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Selective infrared thermography. Application to detection of humidity in buildings.

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Abstract

Humidity is one of the main problems affecting building materials, specially in historical monuments. Its sources can be multiple and, in some cases, very difficult to be determined. Very often, the environmental conditions (high levels of humidity and CO_2 in the atmosphere) make difficult to obtain true results through Infrared Thermography. With the object of solving these problems the "Selective Infrared Thermography Method" has been developed. This technique is based on the use of interferencial filters (developed by the authors) for determining the interferencial areas to analyze. The foremost tests in these studies have been carried out using prisms of gypsum subjected to capillarity processes with different salt dissolutions.

1. Introduction

Humidity is one of the major causes of building decay. The problems generated by moisture present such special characteristics that it can be considered as a very important and current phenomenon to be solved. In order to devise effective ways of studying and solving this humidity weathering phenomenon, it is essential to have available non destructive techniques of diagnosis.

The infrared thermography has proved to be a useful, rapid and non destructive technique for measurements of surface humidity content from different sources ([2], [4] and [6]), but in some cases, the environmental conditions (high levels of humidity and CO_2 in the atmosphere) make it unlikely to obtain true results through infrared thermography. In order to solve these problems the "Selective Infrared Thermography Method" has been developed. This technique is based on the use of interferencial filters to determine the interferencial areas to analyze.

The filters were respectively centered on 2.7 μm and 4.3 μm (bandwidth of 0.5 μm), and obtained by alternately depositing layers of germanium (high refractive index) and silicon monoxide (low refractive index). The multilayer structure of the former is: silicon/ HLH 2L HLH 2L HLH/ air where H and L designate respectively a layer of high (Ge) and low (SiO) refractive index with an optical thickness of $\lambda/4$ (at respective wavelength).The final thickness of the filter is ≈ 2.5 μm.

The Thermocamera works with an InSb quantic sensor which gives a spectral response between 2 and 5.6 μm. The selection of different spectral regions is obtained through multilayer filters that cut down the transmission of infrared radiation in the next regions: between 2.5 and 3 μm (water and CO_2 band) and between 4 and 4.5 μm (CO_2 band). These filters have been selected bearing in mind the spectral response of the Infrared Camera in the H_2O and CO_2 absorption bands.

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In the present paper, measurements have been carried out in gypsum prisms subjected to capillarity processes with some different dissolutions and using specific multilayer filters that select the infrared radiation in the above mentioned range.

2. Experimental

The specimens (prisms of 4 X 4 X 16 cm of gypsum) were maintained in vertical position and inside of a black box in order to avoid the influence of the surrounding radiation. Simultaneously, the camera was located at a constant distance of 0.5 m of the specimen and maintained in perpendicular position to the object during the test.

The experiments were carried out with distilled water, a saturated dissolution of ClNa and a saturated dissolution of Na_3PO_4 at 20°C. The bottom part of the prisms is constantly maintained in contact with the dissolution for 40 min. During that period, measurements of radiation are done using the specific multilayer interferencial filters that select the infrared radiation in the above mentioned spectral range. After that, specimens are maintained in vertical position and weighted periodically.

Figures n° 1-9 show the thermograms obtained in each case using different filters.

3. Discussion

If thermograms belonging to the different capillarity processes are observed and compared, it may be concluded in all cases:

- The water filter (see figures n° 3-6) allows to see only the wetting part of the specimens (compare figures n° 1-3 and n° 3-6).
- The CO_2 filter (see figures n° 7-9) allows to see the full specimen; although a more diffuse image than the one with no filter is obtained.

Additionally, if thermograms corresponding to no-filter tests are studied (figures n° 1-3), a bigger wet area and a more homogeneous water distribution when prisms partially immersed in distilled water are compared with the ones immersed in the salt dissolution can be observed (In the first case, dry and wet areas can be detected in the same value of thermal level). Also, if the form of isotherms is compared, a very important difference between the capillarity suction in distilled water and salt dissolution cases can be seen: In distilled water the external isotherm appears with an homogeneous form all around the specimen and the internal one presents a meniscus form; however for the salt dissolution cases, the external isotherm is wider in the bottom part of the prism and the internal one is plane. That is to say, in distilled water, the capillarity suction is bigger near the external layers (meniscus form) like in the case of a capillary, and the evaporation process occurs in the whole specimen whereas, in the dissolution cases, the water rises easier through the internal layers of the prisms remaining in the bottom of the prism. So, the evaporation process mainly occurs in that area.

That characteristics of isotherms also appears when a water filter is used (see figures n° 4-6). In that cases, only the wet area of the prism is visible. The form of the isotherms is also different and proves again that in distilled water an homogeneous wet distribution is produced (see the rectangular form of the isotherm). On the other hand, the wedge form of isotherms in the salt dissolution cases, shows larger quantities of water in the bottom of the prism which is rising through the internal pores of it. That phenomenon is clearly shown in the Na_3PO_4 dissolution case in which two isothermal levels can be observed using the water filter (see figures n° 9). It means that water is being mainly retained in the bottom part of the specimen.

Finally, the CO_2 filter produces a diffuse image of the specimen (see figures n° 6-9). In this transmission range band (4 μm-4.5 μm) the most water emission effects are lost

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so a poor signal from the material is obtained although it is still possible to detect differences between wet and dry areas. This differences appear more clearly in the Na_3PO_4 dissolution thermogram (figure nº 9) in which two isotherms are located in wet area. That fact confirms the already mentioned with respect to water concentration: Water is homogeneously distributed in the distilled water but mainly retained in the bottom of the prism in Na_3PO_4 dissolution test. The NaCl test could be understood as intermediate between distilled water and Na_3PO_4 tests.

4. Conclusions

The use of specific interferencial filters has been developed in order to improve the results obtained when measurements by means of infrared thermography are carried out in monuments presenting very important problems due to environmental conditions (high levels of humidity and CO_2 in the atmosphere). This Selective Infrared thermography technique is based on the use of interferencial filters for determining the interferencial areas to be analyzed.

The experimental tests carried out in gypsum prisms with interferencial filters have demonstrated that selective infrared thermography is a valuable technique for this purpose.

Through selective infrared thermography it is possible to establish relations among wet areas, shape of capillarity suction in materials and ambient conditions.

Further investigations in buildings are considered of importance because of the promising results already obtained.

Acknowledgment

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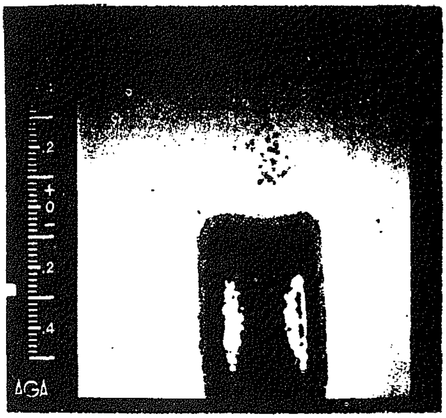

Fig.1. *Thermogram corresponding to no-filter and distilled water test. The homogeneous form of the external isotherm can be observed.*

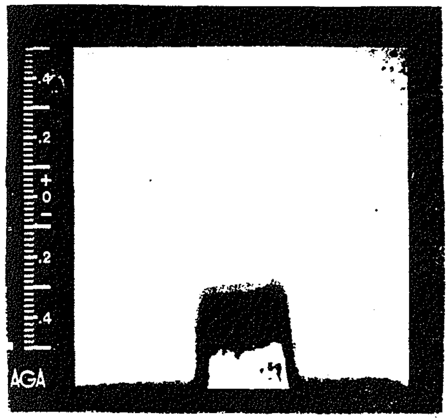

Fig.2 *Thermogram corresponding to no-filter and NaCl dissolution test. The plane form of the internal isotherm can be observed.*

Fig.3. *Thermogram corresponding to no-filter and Na_3PO_4 dissolution test. Two isothermal levels are shown.*

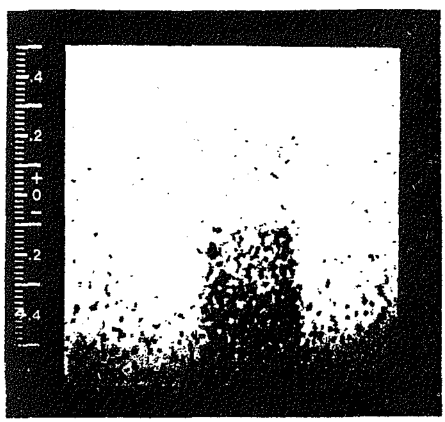

Fig.4. *Thermogram corresponding to distilled water and water filter test. The rectangular form of the isotherm can be observed.*

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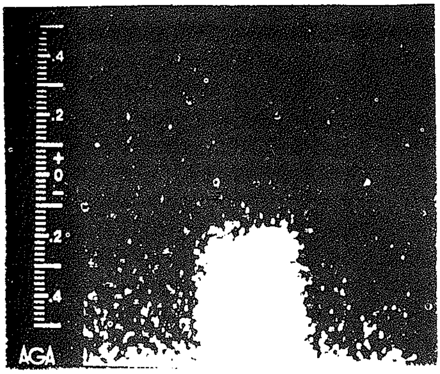

Fig.5. *Thermogram corresponding to water filter and NaCl dissolution test. The wedge form of the isotherm can be observed.*

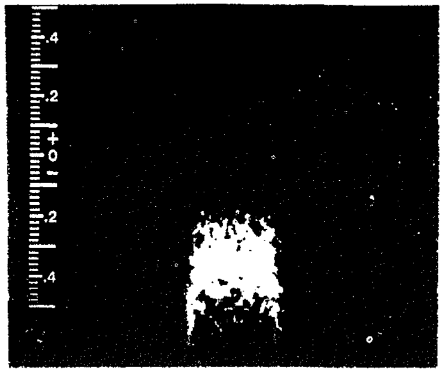

Fig.6. *Thermogram corresponding to water filter and Na_3PO_4 test. Two isothermal levels are shown.*

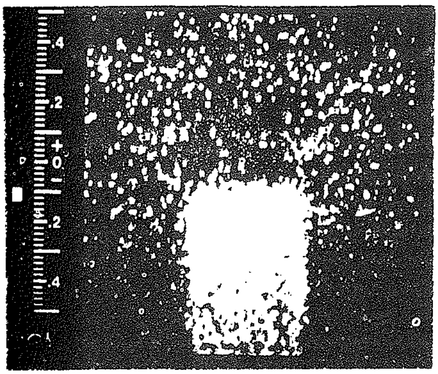

Fig.7. *Thermogram corresponding to CO_2 filter and distilled water test. Dry part of the specimen produces a diffused image.*

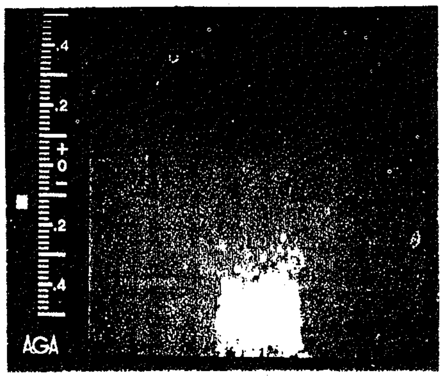

Fig.8. *Thermogram corresponding to CO_2 filter and NaCl dissolution test.*

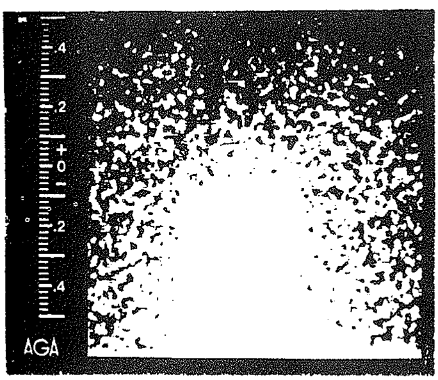

Fig.9. *Thermogram corresponding to CO_2 filter test and Na_3PO_4 dissolution test. Two isotherms are located in the dry area.*