
| 33 | Removal of scaffolding (extern Tower A1) | m2 | 403 | CB14A | 0.75 | - | 302.3 | - | 1 skilled worker |
| 34 | Removal of scaffolding (extern Tower A2) | m2 | 525 | CB14A | 0.75 | - | 393.8 | - | 1 skilled worker |
| 35 | Removal of scaffolding (extern Tower A3) | m2 | 276 | CB14A | 0.75 | - | 207.0 | - | 1 skilled worker |
| 36 | Removal of scaffolding (extern Tower A4) | m2 | 462 | CB14A | 0.75 | - | 346.5 | - | 1 skilled worker |
| 37 | Removal of scaffolding (extern Tower A5) | m2 | 312 | CB14A | 0.75 | - | 234.0 | - | 1 skilled worker |
| 38 | Removal of scaffolding (extern Tower A6) | m2 | 434 | CB14A | 0.75 | - | 325.5 | - | 1 skilled worker |

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|---|---|---|---|---|---|---|---|---|---|
| 39 | Removal of scaffolding (extern Tower A7) | m2 | 325 | CB14A | 0.75 | - | 243.8 | - | 1 skilled worker |
| 40 | Removal of scaffolding (extern Tower A8) | m2 | 336 | CB14A | 0.75 | - | 252.0 | - | 1 skilled worker |
| 41 | Removal of scaffolding (extern wall A1-A2) | m2 | 232 | CB14A | 0.75 | - | 174.0 | - | 1 skilled worker |
| 42 | Removal of scaffolding (extern wall A2-A3) | m2 | 296 | CB14A | 0.75 | - | 222.0 | - | 1 skilled worker |
| 43 | Removal of scaffolding (extern wall A3-A4) | m2 | 320 | CB14A | 0.75 | - | 240.0 | - | 1 skilled worker |
| 44 | Removal of scaffolding (extern wall A4-A5) | m2 | 200 | CB14A | 0.75 | - | 150.0 | - | 1 skilled worker |
| 45 | Removal of scaffolding (extern wall A5-A6) | m2 | 200 | CB14A | 0.75 | - | 150.0 | - | 1 skilled worker |
| 46 | Removal of scaffolding (extern wall A6-A7) | m2 | 480 | CB14A | 0.75 | - | 360.0 | - | 1 skilled worker |
| 47 | Removal of scaffolding (extern wall A7-A8) | m2 | 540 | CB14A | 0.75 | - | 405.0 | - | 1 skilled worker |
| 48 | Removal of scaffolding (extern Tower B3) | m2 | 320 | CB14A | 0.75 | - | 240.0 | - | 1 skilled worker |
| 49 | Removal of scaffolding (extern Woter Tower) | m2 | 70 | CB14A | 0.75 | - | 52.5 | - | 1 skilled worker |
| 50 | Removal of scaffolding (intern Tower A1) | m2 | 96 | CB14A | 0.75 | - | 72.0 | - | 1 skilled worker |
| 51 | Removal of scaffolding (intern Tower A2) | m2 | 79 | CB14A | 0.75 | - | 59.3 | - | 1 skilled worker |
| 52 | Removal of scaffolding (intern Tower A3) | m2 | 72 | CB14A | 0.75 | - | 54.0 | - | 1 skilled worker |
| 53 | Removal of scaffolding (intern Tower A4) | m2 | 82 | CB14A | 0.75 | - | 61.5 | - | 1 skilled worker |
| 54 | Removal of scaffolding (intern Tower A5) | m2 | 96 | CB14A | 0.75 | - | 72.0 | - | 1 skilled worker |
| 55 | Removal of scaffolding (intern Tower A6) | m2 | 82 | CB14A | 0.75 | - | 61.5 | - | 1 skilled worker |
| 56 | Removal of scaffolding (intern Tower A7) | m2 | 72 | CB14A | 0.75 | - | 54.0 | - | 1 skilled worker |
| 57 | Removal of scaffolding (intern Tower A8) | m2 | 82 | CB14A | 0.75 | - | 61.5 | - | 1 skilled worker |
| 58 | Removal of scaffolding (intern Tower B3) | m2 | 40 | CB14A | 0.75 | - | 30.0 | - | 1 skilled worker |
| 59 | Removal of scaffolding (intern Woter Tower) | m2 | 72 | CB14A | 0.75 | - | 54.0 | - | 1 skilled worker |
| 60 | Removal of scaffolding (intern wall A8-A2) | m2 | 360 | CB14A | 0.75 | - | 270.0 | - | 1 skilled worker |
| 61 | Removal of scaffolding (intern wall A2-A4) | m2 | 528 | CB14A | 0.75 | - | 396.0 | - | 1 skilled worker |
| 62 | Removal of scaffolding (intern wall A5-A6) | m2 | 228 | CB14A | 0.75 | - | 171.0 | - | 1 skilled worker |
| 63 | Removal of scaffolding (intern wall A6-A8) | m2 | 495 | CB14A | 0.75 | - | 371.3 | - | 1 skilled worker |
| 64 | Removal of scaffolding (intern wall A4-A5) | m2 | 234 | CB14A | 0.75 | - | 175.5 | - | 1 skilled worker |
| 65 | Removing vegetation by applying biocide (external wall and towers A2-A8) | m2 | 325 | CN53A | 0.03 | - | 9.8 | - | 1 skilled worker |

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|---|---|---|---|---|---|---|---|---|---|
| 66 | Removing vegetation by applying biocide (external wall and towers A6-A8) | m2 | 652 | CN53A | 0.03 | - | 19.6 | - | 1 skilled worker |
| 67 | Removing vegetation by applying biocide (external wall and towers A6-A4) | m2 | 670 | CN53A | 0.03 | - | 20.1 | - | 1 skilled worker |
| 68 | Removing vegetation by applying biocide (external wall and towers A4-A2) | m2 | 330 | CN53A | 0.03 | - | 9.9 | - | 1 skilled worker |
| 69 | Removing vegetation by applying biocide (internal wall and towers A2-A8) | m2 | 290 | CN53A | 0.03 | - | 8.7 | - | 1 skilled worker |
| 70 | Removing vegetation by applying biocide (internal wall and towers A6-A4) | m2 | 10 | CN53A | 0.03 | - | 0.3 | - | 1 skilled worker |
| 71 | Removing vegetation by applying biocide (internal wall and towers A4-A2) | m2 | 142 | CN53A | 0.03 | - | 4.3 | - | 1 skilled worker |
| 72 | Removing vegetation by applying biocide (internal wall and water tower) | m2 | 40 | CN53A | 0.03 | - | 1.2 | - | 1 skilled worker |
| 73 | Tangential sandblasting (with JOS type system)operating with compressed air, with adjustable operating pressure, variable nozzle mounted on pen or gun. (external towers and masanories) | m2 | 4224 | IzA01A | 0.36 | 0.1 | 1520.6 | 422.4 | 2 skilled worker |
| 74 | Tangential sandblasting (with JOS type system)operating with compressed air, with adjustable operating pressure, variable nozzle mounted on pen or gun. (internal towers and masanories) | m2 | 2316 | IzA01A | 0.36 | 0.1 | 833.8 | 231.6 | 2 skilled worker |
| 75 | Restoration interventions according to decay mapping Type A (external wall and tower A2-A8) | m2 | 237 | RMB21B | 17.6 | - | 4171.2 | - | 1 skilled worker |
| 76 | Restoration interventions according to decay mapping Type A (external wall and tower A8-A6) | m2 | 130 | RMB21B | 17.6 | - | 2288.0 | - | 1 skilled worker |
| 77 | Restoration interventions according to decay mapping Type A (external wall and tower A6-A4) | m2 | 191 | RMB21B | 17.6 | - | 3361.6 | - | 1 skilled worker |
| 78 | Restoration interventions according to decay mapping Type A (external wall and tower A4-A2) | m2 | 265 | RMB21B | 17.6 | - | 4664.0 | - | 1 skilled worker |
| 79 | Restoration interventions according to decay mapping Type A (internal wall and tower A4-A2) | m2 | 127 | RMB21B | 17.6 | - | 2235.2 | - | 1 skilled worker |

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|---|---|---|---|---|---|---|---|---|---|
| 80 | Restoration interventions according to decay mapping Type B (external wall and tower A2-A8) | m2 | 92 | RMB21B | 17.6 | - | 1619.2 | - | 1 skilled worker |
| 81 | Restoration interventions according to decay mapping Type B (external wall and tower A8-A6) | m2 | 212 | RMB21B | 17.6 | - | 3731.2 | - | 1 skilled worker |
| 82 | Restoration interventions according to decay mapping Type B (external wall and tower A6-A4) | m2 | 25 | RMB21B | 17.6 | - | 440.0 | - | 1 skilled worker |
| 83 | Restoration interventions according to decay mapping Type B (external wall and tower A4-A2) | m2 | 135 | RMB21B | 17.6 | - | 2376.0 | - | 1 skilled worker |
| 84 | Restoration interventions according to decay mapping Type B (internal wall and tower A2-A8) | m2 | 77 | RMB21B | 17.6 | - | 1355.2 | - | 1 skilled worker |
| 85 | Restoration interventions according to decay mapping Type B (internal wall and tower A8-A6) | m2 | 100 | RMB21B | 17.6 | - | 1760.0 | - | 1 skilled worker |
| 86 | Restoration interventions according to decay mapping Type B (internal wall and tower A6-A4) | m2 | 87 | RMB21B | 17.6 | - | 1531.2 | - | 1 skilled worker |
| 87 | Restoration interventions according to decay mapping Type B (internal wall and tower A4-A2) | m2 | 150 | RMB21B | 17.6 | - | 2640.0 | - | 1 skilled worker |
| 88 | Restoration interventions according to decay mapping Type C (external wall and tower A2-A8) | m2 | 5 | R1MB23C | 17 | - | 85.0 | - | 1 skilled worker |
| 89 | Restoration interventions according to decay mapping Type C (external wall and tower A8-A6) | m2 | 52 | R1MB23C | 17 | - | 884.0 | - | 1 skilled worker |
| 90 | Restoration interventions according to decay mapping Type C (external wall and tower A6-A4) | m2 | 81 | R1MB23C | 17 | - | 1377.0 | - | 1 skilled worker |
| 91 | Restoration interventions according to decay mapping Type C (internal wall and tower A2-A8) | m2 | 19 | R1MB23C | 17 | - | 323.0 | - | 1 skilled worker |
| 92 | Restoration interventions according to decay mapping Type C (internal wall and tower A8-A6) | m2 | 15 | R1MB23C | 17 | - | 255.0 | - | 1 skilled worker |
| 93 | Restoration interventions according to decay mapping Type C (internal wall and tower A6-A4) | m2 | 82 | R1MB23C | 17 | - | 1394.0 | - | 1 skilled worker |

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|---|---|---|---|---|---|---|---|---|---|
| 94 | Restoration interventions according to decay mapping Type C (internal wall and tower A4-A2) | m2 | 90 | R1MB23C | 17 | - | 1530.0 | - | 1 skilled worker |
| 95 | Restoration interventions according to decay mapping Type A+B+C (tower A4) | m2 | 60 | R1MB23C | 17 | - | 1020.0 | - | 1 skilled worker |
| 96 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external A2-A8) | m | 24.5 | RMA16A | 7 | - | 171.5 | - | 1 skilled worker |
| 97 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external A8-A6) | m | 29.1 | RMA16A | 7 | - | 203.7 | - | 1 skilled worker |
| 98 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external A6-A4) | m | 19.1 | RMA16A | 7 | - | 133.7 | - | 1 skilled worker |
| 99 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external A4-A2) | m | 18.2 | RMA16A | 7 | - | 127.4 | - | 1 skilled worker |
| 100 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (Water Tower) | m | 7.6 | RMA16A | 7 | - | 53.2 | - | 1 skilled worker |
| 101 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external B1) | m | 4.2 | RMA16A | 7 | - | 29.4 | - | 1 skilled worker |
| 102 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external B7-A) | m | 9.2 | RMA16A | 7 | - | 64.4 | - | 1 skilled worker |
| 103 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (internal A8-A6) | m | 4 | RMA16A | 7 | - | 28.0 | - | 1 skilled worker |
| 104 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (internal A6-A4) | m | 6.5 | RMA16A | 7 | - | 45.5 | - | 1 skilled worker |
| 105 | Filling lacuna affecting the walls ( external masonry A6-A4) | m3 | 1.68 | RMA16A | 7 | - | 11.8 | - | 1 skilled worker |

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|---|---|---|---|---|---|---|---|---|---|
| 106 | Filling lacuna affecting the walls ( external masonry A4-A2) | m3 | 0.86 | RMA16A | 7 | - | 6.0 | - | 1 skilled worker |
| 107 | Filling lacuna affecting the walls (Water Tower) | m3 | 3.36 | RMA16A | 7 | - | 23.5 | - | 1 skilled worker |
| 108 | Filling lacuna affecting the walls (masonry B7-D) | m3 | 2.45 | RMA16A | 7 | - | 17.2 | - | 1 skilled worker |
| 109 | Filling lacuna affecting the walls (internal A6-A4) | m3 | 1.92 | RMA16A | 7 | - | 13.4 | - | 1 skilled worker |
| 110 | Surface reconstruction with "scuci-cuci" technique of wall facing of solid brick (masonory A4-A5) | m2 | 5.31 | RMB21B | 17.6 | - | 93.5 | - | 1 skilled worker |
| 111 | Surface reconstruction with "scuci-cuci" technique of wall facing of solid brick (tower A2 towards A3) | m2 | 52.5 | RMB21B | 17.6 | - | 924.0 | - | 1 skilled worker |
| 112 | Surface reconstruction with "scuci-cuci" technique of wall facing of solid brick (tower B1, masonry B7-F) | m2 | 200 | RMB21B | 17.6 | - | 3520.0 | - | 1 skilled worker |
| 113 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (external wall and towers A2-A8) | m2 | 97 | RMD06A | 3.6 | - | 349.2 | - | 1 skilled worker |
| 114 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (external wall and towers A8-A6) | m2 | 117 | RMA16A | 3.6 | - | 421.2 | - | 1 skilled worker |
| 115 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (external wall and towers A6-A4) | m2 | 65 | RMA16A | 3.6 | - | 234.0 | - | 1 skilled worker |
| 116 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (external wall and towers A4-A2) | m2 | 175 | RMA16A | 3.6 | - | 630.0 | - | 1 skilled worker |
| 117 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (internal wall and towers A2-A8) | m2 | 200 | RMA16A | 3.6 | - | 720.0 | - | 1 skilled worker |
| 118 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (internal wall and towers A8-A6) | m2 | 77 | RMA16A | 3.6 | - | 277.2 | - | 1 skilled worker |

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|---|---|---|---|---|---|---|---|---|---|
| 119 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (internal wall and towers A6-A4) | m2 | 340 | RMA16A | 3.6 | - | 1224.0 | - | 1 skilled worker |
| 120 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (internal wall and towers A4-A2) | m2 | 101 | RMA16A | 3.6 | - | 363.6 | - | 1 skilled worker |
| 121 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (Water Tower) | m2 | 11 | RMA16A | 3.6 | - | 39.6 | - | 1 skilled worker |
| 122 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (Tower B1) | m2 | 10 | RMA16A | 3.6 | - | 36.0 | - | 1 skilled worker |
| 123 | Restoration of the joints of existing masonry walls with suitable mortar | m2 | 180.43 | RMA16B | 3.9 | - | 703.7 | - | 1 skilled worker |
| 124 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (external wall and towers A2-A8) | m2 | 97 | RMD05B | 9 | - | 873.0 | - | 1 skilled worker |
| 125 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (external wall and towers A8-A6) | m2 | 117 | RMD05B | 9 | - | 1053.0 | - | 1 skilled worker |
| 126 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (external wall and towers A6-A4) | m2 | 65 | RMD05B | 9 | - | 585.0 | - | 1 skilled worker |
| 127 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (external wall and towers A4-A2) | m2 | 175 | RMD05B | 9 | - | 1575.0 | - | 1 skilled worker |
| 128 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (internal wall and towers A2-A8) | m2 | 200 | RMD05B | 9 | - | 1800.0 | - | 1 skilled worker |
| 129 | Rough coating (antique patina) on all internal and | m2 | 77 | RMD05B | 9 | - | 693.0 | - | 1 skilled worker |

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|---|---|---|---|---|---|---|---|---|---|
| | external wall structures (lime, hydraulic lime, bricks, stones) (internal wall and towers A8-A6) | | | | | | | | |
| 130 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (internal wall and towers A6-A4) | m2 | 60 | RMD05B | 9 | - | 540.0 | - | 1 skilled worker |
| 131 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (internal wall and towers A4-A2) | m2 | 101 | RMD05B | 9 | - | 909.0 | - | 1 skilled worker |
| 132 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (Water Tower) | m2 | 11 | RMD05B | 9 | - | 99.0 | - | 1 skilled worker |
| 133 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (Tower B1) | m2 | 10 | RMD05B | 9 | - | 90.0 | - | 1 skilled worker |
| 134 | Removing of roof covering from battlements between tower A3-A4 | m2 | 25.65 | RpCI42C | 0.88 | - | 22.6 | - | 1 skilled worker |
| 135 | Removing of roof covering from battlements between tower A4-A6 | m2 | 33.75 | RpCI42C | 0.88 | - | 29.7 | - | 1 skilled worker |
| 136 | Removing of roof covering from battlements between tower A6-A8 | m2 | 36.45 | RpCI42C | 0.88 | - | 32.1 | - | 1 skilled worker |
| 137 | Removing of roof covering from battlements between tower A8-A2 | m2 | 39.15 | RpCI42C | 0.88 | - | 34.5 | - | 1 skilled worker |
| 138 | Stone masonry for battlements | m3 | 10.62 | RMB17A | 22.5 | - | 239.0 | - | 2 skilled worker |
| 139 | Concrete screed of battlements and baseis of battlements | m2 | 70.8 | CF16B | 1.1 | | 77.9 | | 2 skilled worker |
| 140 | Roofing in teracota tiles for battlements between tower A3-A4 | m2 | 25.65 | CE02B | 1.46 | - | 37.4 | - | 1 skilled worker |
| 141 | Roofing in teracota tiles for battlements between tower A4-A6 | m2 | 33.75 | CE02B | 1.46 | - | 49.3 | - | 1 skilled worker |
| 142 | Roofing in teracota tiles for battlements between tower A6-A8 | m2 | 36.45 | CE02B | 1.46 | - | 53.2 | - | 1 skilled worker |
| 143 | Roofing in teracota tiles for battlements between tower A8-A2 | m2 | 39.15 | CE02B | 1.46 | - | 57.2 | - | 1 skilled worker |
| 144 | Internal or external plaster peeling of any type, both | m2 | 140 | RMA25B | 2.5 | - | 350.0 | - | 1 skilled worker |

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| | rustic and civil. ( Masonry A4-A5) | | | | | | | | |
| 145 | Cleaning and restauration of drain channel | m3 | 5.5 | SVL51A | 1.36 | - | 7.5 | - | 1 skilled worker |
| 146 | Mechanical Inversion of slope of the land | 100m2 | 7.5 | TsE04A | - | 0.125 | - | 0.9 | 1 skilled worker |
| 147 | New draining chanel | m | 60 | AcD08A | 0.58 | - | 34.8 | - | 1 skilled worker |
| 148 | Perforation of the wall for all its thickness with a hole diameter of 4-5 cm with inseretion of stainless steel bar bar Ø16 mm | pieces. | 4 | RpCG18C | 1.24 | - | 5.0 | - | 2 skilled worker |
| 149 | Injection of fibre-reinforced hydraulic lime mortar | pieces. | 4 | RpCU07B | 0.43 | - | 1.7 | - | 1 skilled worker |
| 150 | Partial excavation of foundation. | m3 | 6.6 | TsA03B | 1.64 | - | 10.8 | - | 1 |
| 151 | Execution of RC beams. | m3 | 4.1 | CA03C | 4.5 | - | 18.5 | - | 2 skilled worker |
| 152 | Perforations on solid brick | pieces. | 8 | RpCG18C | 1.24 | - | 9.9 | - | 1 skilled worker |
| 153 | Instalation of tie-rods | 1000kg | 0.56 | CL08A | 40 | - | 22.4 | - | 2 skilled worker |
| 154 | Injections in perforations | pieces. | 8 | RpCU07B | 0.43 | - | 3.4 | - | 2 skilled worker |
| 155 | Partial sharpening of the mortar | m2 | 272 | IzH02B | 0.09 | - | 24.5 | - | 1 skilled worker |
| 156 | Insertion of the ring connectors of stainless steel | pieces. | 8 | RCsP25A | 4.83 | - | 38.6 | - | 5 skilled worker |
| 157 | Restoration of the morat joint | m | 272 | RcsG19F | 0.64 | - | 174.1 | - | 1 skilled worker |
| 158 | Removal of the soil in the lower part of tower B3 | m3 | 63 | TsA03B | 1.64 | - | 103.3 | - | 1 skilled worker |
| 159 | Perforations on solid brick | pieces. | 16 | RpCG18C | 1.24 | - | 19.8 | - | 2 skilled worker |
| 160 | Instalation of tie-rods | 1000kg | 1.163 | CL08A | 40 | - | 46.5 | - | 2 skilled worker |
| 161 | Injections in perforations | pieces. | 16 | RpCU07B | 0.43 | - | 6.9 | - | 2 skilled worker |
| 162 | Intalation of handrail between Towers A3-A2-A1 | kg | 1260 | CL17B | 0.21 | - | 264.6 | - | 3 skilled worker |
| 163 | Instalation of handrail tower A3 | kg | 820 | CL17B | 0.21 | - | 172.2 | - | 3 skilled worker |
| 164 | Instalation of handrail between Towers A3-A4-A5 | kg | 1620 | CL17B | 0.21 | - | 340.2 | - | 3 skilled worker |
| 165 | Instalation of handrail tower A5 | kg | 234 | CL17B | 0.21 | - | 49.1 | - | 3 skilled worker |
| 166 | Instalation of handrail between Towers A5-A6-A1 | kg | 2826 | CL17B | 0.21 | - | 593.5 | - | 3 skilled worker |
| 167 | Instalation of handrail tower A1 | kg | 792 | CL17B | 0.21 | - | 166.3 | - | 3 skilled worker |
| 168 | Instalation of perforated panel between Towers A3-A2-A1 | kg | 1008 | CL17B | 0.21 | - | 211.7 | - | 3 skilled worker |
| 169 | Instalation of perforated panel tower A3 | kg | 662.4 | CL17B | 0.21 | - | 139.1 | - | 3 skilled worker |

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|---|---|---|---|---|---|---|---|---|---|
| 170 | Instalation of perforated panel between Towers A3-A4-A5 | kg | 1296 | CL17B | 0.21 | - | 272.2 | - | 3 skilled worker |
| 171 | Instalation of perforated panel tower A5 | kg | 187.2 | CL17B | 0.21 | - | 39.3 | - | 3 skilled worker |
| 172 | Instalation of perforated panel between Towers A5-A6-A1 | kg | 2260.8 | CL17B | 0.21 | - | 474.8 | - | 3 skilled worker |
| 173 | Instalation of perforated panel tower A1 | kg | 792 | CL17B | 0.21 | - | 166.3 | - | 3 skilled worker |
| 174 | Removal of roof from A6 Tower | 1000kg | 4.941 | CL14B | 10 | 1.7 | 49.4 | 8.3997 | 2 skilled worker |
| 175 | Removal of roof from A4 Tower | 1000kg | 4.941 | CL14B | 10 | 1.7 | 49.4 | 8.3997 | 2 skilled worker |
| 176 | Installing new wooden structure for roof - Tower A2 | m3 | 24.44 | CE28A | 65 | - | 1588.6 | - | 3 skilled worker |
| 177 | Instaling new wooden cover for roof - Tower A2 | m2 | 238.4 | CE02B | 1.46 | - | 348.1 | - | 3 skilled worker |
| 178 | Installing new wooden structure for roof - Tower A3 | m3 | 24.44 | CE28A | 65 | - | 1588.6 | - | 3 skilled worker |
| 179 | Instaling new wooden cover for roof - Tower A3 | m2 | 238.4 | CE02B | 1.46 | - | 348.1 | - | 3 skilled worker |
| 180 | Installing new wooden structure for roof - Tower A4 | m3 | 24.44 | CE28A | 65 | - | 1588.6 | - | 3 skilled worker |
| 181 | Instaling new wooden cover for roof - Tower A4 | m2 | 238.4 | CE02B | 1.46 | - | 348.1 | - | 3 skilled worker |
| 182 | Installing new wooden structure for roof - Tower A6 | m3 | 24.44 | CE28A | 65 | - | 1588.6 | - | 3 skilled worker |
| 183 | Instaling new wooden cover for roof - Tower A6 | m2 | 238.4 | CE02B | 1.46 | - | 348.1 | - | 3 skilled worker |
| TOTAL man/h | | | | | | | 84919.3 | | |

### *8.2.4* Schedule of the work execution

*Tabel 2 Schedule of work*

| Nr. | Works | U.M. | Volume | Labour | Mechanism | | Duration (days) | Nr. of workers | Team componence |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Name | Machine/h | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Phase I of works ( Tower B3) | | | | | | | | | |
| 1 | Preparation works | % | 5 | 55.6 | - | - | 1.4 | 5 | Mixed team |
| 2 | Instalation of scaffolding (extern Tower B3) | m2 | 320 | 240 | - | - | 5.0 | 6 | Carpenter |
| 3 | Instalation of scaffolding (intern Tower B3) | m3 | 40 | 30 | - | - | 0.6 | 6 | Carpenter |
| 4 | Partial sharpening of the mortar | m2 | 272 | 24.48 | - | - | 0.6 | 5 | Mason |
| 5 | Insertion of the ring connectors of stainless steel | pieces. | 8 | 38.64 | - | - | 1.0 | 5 | Skilled workers |
| 6 | Restoration of the morat joint | m | 272 | 174.08 | - | - | 4.4 | 5 | Skilled workers |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Removal of the soil in the lower part of tower B3 | m3 | 63 | 174.08 | - | - | 4.4 | 5 | Skilled workers |
| 8 | Removal of scaffolding (extern Tower B3) | m2 | 320 | 240 | - | - | 5.0 | 6 | Carpenter |
| 9 | Removal of scaffolding (intern Tower B3) | m2 | 40 | 30 | - | - | 0.6 | 6 | Carpenter |
| 10 | Landscape works | % | 2 | 19 | - | - | 0.5 | 5 | Mixed team |
| 11 | Unforseen work | % | 15 | 142.7 | - | - | 3.6 | 5 | Mixed team |
| 12 | Acceptance of works | % | 1 | 11.1 | - | - | 1.4 | 1 | Engineer |
| Phase II of works (Water Tower) | | | | | | | | | |
| 13 | Preparation works | % | 5 | 25 | - | - | 0.8 | 4 | Mixed team |
| 14 | Instalation of scaffolding (extern Woter Tower) | m2 | 70 | 52.5 | - | - | 1.6 | 4 | Carpenter |
| 15 | Instalation of scaffolding (intern Woter Tower) | m2 | 72 | 54 | - | - | 1.7 | 4 | Carpenter |
| 16 | Partial excavation of foundation. | m3 | 6.6 | 10.8 | - | - | 0.3 | 4 | Skilled workers |
| 17 | Execution of RC beams. | m3 | 4.1 | 18.5 | - | - | 0.6 | 4 | Skilled workers |
| 18 | Removing vegetation by applying biocide (internal wall and towers A4-A2) | m2 | 182 | 5.5 | - | - | 0.2 | 4 | Skilled workers |
| 19 | Perforations on solid brick | pieces. | 8 | 9.9 | - | - | 0.3 | 4 | Skilled workers |
| 20 | Instalation of tie-rods | 1000kg | 0.56 | 22.4 | - | - | 0.7 | 4 | Skilled workers |
| 21 | Injections in perforations | pieces. | 8 | 3.4 | - | - | 0.1 | 4 | Skilled workers |
| 22 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (Water Tower) | m | 7.6 | 53.2 | - | - | 1.7 | 4 | Skilled workers |
| 23 | Filling lacuna affecting the walls (Water Tower) | m3 | 3.36 | 23.5 | - | - | 0.7 | 4 | Skilled workers |
| 24 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (Water Tower) | m2 | 11 | 39.6 | - | - | 1.2 | 4 | Skilled workers |
| 25 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (Water Tower) | m2 | 11 | 99 | - | - | 3.1 | 4 | Skilled workers |
| 26 | Removal of scaffolding (extern Woter Tower) | m2 | 70 | 52.5 | - | - | 1.6 | 4 | Carpenter |
| 27 | Removal of scaffolding (intern Woter Tower) | m2 | 72 | 54 | - | - | 1.7 | 4 | Carpenter |
| 28 | Landscape works | % | 2 | 10 | - | - | 0.3 | 4 | Mixed team |
| 29 | Unforseen work | % | 15 | 74.8 | - | - | 2.3 | 4 | Mixed team |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 30 | Acceptance of works | % | 1 | 5 | - | - | 0.6 | 1 | Engineer |
| Phase III of works (Wall A8-A6, wall A5-A6 consolitation works, Tower A8,A7,A6,A5) | | | | | | | | | |
| 31 | Preparation works | % | 5 | 1654.6 | - | - | 20.7 | 10 | Mixed team |
| 32 | Instalation of scaffolding (extern Tower A8) | m2 | 336 | 252 | - | - | 3.2 | 10 | Carpenter |
| 33 | Instalation of scaffolding (extern wall A7-A8) | m2 | 540 | 405 | - | - | 6.3 | 8 | Carpenter |
| 34 | Instalation of scaffolding (extern Tower A7) | m2 | 325 | 243.8 | - | - | 3.8 | 8 | Carpenter |
| 35 | Instalation of scaffolding (extern wall A6-A7) | m2 | 480 | 360 | - | - | 5.6 | 8 | Carpenter |
| 36 | Instalation of scaffolding (extern Tower A6) | m2 | 434 | 325.5 | - | - | 5.1 | 8 | Carpenter |
| 37 | Instalation of scaffolding (extern wall A5-A6) | m2 | 200 | 150 | - | - | 2.3 | 8 | Carpenter |
| 38 | Instalation of scaffolding (extern Tower A5) | m2 | 312 | 234 | - | - | 3.7 | 8 | Carpenter |
| 39 | Instalation of scaffolding (intern Tower A8) | m2 | 82 | 61.5 | - | - | 1.0 | 8 | Carpenter |
| 40 | Instalation of scaffolding (intern wall A6-A8) | m2 | 495 | 371.3 | - | - | 5.8 | 8 | Carpenter |
| 41 | Instalation of scaffolding (intern Tower A7) | m2 | 72 | 54 | - | - | 0.8 | 8 | Carpenter |
| 42 | Instalation of scaffolding (intern Tower A6) | m2 | 82 | 61.5 | - | - | 1.0 | 8 | Carpenter |
| 43 | Instalation of scaffolding (intern Tower A5) | m2 | 96 | 72 | - | - | 1.1 | 8 | Carpenter |
| 44 | Instalation of scaffolding (extern wall A4-A5) | m2 | 200 | 150.0 | - | - | 2.3 | 8 | Carpenter |
| 45 | Instalation of scaffolding (intern wall A5-A6) | m2 | 228 | 171 | - | - | 2.7 | 8 | Carpenter |
| 46 | Instalation of scaffolding (intern wall A4-A5) | m2 | 234 | 175.5 | - | - | 2.7 | 8 | Carpenter |
| 47 | Removal of roof from A6 Tower | 1000kg | 4.941 | 49.4 | - | 1.7 | 1.0 | 6 | Skilled workers |
| 48 | Perforations on solid brick | pieces. | 16 | 19.8 | - | - | 1.2 | 2 | Skilled workers |
| 49 | Instalation of tie-rods | 1000kg | 1.163 | 46.5 | - | - | 1.5 | 4 | Skilled workers |
| 50 | Injections in perforations | pieces. | 16 | 6.9 | - | - | 0.4 | 2 | Skilled workers |
| 51 | Removing vegetation by applying biocide (external wall and towers A6-A8) | m2 | 652 | 19.6 | - | - | 1.2 | 2 | Unskilled workers |
| 52 | Removing vegetation by applying biocide (external wall and towers A6-A4) | m2 | 670 | 20.1 | - | - | 1.3 | 2 | Unskilled workers |
| 53 | Removing vegetation by applying biocide (internal wall and towers A6-A4) | m2 | 10 | 0.3 | - | - | 0.0 | 2 | Unskilled workers |
| 54 | Removing vegetation by applying biocide (external wall and towers A2-A8) | m2 | 325 | 9.8 | - | - | 0.6 | 2 | Unskilled workers |
| 55 | Removing vegetation by applying biocide (internal wall and towers A2-A8) | m2 | 290 | 8.7 | - | - | 0.5 | 2 | Unskilled workers |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 56 | Tangential sandblasting (with JOS type system)operating with compressed air, with adjustable operating pressure, variable nozzle mounted on pen or gun. (external towers and masanories) | m2 | 2112 | 760.32 | sandblasting machine | 0.1 | 15.8 | 6 | Skilled workers |
| 57 | Tangential sandblasting (with JOS type system)operating with compressed air, with adjustable operating pressure, variable nozzle mounted on pen or gun. (internal towers and masanories) | m2 | 1158 | 416.88 | sandblasting machine | 0.1 | 8.7 | 6 | Skilled workers |
| 58 | Perforation of the wall for all its thickness with a hole diameter of 4-5 cm with inseretion of stainless steel bar bar Ø16 mm | pieces. | 4 | 5 | - | - | 0.3 | 2 | Skilled workers |
| 59 | Injection of fibre-reinforced hydraulic lime mortar | pieces. | 4 | 1.7 | - | - | 0.1 | 2 | Skilled workers |
| 60 | Restoration interventions according to decay mapping Type A (external wall and tower A8-A6) | m2 | 130 | 2288 | - | - | 14.3 | 20 | Skilled workers |
| 61 | Restoration interventions according to decay mapping Type A (external wall and tower A6-A4) | m2 | 191 | 3361.6 | - | - | 21.0 | 20 | Skilled workers |
| 62 | Restoration interventions according to decay mapping Type B (external wall and tower A8-A6) | m2 | 212 | 3731.2 | - | - | 23.3 | 20 | Skilled workers |
| 63 | Restoration interventions according to decay mapping Type B (external wall and tower A6-A4) | m2 | 25 | 440 | - | - | 2.8 | 20 | Skilled workers |
| 64 | Restoration interventions according to decay mapping Type B (internal wall and tower A8-A6) | m2 | 100 | 1760 | - | - | 11.0 | 20 | Skilled workers |
| 65 | Restoration interventions according to decay mapping Type B (internal wall and tower A6-A4) | m2 | 87 | 1531.2 | - | - | 9.6 | 20 | Skilled workers |
| 66 | Restoration interventions according to decay mapping Type C (external wall and tower A8-A6) | m2 | 52 | 884 | - | - | 5.5 | 20 | Skilled workers |
| 67 | Restoration interventions according to decay mapping Type C (external wall and tower A6-A4) | m2 | 81 | 1377 | - | - | 8.6 | 20 | Skilled workers |
| 68 | Restoration interventions according to decay mapping Type C (internal wall and tower A8-A6) | m2 | 15 | 225 | - | - | 1.4 | 20 | Skilled workers |
| 69 | Restoration interventions according to decay mapping Type C (internal wall and tower A6-A4) | m2 | 82 | 1394 | - | - | 8.7 | 20 | Skilled workers |
| 70 | Restoration interventions according to decay mapping Type A+B+C (tower A4) | m2 | 60 | 1020 | - | - | 6.4 | 20 | Skilled workers |
| 71 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external A8-A6) | m | 29.1 | 203 | - | - | 1.3 | 20 | Skilled workers |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 72 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external A6-A4) | m | 19.1 | 133.7 | - | - | 1.7 | 10 | Skilled workers |
| 73 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (internal A8-A6) | m | 4 | 28 | - | - | 0.4 | 10 | Skilled workers |
| 74 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (internal A6-A4) | m | 6.5 | 45.5 | - | - | 0.6 | 10 | Skilled workers |
| 75 | Filling lacuna affecting the walls ( external masonry A6-A4) | m3 | 1.68 | 11.8 | - | - | 0.1 | 10 | Skilled workers |
| 76 | Filling lacuna affecting the walls (internal A6-A4) | m3 | 1.92 | 13.4 | - | - | 0.2 | 10 | Skilled workers |
| 77 | Surface reconstruction with "scuci-cuci" technique of wall facing of solid brick (masonory A4-A5) | m2 | 5.31 | 93.5 | - | - | 0.6 | 20 | Skilled workers |
| 78 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (external wall and towers A8-A6) | m2 | 117 | 421.2 | - | - | 3.5 | 15 | Skilled workers |
| 79 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (external wall and towers A6-A4) | m2 | 65 | 234 | - | - | 2.0 | 15 | Skilled workers |
| 80 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (internal wall and towers A8-A6) | m2 | 77 | 277.2 | - | - | 2.3 | 15 | Skilled workers |
| 81 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (internal wall and towers A6-A4) | m2 | 340 | 1224 | - | - | 10.2 | 15 | Skilled workers |
| 82 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (external wall and towers A8-A6) | m2 | 117 | 1053 | - | - | 8.8 | 15 | Skilled workers |
| 83 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (external wall and towers A6-A4) | m2 | 65 | 585 | - | - | 4.9 | 15 | Skilled workers |
| 84 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (internal wall and towers A8-A6) | m2 | 77 | 693 | - | - | 5.8 | 15 | Skilled workers |
| 85 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (internal wall and towers A6-A4) | m2 | 60 | 540 | - | - | 4.5 | 15 | Skilled workers |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 86 | Removing of roof covering from battlements between tower A4-A6 | m2 | 33.75 | 29.7 | - | - | 0.9 | 4 | Skilled workers |
| 87 | Removing of roof covering from battlements between tower A6-A8 | m2 | 36.45 | 32.076 | - | - | 1.0 | 4 | Skilled workers |
| 88 | Internal or external plaster peeling of any type, both rustic and civil. ( Masonry A4-A5) | m2 | 140 | 350 | - | - | 2.2 | 20 | Skilled workers |
| 89 | Roofing in teracota tiles for battlements between tower A4-A6 | m2 | 33.75 | 49.275 | - | - | 1.5 | 4 | Skilled workers |
| 90 | Roofing in teracota tiles for battlements between tower A6-A8 | m2 | 36.45 | 53.217 | - | - | 1.7 | 4 | Skilled workers |
| 91 | Installing new wooden structure for roof - Tower A6 | m3 | 24.44 | 1588.6 | - | - | 19.9 | 10 | Skilled workers |
| 92 | Instaling new wooden cover for roof - Tower A6 | m2 | 238.4 | 348.1 | - | - | 4.4 | 10 | Skilled workers |
| 93 | Removing of scaffolding (extern Tower A8) | m2 | 336 | 252 | - | - | 3.9 | 8 | Carpenter |
| 94 | Removing of scaffolding (extern wall A7-A8) | m2 | 540 | 405 | - | - | 6.3 | 8 | Carpenter |
| 95 | Removing of scaffolding (extern Tower A7) | m2 | 325 | 243.8 | - | - | 3.8 | 8 | Carpenter |
| 96 | Removing of scaffolding (extern wall A6-A7) | m2 | 480 | 360 | - | - | 5.6 | 8 | Carpenter |
| 97 | Removing of scaffolding (extern Tower A6) | m2 | 434 | 325.5 | - | - | 5.1 | 8 | Carpenter |
| 98 | Removing of scaffolding (extern wall A5-A6) | m2 | 200 | 150 | - | - | 2.3 | 8 | Carpenter |
| 99 | Removing of scaffolding (extern Tower A5) | m2 | 312 | 234 | - | - | 3.7 | 8 | Carpenter |
| 100 | Removing of scaffolding (intern Tower A8) | m2 | 82 | 61.5 | - | - | 1.0 | 8 | Carpenter |
| 101 | Removing of scaffolding (intern wall A6-A8) | m2 | 495 | 371.3 | - | - | 5.8 | 8 | Carpenter |
| 102 | Removing of scaffolding (intern Tower A7) | m2 | 72 | 54 | - | - | 0.8 | 8 | Carpenter |
| 103 | Removing of scaffolding (intern Tower A6) | m2 | 82 | 61.5 | - | - | 1.0 | 8 | Carpenter |
| 104 | Removing of scaffolding (intern Tower A5) | m2 | 96 | 72 | - | - | 1.1 | 8 | Carpenter |
| 105 | Cleaning and restauration of drain channel | m3 | 5.5 | 7.5 | - | - | 0.2 | 4 | Mixed team |
| 106 | Mechanical Inversion of slope of the land | 100m2 | 7.5 | - | skid-steer loader | 0.125 | 0.9 | 1 | Mixed team |
| 107 | New draining chanel | m | 60 | 34.8 | - | - | 1.1 | 4 | Mixed team |
| 108 | Landscape works | % | 2 | 661.9 | - | - | 10.3 | 8 | Mixed team |
| 109 | Unforseen work | % | 15 | 4964 | - | - | 41.4 | 15 | Mixed team |
| 110 | Acceptance of works | % | 1 | 330 | - | - | 20.6 | 2 | Engineer |
| Phase IV of works (Wall A4-A2, wall A2-A8 consolitation works, Tower A3,A2,A1) | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 111 | Preparation works | % | 5 | 2533.1 | - | - | 21.1 | 15 | Mixed team |
| 112 | Instalation of scaffolding (extern Tower A1) | m2 | 403 | 302.3 | - | - | 3.8 | 10 | Carpenter |
| 113 | Instalation of scaffolding (extern Tower A2) | m2 | 525 | 393.8 | - | - | 4.9 | 10 | Carpenter |
| 114 | Instalation of scaffolding (extern Tower A3) | m2 | 276 | 207.0 | - | - | 2.6 | 10 | Carpenter |
| 115 | Instalation of scaffolding (extern wall A1-A2) | m2 | 232 | 174.0 | - | - | 2.2 | 10 | Carpenter |
| 116 | Instalation of scaffolding (extern wall A2-A3) | m2 | 296 | 222.0 | - | - | 2.8 | 10 | Carpenter |
| 117 | Instalation of scaffolding (extern wall A3-A4) | m2 | 320 | 240.0 | - | - | 3.0 | 10 | Carpenter |
| 118 | Instalation of scaffolding (intern Tower A1) | m2 | 96 | 72.0 | - | - | 0.9 | 10 | Carpenter |
| 119 | Instalation of scaffolding (intern Tower A2) | m2 | 79 | 59.3 | - | - | 0.7 | 10 | Carpenter |
| 120 | Instalation of scaffolding (intern Tower A3) | m2 | 72 | 54.0 | - | - | 0.7 | 10 | Carpenter |
| 121 | Instalation of scaffolding (intern wall A8-A2) | m2 | 360 | 270 | - | - | 3.4 | 10 | Carpenter |
| 122 | Instalation of scaffolding (intern wall A2-A4) | m2 | 528 | 396 | - | - | 5.0 | 10 | Carpenter |
| 123 | Instalation of scaffolding (extern Tower A4) | m2 | 462 | 346.5 | - | - | 4.3 | 10 | Carpenter |
| 124 | Instalation of scaffolding (intern Tower A4) | m2 | 82 | 61.5 | - | - | 0.8 | 10 | Carpenter |
| 125 | Removing vegetation by applying biocide (external wall and towers A4-A2) | m2 | 330 | 9.9 | - | - | 0.6 | 2 | Mixed team |
| 126 | Removing vegetation by applying biocide (internal wall and towers A6-A4) | m2 | 10 | 0.3 | - | - | 0.0 | 2 | Mixed team |
| 127 | Removing vegetation by applying biocide (internal wall and towers A4-A2) | m2 | 142 | 4.3 | - | - | 0.3 | 2 | Mixed team |
| 128 | Tangential sandblasting (with JOS type system)operating with compressed air, with adjustable operating pressure, variable nozzle mounted on pen or gun. (external towers and masanories) | m2 | 2112 | 760.32 | - | - | 15.8 | 6 | Mixed team |
| 129 | Tangential sandblasting (with JOS type system)operating with compressed air, with adjustable operating pressure, variable nozzle mounted on pen or gun. (internal towers and masanories) | m2 | 1158 | 416.88 | - | - | 8.7 | 6 | Mixed team |
| 130 | Restoration interventions according to decay mapping Type A (external wall and tower A2-A8) | m2 | 237 | 4171.2 | - | - | 26.1 | 20 | Mixed team |
| 131 | Restoration interventions according to decay mapping Type A (external wall and tower A4-A2) | m2 | 265 | 4664 | - | - | 29.2 | 20 | Mixed team |
| 132 | Restoration interventions according to decay mapping Type A (internal wall and tower A4-A2) | m2 | 127 | 2235.2 | - | - | 14.0 | 20 | Mixed team |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 133 | Restoration interventions according to decay mapping Type B (external wall and tower A2-A8) | m2 | 92 | 1619.2 | - | - | 10.1 | 20 | Mixed team |
| 134 | Restoration interventions according to decay mapping Type B (external wall and tower A4-A2) | m2 | 135 | 2376 | - | - | 14.9 | 20 | Mixed team |
| 135 | Restoration interventions according to decay mapping Type B (internal wall and tower A2-A8) | m2 | 77 | 1355.2 | - | - | 8.5 | 20 | Mixed team |
| 136 | Restoration interventions according to decay mapping Type B (internal wall and tower A4-A2) | m2 | 150 | 2640 | - | - | 16.5 | 20 | Mixed team |
| 137 | Restoration interventions according to decay mapping Type C (external wall and tower A2-A8) | m2 | 5 | 85 | - | - | 0.5 | 20 | Mixed team |
| 138 | Restoration interventions according to decay mapping Type C (internal wall and tower A2-A8) | m2 | 19 | 323 | - | - | 2.0 | 20 | Mixed team |
| 139 | Restoration interventions according to decay mapping Type C (internal wall and tower A4-A2) | m2 | 90 | 1530 | - | - | 9.6 | 20 | Mixed team |
| 140 | Restoration interventions according to decay mapping Type A+B+C (tower A4) | m2 | 60 | 1020 | - | - | 6.4 | 20 | Mixed team |
| 141 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external A2-A8) | m | 24.5 | 171.5 | - | - | 2.1 | 10 | Mixed team |
| 142 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external A4-A2) | m | 18.2 | 127.4 | - | - | 1.6 | 10 | Mixed team |
| 143 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external B1) | m | 4.2 | 29.4 | - | - | 0.4 | 10 | Mixed team |
| 144 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (external B7-A) | m | 9.2 | 64.4 | - | - | 0.8 | 10 | Mixed team |
| 145 | Consolidation of structural cracks with preventive sealing of the sub-level cracks with hydraulic lime mortar and aggregates (internal A6-A4) | m | 6.5 | 45.5 | - | - | 0.6 | 10 | Mixed team |
| 146 | Filling lacuna affecting the walls ( external masonry A4-A2) | m3 | 0.86 | 6.02 | - | - | 0.4 | 2 | Mixed team |
| 147 | Filling lacuna affecting the walls (masonry B7-D) | m3 | 2.45 | 17.15 | - | - | 1.1 | 2 | Mixed team |
| 148 | Surface reconstruction with "scuci-cuci" technique of wall facing of solid brick (tower A2 towards A3) | m2 | 52.5 | 924 | - | - | 11.6 | 10 | Mixed team |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 149 | Surface reconstruction with "scuci-cuci" technique of wall facing of solid brick (tower B1, masonry B7-F) | m2 | 200 | 3520 | - | - | 22.0 | 20 | Mixed team |
| 150 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (external wall and towers A2-A8) | m2 | 97 | 349.2 | - | - | 2.2 | 20 | Mixed team |
| 151 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (external wall and towers A4-A2) | m2 | 175 | 630 | - | - | 3.9 | 20 | Mixed team |
| 152 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (internal wall and towers A2-A8) | m2 | 200 | 720 | - | - | 4.5 | 20 | Mixed team |
| 153 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (internal wall and towers A4-A2) | m2 | 101 | 363.6 | - | - | 2.3 | 20 | Mixed team |
| 154 | Reconstruction of the joints through the stripping of old mortars. Interventions on joints recentely repaired (Tower B1) | m2 | 10 | 36 | - | - | 0.2 | 20 | Mixed team |
| 155 | Restoration of the joints of existing masonry walls with suitable mortar | m2 | 180.43 | 703.677 | - | - | 4.4 | 20 | Mixed team |
| 156 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (external wall and towers A2-A8) | m2 | 97 | 873 | - | - | 5.5 | 20 | Mixed team |
| 157 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (external wall and towers A4-A2) | m2 | 175 | 1575 | - | - | 9.8 | 20 | Mixed team |
| 158 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (internal wall and towers A2-A8) | m2 | 200 | 1800 | - | - | 11.3 | 20 | Mixed team |
| 159 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (internal wall and towers A4-A2) | m2 | 101 | 909 | - | - | 5.7 | 20 | Mixed team |
| 160 | Rough coating (antique patina) on all internal and external wall structures (lime, hydraulic lime, bricks, stones) (Tower B1) | m2 | 10 | 90 | - | - | 0.6 | 20 | Mixed team |
| 161 | Removing of roof covering from battlements between tower A3-A4 | m2 | 25.65 | 22.6 | - | - | 0.7 | 4 | Mixed team |
| 162 | Removing of roof covering from battlements between tower A8-A2 | m2 | 39.15 | 34.452 | - | - | 1.1 | 4 | Mixed team |
| 163 | Stone masonry for battlements | m3 | 10.62 | 239 | - | - | 3.7 | 8 | Skilled workers |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 164 | Concrete screed of battlements and baseis of battlements | m2 | 70.8 | 77.9 | - | - | 1.2 | 8 | Skilled workers |
| 165 | Roofing in teracota tiles for battlements between tower A3-A4 | m2 | 25.65 | 37.449 | - | - | 1.2 | 4 | Mixed team |
| 166 | Roofing in teracota tiles for battlements between tower A8-A2 | m2 | 39.15 | 57.2 | - | - | 1.8 | 4 | Mixed team |
| 167 | Removal of roof from A4 Tower | 1000kg | 4.941 | 49.41 | - | - | 1.5 | 4 | Mixed team |
| 168 | Installing new wooden structure for roof - Tower A2 | m3 | 24.44 | 1588.6 | - | - | 19.9 | 10 | Mixed team |
| 169 | Instaling new wooden cover for roof - Tower A2 | m2 | 238.4 | 348.064 | - | - | 4.4 | 10 | Mixed team |
| 170 | Installing new wooden structure for roof - Tower A3 | m3 | 24.44 | 1588.6 | - | - | 19.9 | 10 | Mixed team |
| 171 | Instaling new wooden cover for roof - Tower A3 | m2 | 238.4 | 348.064 | - | - | 4.4 | 10 | Mixed team |
| 172 | Installing new wooden structure for roof - Tower A4 | m3 | 24.44 | 1588.6 | - | - | 19.9 | 10 | Mixed team |
| 173 | Instaling new wooden cover for roof - Tower A4 | m2 | 238.4 | 348.064 | - | - | 4.4 | 10 | Mixed team |
| 174 | Removing of scaffolding (extern Tower A1) | m2 | 403 | 302.3 | - | - | 4.7 | 8 | Mixed team |
| 175 | Removing of scaffolding (extern Tower A2) | m2 | 525 | 393.8 | - | - | 6.2 | 8 | Mixed team |
| 176 | Removing of scaffolding (extern Tower A3) | m2 | 276 | 207.0 | - | - | 3.2 | 8 | Mixed team |
| 177 | Removing of scaffolding (extern wall A1-A2) | m2 | 232 | 174.0 | - | - | 2.7 | 8 | Mixed team |
| 178 | Removing of scaffolding (extern wall A2-A3) | m2 | 296 | 222.0 | - | - | 3.5 | 8 | Mixed team |
| 179 | Removing of scaffolding (extern wall A3-A4) | m2 | 320 | 240.0 | - | - | 3.8 | 8 | Mixed team |
| 180 | Removing of scaffolding (intern Tower A1) | m2 | 96 | 72.0 | - | - | 1.1 | 8 | Mixed team |
| 181 | Removing of scaffolding (intern Tower A2) | m2 | 79 | 59.3 | - | - | 0.9 | 8 | Mixed team |
| 182 | Removing of scaffolding (intern Tower A3) | m2 | 72 | 54.0 | - | - | 0.8 | 8 | Mixed team |
| 183 | Removing of scaffolding (intern wall A8-A2) | m2 | 360 | 270 | - | - | 4.2 | 8 | Mixed team |
| 184 | Removing of scaffolding (intern wall A2-A4) | m2 | 528 | 396 | - | - | 6.2 | 8 | Mixed team |
| 185 | Removing of scaffolding (extern Tower A4) | m2 | 462 | 346.5 | - | - | 5.4 | 8 | Mixed team |
| 186 | Removing of scaffolding (intern Tower A4) | m2 | 82 | 61.5 | - | - | 1.0 | 8 | Mixed team |
| 187 | Intalation of handrail between Towers A3-A2-A1 | kg | 1260 | 264.6 | - | - | 5.5 | 6 | Mixed team |
| 188 | Instalation of handrail tower A3 | kg | 820 | 172.2 | - | - | 0.9 | 25 | Mixed team |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 189 | Instalation of handrail between Towers A3-A4-A5 | kg | 1620 | 340.2 | - | - | 2.8 | 15 | Mixed team |
| 190 | Instalation of handrail tower A5 | kg | 234 | 49.14 | - | - | 0.4 | 15 | Mixed team |
| 191 | Instalation of handrail between Towers A5-A6-A1 | kg | 2826 | 593.46 | - | - | 4.9 | 15 | Mixed team |
| 192 | Instalation of handrail tower A1 | kg | 792 | 166.32 | - | - | 1.4 | 15 | Mixed team |
| 193 | Instalation of perforated panel between Towers A3-A2-A1 | kg | 1008 | 211.68 | - | - | 1.8 | 15 | Mixed team |
| 194 | Instalation of perforated panel tower A3 | kg | 662.4 | 139.104 | - | - | 1.2 | 15 | Mixed team |
| 195 | Instalation of perforated panel between Towers A3-A4-A5 | kg | 1296 | 272.16 | - | - | 2.3 | 15 | Mixed team |
| 196 | Instalation of perforated panel tower A5 | kg | 187.2 | 39.312 | - | - | 0.3 | 15 | Mixed team |
| 197 | Instalation of perforated panel between Towers A5-A6-A1 | kg | 2260.8 | 474.768 | - | - | 4.0 | 15 | Mixed team |
| 198 | Instalation of perforated panel tower A1 | kg | 792 | 166.32 | - | - | 1.4 | 15 | Mixed team |
| 199 | Landscape works | % | 2 | 1013.2 | - | - | 9.0 | 14 | Mixed team |
| 200 | Unforseen work | % | 15 | 7599.3 | - | - | 63.3 | 15 | Mixed team |
| 201 | Acceptance of works | % | 1 | 501.6 | - | - | 31.4 | 2 | Engineer |

### *8.2.5* Storage units

The storage time of materials is considered to be:

- For open storages 3-5 days
- For closed storages 10-15 days

The calculation of on-site storage facilities depends on supply of material to be deposited, which is calculated according to the equation:

$$Q_{rez} = \left(\frac{Q_{tot}}{T}\right) \cdot \alpha \cdot n \cdot k \ (m^2, m^3)$$

, where $Q_{tot}$ – represents the total amount of the material,

$T$ – period of use of the material,

$\alpha$ – the coefficient of non-rhythmic supply with material resources at the warehouse,

$n$ – the duration of storage of material resources in the warehouse, taking into account the storage method

$k$ – the coefficient of non-rhythmic consumption of material resources

Knowing the reserve of materials in the warehouse, it is possible to find the useful surface of the construction site warehouses:

$$A_u = \frac{Q_{rez}}{q}$$

, where $q$ – storage rate for $1\ m^2$ of surface. So, the real surfaces of material deposits on the site could be calculated with following relationship:

$$A_{real} = \frac{A_u}{\beta}$$

, where $\beta$ - Coefficient that takes into account the use of the storage area and the passing's between storages

All things considered, the total amount and size of storage is given in table below:

*Tabel 3 Storage units*

| Nr. | Name of storage | Dimension ($m$) | Area ($m^2$) | Type of storage |
|---|---|---|---|---|
| 1 | Storage for works tools | 12 x 4 | 48 | Closed |
| 2 | Sorted steel | 12 x 4 | 48 | Open |
| 3 | Brick storage | 2 x (12 x 6) | 144 | Open |
| 4 | Scaffolding storage | 2 x (12 x 4) | 96 | Open |
| 5 | Storage for vertical props | 12 x 4 | 48 | Open |
| 6 | Local material storage | 2 x (12 x 4) | 96 | Open |

### *8.2.6* Number of workers

The maxim number of workers at construction site is equal to 30 people. The maximum number of people at site are computed with following relation:

$$N = \frac{N_{max}}{85\%} \cdot 100\% = 36\ (workers)$$

From 100% of total people on site, 85 % are workers; 8% - represents foremen and site managers; 5% - auxiliary stuff; 2% - are security stuff.

$$N_{st} = 8 \cdot 0.36 = 3\ (persons)$$
$$N_{as} = 5 \cdot 0.36 = 2\ (persons)$$
$$N_s = 2 \cdot 0.36 = 1\ (person)$$

The total amount of workers on site are:

$$N_{tot} = (N_w + N_{st} + N_{as} + N_s) \cdot k = (30 + 3 + 2 + 1) \cdot 1.05 = 38\ (workers)$$

*Tabel 4 Site units (Container) [4]*

| Nr. | Name | Nr. of workers | Nr. of workers that are using containers, % | Surface, $m^2$ | | Dimension of container |
|---|---|---|---|---|---|---|
| | | | | Unit | Total | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A. Service unit | | | | | | |
| 1 | Unit for foreman and site manager | 3 | 100 | 3 | 9 | 6 x 2.4 x 2.9 |
| 2 | Rest Unit | 36 | 100 | 0.75 | 27 | 3 x (6 x 2.4 x 2.9) |
| 3 | Dispatch | 1 | 100 | 7 | 7 | 4.8 x 2.4 x 2.9 |
| B. Industrial unit | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | Changing rooms | 36 | 70 | 0.7 | 17.64 | 3 x (6 x 2.4 x 2.9) |
| 5 | Washstand and showers | 36 | 70 | 0.6 | 15.1 | 2 x (6 x 2.4 x 2.9) |
| 6 | Room for heating and drying clothes | 36 | 40 | 0.2 | 2.88 | 6 x 2.4 x 2.9 |
| 7 | Canteen | 36 | 100 | 1 | 36 | 4 x (6 x 2.4 x 2.9) |
| 8 | Medical point | 1 | 100 | 7 | 7 | 4.8 x 2.4 x 2.9 |
| 9 | Water Closet (WC) | 36 | 100 | 0.1 | 3.6 | - |

### *8.2.7* Technical and economical index

*Tabel 5 Table with technical-economic index*

| Nr. | Index name | U.M. | Value |
|---|---|---|---|
| 1 | Total area of permanent site | $m^2$ | 3920 |
| 2 | Total area of temporary site (tower B3 and Water Tower) | $m^2$ | 2880 |
| 3 | Area of temporary units/ constructions | $m^2$ | 370 |
| 4 | Area of storages | $m^2$ | 528 |
| 5 | Length of:<br>- Electric network<br>- Water network<br>- Sewerage network<br>- Road | $m$ | <br>510<br>350<br>95<br>630 |
| 6 | Scaffolding for:<br>- Phase I<br>- Phase II<br>- Phase III<br>- Phase IV | $m^2$ | <br>240<br>110<br>3090<br>3750 |

### *8.2.8* Indication on work safety and health, environmental protection and fire protection

All works that are executed on site must correspond to the requirements and exigencies prescribed in national normative NCM A.08.02-2014 “Securitatea și sănătatea muncii în construcții”.

- General indication

- Before starting the work, all participants must be trained in safety techniques and occupational safety at work place. The training must include:
  - Conducting the construction work at each phase.
  - Safety work rules regarding managing the workplace for the work to be performed.
  - Rules of the fire prevention on site.
  - Preparations for staring work.
  - Maintaining order and cleanliness of the workplace.
  - Preparations for finishing the work.
- In addition to these general measures, a series of measures must also be taken on site to ensure that workers have appropriate sanitary conditions, as well as the purchase of the necessary protective equipment: goggles, safety belts, safety helmets, overalls.

- All workers carrying out construction work must study the standard instructions for the categories of professional specializations developed and approved within the company.
- During the performance of the works, all workers must be equipped with individual and collective means of protection (helmets, safety belts, safety cables, protective fences, etc.). When working at height, all workers must be fastened with seat belts to the load-bearing elements of the building (to the places provided in advance).
- The organization of the construction site, the work areas and the workplaces of the workers must ensure the protection of the work throughout the execution of the works. Roads, crossings and workplaces must be cleaned regularly, and in winter it is pressed with salt sand or slag.
- Along the entire length of the fence, with an interval not exceeding 30 m, warning signs must be placed "Dangerous area, do no cross!"
- Construction waste from the blocks to be built and from the scaffolding must be lowered by means of gutters closed with heads in crates or containers. The lower end of the trough must be located at a height of not more than 1 m from the ground, or from the surface of the containers.

▪ Environmental protection conditions

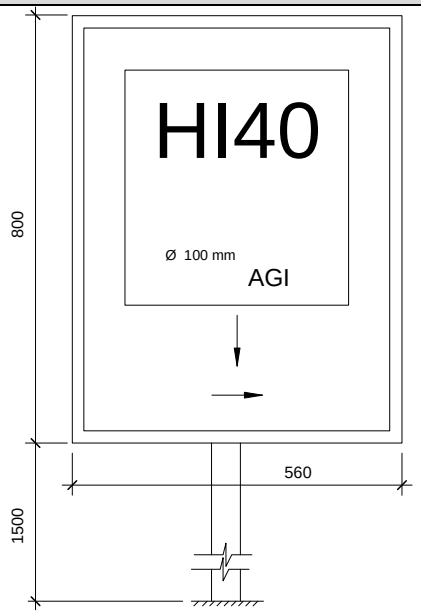
In order to ensure the protection of the environment and control over nature, during the construction, assembly works, the contractor and/or the subcontracting organizations are obliged to:

- store construction waste in the places provided in the project, with their subsequent loading and disposal in urban quarries.
- evacuate construction debris from the upper floors through gutters.
- keep green areas to a maximum, (trees, shrubs, etc.).
- ensures the washing of the wheels of the transport units that will leave the territory of the site

▪ Fire-fighting measures

- On the territory of the construction site, fire-fighting panels must be placed, with the following composition of the fire-fighting inventory set: ax 2 pcs; -boiler 2 pcs; -steak with hook 2pcs; -water vessel, volume 200l; sand box -1 pc.
- Provisional buildings and edifices are equipped with fire extinguishers, workers are trained on fire protection measures at workplaces and on site.
- All roads and paths to the designed fire hydrants must be in working order and free of passage, and must be illuminated at night. The construction site and the building under construction must be kept clean.
- It is forbidden to heat shavings; smoking is allowed only in specially designed places, it is forbidden to keep flammable and easily fusible liquids in open packaging, as well as insulating material stru6k, fibrous materials together with flammable substances.

*Tabel 6 Fire panel*

| Fire hydrant indicator | Fire inventory panel | |
|---|---|---|
|  | - Barrel with water | 250 liters |
| | - Red color bucket | 2 pieces |
| | - Fire sandbox | 2 pieces |
| | - Shovel crowbar | 2 pieces |
| | - Axe | 2 pieces |
| | - Iron fire gaff | 2 pieces |
| | - Extinguisher | 2 pieces |



- References

1. NCM A.07.02-2012 ”Procedura de elaborare, avizare, aprobare și conținutul cadru al documentației de proiect pentru construcții”
2. NCM A.08.02-2014 “Securitatea și sănătatea muncii în construcții”.
3. Council Directive 92/57/EEC of 24 June 1992 on the implementation of minimum safety and health requirements at temporary or mobile constructions sites
4. CP A.08.06:2014 “Instrucțiuni privind elaborarea proiectelor de organizare a construcției”

http://www.containex.ro/-/m/images/ctx/pdf-ctx/technische-beschreibungen/technische-beschreibung-bmsaga.ashx