Chapter 5
IRT Versus Drying: In Situ Tests in Outdoor Environment

5.1 Aim

In this work, the applicability of IRT to assess the drying process of exterior walls after a long-term rainy period was evaluated through in situ tests. The physical phenomenon underlying these measurements was the effect of evaporative cooling and the passive approach was implemented. Simultaneously, a moisture detector was also used to qualitatively assess the evolution of the moisture content of the walls.

The walls under study were coated with similar rendering and painting, but they presented different orientations and, consequently, different exposure to solar. Differences in the exposure to thermal radiation were also found due to nearby obstacles that might have affected the drying process. However, they all presented clear visible signs of the presence of moisture (Barreira et al. 2016).

5.2 Materials and Techniques

The devices used in this campaign were an infrared camera (Fig. 3.4a) and a moisture detector (Fig. 3.4b). The main specifications of the equipment are described in § 3.2.2. The test campaign started when the rain period stopped and the measurements were carried out during six consecutive days, at 10:00, 12:00, 14:00, 16:00 and 18:00 (without solar radiation). Four walls with one-coat mortar as rendering were assessed. Figure 5.1 shows the orientation of the walls and the reference number of each case study. Moisture readings on the walls were made at three different points on each wall (Fig. 5.2).The position of the camera and the points on the walls were always the same.

For the IRT measurements, emissivity was set to 0.9. This value may not correspond to the real emissivity value of the surfaces under study; however, as only the qualitative approach was used, an estimated value of emissivity was considered

E. Barreira and R. M. S. F Almeida, *Infrared Thermography for Building Moisture Inspection*, SpringerBriefs in Applied Sciences and Technology,
https://doi.org/10.1007/978-3-319-75386-7_5

Fig. 5.1 Orientation of the walls and reference number of each case study

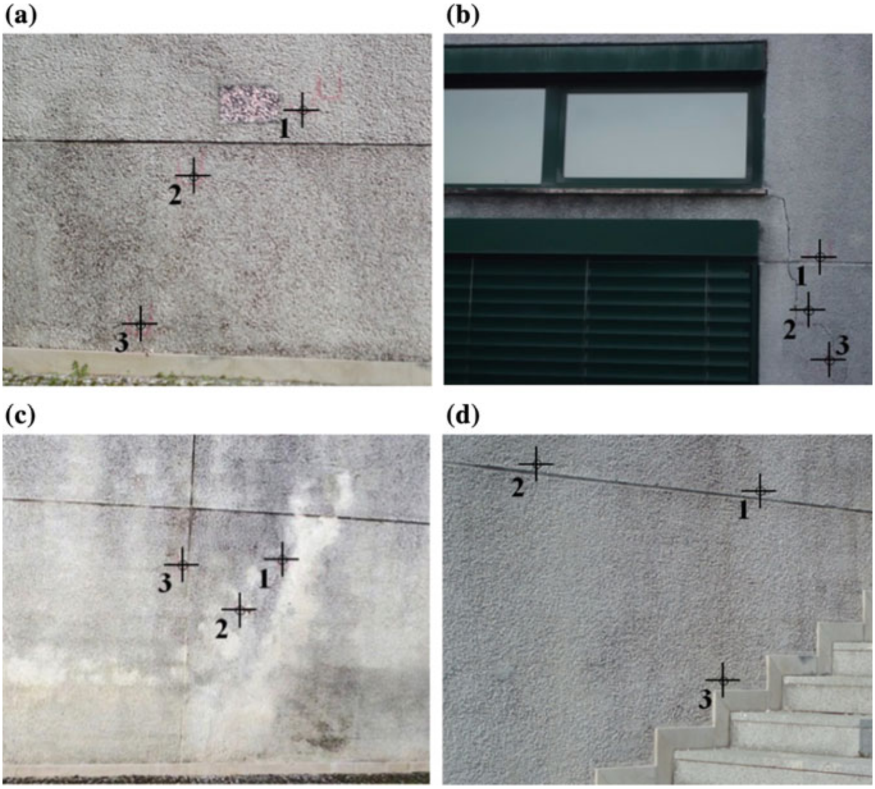

Fig. 5.2 Walls under study with measuring points: **a** Wall 1; **b** Wall 2; **c** Wall 3; **d** Wall 4

acceptable. Correction parameters were introduced before the IRT measurements began. Weather data (temperature, relative humidity, solar radiation and wind velocity and direction) was measured by a weather station located near the walls (Table 5.1).

Table 5.1 Average air temperature, relative humidity, solar radiation and wind velocity and direction measured by the weather station and qualitative evaluation of the climate

Day	Hour	T_{air} (°C)	RH_{air} (%)	Solar Rad (W/m^2)	Wind Vel/Dir (m/s)/(°)	Qualitative evaluation of the climate
1	10:00	9.8	64.1	553	12.2/301.5	Clear sky
	12:00	12.2	57.8	769		
	14:00	14.1	51.0	727		
	16:00	15.2	49.8	422		
	18:00	13.3	66.2	23		
2	10:00	11.0	72.6	559	10.1/117.0	Clear sky, after a foggy night
	12:00	16.0	48.2	766		
	14:00	17.9	40.8	731		
	16:00	18.3	39.7	429		
	18:00	17.1	44.2	22		
3	10:00	14.5	52.3	568	12.2/175.5	Clear sky
	12:00	17.5	32.2	783		
	14:00	19.4	29.3	734		
	16:00	19.8	31.0	422		
	18:00	18.3	41.1	20		
4	10:00	16.0	45.4	567	16.6/94.5	Clear sky
	12:00	19.0	38.6	780		
	14:00	20.6	27.4	742		
	16:00	20.2	29.8	425		
	18:00	17.5	30.2	24		
5	10:00	14.9	34.7	374	10.8/112.5	Cloudy sky
	12:00	18.3	30.2	387		
	14:00	21.0	25.7	516		
	16:00	19.4	31.2	165		
	18:00	16.8	33.1	22		
6	10:00	12.9	46.7	628	25.2/85.5	Clear sky
	12:00	16.0	39.9	842		

(continued)

Table 5.1 (continued)

Day	Hour	T_{air} (°C)	RH_{air} (%)	Solar Rad (W/m^2)	Wind Vel/Dir (m/s)/(°)	Qualitative evaluation of the climate
	14:00	17.4	38.5	783		
	16:00	17.3	44.9	470		
	18:00	14.1	76.4	36		

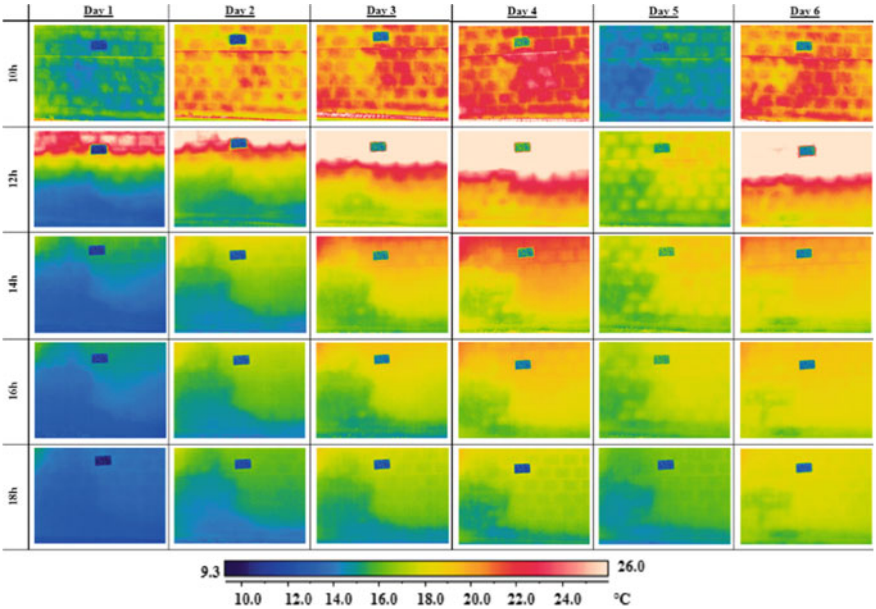

Fig. 5.3 Thermal images—wall 1

5.3 Results

5.3.1 Wall 1

The thermal images taken in wall 1 are shown in Fig. 5.3. The thermal images show that temperatures vary with the hour of the day. They also show that in the first day, the superficial temperatures on the wall were lower than the ones obtained at the end of the test campaign.

Temperatures were higher at 10:00 and at 12:00 because there was direct solar radiation on the wall. During these periods is difficult trying to assess moisture because the effect of sun as a heat source enhances other phenomena rather than moisture, as detachments and materials with different thermal properties (Freitas et al. 2014). Considering the thermal images taken in the afternoon, the temperature values were always lower at 18.00, what was expected as air temperatures are also lower (Table 5.1).

Over the six days of measurements and considering only the thermal images taken at 16:00 and 18.00, there is a clear increase of the surface temperature and a decrease of the area with the lowest temperatures. Although the air temperature generally increased over time, it is possible to say that the wall was drying out because, for similar air temperatures, the temperature values on the wall increased. Taken as an example days 2 and 6 at 18:00, the temperature of the air was 17.1 and 14.1 °C, respectively, and temperatures on the wall were higher in day 6. Darker colours on the thermal images on day 5 are related to the cloudy day that decreased the air temperature and, consequently, the surface temperature.

Based on the previous considerations, it is possible to point that the moist area was mainly located on the left side and at the bottom of the thermal image. Over time, it tended to decrease, and at the end of the measurement period, it was located mostly near the ground.

The results of the moisture detector (Fig. 5.4) support the findings of IRT. On the three points that were assessed, generally, moisture decreased not only over the day but also over the period of measurements. During day 1, there was an increase of moisture at the end of the day that may be related to the runoff of accumulated water on the wall surface. The increase of moisture at the beginning of each day, when compared with last reading of the previous day, was probably due to higher relative humidity of the air during the night that increased moisture at the surface.

Figure 5.4 also shows that point 1, at the highest level, dried out faster than the other two, and at day 6, the readings of the moisture detector were around zero. This may indicate that this part of the wall was less affected by rainwater. The decrease of moisture on point 3, at the lowest level, was sharper than on point 2, located at an

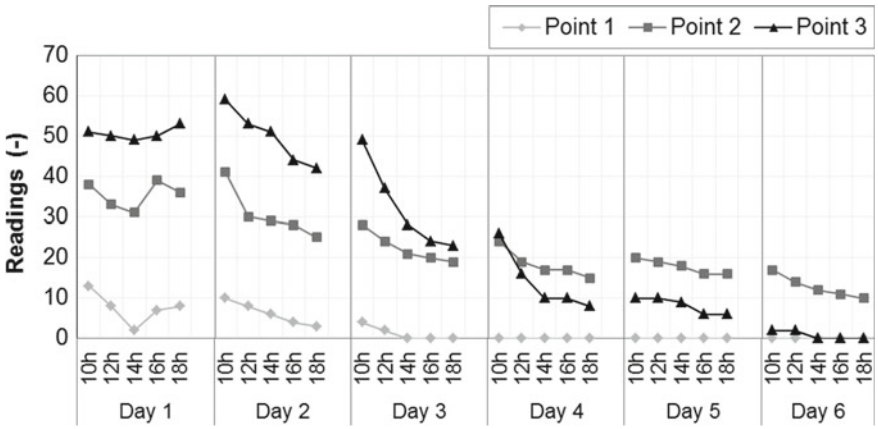

Fig. 5.4 Results of the moisture detector—wall 1

intermediate position. That can be explained because in the surroundings of point 2 there was a joint in the rendering, where accumulated water may have restricted the drying process.

5.3.2 Wall 2

The thermal images taken in wall 2 are shown in Fig. 5.5. The temperatures were higher during the afternoon because there was direct solar radiation on the wall. Shadows are clearly detected in the thermal images and may mask the effect of moisture at 14:00 and 16:00. However, some findings can be enhanced in the remaining results.

As in wall 1, also in this wall the increase of temperature on the right side is clear. There was an increase of the values not only over the day but also over the period of measurements. It is, however, difficult to detach the effect of air temperature, which increased the superficial temperature of the wall, from the increase of surface temperature due to the drop of moisture at the surface. However, when considering days with similar weather conditions, it is possible to notice that at the end of the measurement period the values were higher than at the beginning, pointing to less intense evaporation and, consequently, to a dryer surface.

The results of the moisture detector (Fig. 5.6) were in line with the ones of the thermal images, because moisture decreased over time at all levels. At the end of the

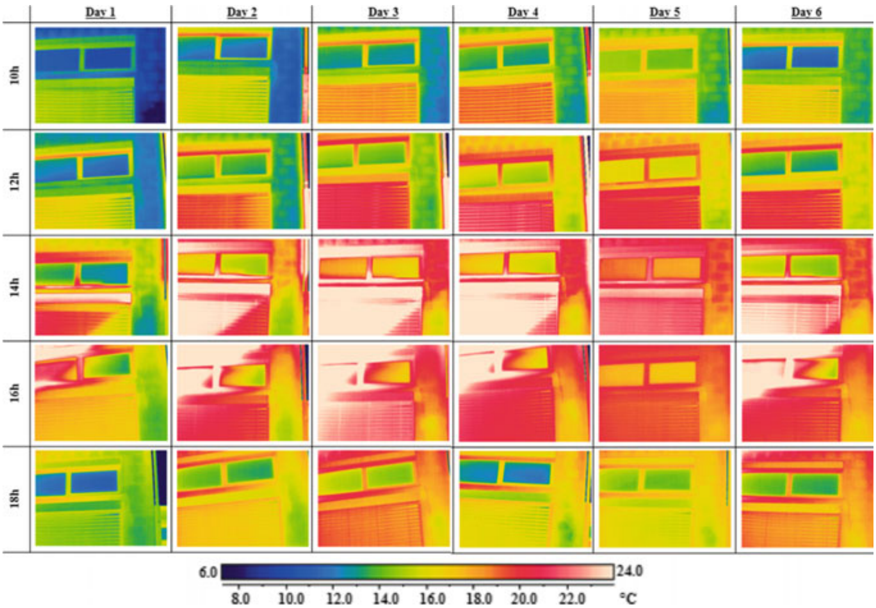

Fig. 5.5 Thermal images—wall 2

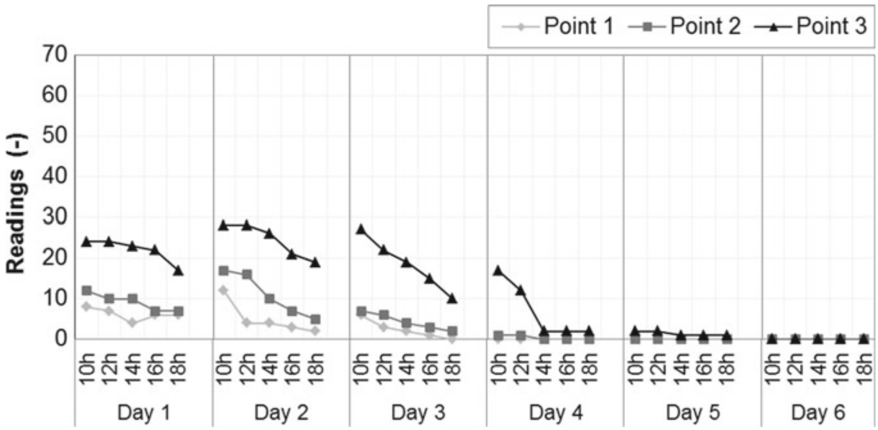

Fig. 5.6 Results of the moisture detector—wall 2

fourth day, the readings were very similar and around zero, indicating that the wall has dried out. Similar results on the three points were somehow expected since they were very close to each other.

5.3.3 Wall 3

The thermal images taken in wall 3 are shown in Fig. 5.7. Temperatures on this wall were lower than in the previous ones because there was no direct solar radiation. Although the effect of the sun was less relevant, these images are not completely conclusive regarding the drying process, mainly due to the thermal patterns resulting from dirt at the surface, different thermal conductivity of the inner layers and/or influence of the surrounding environment, which are problems also verified by Rumbayan and Washer (2014).

Although the results of IRT are not totally clear, the moisture content indicates that the wall dried out over time as at the end of day 6 the readings at all levels were around zero (Fig. 5.8).

5.3.4 Wall 4

As in wall 3, also in this case (Fig. 5.9) the results revealed that tackling the drying process in the outdoor exclusively through qualitative IRT is not straightforward, although a tendency for higher surface temperatures throughout the analysis can be identified. Yet, the air temperature was also increasing, which highlights the

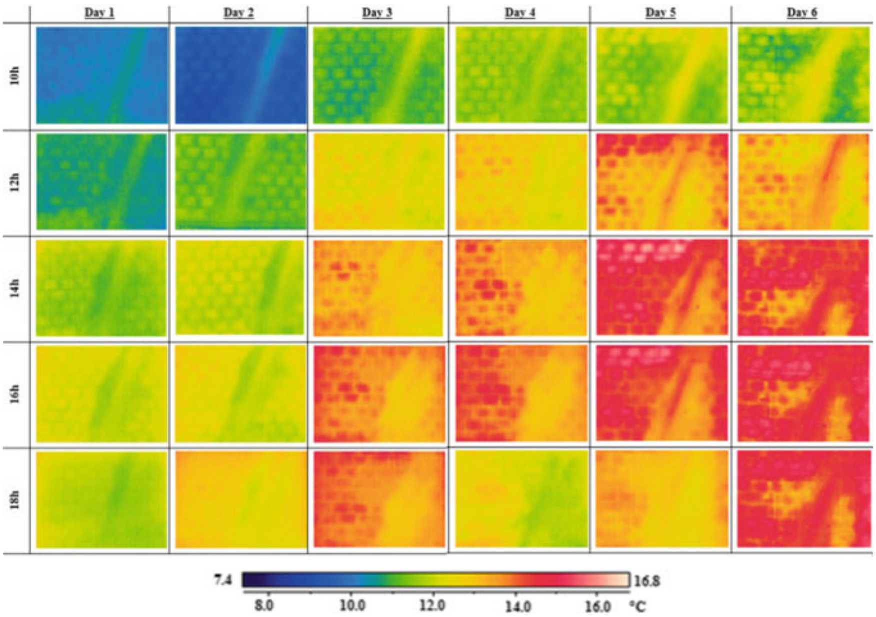

Fig. 5.7 Thermal images—wall 3

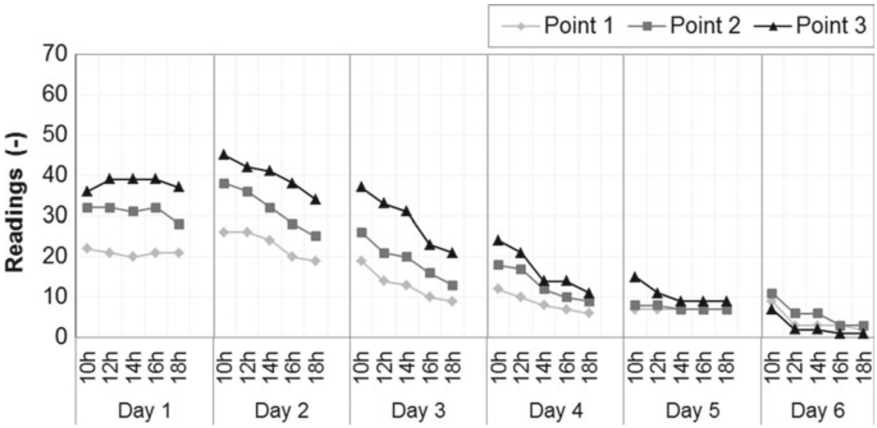

Fig. 5.8 Results of the moisture detector—wall 3

difficulty of isolating the effect of evaporative cooling. In addition, the influence of solar radiation in the thermal images is difficult to assess.

Lerma et al. (2014) could clearly visualise the relationship between evaporation and surface temperature of a material as at the beginning of the process the temperature falls and then tends to equalise the air temperature. However, this test was performed in laboratory, using small samples and under very controlled conditions.

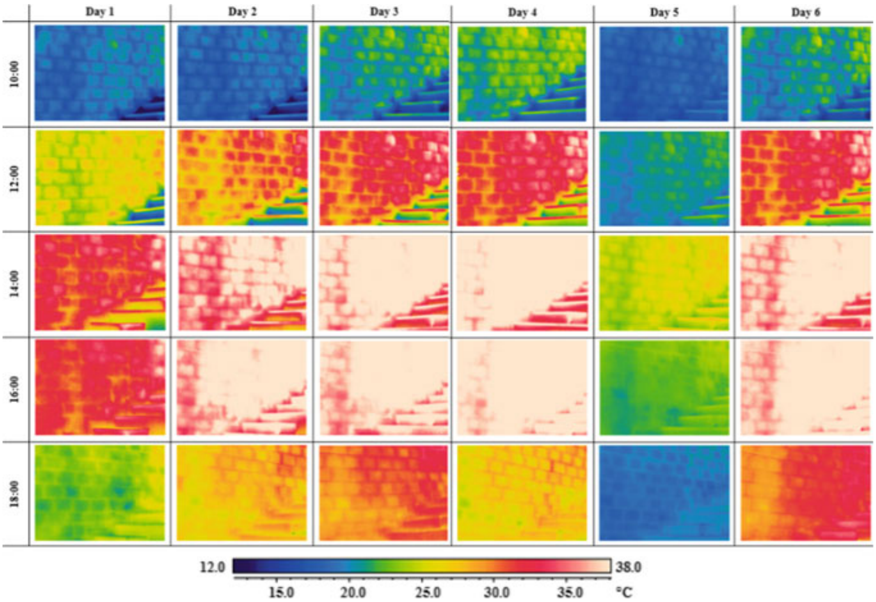

Fig. 5.9 Thermal images—wall 4

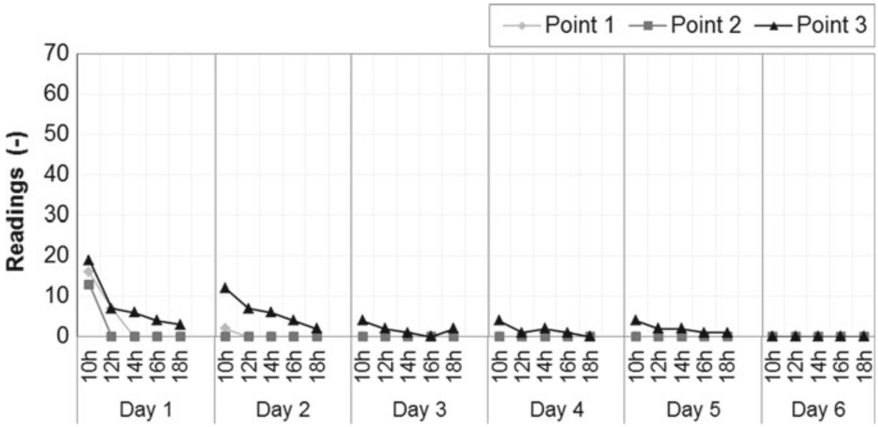

Fig. 5.10 Results of the moisture detector—wall 4

Figure 5.10 shows the results obtained with the moisture detector. From day 2, readings on point 1 and point 2 had null values, which mean that the wall was superficially dry. As expected, point 3 had higher moisture content as it was near the ground, where a larger amount of water was accumulated. However, at the end of day 6, it was also completely dry.

On the other hand, as expected, measurements on the wall 4, the only one facing south, presented lower values of moisture content because there was higher amount of incident solar radiation.

5.4 Discussion of the Results

The results of IRT to assess the drying process were not straightforward. The thermal images were strongly influenced by direct solar radiation, which highlighted other phenomena, like detachments, materials with different thermal characteristics and/or influence of the surrounding environment, sometimes masking the effect of surface evaporation. In addition, the air temperature significantly influenced the surface temperature of the wall, which could have led to misinterpretations of the results, if the time variation of the air temperature was not considered.

Although the restrictions previously indicated, it was possible to point out the drying process, when considering days with similar weather conditions. In fact, generally, at the end of the measurements the temperature values were higher than the ones at the beginning, pointing to less intense evaporation and, consequently, to a dryer surface.

The results of the moisture detector supported the findings of IRT. Generally, locations with higher values corresponded to areas with lower temperatures in the thermal images. Besides, the values of the readings decreased not only over the day but also over the period of measurements. The increase of moisture at the beginning of each day, when compared with last reading of the previous day, was probably due to higher relative humidity of the air during the night that increased moisture at the surface.

When comparing the four cases under study, it is possible to verify that wall 4 dried out faster than the other ones. At day 3, it was almost completely dry. The other walls needed at least 4 days (wall 2) or 6 days (walls 1 and 3) to achieve the same condition. That may be related to the fact that wall 4 was more exposed to direct solar radiation, which intensified surface evaporation.

References

Barreira E, Almeida RMSF, Delgado JMPQ (2016) Infrared thermography for assessing moisture related phenomena in building components. Constr Build Mater 110:251–269

Freitas SS, Freitas VP, Barreira E (2014) Detection of façade plaster detachments using infrared thermography—A non-destructive technique. Constr Build Mater 70:80–87

Lerma C, Mas Á, Gil E, Vercher J, Peñalver MJ (2014) Pathology of building materials in historic buildings. relationship between laboratory testing and infrared thermography. Materiales de Construcción 64(313):009

Rumbayan R, Washer GA (2014) modeling of environmental effects on thermal detection of subsurface damage in concrete. Res Nondestr Eval 25(4):235–252