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Research Article

Structural analysis and evaluation of historical Hurman Castle: recommendations for renovation and strengthening

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Abstract: The structural problems of the Hurman Castle in the rural area of Dağlıca Town, Afşin District of Kahramanmaraş Province are discussed. In the scope of the study, detailed structural evaluation of the castle was carried out according to the on-site inspection, systematic photographing documents and the drawings. Then, the results of this preliminary evaluation were used as inputs of structural analysis and calculations. The structural analysis of the castle were performed by Finite element method. Since Hurman Castle was subjected to serious local demolitions, models of sample structure parts were used to examine the current state of the building. In the models; on the north side, 152 points 67 solid elements; on the west side, 436 points, 265 solid elements were used. Finally, the systematic definitions of the protection solutions, which can be performed as a result of the structural decisions, were given for practical application of renovation and strengthening of the castle.

Keywords: Hurman Castle, Flowability, Workability, Compressive strength.

1.HISTORY AND DESCRIPTION OF THE CASTLE

Afşin Hurman-Rumman Castle was built on a hill overlooking the region, in the town of Marabuz (Dağlıca), on the north side of the district. Afsin is a district of Kahramanmaras city which is located in the Mediterranean region. According to Turkish Cultural Heritage Inventory, there are five castles in Afşin district of Kahramanmaraş. These are Persimmons Hurman Castle, Twin Hill Castle, Lâle Hill Castle, Sütpişiren Castle, Pillow Castles [1]. It can be observed that the castle on the bedrock does not have a perfect plan most probably due to the topographical conditions. Therefore it was built according to the topography of the rock. Although the construction date of the castle is unknown, no building inscription was found on the building. However, the data obtained as a result of its architectural style, construction technique and excavation studies indicate that it was constructed in Roman period.

It is known that the historical past of the castle dates back to the Roman age and the 4th century. The castle, which was understood to be under the direction of the Byzantine in the 6th century and Abbassis in the 8th century, was conquered by the Seljuk Sultan Izzeddîn Keykâvus in 1216 and passed into the Seljuk rule. It was administrated by the Dulkadir Principality in the 14th century and the Mamluk Sultanate sometime after the middle of the 15th century; it has been added to the Ottoman Empire lands since 1522 [2].

Hurman Castle is on the Silk and Spice road. The gate of the castle is on the west side. It was understood that during the Roman era, Kangal was located on the Roman road from Arabisos (Afşin-Efsus) to Sebesteia (Sivas). As in ancient times, Kangal-Afşin-Sivas route remained important in the Ottoman period. Starting from Karakilise village, there is

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another road to Arabissos (Afsin-Efsus). The distance between Karakilise and Maragos-Marabuz (Dağlıca) is 14 Roman Miles [3].

There are many castles in and around Kahramanmaraş city. Many of these castles, which are considered as a necessity to defend the region, are built on rocky hills. The rugged topography of the hill and sharp rocky walls were used while the castles were being built. Hurman (Marabuz) Castle has a plan and scheme on the edge of Hurman stream and on a steep cliff in the east-west direction. According to the topographical structure of the land, the planned structure is approximately 42x87 m. In the construction of the castle, lime mortar, coarse stone and rubble stone materials were used and wood beams were included in the walls which had a thickness of 2.7 m. The fortification walls were reinforced with a total of fourteen towers; three on the east and three on the west, two on the south and six on the north. Fig.1 and Fig.2 show the top view and plan of Hurman Castle, respectively [4].

Fig.1. Top view of Hurman Castle

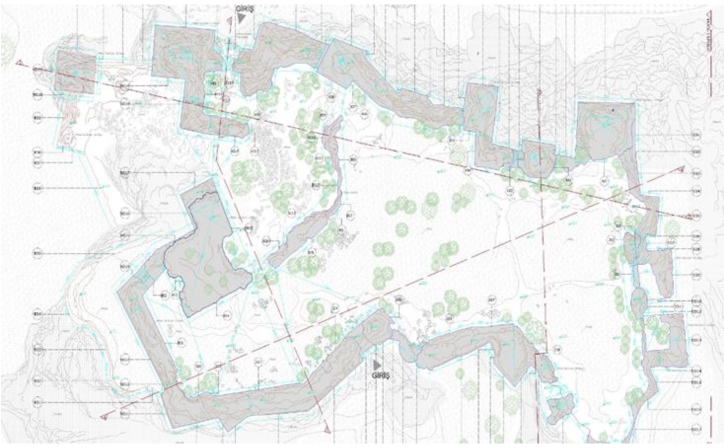

Fig.2. Plan of Hurman Castle

2. STRUCTURAL PROBLEMS

Descriptions of structural problems of the castle and their distribution on the structure are given in this section. It can be said that the problems actually correspond with one another. Although the losses were also observed on the inside of the walls, the losses in all of the walls started from the upper elevations and the exterior. On some of the walls, it was observed that there were losses in the outer sides near the foundation parts. In addition to that, in most of the spans, the partial losses resulted in the loss of the original load bearing form of the structural element. Partial demolitions in the building elements such as the entrance gate arch and interior vaults caused disruption of the bearing form of the structure. This indicate that the deformation will continue with the collapses. There is a loss of effectiveness as a result of both burning and loss of material and strength in the wooden girders that connects the inner and outer walls that hold the rubble stones together. Mortar degradation and disintegration, continuity of loss can be observed in the inner side of the walls. It can be noted that the losses progress in the whole structure from the upper parts of the outer walls to the lower parts. Demolition and geometry distortion due to the material degradation can be observed in building elements such as the arch and vault. These deformations progressed most probably by taking place simultaneously and by triggering each other in some regions. It was clear that these small but continuous losses eventually led to serious local losses [4].

3. STRENGTHENING PRIORITY AREAS AND ELEMENTS

The structural part that stands out on the North Wall is the arched entrance door. The outer wall of the door was completely disappeared and the arch of the door was destroyed around the middle axle. The parts on both sides of the arch stand as a centilever as it is shown in Fig.3. It was clear that the arch has lost its functionality. It is inevitable that the centilever parts will be demolished as a result of the vertical effects or slight seismic movements [4].


Fig.3. Arched entrance door in north wall

West facade was the place where the most serious problems of the castle is examined from the outside. The main reason for this was that the castle was settled on the steep slope, the signs of the castle were placed in different elevations and these signs were connected to each other by the walls settled in a more irregular form. Therefore, in this section, massive collapses on the walls, deformations from the ground up to the foundation level, as well as demolished wall marks can be seen. In this part, while it can be observed that the outer walls are destroyed in serious amounts, the inner stones are observed, the inner stones decomposed in these facade signs. Much more serious rubble stone slope angles have occurred due to both the sign walls on the slope and the sloping of the inner rubble stones. It should be marked that on the west side of the castle, slopes at a higher level than a natural slope were formed. It can be observed that the slope formed by degradation of the stones reaches about 70 degrees. Fig.4 shows the demolitions in the western side of the castle [4].

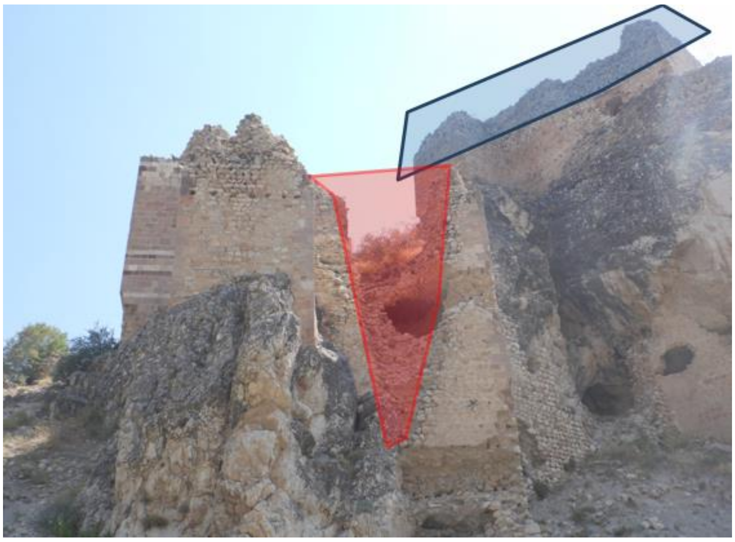
Fig.4. Demolitions in the western side of the castle

4. ANALYSIS BY FINITE ELEMENT METHOD

Since Hurman Castle was subjected to serious local demolitions, models of sample structure parts were used to examine the current state of the building. In the models; on the north side, 152 points 67 solid elements; on the west side, 436 points, 265 solid elements were used. The ground relation of the lowest row walls of the castle was defined with hinge elements. Load types on the models are limited by their own weight and lateral earthquake effects. In vertical loads, no load was taken, which the structure was exposed to, other than its own weight [4-7]. Fig.5 and Fig.6 present the models of current and proposed renovation of north front entrance gate segment, respectively. Fig.7 and

Fig.8 show G+Ex stresses (S11) on the current and proposed renovation of gate segment, respectively. Fig.9 and Fig.10 present G+Ey stresses (S22) on the current and proposed renovation gate segment, respectively [4].

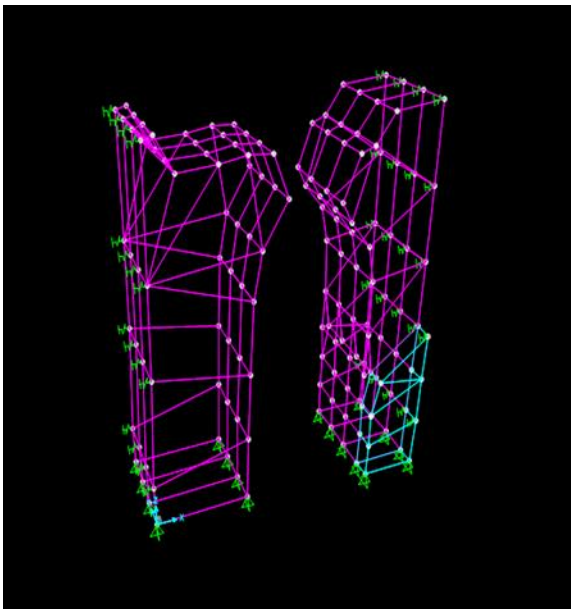

Fig.5. Model of current north front entrance gate segment

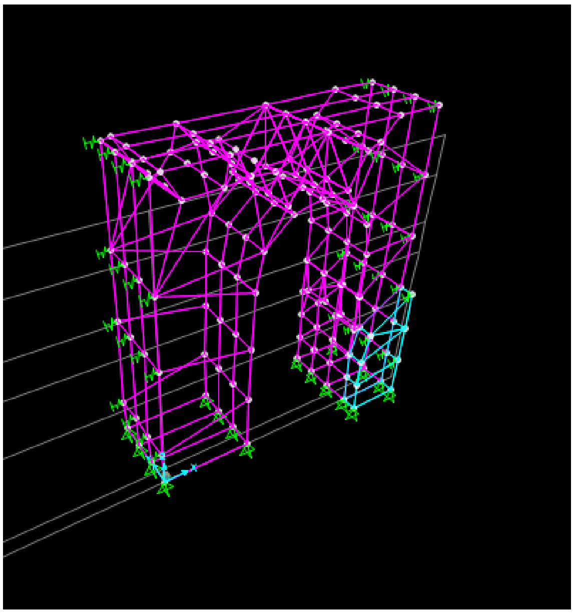

Fig.6. Model of proposed renovation of north front gate segment

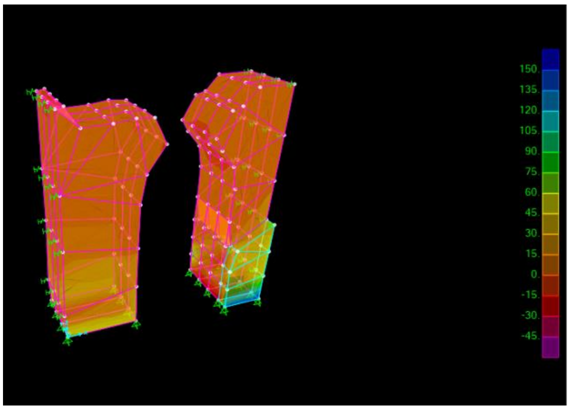

Fig.7. G+Ex stresses on the current gate segment – S11 stress (kPa)

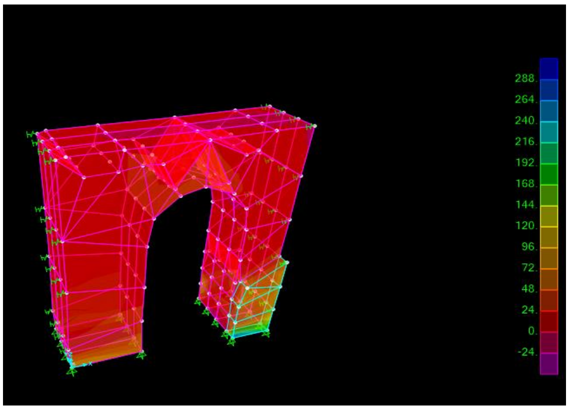

Fig.8. G+Ex stresses on the gate segment of proposed renovation – S11 stress (kPa)

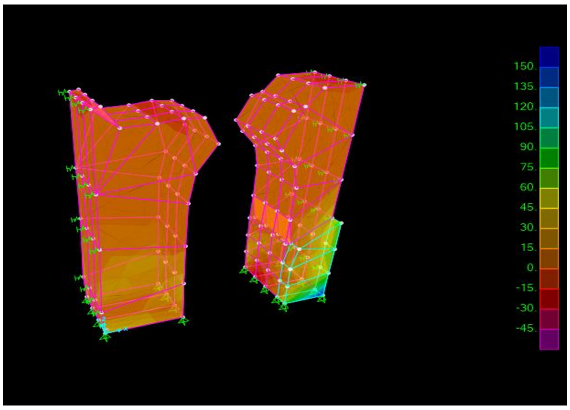

Fig.9. G+Ey stresses on the current gate segment – S22 stress (kPa)

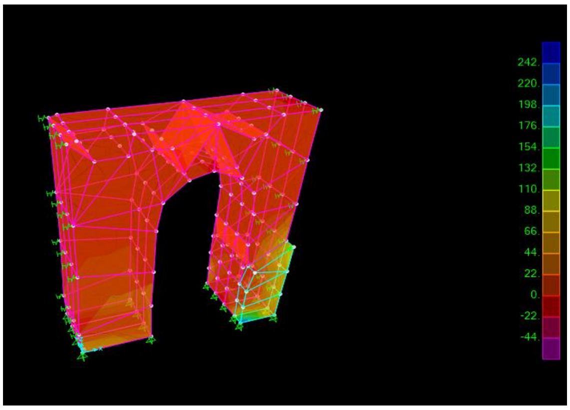

Fig.10. G+Ey stresses on the gate segment of proposed renovation – S22 stress (kPa)

Fig.11 and Fig.12 show the models of current and proposed renovation of sign segment on the west side, respectively. Fig.13 and Fig.14 show G+Ex stresses (S11) on the current and proposed renovation of sign segment, respectively. Fig.15 and Fig.16 present G+Ey stresses (S22) on the current and proposed renovation sign segment, respectively [4].

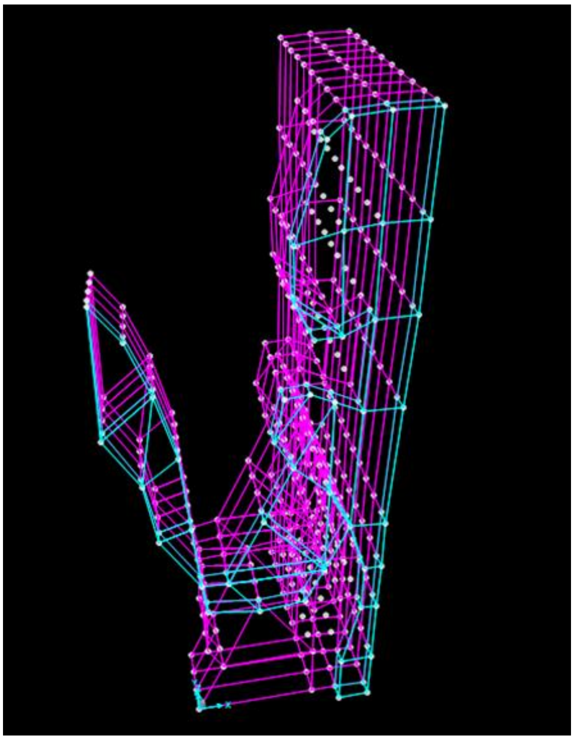

Fig.11. Model of current west front sign segment

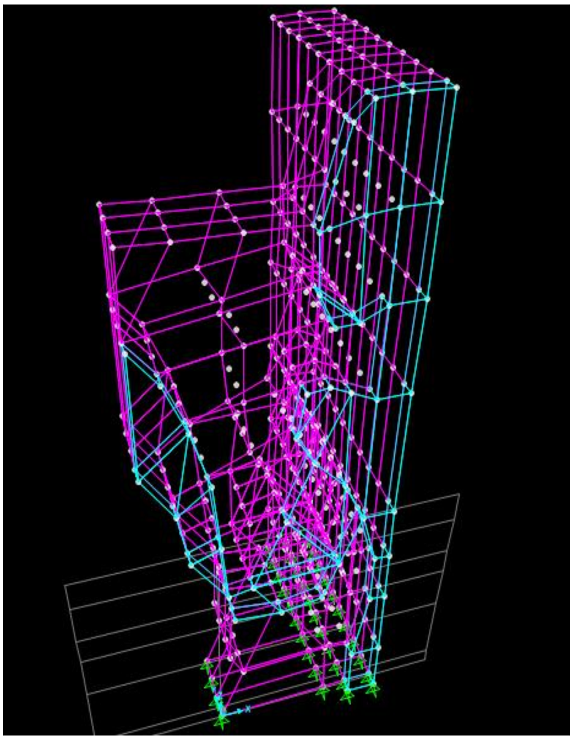

Fig.12. Model of proposed renovation of west front sign segment

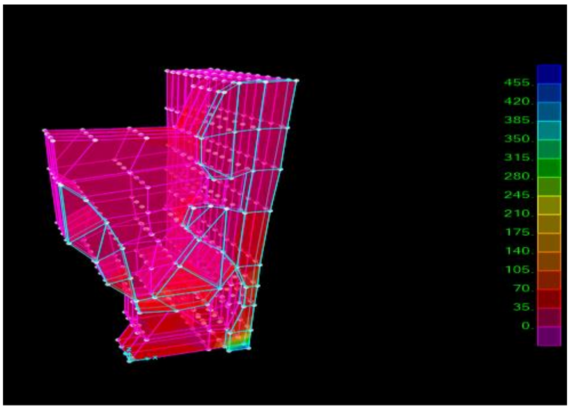

Fig.13. G+Ex stresses on the current sign segment – S11 stress (kPa)

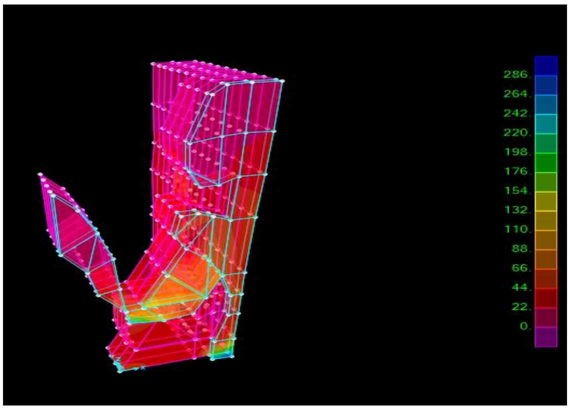

Fig.14. G+Ex stresses on the sign segment of proposed renovation – S11 stress (kPa)

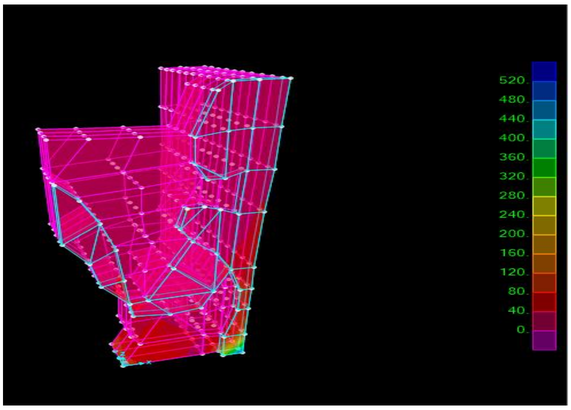

Fig.15. G+Ey stresses on the current sign segment – S22 stress (kPa)

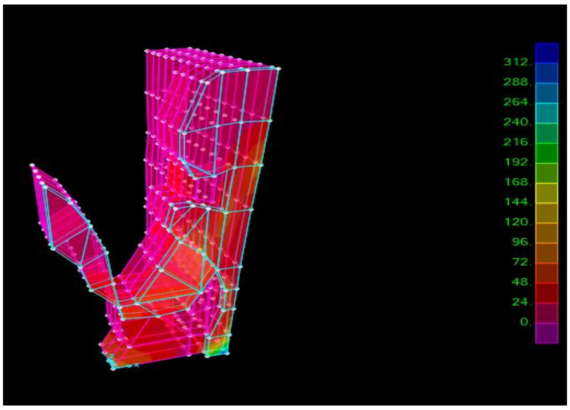

Fig.16. G+Ey stresses on the sign segment of proposed renovation – S22 stress (kPa)

The comparison of two modeling results with DL + EQ combinations in the light of S11 and S22 stresses indicated the need for an improvement. The staging caused by the relatively serious collapses formed in the tower structure was seen as stress accumulation especially in the joints of the centilever parts. It can be said that the stresses accumulated in these parts of the structure will cause problems for the real situation. As a matter of fact, the relatively small tensile stresses accumulated in the mentioned sections disappear in the models showing the renovated structure. It can be noted that homogeneous distributions in both horizontal and vertical stresses can be obtained by renovating the structure even with partial completions [4-8].

4. CONCLUSIONS AND RECOMMENDATIONS

In the light of the data provided by analysis and given under the title of structural problems, the improvements and renewals to the parts of the castle can be described as follows [4];

1. The parts containing the degraded areas are those that will cause further collapses if partial or full completion is not made. Especially long wall parts that have been subjected to variable collapses and lost their parts with out-of-plane movements should be renovated and strengthened with this completion. This type of collapses may continue by destroying the remaining parts under all kinds of lateral effects. Therefore, original-wall horizontal load transfer capability should be restored to the structure by reaching the original wall sections as much as possible with completion in the thinned sections in order to ensure the movement of the signs and the wall sections perpendicular to each other in the horizontal plane. It should be marked that these completions and renovations should be performed with the original masonry techniques. However, it may also be recommended to make the periodic renovations more prominent by using smooth cut rubble stones in order to be perceived by future generations.
2. No crack formation was observed across the whole structure. However, it is recommended that the rubble stones around the structural or capillary cracks detected during renovation are replaced with longer or larger cut stones, thereby eliminating the crack route. Stitching the outer sides of walls to the inner sides is essential to provide friction-based relationship and strength between the internal rubble and the mesh of the outer wall. It should be noted that wooden girders contribute to this strength and relationship. It is very important to replace the degraded wooden girders by a new one.
3. One of the main degradations observed throughout the structure was the decrease of the mortar strength of internal rubble stones due to the environmental conditions, aging, freezing-thawing and wetting-drying cycles. This weakens the relationship between the outer walls and the inner rubble fill. The walls, which were destroyed by out-of-plane motion as a result of weakening, exposed the internal rubble fills to environmental negative effects, and as a result, the inner rubble fills were also degraded due to the weak bonding. Therefore, it is necessary to strengthen the binding between the internal rubble fills to protect the parts.
4. The degradation caused by the effect of salting in the weakened inner filling caused the bond between the walls to break. The porous structure should be changed in order to prevent the transfer of water and salt carried to the building materials and to restore this inner filling to its original form. It is recommended that walls of the structure are injected with a liquid mortar (without aggregate). The injection must be performed through the holes of 20-30 cm deep 1-2 cm diameter corresponding to the original mortar joint sections on the inner and outer surfaces of the wall. It is recommended to apply the injection at vertical and horizontal points with 1.5 m intervals with a maximum pressure of 1 bar. It is recommended that others are closed when injecting through one hole and that the total volume of the applied injection is not more than 10% of the wall volume (volume corresponding to the injection depth - shell volume). The main purpose of strengthening the inner rubble wall (fill), whose thickness is already 2 m, is to support hardened shell formations at a depth of 20-30 cm, thereby increasing bonding between the individual parts and protecting them against surface abrasions. It should be marked that the joint improvement is required throughout the structure. It will be appropriate to perform this process after the injection process using joints. In the improvement of joints, the original mortar content determined as a result of material work should be used.
5. Finally, it is recommended to repair the mortar rows on the walls with the completion of joints, and to provide natural drainage to water by giving a slight slope to the exterior of the structure using original materials at the top of the wall.

These renovation and strengthening recommendations are expressed in order to maintain current state of the structure without further deformation. The fact that the castle structure does not suffer from total losses can be provided with these recommendations. However, since the internal rubble stones of the structure will always be subject to serious environmental impacts, strengthening of the rubble stones against local losses or stone fragment falls can only be ensured through continuous maintenance and repairs. Some parts of the structure may show weakness against seismic and wind effects even after renovation and strengthening. The continuity of repair is essential.

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