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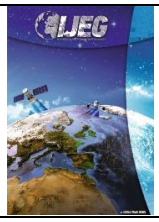

An analysis on the corrosion of a cultural heritage

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Keywords
Corrosion
Cultural Heritage
Çanlı Church
Deformation
Photogrammetry

ABSTRACT

Many historical landmarks and cultural heritage are being constantly destroyed through natural events and human actions. It is important to conduct corrosion analysis and two and three-dimension documentation studies to restore and transfer these landmarks to the new generations. It is particularly important to record, keep these historical heritages digitally and take precautions against the potential corrosion due to the wars, natural disasters and climatic factors that continue to the present. In this study, the corrosion in Çanlı Church (ÇanlıKilise) located in Akhisar village of the province of Aksaray in Turkey was determined and the reasons were examined. By using close-range photogrammetry method, three-dimension models and facade charts of three facades (North, West, South) of Çanlı Church have been acquired, as a result of measurements performed in four different times (2006, 2010, 2016, 2019). Overlapping all these charts in the same scale, the corrosions occurred on the facades of Çanlı Church have been examined. The meteorological data within the period when the measurements were performed were reviewed. As a result, corrosion on the North, West and South facades of Çanlı Church have been found at the level of 8%, 3%, 13% respectively. It was concluded that the storm has greater effect on the corrosion.

1. INTRODUCTION

Cultural Heritage is a treasury that consists of individuals' histories and sustains the common spirit of comradeship and support among them. It documents the experiences the human beings have had throughout the history and ensures the proper building of the future as well as the continuity of the customs called tradition. Cultural heritage is the wealth of a country, for all these reasons (Korumaz et al. 2011). We should protect and take care of it not only for future generations but also for all humanity. It is still very hard even in the 21st century to protect and keep the cultural heritages as they are. The air pollution and seasonal changes, human activities and natural disasters pose a great potential threat for cultural heritages. Protection of cultural heritage is increasingly attracting attention worldwide (Ratnayake et al. 2018).

It is important to perform the maintenance and repairs of these still standing historical landmarks and explore the causes of corrosion, to pass them to the next generations (Bozdoğan and Yılmaz 2019).

Since the corrosion and degradation of the artifacts happen in a short time these landmarks should be examined for a long period and the potential changes should be examined (Demirkesen and Demir 2006).

Photogrammetry is frequently used to document cultural heritages (Yakar et al. 2015). As the digital technology progresses, close range photogrammetry has become more efficient and a cost-effective method (Yılmaz et al. 2000). 3D models and texture mapping help us in detecting the complex structures. (Atkinson 1996).

Ensuring the measure of unattainable or dangerous structures and too high or too low buildings is another major advantage of close-range photogrammetry. Regarding the documentation, this data can be used in the future, shared with other users and easily stored in the computer environment (Arias et al. 2005; Berndt and Carlos 2000; Desmond et al. 2003; Guidi et al. 2004; Pieraccini et al. 2001; Yakar and Yılmaz 2008). Protection of cultural heritage and the factors creating this heritage is one of the primary duties of modern societies. However, this effort is very important not only for transferring it to the next generation but also for

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enlightening and educating people and for a better understanding of cultural heritage. The societies that know their cultural heritage well and understanding it, discovered the inner peace and have always been showing respect to public security understanding. For instance, according to the studies of European Council and UNESCO, the cities with low tendencies to commit crime and engaging in violence are the places where the cultural and historical architectural texture is very well preserved.

There are so many historical, cultural artefacts such as mosques and churches in the city of Aksaray, which was under Roman Empire, Seljuq Empire, several beylics and finally Ottoman rule throughout history. This study aims to determine the corrosion and degradation, deformation amount in other words, occurred in Çanlı Church in time, and considering the meteorological data, the causes of the corrosion was studied within the scope of this study.

1.1. Corrosion in Historical and Cultural Heritage

The word 'corrosion' that is used for structures means that any building wears out and loses material and mass over time, due to weather conditions and other factors affecting the structure. The change that happens in historical artifacts is considered as 'corrosion' Historical structures may change, due to the several reasons such as ground subsidence, floods, storms, by losing their authentic structural balance (Örmecioğlu 2010).

These changes are usually as follows:

- Chemical and physical decays and cracks occurred in structure's material in or out of building, that are called 'deformation'
- vertical and horizontal changes and that are called 'position change'

To determine the exact corrosion, the objects should be constantly monitored depending on the time. By monitoring just for once the amount of corrosion cannot be found. The measurement should be done periodically or in cases where special conditions occur in different times.

The regions and buildings in the world, are being affected by different factors that are temporary or permanent. These factors are as follows:

- Physical attributes of the ground,
- The current weight of the building,
- Kind of material used in the building,
- earth movements in the region,
- The factors such as traffic load, weather, and wind force etc. that affect the building,
- Dynamic pressure of the water.

1.2. *Aksaray Çanlı Church*

There are many historical and cultural heritage in Turkey as in the world. The city of Aksaray hosted several civilizations in its history.

There are plenty of historical and cultural heritage in Aksaray. One of the most significant of those is Çanlı Church. It is in the village of Akhisar about 3 miles northeast of the village center and around 10 miles from Aksaray city (Figure 1).

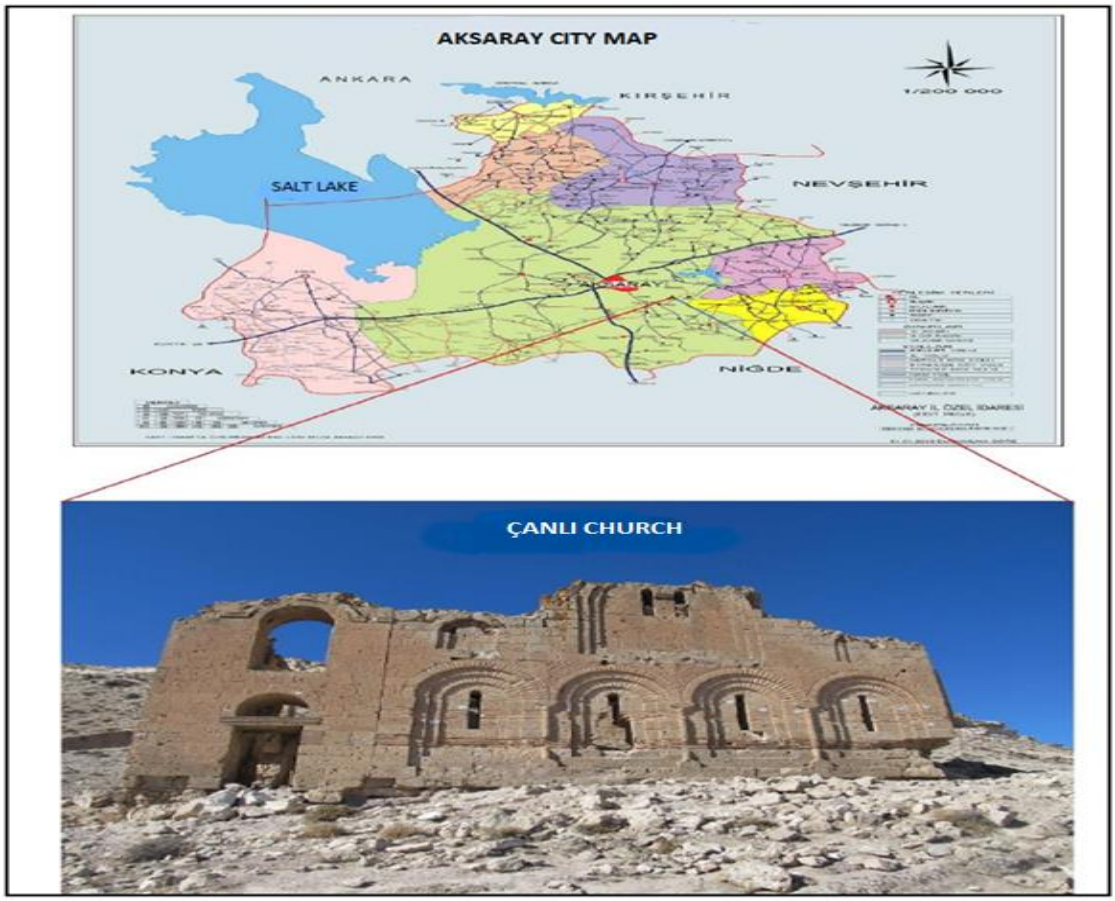

Figure 1. Çanlı Church and its location (Bozdoğan&Yılmaz 2019)

While Çanlı Church is famous for the mummies pulled from its ground, its environment is also known as a significant religious center. Çanlı Church is one of the perfect examples of Byzantine art. It is one of the places that remained intact in the region and reflect the Byzantine art in a best way. Çanlı Church and its environment are one of the most important areas that should be introduced into the tourism. However, it is still like a ruin. The area with various sized houses dating back to 10th-14th centuries and carved into the rocks in the church and its environment, look like a Byzantine town. However, since it has not been put under protection yet and it is far away from the centers and the church still gets the attention of the treasure hunters and thus the destruction is growing. The biggest lack in protection plan may be ignoring the buildings that are located at a far distance. Figure 2 represents a photograph of North-west facade of the church from a study conducted in 1981 (Yılmaz et al. 2007). According to this study, the state of the North-west facade for 2006 can be seen in Figure 3, for 2010 in Figure 4, for 2016 in Figure 5 and for 2019 in Figure 6. The east facade of the church was completely destroyed.

The bell, that the church was named after, could not be seen in the photograph, since it was stolen in ancient times. As seen in the picture, this historical building is about to be destroyed due to the neglect. In addition to the local people looking for treasure, it is also thought that weather conditions have destroyed the structure.

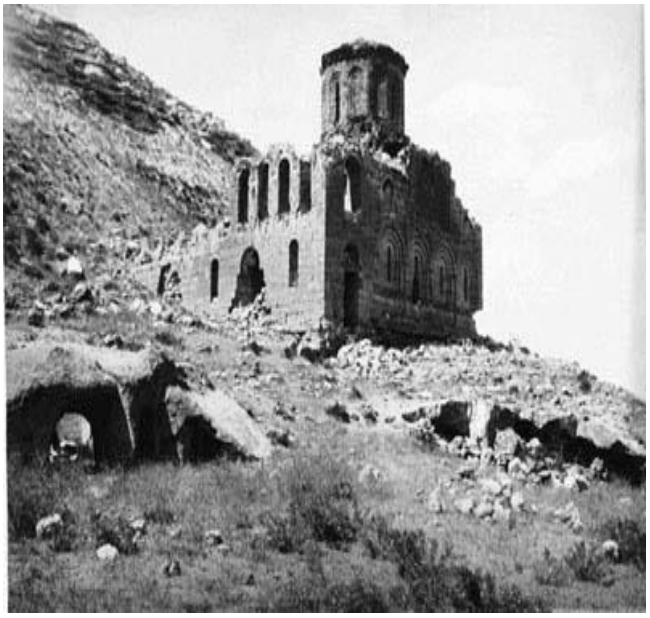

Figure 2. The situation of Çanlı Church in 1981

Figure 3. The situation of Çanlı Church in 2006 (Bozdoğan & Yılmaz 2019)

Figure 4. The situation of Çanlı Church in 2010 (Bozdoğan & Yılmaz 2019)

Figure 5. The situation of Çanlı Church in 2016 (Bozdoğan & Yılmaz 2019)

Figure 6. The situation of Çanlı Church in 2019

2. MATERIAL AND METHOD

A local network has been established in the site. The checkpoints have been marked on church and the coordinates of these points have measured by electronic telemeter and the coordinate was transformed in the system ITRF-96. Then the overlapping photographs of the church have been taken by using a calibrated digital camera.

The date obtained as a result of the measurements in the site, have been transferred to the PhotoModeler Scan Program. By performing photogrammetric evaluation, the facade drawings were made. This procedure has been repeated in 2006, 2010, 2016 and 2019.

The drawing of the north facade of Çanlı Church for 2006 is shown in Figure 7, the drawing for 2010 is shown in Figure 8, the drawing for 2016 is shown in Figure 9, and the drawing for 2019 is shown in Figure 10.

The drawing of the west facade of Çanlı Church for 2006 is shown in Figure 11, the drawing for 2010 is shown in Figure 12, the drawing for 2016 is shown in Figure 13, and the drawing for 2019 is shown in Figure 14. The drawing of the south facade of Çanlı Church for 2006 is shown in Figure 15, the drawing for 2010 is shown in Figure 16, the drawing for 2016 is shown in Figure 17, and the drawing for 2019 is shown in Figure 18.

On the north facade some corrosions indicated by N3, N4, N5, N6, N7 and N8 were found (Figure 10). On West facade the stones in the areas indicated by arrow marks W1, W2, W3, W4, W5 and W6 fell (Figure 12).

A serious deformation is seen in the parts indicated by S4 on the south facade and stone aggregates fell in the part numbered S5. In comparison with the 2006 measurement indicated by S1, S2 and S3, it was found that the stones fell (Figure 15).

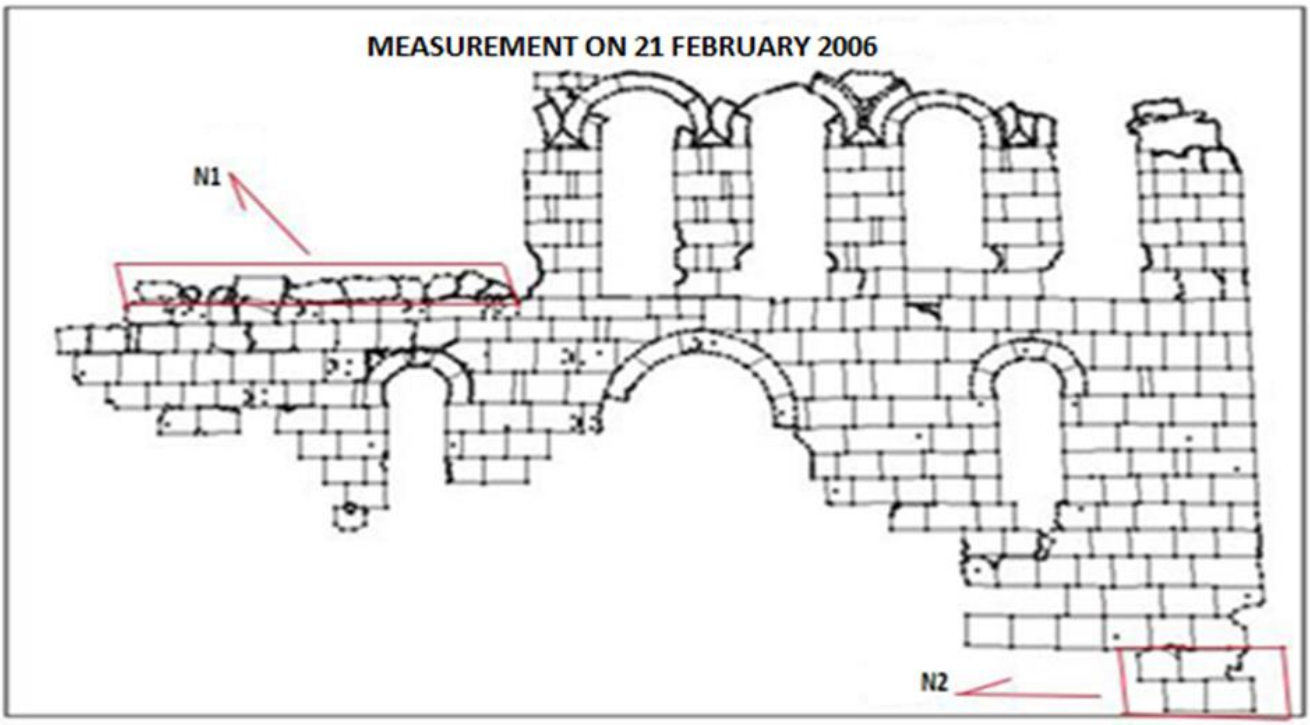

Figure 7. Measurement of Çanlı Church's north facade for 2006 (Bozdoğan & Yılmaz 2019)

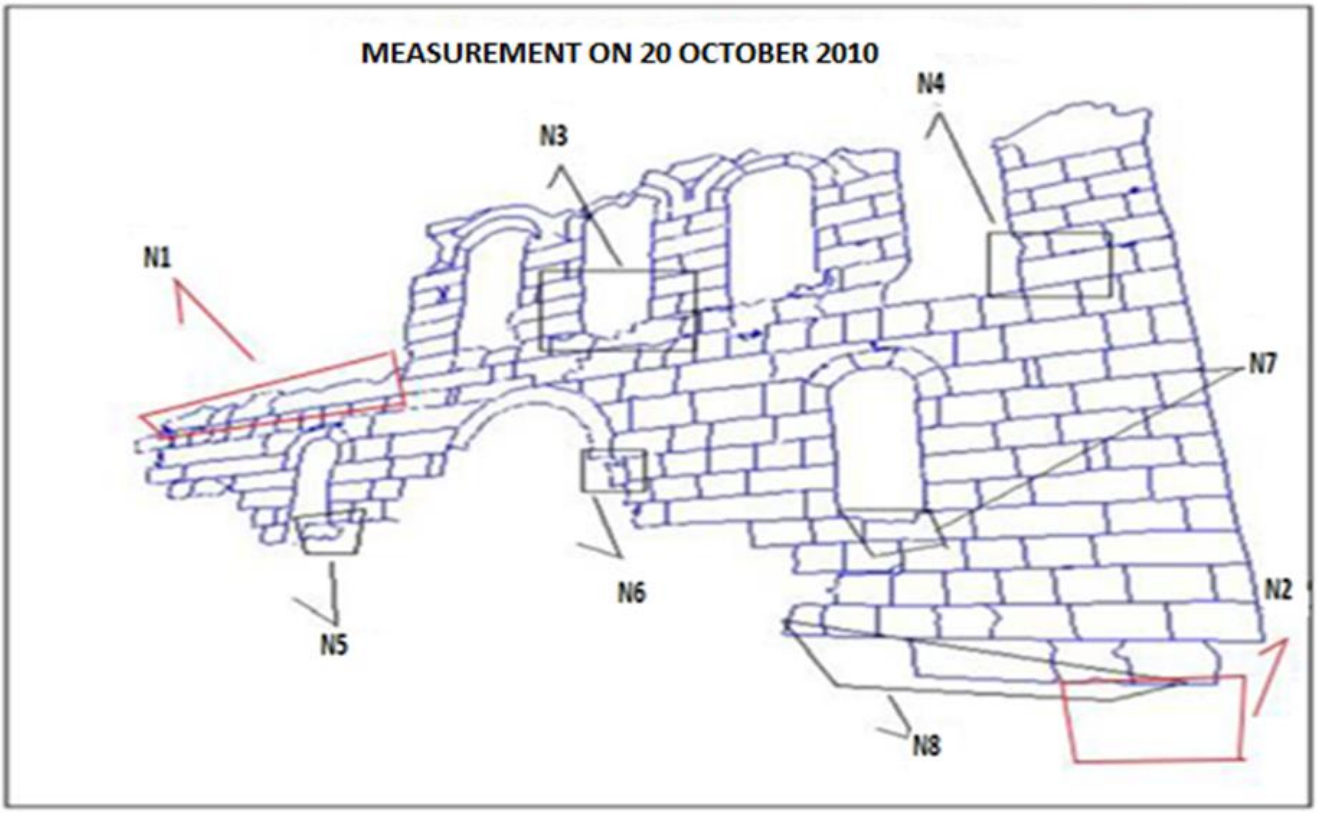

Figure 8. Measurement of Çanlı Church's north facade for 2010 (Bozdoğan & Yılmaz 2019)

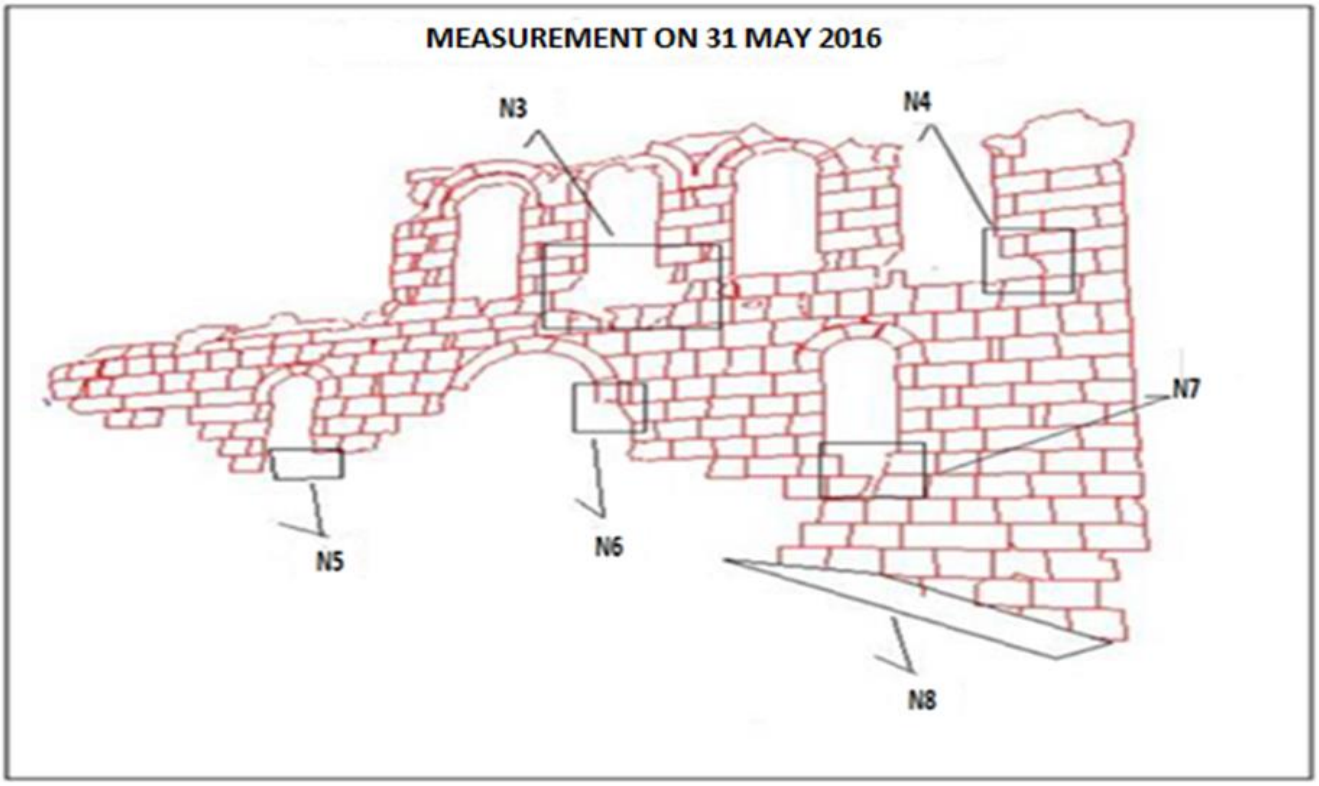

Figure 9. Measurement of Çanlı Church's north facade for 2016 (Bozdoğan & Yılmaz 2019)

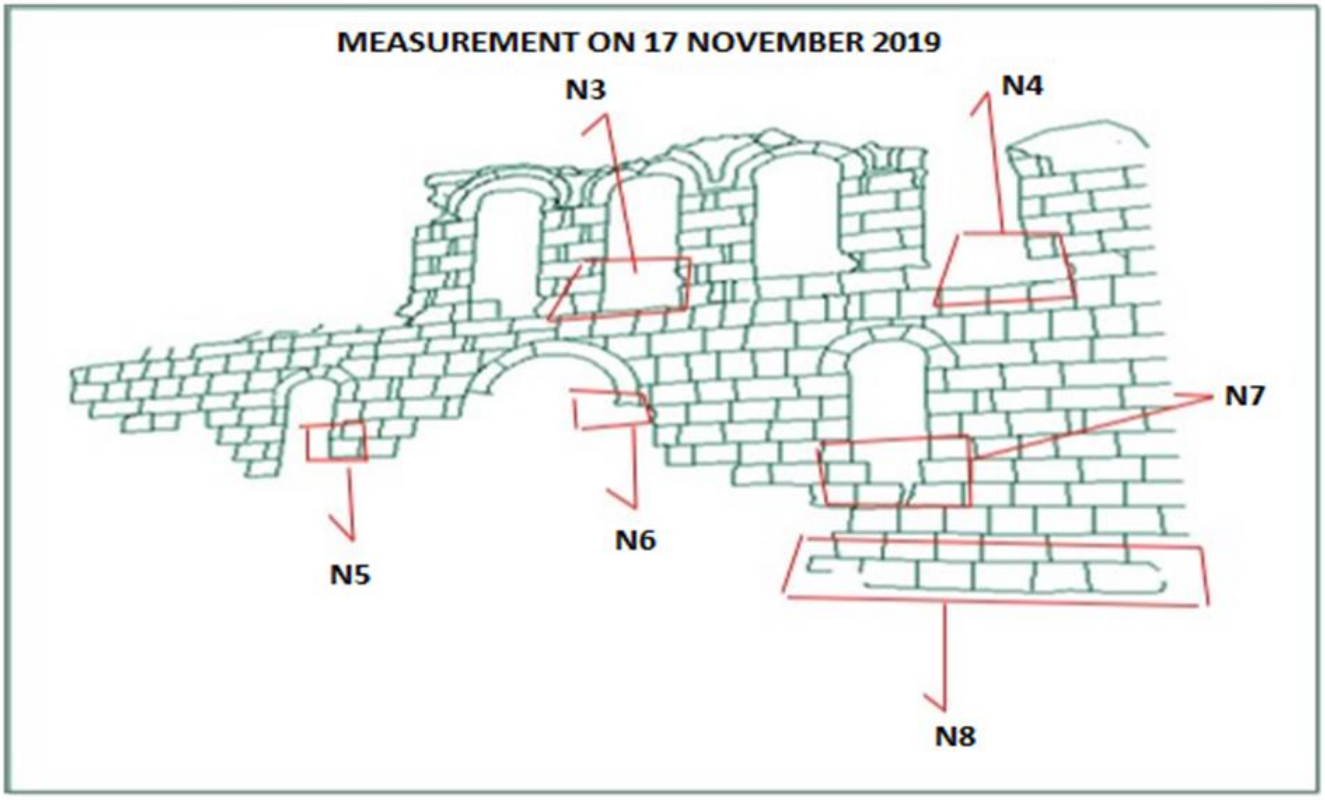

Figure 10. Measurement of Çanlı Church's north facade for 2019

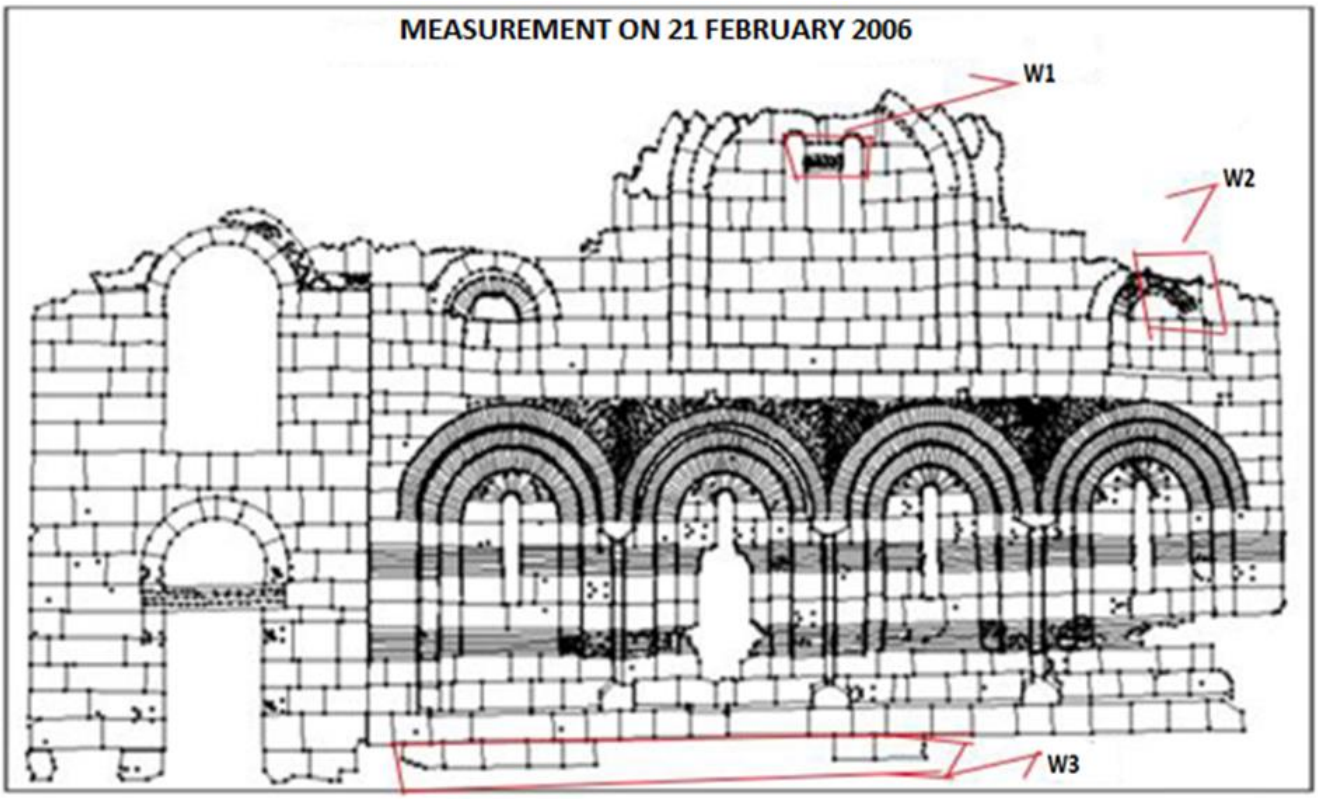

Figure 11. Measurement of Çanlı Church's west facade for 2006 (Bozdoğan & Yılmaz 2019)

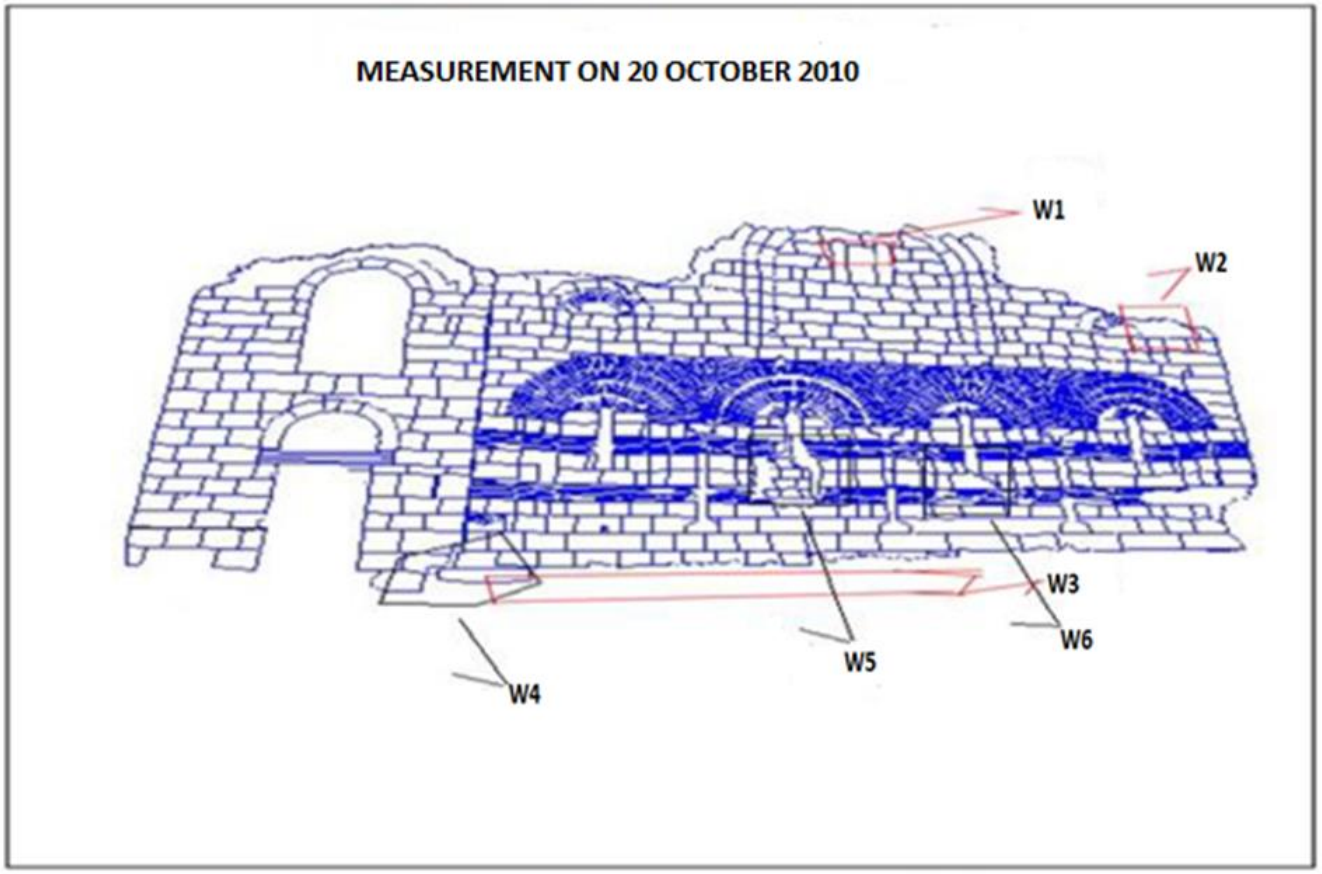

Figure 12. Measurement of Çanlı Church's west facade for 2010 (Bozdoğan & Yılmaz 2019)

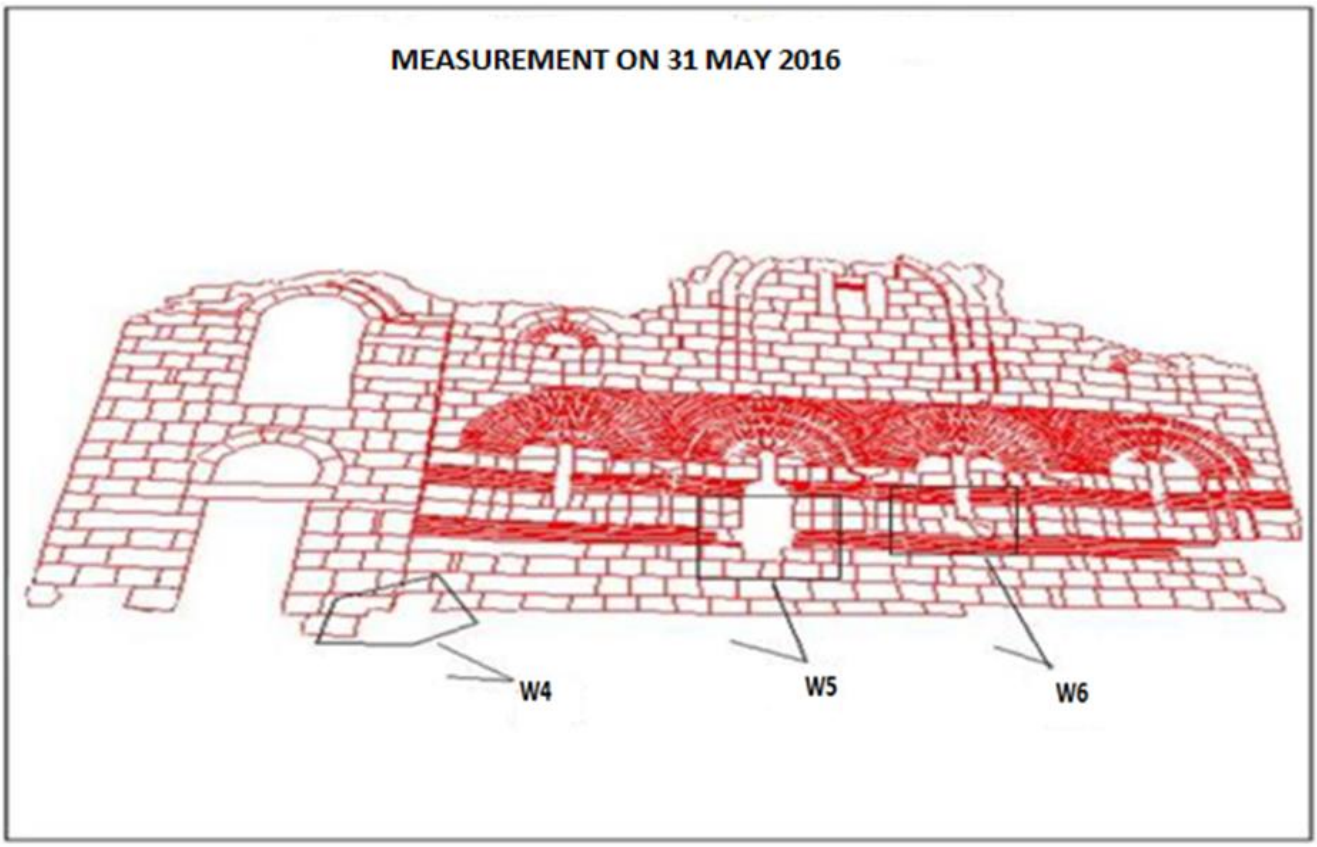

Figure 13. Measurement of Çanlı Church's west facade for 2016 (Bozdoğan & Yılmaz 2019)

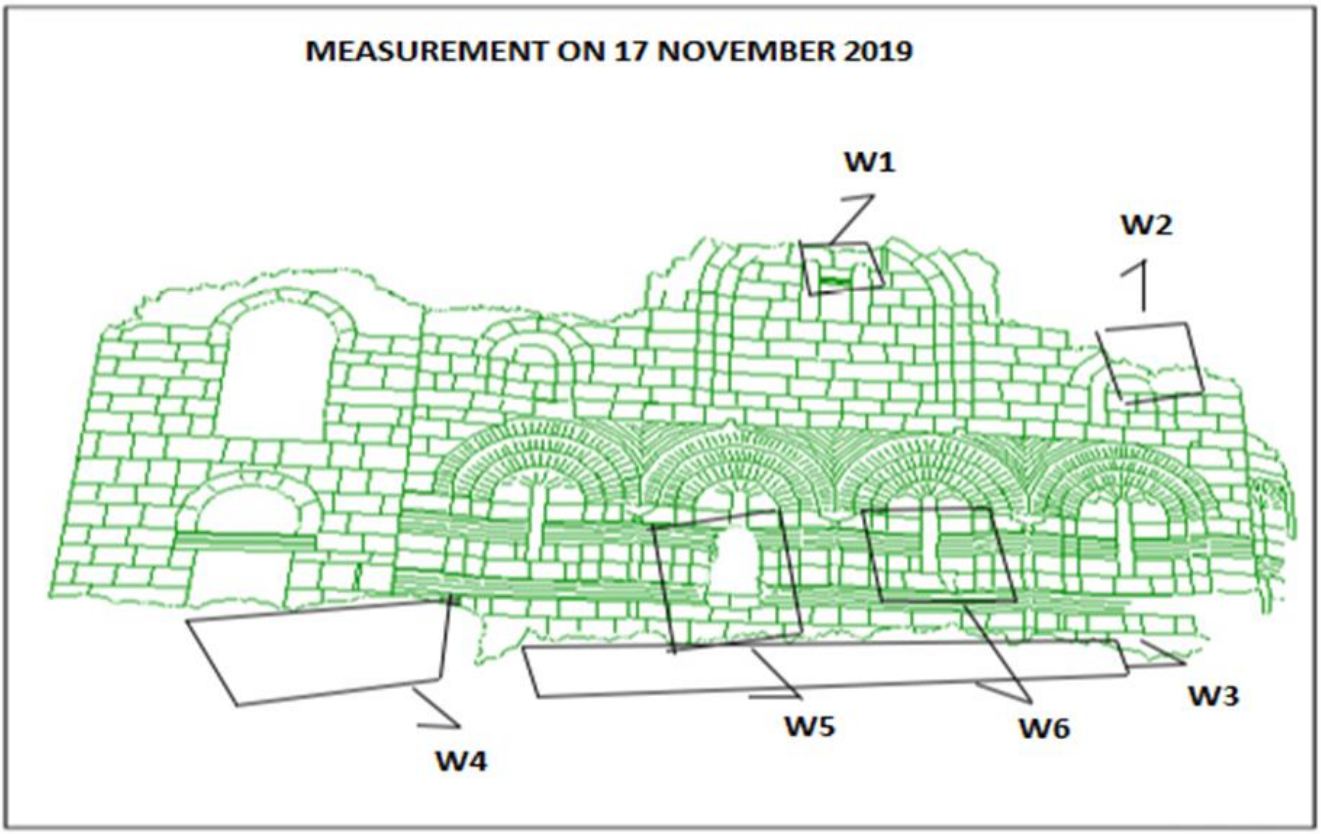

Figure 14. Measurement of Çanlı Church's west facade for 2019

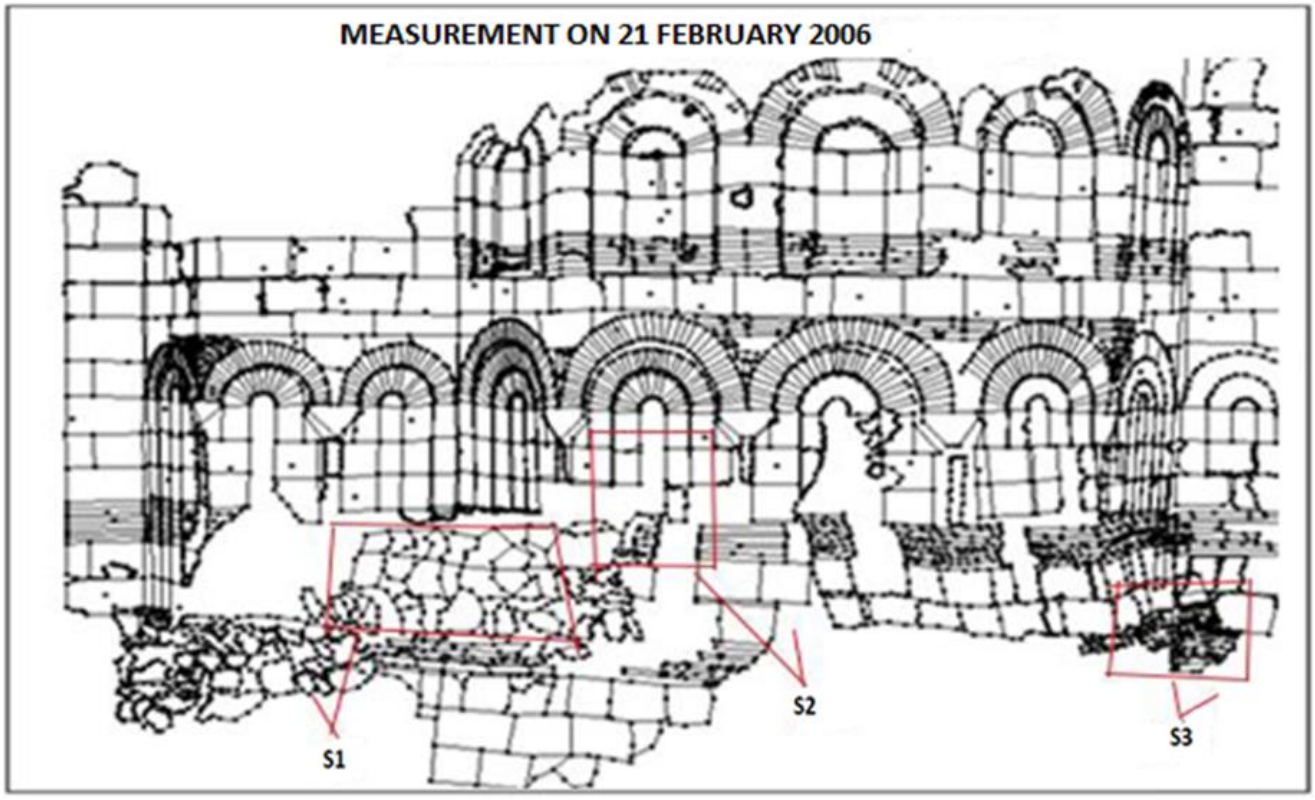

Figure 15. Measurement of Çanlı Church's south facade for 2006 (Bozdoğan & Yılmaz 2019)

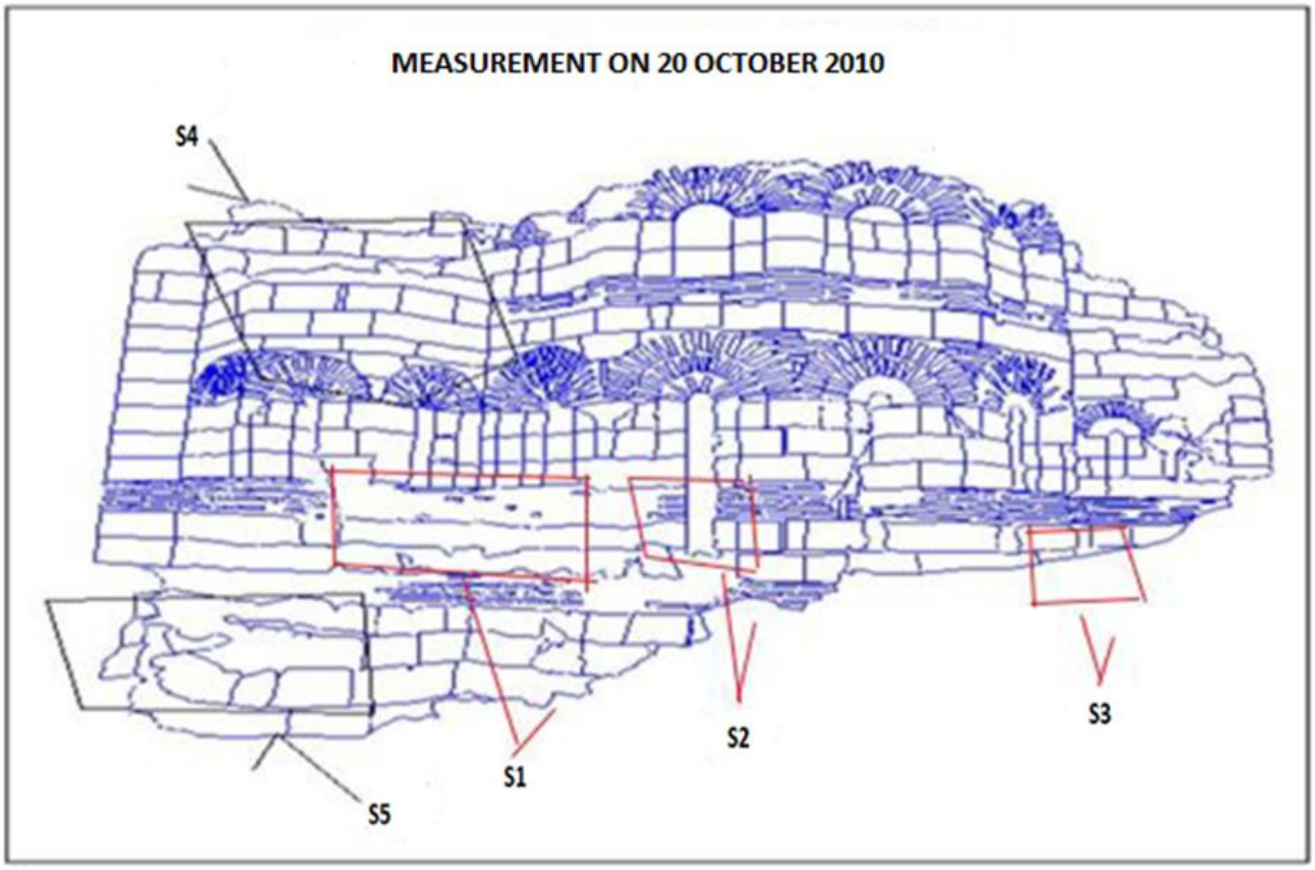

Figure 16. Measurement of Çanlı Church's south facade for 2010 (Bozdoğan & Yılmaz 2019)

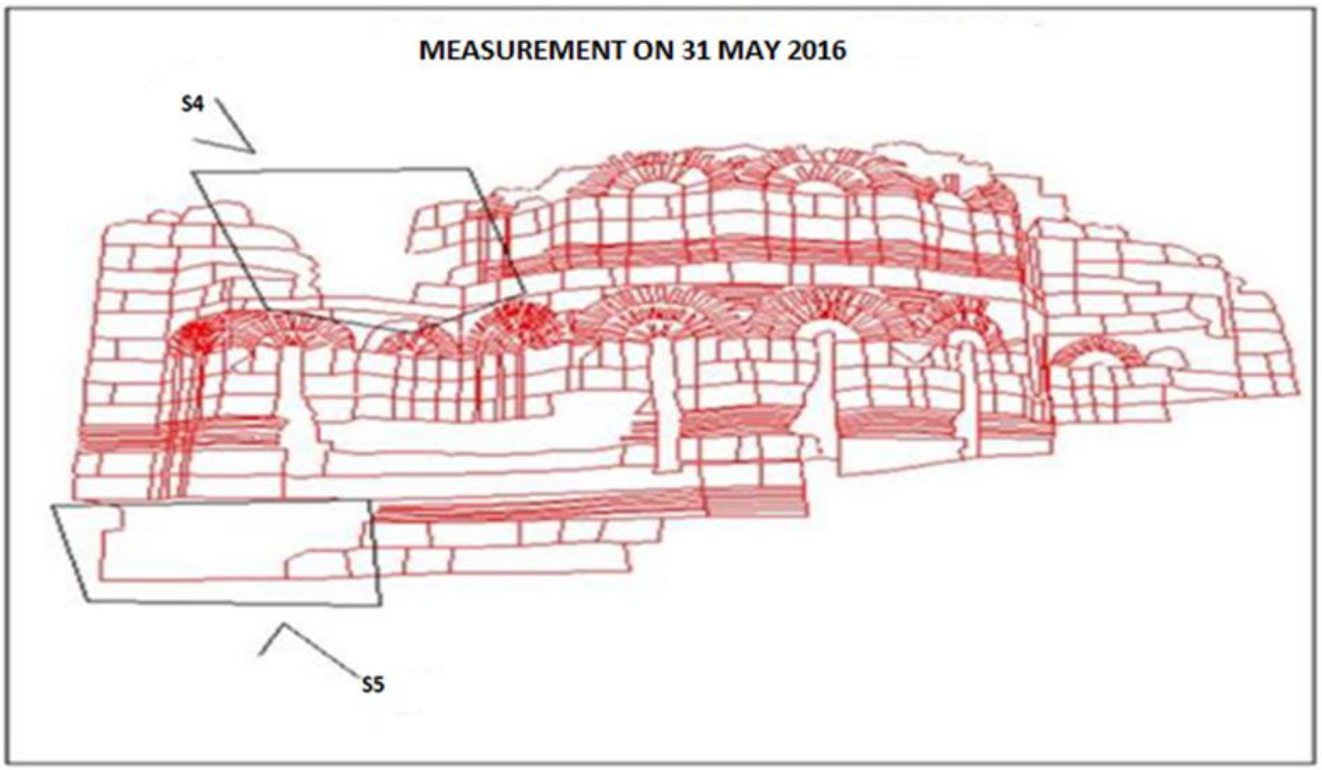

Figure 17. Measurement of Çanlı Church's south facade for 2016 (Bozdoğan & Yılmaz 2019)

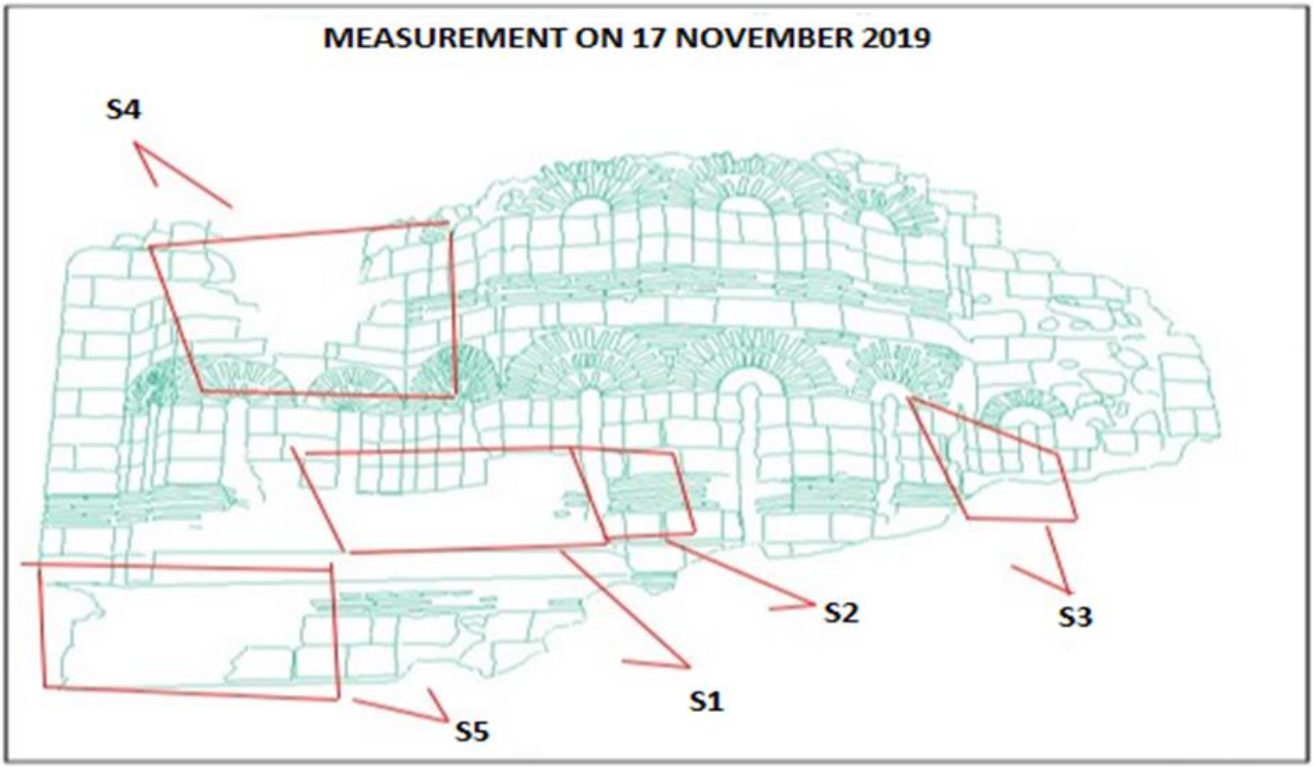

Figure 18. Measurement of Çanlı Church's south facade for 2019

2.1. Meteorological Data

In accordance with the data received from the General Directorate of Meteorology, it was researched what causes the changes occurred in the measurements at different times.

When the meteorological data examined, it was found that the monthly minimum pressure value (hPa) was at highest level (904.9 hPa) in October 2014 and at lowest level (880.1 hPa) in December 2010 (Figure 19).

It was observed that the monthly average temperature (°C) value was highest at 27.3 °C in August 2010 and lowest at -3.7 ° C in January 2008 (Figure 20).

It was seen that the monthly average relative humidity value was highest at 80.1 % in January 2012 and lowest at 27.2% in September 2017 (Figure 21).

When the monthly number of stormy days examined, it was seen that the storm was at highest level in March 2009 and in March 2013 and that it lasted 3 days. After the 7th month of 2018 no storm has been seen (Figure 22).

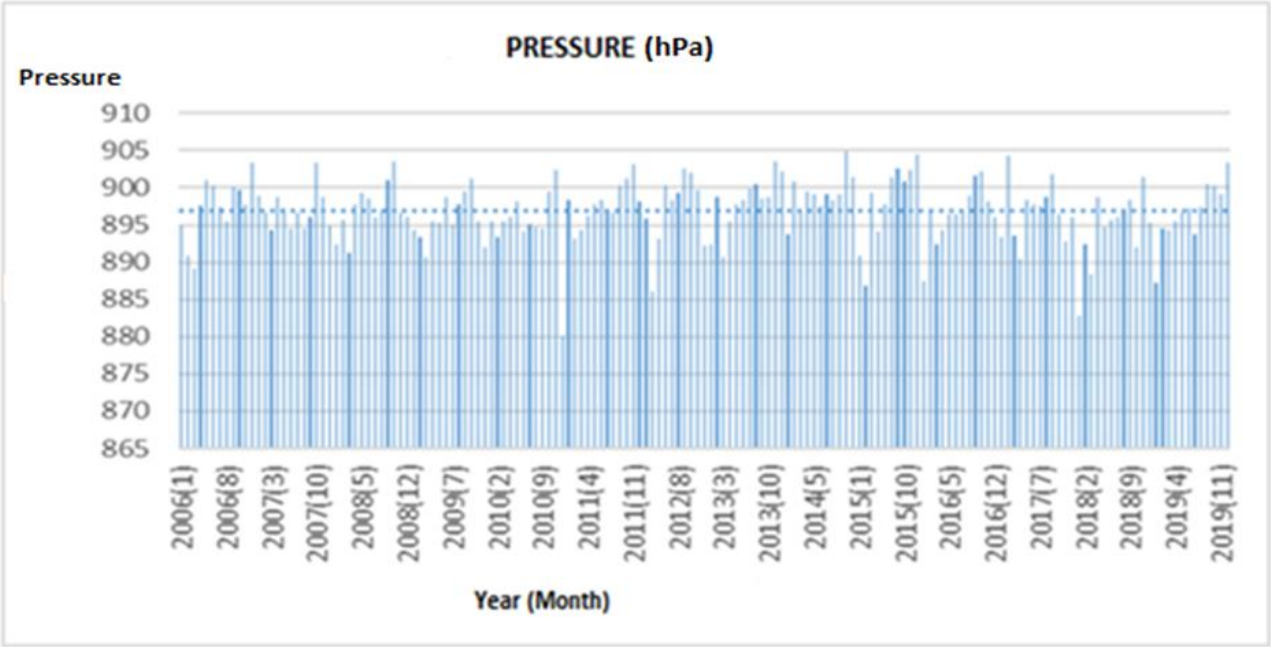

Figure 19. Monthly minimum pressure values

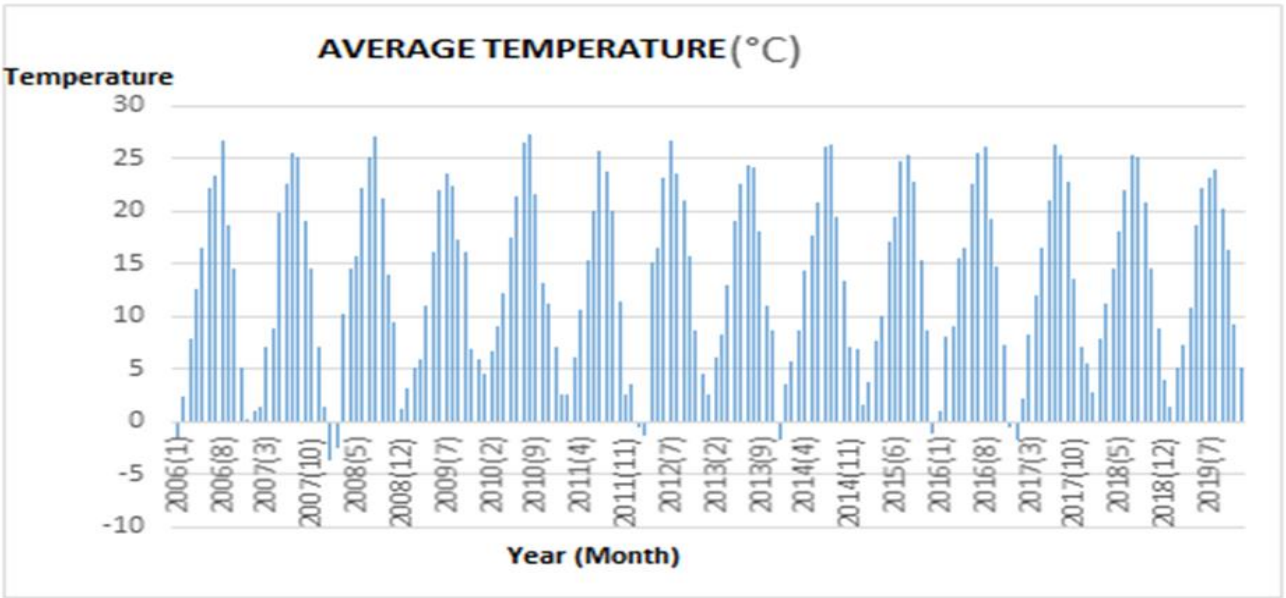

Figure 20. Monthly average temperature values

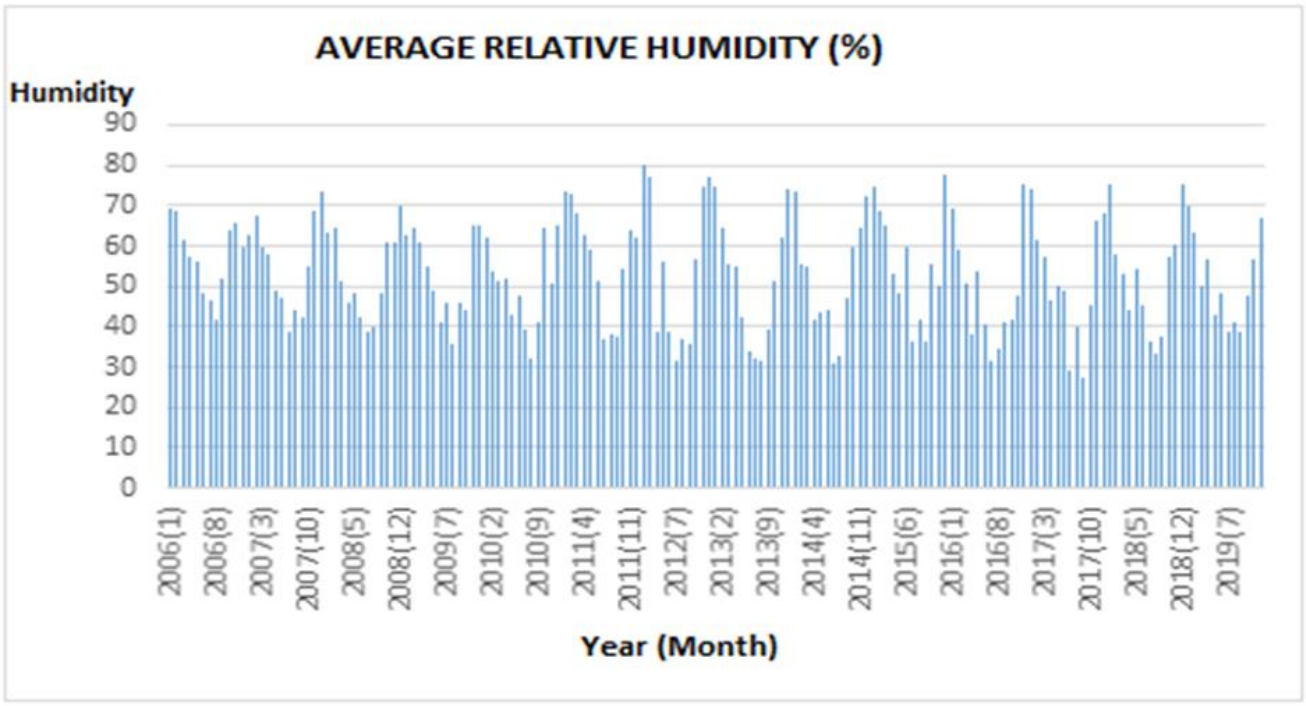

Figure 21. Monthly average relative humidity values

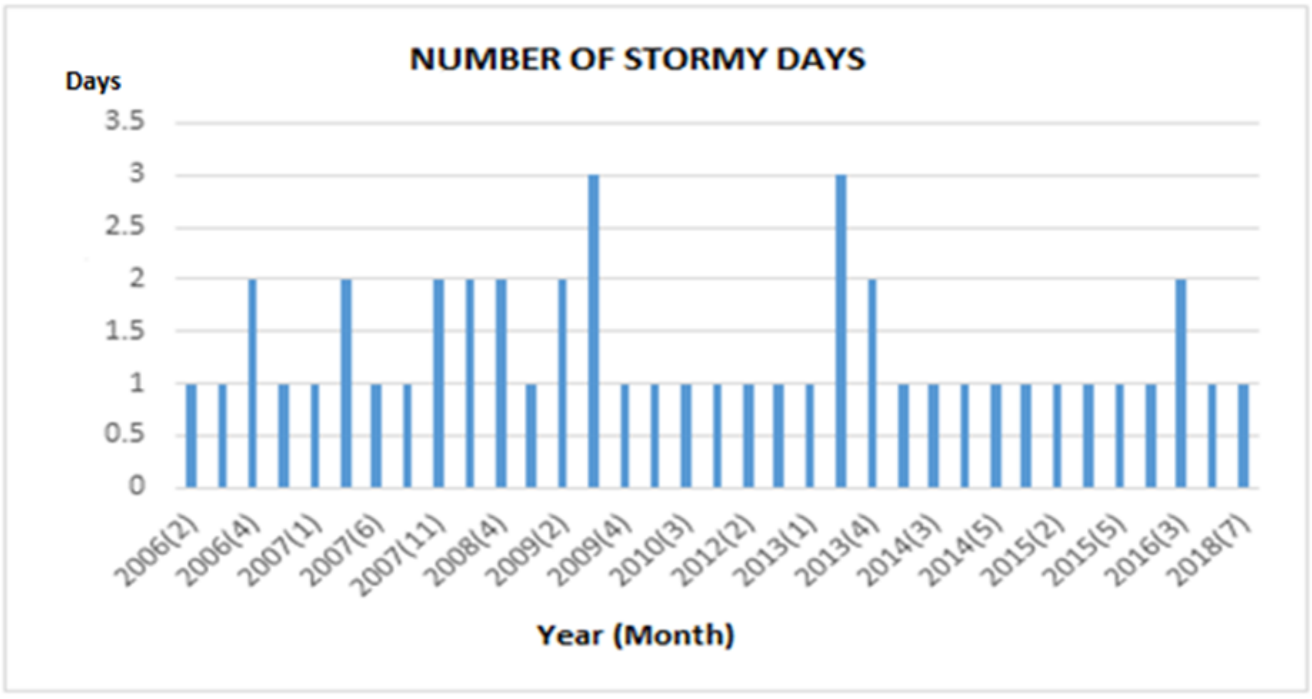

Figure 22. Monthly number of stormy days

When the monthly average snow-covered days examined, it was seen that it was at highest level in January 2017 with 25 days (Figure 23). When the snowy days are examined, it has been seen that the number of snowy days was at highest level in December 2016 and that it was at lowest level in March 2007, in March and April, 2008, in December 2009, in April 2011, in January and December, 2014, in May 2015, in February 2016 and in November 2018 were observed as the lowest number of days (Figure 24).

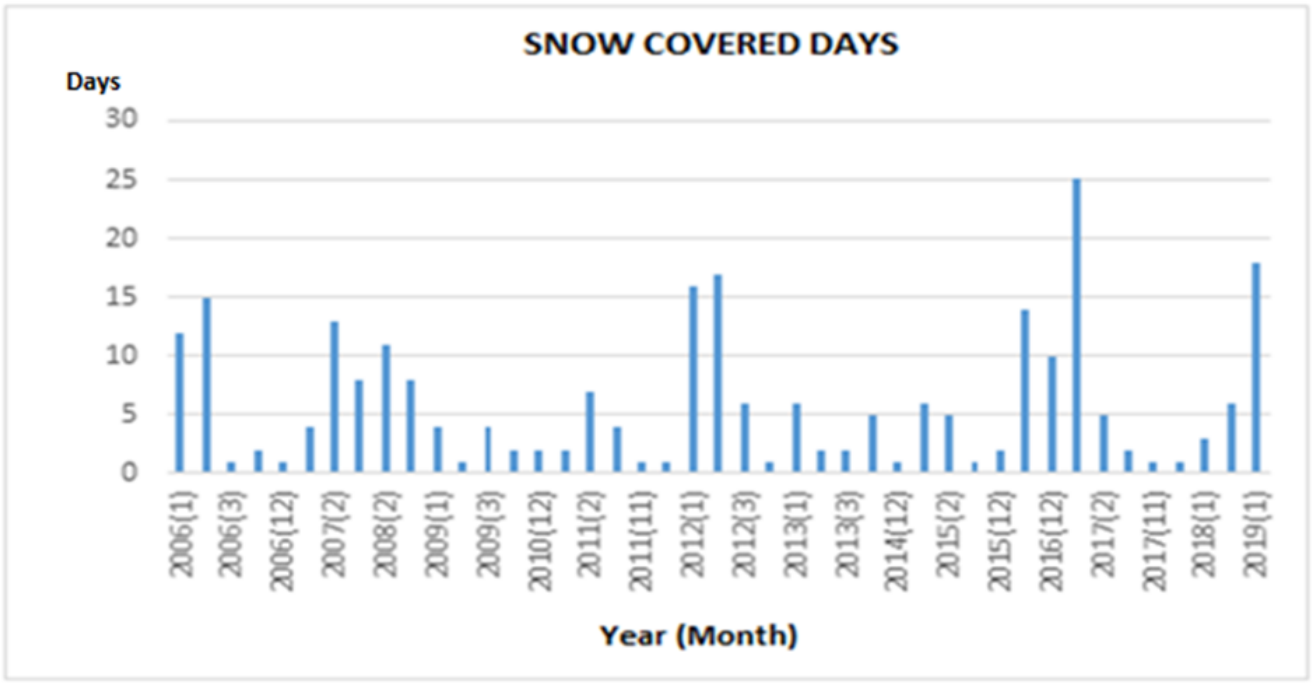

Figure 23. Monthly snow-covered days

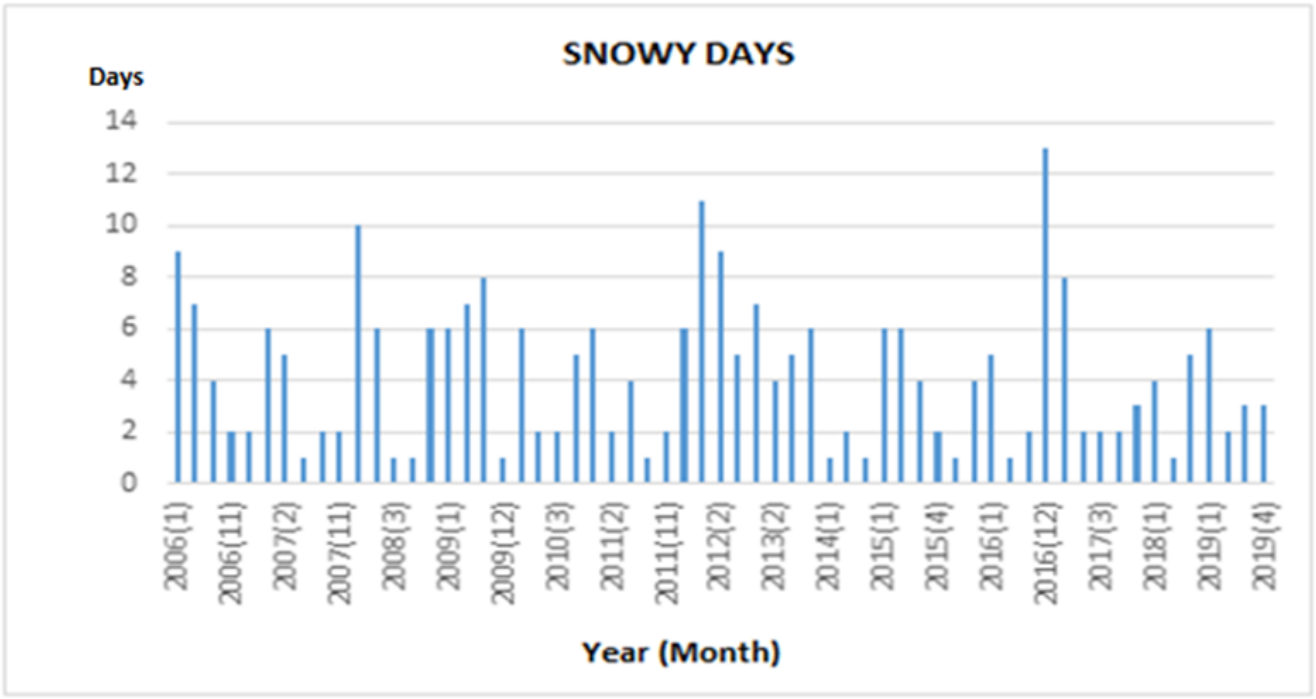

Figure 24. Monthly snowy day

When the monthly average wind speed (m Sec) is examined, it has been seen that it was at the highest level in July 2006 with 3.7 m/Sec and at lowest level in November and December 2019 with 1.2 m/Sec. (Figure 25). When monthly total precipitation (mm) was examined that it was at the highest level in June 2015 with 119 mm and at lowest level in July 2008, in August 2009, in July 2014, in July 2016 and in June and September 2017 with 0.0 mm (Figure 26).

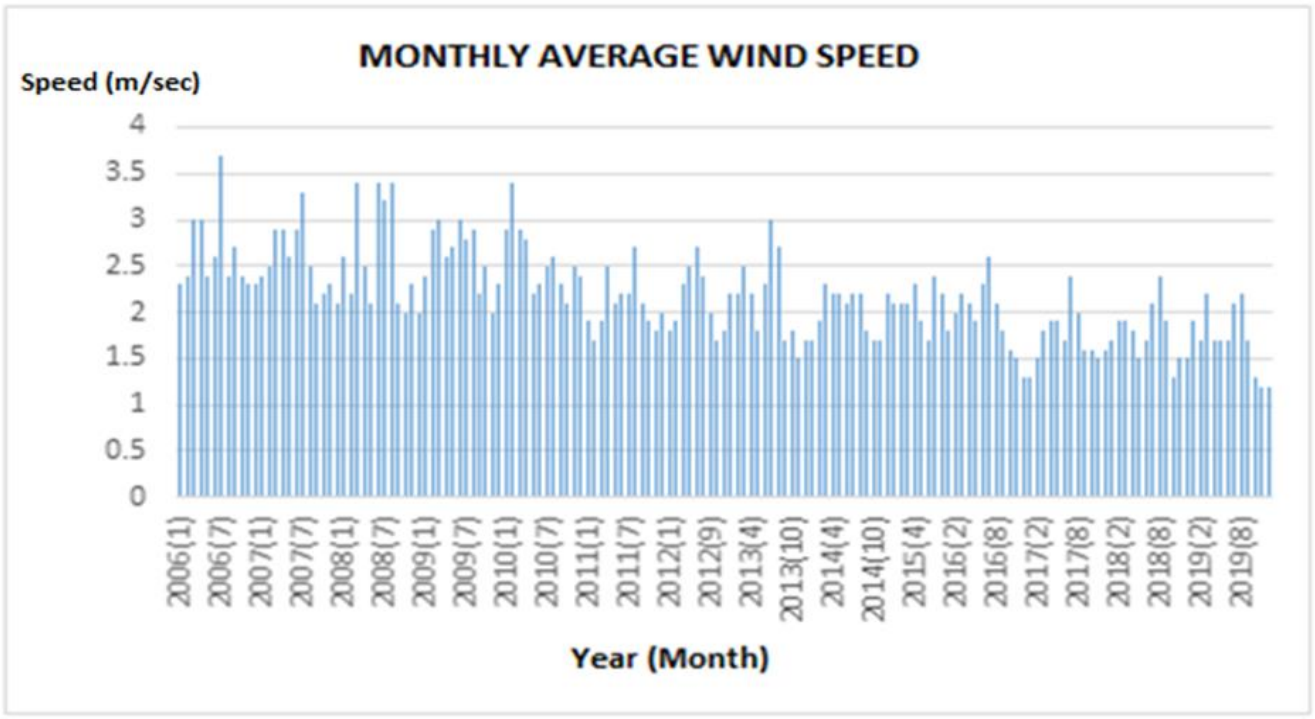

Figure 25. Monthly average wind speed (m/sec)

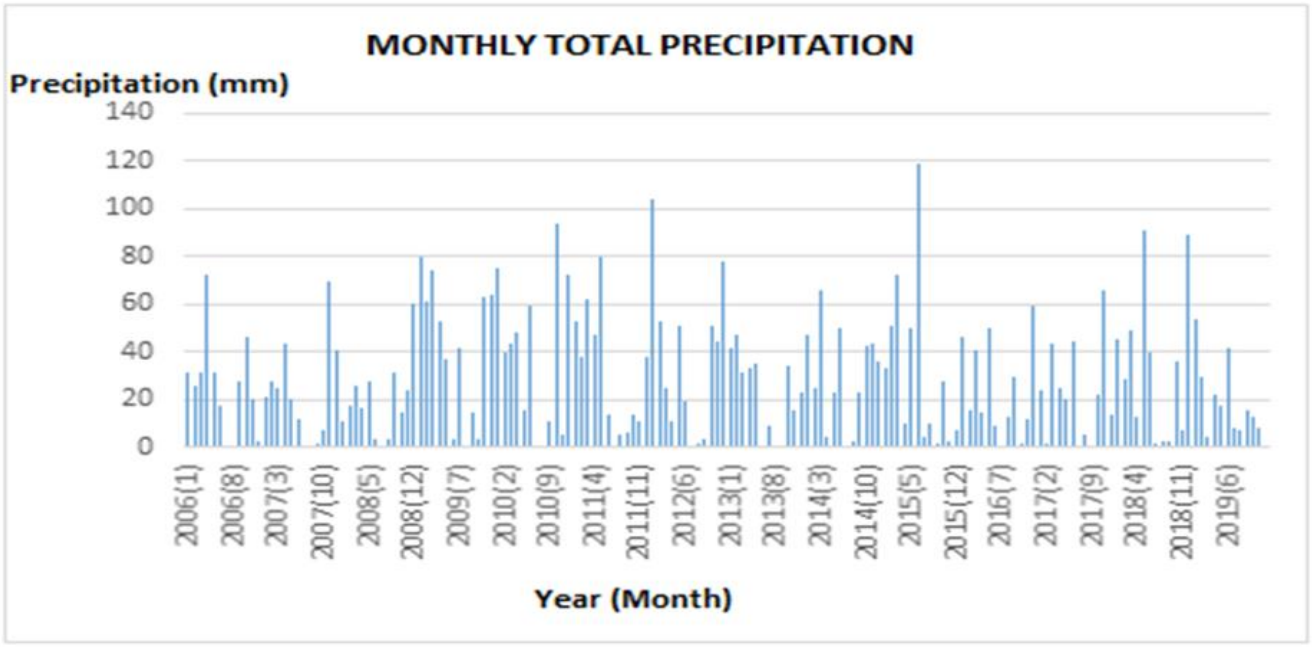

Figure 26. Monthly total precipitation (mm).

3. FINDINGS AND DISCUSSION

In this study, the corrosion occurred in Çanlı Church in Merkez district of the province Aksaray for 13 years, have been reviewed. In this context, the facade drawings obtained from the measurements made on February 21, 2006, October 20, 2010, May 31, 2016 and November 17, 2019 were compared to each other and the corrosion in the church was associated with the data of meteorological events occurred between the dates. On the North facade of the church 6 serious corrosion have been found. It has been seen that the stones fell in three areas on the west facade. On the south facade one serious corrosion has been seen and stone aggregates fell in one place. The corrosion values are seen on Table 1.

Table 1. The corrosion occurred in facades of Çanlı Church

	North	West	South
Area (m^2)	4.251.891	3.860.913	7.629.097
Eroded Area (m^2)	3.911.740	3.745.086	6.637.314
Eroded Rate (%)	8	3	13

When Table 1 was examined, the north facade area was calculated as 4.251.891,00 m^2, the west facade area was 3.860.913,00 m^2 and the south facade area was 7.629.097,00 m^2, in the studies conducted in 2006 and in comparison, with the areas in 2019, it is seen that the highest corrosion is on the South facade with 13%.

When the meteorological data is examined, it is seen that the year 2009 is the stormiest time in the last ten years. It is thought that the corrosion occurred in the church was mostly caused by storm. The storm generally occurred in the north-south direction. That is the why the most eroded facade in the church is the south facade. The falling parts have been toppled towards the inside.

Rainfall, that normally ranged from 2.5 to 72.8 mm in 2006, reached 119 mm by mid-2015. It is believed that this soakage will cause dissolution in the structure. When combined with the heavy storm in 2009, corrosion occurred in the church.

It was found that the snow was not much above average and it has been noted that it did not have any effect on corrosion.

The monthly average wind speed rose to the highest value between 2006-2019 and it is believed that the heavy winds occurred after rain was effective in corrosion.

In addition, when the number of stones for each facade is examined, it has been observed that there has been a serious decrease in the number of stones over the years. The number of stones present in the facades during the years of the study is also given in Table 2.

Table 2. The number of stones on the facades for different years

	North	South	West
2006	331	438	522
2010	320	425	511
2016	305	390	497
2019	295	382	492

4.RESULTS

In this study, the corrosion in the Çanlı Church located in Akhisar village of the province Aksaray and the reasons of corrosion were examined. By using close range photogrammetry method, three-dimension models and facade charts of three facades of Çanlı Church have been acquired, as a result of measurements done in four different times.

Overlapping all these charts in the same scale, the corrosions occurred on the facades of Çanlı Church have been determined.

While the north facade area was 4.251.891,00 m^2, it decreased to 3.911.740,00 m2 and that indicates 8 % corrosion. The West facade area was 3.860.913,00 m^2, it decreased to 3.745.086,00 m^2 and that indicates a 3 % corrosion. The south facade area was 7.629.097,00 m2, it decreased to 6.637.314,00 m2 and that indicates a 13 % corrosion.

In addition, it has been determined that there has been much stone loss and deformation on the facades over the years.

The meteorological data within the period when the measurements were performed were reviewed and it has been concluded that the storm was more effective on corrosion and deformation.

It is crucial to emphasize one more time; as long as the cultural heritages, the common value of humanity, are ignored, they are destined to perish over time.

Author contribution

Ömer Bozdoğan: Field work, Software, Investigation, Data acquisition, writing; **Aydan Yaman**: Field work, Software, Analysis, Writing-Orginal draft preparation; **Hacı Murat Yılmaz**: Metodology, Reviewing and Editing

Conflicts of interest

The authors declare no conflicts of interest.

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