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Observation of behavior of the Ahlat Gravestones (TURKEY) at seismic risk and their recognition by QR code

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Abstract. Protection of cultural heritage and carrying it to the future are at the top of the significant topics of research and implementation in engineering in the 21st century. There are several historical structures in the district of Ahlat located in the east of Turkey on the Lake Van Basin that has harbored many civilizations. Some of such works are the gravestones that are found in the Ahlat Seljuk Cemetery, which is the oldest and largest cemetery in the district. This study firstly provides information about the Ahlat Seljuk Cemetery and the gravestones found in it. Observation-based structural analyses were carried out on these gravestones that are found in this area that are known to have belonged to different civilizations based on their physical and constructional characteristics. These stones were built out of Ahlat stone as single pieces. Information is provided on the damages that have occurred on the gravestones in time and their causes. In general, losses of mass, abrasions, separations, collapses and calcifications due to natural conditions, as well as vegetative formations, were observed in the gravestones. To provide an example of other gravestones within the context of the study, the gravestone that is known to belong to the person named Nureddin Ebu Hasan was selected. As a result of the modeling that was carried out for this gravestone by using the finite elements method, modal analyses were carried out. With these analyses, for the gravestone, period, effective mass participation rates and stress values were calculated. The stress values that were obtained in this study were compared to the material safety stress values that were obtained in previous studies. Additionally, QR code application was created for the gravestone that was selected as an example in the study, and information on this gravestone was transferred to an electronic environment. The QR code application includes different language options, visuals of the gravestone and information on the gravestone. The QR application was also supported with a video of the cemetery where the gravestone is located. With this application, access to information about gravestones will be possible by using tablets and smartphones. With a QR code to be created for each gravestone, these gravestones will obtain identity cards.

Keywords: Gravestone; cultural heritage; seismic behavior; QR code; monitoring

1. Introduction

The values that human beings created directly or with nature in the history of humanity from the beginning to the end of civilization for thousands of years are called "cultural and natural heritage" today. Protection of these values is a common problem of humanity in our day, and it is a matter which should be emphasized (Aköz and Yüzer 2009, ICOMOS 2002, Fetaher 2006, Ademović 2017). Preservation of cultural heritage and its safe transfer to the future is one of the major issues in engineering research and application in the 21st century.

Since this important issue has a common stake in fields of science such as engineering, architecture, art history and archeology, interdisciplinary working groups, which have gained considerable attention in recent years, are becoming popular (Işık *et al*. 2016, 2016a, 2017, Karaşin and Işık 2016). In order to transfer historical heritage to the next generations, studies on earthquake-related seismicity are important nowadays. There are many studies in the literature in this regard (Hadzima-Nyarko *et al.* 2016, 2017, Erdil *et al.* 2018, Backer *et al.* 2018, Catulo *et al.* 2018, Pauletta *et al.* 2018, Ortega *et al.* 2017, Castelazzi *et al.* 2018, Elyamani *et al.* 2017, Preciado *et al.* 2015, Russo 2016, Souami *et al.* 2016, Uğurlu *et al.* 2017, Özbek *et al.* 2017, Nohutcu *et al.* 2017, Döven and Kafkas 2017, Kocatürk and Erdoğan 2017, Ademović, *et al.* 2017, Ademović and Kurtović 2018). Historical structures have a prioritized place in terms of avoiding disruption of the historical texture of residential areas. Knowing about the characteristics of such structures is important for protection of historical and cultural heritage. In the context of protection and survival of historical and cultural assets, it is a necessity in terms of the historical process to systematically transfer the structural characteristics of historical buildings (mosques, bridges, tombs, madrasahs, etc.) into a database (Işık *et al.* 2016b, 2018a). Historical artifacts are priceless cultural assets that link the past to the future. Moreover, historical structures are also an indication of societal engineering experiences, artistic understandings and economic events. In this context, the Lake Van basin has hosted many civilizations such as the Hurri, Urartu, Med, Persian, Sassanian, Seljuk and Ottoman civilizations

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in the historical process. Because the basin is a very old settlement area, it has carried the historical buildings and cultural values left behind by many civilizations until today. Historical structures exist in many different forms that are still being used in the basin, built in ancient times with renovation works. One of the centers in this basin, which has been cradled by many civilizations, is the Ahlat district of Bitlis (Işık and Özlük 2013). Historical cemeteries located in the city of Ahlat and the gravestones in these cemeteries have a different historical prescription. There are many historical buildings belonging to various civilizations in the Ahlat. Historical buildings stand for centuries. The material properties used in the construction of these structures are directly related to construction technologies. In this context, analysis of the structural characteristics of such structures is an engineering activity. Local administrations are important in terms of tourism with the related public institutions and organizations for archiving the structural and historical characteristics related to historical artifacts and being able to easily access this information when requested.

The “Ahlat Seljuk Cemetery”, which is one of the important historical cemeteries in the Ahlat District, was examined in this study. In the study, firstly the structural characteristics and the history of the gravestones in this cemetery are described. At the next stage, solution recommendations are presented by discussing the structural deterioration and damage in these gravestones. There are many studies in the literature on these gravestones which are also on the UNESCO list.

However, to the best of our knowledge, there is no study in the literature on structural analyses, earthquake analyses and transfer of the results of these analyses for these gravestones. Considering this, this study will contribute to the literature. Additionally, an observation-based form will be created via structural analysis, and it will be easier to monitor these gravestones.

This study carried out structural modeling by using the finite elements method for an example of a gravestone made out of Ahlat stone, which is one of the significant elements of the historical texture of Ahlat. For the model that was created, stresses that occurred in different axes found in the software were calculated by variable loading situations. Furthermore, a QR (Quick Response) code application was carried out for a gravestone that was selected as an example. For this, firstly visuals and structural and historical information for the gravestone were obtained. With the help of the algorithm that was created, a QR code was then formed for the gravestone. It was aimed to create an identity card for each of the gravestones, which are abundant in the cemetery. With the help of the QR codes to be created for each gravestone that will be examined, all information about these graves could be transferred to the electronic environment. In the electronic environment that was created, information about the historical structure, visuals and a video of the area are presented. The electronic environment that was created also offers two language options as Turkish and English. Other languages may be added if necessary. It is believed that this application will have a significant place in terms of tourism. Both domestic and international tourists who will visit the region will be ensured to be able to access information on these gravestones very easily and fast. Additionally, with the help of the video that is found in the QR code application; there will be an opportunity for making a more detailed observation.

Fig. 1 Location of Ahlat Seljuk Cemetery

2. Ahlat Seljuk cemetery

This cemetery is known as the largest Turkish-Islamic graveyard in the world located between the Tatvan-Ahlat highways in the eastern part of the district of İkikubbe, west of the district center, in the southern part of the Ahlat-Ovakışla highway. In the cemetery, there are 8169 gravestones in total. From the north to the south, the Taht-ı Suleyman road and the Tatvan were established on the wide plain between the İkikubbe and Harabe Şehir neighborhoods to the east and the west. The location of the studied cemetery today is shown in Fig. 1.

The gravestones that are found in this area have different dimensions and shapes, and they were built in the 11th and 16th centuries. The different forms of these gravestones are an indicator of the different civilizations that have lived in the region. Each civilization constructed gravestones that are unique to it. This situation is useful for historians and makes it easier to understand the historical process. Fig. 2 shows visuals of some gravestones found in the Ahlat Seljuk Cemetery. The greatest variation in these gravestones is their height. The heights of the gravestones in this cemetery reach 4 m. The width and thickness values of the gravestones are very close to each other.

The graves constitute two different parts on the land. The first part consists of sarcophagi in dimensions of coffins on the graves. The second part contains the body stones that are found in the head and/or foot sides. These parts were constructed independently of each other. Visuals of graves that were constructed in different styles are shown in Fig. 3.

The Ahlat Seljuk Cemetery that is located in the district of Ahlat and included in UNESCO’s list of world heritage represents the cultural and historical richness of the region in terms of its gravestones’ types, amounts and epitaphs. Therefore, these gravestones have the status of historical documents. They have also been an important instrument for determining the social and political events of the past. These gravestones that belong to several different civilizations also reflect the several different aspects of their

Fig. 2 Ahlat Seljuk gravestones

(a) Single-body cylindrical sarcophagus (b) Double-body cylindrical sarcophagus (c) Single-body rectangular prism sarcophagus (d) Double-body rectangular prism sarcophagus

Fig. 3 Different types of graves

owners. The grave owner's social status, sex and their status in the military, property-related and civil life has been determined with gravestones. Especially the gravestones that were built in the Seljuk period show the victories in wars.

There are graves belonging to the Ayyubid period from the center of the eastern part towards the south. In these graves, the sarcophagi are in cylindrical shapes. The forms of graves that are the most frequently observed in the cemetery have rectangular prism sarcophagi. These usually belong to the Ilkhanids. They continue up to the period of the Karakoyunlus. Furthermore, the stones that were placed upright on the head and foot sides were also used to determine the owners of the graves. The head and foot stones in the graves include inscriptions and motifs. The great dimensions that are usually found in these graves and not in any other Islamic gravestones, the contents of their epigraphs and the presence of dragon motifs are indicators that these are the successors of the Orkhon Inscriptions (Kültür Portal 2018, Elmastaş 2001, Doğru *et al.* 2017, Karamağaralı 1992).

3. Structural analysis of gravestones

The gravestones were made of a local stone that is called Ahlat Stone. Ahlat stone is also extensively being used as construction material in the region. The rocks that are known with their regional name as Ahlat stone were formed out of lava spreading and cooling in kilometers in the region by the explosion of the volcanic Nemrut Crater. Ahlat stone, which is considered to be geological heritage, contains macro and micro pores that are independent of each other. These stones have various colors like brown, dark brown and ash. Soft Ahlat stone can be formed shape by hand or by machines (Bakış *et al.* 2014, Işık *et al.* 2015). For the gravestones, firstly an observation-based analysis form was prepared. This form was used to record the general damages that have occurred on these stones. This form was given in Table 1.

As the Ahlat stone that was used in the gravestones formed as a result of volcanic activity, it is a soft material. As a consequence of this, damages have occurred in time due to natural causes. Some of the gravestones had loss of material due to abrasion, bending, cracks, fractures and tipping over. There was a lot of vegetative formation in the gravestones and sarcophagi, which harmed the stones to different extents. Work to eliminate these damages has begun in a recent time and is ongoing. There were also calcifications on the gravestones due to humidity effects. The images of the general damage observed in the Ahlat Seljuk Gravestones are shown in Fig. 4.

A number of computer programs that facilitate the transfer of data for calculation and design of today's modern engineering constructions and integration of the results into application projects have been developed. However, since the historical buildings that survived today are generally prestigious structures such as graves, tombs, mosques, palaces, bridges and castles, the shapes and forms of conveyor systems differ from the modern engineering constructions of today. For this reason, the most appropriate calculation method for structural analysis of historical structures is the finite elements analysis method. Numerical modeling may be defined as transformation of load bearing system elements made out of different materials and containing variable cross-sectional geometry into

Table 1 Observation-based structural analysis form for the Ahlat Seljuk gravestones

Parameter	Yes	No	Annotation
Deterioration due to time	×		
Effect of natural conditions	×		
Destruction by people	×		
Active use	×		
Neglect	×		Partially
Casual repairs and renovations		×	
Is the originality preserved?	×		
Removal of Stones	×		Partially
Fracture and breakage in place	×		Partially
Calcification on the surfaces	×		Partially
Algae and vegetative formations	×		
Repair visibility	×		Partially
Presence of germinated soil layer	×		
Cracks and crack properties	×		
Decay on the surface	×		
Darkening on the surfaces	×		Slightly
Mass losses	×		Slightly
Presence of seating effects		×	
Cracks in plant rooting	×		Partially
Horizontal and vertical deformations	×		Partially
Whether the protection measures are adequate		×	
Presence of water entering into the structure	×		
Freeze - thaw effect		×	
Effect of construction in the vicinity	×		
Discoloration and color change	×		
Natural disaster effects		×	
Additional Explanations	Construction work to eliminate these damages has begun and is ongoing.		

Fig. 4 The damage observed in gravestones: a) loss of mass, b) lichen formation, c) calcification, d) breaking damage, e) cracking damage, f) vertical displacement, g) tipping damage, h) partial loss

Fig. 5 The images and inscriptions of the gravestone

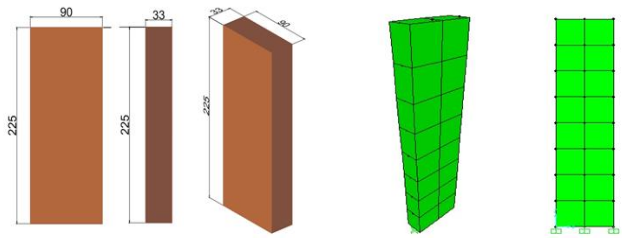

Fig. 6 Dimensions and FE model created in the software for the gravestone

mathematical terms in an accurate and harmonious way based on the main rules of mechanics. To provide an example of all gravestones, in the study, one particular gravestone was chosen for analysis. The gravestone that was considered in the study belongs to Nureddin Ebu Hasan. The dimensions of this gravestone are 2.25 × 0.90 × 0.33 m. The images of this gravestone and the inscription on it are shown in Fig. 5.

The dimensioning process for the gravestone, which was examined in the study that is basis of the structural analysis, is shown in Fig. 6. The modal analysis of the gravestone examined in the study was carried out in the SAP2000 software (Computers and Structures, 2015). The images of the finite element (FE) model obtained in the software are shown in Fig. 6.

Finite element (FE) models provide cost effective solutions in comparison to the experimental alternative, but true success of FE techniques heavily depends on constitutive models for the material and appropriate discretization of the continuum. Masonry is anisotropic due to the presence of discrete sets of horizontal and vertical mortar joints and possesses orthotropic strength and softening characteristics, which depend not only on the properties of masonry's constituent materials but also on their interaction reflecting the workmanship (Dhanasekar and Haider 2008, Ademović 2011). The numerical modelling of masonry structures through FEM is a very computationally demanding task because of two different issues: on the one hand, the typological characteristics of masonry buildings do not allow us to refer to simplified static schemes, while on the other hand, the mechanical properties of the material lead to a widely non-linear behaviour that may be very tricky to predict (Giordano *et*

Table 2 Properties of materials

Material Type	Modulus of Elasticity (kN/m^2)	Specific Gravity (kN/m^3)	Unit Weight (t/m^3)	Poisson Ratio
Ahlat Stone	5×10^6	24	2.45	0.2

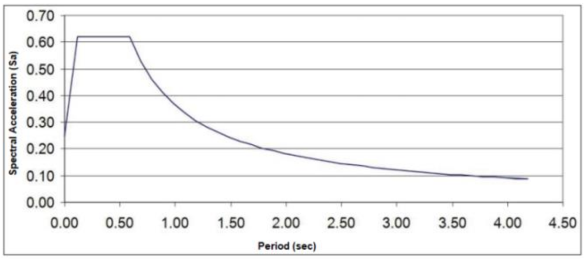

Fig. 7 Spectrum curve for dynamic analysis (TEC 2007)

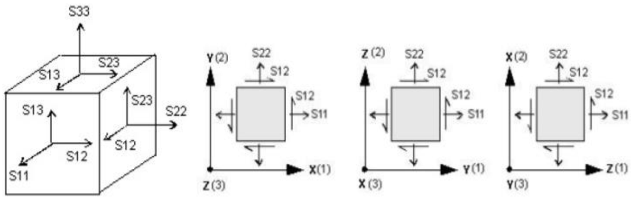

Fig. 8 Sign compliance and directional acceptance (Dabanlı, 2008)

al. 2002, Nikoo *et al.* 2017, Nikkar *et al.* 2017, Hadzima-Nyarko *et al.* 2018, Işık *et al.* 2019).

The finite element model that was prepared consists in total of 27 nodes and 16 shell elements. The material properties of building components were taken from the results of previous studies in the literature and the values recommended for masonry structures in the Turkish Earthquake Code (TEC 2007) (TEC 2007). The properties of the materials that were used in the gravestones are given in Table 2.

On the calculation model that was prepared, two different loadings were applied in the form of static loads and the forces created by ground movements defined in the earthquake spectrum. The spectrum was applied in two principal directions, EQ_X and EQ_Y. The spectrum curve that was used for the dynamic analysis for the gravestone is shown in Fig. 7.

The sign conformance and direction assumptions of the elements that were used in the finite element model are shown in Fig. 8, depending on the assumptions made by the software of the numerical model (Dabanlı 2008).

As indicated in Fig. 8, S11: vertical stress in the (x) direction, S22: vertical stress in the (y) direction, S33: vertical stress in the (z) direction, (S12 = S21): shear stresses in the XY plane. In order to be able to determine the parameters that are needed to create the mathematical model that showed the dynamic behavior of the gravestone that was examined in the study, modal analysis was carried out. A modal analysis is a dynamic analysis method that allows determination of free vibration periods, frequency values, mass participation rates and mode shapes of a building (Mutlu and Şahin 2016). For determination of the dynamic characteristics of the gravestone, modal analysis was performed. The first 18 modes of the modal analysis were considered. It was observed that the mass participation rates in the X and Y directions in the model were above 80%, and there was not much effect of including more modes. According to the modal analysis results of the model, the effective modes, the natural vibration periods and the mass participation rates are shown in Table 3, and the mode shapes are shown in Fig. 9.

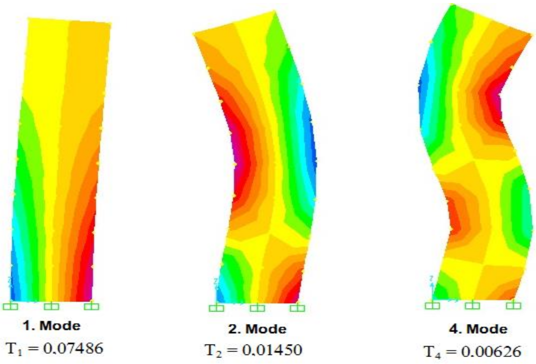

Fig. 9 Mode shapes and period values obtained for the gravestone model

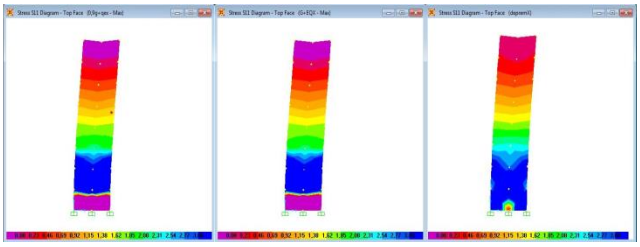

Fig. 10 S11 stress values for different load cases

Static, dynamic and earthquake loads were considered for stress measurements. The static load calculation was made by the software based on material properties. As there was no dynamic value in question for the gravestone, this was accepted as zero. For the earthquake loads, the spectrum defined in the study was utilized. Earthquake loads were defined in two axes as EQx and EQy. Using these values, calculations were carried out for different load combinations. The stress diagrams obtained for different load cases for S11 and the vertical stress values in the X direction in the software are shown in Fig. 10.

The stress diagrams obtained for different load cases for S22 and the vertical stress values in the Y direction in the software are shown in Fig. 11.

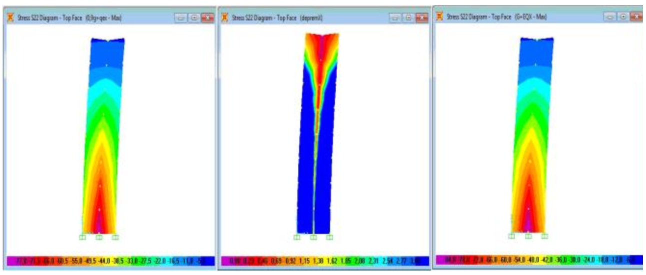

Fig. 11 S22 stress values for different load cases

Table 3 Modal analysis results with effective mass participation ratios of the model

Mode	Period	U_X	U_Z	$\sum U_X$	$\sum U_Z$	R_X	R_Y	R_Z	$\sum R_X$	$\sum R_Y$	$\sum R_Z$
1	0.074858	0.63902	0	0.63902	0	0	0.93357	0.63902	0	0.9336	0.63902
2	0.014500	0.21462	0	0.85364	0	0	0.02435	0.21462	0	0.9579	0.85364
3	0.011192	1.17E^{-20}	0.85702	0.85364	0.85702	0.85702	0.0328	1.17E^{-20}	0.857	0.9907	0.85364
4	0.006264	0.07249	1.57E^{-18}	0.92613	0.85702	1.58E^{-18}	0.00289	0.07249	0.857	0.9936	0.92613
5	0.003884	0.03663	1.52E^{-15}	0.96276	0.85702	1.52E^{-15}	0.00055	0.03663	0.857	0.9942	0.96276
6	0.00379	1.37E^{-18}	0.08987	0.96276	0.9469	0.08987	0.00344	1.37E^{-18}	0.9469	0.9976	0.96276
7	0.002815	0.01977	2.12E^{-14}	0.98254	0.9469	2.12E^{-14}	0.00011	0.01977	0.9469	0.9977	0.98254
8	0.002456	1.25E^{-14}	0.00117	0.98254	0.94806	0.00117	4.47E^{-05}	1.25E^{-14}	0.9481	0.9978	0.98254
9	0.002361	5.45E^{-16}	0.02538	0.98254	0.97344	0.02538	0.00097	5.45E^{-16}	0.9734	0.9987	0.98254
10	0.002285	0.00792	8.40E^{-17}	0.99045	0.97344	8.4E^{-17}	5.8E^{-07}	0.00792	0.9734	0.9987	0.99045
11	0.002136	3.42E^{-14}	0.00014	0.99045	0.97359	0.00014	5.51E^{-06}	3.42E^{-14}	0.9736	0.9987	0.99045
12	0.002135	0.00239	2.05E^{-17}	0.99284	0.97359	2.05E^{-17}	5.63E^{-05}	0.00239	0.9736	0.9988	0.99284
13	0.002097	8.79E^{-15}	0.00094	0.99284	0.97452	0.00094	3.58E^{-05}	8.8E^{-15}	0.9745	0.9988	0.99284
14	0.002007	3.70E^{-15}	0.00069	0.99284	0.97522	0.00069	2.66E^{-05}	3.7E^{-15}	0.9752	0.9989	0.99284
15	0.001972	0.00246	1.21E^{-13}	0.9953	0.97522	1.21E^{-13}	3.86E^{-05}	0.00246	0.9752	0.9989	0.9953
16	0.001956	1.19E^{-15}	0.00144	0.9953	0.97666	0.00144	5.53E^{-05}	1.2E^{-15}	0.9767	0.9989	0.9953
17	0.001904	3.45E^{-16}	0.0022	0.9953	0.97886	0.0022	8.41E^{-05}	3.45E^{-16}	0.9789	0.999	0.9953
18	0.001839	0.00206	3.00E^{-13}	0.99736	0.97886	3E^{-13}	3.51E^{-05}	0.00206	0.9789	0.9991	0.99736

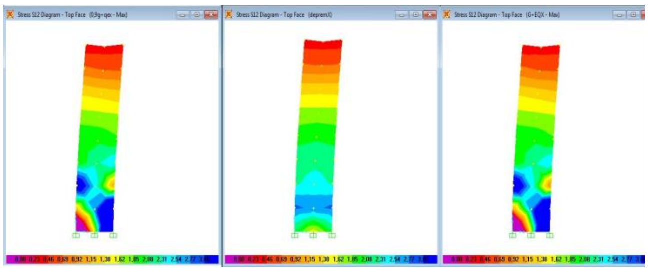

Fig. 12 S12 stress values for different load cases

Table 4 Maximum tensile stress values under different load cases

Load Case	S11 (MPa)	S22(MPa)
G+QE$_X$	0.00692	0.203
0.9G+ QE$_X$	0.00673	0.189

Table 5 Maximum compressive stress values under different load cases

Load Case	S11 (MPa)	S22(MPa)
G+QE$_X$	0.0272	0.135
0.9G+ QE$_X$	0.0253	0.126

The stress diagrams obtained for different load cases for S12 in the X-Y direction in the software are shown in Fig.12

The maximum tensile strength values obtained from the results of the analysis are given in Table 4.

The maximum compressive stress values obtained from the results of the analysis are given in Table 5.

The maximum shear stress values obtained from the results of the analysis are given in Table 6.

Table 6 Maximum shear stress values under different load cases

Load Case	S12 (MPa)
G+QE$_X$	0.00865
0.9G+ QE$_X$	0.00811

The gravestones were constructed as single pieces, and no connection elements were used. This means that the gravestones had rigid behavior. The homogenous structure of the gravestones did not create any weak points in the structure. The very small period values that were obtained also showed the high rigidity of the stones. Considering the different load combinations that were used for the studied gravestone, the highest compressive stress value was 0.203 MPa, the highest shear stress value was 0.00865 MPa, and the highest tensile stress value was 0.00692 MPa. Intensified stresses were observed at the edge parts of the gravestones closer to the base. While no experiment was carried out for the safe stress values for Ahlat stone, the information in the literature was used. While determining compressive strength for Ahlat stone, the average of the compressive strength values of differently coloured Ahlat stones was taken. This value was calculated as 11.16 MPa (Şimşek and Erdal 2004). As Ahlat stone is a product of Mount Nemrut's volcanic activity, it was examined as a volcanic rock, and the minimum tensile strength was taken as 8 MPa. For the safety shear stress value for Ahlat stone, the value of 5.68 MPa was taken into account (Işık and Antep 2018). The values that were calculated for the selected gravestone were much lower than those reported in the literature.

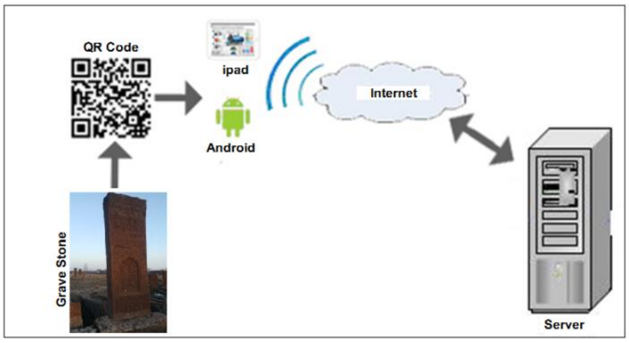

Fig. 13 Application algorithm with QR code

4. QR code application

As a result of the advancements in computers, smart devices and internet technology, as in the case of several other fields, it has also become a necessity to conduct operations about structures in the computer environment. Historical data may also be considered in this context. The demand for more frequent use of information technologies in geometric location and monitoring systems with respect to historical buildings and sites is increasing day by day. In parallel to this, the widespread use of mobile devices such as tablets and smartphones, the fact that they have become small computer systems, they are wireless and easy to carry, as well as the ability to operate very quickly and having a large memory capacity, have increased the use of these devices (Işık *et al.* 2016, 2017a, b, 2018). In particular, the desire to reach correct information through fast and reliable means in the study of historical buildings and areas, which are indispensable parts of tourist attractions, constitutes an important part of this study.

QR code implementation forms the basis for geometric location and tracking systems that can be operated on mobile devices for historical buildings and sites. The application was created to allow online monitoring, modification or addition of information on historical structures by mobile devices with the help of a QR code placed on or near these structures. The general operation algorithm of the application is shown in Fig. 13. Different algorithms were developed for the software system that is shown in Fig. 13. The flow diagram of the algorithm is given in Fig.14. The software is available in two different sections, the administrator panel and the user panel.

The system administrator has the authority to create a data matrix for the building site by inputting the first set of data belonging to the building site using the user name and password of the system administrator, and they also have the authority to delete and change the previously entered data of a user. On the user side, the users read the data symbols pasted on the structure on the smartphone. It is possible to see the data belonging to these structures by means of the read data code.

In order to be able to read the QR code of the building with mobile devices, software for reading the data from the application centers is freely downloaded, depending on the operating system used by the devices. The other part of the monitoring system is the users. Everyone with a mobile device can be a user. The QR code application for the gravestone belonging to Nureddin Ebu Hasan that was studied here is shown in Fig. 15. For this gravestone, the identification number was determined as ID=1. Each gravestone will have a different ID.

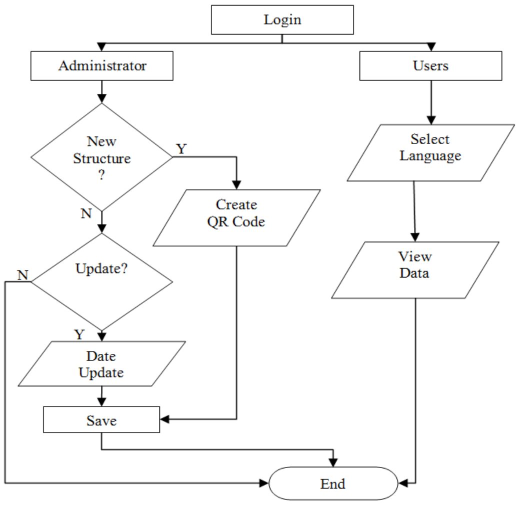

Fig. 14 Software system operation algorithm

Fig. 15 QR code of the gravestone of Nureddin Ebu Hasan with ID = 1

Fig. 16 Language selection menu

The administrator who will enter data for a gravestone will be able to decide upon which information will be displayed. The desired language information is displayed by setting the language option from the menu as shown in Fig. 16.

The user can access the data of the structure by reading QR code attached to the structure. This is illustrated in Fig. 17. Depending on the majority of tourists coming to the region, Turkish and English languages were determined as

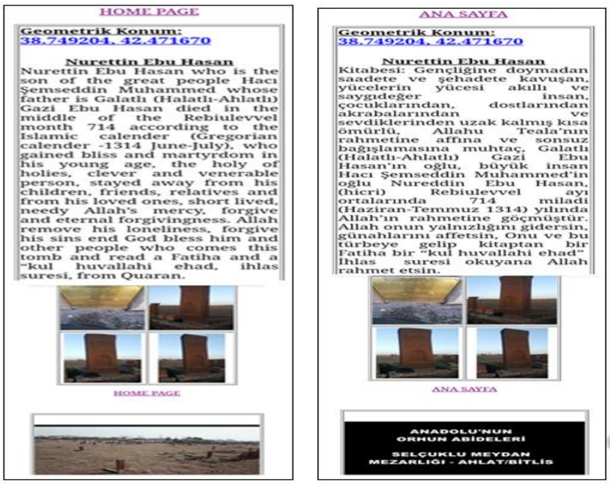

Fig. 17 Mobile device monitoring screens according to two different language options

the options, and the number of options may be increased if needed.

5. Conclusions

This study on Ahlat gravestones that are in the world heritage list of UNESCO where different disciplines worked in collaboration will have a significant place in the literature. Information on Ahlat gravestones was provided, and observation-based analyses were carried out regarding their current status. The behavior of a selected gravestone under earthquake loads was determined, and a QR code application was developed for this gravestone. The video included in the QR code application also adds value to the study.

The study considered the Ahlat Seljuk Cemetery, which is known as the largest historical open-air cemetery of the district of Ahlat. This cemetery is located on an area of approximately 210000 m^2. In the scope of the study, detailed information was provided about this cemetery. As a result of observation-based examinations on the gravestones, a form was created to record the damages that have occurred in them, and information was provided about these damages. These damages were usually time-related damages that occurred under environmental conditions. Losses of mass, abrasions and tears were observed in the gravestones. Additionally, over time, lichen formations in these stones have also damaged them. Moisture effects have occurred in some tombstones due to water exposure in some places. Authorities are continuing to work on correcting these damages, protecting them from damage and preserving them.

During the application phase, Nureddin Ebu Hasan's personal gravestone was chosen as an example. A finite element model was developed using solid elements of the sepulchrically constructed tombstone. S11, S22 and S12 stresses in the software were calculated for the finite element model that was created. Moreover, the mode shapes and period values of the tombstone were obtained. The single-piece construction of the gravestone did not create a weak point in it.

The fact that gravestones have survived since despite natural events and adverse conditions show design of very accurate ideas in terms of the stability of these structures. This shows that historical buildings receive good engineering services. Even in the historical process, this can be regarded as a demonstration of the design of structures in terms of engineering information.

The gravestones that are found in the studied area constitute one of the most significant parts of mausoleum culture based on the phenomenon of burying the dead and praising individuals in ruling positions for the future which may be traced far back among Eastern societies. These gravestones are very valuable structures that need to be transferred to the future generations. This is why the conditions of such structures in surviving the negative effects of time and external variables is particularly important in terms of revealing the destructive effects they have experienced and their conditions regarding preservation. Monitoring these data about historical structures will give meaning to interventions to be made on these structures.

As Ahlat stone has low compressive strength and a spongy, soft structure, it is known to be prone to destruction by abrasion, it is affected by temperature differences, frost and humid environments, and these factors lead to destruction or separation of these stones. Freezing-thawing, which is especially cyclically effective in the cold season, is one of the most important factors in the destruction of the stones in the region. This poses a risk for the gravestones in the area. The result of the analyses that the maximum compressive, shear and tensile stress values were much lower than the strength values reported in the literature for Ahlat stone showed that the loads were safely compensated for. In general, the critical cross-sections in masonry structures are section transitions and connection elements between different cross-sections that form the structure. The gravestone that was examined was in one piece, and no connection elements were used. This integrity of the stone prevented friction forces from forming. This situation especially prevented damage that could be inflicted on the gravestone. Therefore, it may be argued that the critical cross-sections for gravestones are the points where the structure is connected to the ground. The rigid structure of gravestones in general leads the damages on them to be limited.

With the study, historical Ahlat tombstones were moved to an electronic inventory, and an example application was carried out with the aim of creating an identity card in the electronic environment for each gravestone. These ID cards were combined with a database of information. In the study, the data collected from the field were integrated into the electronic environment, and the obtained data were shared in a healthy, easy and fast manner.

In the installed system, all data can be defined, stored, processed and analyzed in an efficient and detailed way in a single database. This way, time and money can be saved in decision-making and implementation processes, and an institutional resource planning infrastructure can be created.

With the method that was discussed in the study, it will be possible to effectively utilize an information-based management process with a consistent structural information system and information-based strategic planning. Additionally, this study will provide the opportunity to access information about these gravestones independently of space.

The study will also make a significant contribution to tourism revenues. Domestic and international tourists will be able to access information about the tombs of Ahlat easily with their tablets and mobile phones. As in all areas of life, the use of technology here will be quite easy and attractive for people.

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