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Research Article

DETERMINATION OF BUILDING MATERIALS WITH IR-THERMOGRAPHY IN HISTORICAL BUILDINGS

Avdan, U.,[1*] Kaplan O[2] and Kaplan G[3]

[1]Anadolu University, Earth and Space Sciences Institute, Eskisehir, Turkey (uavdan@anadolu.edu.tr)

[2] Anadolu University, Earth and Space Sciences Institute, Eskisehir, Turkey (onur_kaplan@anadolu.edu.tr)

[3] Anadolu University, Earth and Space Sciences Institute, Eskisehir, Turkey (g_jovanovska@anadolu.edu.tr)

ORCID ID 0000-0001-7873-9874; ORCID ID 0000-0002-0759-621X; ORCID ID 0000-0001-7522-9924

*Corresponding Author, Received: 18/01/2018, Accepted: 06/03/2018

ABSTRACT: Lately, IR thermography is frequently applied for important purposes in monitoring buildings such as energy leaking, ventilating and air-conditioning installations, electrical and mechanical installations, moisture detection etc. Nondestructive monitoring methods are essential in case of monitoring historical buildings. It is curtail not to destruct any part of the buildings, which are historically important. Therefore, nondestructive methods need to be used while monitoring this kind of buildings. In this study, IR-Thermography was used in order to distinguish different construction materials that were used to build the walls of a historical building. The thermal monitoring was made with Optris PI-450 long wave infrared camera. The results showed that IR monitoring can be useful to distinguish the building materials without destroying the investigated buildings' plaster or facing. It is observed that the best results can be achieved on higher temperatures at IR-Thermography.

Keywords: *Remote Sensing, Building Materials, IR-thermography, Historical Buildings.*

1. INTRODUCTION

The role of remote sensing for historical structures is becoming more and more crucial role in the documentation and restoration process. Many papers can be found on this topic using different remote sensing instruments such as lidar technology (Raimondi, Weibring et al. 1998), unmanned aerial vehicle (Ulvi and Toprak 2016), thermal imaging, etc. Although the infrared light was discovered by William Hershel around 1800, the first imaging instruments were built in the late 1940s and 1950s, built for the American military for night vision (Kaplan 2007). All matter radiates energy at thermal IR wavelengths (3 to 15 µm) both day and night. The ability to detect and record this thermal radiation as images have obvious reconnaissance application. Thermal IR images generally record broad spectral bands, typically 8.0 to 14.0 µm for images from satellites (Sabins 2007). The thermal camera technology can be used as a nondestructive diagnostic technique used in different applications (Malone, Celeste et al. 2005, Pascucci, Bassani et al. 2008). The advantage of thermal imagery to detect the temperature can be of great use in many application and study areas. It is being widely used in the monitoring of animals (Jerem, Herborn et al. 2015, Zheng, Zhu et al. 2016), agriculture (Vadivambal and Jayas 2011), industrial applications, gas detection (Lewis, Yuen et al. 2003), fire detection and military, detection and tracking of humans (Ma, Wu et al. 2016), medical analysis (Jones 1998, Jones and Plassmann 2002), building inspection, and etc. Thermal cameras have been used for years for inspecting heat loss from buildings (Gade and Moeslund 2014). Besides heat loss detection, thermal imaging has been used to detect problems behind the surface and for some ancient buildings, it is of interest to monitor wall's hidden structure that can be done with thermal camera (Grinzato, Bison et al. 2002). The building inspection monitoring has to be conducted with nondestructive methods in historical buildings.

In this paper, an attempt for material classification and material characterization of a historical building has been made. The exterior walls of the building were considered/presumed to be made of stone. The camera used in this paper, Optris PI-450 has a spectral range from 7.5 to 13.5 µm, temperature range -20 to 900 °C/ 200 to 1500 °C, and typical applications, real-time thermographic images in high speed and detection of smallest temperature differences (OptrisInfraredThermometars).

IR thermal monitoring, as a nondestructive monitoring method, especially for historical building it is of great importance. The main purpose of this study was to observe the inner walls of the building. For this purpose, thermal imaging method was used. Within the scope of the study also the exterior walls were observed of The Republic Historical Museum in Eskisehir Turkey in property of Anadolu University and since the results did not fit with the observation discussed in (Nalçakan 1995), the exterior walls also required attention, and the measurements and result are discussed in this paper. The results were compared with building with similar characteristics. Afterwards, an unsupervised classification of the thermal images has been made in order to separate the materials. The results from this study were found to be very useful for the construction work planned in the museum.

2. STUDY AREA

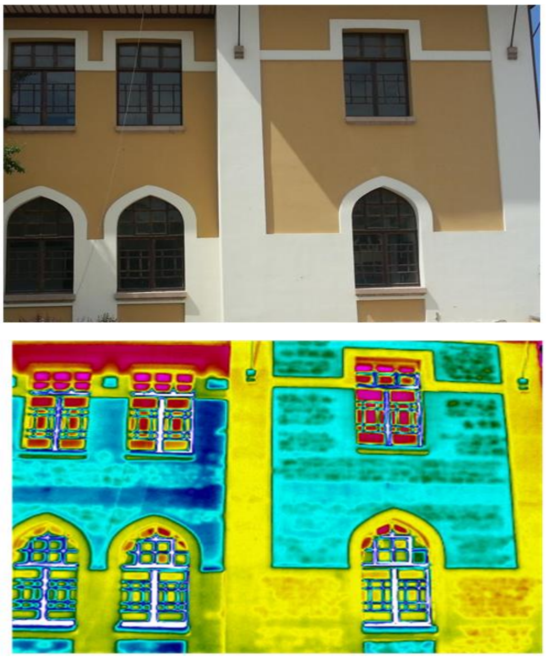
The building studied in this paper, The Republic Historical Museum in Eskisehir Turkey is located in the historical part of Eskisehir, Odunpazari in Turkey. The building has been opened in 1916 and it was first used as a school (Nalçakan 1995). From 1916 until today, it has been used for different purposes. After long years it has been also used as a Directorate of Public Works, Treasury, and girls High School. In 1955, the Ministry of National Defense gave the building for use to the Regional Command and after it was used as a Military Service Branch. In 1980 it was registered as Ancient Artifact. After not being used for a long period, in 1989 the building has been given to Anadolu University to be used as a Republic Historical Museum (Nalçakan 1995). After restoration, the museum has been open for a visit since 23 April 1994 (www.anadolu.edu.tr 2016). Nowadays, the museum is closed due to maintenance.

The building has a basement, ground floor, and first floor, making a three-floors construction. The height of the basement is 3 meters, the ground floor 4.70 meters, and the first floor 4.50 meters. The buildings` first structural system was masonry. The external walls were made of cut stone, the interior walls were lath-and-plaster, slabs, stairs, ceiling, and doors were timber work and the entrance part of the building was floor arch (Nalçakan 1995). Later in the years' unknown reconstruction has been made and most of the materials used in the building remained unknown until today (Figure 1).

Figure 1. Republic Historical Museum – Eskisehir (source: https://www.anadolu.edu.tr/kampuste-yasam/muze-ve-sanat-merkezleri/cumhuriyet-muzesi)

3. METHODS

It is not possible and feasible to remove plaster in historical buildings, except in certain special circumstances. For this purpose, thermal imaging was done at different temperatures inside and outside the museum and at different dates. Optris PI 450 thermal imager was used for measurements made during the study (Figure 2). The temperature range of the camera is between -20°C and 1500°C and the optical resolution is 382x288 pixels (OptrisInfraredThermometars). Once measurements were made, Optris PI Connect software was used to analyze the images. The building was monitored every month from January until May in order to investigate the influences of different weather conditions. Inside the museum, observations were made in January; it has been seen that it is difficult to distinguish different building materials such as concrete and stone because of the cold environment.



When the building materials were heated with heaters, the differences between the materials in the

Figure 2. Visible and thermal image of the same scene of the inspected building

images became clear. Since the air temperature is higher in May, the heater was not used because it was possible to observe the difference between the materials. During the monitoring with the thermal camera, the temperature inside and outside of the building was measured. Of the different thermal conductivity of the brick, stone and concrete materials, they were distinguished very clearly by the IR thermography method. In thermal records, interior walls' material was slightly different from surrounding concrete frame as seen in Figure 3.

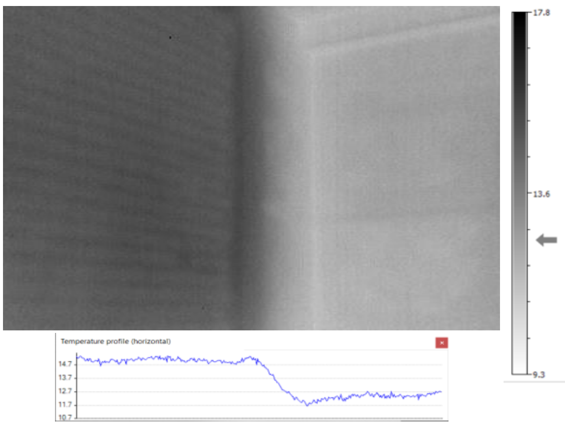


Figure 3. Thermal difference between the interior brick wall (left) and exterior stone wall (right).

The interior walls were observed with a thermal camera and the wall material was predicted to be brick due to the formation of the blocks and pointing stuff. For confirmation of the prediction, plaster was removed on several walls and it was seen that the inner walls have been constructed with brick blocks.

The exterior walls were observed from the inside and from the outside, according to records related to the building (Nalçakan 1995), the exterior walls were known as cut stone walls. Through thermal imaging, it was determined that these walls were built not only by stone walls but also by traditional brick-beamed stone wall type (brick beams are embedded in the stone wall to strengthen it). This information was confirmed by locally removing plaster on certain places (Figure 4).

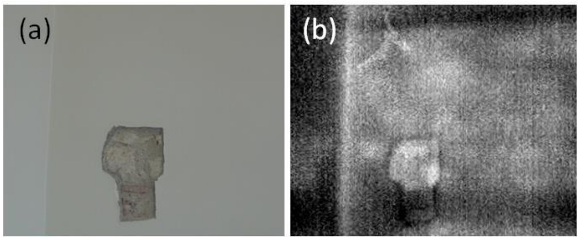


Figure 4. Thermal difference between brick and stone; a) Visible and b) thermal image of the same scene

As an additional control, only 50-meter distance of the Historical Museum, a building – Tiryakizade mosque with the similar building characteristics (stone wall with hacking – traditional Turkish style of construction) was observed and the results were compared.

Unsupervised classification using K-means method with four classes was used for separating the materials, mainly stone and brick from each other.

4. RESULTS AND DISCUSSION

In the study, it has been investigated whether it is possible to use thermal camera images to determine wall materials without plaster or coating removal. At the end of the study, thermal imaging showed that the best results at higher temperatures. The use of the heater in the measurements that were made in the building at low temperatures affects the results positively.

According to the results of the made observations, different materials were seen to have different temperatures despite thick plaster layer. As the exterior walls were observed from the inside and from the outside, different building materials can be seen clearly in the façades that are warmed by the sun (Figure 5).

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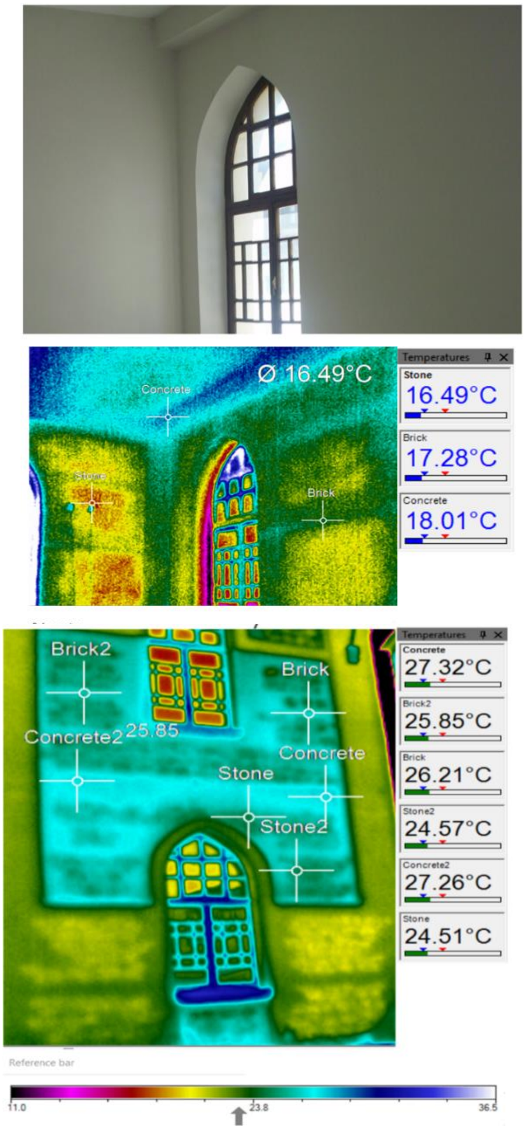

Figure 5. Visible and thermal images from the exterior walls observed from inside the building

The brick temperature was found to be about 1° C colder than the concrete. The temperature of the stone was determined to be around 24.5° C, or 2° C colder than the brick. In the inspections made from inside it was seen that the concrete is the warmest and the stone is the coldest. The thermography method has shown that the locations of different building materials such as stone, brick, concrete can be determined without damaging historical buildings. The results from the exterior walls measured from outside show more clearly the differences of the materials (Figure 6).

The results from the observation made on the exterior walls on the mosque showed the same difference between Figure 6. Temperature difference between concrete, stone and brick

The stone and the bricks of 2°C which shows that the plaster does not affect the observation made over the museum.

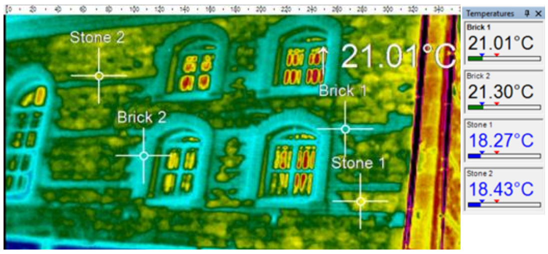

Figure 7. Tiryakizade Mosque Thermal Observations

After observing the results from the measurements it has been concluded that exterior wall has been made in a Turkish traditional ` brick-beamed stone wall ` style as seen in Figure 6 and 7. The results from this study are important for the observed building since until now it assumed that the external walls were made only from stone.

The result from the unsupervised classification were helpful in determining the stone and brick area. The classification was made according to the observed temperature. The results from the unsupervised classification are presented in Figure 7.

Figure 8. Results from the classification

The results obtained in the study demonstrates that the thermography method gives good results in determining building material differences without destroying plaster-covered surfaces. These results reveal that the thermography method is a useful method for the preservation and documentation of our historical and cultural assets.
The results from this study are important for the observed building since until now it assumed that the external walls were made only from stone.

5. CONCLUSION

It was concluded that thermal camera can be used for monitoring historical buildings without destroying the building. In this paper, the results showed that the interior walls of the building were made out of brick. Also, the results showed that the exterior walls of the building were made not only from masonry stone as it was considered, but also from bricks constructed in a Turkish traditional style.

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