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ASBESTOS CONTAINING ROOFING: REMOTE SENSING MAPPING

FOREWORD - Italian legislation (Law 257/92) has prohibited the extraction, import, export, marketing and production of asbestos, asbestos products and products containing asbestos. There are also provisions relating to the mapping of asbestos throughout the national territory (Law no. 93/2001 and Min. Decree 101/03), which entrust this task to the Regional Administrations. The latter, in order to accelerate the acquisition of data on a large scale, are increasingly making use of remote sensing techniques for the geo-localisation of asbestos cement (Ac) roofing. The results recorded to date have shown operating methods that differ from Region to Region.

INAIL'S CONTRIBUTION TO SUPPORT PUBLIC ADMINISTRATIONS

Inail's research activity has devoted great attention to the complex issue of asbestos and to the mapping of areas contaminated by this substance, for the purpose of adopting measures to limit the related risk, protect workers and safeguard resident communities. Taking note of the studies and experiments of remote sensing for the survey and mapping of Ac roofing, the Institute has promoted a Call for Collaborative Research (Bric 57/2016), with the objective of carrying out an assessment of the different techniques for the identification and recognition of surfaces containing asbestos, both of anthropic and natural origin, from remote sensing images. The project, which was joined by the Institute of Methodologies for Environmental Analysis of the Cnr, the University of Modena and Reggio Emilia, the National Institute of Geophysics and Volcanology and the University of Milan Bicocca, with the coordination of the Innovation Department for Technological Innovation and Safety of plants, products and anthropogenic settlements (Dit), has led to defining the state of the art and the best approaches for the remote sensing of asbestos containing roofing. Based on this assessment, guidelines and reference procedures have been defined, which can be used by the authorities in charge and by operators in the sector for the extraction of information useful for the mapping of Ac roofing with these techniques. Inail has also invested in this area by training qualified personnel through scholarships and PhDs (at "La Sapienza" University of Rome).

THE ADVANTAGES OF REMOTE SENSING

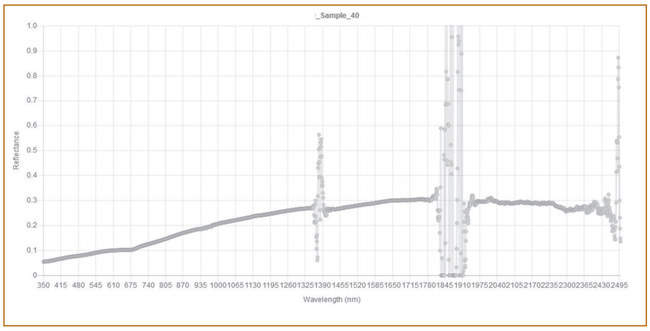
Remote sensing has been used to support traditional census methods (visual inspection of roofing and *on-site* collection of samples to be analysed), as it offers several advantages: 1) makes it possible to carry out remotely a first identification of large potentially contaminated surfaces; 2) significantly reduces the time and costs of mapping, limiting the number of inspections to cases of uncertain identification; 3) enables subsequent periodic updates that can be carried out quickly. Due to its advantages, remote sensing can be considered a prevention tool, because by reducing the number of inspections, the risks for operators are lower, both in relation to accidents (e.g. falls from height) and to the fact that they are less exposed to the asbestos carcinogenic agent. Furthermore, the preliminary acquisition of remote sensing information regarding the investigated places makes it possible, during inspections, to plan for adequate, both collective and individual protection measures.

INFORMATION PROVIDED BY DATA

A remote sensing system consists of a sensor mounted on a platform that captures the area of interest from above, by recording the electromagnetic radiation reflected from the surfaces. The data obtainable from remote sensing, useful for the correct identification of asbestos containing roofing, are: orthophotos, multispectral and hyperspectral images. Orthophotos are geometrically correct photographs that provide information that is useful only for interpretative analyses based on the characteristics of colour, texture and geometry of the scene taken. The multi/hyperspectral images are instead composed of several "layers" (bands), each corresponding to the electromagnetic radiation measured by the sensor within a narrow range of wavelengths. The number of bands corresponds to the number of acquisition channels of the sensor. Based on the number of bands that make up the dataset, we can have multispectral (about ten bands) or hyperspectral (tens/hundreds of bands) images. The information contained in each element of the image (pixel) describes the spectral behaviour (spectrum) of the corresponding surface. This behaviour is determined by the chemical-physical properties of the material. The more numerous the bands and the narrower the spectral range of each (spectral resolution), the greater the degree of detail of the spectrum and therefore the possibility of identifying diagnostic characteristics. Surface recognition in hyperspectral images is based on the position and spectral shape of the diagnostic bands of the materials (spectral signature). Looking at the wavelengths of the Visible and Near Infrared, asbestos minerals have two characteristic absorption peaks around 1.38 and 2.32 μm; in Ac roofing the mineral is present in an average percentage of around 10-20% inside a cement matrix. The possibility of discriminating asbestos on a spectral basis depends on various factors: its quantity and its spectral contrast with respect to the materials of the matrix; the signal/noise ratio of the image; the disturbance introduced by the layer of atmosphere interposed between the surface and the sensor.

DATA ACQUISITION PLATFORMS

Remote data acquisition can be conducted using different types of platforms: satellite, aircraft/helicopter, drone, or from the ground (with spectroradiometers - proximal sensing). They are chosen according to the objective and the results to be obtained, as well as the costs, in terms of money and time. Satellites enable repeated shootings of large areas with a detail (geometric resolution) that for the most recent sensors is about one meter or less, but with a limited spectral resolution. Aerial platforms are used for the acquisition of orthophotos (with centimetre resolution) and for hyperspectral surveys. The latter, with overflights at altitudes between 3000 and 1000 m on average, provide data with resolution of about one meter. With drones it is possible to obtain a centimetre or even millimetre geometric resolution; however, they operate on areas of limited size and with low spectral resolution (lower number of bands) due to the difficulties in equipping them with hyperspectral sensors.



Reflectance spectrum acquired by the National Institute of Geophysics and Volcanology with an ASD Fieldspec spectroradiometer as part of the Bric 57/2016 project.

CLASSIFICATION OF AC ROOFING

The Classification algorithms used in remotely acquired images are primarily based on a *pixel-oriented (Po)* or *object-oriented (Oo)* approach. The *Po* consists of classifying every single pixel that makes up the image based on the spectral information it contains. The *Oo* approach puts a segmentation procedure before the classification, which aims at grouping pixels into objects, subsequently using algorithms that exploit, in addition to the spectral information, other parameters such as the shape and texture of the objects as well as the geometric relationship with respect to adjacent objects; this makes it possible to optimise the use of data acquired by satellite sensors with high geometric resolution but low spectral resolution. Both approaches have been tested for the mapping of Ac roofing: the *Oo* approach has recently been used more frequently, due to the higher cost and lower availability of hyperspectral data with adequate geometric resolution. The processing of remotely sensed images requires auxiliary information to support the preliminary correction and classification phases, as well as to evaluate the accuracy of the results. These include: 1) Spectral field measurements acquired simultaneously with the overflight, to improve the atmospheric correction and evaluate the quality of the reflectance spectra obtained remotely; 2) temperature, pressure and humidity of the air, useful for atmospheric correction; 3) cartographic data and other territorial information, e.g. cadastral data (usable in *Oo* algorithms), results of the censuses of asbestos containing materials required by law; 4) operator inspections carried out before, during and after the overflight or simply survey with drones to validate the obtained maps.

The remote survey of Ac roofing is therefore possible. However, the quality of the result depends on many factors concerning, among other things: the characteristics of the shooting system (e.g. geometric and spectral resolution, view angle); operating conditions (e.g. cloud cover, air humidity, presence of reliefs); the characteristics of the roofs (shape, size, percentage of asbestos, state of conservation, context, etc.); the validity of atmospheric corrections; the classification algorithms and the way in which they are applied (choice of different parameters). These main aspects must be carefully considered, because they affect the quality of the result. Therefore, the maps of Ac roofing obtained by remote sensing must be accompanied by an evaluation of the reliability of the result in terms of classification accuracy. Finally, the possibility of reusing remotely sensed data as an information source for monitoring, analysis and planning purposes, both of urbanised and natural territories should be emphasised, considering the investments made by local authorities.

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Inail - Dipartimento innovazioni tecnologiche e sicurezza degli impianti, prodotti e insediamenti antropici - Direttore: Carlo De Petris
Via Roberto Ferruzzi, 38/40 - 00143 Roma
Tel. 06 548 76 400 • Fax 06 548 76 413 • dit@inail.it